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A Study on the Mechanical Properties of Concrete replaced with GGBFS, Fly Ash, Sodium Silicate and Sodium Hydrauxide in Place of Cement

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Abstract

Geo-polymer concrete is a 'new' material that does not need the presence of Portland cement as a binder. Instead, the source of materials such as fly ash and GGBS that are rich in Silicon (Si) and Aluminum(Al),are activated by alkaline liquids to produce the binder. Hence concrete with no Portland cement. Fly ash was chosen as the basic material to be activated by the geo polymerization process to be the concrete binder, to totally replace the use of Portland cement. To activate the Silicon and Aluminum content in fly ash, a combination of sodium hydroxide solution and sodium silicate solution was used.

Keywords: *Concrete, Fly ash, GGBS, Sodium hydroxide, Sodium Silicate.*

Introduction

In this work, fly ash-based geo-polymer is used as the binder, instead of Portland or any other hydraulic cement paste, to produce concrete. The fly ash based Geo-polymer paste binds the loose coarse aggregates, fine aggregates and other un-reacted materials together to form the geo-polymer concrete, with or without the presence of admixtures. The manufacture of geo-polymer concrete is carried out using the usual concrete technology methods.

As in the OPC concrete, the aggregates occupy the largest volume, i.e.about75-80%bymass,in geo-polymer concrete. The silicon and the aluminum in the low calcium (ASTM Class-F) fly ash a reactivated by a combination of sodium hydroxide and sodium silicate solutions to form the geo-polymer paste that binds the aggregates and other un-reacted materials.

Fly ash

Fly ash, which is largely made up of silicon dioxide and calcium oxide, can be used as a substitute for Portland cement, or as a supplement to it. The materials which makeup fly ash are Pozzolanic, meaning that they can be used to bind cement materials together. Pozzolanic materials, including fly ash cement, add durability and strength to concrete.

Oxides	Mass (%)
SiO2	59.9
Al2O3	24.7
Fe2O3	6.3
SiO2 + Al2O3 +Fe2O3	90.8
CaO	2.0
MgO	1.9
TiO2	1.0
K2O	2.9
Na2O	0.3
SO3	0.1
Loss on Ignition (1000oC)	0.3

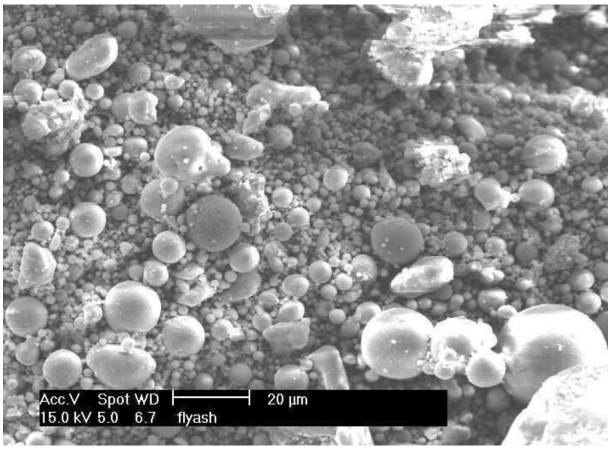


Figure: Image of Fly Ash

Ground granulated blast furnace slag (GGBFS)

Ground-granulated blast-furnace slag (GGBFS) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder.

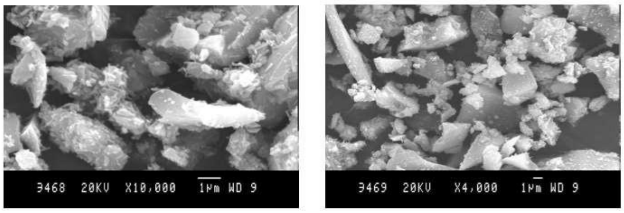


Figure: Image of GGBFS

Table - Characteristics of GGBS

S. No	Characteristics	Percentage
1.	Fineness(m2/Kg)	412
2.	Particle Size (Cumulative%)	94.25/100
3.	Insoluble Residue	0.23
4.	Magnesia Content	8.73
5.	Sulphide Sulphur	0.54
6.	Sulphide Content	0.29
7.	Loss On Ignition	0.17
8.	Manganese Content	0.06
9.	Chloride Content	0.010
10.	GlassContent	90
11.	MoistureContent	0.14

