The Impact of Additively Coal Fly Ash toward Compressive Strength and Shear Bond Strength in Drilling Cement G Class

Novrianti, Dori Winaldi and Muhammad Ridho Efras

Department of Petroleum Engineering , Universitas Islam Riau, Pekanbaru, Indonesia

Keywords: Fly Ash, Pozzolan, Compressive Strength, Shear Bond Strength, Hydraulic Press.

Abstract: The successful of cementing process in petroleum is indicated by the strength value consisting of the compressive stress value and the shear bond strength value. The value of compressive strength permitted in drilling is 500 psi while for shear bond strength is 100 psi. To increase the strength of cement is done by adding pozzolanic additives. One alternative pozzolan that can be used and derived from inorganic waste is coal fly ash. Indonesia has reserves of around 38.9 billion tons of coal with annual production reaching 435 million tons, resulting in a large amount of coal fly ash. The silica contained in coal fly ash is pozzolan which can increase the strength of cement and can reduce costs because it does not need to use additives from industry and can also reduce environmental pollution from fly ash. This study was conducted to determine the value of compressive strength and shear bond strength by using coal fly ash additives with variations in concentrations of 2.5%, 5%, 7.5%, 10%, 12.5% and 15% by weight of cement (BWOC). Making cement suspension samples is done by mixing water, bentonite, polypropylene glycol, CaCl2, and coal fly ash softens the mixer, then it is poured in a mold and left in the water bath. The residence is carried out for 24 hours with temperature 60^0C. Compressive strength and shear bond strength test can be done by utilizing hydraulic pressure. The addition of coal ash can increase the strength of cement. The optimal compressive strength and shear bond strength is obtained on 7.5% BWOC additively ash coal with the value of compressive strength obtained is 1680.39 psi and the shear bond strength is 138.88 psi.

1 INTRODUCTION

Coal is one of the energy sources in Indonesia with estimated reserves of 38.9 billion tons (Suwandi and Suyartono, 2001) Coal is used as a steam power plant (SPP). Coal burning in SPP on the one hand provides benefits for energy availability but on the other hand can have a negative impact because it causes pollutants that can pollute the environment and the health impacts of the population (Finahari et al., 2007).

Burning coal from the boiler will produce waste in the form of fly ash and bottom ash (Suarnita, 2011). It contains silica which can increase the strength of drilling cement which consists of compressive strength and shear bond structure, where the strength of drilling cement is very influential on the success of oil and gas well drilling operations.

Compressive strength is the strength for handling the pressures from the formation and casing, while the shear bond strength is the strength for holding the weight of casing (Prasetyo and Lisantono, 2017). Compressive strength withstands pressures in the horizontal direction and cement strength shear bonds resist pressure from the vertical direction (Samura et al., 2018).

Coal fly ash has pozzolanic properties which contain reactive silica which can reduce free lime ($Ca(OH)_2$) (Salain, 2015). The result of this reaction results in a bond of calcium silica hydrate (C – S – H) which is the nature of cement (Safitri and Djumari, 2010).

Utilizing fly ash on cement has been done frequently. fly ash is gained by coal-burning and burning palm oil. The use of fly ash varies in number but is usually used ¡25% (Roskos et al., 2011). In addition, fly ash can be used as a substitute for cement for concrete compressive strength. In research (Ervianto et al., 2016) the optimum compressive strength is obtained by 7.5% fly ash.

This research aims to determine the impact of coal fly ash on the strength of drilling cement. It was chosen in this study because the amount is widely available and can reduce pollutant waste which can pollute the environment. This research was also conducted

Novrianti, ., Winaldi, D. and Efras, M.
The Impact of Additively Coal Fly Ash toward Compressive Strength and Shear Bond Strength in Drilling Cement G Class.
DOI: 10.5220/0009129801140119
In *Proceedings of the Second International Conference on Science, Engineering and Technology (ICoSET 2019)*, pages 114-119
ISBN: 978-989-758-463-3

to determine the composition of optimal coal fly ash which will produce the value of compressive stress and shear bond optimum structure.

2 RESEARCH AND METHODOLOGY

This research was conducted at the Petroleum Engineering Drilling Laboratory of the Islamic University of Riau. The first step that must be prepared before conducting this research is the preparation of tools and materials, the main material of this research is coal fly ash obtained from the SPP Makmur Sejahtera Wisesa in South Kalimantan.

