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Research paper

Properties of geopolymer pervious concrete made with GGBS

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Abstract

Pervious concrete is a light weight concrete containing voids in the range of 14 to 31%. The usage of pervious concretes has been increased due to its merits on pollution control and environmental considerations. The pervious concretes are also used to reduce the storm water runoff and recharges the underground water table. Eventhough the pervious concrete has lot of merits, it also has consider- able demerits related to strength issues. In order to achieve the strength high cement content mixes may be incorporated which is not a viable solution. In this paper, geopolymer technology has been used to develop pervious concrete. Geopolymer pervious concrete is pro- duced using GGBS as raw material and sodium hydroxide and sodium silicate as activator solution. Five mixes have been developed with varying GGBS content of 450, 460, 470, 480 and 490 kg/m3. The cement to aggregate ratio is fixed at 1:3 for all the mixtures and the water cement ratio is kept constant at 0.3. The compressive strength revealed that strength of around 20 MPa was attained for all the mixtures and strength increases with respect to the increase in GGBS content. There was not significant changes in the permeability property since the aggregate cement ratio is maintained for all the mixtures.

Keywords: *GGBS; Geopolymer; Sodium Silicate; Sodium Hydroxide; Permeability*.

1. Introduction

Pervious concrete is a light weight concrete consisting of coarse aggregate, Portland cement, and water. The typical air voids reported for pervious concrete mixes in the United States range from 14 to 31% [1]. A multitude of experiments have been performed by several researchers on pervious concrete. Malhotra [2] performed experiments on pervious concrete to find the corre- lation between compressive strength and mix design parameters. He concluded that compressive strength depends on the water cement ratio and the aggregate cement ratio. Meninger [3] per- formed various tests on pervious concrete by varying the parame- ters such as water cement ratio, aggregate cement ratio, compac- tion and curing time. The results obtained were similar to those of Malhotra. Meninger also found that the compressive strength of pervious concrete was found to be less than conventional concrete and should be utilized in areas restricted to automobile use and light duty areas. Huang et al. [4] studied the permeability and strength properties of polymer modified pervious concrete. They suggested that it was possible to produce pervious concrete with acceptable permeability and strength through the combination of latex and sand. Shu et al. [5] compared the performance of laboratory and field produced pervious concrete mixtures. Their results showed that the pervious concrete mixtures made with latex exhibited lower porosity and permeability, higher compressive and split tensile strengths, and higher abrasion resistance than those without latex. They also suggested that properly designed and laboratory verified pervious concrete can meet the requirements of permeability and strength properties in the field. Tho-in et al. [6] evaluated the performance of pervious concrete made of high calcium fly ash geopolymer binder. They stated that geopolymer satisfactory mechanical properties. Sata et al. [7] studied the performance of pervious geopolymer concrete using recycled aggregate. They stated that it is feasible to use Recycled concrete (RC) and Recycled brick (RB) as recycled coarse aggregates with high-calcium fly ash geopolymer binder for making pervious concrete with acceptable properties. However, they also stated that the using RC and RB resulted in significant losses in strength as compared to a natural aggregate pervious concrete. Ibrahim et al. [8] studied the performance of pervious concrete by varying the parameters such as coarse aggregate size, coarse aggregate volume, water-to-cement ratio, and cement content. They found that the average water permeability coefficient of pervious concrete produced from poor graded coarse aggregate is approximately 0.021 m/s.

From the International perspective, it has been observed that lot of work has been done of pervious concrete. But work on geopolymer pervious concrete is limited, which has to be strength- ened by performing research related to that field. This research paper mainly aims at developing geopolymer pervious concrete with GGBS as raw material and sodium hydroxide and sodium silicate as activator solution and studying its mechanical and per- meability properties.

2. Materials used

Ground granulated blast furnace slag procured from locally available vendor has been used for the entire study. The chemical composition of GGBS was analysed using XRay florescence test. The results of the XRF analysis are shown in Table 1 and Figure 1 respectively. Coarse aggregate of nominal maximum size 20mm used in this investigation have been procured locally from Srivilliputhur, Tamilnadu, India. Aggregate properties, specific gravity, bulk density and sieve analysis are determined as per the procedures mentioned in IS 2386 (shown in Table 2 and 3). Commercially available Polycarboxylate based high range water reducer was used to maintain the workability in the concrete mix.

