International Journal of Advanced Engineering Research and Science (IJAERS)
Peer-Reviewed Journal
ISSN: 2349-6495(P) | 2456-1908(O)
Vol-11, Issue-1; Jan, 2024
Journal Home Page Available: https://ijaers.com/
Article DOI: https://dx.doi.org/10.22161/ijaers.11.5

Effect of Calcium Carbonate on the Properties of Acid Soluble Cement Slurry

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Received: 01 Dec 2023,

Receive in revised form: 04 Jan 2024,

Accepted: 15 Jan 2024,

Available online: 22 Jan 2024

***Keywords*— Plug cement, Acid soluble cement, Calcium carbonate, thickening time, Compressive strength.**

***Abstract*— *Cementation process in oil well drilling can be challenging, causing serious well control issues. The properties of cement slurry aid the designer to know the accurate dynamic placement of the cement slurry from surface to downhole of the wellbore. It presents the stability of locally sourced $CaCO_3$ and class G cement slurry blend, giving insight to the effective pumpability and setting time for better slurry placement. Utilization of locally source recipes serving as an alternative use to imported additives in the reduction of oilfield cementation operations is imperative, considering the cost of imported chemicals. In this paper, fine $CaCO_3$ identified as an acid-soluble additive was used for the design and formulation of a plug cementation operation through coil tubing for zonal isolations. Four different blends of $CaCO_3$ containing 20%, 25% 30%, 40% BWOC and 100% Class 'G' cement used for the experiment at a test temperature of 175degree F BHST and a slurry density of 15.8ppg to ascertain the impact of $CaCO_3$ on the mixability, pumpability, stability on the cement slurry. The placement time and strength data of cement slurry is very crucial to meeting planned cementing schedule. From the thickening time evaluation, at 40BC an average range of 8hrs-11hrs pumpable time was deduced for all blends. However, the point of departure for 30% $CaCO_3$ BWOC showed a better result. The result helped to provide real-time information about the initial compressive strength development in the slurry specimen and this aids in determining waiting on cement time (WOC). It indicates that the more calcium carbonate in the system, the lesser the strength which means that the presence of calcium carbonate reduces the compressive strength in an acid-soluble cement slurry compared to the neat slurry. The paper presents experimental details on the average wait on cement time and the pumpable time for acid soluble cement slurry, contributing to data gathering and proper well planning before execution and. competency in the use of the slurry designs have been established in this work.*

I. INTRODUCTION

Cementing an oil well may be challenging and lead to major well control concerns owing to the high chance of fluid loss during the operation. This might make the cementing process more expensive than necessary. Remedial cementing, also known as secondary cementing, is carried out if there is a concern about the well's performance throughout any stage of its life cycle, including construction, stimulation, production, and abandonment. This is done to mitigate problems that are associated with primary cement. [9,19, 20, 15]

The remedial cement operation is categorized into two broad categories know as squeeze cementing and plug cementing. The plug cement is the placement of certain volume of slurry into the wellbore leaving it to set. It can be temporary or permanent plug within a cased or open hole section purposefully as a sealant to lost circulation zone, seal-off zones that have depleted over time, during directional drilling operation, as an anchor for well testing in open hole and as an isolation for wells abandonment. Acid soluble cement slurry used as a plug cement requires as much technical, engineering, and operational experience to enable adequate planning and risk assessment to cement placement. Therefore, accurate knowledge of its properties is imperative. [11, 12, 13, 14]

On the topic "A study of acid cement reactions using the rotating disk apparatus" found out that class G cement can be used to prepare cement plugs for sectional isolation and how acids react with the remedial cement plugs [18]. The objective of the work was to understand the nature of the reaction of class G cement plugs with the various acid types to mitigate the instability of plug placement during primary squeeze cementation. From the analytical procedure, the class G cement used was Saudi class G and inductively coupled plasma emission spectroscopy (ICP) was used to analyze the number of different cations (Aluminum, Iron, Calcium,) present in the class G cement then the rotating disk apparatus was used to react the cement plug with various acids for dissolution in a dynamic condition.

