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EXPERIMENTAL INVESTIGATION ON QUICK SETTING ALKALI ACTIVATED CONCRETE

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Abstract: Alkali activated concrete (AAC), gained significant attention by researchers, educators and construction practitioners during past decades. Due to its rapid strength gain and better mechanical properties it proved better alternative to cement concrete. However, its field application is still limited due poor workability and lack of data. Moreover traditional AAC required an elevated curing, which again was a major drawback for in situ construction. Many researchers have tried to eliminate this drawback by using different pozzolanic binders and came up with the AAC that doesn't required any heat curing. This research paper represents strength parameter of AAC cured at ambient temperature and tested at the age of seven days for compressive strength test, splitting tensile strength test and flexural strength test. Three different pozzolanic binder Fly ash (FA), Ground granulated blast furnace slag (GGBFS) and silica fume (SF) have been used to prepare ambient cured AAC.

Key Words: ambient cured alkali activated concrete, Compressive Strength, Split Tensile Strength, Flexural Strength

I. INTRODUCTION

Climate change due to global warming is a critical environmental issue having considerable negative impacts on all living organisms in this world. Global warming is caused by greenhouse gas emissions including the emission of methane, nitrous oxide, and carbon dioxide into the atmosphere. It was reported that globally the production of cement contributed to about 5–7% of total carbon dioxide (CO_2) emission into the atmosphere [14]. CO_2 emission is about 0.7–1.1 tonnes per ton of cement produced and about 50% of this can be attributed to limestone calcination, 40% to fuel combustion in the kiln, and the remaining 10% to manufacturing processes and product transportation [11]. The consumption of cement in the world for 2014 was 3.7 billion metric tonnes. Considering an annual growth of 4%, the consumption of cement by 2020 will be 4.7 billion metric tonnes. Hence, the development of green concrete without OPC has become important. Research investigations on geopolymer concrete and alkali activated concrete as an alternative for OPC concrete started a few decades ago and have recently gained popularity as construction materials. This paper deals only with alkali activated concrete only. [14].

The name geopolymer was formed by a French Professor Davidovits in 1978 to represent a broad range of materials characterized by networks of inorganic molecules (Geopolymer Institute 2010)[1,2].The geopolymers depend on thermally activated natural materials like Metakaoline or industrial byproducts like fly ash or slag to provide a source of silicon (Si) and aluminum (Al). These Silicon and Aluminium is dissolved in an alkaline activating solution and subsequently polymerizes into molecular chains and become the binder.

Professor B. Vijaya Rangan (2008), Curtin University, Australia, stated that, "the polymerization process involves a substantially fast chemical reaction under alkaline conditions on silicon-aluminum minerals that results in a three-dimensional polymeric chain and ring structure" [4]. The ultimate structure of the geopolymer depends largely on the ratio of Si to Al (Si:Al), with the materials most often considered for use in transportation infrastructure typically having Si:Al between 2 and 3.5[5,6].

The reaction of Fly Ash with an aqueous solution containing Sodium Hydroxide and Sodium Silicate in their mass ratio, results in a material with three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bond [7]. However application of AAC is limited due at initial discovery researchers were using FA and metakaoline as a primary binder which required a heat curing. Many researchers have tried to address this issue by replacing different binder content and changing the propositions of alkaline activator. It has been observed that, CaO based pozzolanic binder such as GGBFS and Class C FA, liberates sufficient amount of heat which initiates polymerization process in AAC. It has been observed that incorporation of GGBFS along with FA not only improves mechanical properties of AAC but also contributes in denser matrix due to presence of C-S-H and C-A-S-H gel along with N-A-S-H gel. On the other hand increased fraction of GGBFS leads to poor workability and rapid strength gain due to early polymerization. Also few microcracks has been observed during its hardening. This is due rapid shrinkage that take place due to rapid hardening of concrete.

The objective of this work is to study the effect of pozzolanic binder when replaced with cement for the development of green concrete. This experiment aims to calculate the maximum compressive strength, split tensile strength and flexural strength results on various specimen casted by changing pozzolanic content, alkaline solution to fly ash ratio and sodium silicate to sodium hydroxide ratio under various curing conditions.

