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Experimental Study on the Properties of Concrete using Alkali Activated Fly Ash and GGBS as a Binder

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Abstract: The alkali activation of aluminosilicate materials as binder system derived from industrial byproducts have been extensively studied due to the advantages they offer in terms enhanced material properties, while increasing sustainability by the reuse of industrial waste and byproducts and reducing the adverse impact of OPC production. Fly ash and ground granulated blast furnace slag are commonly used for their content of soluble silica and aluminate species that can undergo dissolution, polymerization with the alkali, condensation on particle surfaces and solidification.

Alkali-activated fly ash-slag (AAFS) concrete is a new mix alkali-activated concrete that has been progressively studied over the past decades because of its environmental advantages and superior engineering properties. However, there is a lack of comprehensive studies on the effect of different factors on the fresh and hardened properties of AAFS concrete. In present work the Fly ash (FA) and ground granulated blast-furnace slag (GGBS) were employed as source materials. FA/GGBS ratios (100/0, 80/20, 60/40, 40/60, 20/80, 0/100). Sodium silicate and Sodium hydroxide (NaOH) solution were used as alkaline activator with a NaOH concentration of 10 M. The ratio of sodium silicate and sodium hydroxide (SS/SH) is kept at 2.5. The main aim is to develop a cement less binder activated by sodium silicate and sodium hydroxide. A series of experiments were carried out to measure workability, compressive strength, splitting tensile strength, flexural strength of AAFS concrete. The result showed that workability of the alkali activated fly ash-slag concrete decreases with the increase of the slag content. Compressive strength, Split tensile strength and Flexural strength of the alkali activated fly ash-slag concrete increases with the increase of the slag content.

Keywords: Fly ash, GGBS, Sodium silicate, Sodium hydroxide, Workability, Compressive strength, Split tensile strength, Flexural strength.

I. INTRODUCTION

Concrete is formed made from numerous constituents like cement, aggregates, water, admixtures etc. Concrete is a composite material composed of granular materials like coarse aggregates embedded in a matrix and bound together with cement. With increased awareness of the CO2 emissions from cement production at this large scale, there has been increased focus on mitigation strategies, including a variety of approaches such as consideration of equipment efficiency, fuel substitution (including increased use of biofuels), strategic concrete composition for specific applications, use of alternative raw materials, and use of material substitutes. Alkali activation is a chemical process in which a powdery aluminosilicate such as a fly ash, GGBS and metakaolin is mixed with an alkaline activator to produce a paste capable of setting and hardening within a reasonable short period of time. Alkali Activated Concrete(AAC) is basically considered as class of cement free concrete mainly an alternate to Portland cement based Concrete. Alkali-activated fly ash-slag (AAFS) concrete is a new blended alkali-activated concrete that has been progressively studied over the past decades due to its environmental benefits and superior engineering properties. Alkali activated Fly Ash slag is the alkali activation of ground granulated blast furnace slag blended with Fly ash (FA).

II. LITERATURE REVIEW

F.G Collins et.al (1999) This paper reports the results of an investigation on concrete containing alkali activated slag as the binder, with emphasis on achievement of reasonable workability and strength of Portland cement concrete at normal curing temperatures. In this experimental work two types of activators were used: sodium hydroxide in combination with sodium carbonate and sodium silicate in combination with hydrated lime. The fresh concrete properties reported include slump and slump loss. The hardened concrete properties showed improvement in strength properties.

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Rostami and Befarnia (2016) This paper aims the effect of partial replacement of slag in AAS concrete with silica fume at percentages of 5%, 10%, and 15% by weight of slag. The alkaline activator solution consisted of a combination of sodium hydroxide (NaOH) and sodium silicate (Na2SiO3). Sodium hydroxide solution was prepared by dissolving pellets with 98% purity in water.

The sodium silicate solution used has the ratio of SiO2/Na2O=2.35 (SiO2=36.5%, Na2O=15.5%, H2O=48%). The 28 days compressive strength increased increasing the percentage replacement of slag with silica fume from 5% to 15%.

K. Y Satya Pavan et al. (2018) The present paper reports the testing of alkali activated concrete and a control ordinary Portland cement. (OPC) mortar.