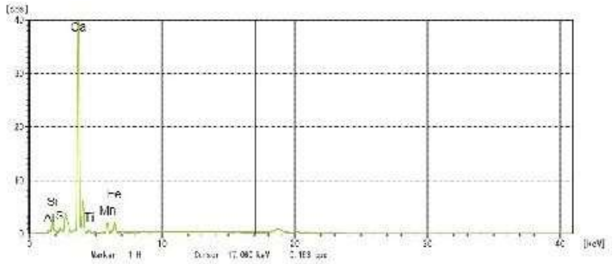

Fig. 1: XRF Analysis of GGBS.

Table 1: XRF Analysis of Clinkers and Gypsums Used in the Study

Oxides	GGBS
SiO_2	29.929
Al_2O_3	10.968
Fe_2O_3	1.084
CaO	52.388
TiO_2	1.498
MnO_2	1.707
SO_3	2.427

Table 2: Properties of Coarse Aggregates

Coarse aggregate	20 mm
Specific gravity	2.80
Water absorption, %	0.40

Table 3: Sieve Analysis of Coarse Aggregate

IS sieve	Weight retained (g)	Cumulative % retained	Cumulative % passing
40	0	0	100
20	1406	46.17	53.13
10	1520	97.53	2.47
4.75	74	100	0

2.1. Mix proportions

All geopolymer pervious concrete (GPC) mixtures were produced with GGBS to aggregate ratio of 1:3 by weight. The Na2SiO3/NaOH ratio and alkali liquid/GGBS ratio were kept constant at 2.5 and 0.3 respectively. The molarity of NaOH was kept constant at 12M for all the mixtures. The proportions of various GPC mixtures used in this investigation are shown in Table 4

Table 4: Mix Proportion for GPC Concrete

Mix ID	GGBS content, kg/m^3	Coarse aggregate, kg/m^3	NaOH lit/m^3	Na_2SiO_3 lit/m^3	Admixture, kg/m^3
GPC450	450	1350	39	96	2.7
GPC460	460	1380	39	99	2.76
GPC470	470	1410	40	101	2.82
GPC480	480	1440	41	103	2.88
GPC490	490	1470	42	105	2.94

2.2. Mixing, curing and casting

The sodium hydroxide and sodium silicate solutions of desired quantity were mixed together about 24 hours prior to the mixing of other ingredients to accelerate the reactivity of the alkaline solution. Concrete ingredients were mixed in a laboratory pan mixer until a uniform mixing is achieved. The concrete were then casted in cubes and cylinders and kept undisturbed for 24 hours. After 24 hours, the moulds were removed and stored at room temperature till the date of testing.

2.3. Testing methods

The compressive strength was performed on 150x150mm cubes at 7 and 28 days respectively as per IS 516 1989. The split tensile test was performed on 100x200mm at 28 days as per IS 516 1989. Flexural strength was carried out on 100x100x500mm prism as per IS 516 1989. The results discussed in the subsequent section are average of three readings. Permeability test was conducted on 100x200mm cylinders as per falling head permeability method. The surfaces are covered with polythene sheets as shown in figure and time is noted for particular measure of water. The experimental setup for measuring the permeability test is shown in Figure 2. Figure 3 and 4 shows the cylinder sample used for split tensile test and flexural strength of GPC respectively.

Fig. 2: Experimental Setup for Measuring Permeability.

Fig. 3: Cylinder Used for Split Tensile Test.

Fig. 4: Flexural Strength for GPC.

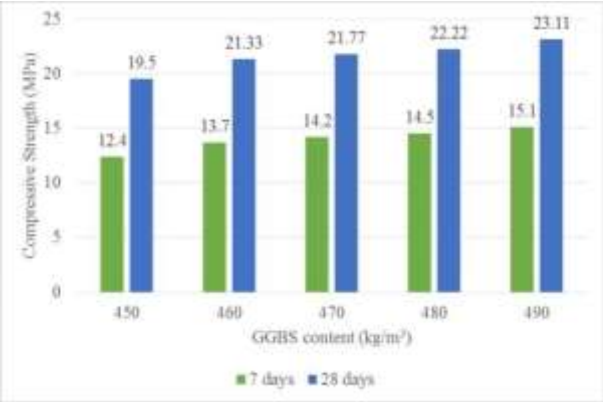

Fig. 5: Compressive Strength of GPC Mixtures.

