Laboratory study influence pore volume in compressive strength foam cement

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Abstract. Pore volume of foam cement is a main factor affected compressive strength in the addition axial load design. Foam agent material used in this research is Sika-aer as a replace the nitrogen gasses. This research study used mix composition cement 1 : silica sand 0.25 : water 0.5and foam agent 0.03% - 0.15% BWOC. The purpose of this study is providing alternative cementing product beside lightweight cement in oil and gas industry with foam cement to mitigate loss circulations. Compressive strength testing was carried out with different time periods and pore volume testing were carried out on each addition/change in foam agent concentrations every cement slurry mixture. Characteristics of bubbles on cement slurry is one of many factors that influences compressive strength parameters. Compressive strength foam cement depends on size, diameters and relationship between bubbles on the cement slurry. This laboratory study produced compressive strength values between 1078 psia – 3745 psia and pore volume values between 15 cc – 17 cc in 5 samples core foam cement with different foam agent concentrations Sika-aer.

1. Introduction
Foam cement is one of type light weight cement that can be used in well construction and intervention operations. Foam cement specially used in weak formations with the possibility of small cracks by reducing the volume of cement slurry where needed pumping on the well. The evaluation process began with taking a core sample foam cement with different foam agent concentrations and testing that core with pore volume analysis continued with compressive strength testing [1]. The primary test performed was finish under trial and error test to get the balancing cement mixture where it has compressive strength minimum 1000 psia according to the API 10 B procedures. Consolidated structures with consideration of pores, voids and the matrix will give ultimate strength with different properties [2]. Compressive strength is directly related to concrete density; concrete of high density exhibits low porosity and high compressive strength, and vice versa, but this is untrue for those mixes made with the inclusion of toner and MK. Therefore, density and porosity are not always the decisive factors over strength, it is possible to produce a light weight and relatively porous [3]. The effects of the dimension and profile (section profile and aspect ratio) of a specimen on the foam Crete compressive strength was examined according to cylinder specimen and cube. Cube could carry higher load than cylinder (by assuming both cross-section and volume as identical) [4].

The result has showed foam cement has many pore volumes, but the compressive strength is allowed under API procedures and through passed on the cementing job. The correlations between compressive strength, coefficient of thermal conductivity, median pore size depending on apparent density were
defined using statistical methods of data processing. The analysis of obtained results has shown that the properties of foam concrete produced by means of vortex jet apparatus (VJA) are fully satisfy the requirements of the Russian and French standards for the foam concretes [5]. Yu et al. tested the pore structure, but their results revealed that with an increasing fractal dimension, compressive strength decreased and porosity increased [6].

The purpose of this study was to determine the influence of pore volume on compressive strength in foam cement.

2. Methodology
The methodology was to use Sika-aer as a foam agent to added on the cement slurry admixtures. The research was used trial mix design from previous research for determine the fixed cement properties and appropriate the foam agent concentrations [7]. Source of data were used in this study has collected from several foam cementing research. The process of collecting data is initially carried out by reviewing paper cementing, identifying a number of references in the review paper to obtain more detailed information and data, classifying parameters used in the paper and making summaries of problem that have not been answered in the studies has been identified. Collected data will be used as the initial assumption in working on the research and continued with the trial mix method to obtain the composition of mixture that is an accordance with the desired pore volume and compressive strength ability. Modification composition of cement slurry are made by a trial mix. In the laboratory as a comparison in conducting research studies made on several variations of foam agents in one of foam cement slurry ratio compositions. That trial mix has done because the foam agent is easily soluble and easily reacts with water [8]. The effect of foam agent is very dependent on the amount of water volume concentrations used in the cement slurry mixture. Comparison of the mixture used in trial mix are cement 1 : silica sand 0.25 : water 0.5. Detailed of composition can be explained below:

- Cement 1 : Sand 0.25 : Water 0.5 + Sika-aer 0.03%
- Cement 1 : Sand 0.25 : Water 0.5 + Sika-aer 0.06%
- Cement 1 : Sand 0.25 : Water 0.5 + Sika-aer 0.09%
- Cement 1 : Sand 0.25 : Water 0.5 + Sika-aer 0.12%
- Cement 1 : Sand 0.25 : Water 0.5 + Sika-aer 0.15%

Main ingredients used in this laboratory research such as: Cement class G, Water (aquades), Silica sand (mesh 80), Foam agent Sika-aer by Sika Indonesia. Main equipment used in this laboratory research such as: Two-inch cube molds and compressive strength testing machines, Base and cover plates, Water curing bath, Cooling bath [9].

3. Result and discussions
Figures 1 shows Concentrations of 0.15% Sika-aer in cement slurry. The spreads of bubbles in the cement mixtures is evenly distributed and stables. The bubbles diameter showing ranges from 0.15 – 0.65 mm micron and generally has uniformity in the mixture so it can be concluded that the pore forms on core cement will have a homogeneous size [10].
Addition of Sika-aer 0.15% of the total volume cement slurry, producing bubbles that are evenly distributed and tend to be homogeneous in foam cement slurry. Observation of foam cement was carried out for 30 minutes testing the stability of bubbles in the mixtures. The bubbles conditions after 10 minutes of observation did not show significant shrinkage until the last observation for 30 minutes. In the observation of cement slurry after 30 minutes, slurry cement was seen to harden, bubbles began to shrink and small pores formed in the mixture [12].

