"EVALUATION OF MECHANICAL PROPERTIES OF ALKALI ACTIVATED DRY LEAN CONCRETE BY REPLACING NATURAL AGGREGATE WITH INDUSTRIAL BY PRODUCT"

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ABSTRACT

In construction field concrete is a material which consists of mixing of cement, aggregates, water and admixtures. Now-a-days a lot of researches are going around the world, by the usage of many waste materials like ground granulated blast furnace slag, fly ash, silica fume, rice husk ash, rubber tires, etc. These waste materials are also called as filler materials in concrete. Irrespective of the nature of their products, almost all industries produce waste. In that only 5% of waste materials are recycled every year around globe. In this study aims to investigate the effects of incorporating industrial by-products, such as fly ash, slag, or recycled aggregates, on the mechanical properties of alkali- activated DLC. By systematically analyzing the compressive strength, flexural strength, and modulus of elasticity of different mixtures, valuable insights can be gained into the potential of these materials for practical applications in the construction industry. Furthermore, understanding the microstructural changes and hydration mechanisms occurring in alkali-activated DLC with industrial by-products will provide valuable knowledge for optimizing mix designs and improving the overall performance of sustainable concrete materials. This research seeks to contribute to the advancement of sustainable construction practices by evaluating the mechanical properties of alkali-activated dry lean concrete with industrial by-products. By harnessing the potential of these materials, we can move towards a more environmentally friendly and economically viable approach to concrete production.

KEYWORDS: Defluoridation, Adsorption, Adsorbents, DLC, Fly ash, recycled aggregates.

1, INTRODUCTION

The total road network of the India is about 4.69 million km in length. Out of which about 53.8% (2.53 million km) are paved. Approximately, 2% of the total road length of the country is made of with concrete. Government of India is encouraging the construction of concrete pavements even at rural levels. The performance of cement concrete pavements is greatly influenced by the uniform support offered by the base or sub-base layer. The current practices of the construction of cement concrete road for highways in India require a base layer of dry lean concrete (DLC) over which pavement quality concrete slabs rest. It is one of the common and popular cement treated sub-base/base for concrete pavements. DLC is a no slump plain concrete with a large ratio of aggregate to- cement in comparison with conventional concrete. It contains less amount of cement paste as compared to conventional concrete. A properly constructed DLC layer plays an important role in enhancing the service life of modern concrete roads. DLC is generally manufactured with ordinary Portland cement (OPC) as per IRC: SP-49: 1998 specification. This specification (IRC SP-49, 1998) advocates the use of other cement such as Portland pozzolana cement (PPC), Portland slag cement (PSC) also in the manufacture of DLC.

The first utilize of alkali activated material was in 1930, when Kuhl studied mixes composed of GGBFS and alkaline solution of KOH. Reactivity of GGBFS by using alkaline solutions of KOH and NaOH investigated by Chasse vent in 1937 . Also, GGBFS was activated with NaOH solution by Purdon in 1940 Alkali-activated concrete (AAC) is defined as a class of cement-free concrete that is an alternative to Portland Cement concrete (PCC) In AAC, the cement is partially replaced by an alternative binder. Instead of using ordinary Portland cement (OPC) and water, AAC uses other supplementary materials like Blast furnace slag (BFS) or Flash Ash (FA) along with an alkaline activator. The greatest advantage of AAC compared to PCC is the significant improvement in the environmental impact. This is mainly based on the CO_2 emissions from clinker calcination process and the high consumed energy of PCC. AAC is considered as an efficient concrete technology for decreasing emissions of CO_2 and recycling of by-products such as GGBFS and FA without using a calcination.

The potential of AAC as a sustainable material to replace ordinary Portland cement concrete is still being studied and researched. It is gaining popularity due to its low energy cost, high strength, and durability compared to ordinary Portland cement. Activation has been introduced as a method of initiating the reaction of the cementitious matrices without the need for much cement. The process of Alkali-Activation is best demonstrated by the reaction of concrete containing both cement and a cementitious matrix. It is gaining popularity due to its low energy cost, high strength, and durability compared to ordinary Portland cement. AAC consists of one or more of aluminosilicate sources (e.g. ground granulated blast furnace slag (GGBFS), fly ash (FA) or silica fume (SF)), one or more of alkali activators (e.g. silicates, hydroxides or carbonates), water, fine and coarse aggregates.

