Investigation of the Use of Organosilane in Consolidation of Petroleum Reservoirs. Case Study; Use of Sand Packs from Petroleum Reservoir Around Bonny LGA and Its Environs.

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Abstract- An experimental approach was used in this study to investigate the effect of chemical soil consolidation using organosilane on some selected sand grains collected from different oil wells. To obtain and evaluate the compressive strength, porosity and permeability of soil samples collected from the three (3) different oil well after they have been chemically consolidated using three (3) different mass concentration of 3g/L, 6g/L and 9g/L of organosilane samples. Three (3) pentagon molds from each of the oil wells was respectively injected with the selected mass concentration of organosilane on all five-sides and on the center for proper and even distribution of the organosilane within the mold, the chemically injected sand samples were then allowed to properly consolidate before been subjected to characterization for compressive strength, porosity and permeability. Results obtained shows an enormous increase in compressive strength for all the consolidated soil samples obtained from various depth of the oil well. Results further reveal the adverse effect of the chemically consolidated agent on the various sand samples.

Indexed Terms- Organosilane, Compressive strength, Porosity, Permeability

I. INTRODUCTION

Hydrocarbon which account for the highest energy source of the world has been the backbone of the power supply that has driven the economy of the beginning of the industrial all through to the technological age. The production of hydrocarbons from underground reservoirs since inception has suffered numerous setbacks as a result of poorly consolidated and unconsolidated formation, flow characteristics, etc. this setback has led to sand production, water saturated oil and gas production, all in the course of hydrocarbon production. All this setback's and more which has been identified and presented in several literatures has made the cost of processing to run into additional millions of dollars. Report from research (Nouri et al, 2003a, b) has revealed that poorly consolidated and unconsolidated reservoir covered about 70% of the worlds hydrocarbons.

To ascertain the effectiveness of chemical consolidation of soil, six samples of resin was considered in a study (Talaghat et al, 2009) of the control of sand grain using chemical method during oil production. In their study, they obtained the soil's flow permeability, porosity and compressive strength after samples of the sand collected from the Ahwaz and Mansoori oil production field, using different percentage composition of appropriate hardener and its resin in a cylindrical mold of sand which is polished. Altering repeating the procedure for all novel samples of the resin, all consolidated samples were now sized for measurement. The study was able to show how a sample of resin and its hardener produced a porosity of 38% to 68%, permeability value within the range of 1500mD to 3500mD, and a compressive strength above 3000psi. Research on chemical consolidators agent and the effectiveness sand control during production (Mohammad Azadi T *et al*, 2021) where they aim at investigating the impact of consolidating agent on various sizes of sand grain, and their respective sand control efficiency in oil production. Reservoir recommendation of chemicals and chemical mixture were made to ensure an excellent structural improvement and low reduction in porosity and absolute permeability. Considering the use of locally-made chemical for sand consolidation as (Mohammad Isamil *et al*, 2020) looked critically into the guiding principles of consolidation process of sand grains using the furamid-500, which is also commonly categories as thermosetting type of resin. Result of the study stated that the furamid-500 is effective and desirable, and that it is quite suitable for loose grains at standard reservoir temperature. Their results further reveal the hydrophilic property of the furamid-500 type of resin. In evaluating a wide range of chemical consolidating agent (Fahd Saeed A. *et al*, 2020) considered chemical consolidating techniques that ranges from nanoparticle to polymer, in order to ascertain the best and the most recent chemical consolidation method, and also the most recent approach adopt so far in the research area. Findings revealed an adverse effect on the porosity and permeability of soil samples, and a significant increase in compressive strength from most of the techniques investigated. In research carried (Philip N & Mike S, 2022) on the historical events where soil consolidation was discussed on in-situ sand control technique using epoxy resin, other chemical consolidating materials were also selected for consideration, as well as several other experimental procedures that has been utilized almost throughout the period of research in this field. They went ahead to discuss various designs, preparation and treatment procedures. Having considered the undesirable effect of sand production in oil drilling (Hisham Ben H *et al*, 2020) in their work on smart control framework on risk mitigation on sand production, where they presented some sand production factor and their associated effects, a prediction model that enable the determination of the probability of sand production from an oil reservoir. In the study of sand consolidation by hot air injection (Alex T, 2013) presented in the text in-situ combustion, where the production efficiency was investigated in a situation where air at 200ºC was injected for seven (7) days into an oil reservoir, and cold air was subsequently injected into the same reservoir in the next seven (7) days. Results revealed how efficiency of oil production was enhanced according to standards at the initial stage of production.

The aim of this work is to experimentally investigate the effectiveness of increasing mass concentration of chemical consolidating agent, by considering 3g/L, 6g/L and 9g/L of organosilane used as the consolidating agent, and to evaluate the compressive strength, permeability and porosity of soil samples at different depth from petroleum reservoir around the bonny local government area after they have been chemically consolidated using the three different mass concentration of organosilane.

