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Strength Performance of Blended Ash Based Geopolymer Mortar

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Abstract. Geopolymer is a based on inorganic alumino-silicate binder system. Geopolymeric materials are formed using materials that containing silica and aluminium such as fly ash and rice husk ash, which activated by alkaline solution. This paper presents the study on the effect of replacement of SSA in RHA based geopolymer, types of curing and different molarity of NaOH used on the strength of Sewage Sludge Ash (SSA) and Rice Husk Ash (RHA) based geopolymer mortar incorporating with three (3) different mix proportions. Based geopolymer mortar was synthesized from treated sewage sludge and rice husk undergoing incineration process in producing ashes, activated with sodium silicate and sodium hydroxide solution by ratio of 2.5:1 and solution to ash ratio of 1:1. Molarity of 8M and 10M NaOH were used. The percentages of SSA replacement were 0%, 10% and 20% by weight. Compressive strength was conducted at age 7, 14 and 28 days to see the development of strength with two curing regimes, which are air curing and oven curing (60°C for 24 hours). From the research conducted, the ultimate compressive strength (6.28MPa) was obtained at zero replacement of SSA taken at 28 days of oven curing with 10M of NaOH. This shows that RHA, which is rich in silica content is enough to enhance the strength of geopolymer mortar especially with high molarity of NaOH.

1 Introduction

Portland cement is a major construction material used worldwide. The crucial issue in manufacturing cement was the calcination of limestones. It is responsible to contribute on the amount of CO_2 emission to the environment. Manufacturing of 1 ton of Portland cement generates 1 ton of CO_2 emission to atmosphere [1]. This issue become critical by years because of the rapid construction development to fulfil the needs. Moreover, waste generated is also one of the crucial issues that have being concern nowadays. Rapid economic development and population growth, inadequate infrastructure and land scarcity was Malaysia's most critical issues in managing the municipal waste. As stated by [2], the per capita generation rate of municipal waste is about 0.5 to 0.8 kg/person/day, which domestic waste is the primary sources. Agriculture waste, industrial waste, domestic waste and construction waste were wastes that are trying to be developed by researchers and commercialize as construction materials in replacing cement.

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Aluminosilicate polymer also known as geopolymer is aluminosilicate network structure that form between the reaction of solid amourphous aluminosilicate (Si-Al) with highly concentrated alkali hydroxide or silicate solution to activate reactive Si and Al [1, 3, 4]. This geopolymer consists of repeating tetrahedral unit (Si-O-Al-O). The sources of materials used in geopolymer production are any pozzolonic materials that containing Si and Al to react with alkaline activators. Mohd Mustafa *et al.* indicated that curing process and activator used were the most important factors that affect the strength performance of geopolymer [5]. Their statement is in line with the study conducted by [6] stated that molarity and curing temperature affected the strength of geopolymer. Commonly, the curing temperatures used in geopolymer were at range 60°C to 120°C for 24 to 90 hours [7-11].

Geopolymer technology is seen to have a potential in replacing conventional concrete and has good opportunity to convert waste into beneficial product in construction industry. Therefore, RHA and SSA are seen as potential waste to use as precursor geopolymer mortar since they have reactive silica and aluminium. With that in mind, the objective of this study is to investigate the effect of SSA replacement in RHA based geopolymer mortar with different molarity of NaOH under two curing regimes.

2 Experimental Programmes

2.1 Materials

Rice husk ash (RHA) and sewage sludge ash (SSA) were used as raw materials in geopolymer mortar. Table 1 presented the total chemical compositions of RHA and SSA used in this study respectively. From that table, it can be seen that these two materials can be combined in order to obtain more reactive silica and aluminium and thus enhanced the geopolymerisation process. Based on the chemical compositions in Table 1, contaminations of silica in RHA is higher than SSA with 74.13% and 39.21% respectively, while SSA gave aluminium content with 19.71% compared to RHA with 0.13%.

The rice husk was obtained from rice mill and was burnt in the ferrocement furnace and lefts for 24 hours under uncontrolled burning. The next 24 hours were used to make sure the ash cool down before collecting process take place and ashes were taken for grinding process using Los Angeles Machine. RHA was found to be amourphous based on the grey colour obtained, while sewage sludge cake was taken from Wastewater Treatment Plant, KLIA Sepang. Sewage sludge cake were dried before burning process takes place at 900°C for 5 hours by using furnace gas. Then, the burnt sewage sludge cake was taken out from the furnace and undergoing grinding process to obtain the fineness.

