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COMPRESSIVE STRENGTH AND SODIUM SULFATE RESISTANCE OF LOW CALCIUM FLY ASH GEOPOLYMER MORTAR CONTAINING WASTE POWDER

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ABSTRACT:

This objective of this study is to utilize recycled waste powder as a partial replacement fly ash of the low calcium geopolymer mortar to develop a sustainable geopolymer material. The recycled waste powder is 1) milled container glass (CP), 2) milled low calcium fly ash geopolymer concrete waste (GP), and 3) milled normal concrete waste (NP). Two recycled waste powder replacement ratio was selected for geopolymer mortar preparation (20%, and 40% by weight). The effect of recycled waste powder on geopolymer mortar was studied by compressive strength and 10% sodium sulfate solution at 7, 14, 28, 56, 90, and 120 days. Sodium hydroxide and sodium silicate were used as activated solutions. The alkaline liquid to binder ratio was 0.75 and that of sodium silicate to sodium hydroxide was 1.0. All samples were cured at 60 °C for 48 hr and held at 23±2 °C until testing. The results show that the compressive strength of controlled mortar increases with increasing concentration of sodium hydroxide solution. The compressive strength increases for 56 days and then decreases exposure to 10%sodium sulfate solution. In addition, the results indicated that the high amount of recycled concrete powder can affect the sulfate resistance, while container glass powder can promote the utilization of waste powder on the sulfate attack of geopolymer mortar may be the quartz phase and ultra fine particles of milled container glass and filled in the gel.

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1. Introduction

Portland cement hurts the environment due to the consumption of high amounts of energy and about 65% of greenhouse gases, CO2 was released into the atmospheres from Portland cement production [1, 2]. Geopolymer is an alternate material that helps to reduce greenhouse gas emissions and may help to stop global warming. As well, it has high durability features when exposed to the environment. The rich silica and alumina compound materials such as fly ash, blast furnace slag, and rice husk ash incorporated with strong alkali solutions such as sodium or potassium solution are used to prepare this material [3, 4]. Curing at high temperatures or curing at room temperature with the addition of calcium oxide can enhance the compressive strength at an early age [5]. Over the duration of the durability behaviour, in particular the resistance of sulphate attack, several research studies have been carried out on the performance of the geopolymer [1, 6, 7]. Sulphate attack is the main

sustainability concern of geopolymer materials used in construction. Consequently, the durability of the geopolymer mortar containing container glass, geopolymer concrete and normal concrete powder is the main focus of this research. The compressive strength after 7 days and after exposure to 10% sodium sulfate solution at 7, 14, 28, 56, 86 and 120 days was evaluated.

2. Experimental Program

2.1 Materials

Fly ash (FA) is classified as Class F fly ash, according to ASTM C618-19 [8]. The mean particle size is 22 µm and 45% of it will retain on a sieve no. 45 µm. Recycled waste powder to replace fatty acids was derived from 1) glass in a ground container (PC), 2) concrete waste in a ground geopolymer (GP) and 3) ordinary ground concrete waste (NP). All powder passed through sieve no. 325 no less than 90% by weight. NP and PG were derived from parrent concrete with a compressive strength of approximately 30 to 40 MPa at 28 days. The sodium hydroxide solution (NH) with a concentration of 8, 12 and 16 molars (M), and the sodium silicate solution (NS) consist of 12.53% Na_2O, 30.24% SiO_2, and 57.23% H_2O by weight have been used as activated alkali solutions. Local river sand from Mae Khong River in Nong Khai Province in the North East of Thailand with a fineness modulus of 2.4 was used as natural fine aggregate. Table 1 presents the chemical compositions and physical properties of raw materials.

Table 1 The chemical and physical properties of binders

Details	FA	CP	GP	NP
SiO_2	35.86	70.30	39.23	23.24
Al_2O_3	15.05	1.91	13.45	4.71
MgO	2.34	1.68	1.55	2.82
CaO	17.16	12.33	21.95	60.12
Na_2O	1.58	12.81	1.11	0.21
K_2O	3.12	0.21	1.87	0.61
Fe_2O_3	17.31	0.42	18.89	3.25
SO_3	5.94	0.07	1.55	2.54
P_2O_5	0.30	-	0.12	0.21
TiO_2	-	-	-	0.26
BaO	0.17	-	-	0.21
LOI	0.10	0.68	0.42	1.86
Blaine fineness (cm^2/g)	2250	5890	6387	5610
7 days strength activity index (%)	92	92	95	96
Mean particle size (µm)	21.65	11.72	10.88	12.16
Specific gravity	2.23	2.53	2.51	2.55