The work "Low-density acid removable cement as a solution for lost circulation across producing formation" confirmed the use of lightweight acid soluble slurry as a plugback cement to cut off "barefoot" (open hole) horizontal segment of a producing well-bore. Implementation of this type of plug cement that is in accordance with oil well cement parameters was done in the Middle East where it was applied as a lost circulation cement for the temporary plug to strengthen the wellbore environment and enable drilling with reduced effect of well control challenges.

In the journal "particle size distribution acid-soluble Cement instituted that a multi-modal particle size distribution cement design was used to achieve the required acid-soluble slurry and set cement properties owing to the fact that the cemented laterals with its numerous advantages still have increased wellbore friction pressure during stimulation resulting to damages.[10]

Considering the minimal pressure required (6500psi as highest-pressure difference between plugs) for placement operation, in "Successful Application of acid-soluble plugs in open hole slotted-liner completion" studied and surveyed several plugs. [23] In the bit to assuage well control issues resulting from huge losses when closed hole circulation drilling techniques (CHCD) is deployed with 5½'' liner and cemented with primary cement for wellbore stability, this has been intricately seen unsafe therefore, open-hole slotted-liner with pre-installed acid-soluble cement (ASC) slurry was evaluated and consider fit for purpose for well completion procedure at the reservoir section in the work. The acid soluble plug used was magnesium-based cement plug where the permeability of the producing zone can be reinstalled with an acidizing process. The ASC was characterized by the following properties: low permeability rate to alley losses, good compressive strength for wellbore stability, exhibits thermal expansion, 100% dissolvable in 15% HCl acid to enhance well productivity, non-contamination with drilling fluids or completions fluids and easily drilled out [16]. The benefit of the study indicated an increase in well production as possible producing zone damage and partial perforation skin effect is reduced, the time and cost required for commission operation are mitigated using the open-hole slotted-liner with dissolvable cement (ASC) and lastly eliminating perforation operation issues (lose of gun in the wellbore).

Conventional Portland cement with a blend of various sized calcium carbonate and magnesium oxychloride cement were the two types of acid-soluble cement slurries in "Detailed Laboratory Experiment of Acid Solubilized Cements as Remedy for Missing Circulation from across Producing Zones." [6] This analytical investigation established stable rheological properties with densities of 13ppg to 15.8ppg (pound per gallon) at 300% $CaCO_3$ bwoc also, lower compressive strength property with increase in the quantity of $CaCO_3$ in the conventional Portland cement-based system due to lower cementitious or binder additive was established but the acid dissolution was not 100% nevertheless, the magnesium oxychloride cement (MOC) type showed complete acid dissolution.

In the work "Low-density acid removable cement as a solution for lost circulation across producing formation" confirmed the use of lightweight acid soluble slurry as a plugback cement to cut off "barefoot" (open hole) horizontal segment of a producing well-bore [5]. Implementation of this type of plug cement that is in accordance with oil well cement parameters was done in the Middle East where it was applied as a lost circulation cement for the temporary plug to strengthen the wellbore environment and enable drilling with reduced effect of well control challenges. It was also introduced to kill and abandon problematic well however, enable re-entering of the well after acidizing the abandoned zone [17]. This work identified that adjustments can be made to the cement type such as its density, thickening time, compressive strength properties, and bonding strength to suit the oil well specification for plug jobs as zonal isolation.

The bulk of the existing literature reviews have taken a quantitative approach and therefore, there is a need for a qualitative approach to the topic. Although some studies have examined different types of acid-soluble cement slurry, the research gaps limit our understanding of how calcium carbonate obtained in Nigeria can impact the properties of a plug acid-soluble cement. There is a lack of research on locally sourced calcium carbonate effect on the properties of acid-soluble cement slurry on its stability in the wellbore deployed to optimize placement time and tensile strength. Therefore, this study aims to analyze the impact calcium carbonate will have on acid-soluble cement slurry properties such as the thickening time, and the compressive strength. All these properties determine the placement time and the stability of the cement slurry in the wellbore when faced with the challenge of curing a lost circulation problem [8]. It will also increase the competency level on the subject.