II. MATERIAL

In this concrete various material used like, fly ash, GGBFS, silica fume, sand, aggregate and activator.

1. Fly ash

Coal Fly ash (FA) is a by-product of the combustion of pulverized coal in thermal power plants. It is removed by the dust collection systems from the exhaust gases of fossil fuel power plants as very fine, predominantly spherical glassy particles from the combustion gases before they are discharged into atmosphere. The size of particles is largely dependent on the type of dust collection equipment. Diameter of fly ash particles ranges from less than 1 μm–150 μm.

Figure 1: Fly ash

2. Ground granulated blast furnace slag (GGBFS)

Ground Granulated Blast Furnace Slag (GGBS) is a by-product of the manufacturing of iron in a blast furnace where iron ore, limestone and coke are heated up to 1500℃.When these materials melt in the blast furnace, two products are produced molten iron, and molten slag. The molten slag is lighter and floats on the top of the molten iron. The molten slag comprises mostly silicates and alumina from the original iron ore, combined with some oxides from the limestone. The process of granulating the slag involves cooling the molten slag through high-pressure water jets. This rapidly quenches the slag and forms granular particles generally no larger than 5mm in diameter.

Figure 1 : GGBFS

3. Silica fume

Silica fume, also known as microsilica, is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete.

Figure 2: Silica fume

4. Sodium Hydroxide

Sodium Hydroxide (NaOH) for the experiment was obtained from Satguru chemicals.

The properties are as below

Specific gravity: 1.7
PH: 14

Figure 4: Sodium Hydroxide

5. Sodium Silicate

Sodium silicate (Na_2SiO_3) for the experiment was obtained from Satguru Chemicals.
The properties are as below
Appearance: Liquid (Gel)
Specific gravity: 1.6

Figure 5: Sodium silicate

Table 1: Location of material

Materials	Available from
Fly Ash	UltraTech cement, Rajula, Gujarat, India
GGBFS	Shapar, Rajkot, Gujarat, India
Silica Fume	Pyramid Industries, Ahmedabad, Gujarat, India

Table 2: Physical properties of materials

Property	Fly ash	GGBFS	Silica fume
Specific gravity	2.14-2.69	2.9	2.22
Moisture Content (%)	0.0-0.38	-	-
Retained on #325 sieve (%)	3.55-36.90	-	-
Blaine fineness (m2/Kg)	158-555	425–470	15000-30000
Physical Form	-	Off white powder	-
Bulk density (kg/m3)	-	1200	-
Particle size	-	-	<1 µm
General use in concrete	-	-	Property enhancer

Table 3: Chemical composition of material confirmed by XRD test

Constitute (%)	Fly ash	GGBFS	Silica fume
Silicon Dioxide (SiO_2)	50	35	90
Aluminium Oxide (Al_2O_3)	28	13	0.4
Ferric Oxide (Fe_2O_3)	12	1	0.4
Calcium Oxide (CaO)	6.5	40	1.6
Magnesium Oxide (MgO)	6	8	1
Potassium Oxide (K_2O)	1.5	0.3	2.2
Sodium Oxide (Na_2O)	0.2	0.4	0.5
Titanium Dioxide (TiO_2)	0.1	0.1	-

III. MIX DESIGN

Following mix design were adopted for casting and cement is fully replaced with the pozzolanic binders like Fly ash, GGBFS and Silica fume. This mix design is prepared from the paper [20].

Table 4: Mix design (Kg/m^3)

	TM1	TM2	TM3
GGBFS	285	285	285
FLY ASH	142.5	142.5	142.5
SF	47.5	47.5	47.5
NaOH(solid)	29.0248	30.1557	31.6635
Water	36.2877	37.7015	39.5865
NaOH solution	65.3125	67.8572	71.25
Na_2siO_3	195.9375	169.6428	142.5
Sand	782.757	793.15	803.543
10mm	352.0975	356.7725	361.4474
20mm	653.8954	662.5775	671.2595
WATER	25	24.77	23.98

IV. EXPERIMENTAL PROGRAM

16 molar sodium hydroxide (NaOH) obtained in crystalline form is mixed with water to form homogeneous sodium hydroxide solution. This solution is then mixed with sodium silicate (Na2siO3) which works as an activator during polymerization process. It is then allowed to settle for 10-12 hours.