II. MATERIALS AND METHOD

- Material

Three different concentrations of organosilane are the consolidation chemical considered in this experimental research investigation. Using a locally produced organosilane with the following mass concentration of 3g/L, 6g/L and 9g/L which is used as consolidation agent for three sand samples obtain from different drilling oil wells. The selected concentration of organosilane samples of will be injected into the three sample's mould of sand from the different oil drilling wells in Niger Delta

Reservoir Parameters	Oil well 1	Oil well 2	Oil well 3
Permeability (mD)	70.39	21.63	12.56
Porosity (%)	25.65	20.27	18.11
Compressive strength (psi)	> 1100	400 – 1100	< 400

- Method

Sand samples from the selected drilling oil wells were molded into a five-sided shape with a thickness of about 12inches. Our consolidating agent will then be injected into the five sides of the sand mold, as well as the center, after which the mold will be cut off for the sand core to be obtained, measured and weighed for the computation of the reservoir parameters considered in this study. The experimental procedure will be repeated for the with other mass concentration of organosilane for the different sand samples of other oil wells.

- Permeability and Porosity Testing

Permeability of soil sample is a measure of the soil's ability to convey fluid samples across it. The consolidation of soil through chemical mean has been shown to have an adverse effect on this property of soil. Hence, the various test investigation of this soil property, will correspond to a reduction of the permeability of the soil sample after the chemical treatment using organosilane. Porosity of soil sample is a measure of the ratio of the volume of space in between the sand particle to the bulk volume of the sand sample. As an adverse effect of the consolidation of the soil by chemical means, is the reduction in porosity of the soil. Each pentagon block of organosilane treated sand mould is then coated to prevent the radial flow of water, and to ensure the accurate measurement and recording of inflow and outflow pressure difference (Δp), volume flow rate (V_r), as well as dimensional parameters such as the samples length (L), diameter (d), and cross-sectional area (A). using these parameters and variables, the permeability is then computed using the Darcy expression

$$K(mD) = \frac{V_r \mu L}{A \Delta p}$$

- Compressive strength Testing

This test investigation is specifically directed on the structural deformation of our chemically consolidated sand samples using organosilane. This is a measure of the maximum axial force which our consolidated sand sample can withstand before straining up to 15 -20% of the total sample size. Our pentagon block mould of organosilane treated sand was subjected to a force from an hydraulic press in order to test for compressive strength. First, the compressive strength of the sand mould treated with the 3g/L organosilane was obtained and recorded in pounds-per-square-inch(psi), followed by the sand mould treated with the 6g/L organosilane which was also recorded in psi, then the compressive strength of our pentagon sand mould that was treated with the 9g/L organosilane was finally obtained and recorded in psi.

III. RESULTS AND DISCUSSION

Considering values of the selected oil wellbore presented in table 1, these properties are based on the sand samples collected at the different range of depth for well-1: 12025 – 12375, well-2: 12050 – 12350, well-3: 11975 – 12300, the respective sand samples collected are sandstone, tight sandstone. According to a data indicator (Omohimoria C. *et al*, 2016), the sand samples from the selected oil well's are from obtained from moderate and weak strength of formation. Considering these realistic values obtained from experimental procedures, the following profiles of results were obtained and presented. In figure 1, results of the permeability of unconsolidated samples, consolidated samples with varying mass concentration of the chemical consolidation agent adopted in this study (3g/l. 6g/l, and 9g/l) for the various oil wells was presented. In figure 2, results of the porosity of the soil samples of both unconsolidated, and consolidated samples with various mass concentration were compared and presented for all sand samples of the selected oil wells. Profiles of the compressive strength of all samples of the consolidated sand grain collected from the oil well was presented in figure 3.

Profile of result presented in figure 1 shows the relationship between the set of values flow permeability of the unconsolidated soil samples from our selected oil wells, and their corresponding chemically consolidated samples with different mass concentration of organosilane. A sharp drop on the trendline is seen between well-1 and well-2, and a relatively less drop in the trendline connecting well-2 and well-3. The various drop between the selected points indicates a significant reduction in the flow permeability of the points representing soil samples of oil wells collected at different depth. From the profile presented, well-1 which have the second greatest depth, and the highest broad range of depth is observed to be at higher soil flow permeability, well-3 which have the least depth (11975) and the second highest range of depth (11975 – 12300 = 350) is seen to have the least soil flow permeability, while well-2 with the greatest depth (12050) and least range of depth (12050 – 12350) is observed to have soil flow permeability value after the highest seen at weel-1. The sharp reduction in the soil's flow permeability observed between the unconsolidated soil samples and the chemically consolidated is the adverse effect highlighted by (Fahd Saeed A. et al, 2020), where they stated exclusively that among other limitation of soil's chemical consolidation is the reduction in the flow permeability of the soil, up to a value of about 50%, in there study of the chemical consolidation.

