STRENGTH AND DURABILITY STUDIES ON ALKALI ACTIVATED CONCRETE

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ABSTRACT:

Rapid infrastructure development has increased the demand for cement production across the world. This increased cement production has been a major contributor to greenhouse gas emissions, which are released during its manufacture. In fact, every tons of cement production roughly produces 0.87 tons of carbon dioxide. Alkali-activated binders have been extensively researched as a potential replacement of ordinary Portland cement concrete to minimize carbon emissions released during OPC production. This study provides the strength and durability performance of alkali-activated concrete. The cement in concrete is partially replaced by the alkali-activated binder. Here, M25 grade of concrete is used. The properties of the alkali activated binder and other concrete ingredients were analyzed. The optimum percentage replacement of cement with alkali was found to be 25%. The strength and durability of alkali activated concrete were studied. The result of this study was concluded by comparing the strength and durability of alkali activated concrete with OPC concrete.

Key words: *Alkali activated binder, Alkali activated concrete, cement replacement, Strength test, and Durability test.*

1. INTRODUCTION

Concrete is the composite material that is created by mixing binding material (cement or lime) along with the aggregate (sand, gravel, stone, brick chips, etc.), water, admixtures, etc. in specific proportions. The strength and quality are dependent on the mixing proportions. Once all the ingredients -cement, aggregate, and water unit of measurement mixed inside the required proportions, the cement and water begin a reaction with one another to bind themselves into a hardened mass. This hardens the rock-like mass is the concrete. The initial hardening reaction usually occurs within a few hours. It takes some weeks for concrete to reach full hardness and strength. Concrete can continue to harden and gain strength over many years. The ordinary Portland cement (OPC) industry generates significant emissions of CO_2 in addition to the excessive consumption of natural resources and energy. This promotes the generation of greenhouse gases in the atmosphere is directly related to climate change. To overcome this difficulties the ordinary Portland cement (OPC) is replaced by alkali activated binder. Alkali activated materials (AAMs) are binders, that are produced through the reaction of an alkali source and alumino silicates. The most commonly used alkali sources are sodium or potassium hydroxides and/or silicates, while alumino silicates may include suitable raw materials and wastes.

1.1. Objectives

- To study the properties of alkali activated binder and other concrete ingredients.
- To determine the strength and durability of alkali activated concrete and
- To compare the test values with the Conventional concrete.

2. MATERIALS USED

2.1 FINE AGGREGATE

Fine aggregates are basically natural sand particles from the land through the mining process, the fine aggregates consist of natural sand or any crushed stone particles. Fine aggregate should be clean i.e. it should be free from lumps, organic material, etc. It should be strong and durable. It should not react with cement after mixing and should not absorb greater than 5% of water. Fine aggregates comprise of natural sand and stone which are graded into Zone 1 to Zone 4 depending on its ability to move through the 600-micron.

Table 1 Physical properties of Fine aggregate

S.NO	PROPERTY	VALUES
1.	Specific gravity	2.67
2.	Fineness modulus	3.72

2.2 COARSE AGGREGATE

Coarse aggregate refer to irregular and granular materials such as gravel, or crushed stone, and are used for making concrete. In most cases, coarse is naturally occurring and can be obtained by blasting quarries or crushing them by hand or crushers. Their angularity and strength affect the concrete in numerous ways. Materials that are large enough to be retained on the 4.7mm sieve size usually constitute coarse aggregate and can reach maximum size of 63mm.the size of the coarse aggregate affects several aspects of the concrete, mainly strength and workability, and the amount of water needed for the concrete mix. It also helps determine how much fine aggregate is needed to produce a concrete batch. The size of the coarse aggregate determines the cement to water ratio. Aggregates should be stored and handled carefully to avoid contamination from dirt. They should not be segregated, and their moisture content should remain relatively constant.