Fly ash coal contains a chemical composition of silica oxide (SiO_2) 74.20%, iron oxide ($_2O_3$) 14.40% and aluminum oxide (AL_2O_3) 5.70% can be used as a mixture of cement since it is pozzolanic. Pozzolan which consists of silica and aluminum which react chemically with calcium hydroxide at ordinary temperatures forms compounds that are cementitious or binding (Dembovska et al., 2017). The chemical composition of coal fly ash can be seen in the table 1, below:

Table 1: Coal Chemical Composition of Fly Ash.

Chemical Composition	(%)
SiO_2	74.20
Al_2O_3	5.70
Fe_2O_3	14.40
C_aO	2.40
M_gO	2.03
K_2O	0.260
$_a2O$	0.06
T_iO2	0.47
P_2O_5	0.051
$M_{n3}0_4$	0.160
SO_3	-

Source: (Haryanti, 2014)

In addition to coal fly ash the materials used in this study are cement, water, bentonite, Calcium cloride ($CaCl_2$), Polypropolin e Glycol (PPG). While the equipment used is Digital Lead, Constant Speed Mixer, Water Bath Temperature Controller, sample mold and Hydraulic Press.

Fly ash sample preparation refers to ASTM C 117-03 where Fly ash coal is filtered with filter numbers 200 mesh (Theodorus et al., 2008). So that when the stirring process can be mixed with other ingredients. Then, the next step is to make cement samples based on IS : 9013 – 1978 Where in this study the sample made consisted of basic cement without fly ash and basic cement using fly ash with concentration 2.5%, 5%, 7.5%, 10%, 12.5% and 15% as found in table 2. Cement powder with bentonite additives, CaCl2, and Coal fly ash is mixed in dry conditions, while water is mixed with PPG.

The mixture of water and PPG was stirred in a mixture with a speed of 4000 rpm after which the cement mixture was also put into a mixer and stirred at a speed of 1200 rpm for 3 minutes. The sample was then poured into a mold and wrapped using aluminum foil. Compressive Strenght and Shear Bond Strenght are tested within temperature of 60^0C.

The equations used to calculate compressive strength and shear bond strength are as follows:

$$CS = K \times P(\frac{A1}{A2})$$

Where:

$$CS = Cement\ Compressive\ Strength,\ psi$$
$$K = Coefficient\ factor,\ function\ of\ high\ comparison\ (h)\ toward\ diameter\ (d)$$
$$P = Maximum\ loading,\ psi$$
$$A1 = Cross\ section\ of\ block\ bearing,\ inch^2$$
$$A2 = Surface\ area\ of\ cement\ samples,\ inch^2$$

The equation used to calculate Shear bond Strength :

$$SBS = K \times P(\frac{A1}{\pi \times D \times h})$$

Where:

$$SBS = Shear\ bond\ strength\ of\ cement,\ psi$$
$$K = Factor\ Coefficient,\ a\ function\ of\ the\ ratio\ of\ the\ height (h)\ to\ diameter (d)$$
$$P = Maximum\ loading,\ psi$$
$$A1 = Cross\ section\ of\ block\ bearing,\ inch^2$$
$$d = Inner\ diameter\ of\ sample\ casing\ (cement),\ inch$$

Testing of compressive strength and shear bond strength test is carried out by using hydraulic press according to SNI03-1974-1990 standards.The values of compressive strength and shear bond strength that have obtained were inputted in the minitab of software to determine correlation and regression analysis.

Table 2: Composition of drilling cement samples

No	Sample	Cement Suspension Composition
1	S0	Cement (C)
2	S1	C + 2.5 Coal fly ash
3	S2	C + 5 Coal fly ash
4	S3	C + 7.5 Coal fly ash
5	S4	C + 10 Coal fly ash
6	S5	C + 12.5 Coal fly ash
7	S6	C + 15 Coal fly ash

3 RESULTS AND DISCUSSION

3.1 Compressive Strength

Testing of compressive strength on basic cement and cement that added to the concentration of fly ash coal consisting of concentration 2.5%, 5%, 7.5%, 10%, 12.5% and 15% bwoc can be seen in the Table 3 and Figure 1 below:

Table 3: Calculation results of the value of Basic Cement compressive strength plus coal fly ash

Cement Suspension (CS) Composition	Value CS (psi)
Cement (C)	790.11
C + 2.5 Coal fly ash	996.61
C + 5 Coal fly ash	1140.11
C + 7.5 Coal fly ash	1680.39
C + 10 Coal fly ash	960.61
C + 12.5 Coal fly ash	703.02
C + 15 Coal fly ash	378.00