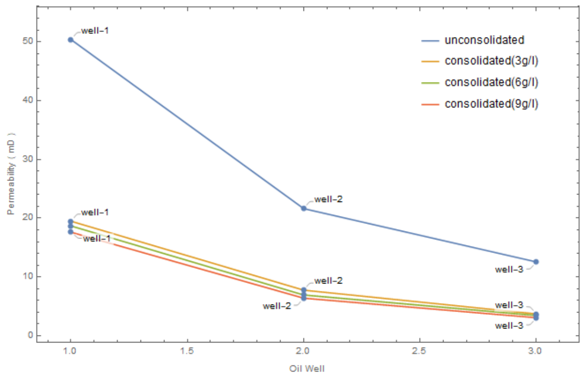

Figure 1: permeability profile against the selected oil-wells for varying mass concentration of our chemical consolidating agent (organosilane)

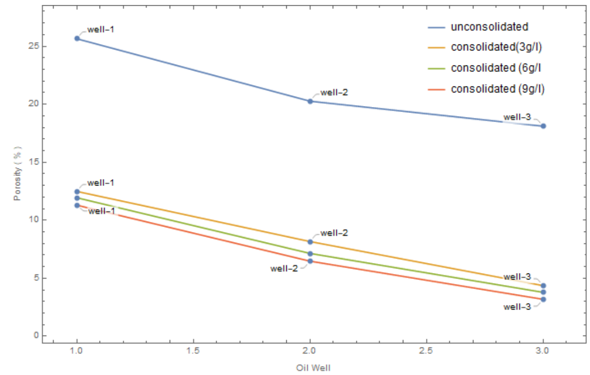

Figure 2: porosity profile against the selected oil-wells for varying mass concentration of our chemical consolidating agent (organosilane)

Also presented in the profile of figure 1 are the trendlines representing the relationship between the various samples of the chemically consolidated samples of our selected oil wells. The trendlines representing the consolidating samples shows pattern similar to the trendlines of the unconsolidated soil samples earlier discussed, but the gradient of the flow permeability is far less that what is observed for the unconsolidated. The physical implication for the results is that the soil's flow permeability drops greatly when consolidated by organosilane, and that the soil's flow permeability decreases as the mass concentration of the organosilane increases. Results further reveal that the impact of the mass concentration of organosilane increases as the soil's flow permeability increases, this is a consequence of the tight overlap observed at well-3 with relatively low flow permeability of soil, and the loose overlap observed at well-1 and well-2.

Figure 2 whose trendlines respectively represent the relationship between the selected oil well of the unconsolidated samples, consolidated samples with 3g/l, 6g/l, and 9g/l. the trendline of the unconsolidated sample show almost a straight decreasing linear line. This trendline's shows a relatively higher gradient of soil's porosity between well-1 and well-2, and a less gradient of soil porosity between well-2 and well-3. Correlation of the pattern of result obtained and represented by the trendline of the unconsolidated soil samples with the depth from which the samples are collected, follows the same physical explanation discussed for the results of the soil flow permeability.

Trendlines between results of the chemically consolidated soil samples also presented in figure 2 shows a significant decrease in the values of soil's porosity from the unconsolidated sample. Also, the pattern of results between the consolidated samples shows almost a straight and linear decrease for all mass concentration of organosilane. Results also show that, increase in mass concentration of organosilane corresponds to decrease in soil's porosity demonstrated in the arrangement of the trendlines.

Profiles of results for the compressive strength of the chemically consolidated soil samples with the different mass concentration of organosilane used for the selected oil well soil sample is presented in figure 3, and the pattern of results obtained shows a linear increase corresponding to the average increase in the gradient soil's compressive strength between well-1, well-2 and well-3. The arrangement of the trendlines representing the various mass concentration of our consolidating agent (organosliane), reveal that the compressive strength of the soil samples increase proportionately as the mass concentration increases.

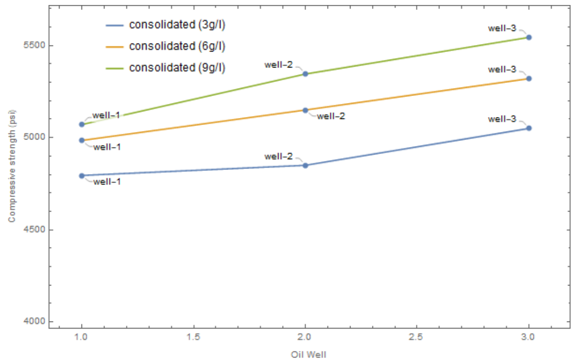

Figure 3: profile compressive strength against the selected oil-wells for varying mass concentration of our chemical consolidating agent (organosilane).

CONCLUSION

This experimental investigation has shown that organosilane greatly increases the compressive strength of soil samples, and increasing mass density of the sample consequently show an increase in compressive strength. This chemical consolidation method of soil consolidation also negatively affects the soil porosity and flow permeability, and increasing mass density of organosilane also corresponds to decreasing soil porosity and flow permeability characteristic values.

RECOMMENDATION

We strongly recommend that samples of other reservoir depths that are not considered in this research work be tested with organosilane, and possibly with other consolidating agent in order to ascertain the effectiveness of different consolidating agent at different soil layers of petroleum reservoir.

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