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Addition of Super Absorbent Polymer for Upgrading of Cement Quality in Iraqi Oil Wells

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Abstract

This study focuses on the use of an optimum amount of Sodium Polyacrylate (SP) for designing cement slurry with the high performance of rheological properties and displacement efficiency. A laboratory study has been carried out on the cement slurry which prepared with SP as superabsorbent polymer. SP has been providing an internal water source that helps in the hydration process, and curing and ultimately increases the cement strength. Also improves the cement performance by improving the cement stability. Several batches were prepared to determine the proper amount of SP to add it in the cement slurry. Also, we studied its effect on cement density, amount of free water in order to observe the rheological properties, and thickening time. Results indicate that the designed cement rheological properties are directly influenced by the shear rate and shear stress on the mix and pump of the cement with the increase of the SP concentration for the rheological improvement. Laboratory data are presented to highlight Polyacrylate’s positive effect on compressive strength, fluid loss control, and free water.

Keywords: Sodium Polyacrylate, Cement additive, Cement Slurry, rheological properties, Superabsorbent polymer.

Introduction

Oil well cementing is the placement of a cement slurry in the annulus space between the well casing and the geological formations surrounding to the well bore to form a solid mass which has supporting and sealing properties. When a certain section of the depth of an oil or gas well has been drilled successfully, the drilling fluid filtrate will penetrate into the formation from a few inches to several feet which cause interaction with the formation minerals in the producing horizons, and the formation of the drilling mud cake cannot permanently prevent the well bore from collapsing. Therefore, oil well cementing was introduced with a number of objectives [1]:

(i) Protecting oil producing zones from salt water invasion.
(ii) Protecting the well casing from exposure to collapse pressure.
(iii) Protecting well casings from wear and corrosion.
(iv) Reducing the risk of formation water contamination by oil, gas or salt water.
(v) Providing isolation zone of different underground formations in order to prevent the exchange of gas or

fluids among different geological formations. In addition, to prevent their exposure to severe temperature, corrosive fluids, and over pressured formations.

The development of Iraqi oil industry during the last two decades has led to introduce new oil wells in the south and north Iraqi oil fields. Some of the new oil wells were conducted using normal cement quality in cementing operation. The faced problems in cementing operation which is a very important level to keep casing save. These problems are related to cement quality because after a period of time the casing severe from corrosion because of bad quality of cement. The main purpose of cementing is to support casing and to isolate zones so it is important to make a strong sheath between the casing and the formation without fractures happened. The use of normal cement quality makes a bad cement bond quality and shows a significant amount of mud losses during drilling through some of the carbonate formations. As a result, it was recommended to use high quality cement instead of the current cement and additives were recommended to be added to improve the quality of the cementing operation. A good cementing operation makes the cement characterized with high consistency, homogeneity, impermeability, and adhesively .

Therefore, we will try to develop poor cement quality to good quality by adding superabsorbent polymer which is Sodium Polyacrylate that working to improve the cement quality and properties like stability of cement and cement strength and reduce leaking of water from cement slurry and reduce initial setting time and final setting time of cement slurries [2, 3]. Figure 1 shows a schematic simulation of the Zb229 oil well cementing process.