The main aim is to develop cement less binder activated by sodium silicate. Fly ash (FA) and ground granulated blast-furnace slag (GGBS) were employed as source materials. GGBS/Fly ash ratios (100/0, 75/ 25, 50/ 50, 25/ 75, and 0/ 100). The ratio of Na2Oto-source material by weight for different mortars ranged between 3% and 5%; as a result, alkali quality coefficient was varied from 1.0 to 1.5. Compressive strength and Flexural strength and Split tensile strength were measured. Test results clearly showed that the compressive strength development of alkali-activated mortar were significantly dependent on the proposed alkali quality coefficient. long term age for FA-based alkali-activated mortar were comparable to those of OPC mortar.

Eslam Gomaa et al. (2018) In this paper, the mechanical properties of alkali activated concrete (AAC) produced from fly ash was studied. The results revealed that the workability and the mechanical properties depended mainly on the calcium content of the fly ashes. The results revealed that with increasing calcium content in the FA, the slump value was reduced and the mechanical properties including the compressive, splitting tensile, and flexure strengths were reduced in case of curing the concrete at an elevated temperature of 70 o C for 24 hours.

The splitting tensile and flexure strengths of the alkali-activated concrete had a good correlation with the design codes (ACI 318 and AS 3600) that were developed mainly for the Ordinary Portland cement concrete.

A. *Objectives of The Study*

1) To study the workability of the concrete by replacing alkaline activated Fly Ash and GGBS with cement
2) To obtain maximum value of compressive strength of concrete by replacing alkaline activated Fly Ash and GGBS with cement.
3) To obtain maximum value of Split tensile strength of concrete by replacing alkaline activated Fly Ash and GGBS with cement.
4) To obtain maximum value of Flexural strength of concrete by replacing alkaline activated Fly Ash and GGBS with cement.

III. MATERIALS AND METHODOLOGY

A. *Cement*

Cement is one of the binding materials in this work. Cement is the important building material in today's construction world. 43 grade Ordinary Portland Cement conforming to IS: 8112-1989 will be used. The Ultra Shakti cement is used in the present work.

B. *Fine Aggregates*

The Local Available sand from CHENAB (REASI DISTRICT), J&K is used in the present work.

C. *Coarse Aggregates*

The local available coarse aggregates (natural stone Aggregates) are used in the present work. The coarse aggregates with maximum size of 20mm will be used in this present work. The coarse aggregates from KALKA CONSTRUCTION STONE CRUSHER PLANT (REASI DISTRICT), J&K used in this work.

D. *Ground Granulated Blast Furnace Slag*

If the molten slag is cooled and solidified by rapid water quenching to a glassy state, little or no crystallization occurs. This process results in the formation of sand size (or frit-like) fragments, usually with some friable clinker like material. The physical structure and gradation of granulated slag depend on the chemical composition of the slag, its temperature at the time of water quenching, and the method of production. When crushed or milled to very fine cement sized particles, ground granulated blast furnace slag (GGBFS)has cementitious properties, which make a suitable partial replacement for or additive to Portland cement. GGBS is taken from STEEL INDUSTRY (GANGYAL), J&K.

Sr.No.	Ingredients	% Content
1	SIO_2	36
2	AL_2O_3	10.5
3	Cao	39.8
4	Mgo	7.9
5	Na_2O	0.3
6	SO_3	2.1
7	K_2O	0.2
8	Fe_2O_3	0.7

Chemical Composition of GGBS

E. Fly Ash

Fly ash is a by-product obtained from coal burning from electric power plants. Fly Ashes are classified as either class F or class C. Class F fly ash has pozzolanic properties and Class C fly ash has pozzolanic properties as well as cementitious properties. In the present study class C Fly ash is used. The Fly Ash obtained from local Supplier **DEV ENTERPRISES (UDHAMPUR), J&K.**

Sr.No.	Ingredients	% Content
1	SIO_2	51.3
2	AL_2O_3	30.1
3	Cao	8.73
4	Mgo	1.6
5	Na_2O	1.7
6	SO_3	1.4
7	K_2O	1.56
8	Fe_2O_3	3.57

Chemical Composition of Fly Ash

F. Alkaline Activators

The alkali activation of waste materials is a chemical process which allows the user to transform the glassy structures (partially or totally amorphous and/or metastable) into a very compact well cemented composites. Alkali activated materials are generally produced by mixing the alkaline activator solutions with the solid raw materials. Any raw materials containing reactive silica and aluminium can be used for alkali activation.