2.2 Mixes proportions and samples preparation

The twenty-one series were considered in this study. The ratio of NS to NH and alkali solution to binder were 1.0 and 0.75, respectively, while the ratio of binder to fine aggregate was 1:2.75. The series of geopolymer mortar with binder as FA only was used as control mix to compare between the modified geopolymer mortar that FA was replaced by CP, GP, and NP were 20% and 40% by weight. All mixtures are prepared in electric pan type mixer at room temperature in the range of 22–25 °C. Table 2 presents the geopolymer mortar mix proportions. At the beginning of the control mix, the FA and NH were mixed for 5 min and after that river sand was added and mixed for 5 min. Finally, NS was added and mixed for 5 min. After mixing, the fresh geopolymer mortar was transferred to 5 x 5 x 5 cm^3 casting molds and cured at room temperature for 1 hour. Then the molds have been wrapped in plastic sheets to prevent moisture loss and put in an oven with a constant temperature of 60°C for 48 hours. The samples were demolded from casting and wrapped again. After that, the samples were left at room temperature with 22-25 °C and 50% relative humidity for 7 days. For the modified series, FA was replaced by each powder (CP, GP, and NP) with 20% and 40% by weight, respectively.

2.3 Test procedures

After curing for 7 days, 3 samples of each series were tested on compressive strength while 18 samples of each series were exposed to sodium sulfate solution with a concentration of 10% (10% Na_2SO_4). The 10%Na_2SO_4 was pre-prepared and renewed after being tested. However, the wet

samples were kept at room temperature for 30 min to control the moisture content before testing. The compressive strength was conducted on 3 samples at every testing age

Table 1 The chemical and physical properties of binders

Samples	FA (g)	Sand (g)	CP (g)	GP (g)	NP (g)	NH (g)			NS (g)
						8 M	12 M	16 M	
Control									
8R	500	1375		-	-	250	-	-	250
12R	500	1375	-	-	-	-	250	-	250
16R	500	1375	-	-	-	-	-	250	250
Modified									
8CP20	400	1375	100	-	-	250	-	-	250
12CP20	400	1375	100	-	-	-	250	-	250
16CP20	400	1375	100	-	-	-	-	250	250
8CP40	300	1375	200	-	-	250	-	-	250
12CP40	300	1375	200	-	-	-	250	-	250
16CP40	300	1375	200	-	-	-	-	250	250
8GP20	400	1375	-	100		250	-	-	250
12GP20	400	1375	-	100	-	-	250	-	250
16GP20	400	1375	-	100	-	-	-	250	250
8GP40	300	1375	-	200	-	250	-	-	250
12GP40	300	1375	-	200	-	-	250	-	250
16GP40	300	1375	-	200	-	-	-	250	250
8NP20	400	1375	-	-	100	250	-	-	250
12NP20	400	1375	-	-	100	-	250	-	250
16NP20	400	1375	-	-	100	-	-	250	250
8NP40	300	1375	-	-	200	250	-	-	250
12NP40	300	1375	-	-	200	-	250	-	250
16NP40	300	1375	-	-	200	-	-	250	250

3. Results and Discussions

3.1 Compressive strength

In this research, Fig. 1 shown compressive strength at 7 days of hardened geopolymer mortar and flowable of fresh geopolymer mortar. It was found that the compressive strength ranges from 29-56 MPa and in the control, samples were higher than those of the modified samples with the same NH concentration. The compressive strength increases when NH concentration increases [9]. For samples with 20% and 40% of replacement, the compressive strength of the modified samples was slightly different or less than those of the control sample mortar due to the loss of the amount of FA. For using CP, all compressive strength decreases due to the voids between the smooth surface of particles and gel. The samples 16NP20 and 16GP40 had higher strength than those of the modified samples due to the high amount of calcium oxide. Here, re-hydration and re-polymerization might be occurred [10]. In addition, the flowable of fresh mortar decreases when concentrations of NH increase. Because the high concentration of NH can leach SiO_2 and Al_2O_3 from FA and enhance high gel formation which leads to an increase of viscosity [11, 12]. The re-polymerization and re-hydration may be enhanced due to the activated calcium ions from GP and NP, but this does not occur with CP [13].

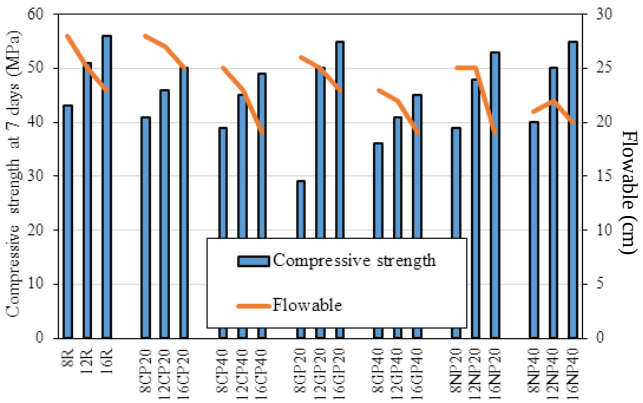
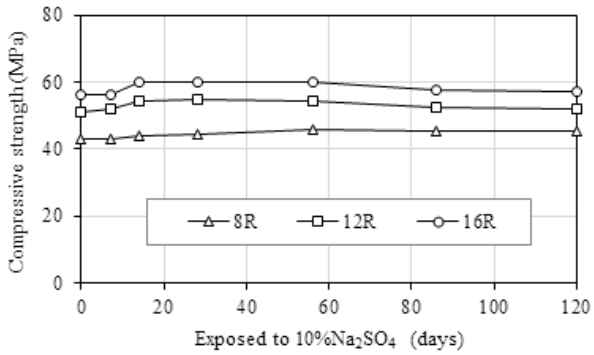