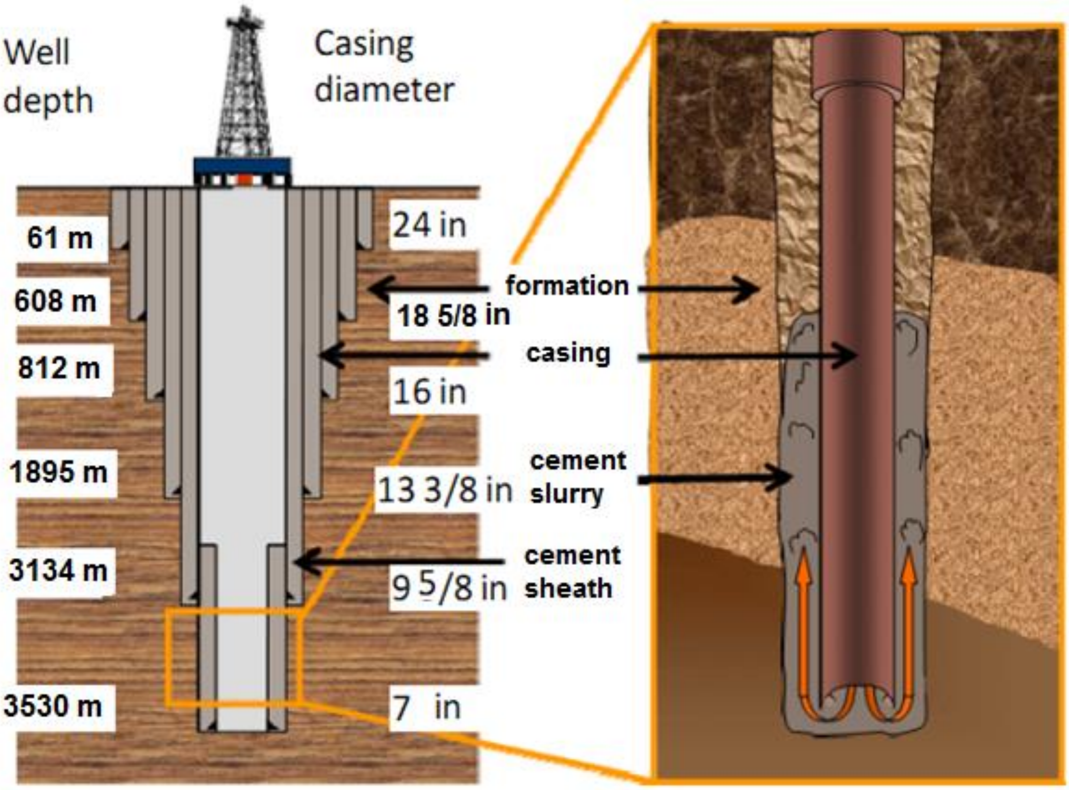

Fig. 1: Schematic simulation of the oil well cementing process in southern Iraq (Zb 229)

Sodium Polyacrylate is a superabsorbent polymer has the ability to absorb water, increase viscosity, protection of producing formation and it can use as a thickening agent which can increase the viscosity of a liquid. It is used in the manufacture of glass, binders, adhesives, absorbents, Coatings, and fake snow [4]. A Sodium Polyacrylate polymer belongs to a group of polymers which could be characterized as plastics, transparency and resistance to breakage and elasticity. All these characterizations make the authors used this material to improve the cement quality used in oil wells.

Experimental Work

Measurement Methods

The following tests are very important to evaluate cement quality:

1. Initial Setting Time

Initial setting time is measured by Vicat Needle apparatus. This test can carry out by measurement the depth of penetration of the Needle has (1 mm) diameter into the cement slurry weight of 300 gm formed of water and cement with a 0.5 water to cement weight ratio at a temperature of 140 ^{o}F. Initial setting time is the time required to make slurry has certain consolidate that make the needle of the apparatus does not penetrate the sample completely, but (3-5 mm) is not penetrated above the lower base. The cement is considered good quality cement if initial setting time is between (95–140) minute from the beginning of cement preparation.

2. Final Setting Time

Final setting time is measured also by Vicat Needle apparatus and it gives an indicator about cement setting time that can retard of continuance of well drilling operations. Final setting time is defined as the time required from start of the cement preparation until the needle cannot penetrate the cement. The cement is considered good if final setting time is about 45 minutes as a maximum limit after initial setting time [5].

3. Filtration of cement slurry

Filtration of cement is measured in the same way of measuring the filtration of drilling mud.

The cement considers good if the filtrate volume of cement slurry which formed of water and cement with ratio equal to 0.5, is not increased more than 850 cm^3 measured with a Baroid apparatus in time 30 minutes and 100 lb/in^2 pressure. In the field and for the application conditions the filter loss is acceptable with a volume of 100-150 cm^3/30 minute in Baroid apparatus.

