

UTILIZATION OF NANOSILICA-PALM SHELL NANOCOMPOSITE TO ENHANCE CEMENT STRENGTH IN WELL CEMENTING OPERATION

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Abstract— The main role of well cementing operation is to adhere the casing with the formation. The successful operation will yield a cement with high strength and good bonding. The cement slurry with high compressive strength and shear bond strength may give a good protection to the casing. Nanocomposite has been used as an additive to accomplish this purpose. The study of palm shell carbon (PSC) variation on nanocomposite has been performed by using biaxial loading test to obtain high performance of compressive strength and shear bond strength according to API specification 10A. From this study, the optimum composition of nanocomposite was at addition 3% PSC with 1090.5 Psi compressive strength and 154.48 psi shear bond strength.

Keywords— Compressive Strength, Shear bond Strength. Nanocomposite, Nanosilica, Palm Shell Carbon.

I. INTRODUCTION

The successful well cementing operation is a key to prolong the well performance in oil and gas industry [9]. A tight and strong cement-casing bond will minimize the possibility of wellbore collapse problem and perform as a barrier-along with casing- to prevent the formation fluid intrusion. Various tests have been conducted to determine the strength of cement in the laboratory. The parameters which can characterize the strength of cement are compressive strength and shear bond strength [5]. The compressive strength of the set and hardened cement has to be high enough before any other operation will be commenced according to API specification 10A [1, 3, and 18]. Moreover, shear bond strength describes the ability of cement to hold the tendency of cracks generation in the casing [6].

Several additives have been applied to increase the strength of the drilling cement with minimal volume such as pozzolanic material [2], an accelerator material such as calcium chloride (CaCl_2) to minimize the time requirement for the cement grout to set [8], fine mineral soils as a grout filler, and expanded the application of magnesium oxide (MgO) [18]. Application of nanoparticle, such as Nanosilica has been demonstrated an additional improvement to the hardened material properties in recent years.

Utilization of nanocomposite was popular in previous years such as in bone regeneration [7], battery capacity improvement [11], and electrical energy storage [17]. In the petroleum industry, nanocomposite was utilized as lost circulation material to prevent the drilling fluid flow further into the formation [10]. Various studies about cement nanocomposites have been implemented to produce an efficient and reliable product in the concrete industry. However, limited studies have been conducted in oilwell cementing. In this study, silica nanoparticle

or Nanosilica and palm shell carbon (PSC) were combined to form nanocomposite material. The raw material of the PSC is a waste from palm oil factory. As a tropical country, Indonesia has a massive quantity of palm tree and the largest palm oil producing country in the world [15].

The objective of this study is to analyze the effect of nanocomposite additive on cement strength. Shear bond strength and compressive strength are two important parameters which may describe the ability of cement slurry to bond with casing or formation rock. An optimum composition of nanocomposite may provide a maximum compressive or shear bond strength can be obtained from this study.

II. DETAILS EXPERIMENTAL

2.1. Materials

This study used class G cement powder (based on American Petroleum Institute (API) standards) which is manufactured by PT Holcim. Cement with G class usually applied in basic well cementing work [13]. Nanosilica from Aldrich Chemistry was purchased and prepared for this study. The characteristic of this nanoparticle was shown in table 1. Meanwhile, The PSC was obtained from CV. Barkat Jaya in Sampit City, Province of Central Kalimantan, Indonesia. PSC was sieved with 200 mesh filter size to obtain a uniform size. Table 2 displayed the characteristic of PSC.

2.2 Sample Preparation and testing Procedure

The preparation of cement slurry should followed standard procedure for sample conditioning and testing in API specification 10A. A high speed propeller mixer should be set to mix cement powder, fresh water, and additives. The speed was maintained at 4000 RPM for 5 minutes to achieve a consistent and stable slurry. Six nanocomposite compositions

for cement slurries have been prepared and organized for this study (Table 3). After completing the mixing process, all samples should be arranged for the hardening process. The hardening temperature should be constant at 180°F for 24 hours. Samples were removed from the mold and were placed in the hydraulic press apparatus for the next test.

