EFFECT OF GROUND GRANULATED BLAST SLAG (GGBS) TO THE BONDING STRENGTH OF GEOPOLYMER MORTAR AS REPAIRING MATERIAL

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ABSTRACT: The bonding strength of geopolymer mortar is very important for binding the old concrete with the latest concrete when act as repair material. The present study is aim to determine the best ratio between GGBS and fly ash in order to find the optimum bond strength under ambient temperature. There are five different ratios of GGBS to fly ash that had been tested in this research which are GGBS: FA= 10:90, 20:80, 30:70, 40:60, and 50:50. The different mixture of GGBS and fly ash is added with the alkaline solution (12M of sodium hydroxide and sodium silicate) and sand which have been mixed then rapped cured under ambient temperature. Once the mixing is done completely, pour the mixture into the metal mold and attach with the OPC concrete substrate. The bonding strength of this research were tested by using slant shear test in 7 days, 28 days and 60 days of curing. From the result tested, GGBS: FA= 30:70 could concluded as the best ratio for presenting the optimum bonding strength in this research since the bond strength for GGBS: FA=30:70 had obtain optimum strength under long curing time (9 MPa in 28 days cured and 10.6 MPa in 60 days cured). The maximum compressive strength of 46.4 MPa was observed at geopolymer mortar with GGBS: FA = 30:70. There are many factors affecting the bond strength of geopolymer which are slow setting time of fly ash and GGBS, curing temperature, size of GGBS and also the mixture proportion. The present study had concluded that GGBS: FA= 30:70 in geopolymer mortar are the best for presenting the bond strength.

KEYWORDS: *Geopolymer; Ground Granulated Blast Slag; Repair Material; Bonding Strength; Fly Ash*

1.0 INTRODUCTION

Geopolymer was formed to describe an alternative cementitious material which has ceramic-like properties [1]. It is an environmental friendly material that have not emit greenhouse gases during polymerization process. From the rapid growth of research and development related to geopolymer, it had indicated that the potential to implement as binder at various application including the field of concrete infrastructure rehabilitation. The bonding properties of the geopolymer are reported higher than cement-based repair material [2-3].

The presence of calcium content is the significant role in compressive strength development. GGBS is a byproduct from the blast furnaces slag which rich in calcium ion [4]. This shows that the strength of geopolymer mortar could be affected by the GGBS. The geopolymer has shown the huge advantage compare with Portland cement. However, the value of geopolymer act as repair material in the building maintenance still could be enhanced. Different mixture design ratio of GGBS with fly ash could result in different bonding strength. Without a proper mixture design component, the strength of the geopolymer may be reduced. A good bonding is vitally important in the concrete repair.

There are also some researcher had concluded that the compressive strength of geopolymer increased with the addition of GGBS. However, the bond strength of geopolymer with addition of GGBS is still not identify clearly [5-6]. Not only with that, GGBS could also help for reducing the curing time. In this research, the bonding strength of the geopolymer had been tested through slant shear test. The objective of this research is to analyze the effect of GGBS percentage to the bonding strength of the geopolymer mortar.

2.0 EXPERIMENTAL PROCEDURE

2.1 Raw Material

The normal raw material used to form geopolymer mortar are fly ash, ground granulated blast slag (GGBS), sodium silicate, sodium hydroxide and also the fine aggregate. The fly ash was obtained from Cement Industries of Malaysia Berhad, CIMA which located at

Chuping, Perlis. The fly ash is sieved for getting the particle size whom passing through 0.03mm size. While for GGBS, the size shall be passing through 0.21mm with specific gravity of 2.9. A chemical composition with 30.1% SiO_2, 9.4% of Na_2O and 60.5% of H_2O in sodium silicate had been applied in this research. The sodium hydroxide powder used in this research is fixed as 99% purity and 12M [7].

2.2 Mix Design and Process

The Ordinary Portland cement (OPC) mortar grade 30 had been prepared for act as substrate. All the OPC substrate are prepared according with the concrete mix design form that had been set and cured for 28 days before binder with geopolymer mortar. The geopolymer mortar was mixed with the ratio set. Na_2SiO_3 and NaOH ratio is fixed 2.5, the ratio of alkaline solution to fly ash (AS: FA) is settled up as 2 and the sand to fly ash and GGBS ratio was fixed as 2.33. All the mix design shall always be fixed except the ratio between fly ash and GGBS during experiment. The ratio between fly ash and GGBS are set for five different type of ratio for test which shown in Table 1.

