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Comparative Study on Durability Characteristics of Conventional Concrete and Alkali –Activated High Density Concrete

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ABSTRACT: The present study focuses on the comparative study of conventional high-density and geo-polymer density concrete using high-density aggregates, Geopolymer concrete with high-density aggregates which is cement-less concrete binder that is based on an alumina silicate reaction of fly ash and GGBS (Ground Granulated Blast Furnace Slag).The characteristics of strength have been evaluated by conducting a compressive strength test and durability properties have been evaluated by using water absorption, acid attack test, chloride test, sulphate test, and porosity test. The mix design is done for geo polymer and conventional concrete using both the aggregates, Trials have been conducted for water cement ratios for M70 mix design. The types of mixes were CHNM (conventional concrete with normal aggregates), CHHM (conventional concrete with hematite aggregates) and CHMM (Conventional concrete with magnetite aggregates), GHNM (Geopolymer concrete with normal aggregates), GHHM (Geopolymer concrete with hematite aggregates) and GHMM (Geopolymer concrete with magnetite aggregates). Conventional concrete cubes by using normal and hematite aggregates, geo polymer concrete cubes using normal and hematite aggregates and by replacing the cement by GGBS 50%, Fly ash 45%, Silica fume 5% and by using alkaline activators such as sodium silicate and Sodium hydroxide has been casted to check the strength, quality, and durability. All the cubes were cured for the standard period time of 28 days. After the curing period, the compressive strength test was conducted for 7 days and 28 days intervals. The geopolymer high-density concrete with the Magnetite aggregates gave a high resistance to the load compared to the other six samples. For the durability tests the cubes were soaked in Hydrochloric acid by the weight of 5% of water for the acid attack test, Sodium chloride 5% by the weight of water for the chloride attack test, and magnesium sulphate for the sulphate attack test. The weights of the cubes were taken for the regular time intervals. A water absorption test and porosity test were conducted as per the standard codes and an ultrasonic pulse velocity test was conducted to check the quality of the concrete cubes. In all the tests that have been conducted, it is observed that conventional and geo polymer concrete cubes magnetite aggregates are showing better resistance to all durability tests that have been conducted.

KEYWORDS: High density, Geo-polymer, Strength, Fly ash, Ggbs, durability, Acid attack, Chloride attack.

I. INTRODUCTION

Ordinary Portland Cement (OPC) is widely used in reinforced concrete but contributes to high CO_2 emissions due to its energy-intensive production. To mitigate this, mineral admixtures such as fly ash, rice husk ash, and ground granulated blast furnace slag (GGBS) are used as partial replacements for OPC, which both reduces environmental impact and improves concrete durability. Geopolymer concrete, an eco-friendly alternative, utilizes aluminosilicate materials like fly ash and GGBS with alkaline activators, creating a durable matrix that resists chemical and heat-related degradation. This geopolymerization process requires less energy, making it a sustainable choice in concrete applications, especially

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in aggressive environments. High-density concrete, using heavy aggregates like barite and magnetite, provides enhanced density and mass, useful for radiation shielding in nuclear facilities, hospitals, and research centres. This high-density concrete also offers increased stability for offshore structures and underwater applications.

Concrete durability, crucial for long service life, is primarily determined by low porosity and permeability, enabling resistance against degradation like alkali-silica reactions, sulphates, and corrosion. Mineral admixtures, by altering the pore structure, enhance concrete's resistance to water-related deterioration such as frost damage, sulphate attack, and reinforcement corrosion. Incorporating admixtures like silica fume and metakaolin significantly increases durability, making them valuable for modern, eco-friendly concrete solutions.