4. Free Water (Stability)

Free water is evaluated according to the ratio of displaced water from the cement slurry formed of water and cement with a weight ratio of 0.5, placed in a pipe with a volume of 250 cm^3. The cement is considered good if the displaced water does not increase more than 1% of the total slurry volume (2.5 cm^3) after leaving slurry quietly for two hours under lab conditions.

5. Mechanical Strength of cement rock

The mechanical strength of cement rock is evaluating either by compressive strength or by tensile strength and the cement consider good if cement rock has compressive strength not under 500 lb/in^2 during the first eight hours .

6. Specific gravity of cement slurry

The cement is considered good if the specific gravity is formed from water and cement with weight ratio 0.5, between 1.80 (112.37 lb/ft^3) and 1.84 (114.86 lb/ft^3).

Materials

The materials used in this study are:

1. Sodium Polyacrylate

Sodium Polyacrylate is known as water-lock. Figure 2 shows the chemical composition of the sodium Polyacrylate. It is a sodium salt of Polyacrylic acid with the chemical formula [-CH_2-CH (CO_2Na) -] $_n$. It has the ability to absorb as much as 200 to 300 times its mass in water. As you can see in Figure 3, the water was fast absorbed by the sodium Polyacrylate and solidified leaving no liquid behind in the cup. Sodium Polyacrylate is an anionic polyelectrolyte with negatively charged carboxylic groups in the main chain [4]. The material was provided from Powder Pack Chem, Product Code: 9003-04-7: Mumbai, India, with high purity. Polyacrylate being a powder is dry blended with cement at different concentrations depending on the application. Polyacrylate can also be used in neat cement (is cement mixed with water with no additives) or density slurries improve stability, fluid loss, free water, and compressive strength.

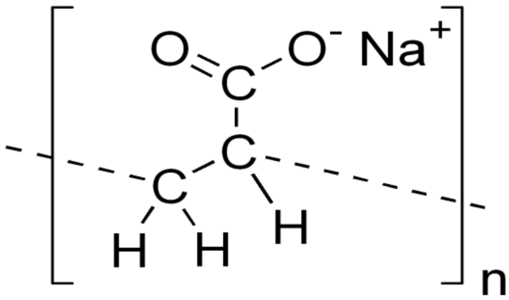

Fig. 2: Sodium Polyacrylate chemical compound [6]

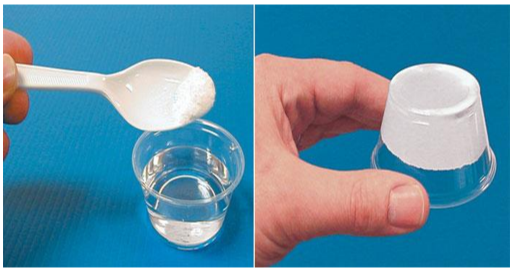

Fig. 3: Sodium Polyacrylate to be mixed with water and turned into a gel

2. Cement slurry

Cement slurry was prepared according to the cementing program in Zubair Field, Basra, Iraq. The mixing method strongly influences on slurry and set cement properties. The composition of the cement slurry formulation is shown in Table 1.

Slurry Feature

The variables involved in the design of the cement slurry can be summarized in Tables 2 and 3.

Table 1: Percent of cement composition used

Cement materials	First combination	Second	Third	Forth
Cement (gm)	270	270	270	270
Silica sand (gm)	42	42	42	42
Water (ml)	125	125	125	125
Sodium Polyacrylate (%)	0	5	10	15

Table 2: Standard Specification of cement slurry

Variables	Unit	Value (min.)	Value (max.)
Density of cement Slurries	lb/ft^3	110	123
Free water	cc	<2.5	2.5
Initial Setting Time	min	95	140
Final Setting Time	min	140	185
Fluid loss	cc/30 min	100	150
Compressive strength after 8 hours	Psi	500	>500

Table 3: Specification of Tail cement slurry for Zb-229 and cement slurry of present work

Variables	Unit	Zb229	Present work
Density of cement Slurries	lb/ft^3	118.2	113.5
Free water	cc	2	1.35
Initial Setting Time	min	NA	145
Final Setting Time	min	275	190
Fluid loss	cc/30 min	NA	100
Compressive strength	Psi	945	1708

Results and Discussion

Cement slurry must be tested before starting the cementing process. Evaluation of cement slurry can be done through the following tests:

1. Cement Strength Tests

Where examined the compressive strength using all sample cement prepared according to Table 1 at curing time periods, 8 hours, by using pressing affixed amount 3000 psi. Figure 4 shows the results after 8 hours curing time were the cement slurry where the concentration of Sp 15% has a higher compressive strength which reached up to 1700 psi. Figure 5 shows the models of cement with different additions of material. The figure shows the addition of 0, 5, 10, and 15% (weight percent) of SP.