Table 1: Mixture proportion of the geopolymer mortar

	GGBS: FA	GGBS (g)	Fly ash (g)	NaOH (g)	Na_2SiO_3 (g)	River sand (g)
Mix 1	10:90	23.76	213.84	47.50	71.30	831.60
Mix 2	20:80	47.52	190.08	47.50	71.30	831.60
Mix 3	30:70	71.28	166.32	47.50	71.30	831.60
Mix 4	40:60	95.04	142.56	47.50	71.30	831.60
Mix 5	50:50	118.8	118.8	47.50	71.30	831.60

The fly ash, GGBS and also the fine aggregate is first dry mixed together in a pan mixer. The fine aggregate shall be prepared in saturated surface dry (SSD) condition. The prepared alkaline liquid is then continue mixed with the dry material continually. After the mixed had been completely, pour the mixer into the metal mold with three layers compacted to remove the trapped air [8]. For testing sample, the mixture is poured to the mold (50mm x 60mm x 120mm) that contain of OPC concrete substrate as shown in Figure 1. The mixture also poured into the 50mm x 50mm x 50mm of cube samples for compressive strength testing at 28 days. All samples have been cured at ambient temperature to suite with the application as repair material.

Figure 1: Molding of geopolymer mortar

3.0 RESULT AND DISCUSSION

3.1 Bonding Strength

There are many factors could be affecting the bonding strength of the geopolymer. In this research, all the material used had been fixed except the percentage of GGBS and fly ash. Hence, the result showed are affected by the percentage of GGBS contained. With different percentage of GGBS contained in geopolymer mortar could result the different bonding strength and also the bond growth rate. Figure 2 showed the bonding strength and the flow of bond growth rate for 7 days, 28 days and 60 days.

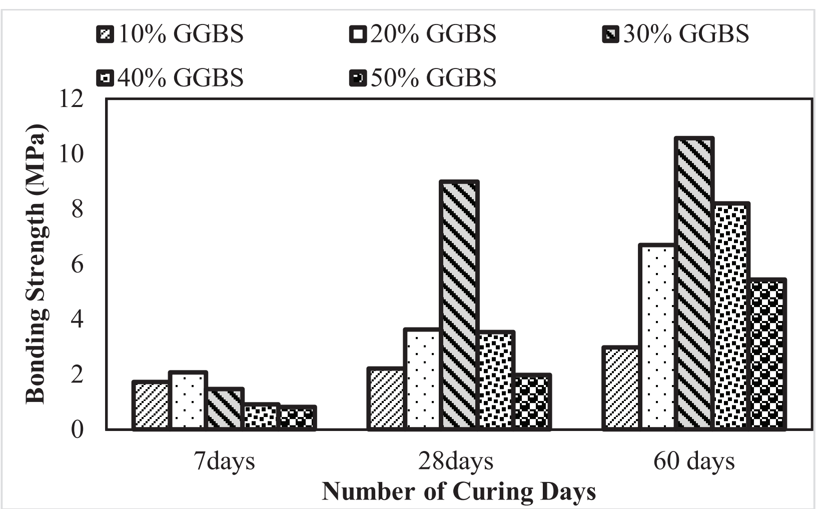

Figure 2: Slant shear strength of geopolymer mortar with different percentage of GGBS against curing days

The result had shown the best performance for bonding strength after 7 days cured is the geopolymer mortar with ratio GGBS:FA=20:80. However, the bonding strength shows higher in geopolymer with ratio GGBS: FA= 30:70 when the curing days was after 28 days and 60 days. This is due to the reaction rate for GGBS and fly ash is slow [10]. Hence, there would be require more curing time in order to increase the bond strength. As a result, the bonding strength of geopolymer with ratio GGBS:FA= 30:70 become stronger than the geopolymer with GGBS: FA=20:80 after 28 days cured under ambient temperature. The result of bond strength is comparable to the previous study [14-15] through cured at ambient temperature.