1.1 Objectives of the Study:

1. To evaluate the mechanical properties of conventional Dry Lean Concrete [DLC].
2. To evaluate the mechanical properties of Alkali Activated Dry Lean Concrete.
3. To do a comparative studies on convectional DLC and Alkali activated DLC.

2 MATERIALS AND METHODOLOGY

In this chapter the properties of different materials used in making the concrete for evaluating the durability and strength properties. The mix mainly contains Ground granulated blast furnace slag (GGBFS) as replacement of cement and alkaline activators. In the present investigation the primary materials include

1. Cement
2. Fine aggregate
3. Coarse aggregate
4. Ground granulated blast furnace slag (GGBFS)
5. Alkaline activators
6. Water

2.2 PROPERTIES OF MATERIALS

2.2.1 Cement

In the present study Ordinary Portland cement (OPC) of 43 Grade manufactured by Birla Cements is used, it was procured from, Udyambag Belagavi. JK Super cement OPC 43 confirms to IS 8112. It is greenish gray in color and found cool when hand is inserted inside the cement bag.

Table 2.1 properties of cement

Sl.No	Property	Lab Results	Standard result
1	Specific gravity IS:4031 (PART11)-2005	3.14	3.12 – 3.19
2	Normal consistency IS:4031 (PART4)-1995	32%	20 – 26%
3	Fineness IS:4031 (PART1)-2005	3.5%	10%
4	Initial setting time IS:4031 (PART5)-1988	35 min	30 min
5	Final setting time IS:4031 (PART5)-1988	130 min	600 min

2.2.2 Fine aggregates

In the present study the fine aggregate of less than 4.75 mm sizes is used. Fine aggregates are procured from the vendor shop, near 3 gate Belagavi. The obtained aggregates were free from dust particles. For increased workability and for economy as reflected by use of less cement, the fine aggregate should have a rounded shape. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent.

Table 2.2 Properties of Fine Aggregate

SI.No	Property	Lab Results	Standard result
1	Specific gravity IS:2386 (PART 3)- 1997	2.6	2.6 – 2.9
2	Water absorption IS:2386 (PART 3)- 1997	2.5%	2.5 - 3
3	Sieve analysis (IS 383 – 2016)	Zone 1	-

i) Coarse aggregate

In the present study the coarse aggregate of 20 mm sizes is used. Coarse aggregates are procured from the vendor shop, near 3d gate Belagavi. The obtained aggregates were round and angular in shape and free from dust particles.

Table 2.3 Properties of Coarse aggregate

Sl.No	Property	Lab Results	Standard result
1	Specific gravity IS:2386 (PART 3)- 1997	2.72	2.6 – 2.9
2	Water absorption IS:2386 (PART 3)- 1997	1.33%	2.5 - 3
3	Impact test IS:5640-1998	9.91%	Less than 30%
4	Flakiness test IS:2386 (PART 1) 1997	21.04%	15 to 25%
5	Elongation test IS:2386 (PART 1) 1997	20.52%	Not more than 25%

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. Ground granulated blast furnace slag is a latent hydraulic binder forming calcium silicate hydrates (C-S-H) after contact with water. It is a strength-enhancing compound improving the durability of concrete.

2.2.3 Alkaline activators

The alkaline activators are necessary to be reacted with the alumino-silicate source to produce cementitious materials. Usually, alkaline salts are utilized as alkaline activators for AAC. Among of all these activators, sodium hydroxide (NaOH) and Sodium silicate (Na_2SiO_3) are the most widely available chemicals and the same was used for concrete mix. NaOH is obtained by brine electrolysis. Four types are available commercially: solids, flakes and beads. Solids are obtained by cooling molten caustic soda. Flakes are produced by passing molten NaOH through cooled flaking rolls to obtain uniform thickness flakes. Beads are manufactured by feeding the molten liquid into a prilling tower carefully which produce spherical beads of uniform size Na_2SiO_3 is generally produced from silica and carbonate salts by calcination and dissolving in water according to the required ratios.