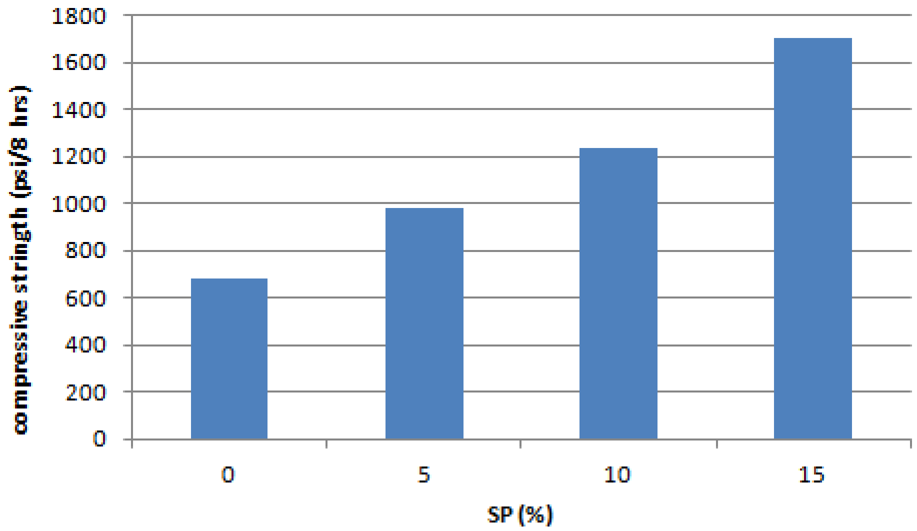

Fig. 4: Compressive strength of cement rock with different SP wt %

Fig. 5: models of SP addition to the cement

2. Density

In this experiment the density increases by adding different SP wt %. Figure 6 show that the highest density is 113.5 lb/ft^3 with the addition of 15 wt % of SP. Generally SP addition didn't make significant change in density of prepared cement slurry.

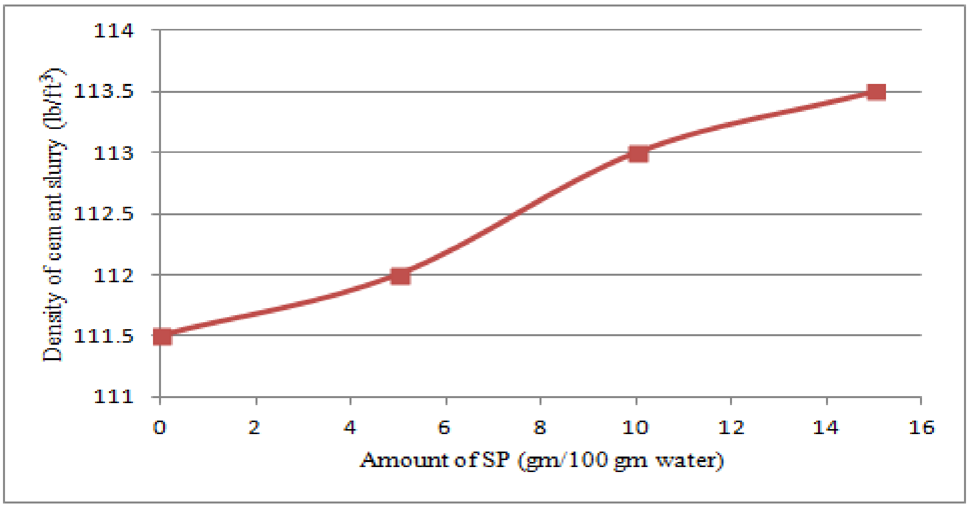

Fig. 6: shows the relationship between density and SP addition

3. Shear Rate and Shear Stress

Shear rate and shear stress also had been studied in this study. Figure 7 shows the results of adding SP on shear rate verses shear stress. We note that the adding of SP decreases the relationship between shear stress and shear rate and in a constant ratio of change about 13%. It is highly affect the performance of slurry and water cement ratio with 15 wt % of SP to a great extent improve its strength and durability to compacted slurry reduce permeability and binding to the slurry.

