ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 3, March 2017

An Experimental Investigation on Behavior of High Volume Alkali Activated Flyash Concrete

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***Abstract:*— The usage of plain cement concrete in construction fields is a regular practice which has benefits on the other hand there are disadvantages also like emission of harmful gases and depletion of natural resources. As a part of remedial measures this project deals with the High volume Alkali Activated FlyAsh Concrete which reduces usage of OPC and increases quality of concrete. For obtaining better performance for FlyAsh, initially it has to be activated by any suitable base solution. The methodology involves partially replacing cement with 60% and 80% of FlyAsh with NaOH as alkali activator of 3M and 4M morality, adding with a variation of 3%, 5% and 7% with respect to weight of FlyAsh is considered. Results obtained after testing different mixes of High volume Alkali Activated FlyAsh Concrete under various tests and procedures of activation binding to IS codes show significant and desirable results when compared to controlled concrete but for final days of curing than initial ones.**

***Keywords:*-- Alkali activation, Activator, FlyAsh (FA), Molarities, NaOH, Compressive Strength, Durability**

I. INTRODUCTION

It is widely known that a heavy energy will be released during the manufacturing of OPC with consuming similar amount of energy and at the same time contibutes a large volume of CO2 to the atmosphere. But till today OPC is still the main binder in concrete construction and helping to search for more eco-friendly materials.One of the alternative is utilization of industrial by-products by activating them with alkali solution as binder which contains silicate materials (Gjorv, 1989; Philleo, 1989).

The most common substitute binder for cement is FlyAsh. To improve the physical, chemical and mechanical properties of cement and concrete, FlyAsh can be used as pozzolanic material (Swamy, 1986). FlyAsh reacts with Ca(OH)2 in the hydration process of OPC forming Calcium silicate hydrate (C-S-H) as the end product of that process. Thus, FlyAsh will not show any reaction with cement until hydration process starts.

Therefore the delay will cause the delay in development of strength in early ages of concrete when compared with OPC concrete. Recent development in research resulted in 100% usage of FlyAsh as a binder material by activating it with alkali solution like NaOH, Silicate Salts etc, (Bakharev, Sanjayan &Cheng, 1999; Talling & Brandster, 1989).

There are two methods of activation by alkali solution, 1. Using low and mild soultions containg silicates and calcium for activation, will produce hydrate gel (Brough & Atkinson, 2002; Deja, 2002). 2. Formation of inorganic binder through polymerization process by actvating with high alkali solution (Barbosa, Mackenzine, & Thaumaturgo, 2000; Sindhunata, 2006).

The term AAFCic is used to characterise this type of raction from previous one, and accordingly, the name AAFC has been adopted for this type of binder (Davidovits, 1994). The product obtained from this reaction diffierentiates AAFC from other alkali activated materials.

II. LITERATURE REVIEW:

K.J.Owens,has done number of studies on the activation of high volume FlyAsh pastes (50% FlyAsh substitution of PC) using chemical (alkali) activators like sodium sulphate, calcium sulphate and sodium hydroxide at a dosage of 1% wt. binder, 10% wt. binder and 1 Molar, respectively. Paste cubes of size 50mm were manufactured in accordance with BS EN 196-3: 2005. Sodium sulphate and sodium hydroxide were also dissolved in the mixing water prior to mixing. Anhydrite was added and mixed in advance with the OPC and FlyAsh in the mixer. The temperature of the mixing water was also controlled and in each case was kept at 20.50C (± 0.5). Based on the results presented, the suggestion would be for room temperature curing, sodium sulphate is effective along with SP. For elevated temperature curing at 600c, Calcium sulphate is effective. Sodium sulphate showed to be the optimum activator when cured at 200C whilst calcium sulphate showed to be the optimum activator when cured at 600C.

Malhotra, 1996, Pozzolanic material means combination of siliceous and aluminous material, which is considered as little or no cementitious properties but it is finely divided in particle size and they chemically react with calcium hydroxide at room temperatures in the presence of moisture, to form new compounds possessing cementing properties like OPC. The common pozzolanic materials in use are low calcium Class FFA and Silica Fume.

