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COMPRESSIVE AND SHEAR BOND STRENGTH OF OIL WELL CE-MENT WITH CALCIUM CARBONATE AND SILICA FUME

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INTRODUCTION

When a certain section of the depth of an oil or gas well has been drilled successfully, the drilling fluid cannot permanently prevent the well bore from collapsing. Therefore, oil well cementing was introduced in the late 1920s (Joshi and Lohita, 1997) with a number of objectives: (i) protecting oil producing zones from salt water flow, (ii) protecting the well casing from collapse under pressure, (iii) pro-tecting well casings from corrosion, (iv) reduc-ing the risk of ground water contamination by oil, gas or saltwater, (v) bonding and support-ing the casing, and (vi) providing zonal isola-tion of different subterranean formations in order to prevent exchange of gas or fluids among different geological formations.

Oil well cementing is the process of placing cement slurry in the annulus space between the well casing and the geological formations surrounding to the well bore in order to provide zonal isolation in oil, gas, and water wells (Shahriar, 2011). The goal of the well cementing is to exclude fluids such as water or gas to move from one zone to another zone in the well. Incomplete zonal isolation and/or a weak hydraulic seal between the casing and the cement and between the cement and the formations, may cause oil spills and the well may never run at its full producing potential (Cal-vert, 2006). The appropriate cement slurry de-sign for well cementing is a function of various parameters, those are physical and chemical characteristic. Both physical and chemical characteristic of oil well cement (OWC) slurries must be optimized to achieve an effective well cementing operation. The schematic of a cemented well is depicted in Figure 1.

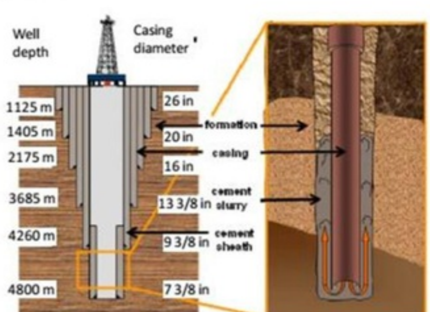

Figure 1. Schematic of a cemented well (Plank, 2011)

Over the last few decades, several types of new chemical admixtures such as super plasticizers, retarders, expanders, viscosity modifying ad-mixtures, etc. have been introduced to optimize the physical and chemical characteristic of oil well cement (Shahriar, 2011). For example, by calcium carbonate as an additive for the cement slurry, it will change the mechanical properties of the cement compare to the ordinary portland cement without additive. Properties that chang-ing are shear bond strength (from 2.16 MPa to 13.07 MPa), and compressive strength (from 24.69 MPa to 19.36 MPa). It can be said that the calcium carbonate will improve the shear bond strength but in other hand it will reduce the compressive strength of the cement (Paramatatya, 2014). There is also another ad-ditive that can improve the mechanical proper-ties of cement, and that is silica fume. By add-ing silica fume to the cement slurry, it will improve the compressive strength (from 28.61 MPa to 31.64 MPa). It can be said also that the silica fume can be used as an additive to im-prove the compressive strength of the cement (Souza et al., 2012).

So it can be seen from the discussion above that to improve the shear bond strength of the cement slurry is adding with the calcium car-bonate and to improve the compressive strength of the cement slurry is adding with silica fume. Therefore, to improve both the shear bond and the compressive strength of the cement slurry is adding the cement slurry with calcium carbonate and silica fume.

LITERATURE REVIEW

Oil well cement stability

According to American Petroleum Institute (API) Specification 10A (2002), compressive strength for oil well cement is defined as the capability to restrain the forces that come ei-ther from the formation or the casing. The minimum allowable compressive strength for oil well cement is 500 psi (3.447 MPa). The compressive strength of the cement will be calculated by using the following equation:

– (1)

where:

$f'c$ = compressive strength, kgf/cm^2
P = maximum load, kgf
A = specimen cross section area, cm^2

According to API Specification 10A (2002), the shear bond strength for oil well cement is defined as the capability to restrain the forces from the weight of the casing. The minimum allowable shear bond strength for oil well cement is 100 psi (0.689 MPa).

The shear bond strength of cement will be calculated by using the following equation (API Specification 10A, 2002):

— (2)

where:

SBS = compressive strength, kgf/cm^2
P = maximum load, kgf
D= specimen diameter, cm
h= specimen height, cm

Expanding Additive

Expanding of cements means expansion of cement relative volume (an external part of cement visually becomes bigger) due to cement bulk expansion (Danjuschewskij, 1983). This occurrence is caused by:

a. Chemical contraction that formed another hydrated products on liquid phase condition, i.e. crystallizing of dissolved salt at high temperature.
b. The presence of expanding materials in cement slurry before hardened condition, i.e. CaO, MgO, CaSO4, etc.
c. The presence of electrolyte around the cement bulk after the hardened condition.

