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Durability of Fly Ash Based Geopolymer Concrete Infilled with Rubber Crumb in Seawater Exposure

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Abstract. Geopolymer is an alternative binder to replace Ordinary Portland Cement (OPC)in construction industry. Source materials that rich in silica (Si) and alumina (Al) were activated by using alkaline solution. Production of tires keep increasing every year and due to its non-biodegradable properties it causes problems for disposal process. In current scenario, waste materials should be used or recycled so that the existing natural resources can be saved and at the same times it can protected environment. In this paper, the effect of rubber crumb on fly ash based geopolymer concrete have been investigated by immersing the samples in seawater for 28 and 60 days. The rubber crumb was used to replace coarse aggregates from range 5% until 20%. The ratio of fly ash/alkaline activator and sodium silicate/sodium hydroxide(NaOH) ratio were fixed at 2.0 and 2.5. It has been shown that the compressive strength decreased when the content of rubber crumb increased. The highest compressive strength (39.6 MPa) was obtained at 5% replacement of rubber crumb when exposure to seawater for 28 days. The density of geopolymer samples also increased when immersed in seawater for all samples. The lack of bonding between rubber crumb and geoplymer paste cause increasing in porosity hence reduced the strength, increment in density and changes in weight of geopolymer samples.

1. Introduction

Geopolymer is an alternative binder for Ordinary Portland Cement (OPC) where it possesses high strength, good resistance against aggressive environment as well as natural sustainability for industrial ecology. The main constituents that important in geopolymer production were alkaline activator and source materials that rich in silica (Si) and alumina (Al). The benefits of using geopolymer in term of environmental issues were potential reduction in greenhouse gases emission and utilization of waste materials [1-2]. The common source materials used were fly ash, ground granulated blast furnace slag (ggbs), kaolin, metakaolin and silica fume [3-5].

Disposal of waste tire involve with environmental issues where the heavy metals in tires generate risk when it was disposed in the landfill [6-7]. The leaching of toxins from the metals inside the tires when the landfill was wet will disturb the groundwater quality [6]. In Malaysia, it was estimated about 57,391 tonnes of waste tires generated annually where 60% of it were disposed via unknown routes [8]. The accumulation of utilized tires at landfill sites also showed the danger of uncontrolled flames, creating a complex blend of chemicals harming the earth and defiling soil. The utilization of rubber crumb in concrete has been started since last two decades to reduce environmental impact [9-10]. The findings from the past researches showed that the compressive strength and flexural strength decreased when the content of rubber crumb increased [11-15]. Nevertheless, the properties such as the ductility and impact resistance improved [9-13]. Generally, the rubber crumb was used in concrete to replace either fine aggregate or coarse aggregate.

Park et. al [6] investigate the effect of adding rubber crumb in three different type of fly ash based geopolymer as partial replacement of fine aggregate. It was found that the content of calcium oxide (CaO) in fly ash play significant role in the compressive strength of rubberized geopolymer concrete [2]. Besides that, the replacement of rubber crumb up to 20% cause reduction in compressive strength approximately 15%. According to Azmi et al. [14], all geopolymer samples with inclusion of rubber crumb (5%, 10%, 15% and 20%) displayed strength reduction when tested on 7 and 28 days. However, the strength of all geopolymer samples still higher compared to normal rubberized concrete. It can be seen from the previous research, the utilization of rubber crumb in geopolymer concrete was not investigated thoroughly. Most of the researches focused on effect of rubber crumb percentage for the short term performance.

In the present study, rubber crumb were added in fly ash based geopolymer concrete as replacement for coarse aggregate. The amount of rubber crumb added in ranges of 5% until 20% and control samples were prepared for comparison purpose. The durability of the samples in term of compressive strength, density and changes in weight after expose in marine environment for 28 and 60 days were observed.

2. Materials and methods

2.1. Materials

The main constituents used to produce geopolymer are class F fly ash and alkaline activator. The fly ash was obtained from CIMA, Perlis, Malaysia and its chemical composition has been determined by using X-Ray Fluorescence (XRF) as showed in Table 1.

Table 1. Chemical composition of fly ash.

Constituents	Mass (%)
SiO_2	55.9
Al_2O_3	27.8
CaO	3.95
Fe_2O_3	7.09
TiO_2	2.25
K_2O	1.55
SrO	0.37

Figure 1. Rubber crumb.

Sodium silicate and sodium hydroxide (NaOH) were used as alkaline activator. Crushes stone was used as coarse aggregates with maximum size 20mm and river sand as fine aggregates with size not more than 4.75mm. The rubber crumb was obtained from motorcycle scrap tires where it was cut with size 0.5cm to 1cm as given in Figure 1.