II. MATERIAL AND METHODS

This analytical study is centered on describing and evaluating the effect of calcium carbonate on the properties of an Acid soluble cement slurry. Description of the materials and equipment in the experimental study used in achieving the objective of this study is stated below. [1, 2, 4, 7]

2.1 Materials

- Mixer
- Atmospheric Consistometer
- Pressurized consistometer
- FANN – 35 Rotational viscometers for Rheology
- Fluid loss equipment
- Free Water separation
- Ultrasonic cement analyzer (UCA)

2.2 Additives

i. Class G cement
ii. Calcium carbonate fine
iii. Deformer
iv. Friction reducer
v. Fluid loss additive (a synthetic co-polymer)
vi. Fluid loss additive (a synthetic polymer)
vii. Retarder
viii. Freshwater

2.3 Cement Slurry Formulation

From Table 2.3 below the slurry was designed and formulated with various ratios of locally sourced $CaCO_3$ mixed with conventional Portland cement to generate Acid soluble cement slurry (ASC) which was homogenously mixed, conditioned to the test temperature of 175degree F to obtain the thickening time and compressive strength properties.

Table 2.3 Recipe of Acid soluble cement slurry

MATERIAL	CONCENTRATION
Dyckerhoff Class G	Varied (80,75, 70, 60,100)
Calcium Carbonate (CaCO3)	Varied (20, 25, 30, 40, 0)
Dispersant	0.3%BWOC
Fluid Loss Additive (Polymer)	0.5%BWOC
Fluid Loss Additive (Co-Polymer)	0.5%BWOC
Retarder	0.15%BWOC
Defoamer	0.05gps
Fresh Water	41.67 L/100kg

2.4 Methods

The experimental work was carried out in a cement laboratory, so results will be subject to ambient weather conditions during the experimental work.

This section gives the detailed procedure of equipment usage, slurry conditioning procedure, thickening time procedure and ultrasonic compressive strength procedure of the slurry design.

2.4.1 Weighing

The weighing scale was used to measure the design recipes. This helps to keep tabs on the accurate amount of the recipe needed for preparation of the product.[3]

Fig.2.1 Weighing Scale

2.4.2 Mixing

After measuring the additives, a warring blender as shown in fig 2.1 below was used to mix a homogeneous slurry. Mixing of the additives required following the right mixing order as follows: Water, deformer, friction reducer, fluid loss additives, retarder, and a mixed blend of cement and calcium carbonate in their ratios,

Turning the blender to 4000 rpm while adding the additives, and then turning the blender speed to 12,000 rpm for 30seconds makes a cement slurry that is ready to be conditioned. [3, 4 ,7]

Fig.2.2 Fann Model 7000 Mixer

2.4.3 Thickening Time Test Procedure

This test evaluates the time at which the slurry sets, and the HTHP consistometer is used for the test. The cement slurry was conditioned to the BHST in the atmospheric consistometer shown in fig 2.3 then placed into the pressurized consistometer as shown in fig 2.4 to determine the thickening time of the slurry for the various blend ratios [24, 25]. The following procedures are followed for the evaluation: All parts of the assembly cup are gathered; the cup thread is greased.

and correctly coupled, then the slurry was poured in, and the hexagonal plug (pivot bearing) screws the cap tightly and excess air and slurry is removed. Place the slurry cup into the pressurized consistometer. Start within 5 minutes, by turning on the motor and the drive table rotates the slurry cup at 150 rpm. The potentiometer is placed on the rotating slurry cup, aligning the slots in the potentiometer with the inside of the cylinder and the bar drive is engaged and all set-ups of the test are carried out according to recommended practice. Input the test parameters into the computer software to perform the test to the testing temperature, pressure and Ramp time as the heater and timer are switched on to start data acquisition. After the test result was obtained, the controller/ software was turned off and result generated, the chamber was allowed to cool and the consistometer was open to remove and clean the potentiometer with WD-40 solvent. Slurry cup was disassembled, and all components cleaned.