II. LITERATURE SURVEY

The reviewed papers focus on the durability of various advanced concrete types, particularly in harsh environments. Geopolymer concrete (GPC) shows superior resistance to heat, chloride penetration, acid attack, and abrasion, with enhanced performance from fibres and nano-silica additives. Reactive Powder Concrete (RPC) exhibits high durability against chloride ion penetration and salt crystallization but deteriorates significantly under high sulfuric acid concentrations. Concrete in nuclear power plants benefits from mineral admixtures and modified matrices to resist electrochemical corrosion, temperature changes, and radiation effects. Studies on pozzolanic and fibre-reinforced concretes demonstrate their potential in increasing strength and durability, with geopolymer coatings further enhancing concrete longevity. Findings suggest that low water-cement ratios, specific admixtures, and geopolymer or pozzolan coatings contribute to improved performance, especially in marine or acidic environments.

III. METHODS AND METHEDOLOGY

3.1 Materials used

Cement: Ordinary Portland Cement of Grade 53 grade conforming to IS 12269-2013 was used in the preparation of the concrete test specimen which also includes fly ash. GGBBS, silica fume. The Specific gravity of Cement, fly ash, GGBS and Silica Fume are 3.07, 2.13 and 2.14 are chemical composition are used.

Aggregates: Coarse aggregate, Hematite aggregate and magnetite aggregate (size<20 mm) were used. The specific gravity of is 2.67, 4.07 and 3.6 respectively.

Fine aggregate: M sand passing through 4.75 mm sieve was used. The specific gravity and fineness modulus were 2.3 and 3.8 respectively.

Alkali Activators: The most common alkali activators used are sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3).

Table 1: Chemical Properties of Fly ash

SL. NO.	Chemical Composition	values
1	Silicon dioxide (SiO_2) plus aluminium oxide (Al2O:) plus iron oxide (Fe2O:), percent by mass, (Minimum)	86.56
2	Silicon dioxide (SiO2), percent by mass. (Minimum)	51.96
3	Magnesium oxide (MgO), percent by mass- (Maximum)	1.81
4	Total Sulphur as Sulphur trioxide (SO3), percent by mass, (Maximum)	0.16
5	Loss on ignition, percent by mass, (Maximum)	3.02
6	Available alkalis as sodium oxide (Na2O), percent by mass, (Maximum)	0.78
7	Total Chlorides in percent by mass, (Maximum)	0.004

Table 2:Chemical Properties of GGBS

SL. no	Chemical Composition	Values
1	Manganese Oxide (MnO)	0.12
2	Magnesium Oxide (MgO)	7.83
3	Sulphide Sulphur(S)	0.51
4	Sulphate (as SO_3)	0.24
5	Insoluble Residue (I.R)	0.29
6	Chloride Content (Cl)	0.009
7	Glass Content	92
8	Loss on Ignition (L.O.I)	0.18
9	Moisture Content	0.01
10	$\frac{CaO + MgO + \frac{Al2O3}{3}}{SiO2 + \frac{2Al2O3}{3}}$	0.01
11	$\frac{CaO + MgO + Al2O3}{SiO2}$	1.11

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3.2. Mix proportion

Several trail mixes were conducted on the conventional high-density concrete; the mix design was carried out for M70 grade of concrete. Cementitious materials were cement, Fly ash (15%), Silica fume (5%). The procedure of the mix design is taken from the code book IS 10262-2019. Three trial mixes were made with use of different aggregates (coarse aggregates, Hematite aggregates and Magnetite aggregates) hence the aggregates content changed with respect to their densities and water cement ratios was kept constant for all the three mixes i.e., 0. 26. In the same way several trail mixes were conducted for Geo-polymer High-Density concrete, the mix design was carried out for M70 grade of concrete. Cementitious materials include fly ash (40%), GGBS (50%) silica fume (5%). The procedure of the mix design is taken from the (Abhishek C Ayachit et.al., 2016). Three mix design were carried out by changing the aggregates (coarse aggregates, Hematite aggregates and Magnetite aggregates). The Water-geopolymer solids ratio were kept constant for all the three mixes i.e., 0. 26, Ratio of NaoH to Na_2Sio_3 was 2.5. The mixes were proportioned by absolute volume method and mix proportions were calculated for all the mixes.