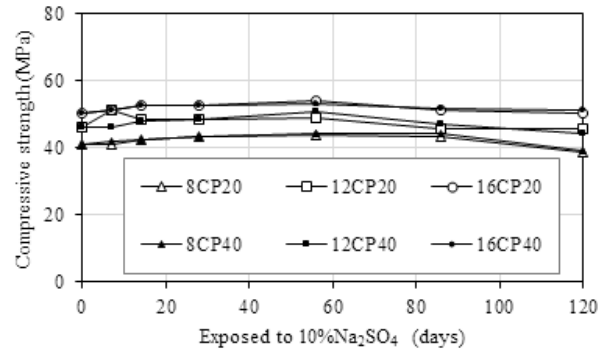
Figure 1 Compressive strength at 7 days of hardened geopolymer mortar and flowable of fresh geopolymer mortar

3.2 Geopolymer mortar exposed to 10% Na_2SO_4

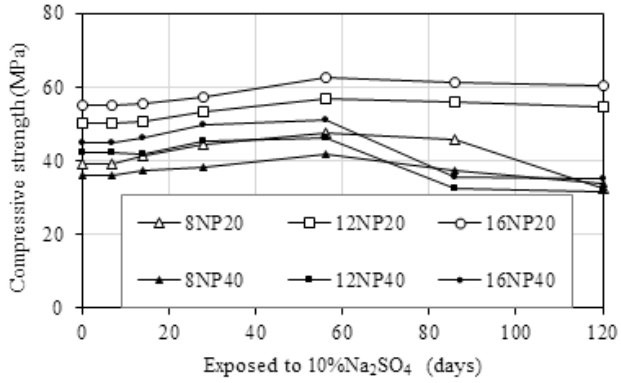
The compressive strength after a 10%Na_2SO_4 attack after 120 days is presented in Fig.2 (a)-(d). In most cases, the exposure period increases, the compressive strength increases up to 56 days and then decreases except 12GP40 and 16GP40, the compressive strength decreased after 28 days that illustrated in Fig. 2 (d). The compressive strength loss for 86 days of exposure is like that of 120 days of exposure. Most of the samples with high NH concentrations had better resistance to 10%Na_2SO_4 than those samples with low NH concentration [9]. After 120 days, the samples with 20% of NP and GP improved their compressive strength by about 13%, while the sample with a 40% replacement that its strength decreased about 21%. The 16NP20 had higher compressive strength than those of the samples and is illustrated in Fig. 2 (c). The 40%GP had better resistance than the sample with 40%NP due to the re-polymerization from GP [14-16]. Fig. 2 (b) shown the FA replacement with CP significantly differed after being exposed to 10%Na_2SO_4. That similarity with control samples can be attributed to the filler effect of CP particles and its resistance against 10%Na_2SO_4 that is more than NP and GP due to its quartz phase (non-reacted). However, the main constituent of geopolymer is made of an amorphous alumino-silicate matrix derived from FA. Therefore, the decreasing of the durability of geopolymer can be indicated by the reduction of FA. For example, the compressive strength was lower than control when FA was reduced by 20 and 40% at the same NH concentration [17].



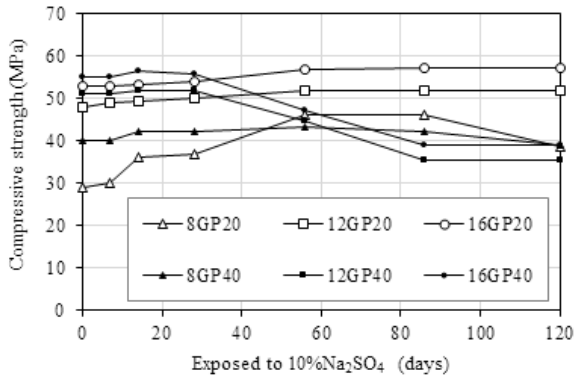
(a)



(b)



(c)



(d)

Figure 2 The compressive strength of geopolymer mortar samples exposed to 10%Na_2SO_4;
(a) Control geopolymer mortar,
(b) Geopolymer mortar containing CP,
(c) Geopolymer mortar containing NP, and
(d) Geopolymer mortar containing GP.

4. Conclusion

In this paper, the analysis on the compressive strength after using 10% Na2SO4 to attack geopolymer mortar for 0 to 120 days. The main conclusion is as follows:

1) The geopolymer containing waste powder exhibits lower compressive strength than the control samples and can resist sulfate solutions up to 56 days except the 12GP40 and 16GP40.

2) The geopolymer mortar containing crushed geopolymer concrete shows better sulfate resistance than geopolymer mortar containing crushed normal concrete.

3) The amount of fly ash is the main of sulfate resistance.

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