Table 2.4 Components of Sodium silicate (Na_2SiO_3)

Specific gravity	1.63 – 1.645
Na2O	16 to 17
SiO_2	35 to 36 %
Wt Ratio	1:2.1 ± 0.1

2.3 METHODOLOGY

1. A good quality concrete is produced by careful mixing of cement, sand, coarse aggregates, water in proper proportions so as to obtain an optimum quality and economy.
2. In the present project work, an attempt was been made to study the various characteristics properties of concrete by replacing cement with Industrial waste. The concrete mix design was carried out for M-10 grade concrete. At the same time, tests were carried out on cement, Fine aggregates and coarse aggregates.
3. The cement in concrete was replaced by ground granulated blast furnace slag (GGBFS) in addition to alkaline activators. Three trials of mix design were prepared with 3%, 4% and 5% of alkaline activators. The alkaline activators added were sodium hydroxide (NaOH) and sodium silicate (Na2SiO3)
4. The reaction between the activators, namely sodium silicate and sodium hydroxide produce large amounts of heat. The activators were, therefore, separately mixed together first according to the required proportions and left to cool down for 5 hours before being added to the remaining components of the mix in the mixer (cementitious matrix, coarse and fine aggregates, and water). For compressive strength, oncrete cubes of size (150mm x 150mm x 150mm) were casted and for flexural strength, concrete beams of size (500mm x 100mm x 100mm) were casted and for water absorption test, concrete cubes of size (150mm x 150mm x 150mm) are casted. After 7 days of curing, the various properties of concrete were tested and the results are analyzed.
5. The cubes later were kept immersed in 5% of concentrated acid solution to determine the durability properties. The acid used was sulfuric acid (H2SO4).

2.4 RESULTS AND DISCUSSIONS

Results of experiments on compressive strength, flexural strength and water absorption test for cement replaced by Ground Granulated Blast Furnace Slag (GGBFS) is been presented below with those of control concrete.

3.1 COMPRESSIVE STRENGTH TEST

The compressive strength of concrete is determined for the following The Compressive strength test for Conventional concrete of M10 Grade and Alkali activated concrete with 3%, 4% and 5% of alkaline activator was performed for 150mm x 150mm x 150mm size. Three trials were conducted cubes and average of it was noted. The Compressive strength of specimen was calculated by dividing maximum load carried by the specimen by cross-sectional area of the specimen cubes.

$$\text{Compressive Strength of Concrete} = \frac{\text{Max Load Carried by Specimen Top}}{\text{Surface Area of Specimen}}$$

3.2 MIX DESIGN

Calculation for 1m³ as per IS 10262: 2009 and IRC: SP 49 – 2014

Table 3.1 Mix Design of Dry lean concrete and Alkali activated concrete

Grade designation	Dry lean concrete (DLC)	Alkali activated concrete (AAC) (3% of Alkaline Activator)	Alkali activated concrete (AAC) (4% of Alkaline Activator)	Alkali activated concrete (AAC) (5% of Alkaline Activator)
Type of Binder	Cement OPC 43 grade	GGBFS	GGBFS	GGBFS
Max nominal size Aggregate	20mm	20mm	20mm	20mm
Binder content	155 kg	155 kg	155 kg	155 kg
Water content	6.52% of total weight of material	6.52% of total weight of material	6.52% of total weight of material	6.52% of total weight of material
Sodium Hydroxide (NaOH)	—	2.5 kg	3.33 kg	4.15 kg
Sodium Silicate (Na2SiO3)	—	18.75 kg	25 kg	31.25 kg
Fine aggregate	829.8 kg/m³	836.19 kg/m³	951.1 kg/m³	945.97 kg/m³
Coarse aggregate	1264.6 kg/m³	1306.3 kg/m³	1485.88 kg/m³	1477.87 kg/m³
Water content	158 litres	135 litres	135 litres	135 litres
Ratio	1:14	1:15	1:17	1:17.8