Rubiandini et al (2005) stated that the second item (b) is the merit condition that might bring to increase the shear bond strength of oil well cement.

EXPERIMENTAL PROGRAM

Materials and specimens

The cement slurry made of portland cement, water, calcium carbonate and silica fume. Fourty five cylinder specimens with the size of (75 x 150) mm were made for compressive strength testing and fourty five cylinder specimens with the size of (25.4 x 50.8) mm were made for shear bond strength testing. Five variants of the specimen were made in this study. The variant were cement slurry with (0% Calcium Carbonate + 0 % Silica Fume) as a reference specimen; (5% Calcium Carbonate + 5 % Silica Fume); (10% Calcium Carbonate + 10 % Silica Fume); (15% Calcium Carbonate + 15 % Silica Fume); (20% Calcium Carbonate + 20 % Silica Fume).

Specimens testing

The compressive strength and the shear bond strength of the cement slurry were tested at 7, 14, and 28 days. In each testing, three specimens of each variant were tested to find the average compressive strength and three specimens of each variant were also tested to find the average shear bond strength of the slurry cement. The Universal Testing Machine with the capacity of 30,000 kgf was used to conduct compression and shear bond test of cylinder specimens. The compressive strength and the shear bond strength were tested following the American Petrolium Institute (API) Specification 10A (see Figure 2 and 3).

Figure 2. Compressive strength testing

Figure 3. Shear bond strength testing

RESULTS AND DISCUSSION

Compressive strength

Compressive strength was tested at the age of 7, 14, and 28 days. The test was conducted using Shimadzu Universal Testing Machine (UTM) and it was following the API Specifica-tion 10A (2002) as the reference for the stand-ard of the test. The compressive strength value of the cement with the size 75 mm x 150 mm can be seen in Table 1.

Table 1. The compressive strength (Prasetyo, 2016)

Variant	Compressive strength (MPa)		
	7 days	14 days	28 days
0% SF + 0% CC	19.776	21.124	22.253
5% SF + 5% CC	19.239	19.64	19.803
10% SF + 10% CC	11.317	12.272	12.963
15% SF + 15% CC	9.897	10.197	10.264
20% SF + 20% CC	8.665	8.718	9.526

Table 1 shows that the compressive strength of the cement is decreasing when the calcium car-bonate is added to the cement. The strength is decreasing because the amount of calcium car-bonate that is too much and it cannot react properly with the cement. The excessive amount of the calcium carbonate forming a group of calcium carbonate in a powder condi-tion. This excessive amount of the calcium carbonate cause the cement has pores and it will decrease the compressive strength. So it can be understood from this results that maxi-mum portion of the silica fume and calcium carbonate to make the compressive strength of cement slurry is 5 % SF + 5 % CC because the compressive strength is almost the same with the reference specimen.

Shear bond strength

Shear bond strength test is done at the age of 7, 14, and 28 days. The test was conducted using Shimadzu Universal Testing Machine (UTM) and it was following the API Specifica-tion 10A (2002) as the reference for the stand-ard of the test. The shear bond strength value of the cement with the size 25.4 mm x 50.8 mm (1 inch x 2 inch) can be seen in Table 2.

Table 2. The shear bond strength (Prasetyo, 2016)

Variant	Shear bond strength (MPa)		
	7 days	14 days	28 days
0% SF + 0% CC	2.640	3.027	3.139
5% SF + 5% CC	6.063	6.706	6.849
10% SF + 10% CC	3.544	3.648	3.695
15% SF + 15% CC	2.661	2.939	3.065
20% SF + 20% CC	2.463	2.578	2.596

Table 2 shows that the shear bond strength for the specimen with variant 5 % SF + 5 % CC increased compared to the reference specimen (0 % SF + 0 % CC), however after that the shear bond strength was decreasing. So it can be said that the optimum portion to improve the the shear bond strength is 5 % SF + 5 % CC.

CONCLUSION

Based on the experimental program, several conclusions can be drawn as follows:

1. The compressive strength of the cement will be reduced if the calcium carbonate is added to the cement. This is caused by the excessive amount of calcium carbonate that forms a group calcium carbonate that still in a powder state makes the cement has pores.
2. By adding silica fume as an additive to combine with calcium carbonate, it can reduce the loss of compressive strength that is caused by calcium carbonate.
3. The shear bond strength of the cement will increase when the calcium carbonate is added, but will decrease when the calcium carbonate is too much so it cannot reacts properly with cement and creates a layer of calcium carbonate in the surface of the cement and also creates pores to the cement that will disturb the bond between cement and steel casing.
4. Based on the result of this research, the optimum amount of calcium carbonate and silica fume that can be use is 5% because with 5% of calcium carbonate and 5% of silica fume, the reducing of compressive strength is the smallest and the shear bond strength is increased compare to the others specimen with 10%, 15%, and 20% calcium carbonate and silica fume.

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