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To cite this article: R Premkumar *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **561** 012055

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Durability Performance of Fly Ash and Steatite Powder Based Geopolymer Concrete

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Abstract: This paper deals with the study of durability properties of fly ash and steatite powder based Geopolymer concrete. The activating alkali used was 10 M sodium hydroxide and sodium silicate solution. The ratio of sodium hydroxide and sodium silicate ratio was 1:2.5. The range of replacement levels of flyash with steatite powder was from 0 – 50 %. In order to improve the workability of geopolymer concrete, a PC based admixture Glenium B233 has been used for all the mixtures. In addition to that the concrete has been cured at oven at 70°C for about 48 hours. The following durability index properties such as water absorption, sorptivity, rapid chloride penetration test and acid attack test were measured at 28 days. The observed results indicated that, increase in steatite powder demonstrates low water absorption and low permeability representing that the material was in a high dense pore structure. Additionally in acid resistance test, there was a decline in the percent losses of compressive strength with particular time period but then again the declination was lower when compared to increase in steatite powder.

1. Introduction.

Geopolymer is a special concrete which has several advantages like high strength, high acid/alkaline resistance, heat resistance, excellent mechanical properties and environmental responsiveness. Owing to the increased usage of byproducts among the industries, several research has been focused towards the alkali activation of metakaolin and fly ash [1]. Sodium silicate is one of the most recent chemical additives that are in use to reduce the binder content in cemented backfill CPB and increase its strength [2]. Alkali-activation technology is a suitable alternative for the invention of environmentally sociable cementitious materials. Alkali activated binders can develop benefits such as high mechanical strength at early ages, higher resistance to acid attack and high performance when exposed to elevated temperatures, depending on the nature and dose of the precursor and activator used, and the curing conditions adopted [3]. Shanmugasundaram et al. [4] Studied the pozzolonic activity by the replacement of cement paste by UFNSP up to 25% of mass of the cement. Based on a study on microstructures bonding behavior of cement paste, found that dense concrete structure was due to the growth of portlandite by 20% percent replacement of USNSP. Faiz et al [5] founded that geopolymer concretes possessed better durability properties with the use of recycled coarse aggregate. In sorptivity test and water absorption test the correlation was strong between compressive strength and volume of permeable voids. Francis et al. [6] concluded that compared with normal cement concretes outstanding durability properties were obtained when 20% of silica fume was added with fly ash based geopolymer concretes. The steatite powder contains robust binding materials in which silica content is high [9]. A number of studies on different binding materials like GGBS, flyash, metakaolin, etc. [1],[7] were conducted either individually or combined. So this research was done on the durability properties of steatite powder based geopolymer concretes



2. Experimental Investigation

2.1 Constituent materials

Class F fly ash was collected from National Thermal Power Corporation, Thootukudi, Tamil Nadu (India). The steatite powder was obtained from the Ultra fine minerals Pvt. Limited India. The Steatite powder was tested for its physical and chemical properties and was listed in Table 1. Coarse aggregate passing through 12.5mm sieve was used. The specific gravity of the coarse aggregate used was 2.75. Quarry dust obtained from hard granite stone by crushing was used as partial replacement of fine aggregate. Table 2 shows the physical and chemical properties of quarry dust and fine aggregate. The alkali activator solution used consisted of a mixture NaOH and Na₂SiO₃ solution. In this study sodium hydroxide concentration of 10M was used to manufacture various specimens. NaOH and Na₂SiO₃ were mixed in ratio of 1:2.5 based on previous work on geopolymer concrete [7]. A PC based admixture Glenium B233 was used to increase the workability of geopolymer concrete.

2.2 Mix Proportions and preparation of specimens

The fly ash was initially replaced at 10%, 20%, 30%, 40%, and 50% with steatite powder. There is no proper mix design procedure for Geopolymer concrete using fly ash, GGBS and alkaline solutions. Hence mix design was adopted from the previous work on geopolymer concrete. Quarry dust and coarse aggregate were dry mixed in the pan mixer for 2 minutes followed by the addition of the fly ash and steatite powder and mixed thoroughly for few minutes. Alkali solutions were added in correct proportions along with extra water. Glenium B233 was used to increase the workability of concrete specimen. As the workability was obtained the mixed concrete was laid on the cube mould and tamped for 25 times for every layer accordingly.

The specimens after casting were fully covered with polythene bags for a period of 24 hours. Then the specimens were kept in the oven at 70 ° C for duration of 48 hours. Later the specimens were taken out after 28 days. In order to determine the durability performance of Geopolymer concrete specimens, cube sizes of 100mm x 100mm, cylinder 100mm x 200mm and 100mm x 50mm were prepared. In the durability investigation, water absorption test, sorptivity test, rapid chloride penetration test and acid attack test were conducted.

