American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-10, Issue-8, pp: 07-11
www.ajer.org
Research Paper Open Access

Laboratory Investigation of Slag Mix Cement Slurry for Improved Well Completion Performance.

Akpoturi Peters
Department of Petroleum Engineering
Federal University of Petroleum Resources Effurun, Delta State.

ABTRACT
Numerous effort has recently been embarked upon, on a number of initiatives to reduce well cost and associated well cost. This drive has led to the laboratory investigation of slag-mix cement in Irri field, in Isoko South Local Government Area of Delta State.. The trial attracted a saving of 55% on slurry cost compared to class "G" cement. A bond log taken to evaluate the job indicated excellent cement bond across the cemented interval. In addition, the use of slag-mix was found to be an effective way of disposing spent mud. Similar trial carried out in in other fields in the Niger Delta, confirmed the same results. In view of these facts, use of stag-mix in different operation in the Niger Delta wells will enhance economic growth and maximize profit in the long run .
KEYWORDS; *Slag- mix, cement, slurry, well, costing, disposing and water based mud*

Date of Submission: 18-07-2021 Date of acceptance: 03-08-2021

I. INTRODUCTION

Slag-mix is a slurry formulated from water based mud and ground blast furnace slag (BFS) a waste product of iron smelting process(1). The three additives required to formulate the slurry are caustic soda and sodium carbonate (activators), and lignosulphonate. In the presence of chemical activator, the slurry sets to a cement-like-solid called slag-mix cement. This mud-to-cement technology has a high chemical bonding with great tixial strength.(2) .

advantages of slag-mix in Niger Delta operations, are reduced cementing cost, improved mud displacement, improved annular gas migration control and reduced impact on the environment from mud disposal. The trial involved cementing the 7"intermediate casing section using the slag-mix slurry.(3,4)

II. METHODOLOGY

The raw material required to formulate slag-mix slurry are slag, mud ,sodium hydroxides, Sodium carbonate and lignosulphonate. With the exception of slag, the other chemicals were sourced locally. The slag was gotten from DSC Ovwian Aladja from, Nigeria. This slag meets ASI MC-989 specification on 'standard specification for granulated BFS for use in concrete and mortars. The grade of the slag is ASTM 120. It has an amorphous (glass) content of more than 85% and fineness of 600m^2kg. .

Cement is a major contaminant to slag-mix slurry. One area of concern was to execute the trial investigation without contaminating the slag with class "G" cements since the silos at the well site are used for storage of Cement. The first option was to mobilize a separate cement barge while the second option was to use the existing cement barge. Because of the huge cost involved in mobilizing new cement barge, the second option was selected, the cementing contractor however replaced one of the cement silos with a new silo for bulking the slag for the purpose of the laboratory investigation.

LABORATORY EXPERIMENT;

Laboratory tests were carried out prior to spudding the trial well. The purpose was to get a guide on the expected recipe, The KCI-Polymer mud used for the pre-trial tests was prepared such that its properties matched the KCI-Polymer mud in the well drilling program. Additives used were sodium hydroxide, sodium(retarder/dispersant). The optimum recipe determined (activators), and chrome free lignosulphonate after a series of tests gave a thickening time of 6 and 4hours for lead and tail slurries respectively. Similarly, the twenty-four hour compressive strengths for this slurries respectively, recipe were 1000 psi and 1800 psi for the lead and tail.

The laboratory tests revealed that addition of specified quantity of slag to the base mud to achieve the desired slurry weight resulted in a viscous slur' too difficult to pump. This was due to high yield point of the mud. Following this observation, the mud was diluted with water and dispersed using chrome free lignosulphonate. This way, it was possible to add the correct quantity of slag while maintaining slurry with good flow behaviour. This was found to be an advantage because the higher the concentration of slag in the mix, the more the compressive strength of the slag-mix cement.(5)

A lead and tail slurries with density of 0.702 psi/ft and0.780 psi/ft respectively were designed for the Job. The aim was to achieve higher annular fill at reduced BHP to avoid breaking down exposed weak formation. The table below shows the designed recipe per barrel of KCI-Polymer mud.