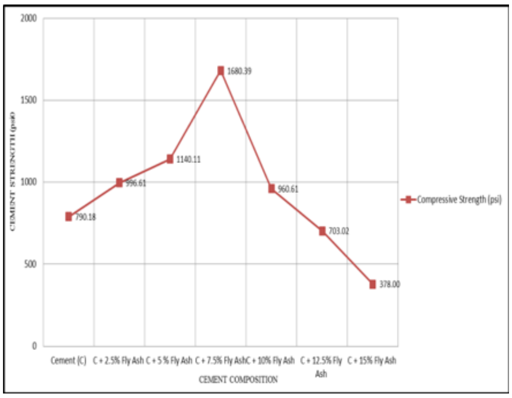

Figure 1: Value of Compressive Strength

Figure 1 shows coal fly ash affects the compressive strength value. Where the composition of coal fly ash within the concentration of 2,5%, 5% and 7.5% increases the value of the compressive drilling cement structure. However, the addition of fly ashcoal at a concentration of 10%, 12.5% and 15% causes a decrease in the value of compressive strength, the optimum compressive strength value is obtained within a concentration of 7.5% is the concentration that produces.

The improvement in the value of compressive strength in coal fly ash is caused by fly ash being one of the pozzolanic ingredients (ASTM, 2001). According to Salain (Salain, 2015) with the presence of pozzolanic properties on fly ash containing reactive silica, it can function to reduce free lime (Ca(OH)2). The result of this reaction results in a bond of calcium silica hydrate (C – S – H) which is the nature of cement. With composition C – S – H the right strength of cement will increase (Safitri and Djumari, 2010). While the decrease in the value of compressive strength ash coal in concentrations above 10% is due to imperfect pozzolanic reactions. This is because the higher the concentration of coal fly ash, the less the amount of cement, so the amount of tricalcium silicate (C3S) and dicalcium silicate (C2S) which is a compound that is responsible for the strength of cement decreases and the bonding power does not run perfectly (Munir, 2008). According to Safitri & Djumari (Safitri and Djumari, 2010). The addition of a lot of coal fly ash will cause many silica elements that cannot react with calcium. So the bond C – S – H imperfect results in a low grade of cement strength.

3.2 Shear Bond Strength

Shear Bond Strength testing was done on the base cement and cement added with the concentration of fly ash coal consisting of the addition of fly ash coal as much as 2.5%, 5%, 7.5%, 10%, 12.5% and 15% bwoc and the results can be seen in table 4 and figure 2 below:

Table 4: Results Calculation of shear bond strength of Basic Cement plus coal Fly Ash

Cement Suspension Composition	Value SBS (psi)
Cement (C)	92.58
C + 2.5 Coal fly ash	98.20
C + 5 Coal fly ash	112.42
C + 7.5 Coal fly ash	138.48
C + 10 Coal fly ash	133.95
C + 12.5 Coal fly ash	120.09
C + 15 Coal fly ash	94.18

In figure 2 shows that the addition of coal fly ash also affects the value of the drilling cement shear

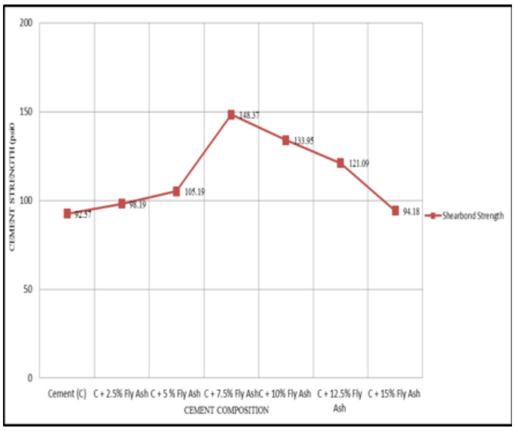

Figure 2: Value of Shear Bond Strength.

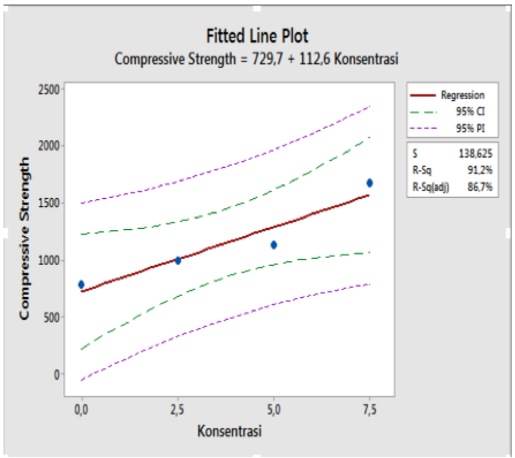

Figure 3: Fitted Line Plot Versus Compressive Strength Concentration.

