ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 9, Issue 2, March 2020

Effect of Calcium Carbide filtrate as a supporter on Compressive Strength of Fly Ash Geopolymer

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Abstract: ***This article presented the use of calcium carbide residue (CCR) for enhancing the strength development of fly ash (FA) geopolymer cured at ambient temperature. The use of CCR to replace FA at the dosages of 0%, 10%, 20%, and 30% by weight of binder and liquid to binder ratios of 0.6, 0.7, 0.8 and 0.9 were investigated. Sodium hydroxide and sodium silicate solutions were used as liquid portions in the mixture. All geopolymer mortars were manufactured with constant sodium silicate to sodium hydroxide ratio of 2.0, sand to binder ratio of 1.5, and cured at ambient temperature. Test results showed that the use of CCR to replace FA resulted in decreasing setting time, while compressive strength tended to increase. The CCR replacement of 30% and liquid to binder ratio of 0.7 gave the highest 28 day-compressive strength, which was 45.8 MPa.***

Keywords: **Geopolymer, Fly ash, Calcium carbide residue, Compressive strength.**

I. BACKGROUND AND OBJECTIVES

The geopolymer technology is a new material for avoiding the negative impact on environmental and ecology. The manufacturing geopolymer emited low CO_2 emission compared with that of Poltland cement (Zhuang et. al., 2016). In Thailand, fly ash from Mae Moh power plant showed to be a good precursor material for obtaining high compressive strength. This was due to it consisted of SiO_2 and Al_2O_3 (Chindaprasirt et. al., 2007; Chindaprasirt et. al., 2011; Phoo-ngernkham et.al., 2013; Sukmak et., al., 2013). However, fly ash geopolymer system showed slow in the setting and hardening matrix when cured at room temperature. To solve this problem, many researchers (Temuujin et al., 2009; Pangdaeng et. al., 2014; Suwan and Fan, 2014) tried to use of calcium promoters for enhancing the strength development of fly ash geopolymer. In addition, calcium carbide residue is a by-product of acetylene production process through the hydrolysis of calcium carbide (CaC_2) regarded as a sustainable cementing agent. Calcium carbide residue is mainly composed of calcium hydroxide in a slurry form

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(Amnadnua et. al., 2013; Horpibulsuk et. al., 2012; Horpibulsuk et. al., 2013; Kampala et. al., 2013). In the past decade, calcium carbide residue was used as a new cementitious material with rice husk ash to form calcium silicate hydrate (C-S-H) similar to the hydration products of Portland cement (Jaturapitakkul et. al., 2003). Therefore, this research aims to investigate the usage of calcium carbide residue to improve the strength development of fly ash geopolymer. The obtained results should be very beneficial to the understanding and to the future applications of geopolymer material.

II. METHODS

A. Materials

The starting materials used in this study were fly ash (FA) from electrical power plant and calcium carbide residue (CCR) from acetylene gas industrial. The 10 molar sodium hydroxide (NH) and sodium silicate (NS) with 13.89% Na_2O, 32.15% SiO_2, and 53.96% H_2O were used as alkali solutions. The NH was obtained from dissolving sodium hydroxide pellets in distilled water and allowed to cool down at room temperature. Local river sand with specific gravities of 1.81 was used as fine aggregate for making geopolymer mortar. The liquid to binder and CCR replacement were investigated.

Table 1: Chemical compositions of FA and CCR

Materials	Chemical compositions (%)									
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_3	Other	LOI
FA	29.32	12.96	15.64	25.79	-	2.93	2.94	4.29	3.00	0.30
CCR	6.16	3.54	0.18	89.24	0.37	-	-	0.50	-	-

The chemical compositions of FA mainly consisted of SiO_2 Al_2O_3, CaO and some impurities. The FA had a sum of SiO_2, Al_2O_3 and Fe_2O_3 at 57.92% with the high CaO content of 25.79%. While CCR mostly consisted of CaO and SiO_2 as shown in Table 1.