Sodium hydroxide and sodium silicate were used as alkaline activator in this research study. The ratio of sodium silicate to sodium hydroxide was 2.5:1 by weight. Local sand was used as fine aggregates having a fineness modulus of 3.

2.2 Experimental methods

In the production of the geopolymer mortar, alkaline activators were prepared 24 hours before the casting process takes place so that the solutions sufficiently combined. The activator solutions consist of sodium silicate solution (Na_2O = 10.6%, SiO_2 = 26.5% and H_2O = 62.9% by mass) and either 8M or 10M of sodium hydroxide. The mixes were prepared by using a Hobart mixer and cast in 50mm cubes mould and mechanically compacted using vibrating table. The ratio of RHA to sand was 1:2 and RHA was replaced by 0%, 10% and 20% of SSA by weight. Additional water was added during mixing to make sure the homogeneity of the mortar. The samples were sealed using wrapping plastic before subjected to oven curing at 60°C for 24 hours, while the other batch of samples was exposed to air curing. Compressive strength test was conducted at the age of 7, 14 and 28 days.

Table 1. Total chemical compositions of the used RHA and SSA.

Chemical Composition	RHA	SSA
SiO_2	74.13	39.21
Al_2O_3	0.13	19.71
Fe_2O_3	0.32	6.59
CaO	0.65	2.30
MgO	0.66	1.25
SO_3	0.53	2.63
K_2O	2.87	2.27
Na_2O	0.03	0.24

3 Experimental Results and Discussion

3.1 Effect of SSA replacement in strength of RHA based geopolymer mortar

The strengths of different replacement of RHA and SSA geopolymer mortar cured at 60°C for 24 hours with 10M of NaOH were illustrated in Fig. 1. For 100% of RHA based geopolymer mortar at the age 7, 14 and 28 days, the strengths were 2.70, 5.70 and 6.28 MPa respectively. However, with 10% replacement of SSA, it displays strength of 1.93, 3.43 and 3.24 MPa, while the strength for 20% SSA replacement was 2.10, 3.54 and 3.98 MPa at ages 7, 14 and 28 days respectively. It is clearly showed that there are significant increases in strength for 100% RHA, while with replacement 10% and 20% of SSA exhibited decreasing in strength and the strength increased linearly due to age of curing. RHA is rich in silica contains as compared to SSA up to 74.13% as in Table 1. In geopolymerisation, silica content is one of the crucial factors that affect the creation of Si-Al network. Meanwhile, SSA with high in alumina contains compare to RHA is one of the potential waste in combination with RHA (high in silica) as based in geopolymer since it has a quality in strength.

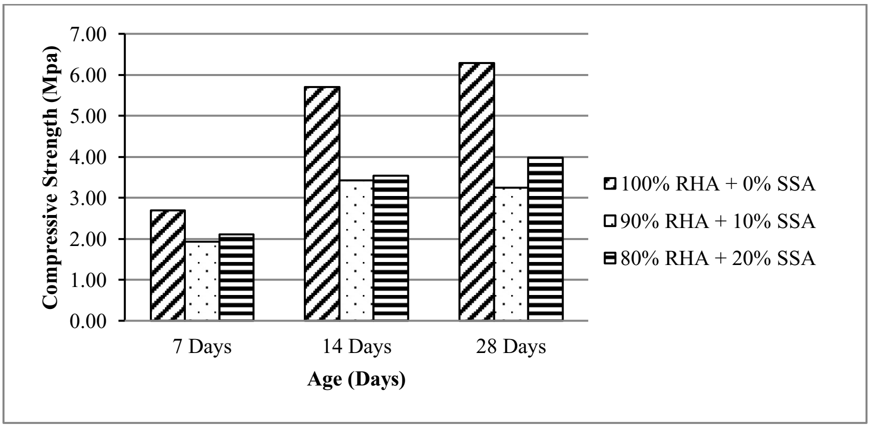

Fig. 1. Compressive strength of RHA and SSA based geopolymer mortar with 10M NaOH and oven cured.