This solution is then used to form AAC as per the design mix for which moulds of required size are used and greased. This concrete filled in moulds are compacted, vibrated and allowed to settle for 24 hours. Specimen so obtained after demoulding undergoes ambient, hot water and oven curing.

Figure 6: Preparation of moulds

Figure 7: Concrete mixing-1

Figure 8: Concrete mixing-2

Figure 9: Placing concrete

Figure 10: Curing of specimen

Figure 11: Failure of specimen

RESULTS

Cubes specimens were tested for compressive strength and cylindrical specimens were tested for spilt tensile strength in the Compressive Testing Machine of capacity 2000 KN. Beam specimen were tested for flexural strength in the Universal Testing Machine of capacity 2000 KN. An average of three specimens were tested for each strength tests.

A. compressive strength test [18]

Table 5: Compression strength test result

Mix design	Sample no	Weight (kg)	Load (KN)	Strength (MPa)
T1	1	8.35	1413.7	62.83
T2	2	8.42	1253.8	55.72
T3	3	8.45	1313.4	58.37

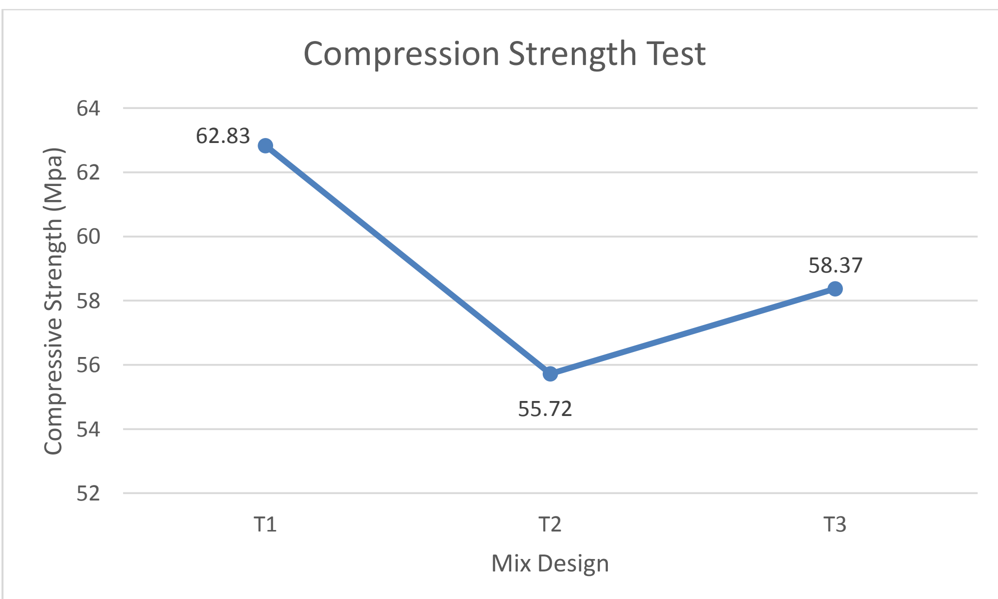

Figure 12: Compression Strength Test Result

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B. split tensile strength [19]

Table 6: Spilt Tensile Strength Test Result

Mix design	Sample no	Weight (kg)	Load (KN)	Strength (MPa)
T1	1	12.86	372.3	5.26
T2	2	12.35	240.4	3.4
T3	3	12.86	239	3.38