Table 2: Mix proportions of geopolymer mortar

Symbols	FA (g)	CCR (g)	Sand (g)	NH (g)	NS (g)
0.6FA0CCR	100.0	-	150.0	20.0	40.0
0.6FA10CCR	90.0	10.0	150.0	20.0	40.0
0.6FA20CCR	80.0	20.0	150.0	20.0	40.0
0.7FA30CCR	70.0	30.0	150.0	20.0	40.0
0.7FA0CCR	100.0	-	150.0	23.3	46.7
0.7FA10CCR	90.0	10.0	150.0	23.3	46.7
0.7FA20CCR	80.0	20.0	150.0	23.3	46.7
0.7FA30CCR	70.0	30.0	150.0	23.3	46.7
0.8FA0CCR	100.0	-	150.0	26.7	53.3
0.8FA10CCR	90.0	10.0	150.0	26.7	53.3
0.8FA20CCR	80.0	20.0	150.0	26.7	53.3

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0.8FA30CCR	70.0	30.0	150.0	26.7	53.3
0.9FA0CCR	100.0	-	150.0	30.0	60.0
0.9FA10CCR	90.0	10.0	150.0	30.0	60.0
0.9FA20CCR	80.0	20.0	150.0	30.0	60.0
0.9FA30CCR	70.0	30.0	150.0	30.0	60.0

B. Mix proportion and mix detail

The mix proportions of FA geopolymer containing CCR are summarized in Table 2. All geopolymer mortars were manufactured with constant NS to NH of 2.0 and sand to binder of 1.5. The different liquid to binder ratios of 0.6, 0.7, 0.8, and 0.9 by weight of binder was investigated. The FA and CCR were mixed at various FA:CCR ratios of 100:0, 90:10, 80:20 and 70:30 with an abbreviation of FA0CCR, FA10CCR, FA20CCR, and FA30CCR, respectively. The mix proportions of FA geopolymer containing CCR in this study are summarized in Table 2.

For the mixing of geopolymer mortar, binder and sand were dry mixed for 1 minute or until the mixture was homogenous. The NS and NH solutions were then added and the mixing was done for another 3 minutes.

C. ***Testing procedure for FA geopolymer mortar containing CCR***

The setting time of geopolymer mortar were tested in accordance with ASTM C191 (2013). While the 50x50x50 mm cube samples were used for compressive strength test in accordance with the ASTM C109 (2002). The samples were demoulded at the age of 1 day and immediately wrapped with vinyl sheet to protect moisture loss and kept in the controlled room. The compressive strengths are measured at the age of 28 days at room temperature. The reported results are the average of three samples.

III. RESULTS

A. Setting time

Test results of setting time of FA geopolymer with various liquid to binder ratios and amounts of CCR replacement are shown in Fig. 1.