Fig.2.3 Atmospheric Consistometer

Fig.2.4 Pressurized Consistometer

Fig.2.5 Parts of the pressurized consistometer

2.4.4 Ultrasonic Cement Analyzer (UCA) test procedure

The test is done to analyze the slurry strength. It is the ultrasonic strength of the slurry when spotted in the wellbore [21]. The following procedures were taken for the testing. The conditioned cement slurry was filled into the cell to the level gauge and the transducers coated with ultrasonic couplants (gels). O-rings were inspected for damage to ensure no pressure loss. All the algorithms for the cement density and design are selected in the computer software. Then the equipment is pressurized to 3000psi for the transit signal. During a typical cure, temperature and pressure are applied beginning with the recording of the transit time and ending when the test is completed. After a result has been obtained, the machinery is shut down, dismantled, and cleaned.

Fig.3.8 Ultrasonic Cement Analyzer

III. RESULTS AND DISCUSSIONS

The following results are discussed below in accordance with the slurry properties considered in this work.

3.1 Thickening Time

Each combination of acid-soluble cement and plain cement was tested for how long the resulting slurry could remain liquid under downhole conditions and pump effectively to the wellbore using a procedure called the thickening time test. This placement time which is very crucial should be simulated to meet the planned cementing schedule as possible. Typically for a batch-mixed cement job where a liner hanger is used, the periods that make up pumpable cement are the slurry batch mixing time, pump time, liner plug release time, displacement time, liner hanger setting time, circulation or reverse out time, and safety margin of 2hours. Therefore, the minimum thickening time is engineered to consider all of this to optimize good slurry design and planning. The thickening time chart from Figure 3.1-Figure 3.5 was summarized in Table 3.1 of the acid-soluble cement slurry showing a time range of 8 hours to 11 hours, indicating longer setting time. This placement time which is very crucial should be simulated to meet the planned cementing schedule as possible. The ratio of 30/70 showed good PoD (point of departure). The right data development and competency in the use of these slurry designs have been established in this work.

Table 3.1 Thickening time Evaluation (BHCT:175°F, BHP: 6400psi, Heating Time: 48Mins)

	20/80 Ratio (HH:MM)	25/75 Ratio (HH:MM)	30/70 Ratio (HH:M M)	40/60 Ratio (HH:MM)	100% Cement (HH:MM)
30Bc	09:20	08:40	07:39	08:08	10:59
40Bc	09:28	08:47	07:48	08:09	11:02
50Bc	09:34	09:17	07:52	08:11	11:25
70Bc	09:59	09:22	08:17	08:13	11:28
100Bc	10:05	09:25	08:20	09:02	11:29