3.3 Performance evaluation of concrete by following tests

- Compressive strength
- Flexural Strength
- Water absorption test

3.3.1 COMPRESSIVE STRENGTH TEST RESULT

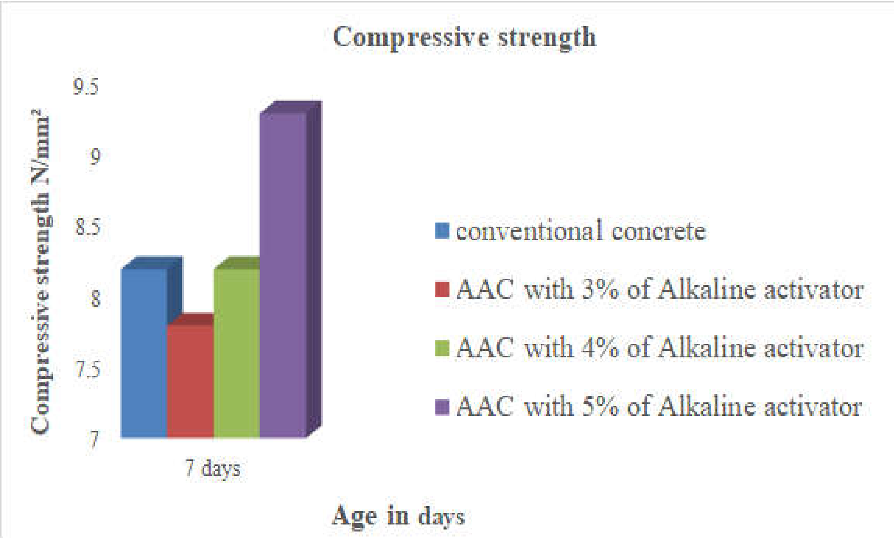

Fig.3.1 Compressive strength results

From above graph we can observe the variation of 7 days compressive strength when the Alkaline activator changes in AAC. The compressive strength for AAC with 3% of Alkaline activator was less compared to conventional concrete. The compressive strength for AAC with 4% and 5% of alkaline activator was greater than the conventional concrete. The strength of concrete was noticed to be increasing as the percentage of alkaline activator is increased. i.e. (from 3% to 5%). This is due to polymerization reaction caused by aluminosilicate with the alkaline liquid, leading to the formation of N-A-S–H bonds.