Regression Analysis: Compressive Strength versus Konsentrasi

```
The regression equation is
Compressive Strength = 729,7 + 112,6 Konsentrasi

S = 138,625   R-Sq = 91,2%   R-Sq(adj) = 86,7%

Analysis of Variance

Source      DF      SS      MS      F       P
Regression   1  395966  395966  20,61  0,045
Error        2   38434   19217
Total        3  434400
```

Fitted Line: Compressive Strength versus Konsentrasi

Correlation: Compressive Strength; Konsentrasi

```
Pearson correlation of Compressive Strength and Konsentrasi = 0,955
P-Value = 0,045
```

Figure 4: Regression Analysis compressive strength versus concentration.

bond structure. As the compressive stress test results, the results of the BPD shear test test also show the same results where the addition of coal fly ash at a concentration of 2.5%, 5%, and 7.5% increases the drilling cement shear bond value while increasing the concentration of coal fly ash with a concentration of 10%, 12.5% and 15% cause a decrease in the value of drilling cement shear bond structure. Therefore, it can be concluded that the 7.5% of coal fly ash concentration can produce the optimum shear bond value.

3.3 Regression Analysis and Correlation between Test Parameters against Concentration

3.3.1 Compressive Strength against Concentration 0-7.5% of Coal Fly Ash

The concentrations used in this study were 0, 2.5%, 5%, 7.5%, 10%, 12.5% and 15% coal fly ash. From the concentration testing, regression testing and correlation to the results of compressive strength were carried out. The following are the results of regression analysis and correlation on 0- 7.5% of coal fly ash concentrations against compressive strength.

Judging from the software output above in the analysis of variance, the p-value is 0.045, which means that it is smaller than the value of the significant criteria used by the evidence level of 95% so that the α value is 5% or 0.05. In the probability value approach (p-value) if the value of probability (p-value) is smaller or equal to the level of significance (α) then the zero hypothesis is accepted. But if the probability value is greater than the significance level, the zero hypothesis is rejected (Gio et al., 2016). Value of p-value is 0.045 which means smaller than the significance value (α) which means that the linear regression model meets the linearity criteria.

Value of R-sq (adj) obtained is 86.7% which means that the compressive strength variable can be explained by 86.7% by the concentration variable. The remaining 14.3% is explained by other variables other than concentration. The equation obtained is compressive strength = 729.7 + 112.6 concentration means that an increase of 1 concentration has a positive effect on compressive strength of 112.6.

3.3.2 Shear Bond Strength against Concentrations of 0- 7.5% Coal Fly Ash

The following are the results of regression analysis and correlation on concentrations of 0-7.5% coal fly ash against shear bond strength. Judging from the software output above in the analysis of variance, a significance value or p is obtained which is equal to

0.043, which means that it is smaller than the significant criterion value, which is used a confidence level of 95% or 0.05. This means that the value of the P-value smaller than 0.05 indicates that the linear regression model meets the linearity criteria.

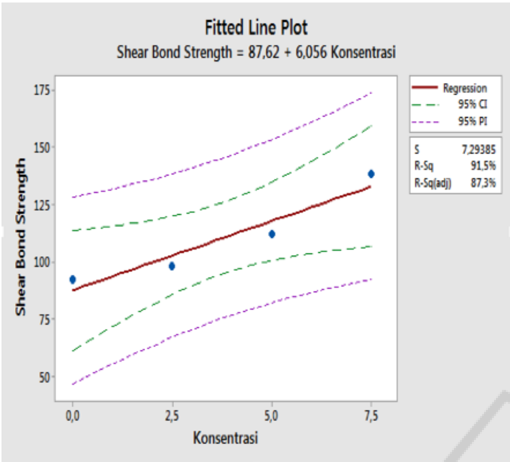

Figure 5: Regression Analysis Shear Bond strength versus concentration.

Regression Analysis: Shear Bond Strength versus Konsentrasi

```
The regression equation is
Shear Bond Strength = 87,62 + 6,056 Konsentrasi

S = 7,29385   R-Sq = 91,5%   R-Sq(adj) = 87,3%

Analysis of Variance

Source      DF       SS       MS      F      P
Regression   1  1146,10  1146,10  21,54  0,043
Error        2   106,40    53,20
Total        3  1252,50
```

Fitted Line: Shear Bond Strength versus Konsentrasi

Correlation: Shear Bond Strength; Konsentrasi

```
Pearson correlation of Shear Bond Strength and Konsentrasi = 0,957
P-Value = 0,043
```

Figure 6: Regression Analysis Shear bond strength versus concentration.