Table 2 Physical properties of Coarse aggregate

S.NO	PROPERTY	VALUES

1.	Specific gravity	2.84
2.	Fineness modulus	4.45

2.3 ALKALI ACTIVATED BINDER

Most of the works on alkali-activated binders have been carried out for the activation of granulated blast furnace slags by an alkaline solution. Blast furnace slag is a calcium-rich by-product of the metallurgical industry and can achieve high compression strengths after activation with an alkali solution. In general, two types of reaction mechanism of alkali-activated binders can be established. The first system involves the activation of calcium-rich raw materials like blast furnace slags, with high content of Si, Al and Ca atoms. The activation is realized using moderate alkaline solutions leading to calcium silicate hydrates-like phases as reaction products. The second mechanism involves the alkali activation of low-calcium, respectively calcium-free prime materials using medium to high alkaline solutions, leading to a polymeric network with formation of amorphous zeolite-like phases and high mechanical strength similar to OPC. Alkali-activated binder has both advantages and disadvantages.

Table 3 physical properties of alkali activated binder

S.NO	**PROPERTY**	**VALUES**
1.	Specific gravity	2.5
2.	Normal Consistency	32% of water added

Fig. 1.Alkali activated binder

2.3 CEMENT

Cement can be defined as the bonding material having cohesive and adhesive properties which makes it capable to unite the different construction materials and form the compacted assembly. Ordinary Portland cement is the most widely used building material in the world with about 1.56 billion tones produced each year. Annual global production of Portland cement concrete is around 3.8 million cubic meter per year. Cement is usually manufactured by two process, wet process and dry process. OPC 53 Grade cement is required to conform to BIS specification IS: 12269-1987 with a designed strength for 28 days being a minimum of 53MPa. 53 Grade OPC provides high strength and durability to structures because of its optimum particle size distribution and superior crystallized structure. 53 Grade cement attains higher early strength as compared to any other grade of cement but because of early gain, does not increase much after 28 days.

Table 3 Physical properties of alkali activated cement

S.NO	PROPERTY	VALUES
1.	Specific gravity	3.15

3. PREPARATIONS OF MIX AND CASTING OF SPECIMENS

The process of specifying the most economical and practical combination of materials or selecting suitable materials for producing concrete of required strength is known as mix design. The grade of concrete used in the present investigation is M25. The mix proportion is designed by using IS 10262-2019 and the mix obtained with the w/c ratio of 0.55. The mixing of concrete is done manually. The cube, cylinder and prism specimens were casted for M25 grade conventional and alkali activated concrete. The alkali activated concrete specimens were casted with the optimum percentage replacement of alkali binder (25%) with cement. The results were compared with the OPC concrete.

4. RESULTS AND DISCUSSIONS

4.1 Strength parameters

4.1.1 Compressive strength test: The cube specimen is placed in the universal testing machine in such a way that the axis of test specimen is carefully aligned with the center of thrust of the steel plate in the testing machine. The movable part is rotated gently by hand so that uniform seating may be obtained. The load is applied gradually without shock and increasing continuously until the failure of specimen takes place.

Table 4. Test results of compressive strength

S.no	Description	C.S area (mm^2)	Avg. compressive strength (N/mm^2)	
			7 days	28 days
1.	C.C	22500	26.56	29.53
2.	15% alkali	22500	25.5	27.8
3.	25% alkali	22500	26.75	29.92
4.	35% alkali	22500	26.15	28.2