Popovics, 1992, has stated that cementitious materials are classified into two types they are i) finely divided and ii) non-crystalline or poorly crystalline similar to pozzolans, but will contain sufficient calcium for forming major compounds which will have cementing properties after addition of water. As such, the energy released during hardening is slowed down and becomes active only when an activator is added, such as calcium hydroxide Ca(OH)2 or some other strong alkali compound. When this type of cementitious material if mixed with OPC and water, it becomes activated due to the addition of calcium hydroxide, developed during the hydration of the cement. The best suitable examples of latent cementitious materials are High calcium (class CFA), and ground granulated blast-furnace slag (GGBS).
Krivenko (1994), has experimented on alkali activation and stated that alkali activation is the term used to indicate that stimulation of pozzolanic reaction by using alkalis or alkali earth ions or to release the latent cementitious properties of inorganic materials which are finely divided. The latent cementitious materials can be natural minerals or industrial by-products consisting mainly silicates, alumino-silicate and calcium. A classification of alkali activated cementitious material depends upon the composition of hydration products which were proposed by:

1. The alkalialumino-silicate composit (R-A-S-H, where R= Na or K were termed as "geo-cements", by giving special importance to the similarity in the formation process of these materials to the geological process of forming the natural zeolites. A special case in this is the formation process is a poly condensation rather than hydration which was named as "Geo-polymer" (Davidovits, 1994).

2. The alkali–alkali earth compounds (R-C-A-S-H) where the hydration products are low basic calcium silicate hydrates (C-S-H gel with low Ca/Si ratio). Alkali activated slag and AlkaliOPCs are included into this type.

M. Dakshene, (ISSN: 2321-4902 Volume 1 Issue 4) has experimented and stated that FlyAsh obtained from thermal power plant (coal burning power plant) was chemically activated, used as absorbent for oxalic acid removal with low cost, which causes major pollution in water system. The AFA was described for the distinctive features under mineralogical, physiochemical and morphological properties by XRD test, FT-IR test and SEM test. Results showed that AFA due to increased amorphous property is more activated over surface for the removal of acid waste as an absorbent. Uniform particle size sample has been obtained by drying and sieving Class FFA, which is collected from KSTPS (Kota super thermal power plant), Rajasthan. In both FA and AFA has the presence of quartz, mullite and calcite. Crystallite size has been decreased from 33 nm to 11 nm on NaOH treatment. It is evident from XRD test results showed that crystalline component present in FA has been removed by chemical activation thus the crystallinity of the sample has been reduced and increase in amorphous nature showed the presence of Nano crystalline phase in the sample.
MiroslavMikoč, (ISSN 1330-3651UDC/UDK 691.333:620.17) found alkali-AFA was used as a binder instead of OPC in the preparation of concrete. The alkali activators used are Sodium hydroxide and water glass. Fractions of natural aggregate of sizes 0-4 mm; 4-8mm and 8-16mm were replaced by granulated steel slag which is air-cooled, fraction of 4-8mm and 8-16 mm and the silica fume replaces the fraction of river sand. Two different temperatures are used for curing the obtained samples. The first was cured at room temperature and the other was subjected to steam curing for 8 hours and left for curing at room temperature till the testing date. The compressive strength test was carried out and tested by using cube samples 150 ×150 × 150 mm after 3 and 28 days of curing. The results of the present work have shown that low-calcium FA-based Geo-polymer concrete can substitute the use of OPC in concrete.

III. MATERIALS AND PROPERTIES:

Introduction:

Several materials are used to manufacture good quality concrete. It is significant to recognize the properties of ingredients like cement, aggregate and water as they impart strength and durability of the concrete. The physical and chemical properties of cement, sand, gravel and water used in the investigation were analyzed based on the standard experimental procedure laid down in the standard IS codes. These standard experimental procedures were adopted for the determination and study on standard consistency, initial and final setting times, specific gravity, slump, compaction factor

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 3, March 2017

test, compression strength test of concrete etc.

Table 1 Physical Properties of Cement

S.No	Characteristic of cement	Value
1	Fineness of cement	94.76%
2	Normal consistency	33%
3	Initial setting Time	40 minutes
4	Final setting time	350 minutes
5	Specific gravity	3.14

Properties of FA:

Table 2 Physical Properties of FA

S. No	Characteristics	Percentage
1	Silica,SiO2	49-67
2	Alumina,Al2O3	16-28
3	Iron oxide,Fe2O3	4-10
4	Lime, CaO	0.7-3.6
5	Magnesia, MgO	0.3-2.6
6	Sulphur trioxide, SO3	0.1-2.1
7	Loss of ignition	0.4-0.9
9	Specific gravity	2.3

Properties of Fine Aggregates:

Table 3 Physical Properties of Fine aggregate

S.No	Properties	Results
1	Specific gravity	2.6
2	Bulking of sand	5
3	Particle size variation	0.15 to 4.75
4	Water absorption	1
5	Bulk density of sand	1460
6	Fineness modulus	2.8

