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An Experimental Study on Effect of Palm – Shell Waste Additive to Cement Strenght Enhancement

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Abstract

Enhancing the cement strength through attaching chemical additive has been popular to meet the required condition for a particular well-cementing job. However, due to a low oil-price phenomenon, pouring and additive should be reconsidered because it can raise the cost and make the project become uneconomic. Another additive material in nanocomposite form will be introduced through this experimental study. The nanocomposite material consist of silica nanoparticle, known as "Nanosilica" and a palm-shell-waste, which is abundant in Indonesia. Before making a nanocomposite, the palm-shell should be burned to obtain a charcoal form, ground and sieved to attain a uniform size.

The study focuses on the two parameters, compressive strength and shear bond strength, which can reflect the strength of the cement. These values are obtained by performing a biaxial loading test to the cement sample. Various samples with different concentration of nanocomposite should be prepared and following the mixing, drying, and hardening process before the loading test is carried out. The result from the test shows a positive indication for compressive strength and shear bond strength values, according to the representative well cementing standards. Increasing the nanocomposite concentration on the cement will increase these values. Furthermore, an investigation on the temperature effect confirms that the sample with 700°C burning temperature have highest compressive-strength and shear-bond-strength values. This is a potential opportunity utilizing a waste-based material to produce another product with higher economic value.

Keywords: Nanosilica, Nanocomposite, Compressive Strength, Shearbond Strength, Cementing.

1. Introduction

The cement strength issue is a common problem in the oil-well cementing operation. The strength can be reflected from its Compressive strength (CS) and Shear-bond Strength (SBS) values, which is appropriate to the proper standard. (Rubiandini et al., 2005) In oil and gas industry, these values should refer to the American Petroleum Institution standard (Institut, 2002). CS defines as the ability of cement to withstand the horizontal force such as formation and casing pressure while SBS describes the capacity of the cement in resisting the vertical force such from the casing string weight. (Palmer, 1990)

Enhancing the slurry with chemical additives is a solution to keep our design consistent with the required condition. (Rubiandini et al., 2005) Enhancement of pozzolanic material and other supportive material into the slurry has successfully increased the cement strength. (Siregar, n.d.) According to ASTM C618-93, material which contains silicon oxide, iron oxide, and aluminium oxide more than 70%can be utilized as an additive material. (Al-Dahlaki, 2007) Other engineered particle such as silica, iron oxide, and aluminium oxide nanoparticle can raise up the cement strength and reducing the filtration loss phenomenon (Ershadi et al., 2011)

This experimental study uses nanocomposite additive, a combination of Nanosilica and palm-oil shell, which is commonly found in Indonesia. Palm-oil trees flourish in almost over 33 million acres, where 70% of this plantation site lies in Sumatera. An abundant source of palm-oil, which is nearly 17.3 ton per year, leads to other waste product such as liquid waste, (Palm Oil Mill Effluent, POME), fibres, and shell. (Dirjenbun, 2015) One ton of Palm-oil will dispose 700 kg POME and 190 kg of fibres and shell. (Haryanti A., Norsamsi,Sholiha P.S.F., 2014). The shell from the palm-oil-fruit contains silica (Worathanakul et al., 2009). Moreover, another work by (Bae, 2016) has yielded an optimum concentration for nanocomposite additive, where

CS and SBS reach its maximum values for sample with 3wt%nanocomposite additive.

The Effect of heating temperature has been observed (Hadiguna, 2016). Experiment by using palm-shell carbon additive have shown the optimum heating temperature is 700°C. However, the optimal temperature for a sample with nanocomposite temperature is not studied yet. The objective of this paper is to investigate the effect of the heating temperature to cement strength.

2. Material and Methods

2.1. Material

The CS and SBS values can be obtained by performing the tri-axial test. The sample should be prepared carefully to keep the quality of the recorded data. A class G cement powder from PT Holcim has been purchased. Class G cement is applicable in the well cementing environment (Falode et al., 2013). Furthermore, nanosilica from Aldrich Company, where the physical properties are listed in the table 1, is procured.

Table 1.

Characteristic of Nanosilica (Novriansyah et al., 2015)

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

One of the Palm-Oil Company in Indonesia, CV Berkat Jaya, located in Sampit, Kalimantan has supported us by providing the shell from the palm-oil fruit. The shell was ground and sieved to obtain the uniform size (200 mesh). The shells in powdery form, is then heated by using the oven furnace. To see the effect of heating temperature, six shells sample will be roasted with different temperature, from 500°C to 900°C with 100°C escalation to obtain its charcoal form, known as Palm Shell Carbon (PSC).