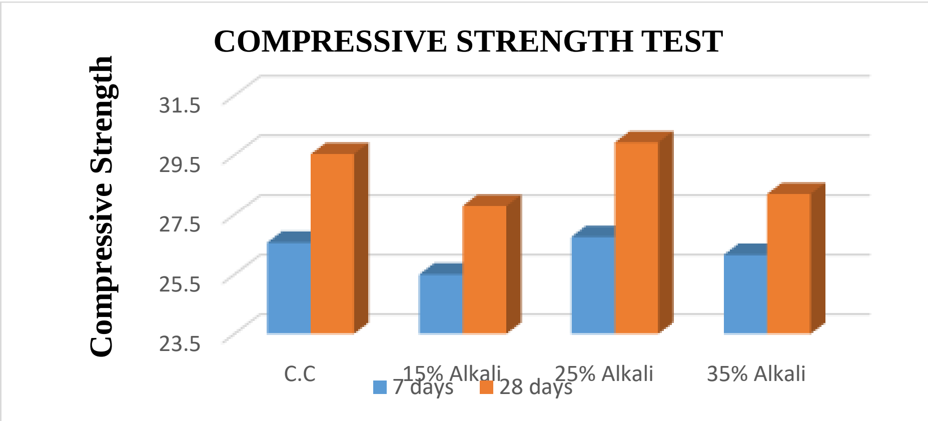

Fig 2 Compression of compressive strength test results

4.1.2 Flexural strength test: Flexure test is used to evaluate the tensile strength of the concrete in an indirect way. It tests the ability of unreinforced concrete beam to withstand failure in bending. The results of flexural test on concrete expressed as a modulus of rupture which denotes as (MR) in MPa or N/mm^2. The flexural test on concrete can be conducted using three point load test. The flexural strength is found by casting the prism specimen of size 500mm x 100mm x 100 mm. After 24hrs, the specimen was demoulded and put it in the curing for 28 days and then test is conducted. The specimen is placed in the position as moulded and is placed on the support blocks. The load shall be applied at a constant rate to the breaking point. The flexure strength is conducted and calculation done as per IS 516-1959.

Table 5 Test results of flexural strength

S.NO	DESCRIPTION	SIZE OF THE SPECIMENS (mm)	MODULUS OF RUPTURE,(N/mm^2)
1.	C.C	500 X 100 X 100	6.04
2.	15% alkali	500 X 100 X 100	6.50
3.	25% alkali	500 X 100 X 100	6.86
4.	35% alkali	500 X 100 X 100	5.51

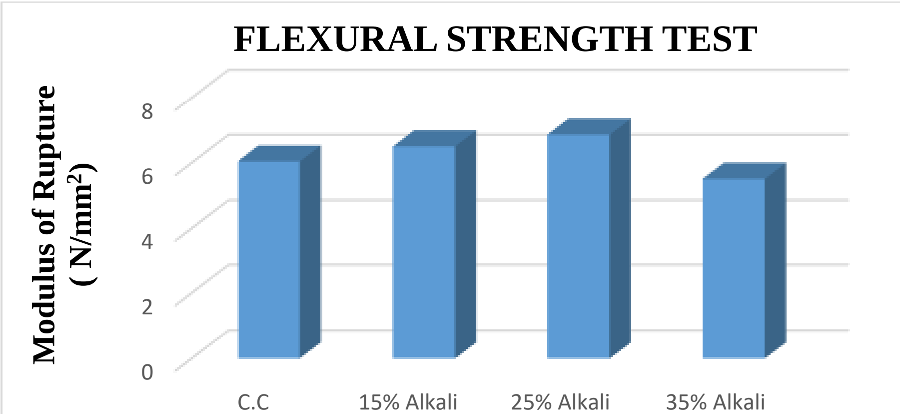

Fig 3 Compression of flexural strength test results

4.1.3 Modulus of elasticity on concrete: Modulus of elasticity of concrete is the measurement of the stiffness of the concrete which is a good indicator of strength. It is defined as the ratio of the applied stress to the corresponding strain. The modulus of elasticity of concrete was found out using the cylindrical specimen of size 150mm diameter and 300mm height. After 24 hours, the casted cylinder specimens were removed from the mould and put it in the curing for 28 days and then test is conducted. The specimens are placed in the compression testing machine with the dial gauge attached in the cylinder to find out the change in length of the specimen. The load shall be applied at a constant rate until the maximum load taken by the cylinder.

Table 6 Test results of modulus of elasticity

S.NO	**DESCRIPTION**	**AREA OF SPECIMEN**	**MODULUS OF ELASTICITY, E_c (N/mm^2)**
1.	C.C	17671.45	33888.88
2.	15% alkali	17671.45	19230.76
3.	25% alkali	17671.45	36875
4.	35% alkali	17671.45	16666.66