Table 1: Pre-trial recipe

	Lead	Trial
Base mud density	0.458 psi/ft	0.478 psi/ft
BFSconcentration	416ppb	645ppb
NaOH conc.	6 ppb	5.5 ppb
Na_2CO_3conc._	10ppb	l2ppb
lignosulphonate	2.5 ppb	4 ppb
Slurry density	0.703 psi/ft	0.780 psi/ft

III. DISCUSSION;

One of the silos on the cement barge was used to store class '0' cement. All the lines from the three the slag white the remaining three silos were used to class "G' cement silos were shut off to avoid accidentally mixing the slag with class "G" cement. The remaining cement lines, surge and mixing tanks were cleaned with water before the investigation. The mud was isolated in one of the mud tanks two days prior to the study. Samples of the mud, water and chemicals were taken to the laboratory to determine the final recipe. The actual sample gave a shorter thickening time compared to the recipe designed during the pre-trial tests. Consequently, the recipe was therefore re-designed as shown below. This observation indicates the need to design final slag-mix recipe with actual samples of chemicals, water and slag. Two trial test was carried out to ascertain a better test and investigation processes.

Table 2 Final recipe

	Lead	Tail
Base mud density	0.468 psi/ft	0.468 psi/ft
BFS concentration	417 ppb	655 ppb
NaOHconc.	6ppb	5ppb
Na_2CO_3 conc.	l0ppb	12ppb
lignosulphonate	5 ppb	9 ppb
Slurry density	0.702 psi/ft	0.780psi/ft

The first step in the slurry mixing process was diluting the mud to reduce its yield point followed by adding the dispersants and activators. This was followed by adding the slag on the fly to the treated mud in the cement mixer. Mixing and displacing of the slurry was completed without any problem. A total of 119bbls of slag-mix slurry formulated from 65bbls of spent KCI-Polymer mud was used to cement the casing.

While drilling the shoe track, the properties of the circulating mud did not change indicating that slag-mix is compatible with water based mud unlike class "G" cement.

After drilling the shoe track and 30 ft. of virgin cement, formation, a limit test was carried out to ensure that the7 casing shoe can withstand 0.695 psi/ft recommended in the well program based on local experience. The casing seat was leak-proof up to the maximum allowable surface pressure of I 500 psi corresponding to EMO of 0.695 psi/ft. This test confirmed that the slag-mix cement has developed the required strength.

The VDL/CBL/CET log confirmed top cement at the expected depth confirming that shrinkage is not a problem with slag-mix on setting. The log indicated good quality bond with average reading of ± 6mVacross the cemented interval. Despite several gas sands across the cemented interval, there was no gas channeling observed in the logs confirming that slag-mix can block gas migration.

The total cost of consumable (slag and additives) for the119bbls of slag-mix slurry is $13,559. The estimated cost for the same volume of conventional class "G' cement and gas bloc cement slurries were $26,125 and$49,972 respectively. This represents 55% and 75%cost savings on class "G" cement and gas bloc cement respectively.

Further study;

Following the successful trial of slag-mix cement in the Niger Delta, a comparative study was carried out with slag from other sources to determine the quality of Nigerian slag (from DSC, Ovwian Aladja) and compare it with slag from other sources that meets ASTM specification The composition, density and x-ray diffraction data determined showed a marked difference in some properties between the Nigerian slag and the slag from other Sources. The tests investigation indicated that Nigerian slag has an abnormally high iron content of 19% compared to expected level of around 1%. The Si02 and Al_2O_3 Contents are Well below the expected concentration, while the CaO, MgO and S contents are within the normal level, Furthermore, the specific gravity of the local slag is335 as against the expected value of 2.95 probably due to its high iron content,

Table 3: Comparison of Nigerian slags with slag from other notable sources.