Table 1. Properties of Steatite Powder

Blaine surface area (m ² /kg)	Loss of Ignition	Particle Mean Dia (µm)	Density	SiO ₂	Al ₂ O ₃	MgO	Fe ₂ O ₃	C _a O
750	3.33%	< 5	2.7	62.67%	0.24%	33.26%	0.30%	0.20%

Table 2. Properties of Quarry dust and Sand

	Quarry dust	Sand
Specific gravity	2.73	2.63
Fineness modulus	3.4	2.65
Aggregate Zone IS383-1970	Zone II	Zone II

Table 3. Concrete Mix Proportions

Mix	Fly ash (kg/m ³)	Steatite powder (kg/m ³)	NaOH (kg/m ³)	Na ₂ SiO ₃ (kg/m ³)	Quarry dust (kg/m ³)	Coarse Aggregate (kg/m ³)	W/GPB (lit)	Extra Water (lit)
GS0	505	0	51	126	587	1247	120	13
GS10	455	51	51	126	587	1247	120	13
GS20	404	101	51	126	587	1247	120	13
GS30	354	152	51	126	587	1247	120	13
GS40	303	202	51	126	587	1247	120	13
GS50	253	253	51	126	587	1247	120	13

2.3 Durability Properties

The water absorption test and sorptivity test were performed as per ASTM C 642-82 code, on the 100mm sized cube specimen. Sorptivity test specimen sides were sealed by insulation coating and were kept in water immersed to a depth of 5-10mm. The experiment results were taken at regular interval of 30 minutes for a time period of 4 hours. According to ASTM C 1202-97, Rapid Chloride Penetration Test was one of the major determinations of chloride ion penetration, which was carried out on the 100 x 50mm cylinder sized specimens [9]. In this test DC electric charge 60 V was passed side to side of concrete specimens. One side of the concrete cylinder specimen face was exposed to sodium chloride solution of 3% concentration and the other side of specimen side was exposed to 0.3M NaOH solution. The experiment results were taken at regular interval of 30 minutes for a time period of 6 hours. The acid resistance test was conducted to determine the sulphate and chloride resistance on the geopolymer concrete cube specimen of size 100mm. Owing to the immersion in both acid solutions, a decrease in the mass of the specimen at regular intervals of time period related to compressive strength of concrete was observed.

3. Results and Discussion

3.1 Sorptivity Test

The correlation coefficient values of initial water absorption of geopolymer concrete in sorptivity test was shown in Figure 1. From the results, it is observed that for GS20, the correlation coefficient was 15% less than that of GS0 specimen. An increase in the steatite content leads to the decrease in correlation coefficient in sorptivity test. It was manifested that the decrease in absorption was due to the decline in the capillary rise as it possessed due to substandard properties of steatite powder. It may be concluded that partial replacement of steatite powder along with quarry dust reduces the porous nature of Geopolymer concrete structures.

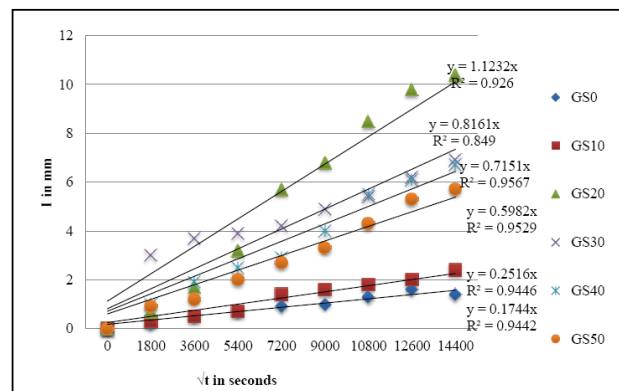


Figure 1. Initial water absorption of Geopolymer concrete containing steatite powder

3.2 Water Absorption Test

The correlation coefficient between water absorption and varying percentages of steatite powder say GS0, GS10, GS20, GS30, GS40, and GS50 was shown in figure 2. The water absorption of geopolymer concrete was reduced by increasing the percentage of steatite powder, which in turn reduces the permeability content in the specimens. There was a slow fall trend in water absorption in the specimen GS30 and GS40 and nearly no changes between GS40 and GS50.

3.3 Rapid Chloride Penetration Test

Rapid chloride penetration test illustrates the total electric charges that pass through the specimen of Geopolymer concrete. In Table 4, the test results were compared with the limiting values on ion penetrability of concrete specimens recommended by ASTM C 1202. As the results were in lower limit, the concrete was more resistant to the chloride ion penetrability. Corresponding to the increase in the percentages of steatite quantity of electric charge values increase but the rise was within the standard of limiting grades as per ASTM C 1202. It was concluded that partial replacements of

steatite with fly ash have no undesirable effect on resistance of concrete specimen against chloride ion penetration of concrete.