3.3 Methodology

Six types of concrete mix were designed i.e., CHNM (conventional concrete with normal aggregates), CHHM (conventional concrete with hematite aggregates) and CHMM (Conventional concrete with magnetite aggregates), GHNM (Geopolymer concrete with normal aggregates), GHHM (Geopolymer concrete with hematite aggregates) and GHMM (Geopolymer concrete with magnetite aggregates). Once all the materials are batched the materials of conventional and geopolymer concrete were mixed in an electrically operated mixer with a horizontal shaft. After mixing the concrete is poured in to 150mm x 150mm x 150mm moulds and compacted. It is demoulded after 24 hours and kept for water curing in water tank. A total of 120 cubes were casted, considering 2 specimens of each test. The slump test was carried out to check the workability of the concrete.to know the strength after curing for 28 days compression test was carried in compression testing machine whose load bearing capacity was 2000KN/m. To check the durability of the concrete several tests were performed. The concrete samples were kept in acid solutions such as hydrochloric acid, sodium sulphate, sodium chloride. Also, porosity, water absorption tests were conducted. The compression strength test was carried out after the samples were cooled to room temperature (27°C) as per IS 516-1959.

IV. RESULTS AND DISCUSSION

4.1 Compressive Strength

A total of 6 cubes for each were casted for CHNM, CHHM, CHMM and GHNM, GHHM, GHMM. The samples were demoulded after 24 hours of pouring. Conventional concrete was kept for water curing and geopolymer concrete were kept for water curing for 7 days and 28 days. After 7 and 28 days the samples were taken out form the curing tank and kept for drying in the room temperature(27^0C) and strength was conducted in compression testing machine. The results obtained are shown in the figure1

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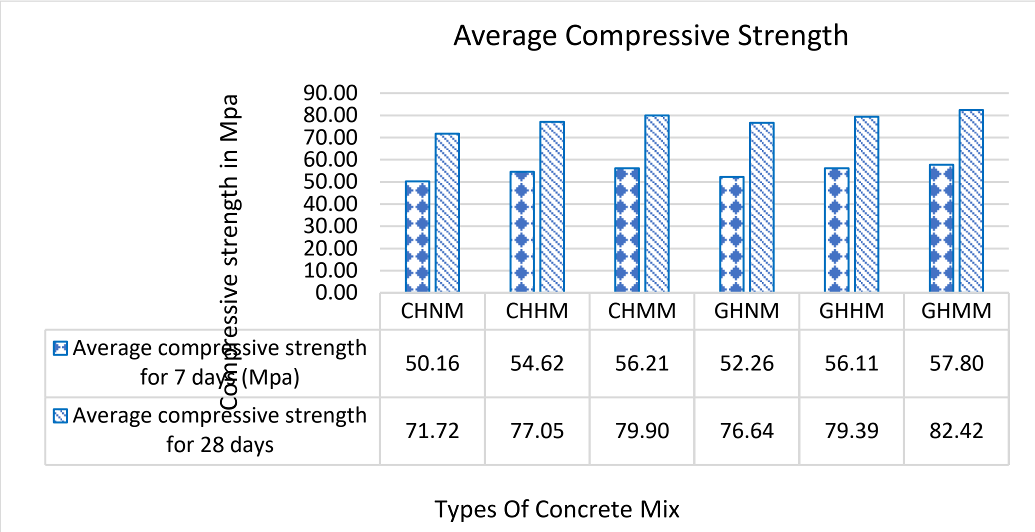

Figure 1: shows the Compressive Strength results of the different concrete mixes after curing the samples for 7 and 28 days. Hence from the figure it is observed that the magnetite geo-polymer mix has the higher strength.

4.2 Acid attack test

To test acid resistance, a specimen measuring 150mm x 150mm x 150mm was submerged in a solution of 10% hydrochloric acid (2N) diluted with water for 8 weeks, starting at the age of 28 days. After this period, the specimens were removed, and measurements were taken to determine the average weight loss and compressive strength.