Component	Nigeria slag (wt%)	oslo slag (wt%)	armycircle (wt%)
SiO_2	19.1	36	36.2 1.35 -
Al_2O_3	3.78	8	9.82
Fe_2O_3	19.3	0.5	1.20
CaO	36.2	37.5	38.0
MgO	14.8	12	12.6
SO_3	0.27	-	1.81
K_2O	0.05	1	0.31
Na_2O	0.07	1	0.21
TiO_2	1.35	3.5	-

Table 4: Recipe ad total quantity of additives used

Additives Lead	Lead slurry Slag lb/bbl of diluted mud	Tail slurry lb/bbl of diluted mud	Total consumed
Slag	417	655	40,000 lbs
Sodium Hydroxides	6	5	6 drums
Sodium Carbonate	10	12	21 sxs
Chrome Free Ligno	5	8.5	12 sxs
Defoamer (D047)	0.1	0.1	10 gals

Table 5: Mud and Slag-mix properties

Diluted mud	Original mud	Diluted mud	Treated mud	Lead S-Mix Slurry	Tail S-Mix Slurry
Volume (bbls)	65	87	87	65	54
S.G	1.11	1.08	1.08	1.62	1.8
PV (cP)	26	18	19	51	209
YP (lbs/ft^2)	18	8	2	5	30
Fluid loss (ml/30mins)	3.4	3.7	3.7	10	10+
Ph	9.0	9.0	13+	13.5	13
Slurry Yield (bbl/bbl)	-	-	-	1.44	1.673
24hr Comp. str. (psi)	-	-	-	1000	1812

CrO_2	0.2	-	-

Although there was no compressive strength test, the composition of the local slag indicates a slag of low reactivity that could yield low compressive strength. Hence, the local slag needs re-processing or alternatively optimizing the smelting process to lower the iron content. This is a challenge to Nigerian Engineers in view of the huge cost savings in using slag for cementing in well completions operations

IV. CONCLUSION;

The laboratory investigation trial confined that slag-mix is cheaper than class'G' cement. In addition it satisfied all standard cement quality requirements. Following the successful trial, a number of upcoming wells in SPDC are planned to be cemented using slag-mix cement.

REFERENCES

[1]. P. Fletcher 'Determination of the quality of a blast furnace slag from Nigeria". January 2006.
[2]. M. 0. Akinlade: "Slag-mix cementation on Nembe creek woll-62" June l994.
[3]. J. P. M. van Vliet and P. T. M. Reijrink "Slag-mix as anti-gas migration cement" Shell research report, SP94-2326, 2011.
[4]. ASTM C-989 Standard specification for ground blast furnace slag for use in concrete and mortars; American Society for Testing and Material Philadelphia, 2009,
[5]. J.J NAHM, R. N. Romero, K. Javanmardi K D.Flodberg, V. E. Unger, R. Keedy, M A. Beckemeier"Development and early field experience with slag-mix. August, 2009.

Thickening time (hrs)	-	-	-	5	3.25
BHST/BHCT (^0F)	-	-	-	148/120	148/120

Table 6 : Comparison of Compressive strengths

Slurry Weigth (psi/ft)	BHST	24-hr compressive strength for Slag-mix (psi)	24-hr compressive strength for class G cement (psi)
0.676	120	1040	1200
0.738	120	1800	1650
0.758	180	1860	1800

Figures for class "G" cement were obtained from Dowell's cement Laboratory database.

Table 7A : Slag-mix slurry cost for the trial

Additives	Unit weight	Total used	Unit cost, $	Total cost, $
Sodium Hydroxide	50kg/drum	6 drums	79	474
Sodium Carbonate	25kg/sx	21 sxs	19	399
Chrome free ligno	25kg/sx	12 sxs	16.5	198
D047	5gal/can	10 gal	688	688
Slag	Bulk	40,000 lb	0.195	7800
Total Product Cost				**$9,559**

Table 7B : Equivalent cost for conventional class"G" Cement slurry.