Alkaline Activators

To activate the fly ash, a combination of sodium hydroxide solution and sodium silicate solution was chosen as the alkaline activator. The Alkaline solution used for experimental investigation is a combination of Sodium silicate solution and Sodium Hydroxide solution. It is seen that the Geo-polymers with Sodium Hydroxide solution exhibit better Zeolitic properties than Potassium Hydroxide activated Geo-polymers.

Table Maximum Limits of Impurities

Minimum Assay(Acidimetric) Maximum Limits of Impurities	96%
Carbonate	2%
Chloride	0.1%
Phosphate &Arsenic	0.0001%
Sulphate	0.01%
Iron	0.005%

Tests to be conducted

Compressive Strength Test

For each set nine standard cubes were cast to determine 7-days,28 day and 90 days compressive strength after curing. Also nine no. of cube was casted to know the compressive strength of concrete. The size of the cube is as per the IS 10086 – 1982.

Split tensile strength

For each set 9 cylinders were casted and tested for 7 days, 28 days and 90 days for determining the split tensile strength for the optimum proportions of fly ash, silica fume replacements and steel slag additions.

Flexural Test

It is the ability of a beam or slab to resist failure in bending. The flexural strength of concrete is 12 to 20 percent of compressive strength. Flexural strength is useful for field control and acceptance for pavement .but now a days flexural strength is not used to determine field control, only compressive strength is easy to judge the quality of concrete. To determine the flexural strength of concrete four numbers of prism were casting. Then it was cured properly.

Flexural strength = $PL/BD^{2.}$; Where P is load;L= Length of Prism;B = Breadth of Prism;D = Breadth of Prism.

Durability Test

For each set 3 were casted and tested for 90 days for determining the compressive strength for the optimum proportions of fly ash, silica fume replacements and steel slag additions while cured in acidic and base water.

Capillarity Test

Two cube specimens were cast for concrete cube to determine capillary absorption coefficients after 28 days curing. This test is conducted to check the capillary absorption of different binder mix mortar matrices which indirectly measure the durability of the different concrete matrices.

The capillary absorption coefficient (k) was calculated by using formula:

k=Q/A* sqrt (t)

where Q is amount of water absorbed
A is cross sectional area in contact with water; t is timeD = Breadth of Prism

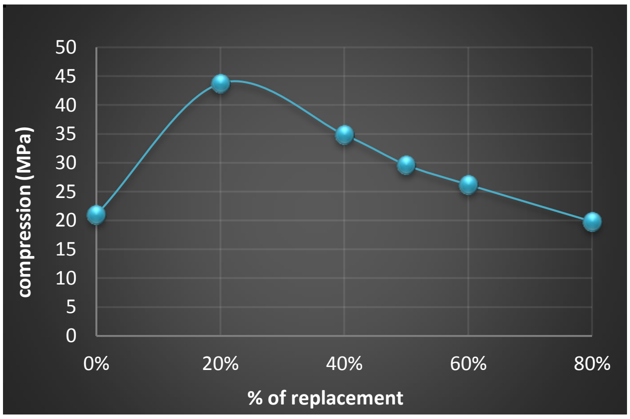
Permeability test

This test covers the laboratory determination of the D'Arcy coefficient of water permeability of hardened concrete specimens using a Concrete Permeameter. The samples are either cored from existing concrete structures or taken from moulded cylindrical specimens.