Table 2

Comprise the chemical compositions of the PSC

Chemical Compounds	Content (%)
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	2.30

Source : Siregar, 2012

2.2. Experiment Procedure

Six cement samples will be prepared based on the table 3. Water should be kept in turbulent condition by maintaining a high speed propelled mixer in constant condition (1200 + 500 RPM). It is important because the cement and the palm-oil shell should mixed completely. After the cement powder and the palm-oil are decanted into the mixing container, the mixer speed will be increased to the 4000 + 200 RPM for 15 minutes. Cement suspension is then placed into the mold and dried for 24 hours at 140°F. After sample totally dried, a sample is taken out and then positioned in the hydraulic press apparatus. A certain amount of hydraulic force will burdened to the sample until the crack was generated and the rock rupture. The load was recorded as maximum load and CS and SBS values can be calculated by using this parameter. The procedure will be repeated for other sample with different heating temperature of PSC. The structure and the crystal content of the sample will be identified by using X-Ray Diffraction (XRD) and Scanning Electron Microscope (SEM) apparatus.

Table 3

Cement Slurry Composition

Sample Name	Explanation
S1	0.019%Nano-SiO2 + 3%PSC 400°C
S2	0.019%Nano-SiO2 + 3%PSC 500°C
S3	0.019%Nano-SiO2 + 3%PSC 600°C
S4	0.019%Nano-SiO2 + 3%PSC 700°C
S5	0.019%Nano-SiO2 + 3%PSC 800°C
S6	0.019%Nano-SiO2 + 3%PSC 900°C

3. Results and Discussion

The effect of heating temperature on CS and SBS values is depicted in Fig 1 and 2 respectively. According to the API standard, the CS and SBS values are acceptable and can be implemented in the field condition. The positive trend has been illustrated in the Fig 1, where the CS value increases up to more than 1400 psi for sample with 700°C heating temperature, compared to the sample with 500°C heating temperature. However, the greater CS value is not established for the sample with higher heating temperature. Similar thing occurred in the SBS plot in Fig 2, where the highest SBS value was recorded for the sample with 700°C heating temperature.

Fig 1 and 2 clearly expresses that CS and SBS values will improve if the heating temperature of the PSC higher. Performing the heating process with higher temperature will trigger the charcoal purification process, yield to the increment of PSC-active-carbon-content up to 90% More carbon active improve the bonding quality of the cement, resulting higher CS and SBS value. However, the active carbon will decrease after the heating temperature exceeds 700^{0} C. This due to the presence of hydrogen gas, which can lessen the bonding quality of the cement.

Fig 3.a and 3.b display the XRD result of the samples with different heating temperature. Sample with 700°C heating temperature in Fig 3.a exhibit a higher trend, compared to the other with 300°C in Fig 3.b. Furthermore, sample with higher heating temperature has greater crystal content (82.2% compares to 62.5%). Sample with greater crystal content tend to strengthen the inter-particle bonding, resulting a high strength concrete.