Table 1 shows types of cement slurry are made, namely M80-A, M80-C, M80-D, M80-E, M80-F. the material of each samples is made in the same in order to obtain a comparison representative testing result.

Table 1. Cement slurry ratio mesh 80 [11].

| Sample Code | Material Ratio | Cement | Sand | Water | Sika-aer (%) |
|-------------|----------------|--------|------|-------|--------------|
| M80-A       |                | 1      | 0.25 | 0.50  | 0.03         |
| M80-C       |                | 1      | 0.25 | 0.50  | 0.06         |
| M80-D       |                | 1      | 0.25 | 0.50  | 0.09         |
| M80-E       |                | 1      | 0.25 | 0.50  | 0.12         |
| M80-F       |                | 1      | 0.25 | 0.50  | 0.15         |

Figure 2 explains the pore volume values of the samples with the Sika-aer addition 0.03%, 0.06%, 0.09%, 0.12% and 0.15% will increase the value of the pore volume foam cement was 15.487 cc, 15.573 cc, 15.773 cc, 16.303 cc and 17.774 cc. The measured pore volume illustrates that the addition of concentrations Sika-aer will increase the number of pores in the matrix core foam cement, so the pore volume in the rock samples will be even greater [13]. The nature of the Sika-aer foam agent as a water entraining agents that is easy to react with water in the cement slurry mixtures which is has a very close influence with the porosity value, bulk density and permeability sample foam cement [14]. The porosity of foam cement is a very important characteristics be taken into account because it influences other parameters such as compressive strength including durability [15]. The porosity of foam cement facilitates fluids migration in the hardened foam cement matrix. Porosity depends on the degree of fluids flow assurance such as water absorption, sorption, and permeability [16].

Figure 1. Sika-aer concentrations on cement slurry mixtures [11].
The result of the manufacture of specimen core foam cement combined with several compressive strength values. Compressive strength testing was carried out in three consecutive tests to measure the increase values of compressive strength from each core foam cement samples [17].

Compressive strength data can be seen on table 2. The table shows data on increasing compressive strength achieved stability after testing samples on the third testing. Five concentrations variations of foam agent from one ratio foam cement slurry composition to compressive strength testing for three consecutive days. The value of compressive strength measured on the third day was 3745.333 psia, 3097.410 psia, 2676.772 psia, 2289.892 psia and 1701.459 psia. Compressive strength value of samples M80-F on the first day was 1078.104 psia, the second day was 1592.307 psia and on the third day was 1704.459 psia.

**Table 2. Compressive strength testing data.**

| Sample Code | Foam Concentration (%) | Compressive Strength |
|-------------|------------------------|----------------------|
|             |                        | I (30 Oct) | II (31 Oct) | III (1 Nov) |
| M80-A       | 0.03                   | 2950.488   | 3590.791   | 3745.533    |
| M80-C       | 0.06                   | 2345.680   | 2997.434   | 3097.410    |
| M80-D       | 0.09                   | 1786.915   | 2531.883   | 2676.772    |
| M80-E       | 0.12                   | 1311.397   | 2088.587   | 2289.892    |
| M80-F       | 0.15                   | 1078.104   | 1592.307   | 1701.459    |

The value of compressive strength cement can be explained as the strength of cement to with stand pressure/ originating pressure from the wall of the formations well and casing frictions [18]. The minimum strength of cement in resisting formations and casing pressure recommended by the API for continued drilling operation sis 6.7 Mpa (1000 psia) [19]. Figure 3 Shows the result of compressive strength test.
Figure 3. Compressive strength and foam ratio relationship curve.

An increasing value of compressive strength forms a linear line that is parallel at each stage when testing five samples of core foam cement. The compressive strength value is strongly influenced by evaluation of pore volume matrix core, grain density and porosity core foam cement. The value of compressive strength on the third result test is being stable because the increase in the second test value is not much different.

Increasing the value of compressive strength, a long with the age of foam cement samples. The increase in the value of compressive strength on third test was not too significant when compared to the increase in the value of compressive strength on the second test.

The value of pore volume 17.774 cc can be explained that although there are many air cavities in the matrix core foam cement, the air cavity is not related to each other. The value of compressive strength foam cement M80-F which reached 1701.459 psia explained that core foam cement has a low density but still has resistance to be able to withstand formations pressure and minimum casing pressure recommended by the API.

4. Conclusion
The value of pore volume and compressive strength foam cement was influenced by bubbles characteristics test in cement slurry as evidence by making samples with a composition of foam agent concentrations. The smaller pore volume value affected the increasing value of compressive strength foam cement. The result of trial mix state that the ratio of cement slurry composition produced core foam cement with lower pore volume and density values.

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