CEMENT PROPERTIES EFFECTS TO STEEL CORROSION RATE

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Abstract

Series of experiments were conducted in analysing the effect of fluid loss rate of cement slurry due to the existence of permeability contributing to the corrosion rate of cement slurry. Both class G and ordinary Portland cement (OPC) with different fluid loss were used to compare the cement protective effect on corrosion. The fluid loss was measured according to the API spec 10. 3.5% Natrium Chloride (NaCl) solution was used as the corrosion environment for reservoir and atmospheric conditions. A laboratory experiment is was done to study the influence of permeability for both types of cement. Permeability value was changed by alternating water cement ratio. Steel was put into cement mixture and left submerged in a brine solution. Submersion was done in atmospheric condition with a fixed temperature of 32^0C and 52^0C for reservoir condition. For both experiments, the A.C. Impendence technique was used. Results were discussed in depth to state that cement slurry with higher fluid loss will give a lower corrosion resistance, Rp and thus increasing the corrosion rate. Corrosion rate is higher at reservoir condition and both class G and OPC show the same characteristic and behaviour. However class G cement shows better corrosion effective characteristic. Results from the permeability experiment shows that the permeability of OPC system is higher than the class G cement as well as the permeability being higher in reservoir condition rather than atmospheric condition.

Introduction

In Malaysia, class G cement is used widely in cementing the oil well. Class G cement is an imported cement The components of the cement are Tricalcium Silicate (C_3S), Dicalcium Silicate (C_2S), Tricalsium Alumina (C_3A), Tetracalcium Aluminopherite (C_4AF), and Gypsum (CSH_2). In general, this cement has low hydration rate and forms a tight bond between the pebbles and the casing. It holds its properties at oil well temperature and pressure because it is made in such a way to suite the usage in a depth of 2440m and temperature between 80-200 ^0F. It protects the casing from any aggressive oil well liquid.

The Ordinary Portland cement (OPC) is a locally produced cement. OPC is basically used in construction work. It has a medium hardening rate and capable of holding the mineral fractions when mixed with water. The components of the cement are same as class G cement except that they vary in different ratios. In the process of making OPC rich calcium is mixed with silicon and usually they are in the form of lime and clay respectively. Portland cement is greyish in colour identifying the presence of iron.

Cementing is one of the fundamental techniques in oil well design approach. It serves its purpose as a protective material in preventing the casing from corrosion. Liquid formation characteristics such as mineral content, microrganisms, bes, acidity, leads to steel corrosion and this could be prevented by cementing. In running these experiments we determine the best conditioned cement for oil well, because it involves the study of permeability and fluid loss from the cement slurry.

Parameters like well depth, well temperature, viscosity, water content, well pressure, density of slurry were taken into account in making the cement slurry. Fluid loss from the slurry is caused due to hydration, cement structure, pressure, temperature and sea water. In addition, corrosion is a reaction where there are electrochemical corrosion, anode process, and cathode process basically involving discharge of ions.

Methodology

Apparatus such as cement mixer (two speed propeller) at 4000 rpm low speed, scaled cylinder were used to prepare the cement slurry. The slurry was prepared according to API Spec.10. Cement sample goes through a micrometer 850 filter before the preparation. Then it is mixed with distilled water where the temperature is maintained around $80\pm5\ ^0F$ and $80\pm10\ ^0F$ for the cement. Water cement ratio is changed according to respective requirement. The minimum water cement ratio allowed for the OPC and G class is 0.38 and 0.44 respectively. Finally the cement is mixed well in a mixer for not more than 15 minutes.