2.2. Mix designs and mixing process

The details mix design of geopolymer concrete are given in Table 2. Five concrete mixes were designed with 0, 5, 10, 15 and 15% rubber crumb. The ratio of fly ash/alkaline activator and sodium silicate/NaOH were fixed at 2.0 and 2.5 for the whole samples [15]. The mass ofaggregates to fly ash was 70% and 30% where the proportion of coarse aggregates and fine aggregate are 60% and 40% of the total mass of aggregates used. Meanwhile, the concentration of NaOH solution was fixed at 12 Molar [15]. Geopolymer paste were produced first by mixed fly ash and alkaline activator for 3 minutes. Then the rubber crumb, fine and coarse aggregates were added into the mixture and mixed for another 5 minutes. After mixing, the geopolymer concrete mixture was cast in 100mm x 100mm x 100mm steel mould and left at room temperature for 3 days before immersed in seawater. The geopolymer concretes were exposed in seawater for a period of 28 and 60 days.

The effect of seawater on GPC0, GPC5, GPC10, GPC15 and GPC20 were evaluated through compressive strength, weight changes and density.

Table 2. Mix proportion of geopolymer concretes.

Mix No.	Rubber Crumb	Fly Ash	Coarse Aggregate	Fine Aggregate	NaOH solution	Sodium silicate solution
GPC0	0	624	1310	874	89	223
GPC5	65.5	624	1244.5	874	89	223
GPC10	131	624	1179	874	89	223
GPC15	196.5	624	1113.5	874	89	223
GPC20	262	624	1048	874	89	223

3. Results and discussions

3.1. Compressive strength

Compressive strength of geopolymer samples with inclusion of rubber crumb are shown in Figure 2.

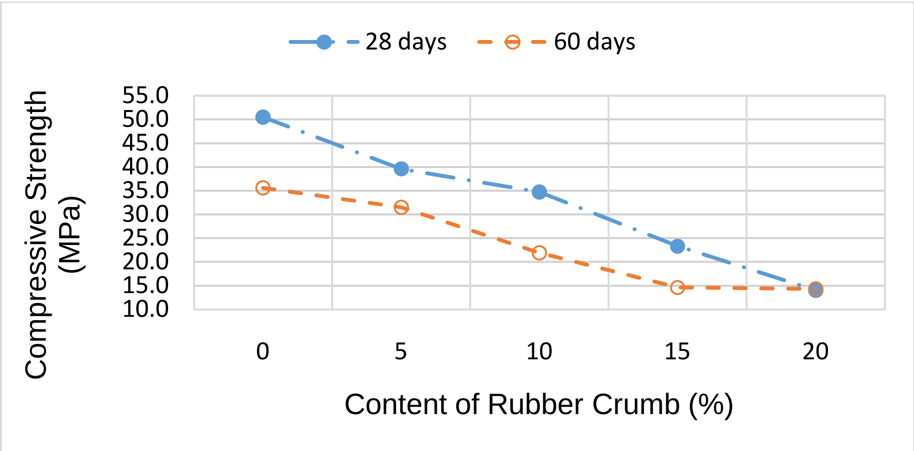

Figure 2. Compressive strength of geopolymer concrete exposed to seawater.

The geopolymer samples showed reduction in strength when percentage of rubber crumb added increased for 28 and 60 days exposure period. The control sample (GPC0) displayed high strength (50.5 MPa) after being exposed for 28 days in seawater. The maximum compressive strength of

39.6MPa and 31.5MPa was recorded by GPC5 for both exposure periods. Nevertheless, the strength decreased when rubber crumb was added where the reduction in strength between control sample and GPC5 was 22% for 28 days exposure periods. However, there is only slight difference in strength for GPC20 for both exposure periods. The reduction in strength when the content of rubber crumb increase was due to lack of bonding between geopolymer paste and rubber crumb. Moreover, the insufficient bonding also leads to high internal stress which is perpendicular to the direction of applied load.

3.2. Density and weight changes
The addition of rubber crumb in geopolymer concrete reduce the density as shown in Figure 3. It was observed that the density decreased when the percentage of rubber crumb increase due to the low unit weight of rubber crumb. The lowest density of 2190 kg/m^3 was recorded by GPC20 and the control sample (GPC0) recorded 2360 kg/m^3. Besides that, the rubber crumb content also influence the porosity of geopolymer concrete. When the geopolymer samples exposed to seawater for 28 and 60 days, an increment in weight were recorded for all samples.