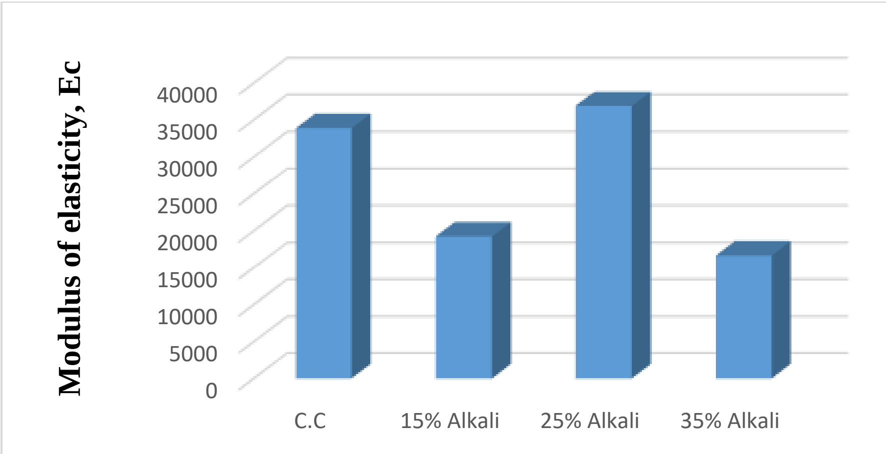

Fig 4 Compression of modulus of elasticity on concrete

4.2 DURABILITY PROPERTIES

4.2.1 Water Absorption: Concrete cube specimens of size 150 × 150 × 150 mm for conventional and alkali activated concrete were casted. After 28 days of curing, the specimens were taken out and dried in an oven at a temperature of 100ºC to 110ºC for 24 hours. The samples has been removed from the oven and allowed to cool in dry air to a temperature of 20ºC to 25ºC. The dry weight of the each specimen was taken using an electronic weighing balance and then the specimens were immersed in water. The wet weights are recorded for every ½ hour up to 2½ hours, after which the reading is noted for every 1 hour up to 4 hours and finally at 24 hour and 72 hour.

Table 7 Test results of water absorption of concrete

S.NO	DESCRIPTION	AGE OF THE SPECIMENS	AVERAGE % WATER ABSORPTION
1.	C.C	28 days	1.0
2.	15% Alkali	28 days	1.16
3.	25% Alkali	28 days	0.98
4.	35% Alkali	28 days	1.14

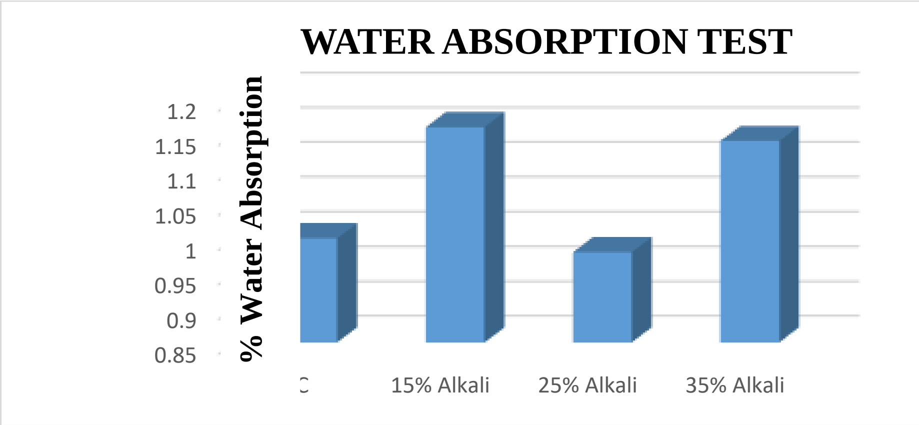

Fig 5 Compression of water absorption test results

4.2.2 Sorptivity: The cylinder specimens of size 100mm diameter and 50mm height were used in this thesis. The specimens are dried in an oven at a temperature of 85°C are drowned with water level not more than 5mm above the base of the specimen. The flow from peripheral surface is prevented by sealing properly with the non-absorbent coating. The quantity of water absorbed in the time period of 30minutes is calculated by measuring the weight of the specimen. Surface water on the sample is wiped off with a dampened tissue and each weighing operation is completed within 30 seconds.

Table 8 Test results of Sorptivity of concrete

S.NO	DESCRIPTION	AREA OF SPECIMEN, cm^2	SORPTIVITY, cm
1.	C.C	314.15	4.065×10^{-3}
2.	15% Alkali	314.15	4.255×10^{-3}
3.	25% Alkali	314.15	3.874×10^{-3}
4.	35% Alkali	314.15	4.449×10^{-3}