As concentration increase improves early compressive strength and reduces the free water; increase the viscosity of cement slurry and their packing untimely will decrease permeability.

The addition of SP more than 15 wt % of SP will increase pump pressure and sometimes lead to stop circulation [7].

The filtration should be little in order not to affect the productive zones and mainly not to have high consistency for cement slurry to avoid the above mentioned problem.

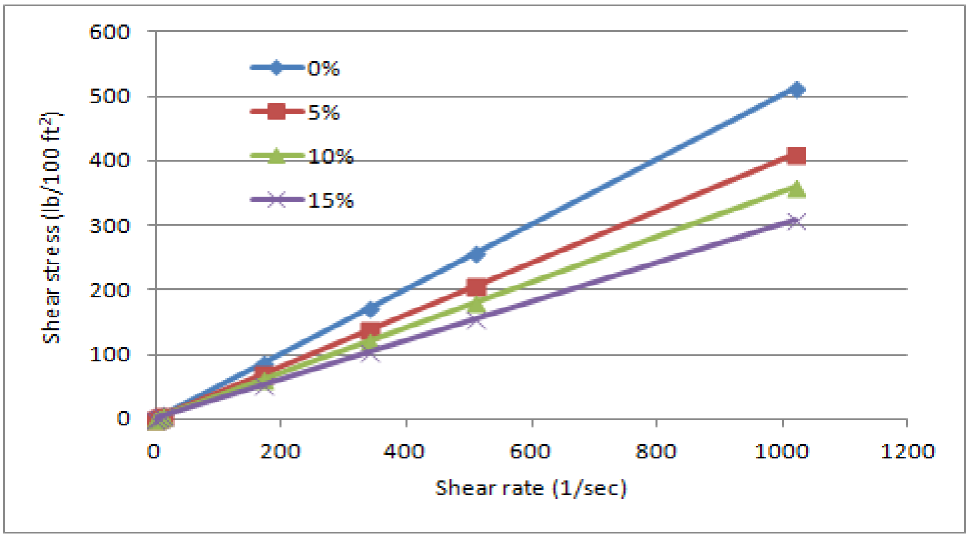

Fig. 7: shows the relationship between shear rate and shear stress

4. Initial and Final Setting Time

Figure 8 shows the relation between the initial and final setting time with different SP wt %. As shown in the figure the adding of sodium Polyacrylate have a negative effect on initial and final setting time and the amount of change reached to the highest value of reduce between 10-15% by adding. The adding of Sodium Polyacrylate accelerates the initial and final setting time. Adding 15% of Sp reduces from 187 to 145 min and from 245 to 190 for the initial and final setting time respectively.