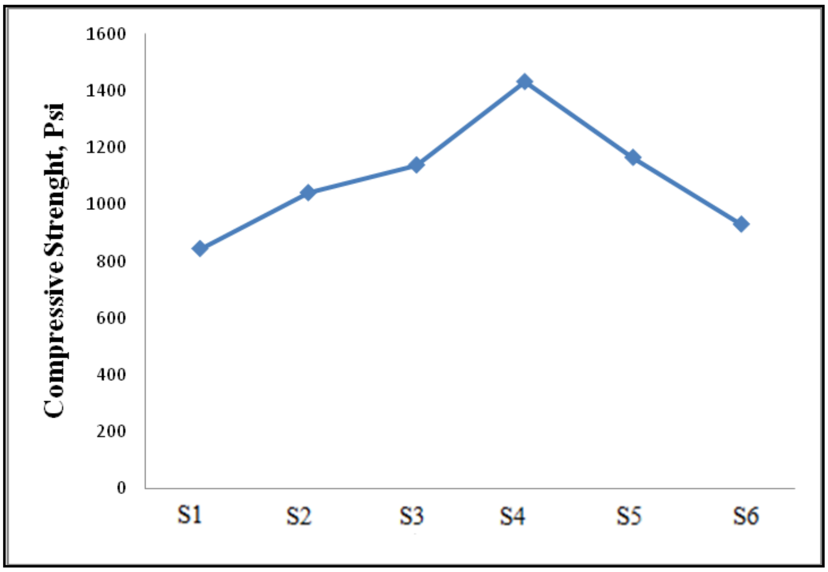

Fig 1. Compressive Strenght of Sample

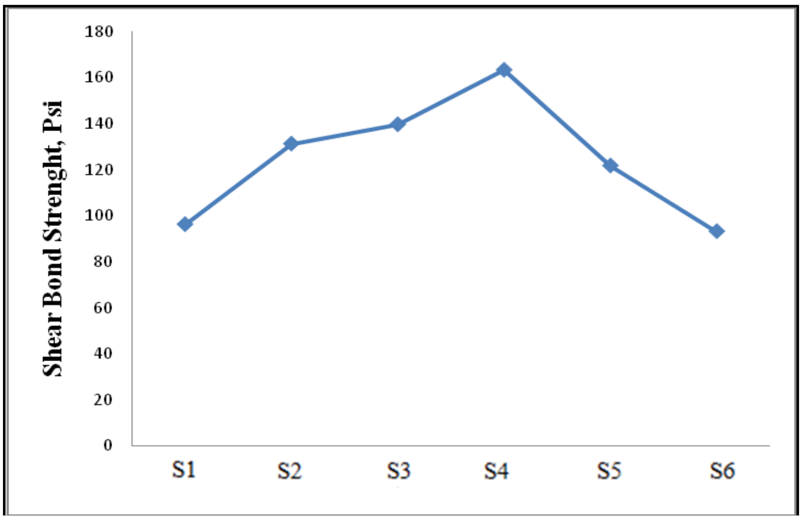

Fig 2. Shear Bond Strenght of Sample

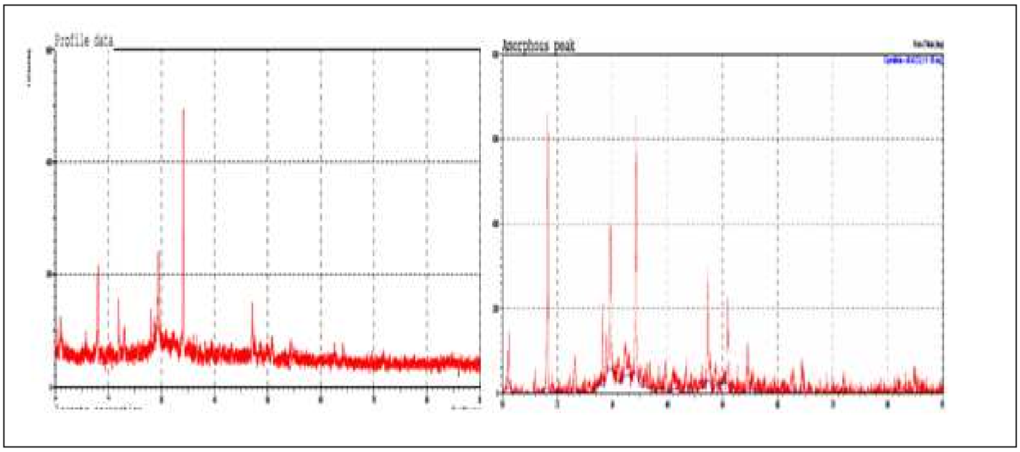

Fig 3a (left). XRD Curve from PSC 700°C sample , b (right) XRD Curve from PSC 300°C sample

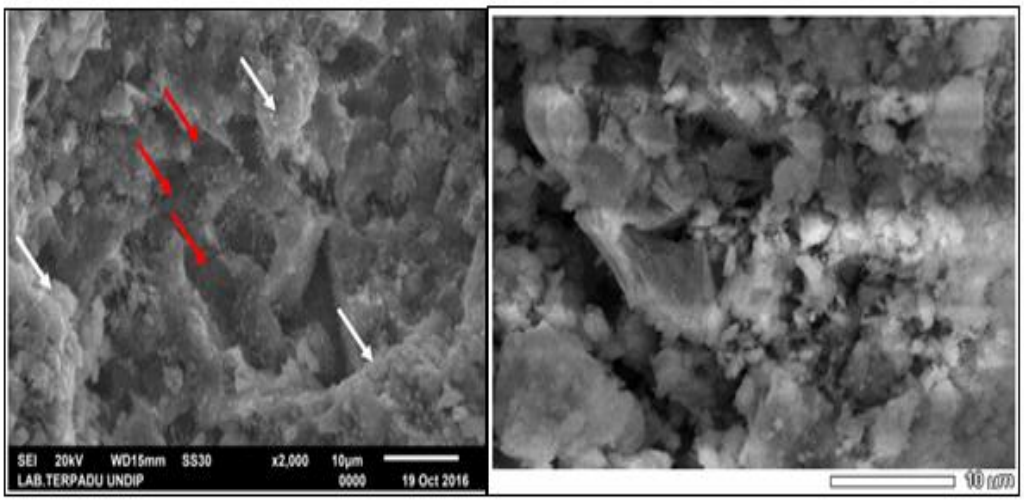

Fig 4a. (Left) Surface Structure sample with 700°C PSC, b. (right). Surface Structure sample without PSC

Result from The SEM have indicated the PSC temperature has effective covered more pore space in the cement sample. It is clearly shown in Fig 4.a and 4.b, where the sample without PSC (Fig 4.b) has wider void space (darker area) when we compare to the sample with PSC (Fig 4.a). Hence, the presence of the PSC material, combined with Nanosilica can plug more pore, resulting a more compact structure of cement.

4. Conclussion

An experimental study has been accomplished to investigate the effect PSC heating temperature to the cement strength in the oil-well cementing job, which are described from the CS and SBS Value of the cement. The object of the experiment is a cement concrete, which is enriched with the nanocomposite additive. The nanocomposite comprises of Nanosilica and PSC, a waste material from the palm-oil mill. Result from the tri-axial loading test conclude that the more heating temperature of the PSC, the higher CS and SBS value will be acquired. An optimum heating temperature, which yield the highest CS and SBS value, is obtained for a sample with 700°C heating temperature PSC. Moreover, result from the XRD and SEM result confirm that PSC has a potential opportunity to be a product with a higher economic value.

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