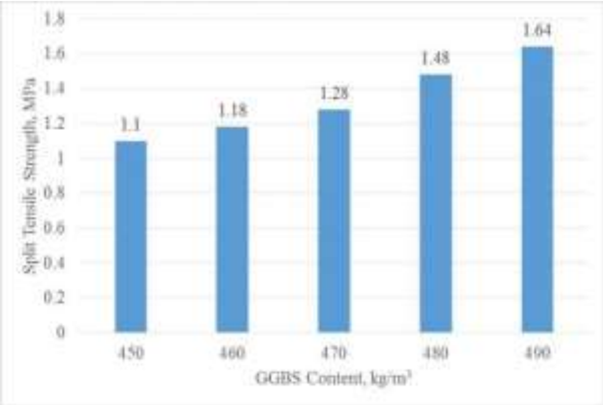

Fig. 6: Split Tensile Strength of GPC Mixtures.

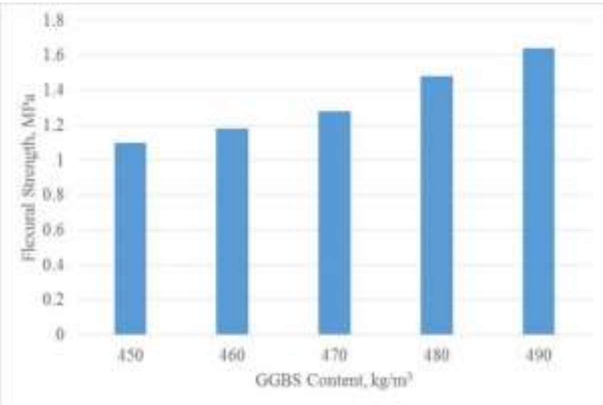

Fig. 7: Flexural Strength of GPC Mixtures.

3. Results and discussion

3.1. Effect of GGBS content on the compressive strength

Figure 5 shows the compressive strength results of GPC concretes with various GGBS contents at 7 and 28 days respectively. From the 7 days compressive strength results it is been observed that there is slight increase in the strength of GPC mixes with respect to change in GGBS content from 450 to 490kg/m3. The strength increase was around 20% from change of GGBS content from 450 to 490kg/m3. The strength was increased around 50% from 7 days to 28 days for all the mixtures. Figure 7 shows the split ten- sile strength results of GPC mixtures at 28 days. The split tensile strength followed the same trend as that of compressive strength. The split tensile strength results varied from 0.6 MPa to 1.03 MPa by varying the GGBS content from 450 to 490 kg/m3. Figure 8 shows the flexural strength of GPC concretes at 28 days for differ- ent GGBS contents. The flexural strength also followed the same trend as that of compressive strength results.

Table 5: Penetration Time of GPC Mixtures

Mix ID	Penetration time (sec- onds/lit)
GPC450	20
GPC460	19
GPC470	18
GPC480	17
GPC490	16

Table 5 shows the penetration time of all GPC mixtures at 28 days for one litre of water. It is been observed that for 450 kg/m3 the penetration time is 20 seconds and it is reduced with respect to the increase in GGBS content. It is obvious that more cementitious content may fill the voids and results in the reduction in the per- meability properties which is evident from the results of penetra- tion time test.

4. Conclusion

The following conclusion can be drawn from the investigation carried out on GPC mixtures

- The compressive strength of all GPC mixtures was around 20 MPa at the age of 28 days, which is more positive for us- ing the GPC mixtures for pavement appli- cations
- The compressive strength increases with increase in GGBS content, but the increase in not significant due to the porous nature of the concrete
- The split tensile strength and flexural strength follows the same trend as that of compressive strength
- The permeability test revealed that permeability increas- es with decrease in cementitious content and vice versa

Acknowledgements

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