The mixture of sodium hydroxide (NaOH) and sodium silicate have proved to deliver the best performance in alkali activated binders. The alkaline activator solution was prepared by dissolving the sodium hydroxide flakes in sodium silicate solution in proper proportion in order to achieve the desired activator modulus (Ms=SiO2/Na2O) and desired sodium oxide dosage. The solution was stirred properly and laboratory water was added in order to bring the solution to contain total water content equivalent to water/binder (w/c) 0.42 of total binder content. The solution was stored in a tight plastic container at least one day prior to the mixing. The solution was brought to the desired total water content by mixing extra water during the time of the casting of the specimen. In the present work, a combination of sodium hydroxide and liquid sodium silicate is used as the alkaline activator. 10 M of sodium hydroxide (SH) and sodium silicate (SS) with 31.1 wt.% SiO2 and 12.5 wt.% Na2O were used as alkali-activators. The molecular ratio of SiO2 to Na2O of SS is 2.48. The Ratio of SS/SH is kept 2.5. The Alkaline Activators obtained from LUPIN LMT. (SAMBA), J&K.

G. Water

Potable water is used in this work.

H. Concrete Mix Design

In the present work M30 concrete grade was designed. Concrete mixes were prepared by completely replacing cement with alkali activated fly ash and slag. The Fly Ash to the slag ratio will be (100/0,80/20,60/40,40/60,20/80 and 0/100). Concrete with 0% Fly ash and 0% Slag is termed as normal mix.

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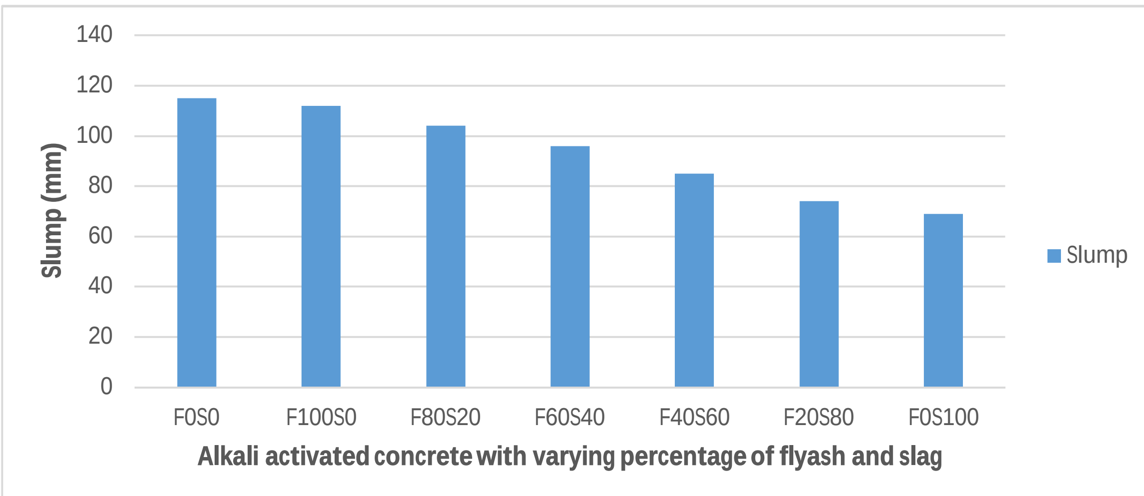
IV. RESULT AND DISCUSSION

A. *Workability of Concrete*

In this present experimental work workability was measured by slump cone test. The results of workability test performed on different mixes are tabulated below:

Sr.No.	Concrete designation	Slump(mm)
1	F0S0	115
2	F100S0	112
3	F80S20	104
4	F60S40	96
5	F40S60	85
6	F20S80	74
7	F0S100	69



B. *Compressive Strength Test*

The concrete is basically designed for compression as it is strong in compression and weak in tension. In the present experimental work, compressive strength of concrete is calculated for different percentage of alkali activated fly ash-slag after 7 and 28 days curing is mentioned in table below

Sr.No.	Concrete Designation	Sample 1	Sample 2	Sample 3	7days Avg. compressive strength (MPA)
1	F0S0	23.9	24.2	25.7	24.6
2	F100S0	25.4	25.9	27.6	26.3
3	F80S20	25.8	26.3	28.6	26.9
4	F60S40	25.7	26.9	28.8	27.15
5	F40S60	26.6	28.3	29.3	28.09
6	F20S80	28.7	29.8	31.2	29.92
7	F0S100	26.8	27.8	27.3	27.3