3.2 Effect molarity of NaOH on the compressive strength of geopolymer mortar

The effect of molarity on the RHA and SSA based geopolymer mortar are discussed. Fig. 2 illustrated the compressive strength of different SSA replacement with different molarity of NaOH at age 28 days of air curing conditions. Each SSA replacement showed that 10M of NaOH gave high compressive strength as compared to 8M with 5.8MPa (100%RHA 0%SSA), 4.5MPa (90%RHA 10%SSA) and 3.5MPa (80%RHA 20%SSA), while 4.8MPa (100%RHA 0%SSA), 3.42MPa (90%RHA 10%SSA) and 3.20MPa (80%RHA 20%SSA) respectively. The results of this study were in line with [13], stated that higher concentration of NaOH solution resulted in higher compressive strength. It is suggested that by increasing the molarity of NaOH, the strength of geopolymer mortar increase with increasing age of curing. Nevertheless, too high molarity of NaOH solution and too high temperature induce in curing process could lower the strength because of the break of Si-Al bonding. It is suggested that the strength decreasing with higher SSA replacement in RHA based geopolymer mortar however there are an increment due to age of curing for each replacement.

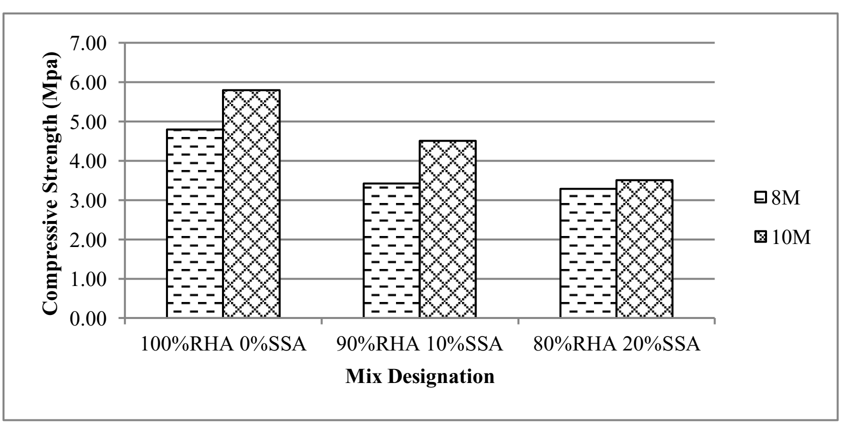

Fig. 2. Variation of compressive strength at age 28 days of air curing.

3.3 Effect of curing condition on the compressive strength of geopolymer mortar

The strength of RHA geopolymer mortar cured at 60°C for 24 hours and air curing with molarity of 8M and 10M of NaOH were illustrated in Fig. 3. For 8M NaOH at the age of 7, 14 and 28 days, the strengths were 2.00MPa, 4.53MPa and 4.80MPa (air cured) and 2.54MPa, 5.12MPa and 5.72MPa (oven cured) respectively. For molarity of 10M NaOH, the strengths were 2.19MPa, 4.81MPa and 5.80MPa (air cured) and 2.70MPa, 5.70MPa and 6.28MPa (oven cured). It is clearly showed that there are linear increments on the strength of RHA based geopolymer mortar on age and method of curing. On the other hand, with higher molarity, the compressive strength increased.