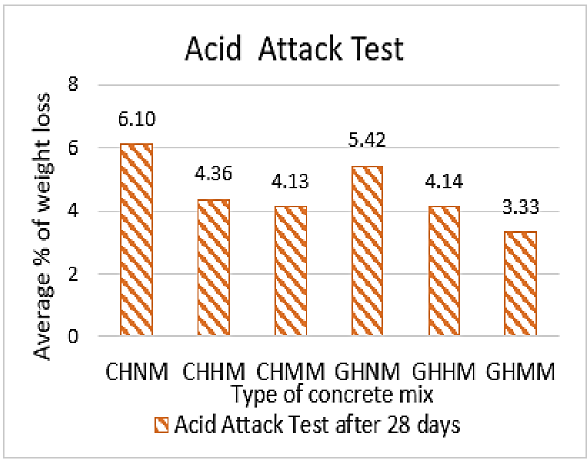

Figure 2: Acid test results (% of weight loss)

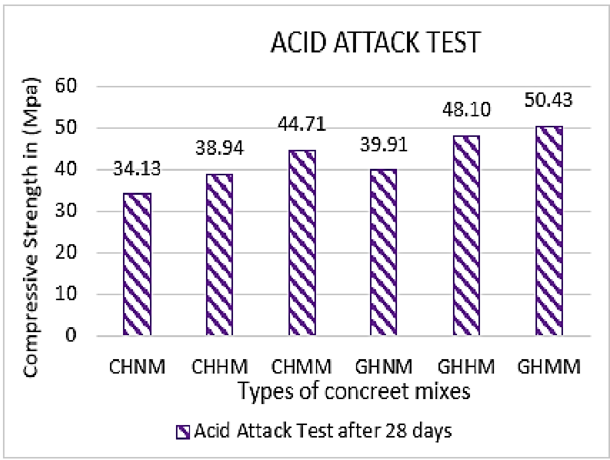

Figure 3:Acid test results (Compressive Strength)

Figure 2 and figure 3 shows the % of weight loss in cubes after 28 days immersion in sulphuric acid. To check the strength, compressive strength was conducted. Results shows that geo-polymer magnetite mix shows greater resistant to acid.

4.3 Sulphate attack test

To test Sulphate attack, 10% of sodium sulphate solution is prepared and specimen measuring 150mm x 150mm x 150mm was submerged in a solution for 8 weeks, starting at the age of 28 days. Sulphate attack test to be conducted for

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period of 56 days. Sulphate attack test to be conducted for period of 56 days. After this period, the specimens were removed, and measurements were taken to determine the average weight loss and compressive strength.

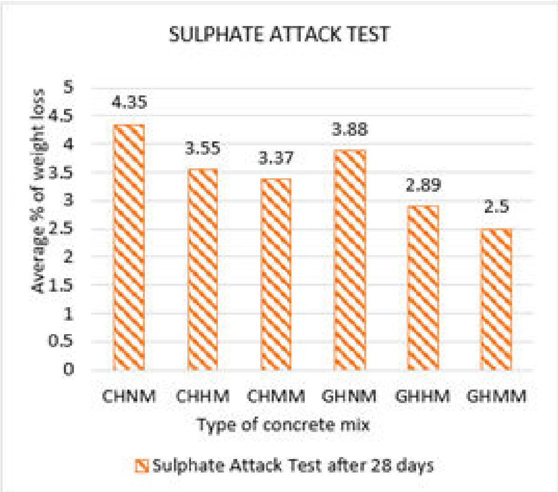

Figure 4:Sulphate test results (% of weight loss)