3.4 Acid Resistance Test

The percentage weight loss in compressive strength of the Geopolymer concrete results were shown in figure 3 & 4. The value of strength G25 decreased continuously with respect to time of immerse in solution. In the results shown weight loss in compressive strength was 10 to 12 % of initial strength of Geopolymer concrete before immersing acid solution such as HCL & H2SO4. Based on this test result GS20 specimen was porous, so the value was higher compared with all other cases. Since the fly ash was partial replaced with steatite powder, the values were low for fly ash based geopolymer specimens exposed to above mentioned solutions. It was clear that very dense concrete specimens were developed using the steatite and quarry dust.

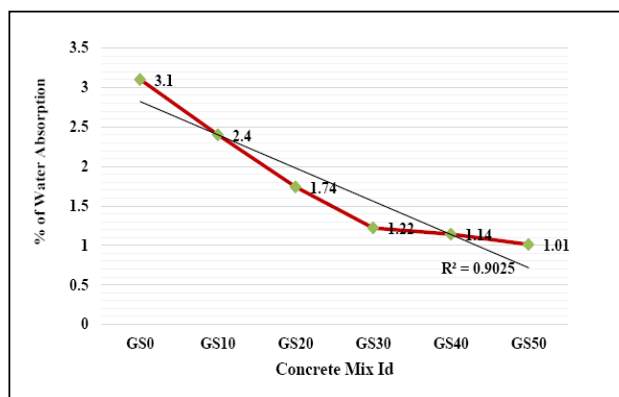


Figure 2.Water Absorption for various percentage of steatite power based Geopolymer concrete

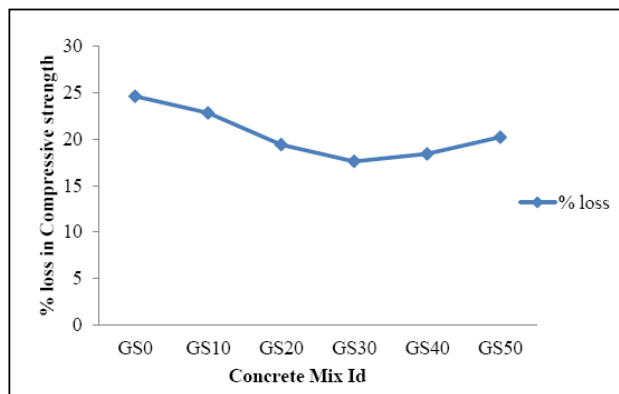


Figure 3. Percent loss in compressive strength in Sulphate Resistance Test

Table 4.Result on RCPT

MIX	Quantity of Electric Charge (C)	As per ASTM
GS0	1321	Low
GS10	1456	Low
GS20	1467	Low
GS30	1430	Low
GS40	1457	Low
GS50	1627	Low

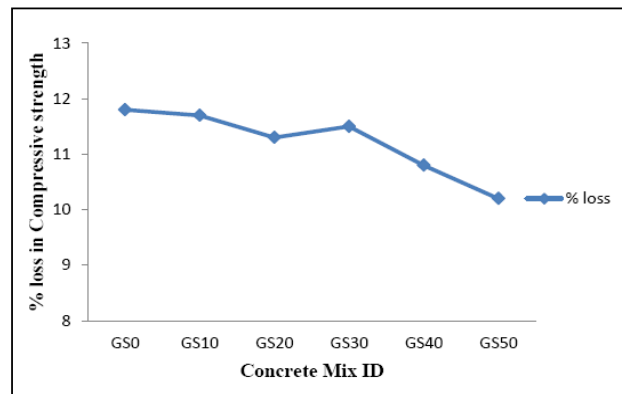


Figure 4. Percent loss in compressive strength in Chloride Resistance Test

4. Conclusion

The following conclusions was obtained from the preliminary study on durability performance of partial replacement of fly ash with steatite powder and quarry dust,

Application of steatite and quarry dust materials reduces the voids on all the specimens due to particle size of the materials. Owing to the low permeability content in the specimens there was a decline in water absorption test results where an increase in the steatite powder percentages gradually decrease the water content.

- The addition of steatite powder reduces the pores in concrete and also improved the microstructure of GPC specimens. The voids in the specimen structure were engaged by very fine particles in binding materials like steatite. This was the cause for the worthy result in sorptivity test.
- Rapid chloride penetration test result indicates that in all geopolymer concrete the ion penetration value was within the permissible limit as per specification ASTM C1202. Also addition of steatite powder had no adversative effect on chloride resistance of geopolymer concrete.
- Acid attack tests - sulphate and chloride resistance test results showed insignificant weight loss for all type of geopolymer concrete. In this connection loss in compressive strength of all the geopolymer concrete specimens was less than 20% to 35%.

Acknowledgments

The authors would like to place their gratitude to the Kalasalingam Academy of Research and Education students S.Sahaya PavithraM.Tech Structural Engineering and Ramesh M, EsakkiMuthu E, Manoj Kumar M of B.Tech. Civil Engineering for their help in casting and testing of the geopolymer concrete.

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