The fluid loss were measured using filter press, (USA Standard Sieve Series, No. 325) and scaled cylinder. The cement slurry is left in a consistormeter to achieve required temperature. Then the slurry is shifted to the filter press. where there is a tube to collect filter water. Experiments were done at $100\pm$ 5psi and 1000 ± 10 psi. Time is taken at 1/4, 1/2, 1, 2, 5, and addition of 5 minutes till 30 minutes in collecting the filtrate. The fluid loss rate was calculated using the formula below:

$$Q_{30} = Q_t + 5.477/t^{0.5}$$

Q_{30} = amount of filtrate after 30 minutes
Q_t = amount of filtrate at time t
t = time in minutes when the experiment stops

Corrosion analysis were done by using 50 litre, 3.5% NaCl solution. Specimen was made by pouring the slurry in a mould where it has holes at the bottom and closed in filter paper (Barold, catalogue no. 988).Mild steel 2 inch in diameter, and 5 inch in height were used to study the corrosivity 10 samples of Portland cement and G class cement were used in analysing the effects. The water cement ratio was manipulated so that a relationship could be developed between corrosion and ratios. The specimen was left in NaCl solution at room temperature and 52^oC in a heated container for atmospheric and reservoir conditions respectively. Corrosion rate was measured using the electrochemical impedence system (model 388). Component Ac Impedence Software Model 388 supplies the wave transmission to the electrochemical system and analyses the reception.

Permeability rate were also measured using the permeability measurement unit. The unit consist of a copper mould, mould holder, and mercury cylinder. The cement slurry is left in a water bath before it goes through the unit. The mercury cylinder instigates pressure force in order to have water movement in the cement. Scaled pipette was used to measure the water flow in the cement. Respective data was taken and the permeability rate was calculated using the formula below.

K	=	105 * (QmL/AP)
K	=	Permeability (mm^2)
m	=	Viscosity of water (Pa.s)
L	=	Height of sample (cm)
A	=	Surface of sample (cm^2)
P	=	Pressure difference (kPa)

Results And Discussion

There were 20 samples involving class G cement and Portland cement used in this experiment. Graphs were plotted to analyse the effects of water cement ratio and fluid loss to the corrosion at atmospheric and reservoir conditions. Fig. 1 shows the rate of fluid loss plotted against water cement ratio. The fluid rate loss is proportional to water cement ratio. This is due to sparseness between the cement particles when more water is added thus creating a larger void, adding more water reduces the viscosity of the slurry and increases the permeability. From Fig 1 it could be stated that class G cement has higher fluid loss compared to OPC. This due to low hydration rate in class G cement owing to low content of tricalcium aluminate.

Fig 2 shows the relationship between the solution resistance, Rs, and fluid loss. Solution resistance varies inversely against fluid loss. This supports the literature study where higher fluid loss makes the cement even more porous. This is due to the changes in microstructure of the cement. High fluid loss limits the water trapped between the capillary and gel layer which makes hydration higher. In this case hydration is stopped.

The graph in Fig 3 shows the plot between the corrosion resistance Rp and fluid loss. The graph has the same shape as Fig.2. High fluid loss makes the cement even more porous with a low Rs, ion penetration takes place where electrochemical reaction plays its part. This leads to corrosion.[Wilkin & Lawrence]. High porosity contributes to higher corrosion rate.

A few graphs were plotted to analyse permeability studies. Fig 4 depicts variability between water cement ratio and permeability. From the graph permeability varies proportionally against water cement ratio. The same reasoning was made where there is more water the sparseness is higher leading to a greater distance between the particles. The voidage is higher where there are less forces and making the permeability higher as well. From Fig 4 it was concluded that OPC has higher permeability compared to class-G cement and this is due to higher content of C_3A in OPC where hydration is higher.

Finally Fig 5 illustrates the effect of permeability towards steel corrosion. Steel corrosion increases when permeability increases. As discussed above the corrosion rate was determined using the Ac Impendence technique. Higher permeability reduces the solution resistance Rs where it creates higher voidage leading to steel corrosion.

Conclusion

Experiments involving fluid loss and permeability which eventually leads to corrosion were analysed in different situation. Understanding and the outcome of the experiments especially dealing in corrosion rates will be utmost useful for engineers. From the experiments done a few fundamental conclusions could be drawn out.

At atmospheric condition, higher fluid loss results a lower solution resistance Rs. This is due to water trapped in the cement structure. Solution resistance will increase according to time especially for low fluid loss cement. Higher fluid loss rate at atmospheric causes corrosion resistance, Rp which ultimately increases corrosion rate.