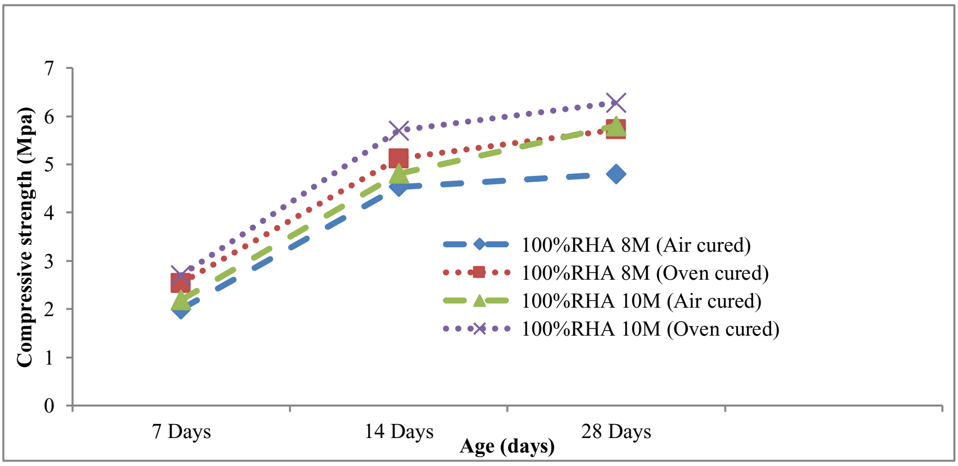

Fig. 3. Compressive strength of 100%RHA 0%SSA based geopolymer mortar.

From the Fig. 3, it can be clearly seen that the specimens cured at 60°C for 24 hours exhibited higher compressive strength as compared to air cured specimens with a relative difference of 16%. It can be seen, by inducing heat to the specimens during curing process, polymerisation effectively could gain strength at early age as low as at 7 days [12]. For the specimens cured at oven cured with 10M NaOH shows significant increase in strength than 8M NaOH along the age of curing process with 6.28MPa and 5.72MPa taken at 28 days respectively. While the specimens under air cured was 5.80MPa (10M) and 4.80MPa (8M) respectively. This suggested that increasing in molarity of NaOH with inducing heat could increase the polymerisation rate reaction in RHA based geopolymer mortar. These two parameters gave significant effect on the strength of geoplymer mortar which is giving high rate of polymerisation reaction and it is in line with finding by [14], in which their suggested that increasing in molarity and heat increase the strength of geopolymer mortar.

Fig. 4 illustrated the compressive strength of 10% replacement of SSA by weight in RHA based geopolymer mortar with respect to ages and two curing regimes. By replacing with 10% of SSA, the specimens' exhibited lower strength as compared to 0% replacement of SSA, however there was a linear increased in strength up to age 28 days. Based on the Fig. 4, specimens cured in air curing with 10M of NaOH gave higher strength than specimens cured at oven with 4.5MPa and 3.4MPa respectively at 28 days. By replacing RHA with SSA it is can be seen that air curing gave high strength than oven curing.

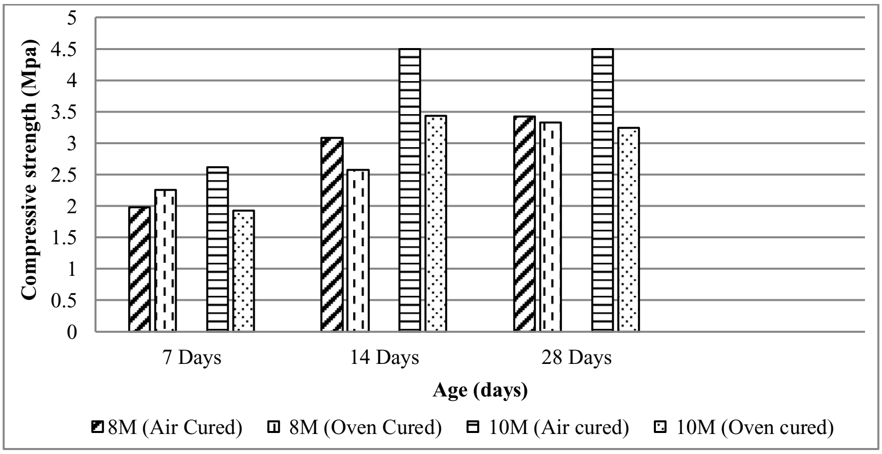

Fig. 4. Compressive strength of 10% SSA with RHA based geopolymer mortar.

4 Conclusions

From the study conducted, the following conclusions were made:

a. The influences of SSA replacement in RHA based geopolymer showed decreasing in value of compressive strength. . However, it is clearly showed that there still an incremental value of strength with prolong periods of curing.
b. The compressive strength of RHA based geopolymer mortar gave higher strength than SSA and RHA based geopolymer.
c. The compressive strength of the geopolymer increased with increasing in the molarity of NaOH solutions up to 10M.
d. Inducing heat through oven curing on the geopolymer mortar plays a major role for the strength development of geopolymer mortar.

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