Then get the value of R-sq (adj) 87.3%, which means that the variable shear bond strength can be explained by 87.3% by the concentration variable. The remaining 13.7% is explained by other variables other than concentration. The equation obtained was shear bond strength = 87.62 + 6.056 concentration, meaning that the increase in 1 concentration gave a positive effect on the shear bond strength which was equal to 6.056.

4 CONCLUSIONS

Addition of coal fly ash has an effect on the value of compressive strength and shear bond drilling cement structure. Based on the results of the research the value of optimum compressive strength was obtained at a variation of 7.5% concentration of 1680.39 Psi. The optimum shear bond strength value was also obtained at a variation of 7.5% concentration of 138.48 Psi. From the results of laboratory tests using Minitab software for concentrations of 0-7.5% coal fly ash the compressive strength equation = 729.7 + 112.6 concentrations was obtained, the correlation value of 0.995, P-value 0.045. The value of the linear regression results for shear bond strength with a concentration of 0-7.5% found that the shear bond strength equation = 87.62 + 6.056 concentrations, the correlation value of 0.957, P-value 0.043.

ACKNOWLEDGEMENTS

Thank you to the Petroleum Engineering Study Program drilling laboratory, Faculty of Engineering, the Islamic University of Riau which has provided time and opportunity to conduct research.

REFERENCES

ASTM, C. (2001). 618 (2001). *Standard specification for coal fly ash and raw or calcined natural pozzolan for use as a mineral admixture in concrete. Annual Book of ASTM Standards*, 4:310–313.

Dembovska, L., Bajare, D., Pundiene, I., and Vitola, L. (2017). Effect of pozzolanic additives on the strength development of high performance concrete. *Procedia Engineering*, 172:202–210.

Ervianto, M., Saleh, F., and Prayuda, H. (2016). Kuat tekan beton mutu tinggi menggunakan bahan tambah abut terbang (fly ash) dan zat adiktif (bestmittel). *Sinergi: Jurnal Teknik Mercu Buana*, 20(3):199–206.

Finahari, I. N., Salimy, D. H., and Susiati, H. (2007). Gas c02 dan polutan radioaktif dari pltu batubara. *Jurnal Pengembangan Energi Nuklir*, 9(1).

Gio, P. U. et al. (2016). Belajar olah data dengan spss, minitab, r, microsoft excel, eviews, lisrel, amos, dan smartpls.

Haryanti, N. H. (2014). Uji abu terbang pltu asam asam sebagai bahan pembuatan bata ringan. *Jurnal Fisika FLUX*, 11:127–137.

Munir, M. (2008). *Pemanfaatan abu batubara (fly ash) untuk hollow block yang bermutu dan aman bagi lingkungan*. PhD thesis, program Pascasarjana Universitas Diponegoro.

Prasetyo, A. M. A. and Lisantono, A. (2017). Compressive and shear bond strength of oil well cement with calcium carbonate and silica fume. *Jurnal Teknik Sipil*, 13(4):255–259.

Roskos, C., Cross, D., Berry, M., and Stephens, J. (2011). Identification and verification of self–cementing fly ash binders for 'green'concrete. In *proceedings of the 2011 world of coal ash (WOCA) conference—May 9–12, 2011 in Denver CO, USA*.

Safitri, E. and Djumari, D. (2010). Kajian teknis dan ekonomis pemanfaatan limbah batu bara (fly ash) pada produksi paving block. *Media Teknik Sipil*, 9(1):36–39.

Salain, I. m. A. K. (2015). Perekat Berupa Campuran Semen Portland Tipe I. *Prosiding Seminar Nasional Teknik Sipil 1 (SeNaTS 1)*, 1(April):113–118.

Samura, L. et al. (2018). Pengujian compressive strength dan thickening time pada semen pemboran kelas g dengan penambahan additif retader. *Petro*, 6(2):49–54.

Suarnita, I. W. (2011). Kuat tekan beton dengan aditif fly ash ex. pltu mpanau tavaeli. *SMARTek*, 9(1).

Suwandi and Suyartono (2001). Hidup dengan batubara (dari kebijakan hingga pemanfaatan).

Theodorus, A., Sugeng, B., Suratman, I., and Hermawan, R. (2008). Kajian efektifitas semen dan fly ash dalam campuran soil cement memakai tanah lempung dan pasir pulau timor. *Journal of Civil Engineering*, 15(2):69–84.