At reservoir condition low fluid loss rate leads to higher solution resistance which goes exactly the same as atmospheric condition. For higher fluid loss rate cement, the corrosion resistance Rp is higher thus making the corrosion rate slower. Overall, higher fluid loss rate at atmospheric condition leads to a higher corrosion rate and lower corrosion rate at reservoir condition. Class G cement has a higher fluid loss rate compared to Portland cement only for a certain period. Nevertheless, after the period solution resistance for this cement tends to overtake the OPC leading to a lower fluid loss rate [Fig 6]. Therefore class G cement shows better characteristics in protecting steel corrosion.

Series of experiments were done to subdue a relationship with permeability. Permeability for both OPC and G class cement varies proportionally with water cement ratio. It was known that, permeability for both types of cement at reservoir condition is higher than atmospheric condition. This is due to high temperature where it makes hydration faster as well as crystals being formed in the structure. It was concluded that higher the permeability higher the steel corrosion would be. Overall results from the experiments show that permeability of OPC cement system is higher than G class cement. In order to change this manner, there is a need of adjustment to be done on the basis of water cement ratio.

Acknowledgment

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Fig1: Fluid Loss Rate for Class G Cement & OPC at 100 psi &125⁰F(HT), 1000PSi & 125⁰F (R) and 100psi & 80⁰F(A)