Through the ratio GGBS:FA= 30:70 contained in geopolymer mortar, the bond growth rate had been increased speedily between 7 days cured to 28 days cured (541.2%) and 28 days cured to 60 days cured (17.5%). This is because the Ca^+ ion contained in the GGBS are sufficient enough for the hydration rate to reach the optimum. The Ca^+ ion occur in GGBS improve the strength of the geopolymer mortar [5, 11]. However, the geopolymer with ratio of GGBS to fly ash exceeded 30:70 had shown low bonding strength compare with the GGBS: FA=30:70 since Ca+ ion contain in GGBS are being excess after ratio GGBS: FA= 30:70 contained.

This analysis also conclude that the growth rate is affected by the hydration rate of the geopolymer. Ones of the factor affecting the bond growth rate could be the size of GGBS [12]. The exposed surface area would become high as the size of GGBS smaller. Due to this reason, the connection of GGBS with others would be high and thus increase the hydration rate.

Besides that, the temperature is also act as a main role in bond strength of the geopolymer mortar. From the previous research by other researcher had stated that the higher the curing temperature could efficient the bond strength growth [1]. However, there are only cured under ambient temperature in this research since the research are more focus under repair material.

The mix proportion of the geopolymer mortar could be one of the affecting factors in bonding strength. As refer the research done by other researcher had shown that concrete with ratio of GGBS: FA= 50:50 had obtained highest strength after 14 days [13]. However, the mix proportion with the ratio of GGBS: FA =30:70 had been determined as optimum bond strength. Hence, this could be concluded that the mix proportion would be ones of the main characteristic in determine the bond strength. The different mix proportion design will give different properties of the mortar/concrete strength.

3.2 Compressive Strength

The compressive strength of geopolymer mortar at various percentage of GGBS at 28 days is shown in Figure 3. The compressive strength of the mortar is increasing until GGBS: FA = 30:70 with the value of 40.4 MPa, then start to decrease with further increase of percentage of GGBS. The sufficient binder of fly ash and GGBS is very important to bind the aggregate contents in achieving the best interlocking transition zone between the binder and aggregate (sand).

The inclusion of sand in geopolymer mortar also means including a strong particle in the system and helps improve the mechanical properties of geopolymer [14]. However, insufficient binder to bind the aggregate will reduce the strength and performance of geopolymer mortar.

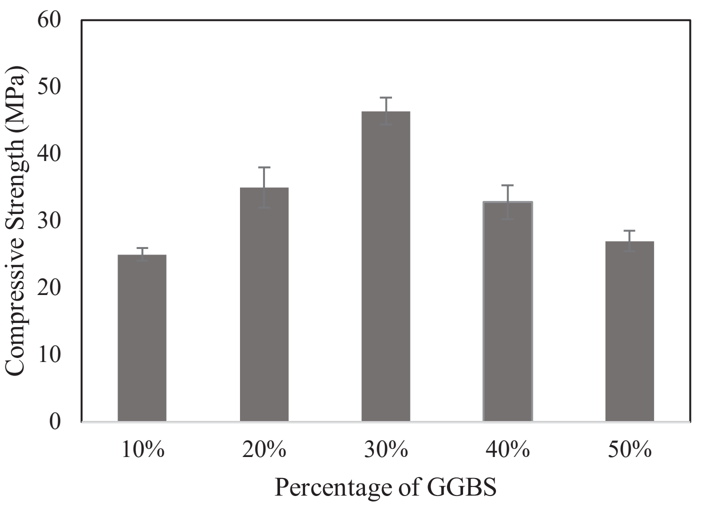

Figure 3: The compressive strength of geopolymer mortar at 28 days

In addition, the compressive strength of geopolymer mortar at GGBS: FA = 30:70 had satisfied the requirement highlighted by the specification of Public Work Department that specifies the compressive strength for repair work should be 45 MPa within 28 days curing period.

4.0 CONCLUSION

The geopolymer mortar with GGBS: FA =30:70 is the best for bond strength and compressive strength under the mixture proportion set up cured at ambient temperature. The setting time of the fly ash and GGBS are greater hence the geopolymer mortar require more curing days in order to reach optimum bond strength. The mixture proportion of the geopolymer mortar resulted in different bond strength through different ratio of GGBS with fly ash.

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