Additives	Conc. (gal/sx)	Total gal	Unit cost ($/gal)	Total cost $
D603	0.16	155.52	53.56	8330
D604	0.16	155.52	31.84	4953
D047	0.005	5	68.79	344
Pre flush(CW100)		1260	1.445	1821
Cement		24.639 MT	$270.99/MT	6677
Total Product cost				**$22,125**

Table 7C : Equivalent cost for gas block cement slurry

Additives	Conc. (gal/sx)	Total gal	Unit cost ($/gal)	Total cost $
D047	0.005	5	68.8	344
D080	0.008	7.8	29	226
D081	0.001	1	29	29
D600	1.8	1750	20.5	35,875
Pre flush(CW100)		1260	1.445	1821
Cement		24.639 MT	$270.99/MT	6677
Total Product cost				**$44,972**

Tank dead volume =30 bbls. Slurry yield =0.206 bbls/sx. Mix water required =.076 bbls/sx.

Fig 1: 7" Casing Limit Test Plot

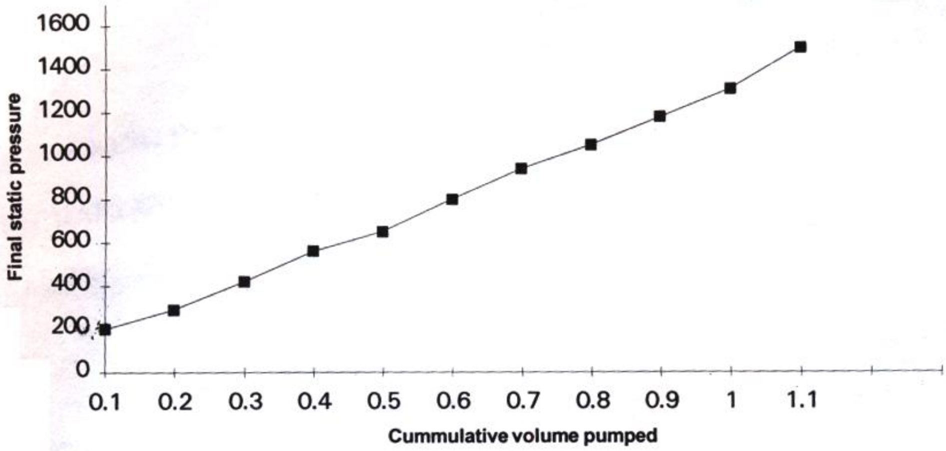
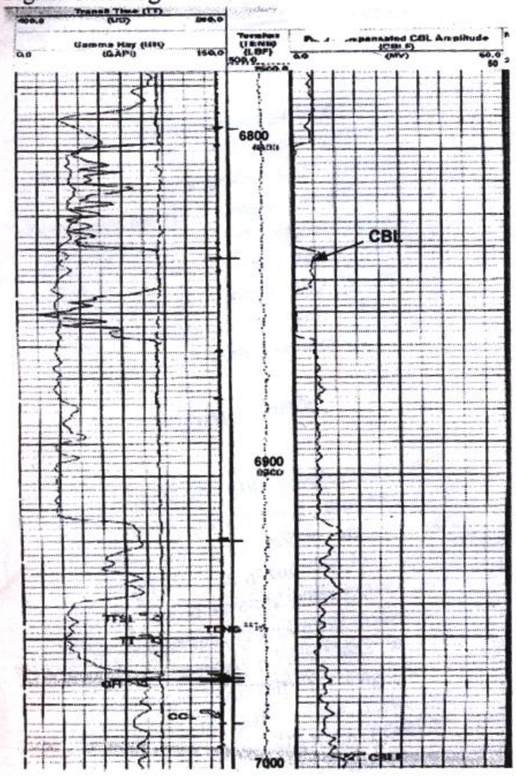


Fig. 2: CBL Log



Akpoturi Peters. "Laboratory Investigation of Slag Mix Cement Slurry for Improved Well Completion Performance."*American Journal of Engineering Research (AJER)*, vol. 10(8), 2021, pp. 07-11.