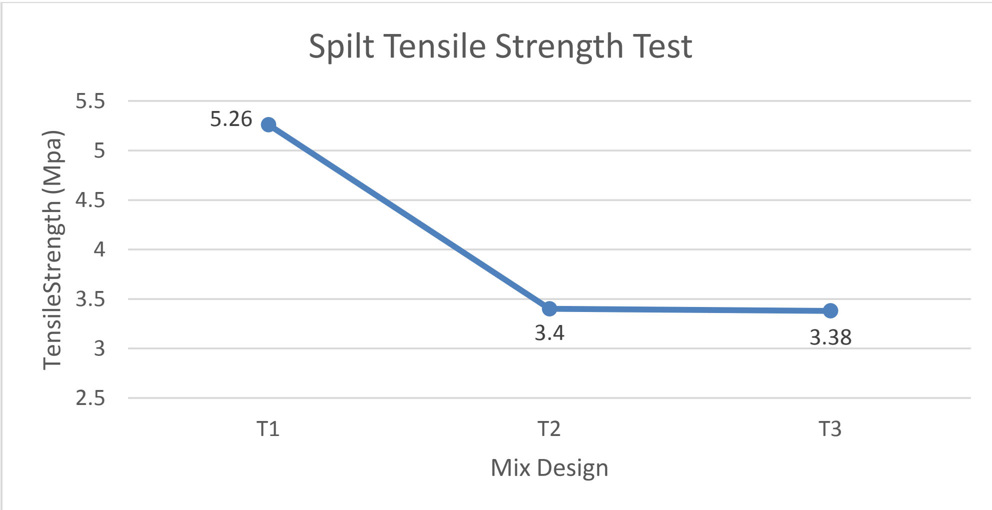

Figure 13: Spilt Tensile Strength Test Result

C. flexure strength test [18]

Table 7: Flexural Strength Test Result

Mix design	Sample no	Strength (MPa)
T1	1	5.7
T2	2	5.04
T3	3	5.66

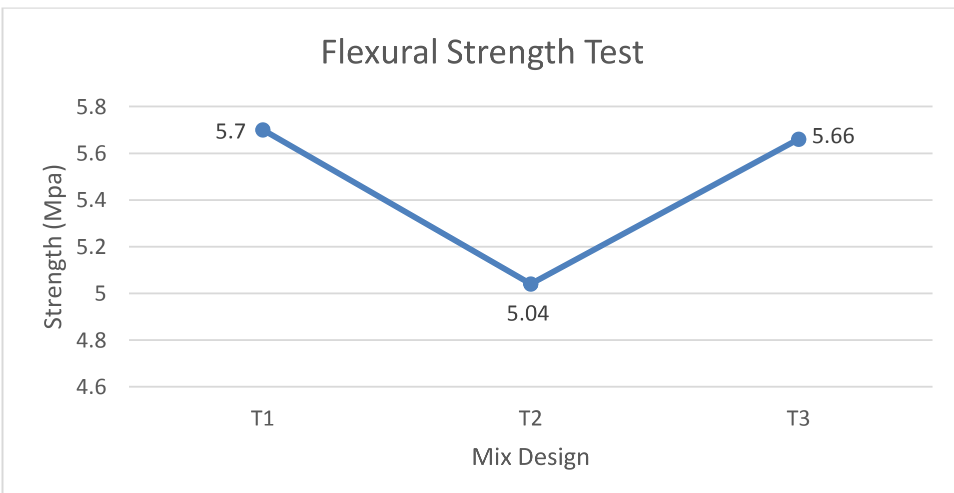

Figure 14: Flexural Strength Test Result

Discussion:

It was observed with the experimental results that compressive strength, split tensile strength and flexural strength is high when T1 design mix concrete is used. In this design, sodium silicate to sodium hydroxide ratio is kept constant at 3, whereas, the solution to binder content ratio was maintained to be 0.55 under ambient curing condition.

V. CONCLUSION

After the experimental work on AAC, following conclusion can be drawn

1. Ratio of sodium silicate to sodium hydroxide significantly affect the strength of the AAC.

2. It is observed that incorporation of GGBFS and SF significantly improved the strength properties of AAC however it reduces the workability and setting time at greater extent.

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