Table1: Characteristic of Nanosilica

Physical properties	Explanation
Density	2.17-2.66 gr/cm ³
Melting point	± 1700 °C
Boiling point	2230 °C
Color	White
Particle size	10-20 nanometer
Bulk Density	0.011 gr/ml

Table 2: Characteristic of PSC

Physical properties	Explanation
Ash	1.82%
Volatile Matter	4.24%
Fixed Carbon	90.45%
Calorie	5402 kcal/kg

Table 3: Composition of Nanocomposite in Cement Slurry

Sample Name	Nanocomposite Composition
S0	0.02% Nano-SiO ₂ + 0% PSC
S1	0.02% Nano-SiO ₂ + 1% PSC
S2	0.02% Nano-SiO ₂ + 2% PSC
S3	0.02% Nano-SiO ₂ + 2.5% PSC
S4	0.02% Nano-SiO ₂ + 3% PSC
S5	0.02% Nano-SiO ₂ + 3.5% PSC

Compressive strength and shear bond strength parameters are obtained from biaxial loading test by using hydraulic press apparatus. This apparatus exerted a certain amount of vertical pressure to each slurry sample. The sample withstood the pressure until the failure condition was reached. The pressure where failure starts to exist per sample cross-sectional area was compressive strength. The same procedure was conducted to obtain shear bond strength. The differences between those parameters was the geometry of slurry sample which related to sample cross sectional area.

Scanning electron microscope (SEM) to image the effect of the nanocomposite on cement surface structure, energy dispersive X-ray spectroscopy

(EDX) to quantify the chemical compound of cement, and X-Ray Diffraction (XTD) measurements were performed for each slurry sample.

III. RESULTS AND DISCUSSION

The effect of the PSC concentration to cement compressive strength parameter was shown in Fig.1. From the Fig. 1, it was generally evidenced the rise of cement compressive strength when the PSC concentration increase. The Addition of 3wt% PSC will increase the compressive strength value up to 1090.5 psi (72.7% increment compared to the cement composition without PSC (S0)), respectively. However, the compressive strength significantly decrease for slurry with 3.5 wt% PSC. A slight increment of shear bond strength can be shown in fig. 2 by increasing the concentration of PSC. Shear bond strength value tend to increase up to 154.48 psi - compared to cement sample without PSC - by adding 3wt% of the PSC, respectively. However, the addition of 3.5 wt% PSC will make the shear bond strength decrease.

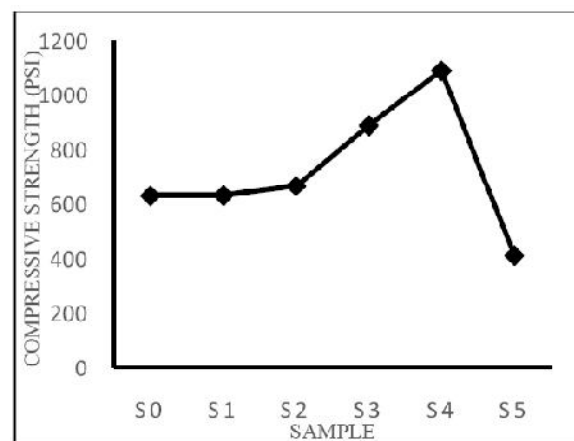


Fig. 1: Compressive Strength of Sample

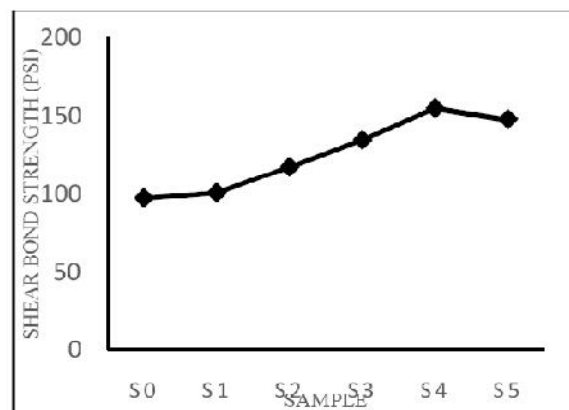


Fig. 2: Shear Bond Strength of Sample

The compressive strength and shear bond strength test confirmed that the Nanosilica-PSC nanocomposite improves the cement strength. The PSC, which contain 30.1% of silica (SiO₂) (Table 4), in combination with Nanosilica performs as a filler in

the cement slurry. The reaction of SiO_2 with calcium hydroxide (Ca(OH)_2) which is liberated from cement yields a stable and durable cementitious compound [16]. On the other hand, inter-particle bond of nanocomposite plays an important role in the material strength enhancement. The nanoparticle, a nanometer size particle, has high surface area which can improve the reactivity of the material. However, the addition of nanoparticle are not always improves the strength of the material. There is an optimum value which can give better strength performance.