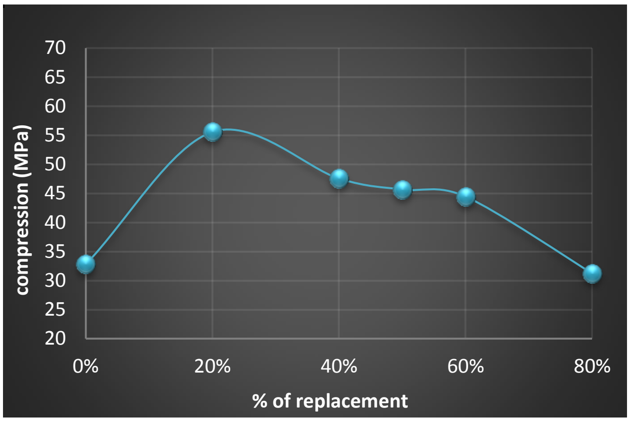
Results

After testing the specimens the results are as follows

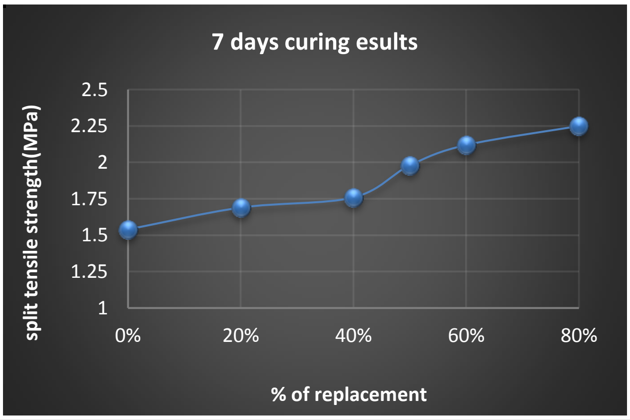
Compressive strength of concrete for 7 days



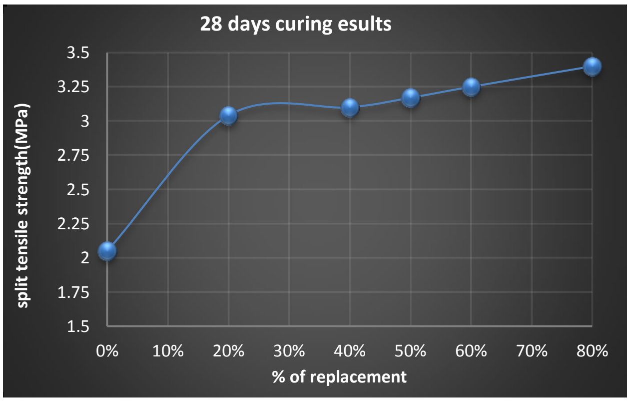
Compressive strength of concrete for 28 days



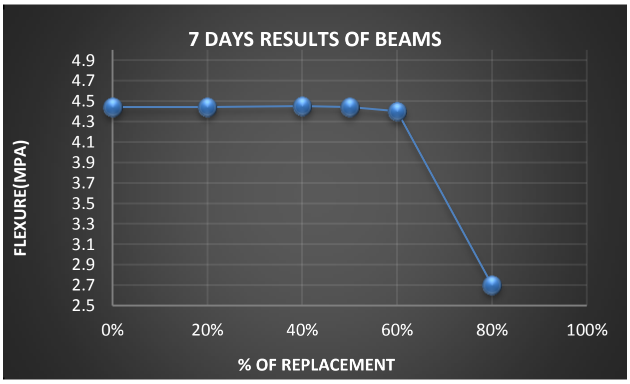
Split tensile strength of concrete for 7 days



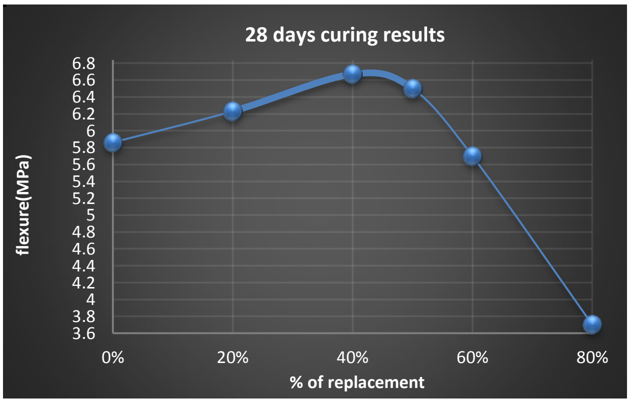
Split tensile strength of concrete with different proportions of admixtures for 28 days