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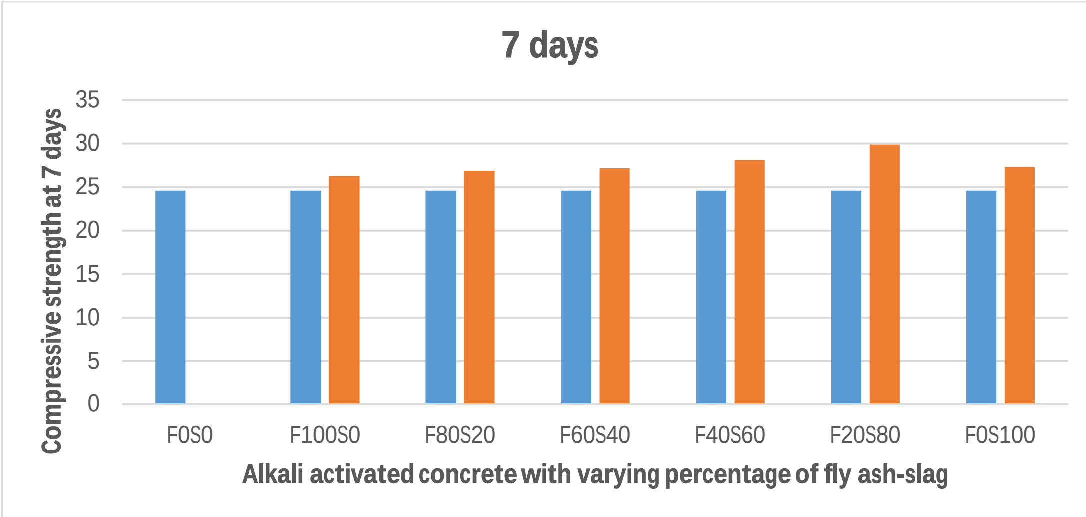
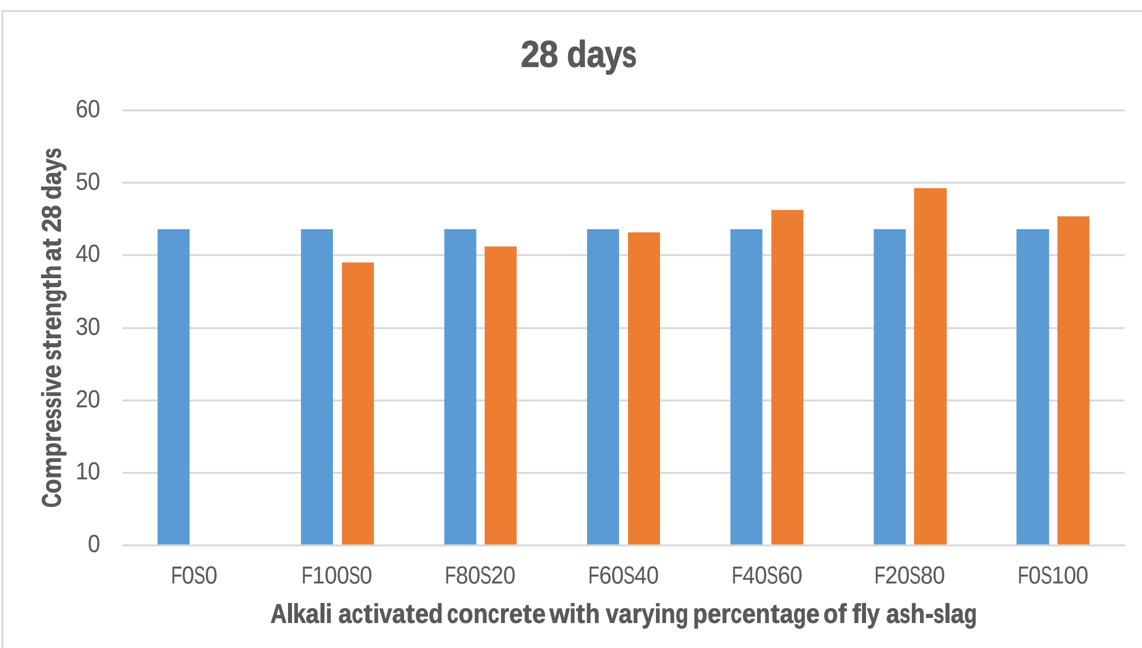