IV. EXPERIMENTAL PROCEDURE FOR ACTIVATION OF FLYASH:

1) FlyAsh of class F is sieved from 90 microns sieve and made free from lumps.
2) By reverse calculation of Molarities, weight of NaOH pellets 3M or 4M solution is obtained.
3) FlyAsh of required weight is taken and initial oven drying is done so as to remove any moisture content.
4) Based on the weight of FlyAsh amount of NaOH to be added is calculated.
5) NaOH solution is mixed with the FlyAsh with help of machine or through hand.
6) The entire mixture is oven dried at 100-1500 C for 24 hours.
7) After 24 hours lumps will be formed. The same are made into fine powder.
8) When the lumps are formed, we can conclude that, FlyAsh is activated.
9) FA + NaOH(3M/4M) @1500 C N-S-H gel

V. RESULTS

1. *COMPRESSIVE STRENGTH RESULTS:*

Table 4 Compressive Strength Results

S. NO	SAMPLE	AVERAGE COMPRESSIVE STRENGTH (N/mm^2) FOR AGE OF CONCRETE (Days)				
		3	7	28	56	90
1	Controlled mix	21.69	27.78	35.50	42.23	48.12
2	60% FA+ 3% 3M NaOH	14.46	18.60	22.80	31.10	45.44
3	60% FA+ 5% 3M NaOH	16.17	20.20	24.40	32.70	48.63
4	60% FA+ 7% 3M NaOH	18.20	22.40	26.60	34.90	49.65
5	80% FA+ 3% 3M NaOH	12.60	17.20	21.40	29.70	38.34
6	80% FA+ 5% 3M NaOH	13.35	18.20	22.40	30.70	40.59
7	80% FA+ 7% 3M NaOH	15.58	20.40	24.60	32.90	43.32
8	60% FA+ 3% 4M NaOH	17.20	20.13	24.36	28.00	55.12
9	60% FA+ 5% 4M NaOH	20.11	22.13	25.29	31.56	56.35
10	60% FA+ 7% 4M NaOH	21.42	23.11	26.44	34.67	59.34
11	80% FA+ 3% 4M NaOH	15.78	18.71	20.09	26.22	50.93
12	80% FA+ 5% 4M NaOH	17.78	20.09	21.42	29.33	51.99
13	80% FA+ 7% 4M NaOH	19.24	22.04	23.20	32.89	53.00

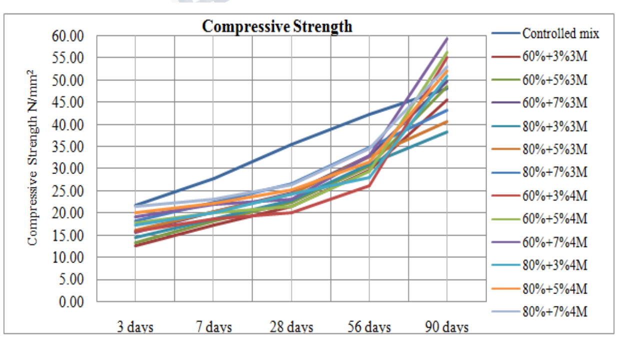
From the above table and the graph, states that concrete mix of 60%FA+7% 4M NaOH is exhibiting higher Compressive strength than any other mix including controlled concrete.

2. SPLIT TENSILE STRENGTH RESULTS:

Table 5 Split Tensile Strength results

AGE OF CONCRETE	PROPORTIONS	AVERAGE SPLIT TENSILE STRENGTH (N/mm²)
28 DAYS	CONTROLLED MIX	2.89
	60% FA+3% 3M NaOH	3.62
	60% FA+5% 3M NaOH	3.88
	60% FA+7% 3M NaOH	4.10
	80% FA+3% 3M NaOH	3.27
	80% FA+5% 3M NaOH	3.66
	80% FA+7% 3M NaOH	3.96
	60% FA+3% 4M NaOH	3.91
	60% FA+5% 4M NaOH	4.11
	60% FA+7% 4M NaOH	4.30
	80% FA+3% 4M NaOH	3.72
	80% FA+5% 4M NaOH	3.88
	80% FA+7% 4M NaOH	4.03

From the above table it clearly states that concrete mix of 60%FA+7% 4M NaOH is exhibiting high tensile strength than any other mix including controlled concrete.