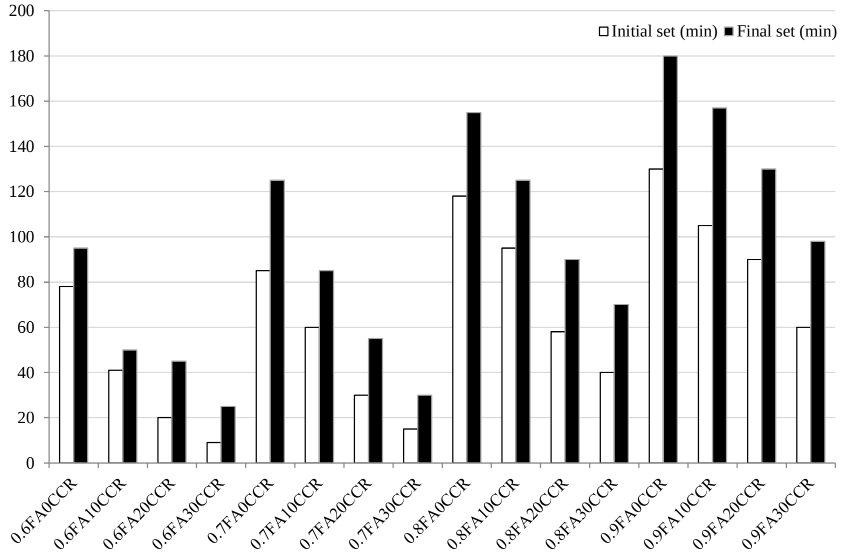

Fig. 1: Setting time of FA geopolymer mortar containing CCR

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The setting time of geopolymer mortars were increased with liquid to binder ratio increased; however, it decreased with CCR replacement increased. For example, the initial setting time of 0.7FA0CCR, 0.7FA10CCR, 0.7FA20CCR and 0.7FA30CCR mortars were 85, 60, 30 and 15 min, while the final setting time were 125, 85, 55 and 30 min, respectively. The setting time of geopolymer mortar tended to obviously decrease with increase in CCR replacement. The addition of calcium oxide from CCR can be accelerated the setting and hardening of FA geopolymer mortar similar to FA-PC geopolymer as reported by previous study (Phoo-ngernkham et al., 2013). The calcium ion from CCR reacted with silicon and/or aluminum ions from FA to form calcium silicate hydrate (C-S-H) and/or calcium alumina silicate hydrate (C-A-S-H) in a similar way as cement hydration products.

B. Compressive strength

The compressive strength of FA geopolymer mortar with various liquid to binder ratios and amounts of CCR replacement are shown in Fig.2. The compressive strength of FA geopolymer mortar decreased with increasing liquid to binder ratio, while the strength of mortars seemed to increase with increasing CCR replacement. For example, the compressive strength of 0.7FA0CCR, 0.7FA10CCR, 0.7FA20CCR and 0.7FA30CCR mortars were 35.56, 41.84, 44.40, and 45.82 MPa, respectively. The silicon and aluminum ions from FA and calcium ion from CCR can react with high alkali solutions to form calcium silicate hydrate (C-S-H) and/or calcium aluminosilicate hydrate (C-A-S-H) and geopolymer gel (N-A-S-H) gels (Pangdaeng et. al., 2014, Phoo-ngernkham et. al., 2015). All reaction products were important for enhancing the strength development of geopolymer matrix.

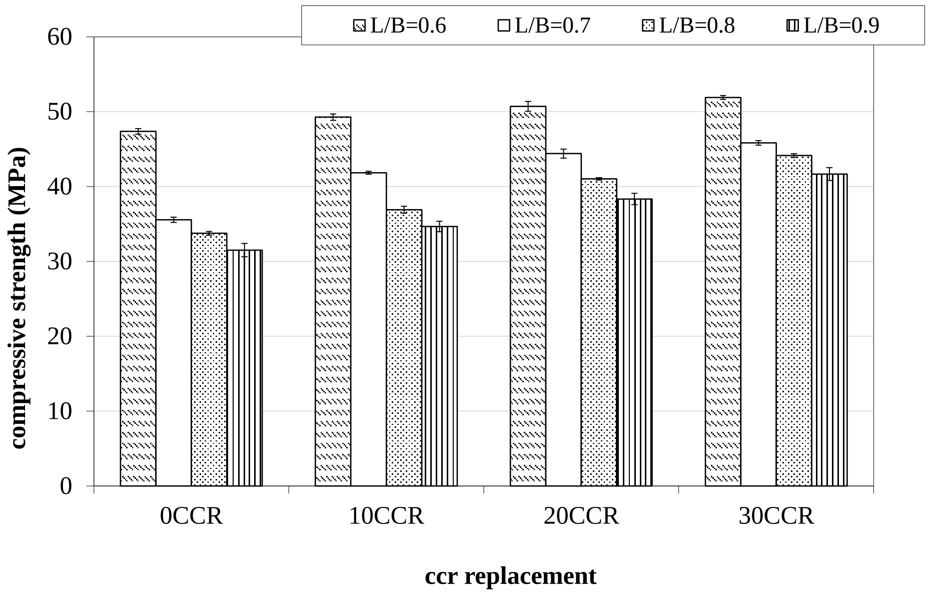

Fig. 2: Compressive strength of FA geopolymer mortar containing CCR

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