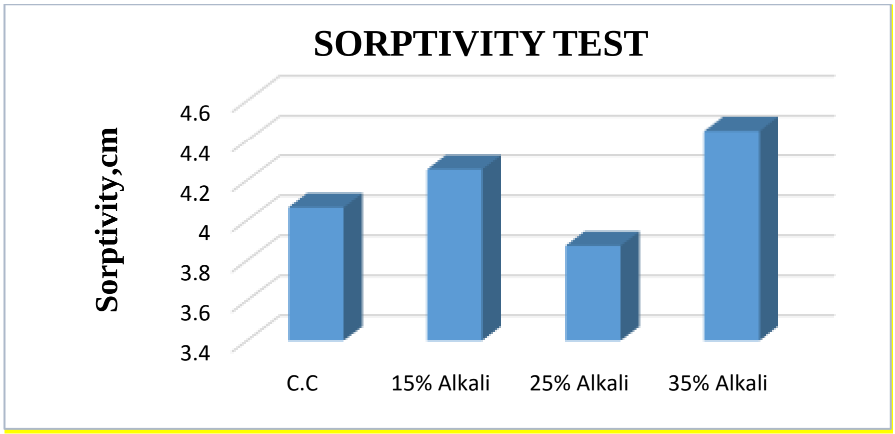

Fig. 6. Sorptivity test results

5. CONCLUSION

Conclusion of thesis can be drawn by the experimental investigation for mechanical and durability properties of concrete with alkali binder as a partial replacement of cement. And the result values are compared with the conventional concrete.

1. The compressive strength of 25% replacement of cement with alkali binder at 28 days strength is increased by 1.3% when compared with the conventional concrete. For other % replacement mixes, the compressive strength is decreased.
2. The split tensile test of 28 days strength for 25% replacement of cement with alkali binder is increased by 10.33% which is higher than the conventional concrete.
3. The flexural strength test of 25% replacement of cement of cement is increased by 13.57% when compared with conventional concrete.
4. The modulus of elasticity of concrete with 25% replacement cement with alkali binder is increased by 8.8% when compared with the conventional concrete.
5. The water absorption test of 25% replacement of cement with alkali binder gives better result than the conventional concrete. Which means the alkali activated concrete absorbs less amount of water when compared with conventional concrete.
6. The Sorptivity test of 25% replacement of cement with alkali binder 4.69% better result when compared with the conventional concrete.
7. The replacement of cement with alkali binder helps to reduce the emission of Co_2 from the Ordinary Portland Cement (OPC) industry and it protects the environment.
8. Results of this present study shows that the 25% replacement of cement with alkali binder gives better result in the mechanical and durability properties of concrete when compared with conventional concrete.

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REFERENCES

1. **William G. Valencia-Saavedra, Ana María Aguirre-Guerrero & Ruby Mejía de Gutiérrez,** Alkali-activated concretes based on high unburned carbon content fly ash: carbonation and corrosion Performance, 2020.
2. **Md Manjur A. Elahi, Md. Maruf Hossain, Md Rezaul Karim, Muhammad Fauzi Mohd Zain, Christopher Shearer,** A review on alkali-activated binders: Materials composition and fresh properties of concrete, 2020.
3. **Robert J. Thomas, Sulapha Peethampara,** Alkali-activated concrete: Engineering properties and stress–strain Behavior, 2015.
4. **Linda Monfardini, Fausto Minelli,** Experimental study of alkali activated concrete: Structural applications ProScience 2 (2015) 59-64.

5. **Md. Rezaul Karim, Md. Maruf Hossain, Md Manjur A Elahi and Muhammad Fauzi Mohd Zain,** Effects of source materials, fineness and curing methods on the strength development of alkali-activated binder.
6. **H. Choo, S. Lim, W. Lee, C. Lee,** Compressive strength of one-part alkali activated fly ash using red mud as alkali supplier. Construction and Building Materials 125 (2016) 21–28.
7. **Jannie S.J. van Deventer, Rackel San Nicolas, Idawati Ismail, Susan A. Bernal, David G. Brice and John L. Provis,** Microstructure and durability of alkali-activated materials as key parameters for standardization, 2014.
8. **Shriram Marathe, Mithanthaya I R., Sahithya S. Shetty,** Research on Eco-friendly Alkali Activated Concrete Incorporating Industrial Wastes International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8, Issue- 9S2, July 2019 .
9. **Osama Ahmed Mohamed,** A Review of Durability and Strength Characteristics of Alkali-Activated Slag Concrete, 2019.
10. **Maochieh Chi,** Mechanical strength and Durability of alkali-activated fly ash/slag concrete Journal of Marine Science and Technology, Vol. 24, No. 5, pp. 958-967 (2016).