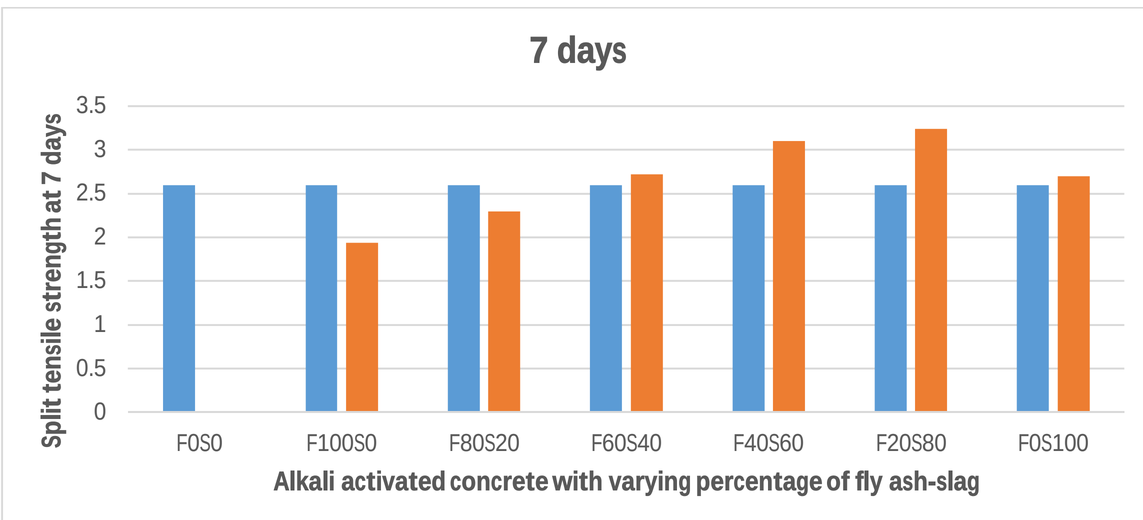
Sr.No.	Concrete Designation	Sample 1	Sample 2	Sample 3	28days Avg. compressive strength (MPA)
1	F0S0	41.1	42.6	43.9	43.6
2	F100S0	39.1	38.9	39.2	39.06
3	F80S20	42.1	41.8	39.8	41.24
4	F60S40	42.3	43.3	43.8	43.15
5	F40S60	46.4	45.4	46.9	46.24
6	F20S80	48.5	49.6	49.6	49.26
7	F0S100	44	45.8	46.2	45.34



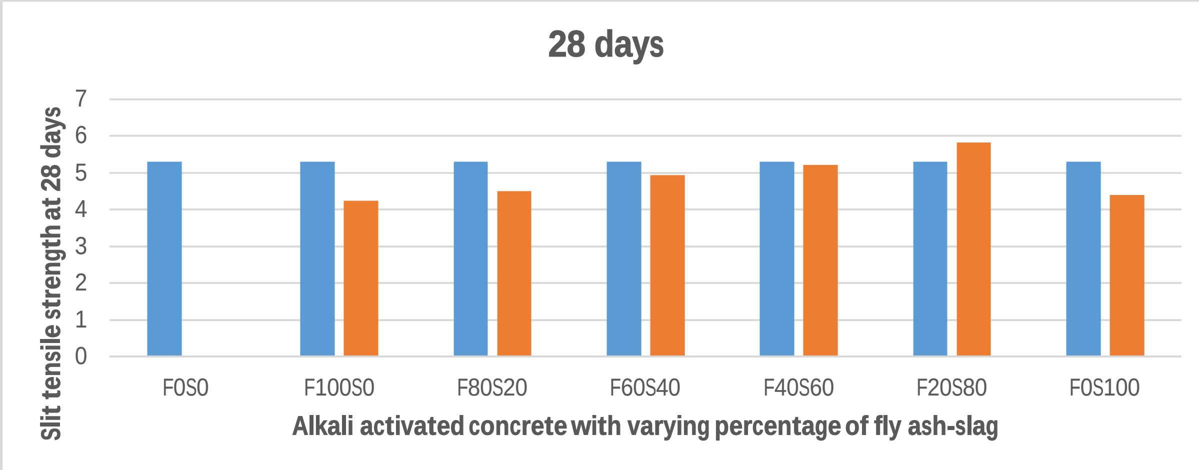
C. Split Tensile Strength

Split Tensile strength of alkali activated concrete was determined at 7days and 28days. Cylindrical beams of dimension 15cm diameter and 30cm height were used for split tensile strength. The universal testing machine was used to test split tensile strength. The results of Split Tensile Strength are tabulated below:

Sr.No.	Concrete Designation	Sample 1	Sample 2	Sample 3	7days Avg. split tensile strength (MPA)
1	F0S0	2.2	1.9	3.7	2.6
2	F100S0	1.8	2.2	1.8	1.94
3	F80S20	2.2	2.8	1.9	2.3
4	F60S40	2.7	2.9	2.6	2.72
5	F40S60	3.2	2.9	3.2	3.1
6	F20S80	3.5	3.8	2.5	3.24
7	F0S100	2.5	3.2	2.4	2.7



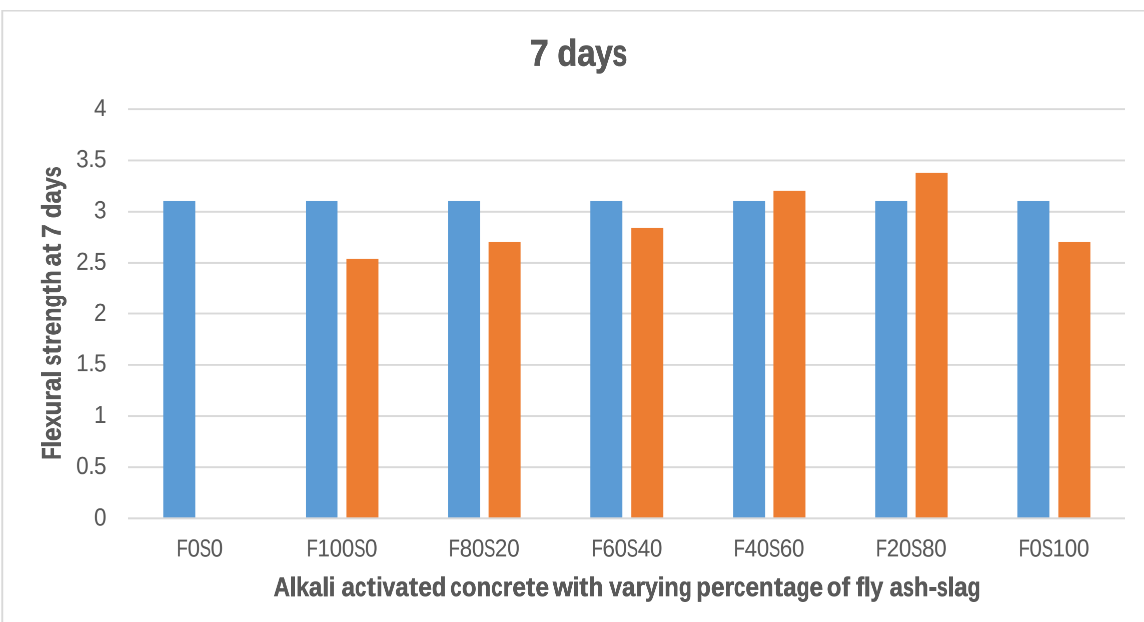
Sr.No.	Concrete Designation	Sample 1	Sample 2	Sample 3	28days Avg. split tensile strength (MPA)
1	F0S0	4.5	4.9	6.5	5.3
2	F100S0	5.1	4.2	3.4	4.24
3	F80S20	5.2	4.3	4.1	4.51
4	F60S40	4.7	5.2	4.9	4.94
5	F40S60	5.6	5.1	4.9	5.21
6	F20S80	5.4	5.8	6.4	5.82
7	F0S100	3.8	4.6	4.8	4.4