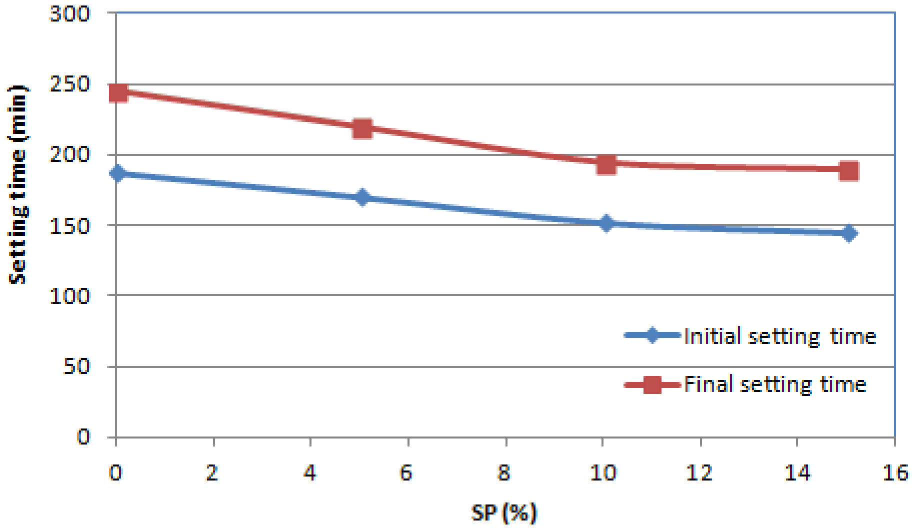

Fig. 8: Initial and final setting time

5. Free Water and Filtration

The cement slurry has free water equal to 3 cc without adding the SP, but after adding it the free water decrease. Figure 9 shows the relation between the free water with different SP wt %. We note that adding of SP decreases the free water in a constant ratio of change about 25%. It is highly affected on the stability of slurry and water cement ratio with 15 wt % of SP which decreased by more than 50% of free water. The displaced water from the cement slurry formed was from (3-1.3 cc).

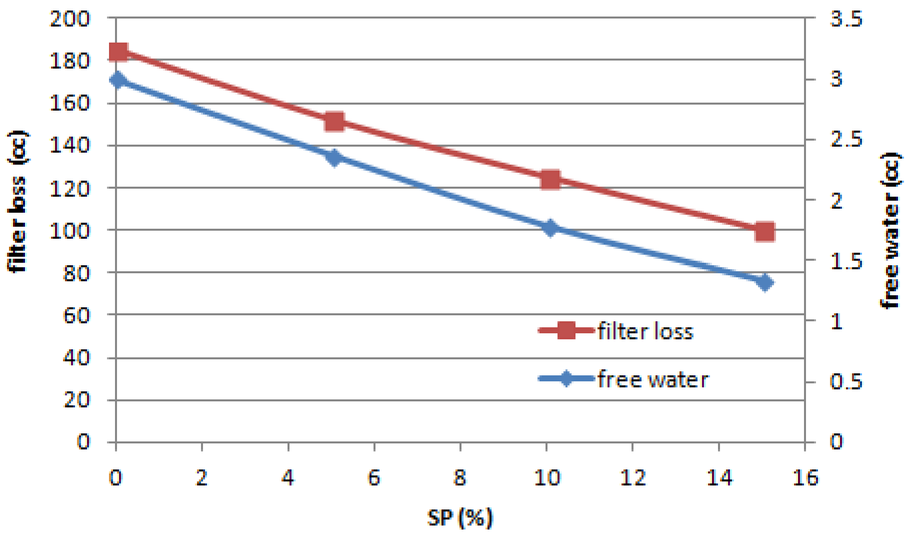

Fig. 9: shows the relationship between filter loss, free water with SP addition

Also, Figure 9 shows the relation between the filter loss with different SP wt %. The cement slurry has filter loss of 185 cc without adding the SP, but after adding it the quantity decrease. We note that the adding of SP decreases the filter loss in a constant ratio of change about 20%.

Conclusions

The use of Sodium Polyacrylate in cement increased the cement strength due to internal curing process. The concentration of Sp 15% has increased the compressive strength from 680 to 1700 psi. The excessive amount of Sodium Polyacrylate used in cement has a substantial significant effect on the cement strength. SP addition didn't make significant change in density of prepared cement slurry. Specific weight of cement slurry in all the reading considered moderate type. SP was highly affected the performance of slurry and water cement ratio. SP to a great extent improve its strength and durability to compacted slurry reduce permeability and binding to the slurry. Also, the adding of Sodium Polyacrylate accelerates the initial and final setting time. It decreases the initial and final setting time and that's considered good cement. Finally, the adding of SP decreases the free water and filter loss because of his superabsorbent ability of water. It highly affect the stability of slurry and water cement ratio, but the addition of SP should not be more than 15 wt % to avoid the increase pump pressure because increase the viscosity of cement slurry and sometimes lead to stop circulation.

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