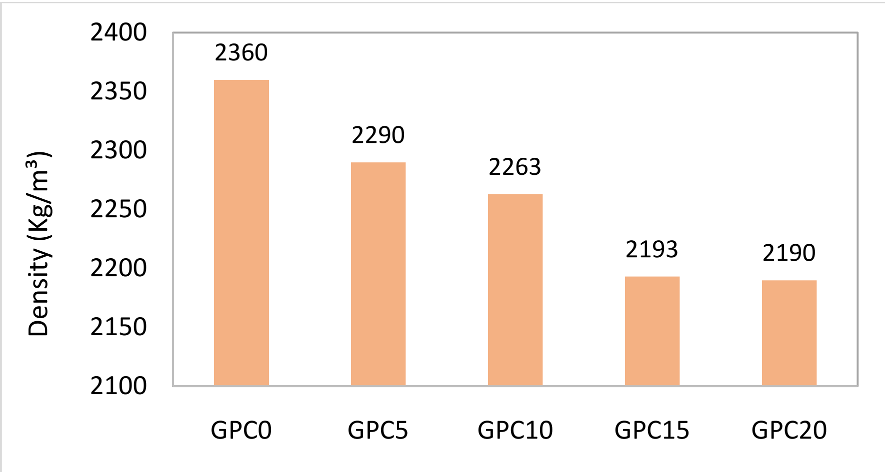

Figure 3. Changes in density after inclusion of rubber crumb.

The changes of weight for geopolymer samples that have been immersed in seawater for 28 and 60 days were shown in Figure 4. From the result, it showed that changes in weight for 28 days were fluctuate for different percentage of rubber crumb contents. The geopolymer sample with 15% replacement of rubber crumb (GPC15) showed maximum changes in weight (1.33%) and the lowest changes in weight was recorded on sample with 5% replacement of rubber crumb (GPC5).This result was consistent with the maximum compressive strength recorded by GPC5. However, weight changes for GPC20 decreased rapidly compared with GPC15. This may be due to the properties of rubber crumb itself which is impermeable of water, as such high content of rubber crumb less water was absorb by the GPC20 samples.

All the samples displayed an increment in weight when the content of rubber crumb increased for 60 days exposure periods as illustrated in Figure 4. The weight changes also more significant compared to 28 days exposure period. The control samples (GPC0) for both exposure periods recorded almost similar weight changes which is 0.84% and 0.85%. Meanwhile, the lowest weight change for 60 days exposure period was shown by GPC5 (0.85%).

If compared with 28 days exposure period, an increment almost 50% was displayed by GPC5. Moreover, GPC20 also displayed maximum increment of weight changes (1.9%) due to high content of rubber crumb and also improper compaction during moulding process lead to this result. As can be seen in Figure 5, GPC20 samples was covered with rubber crumb which reduced the strength and lead to excessive seawater absorption due to heterogenous mixture between geopolymer paste and rubber crumb.

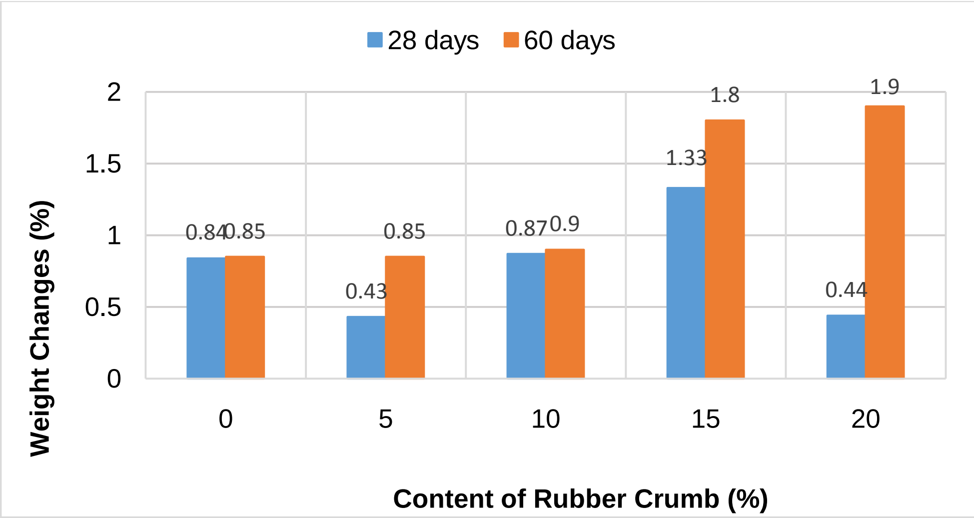

Figure 4. Weight changes of geopolymer samples after exposure periods of 28 and 60 days.

Figure 5. GPC20 after compressive strength testing.

Besides that, the size of rubber crumb also for this study also lead to reduction of compressive strength.

4. Conclusions

This study highlights the influence of rubber crumb range from 0% to 20% in fly ash based geopolymer concrete exposed to seawater for a period of 28 and 60 days. The following conclusion are presumed.

a) The inclusion of rubber crumb decreased the compressive strength where 5% of rubber crumb contribute to reasonable compressive strength. The strength tends to decrease when exposure period in seawater increased.

b) The density of geopolymer concrete reduced when rubber crumb was added due to its lightweight properties.

c) All geopolymer samples recorded weight gain when exposed to seawater. GPC20 recorded the highest weight gain due to heterogeneous mixture between geopolymer paste and rubber crumb as well as the size of rubber crumb itself. The higher content of rubber crumb, increased the porosity of geopolymer hence more water can penetrate hence reduce the strength and increased the weight of samples.

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