3.1.1 Thickening Time Charts for all blends of slurries

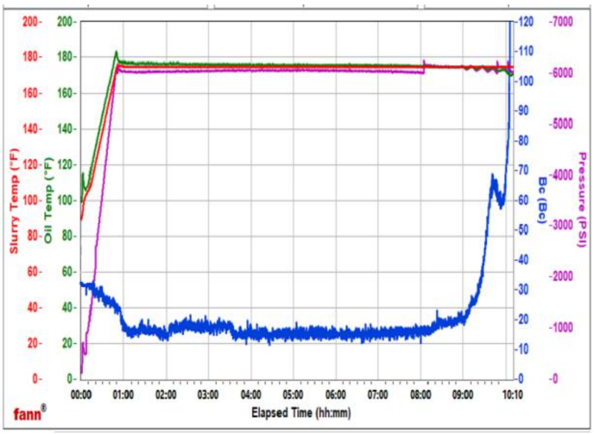

Fig.3.1 Thickening time for blend mixture 20/80

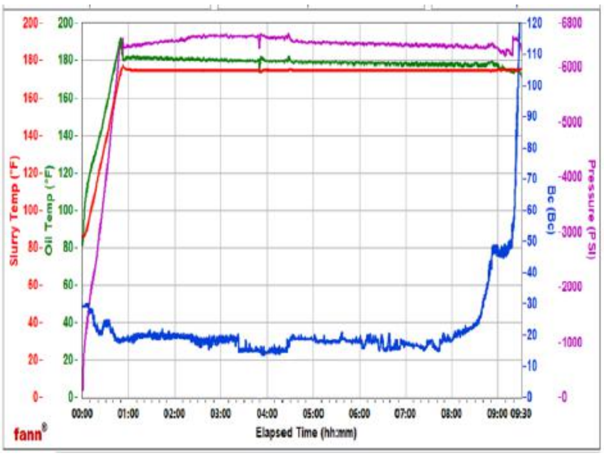

Fig.3.2 Thickening time for blend mixture 25/75

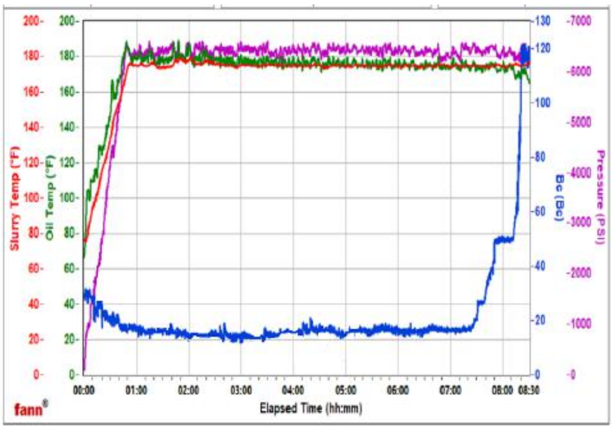

Fig.3.3 Thickening time for blend mixture 30/70

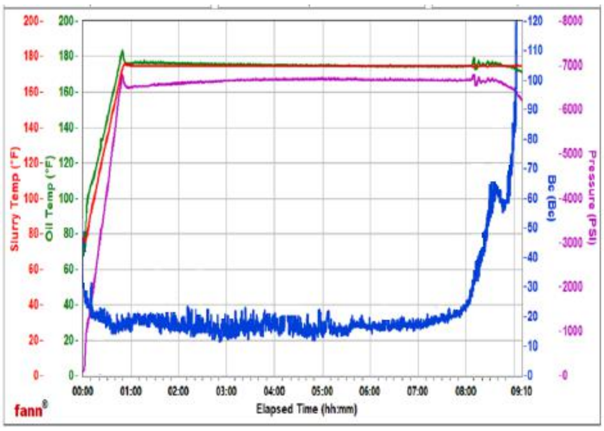

Fig.3.4 Thickening time for blend mixture 40/60

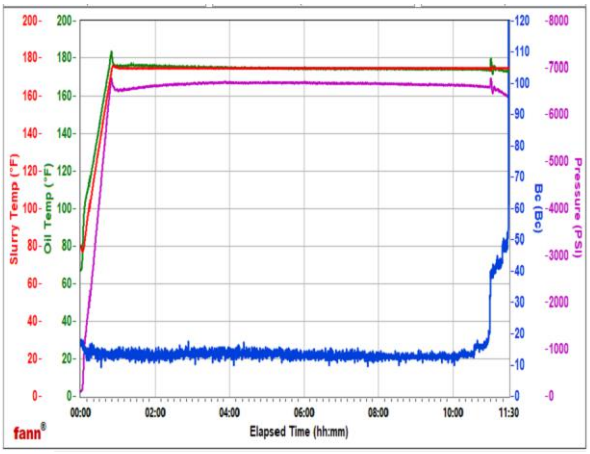

Fig.3.5 Thickening time for 100% cement

3.2 Compressive Strength (UCA)

Ultrasonic cement analyzer (UCA), a non-destructive test type for compressive strength of cement slurry measures and records the inverse P-wave of the velocity through the slurry as a function of time. After the conditioned slurry was inserted into the testing equipment, the cement bond log was calibrated by calculating the attenuation time using the sonic time plot shown in Fig 3.6 – Fig 3.1.0. The result helped to provide real-time information about the initial compressive strength development in the slurry specimen and this aids in determining waiting on cement time (WOC). The compressive strength which provides the strength data of the slurry under downhole conditions was evaluated and the sustained compressive strength reading was taken as shown in Table 3.5, and as a summary of all the design specimens in Fig 3.6 to Fig 3.1.0. indicates that the more calcium carbonate in the system the lesser the strength which means that the presence of calcium carbonate reduces the compressive strength in an acid-soluble cement slurry**.** it is important to note that the slurries designed in this work using locally sourced additive fit for purpose for a plug cement operation depending on well parameters that need longer timing as the strength development of the slurries at 50psi and 500psi was within a range of 9hrs-10hrs. Standard authorities adhere to compressive strength for a cementing process as follows: 50 to 200psi is adequate to support casing, 500psi is adequate for cement drill-out, 1000psi for perforation, 2000psi for stimulation of wellbore and the sidetracking job should have a pressure more than adjacent formation[22]. The experimental details obtained can contribute to data gathering and proper well planning before execution.

Table3.2 UCA test Evaluation

	20/80 Ratio	25/75 Ratio	30/70 Ratio	40/60 Ratio	100% Cement
50psi (hh:mm)	09:22	10:01	09:27	09:56	07:36
500psi (hh:mm)	10:44	11:31	10:52	11:40	08:34
12hr CS (psi)	850	630	837	577	1184
24hr CS (psi)	1748	1456	1831	1411	1868