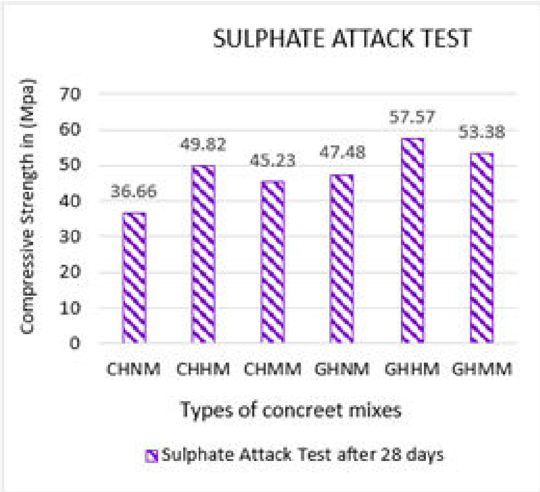

Figure 5:Sulphate test results (Compressive Strength)

Figure 4 and figure 5 shows the % of weight loss in cubes after 28 days immersion in sulphuric acid. To check the strength, compressive strength was conducted. Results shows that geo-polymer magnetite mix shows greater resistant to sulphate attack.

4.4. Chloride attack test

A chloride test is done to check the resistance of the concrete to chloride attack. Sodium chloride solution of 10% is prepared. and specimen measuring 150mm x 150mm x 150mm was submerged in a solution for 8 weeks, starting at the age of 28 days. After this period, the specimens were removed, and measurements were taken to determine the average weight loss and compressive strength.

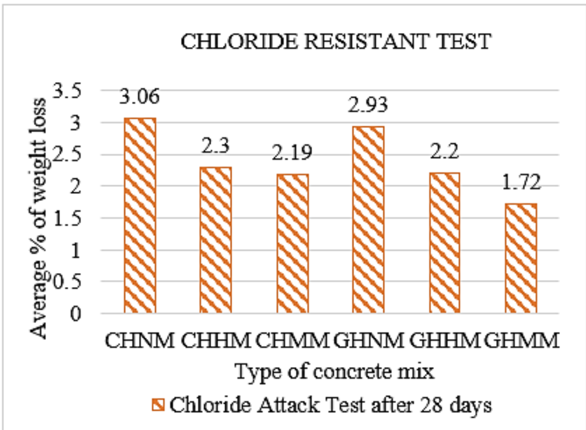

Figure 6:Chloride attack test results (% of weight loss)

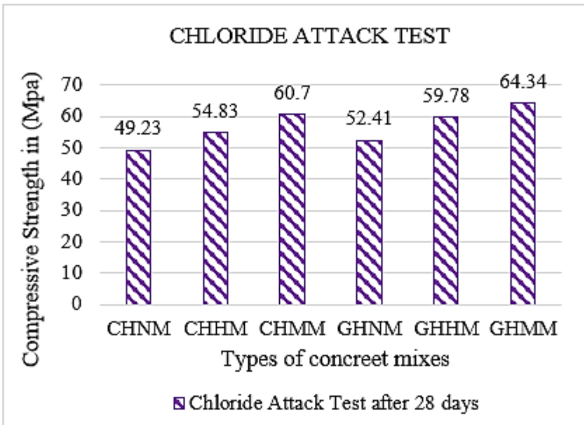

Figure 7:Chloride attack test results (Compressive Strength)

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Figure 6 and figure 7 shows the % of weight loss in cubes after 28 days immersion in sulphuric acid. To check the strength, compressive strength was conducted. Results shows that geo-polymer magnetite mix shows greater resistant to chloride attack.

4.5 Water absorption test

Water absorption is the capacity of a concrete sample to absorb water when submerged under specific conditions. Water absorption is usually measured by immersing a dry concrete sample in water and determining the increase in mass due to absorbed water. This is done under saturated conditions, typically after 48 hours of immersion, as per standards like ASTM C642.