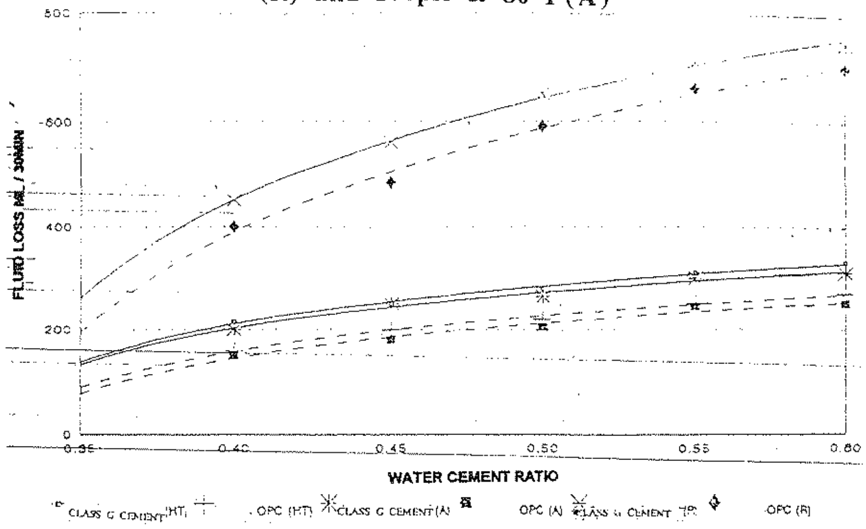

Fig 2: Effect of solution resistance towards Fluid Loss

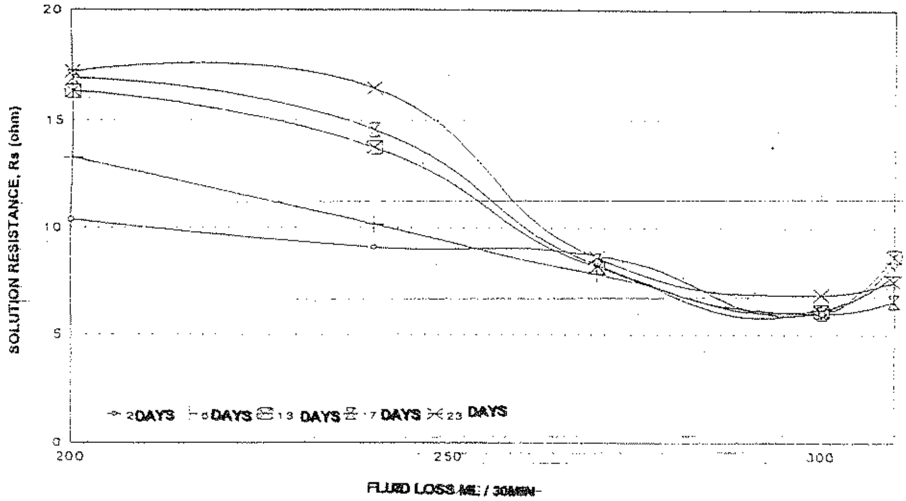

Fig 3: Effect of Corrosion Resistance towards Fluid Loss

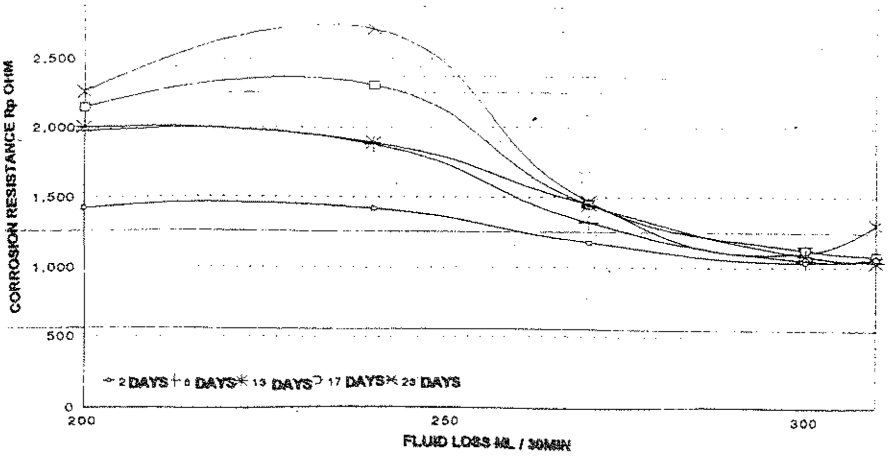

Fig 4: Effect of Permeability to water cement ratio for reservoir & atm condition

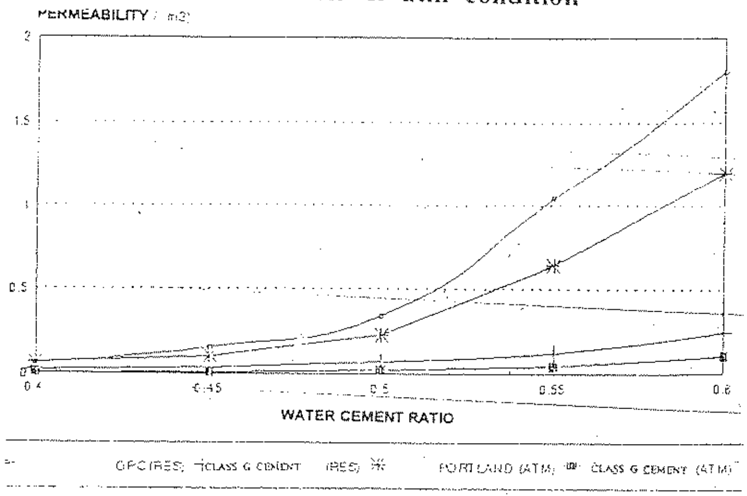

Fig 5: Effect of Permeability towards corrosion rate

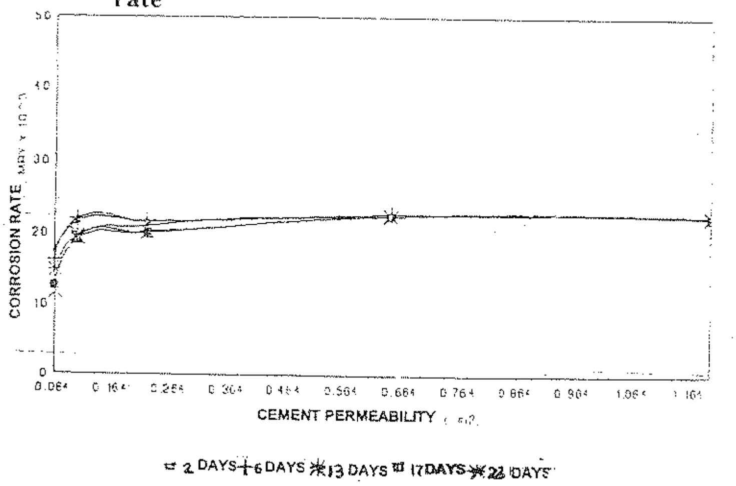

Fig 6: Comparison of solution resistance between class G cement and OPC at reservoir condition