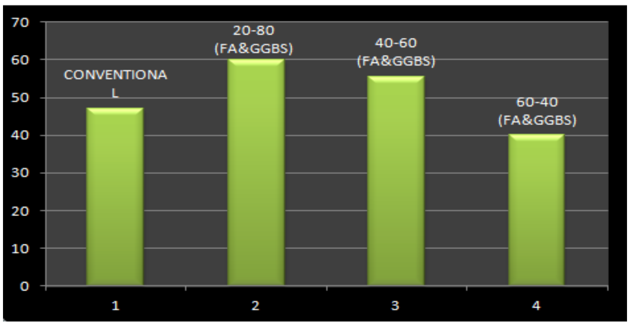
Flexural strength of concrete for 7 days



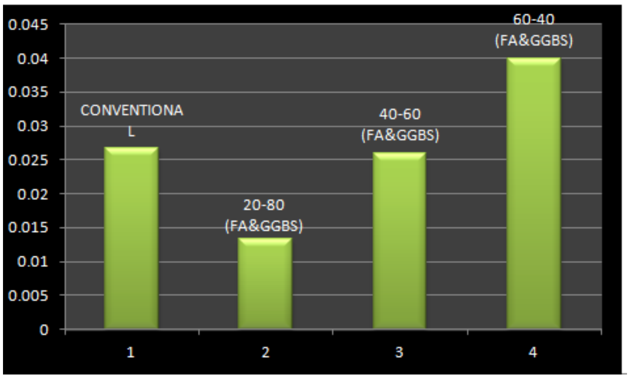
Flexural strength of concrete for 28 days



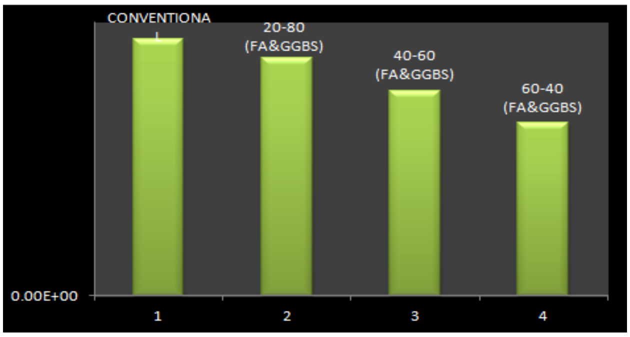
Durability of concrete



Capillarity of Concrete



Permeability of Concrete



Conclusions

- Based on the experimental work reported in this study, the following conclusions are drawn:
- Higher concentration (in terms of molar) of sodium hydroxide solution results in higher compressive strength of fly ash-based geo-polymer concrete
- Higher the ratio of sodium silicate-to-sodium hydroxide ratio by mass, higher is the compressive strength of fly ash-based geo-polymer concrete
- For compression members we are suggesting binder mix comprises of 20% fly ash and 80% GGBS i.e. approx. 1.95 times greater than the conventional.
- But the above proportion shows somewhat poor results in tension when compared to the 40%-60% proportion.
- As the curing temperature in the range of 30oC to 90oC increases, the compressive strength of fly ash-based geo polymer concrete also increases.
- However, the increase in strength beyond 24 hours is not significant.
- The addition of naphthalene sulphonate-based super plasticizer up to approximately 1% of fly ash by mass, improves the workability of the fresh fly ash-based geo-polymer concrete with very little effect on the compressive strength of hardened concrete.
- The slump value of the fresh fly-ash-based geo-polymer concrete increases with the increase of extra water added to the mixture.
- As the ratio of water-to-geo-polymer solids by mass increases, the compressive strength of fly ash-based geo-polymer concrete decreases.
- The average density of fly ash-based geo-polymer concrete is similar to OPC concrete.
- As the ratio of water-to-geo-polymer solids by mass increases, the compressive strength of fly ash- based geo-polymer concrete decreases. The average density of fly ash-based geo-polymer concrete is similar to OPC concrete.

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