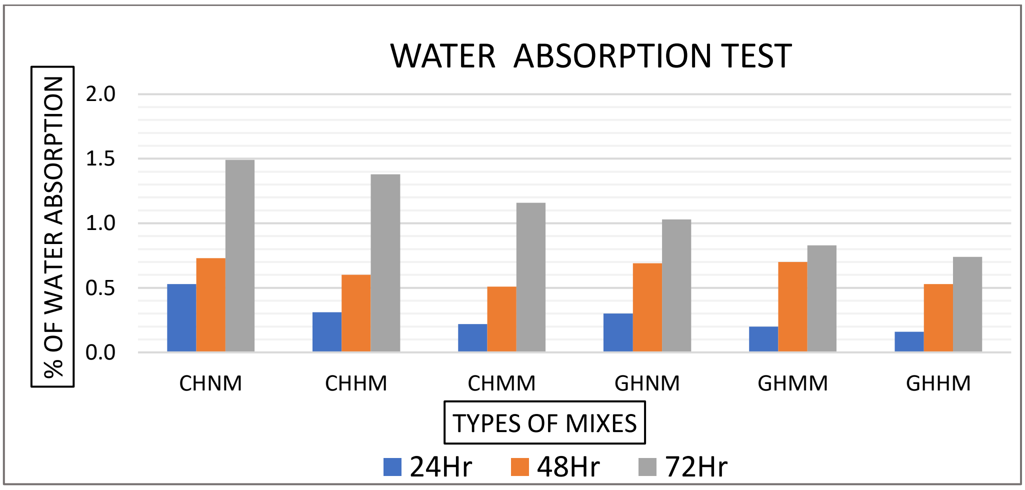

Figure 8: Water absorption test result

Figure 8 shows the water absorption test results for different mixes. It is observed that geo-polymer magnetite mix have lesser water absorption compared to all other mixes.

4.6 Porosity

Porosity is the ratio of the volume of voids (pores) to the total volume of the material. It represents the total pore space within the concrete, including both capillary and gel pores. The most common method to estimate porosity in concrete is by determining the volume of permeable voids (as in ASTM C642).

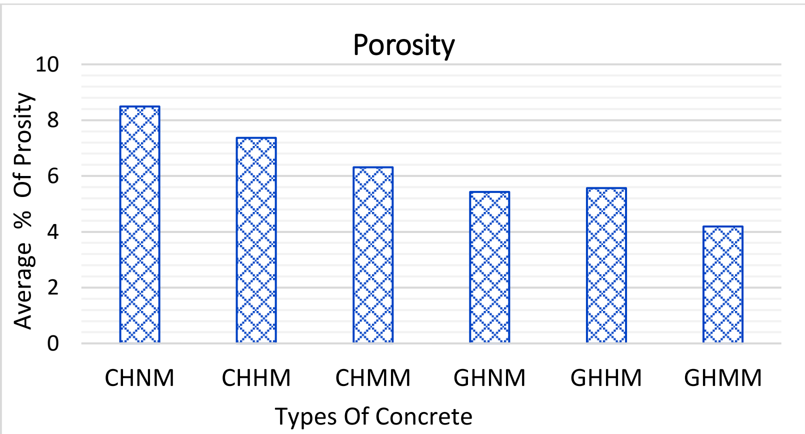

Figure 9: Porosity test results

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V. CONCLUSION

Based on the study, the following observations were made from the theoretical, experimental and analytical perspective. To test the fresh properties of concrete, the slump test was conducted for all mixes and true slump was achieved. Compressive strength increases with replacement of normal aggregates by hematite and magnetite aggregates. The compressive strength of all the geopolymer mixes was high compared to conventional. Geo polymer concrete shows better resistance to all the durability tests conducted, due to the usage of high-density aggregates and Alkali solutions. Geo polymer has comparatively 30-50% higher resistance than conventional concrete. The porosity is less in geopolymer concrete compared to conventional concrete. The density of the geopolymer hematite concrete is more than conventional concrete and conventional hematite concrete. It is found that the geopolymer Magnetite concrete possess high mechanical properties in all the tests compared to other mixes. Geopolymer Magnetite concrete can be considered as high- density concrete and further studies can be carried out to check its suitability for use in nuclear or thermal power plants.

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