3.3.3 FLEXURAL STRENGTH TEST RESULTS

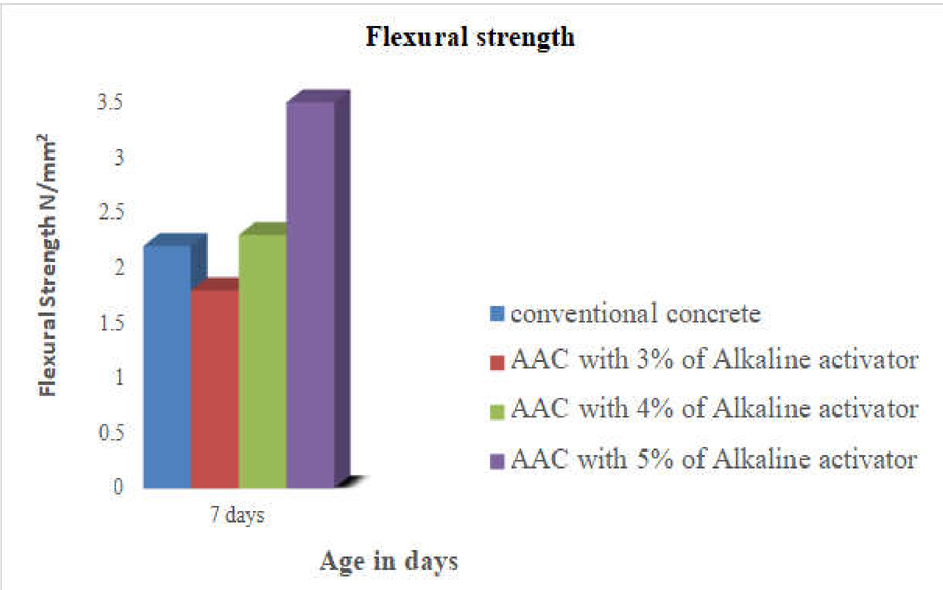

Fig.3.2 Flexure strength results

From above graph we can observe the variation of 7 days Flexural strength when the Alkaline activator changes in AAC. The Flexural strength for AAC with 3% of Alkaline activator was less compared to conventional concrete. The compressive strength for AAC with 4% and 5% of alkaline activator was greater than the conventional concrete. The strength of concrete was noticed to be increased as the percentage of alkaline activator was increased. i.e. (from 3% to 5%).

3.1.2 WATER ABSORPTION TEST RESULT ON CONCRETE

A = Mass of oven dried sample in kg

B = Mass 0f surface dry sample in air after immersion in kg

$$\text{Water absorption} = \frac{B-A}{A} \times 100$$

Table 3.2 Water absorption test result on Conventional concrete and AAC

Type of concrete	For M10 grade			Water absorption (%)
	Trial no	A (kg)	B (kg)	
Conventional concrete	1	7.2	7.7	6.9
	2	7.3	7.8	6.8
	3	7.2	7.7	6.9
	Average			6.8
AAC with 3% of alkali activator	1	7	7.4	5.7
	2	7.1	7.5	5.7
	3	7.2	7.58	5.3
	Average			5.6
AAC with 4% of alkali activator	1	7.2	7.6	5.54
	2	7.3	7.68	5.2
	3	7.3	7.7	5.4
	Average			5.4
AAC with 5% of alkali activator	1	8.2	8.6	4.8
	2	8.2	8.55	4.2
	3	8.15	8.5	4.3
	Average			4.4

From the above table it can be observed that the water absorption of concrete goes on decreasing as increase in the percentage of Alkali activator in AAC. The water absorption capacity for Alkali activated concrete for 3%, 4% and 5% of Alkali activator are 5.6%, 5.4% and 4.4% respectively. The water absorption of conventional concrete is 6.8% which is greater than the water absorption for AAC with 3%, 4% and 5% of alkali activator. The rate of water absorption goes on decreasing as increase in the percentage of Alkali activator in AAC.

CONCLUSIONS

The main aim of this project was to study the mechanical and durability properties of the Alkali activated concrete with ground granulated blast furnace slag (GGBFS) as binder and Alkaline activator. A comparison was made between conventional concrete and Alkali Activated concrete having GGBFS as binder and various percentage of Alkaline Activator such as 3%, 4% and 5%. By this experimental investigation we concluded the following results.

1. The Compressive strength of AAC increased as the percentage of Alkaline Activator is increased. i.e 7.8 N/mm² for 3% of Alkaline solution, 8.2 N/mm² for 4% of Alkaline solution and 9.3 N/mm² for 5% of Alkaline solution.
2. The compressive strength for 4% and 5% of Alkaline activator was greater than conventional concrete and was lesser for 3% of Alkaline activator.
3. The Flexure strength of AAC increased as the percentage of Alkaline Activator is increased. i.e 1.8 N/mm² for 3% of Alkaline solution, 2.3 N/mm² for 4% of Alkaline solution and 3.5 N/mm² for 5% of Alkaline solution.
4. The Flexure strength for 4% and 5% of Alkaline activator was greater than conventional concrete and was lesser for 3% of Alkaline activator.
5. The Alkali Activated concrete manufactured with GGBFS 4% and 5% of Alkaline activators satisfy the requirement criteria of Dry lean concrete as per IRC: SP-49 specification in terms of strength development, aggregate-to-cement ratio, and moisture content etc.
6. A slight change in the color of cubes was observed after removal of cubes from sulfuric acid (H_2SO_4) and the density of concrete was affected which was confirmed from reduction in weight of the cubes.

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