3.2.1 UCA- Compressive Strength Charts

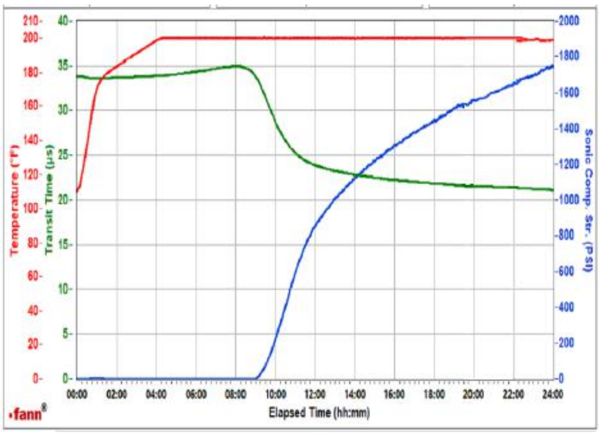

Fig.3.6 Compressive Strength for blend mixture 20/80

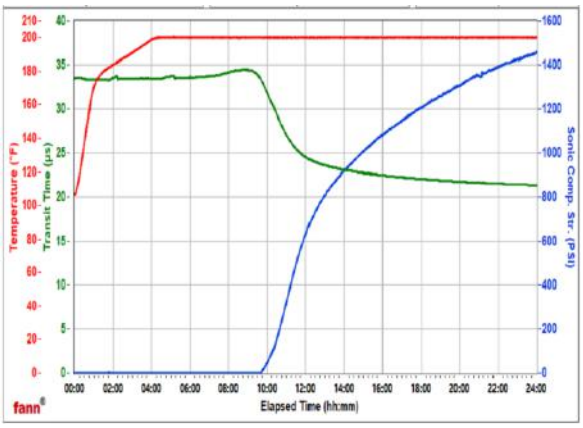

Fig.3.7 Compressive Strength for blend mixture 25/75

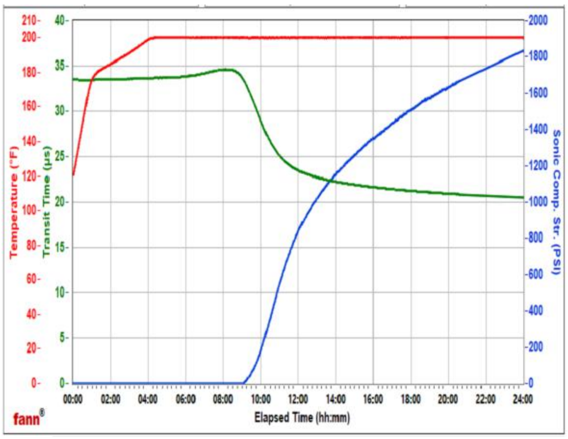

Fig.3.8 Compressive Strength for blend mixture 30/70

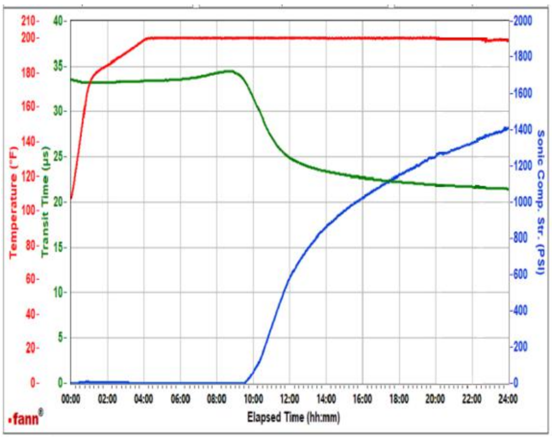

Fig.3.9 Compressive Strength for blend mixture 40/60

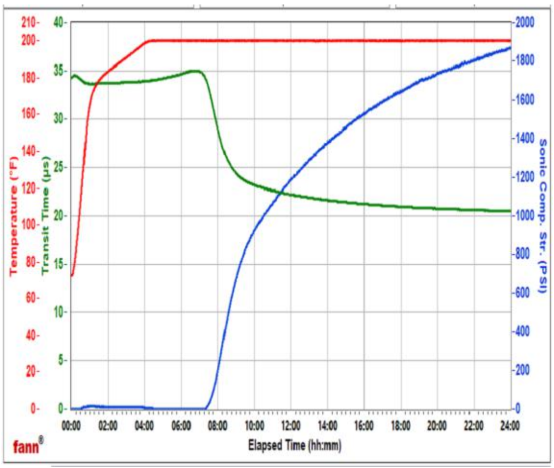

Fig.3.1.0 Compressive Strength for 100% Cement

IV. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

Materials such as fluid loss additives, viscosifier, retarder, deformer, dispersant, cement, and locally sourced fine calcium carbonate needed for the experiment were identified for successful analysis. The concentrations of the additives were formulated to give a stable designed slurry. Calcium carbonate of varying ratios (0, 20, 25, 30, and 40%) BWOC were analyzed. From the analysis, it was deduced that 30% calcium carbonate by weight of cement gave the optimum thickening time (TT) and compressive strength. This is because the point of departure for TT and the wait on cement (WOC) time was better than other ratios used in this work.

4.2 Recommendation

The downhole temperature for production zone is typically between 145ºF to 190ºF. This research was conducted at 175ºF. Hence, it is recommended to conduct further research at temperatures below and above 175ºF to increase data gathering and proper well design and execution.

ACKNOWLEDGEMENT

The authors would like to appreciate the support of Halliburton Fluids laboratory and Baker Hughes cementing professionals in Nigeria. The Authors would also like to appreciate the University of Port Harcourt and Prof. Joel Ogbonna of the World Bank Center of Excellence in Oilfield Chemicals Research for their guidance to the successful completion of this experimental research.

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