3. NON-DESTRUCTIVE TEST RESULTS:

Ultra Sonic Pulse Velocity Results

Table 6 Ultra Sonic Pulse Velocity Test results:

S.No	Samples	Length (mm)	Path time (μ-sec)	Average pulse velocity (km/sec)	Quality
1	Controlled mix	150	34.63	4.33	Good
2	60% FA +3% 3M NaOH	150	35.80	4.15	Good
3	60% FA +5% 3M NaOH	150	35.00	4.19	Good
4	60% FA +7% 3M NaOH	150	38.7	4.28	Good
5	80% FA+3% 3M NaOH	150	39.7	3.77	Good
6	80% FA+5% 3M NaOH	150	35.8	4.18	Good
7	80% FA+7% 3M NaOH	150	36.33	4.15	Good
8	60% FA+3% 4M NaOH	150	33.48	4.29	Good
9	60% FA+5% 4M NaOH	150	35.34	4.15	Good
10	60% FA+7% 4M NaOH	150	35.72	4.15	Good
11	80% FA+3% 4M NaOH	150	38.77	4.26	Good
12	80% FA+5% 4M NaOH	150	39.40	3.81	Good
13	80% FA+7% 4M NaOH	150	39.78	3.86	Good

From above table it is observed that, the average pulse velocity for all proportions of concrete are in between 3.5 km⁄sec to 4.5 km⁄sec. As per BS 12504-4, 2004 code it is concluded that all the samples are graded as good quality concrete.

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ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 3, March 2017

4. DURABILITY TEST RESULTS:

Water Absorption Test results:

Table 7 Water absorption test results

S.NO	Sample	Wet weight (kg)	Dry weight (kg)	Water absorption in %
1	Controlled mix	9.56	9.40	1.70
2	60% FA +3% 3M NaOH	9.52	9.42	1.06
3	60% FA +5% 3M NaOH	9.53	9.45	0.84
4	60% FA +7% 3M NaOH	9.44	9.39	0.53
5	80% FA+3% 3M NaOH	9.44	9.35	0.96
6	80% FA+5% 3M NaOH	9.46	9.40	0.63
7	80% FA+7% 3M NaOH	9.49	9.44	0.53
8	60% FA+3% 4M NaOH	9.43	9.33	0.56
9	60% FA+5% 4M NaOH	9.56	9.44	0.89
10	60% FA+7% 4M NaOH	9.32	9.29	0.81
11	80% FA+3% 4M NaOH	9.50	9.43	0.55
12	80% FA+5% 4M NaOH	9.48	9.40	0.56
13	80% FA+7% 4M NaOH	9.46	9.34	0.78

The above table shows that the considered mix proportions are durable under water absorption criteria. All the samples are under the permissible limits of the test procedure.

VII. CONCLUSIONS:

The Research on the waste construction materials is very important because, construction materials are gradually increasing with the increase in population and urban development. The reason that many investigations and experiments had been carried out on waste material is Fly Ash and this material is less cost, and highly available. So, using of this material we get so many benefits in the construction industry. The main aim of this research work is to find out the strength and durability properties of Alkali Activated Fly Ash Concrete at the same to reduce the pollution and to save natural resources. Based on the experimental work and obtained results, the following conclusions are drawn

- At 90 days curing 60% Fly Ash + 7% NaOH 4M mix has a maximum value of 59.34 N/mm2 than 80% Fly Ash + 7% NaOH 4M and 24% higher when compared with the controlled concrete results.
- Split Tensile Strength of 60% Fly Ash + 7% NaOH 4M is 4.30 N/mm2 than 80% Fly Ash + 7% NaOH 4M.
- Durability test results and NDT test i.e Ultra Sonic Pulse Velocity Test results have shown that for all the mix proportions has satisfied the minimum requirements as per IS 13311 (Part1): 1992 and concluded as Good durable concrete.
- In NDT test i.e Ultra Sonic Pulse Velocity Test 60% Fly Ash + 7% NaOH 4M has shown maximum average pulse velocity of 4.15 km/sec and the Average pulse velocity for all mix proportions is higher than Controlled mix.
- From water absorption test results, the 80% Fly Ash + 7% NaOH 3M has an absorption percentage of 0.53 and absorption for High volume AAFC for 60% replacement of cement with FA of molarity 4M are 68% lesser than controlled concrete at 28 days curing period.
- XRD results have shown the formation of particles after activation and removal of non-cementing material. But change of the microstructure of the particle reduces the compressive strength nearly by 30% for 80% Fly Ash + 7% NaOH 4M when compared with 60% Fly Ash + 7 % NaOH 4M

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ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
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