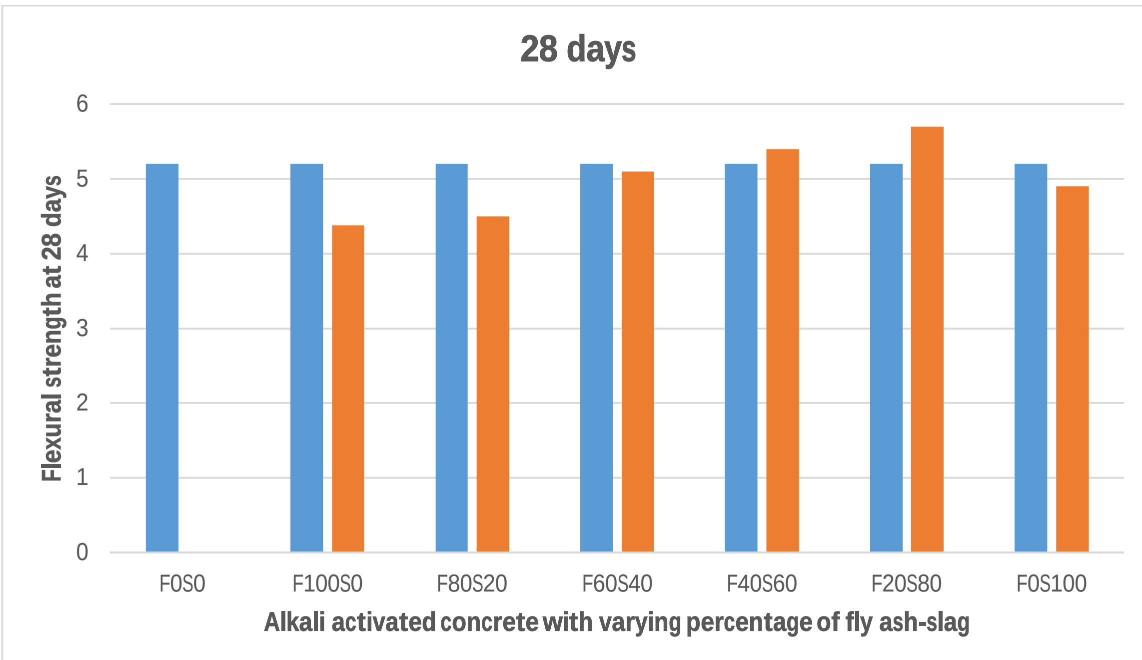
D. Flexural Strength Test

Flexural strength of alkali activated concrete was determined at 7days and 28days. The test is conducted on beams of size 500mm × 100mm × 100mm. The results of Flexural Strength are tabulated below:

Sr.No.	Concrete Designation	Sample 1	Sample 2	Sample 3	7days Avg. Flexural strength (MPA)
1	F0S0	2.8	3.4	3.1	3.1
2	F100S0	2.6	2.4	2.6	2.54
3	F80S20	2.9	2.2	3.0	2.7
4	F60S40	3.1	2.5	2.9	2.84
5	F40S60	2.8	3.2	3.6	3.2
6	F20S80	3.4	3.5	3.2	3.38
7	F0S100	2.6	2.4	2.8	2.6



Sr.No.	Concrete Designation	Sample 1	Sample 2	Sample 3	28 days Avg. Flexural strength (MPA)
1	F0S0	5.5	5.3	4.8	5.2
2	F100S0	4.14	4.6	4.4	4.38
3	F80S20	3.9	4.7	4.9	4.5
4	F60S40	4.8	5.6	4.9	5.1
5	F40S60	5.7	5.4	5.1	5.4
6	F20S80	5.3	5.6	6.2	5.7
7	F0S100	4.9	5.2	4.6	4.9



V. CONCLUSIONS

A. Workability result prove that workability of concrete decreases with increasing percentage of slag content. This may be due to presence of silicate in alkali activated concrete that brings a sticky characteristic in concrete and accelerated reaction between calcium and slag and fly as particles.

B. Results of Compressive strength concluded that with increasing percentage of slag the compressive strength increases. The compressive strength value decreases with increase in fly ash contents. It may be due to slag-based concrete has a finer pore structure than that of alkali-activated FA-based concrete.

C. The maximum value of compressive strength is obtained at 20% Fly ash and 80% Ground Granulated Blast Furnace Slag.

D. The split and Flexural strength showed similar trends as that of compressive strength. The optimum value in terms of split tensile strength is obtained at 20% Fly Ash and 80 % slag that is 5.82Mpa. . As the amount of GGBS increased, the splitting tensile strength increased due to the formation of C-A-S-H gel in the AAFS concrete specimens.

E. The maximum value in terms of Flexural strength is obtained at 20% Fly Ash and 80% slag that is 5.7Mpa.

F. Average compressive strength, Avg. Split Tensile strength and Avg. Flexural strength in F20S80 increased by 17.78%, 19.75% and 8.28% at 7 days as compared to conventional concrete.

G. Average compressive strength, Avg. Split tensile strength and Avg. Flexural strength in F20S80 increased by 14.74%, 8.93% and 8.7% at 28 days as compared to conventional concrete.

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