Table 4: the composition of PSC

Compound	(%)
MgO	4.9
Al_2O_3	2.2
SiO_2	30.1
P_2O_5	19.6
SO_3	3.28
K_2O	17.5
CaO	14.6
Fe_2O_3	5.08
CuO	0.388
ZnO	2.20

The effect of nanocomposite on cement surface structure was shown in figure 4a and 4b. These figures were taken by using SEM apparatus and compared the cement surface structure. Figure 4a imaged the surface structure of the cement sample with Nanosilica additive. This figure clearly confirmed that the Nanosilica is not effectively fill the inter-particle pore (black sections) of the cement sample. These inter-particle pores could be occupied by a fluid or gas which can impair the strength of cement. Compared to figure 3b, almost surface structure was covered by the Nanosilica-PSC nanocomposite. The Nanosilica-PSC nanocomposite have successfully confirmed its effectiveness as a cement filler which can prevent fluid or gas occupied the inter-particle pore.

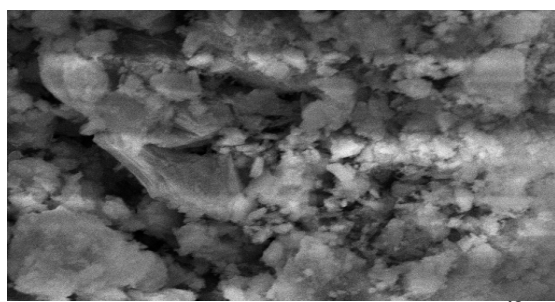


Figure 3a: Surface Structure from S0 sample

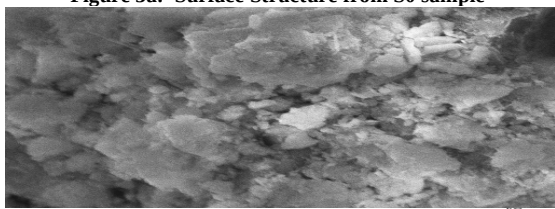


Figure 3b: Surface Structure from S4 sample

Table 5: Chemical Compounds of S0 and S4 sample

Compound	Mass S0(%)	Mass S4 (%)
C	13.20	19.23
MgO	0.96	1.29
Al_2O_3	3.77	5.46
SiO_2	14.22	20.12
SO_3	4.54	3.26
Cl	0.31	0.61
K_2O	-	0.55
CaO	60.34	46.78
FeO	2.66	2.70
Total	100.00	100.00

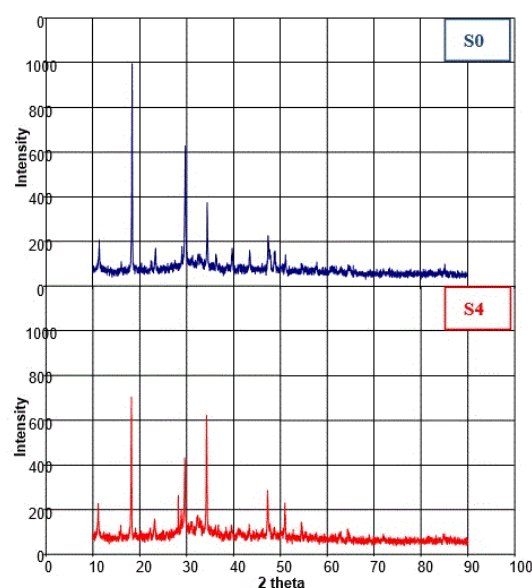


Figure 4: XRD curve from S0 and S4 Sample

Table 5 compared the chemical compound of cement with nanosilica additive (S0) and cement with nanocomposite additive (S4). Results from EDX apparatus shown the increment of the chemical compounds in cement slurry, exclude calcium oxide (CaO) and sulfur trioxide (SO_3). Decrement of calcium oxide in S4 sample due to the existence of the PSC which can enhance some of chemical compounds in the cement slurry. Figure 4 Shown the comparison of XRD result from S0 and S4 sample. Analysis from XRD response curve yield a crystallization in S4 is around 68.46 %. Moreover, the material with high crystallization value will increase the inter-particle bond strength resulting a sample with highly strength value.

CONCLUSIONS

Nanosilica-PSC Nanocomposite additive has been implemented to enhance the cement strength in this study. Several experiments have been conducted to obtain a representative combination of compressive strength and shear bond strength value. From the

experiments, optimum concentration of nanocilica and PSC 0.02% and 3% respectively. These combination will yield the highest compressive strength value (1090.5 psi) and 154.48 psi for shearbond strength value. Comparison from XRD test, the crystallization value is around 68.46%. It is evidenced that addition of PSC can enhanced the strength of the cement slurry, compared to sample without PSC (S0).

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