Performance Evaluation of Ambient Cured Alkali Activated Slag concrete Exposed To Acidic Environment

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Abstract- *The usage of cement is increasing day by day for satisfying the need of development of infrastructure facilities. As the emission of carbon dioxide during the production of cement is more and thus causes serious problems to degradation of environment. In view of this, there is a significant expectation on the researchers to reduce co2 emission. In order to reduce the usage of ordinary Portland cement, there is a need to find the alternate material to the cement.Geopolymers are increasingly receiving popularity as novel binders and are emerging as an alternative to OPC binders. The superior performance of geopolymer binders compared with Portland cements in terms of corrosion and fire resistance is attributed to the absence of water and calcium in their structure. The impact of carbon dioxide emission due to production of Portland cement can be reduced with supplementary cementitious materials. Ground granulated blast-furnace slag (GGBS) is the waste materials comprising pozzolanic properties but their disposal is causing impact on the environment and Copper slag is an individual by product material produce by copper smetting and refining processes. Copper slag is a by-product material produced from the process of manufacturing copper. The disposal of this material is already inflicting environmental issues round factories. The utilization of industrial waste product in concrete has been a major step on waste reduction. Ground granulated blast furnace slag can be effectively used in concrete as a cementitious material because of their high content of silica and pozzolanic properties which plays an important role in achieving high strength and durability in concrete. To Substitute the cement we can utilize GGBS that is accessible as a waste material delivered by steel enterprises separately. This paper presents an experimental investigation on the acid resistance of geopolymer concrete cured under ambient conditions and also reviews the works done for evaluation of the response of geopolymer concrete when exposed to various acids for a certain period of time.*

Keywords- Copper slag (CS), Ground granulated blast-furnace slag (GGBS), Sodium Hydroxide (NaOH), Sodium Silicate (Na_2SiO_3), Compressive strength, split tensile strength test, Acid immersion.

I. INTRODUCTION

In the construction field, Cement is the main ingredient for the production of concrete. But the production of cement requires large amount of raw material. During the production of cement burning of lime stone take place which results in emission of carbon dioxide (CO2) gas into the atmosphere. There are two different sources of CO2 emission during cement production. Combustion of fossil fuels to operate the rotary kiln is the largest source and other one is the chemical process of burning limestone.

In the last three decades, supplementary cementitious materials such as fly ash, silica fume and ground granulated blast furnace slag have been judiciously utilized as cement replacement materials as these can significantly enhance the strength and durability characteristics of concrete in comparison with ordinary Portland cement (OPC) alone, provided there is adequate curing. Fly ash addition proves most economical among these choices, even though addition of fly ash may lead to slower concrete hardening. However when high strength is desired use of silica fume is more useful however, this product is rather expensive.

Copper slag is an individual by product material produce by copper smetting and refining processes. Copper slag is a by-product material produced from the process of manufacturing copper. The disposal of this material is already inflicting environmental issues round factories.New sort of concrete comprised of source material like fly ash, ground granulated blast furnace slag (GGBS), rice husk ash, metakaolin and alccofine and so on and a solution called alkaline activator or alkaline solution arranged by utilizing sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) of appropriate fixation. Rather than sodium silicate and sodium hydroxide we can even utilize potassium hydroxide (KOH) and potassium silicate (K_2SiO_3) yet numerous scientists proposed to utilize sodium based alkaline activators to reduce off cost of the alkaline solution and to improve solution which can upgrade the limiting property of the source material taken to get ready geopolymer concrete.

The main objective of the present study is to know the performance of copper slag and GGBS mixes at different percentages of alkaline solutions on properties of geopolymer concrete and detecting workability, compressive strength and tensile strength on comparison with conventional concrete when immersed in different acids.

II. REVIEW OF LITERATURE

This part of the study deals with the review of several research papers related to compressive strength and workability of geopolymer concrete posed by employing various source materials such as copper slag and Ground granulated blast-furnace slag etc. But considering availability of material and cost considerations many researchers studied various properties of geopolymer concrete are given below.

Anas Shahid Multani, A K Nigam (2017) Investigated on Partial Replacement of Cement with Metakaolin in Association with Super Plasticizer. Metakaolin seems to be an auspicious additional cementitious material for superior cement. Properties of cement with metakaolin are for the most part favoured added substances in superior cement. The metakaolin consolidations increment the quality of the concrete specimens. In this work, the impact of various contents of Metakaolin included to concrete containing super plasticizer its compressive quality strength and workability has been contemplated. Samples with 0%, 5%, 10%, 15%, 20% and 25% content of metakaolin replacing the cement have been evaluated for M30 grade. The outcomes have been contrasted and those for the control test and practicality of adding metakaolin to concrete has been examined. It was watched that up to 15% of concrete can be supplanted with metakaolin blended with superplasticizer.15% substitution is the ideal rate at which expanded quality of test sample is seen from the base sample test.

Saxena, S. K., Kumar, M., & Singh, N. B. (2018) compared the results of geopolymer cement with opcinterms of compressive strength , durability test by using sulphuric acid. The geopolymer cement was made by using fly ash , Alkaline Solution (14M NaOH) and Silicate solution (Sodium silicate solution) And also he used alccofine powder which has have similar properties of silica fume. Finally he concluded that compared to OPC this designed mix (geopolymer mix) giving better reliable results than OPC in terms of durability, Compressive strength.

Junaid, M. T., Kayali, O., Khennane, A., and Black, J. (2015) In this paper he decided the mix proportions geopolymer concrete (GPC) by utilizing Calcium Class F Flay Ash and Alkaline solutions of sodium silicates and sodium hydroxide. For the distinctive mix plans he discovered ideal substance of alkaline fluid to fly ash (AL/FA) proportion, water to geopolymer concrete (W/GPS) proportion and Alkaline to water (AL/W) proportion.

Sangeetha, P.S.Joanna (2014) studied the structural behavior of RC beams with GGBS concrete. The results obtained from experiments states that the ultimate moment capacity of GGBS was less than the controlled beam when tested at 28 days, but it increases by 21% at 56 day. The measured crack width at service load ranged between 0.17 to 0.20mm and is within the limits (IS456-2000).

III. MATERIALS AND METHODS

The experimental investigation work is started with various tests on the constituent materials. The constituent materials are given below.

1. Cement
2. Coarse aggregate
3. Water
4. Copper Slag
5. Ground granulated blast-furnace slag.
6. Super plasticizer

Cement

Ordinary Portland Cement (OPC) was used in the experimental work which is conforming to I.S 4031-1988.The O.P.C is classified into three grades, those are 33grade, 43grade and 53 grade, depending upon the strength of the cement in this experiment 43grade cement is used.

Fine Aggregate

Fractions from 4.75 mm to 150 microns are termed as fine aggregate. Locally available river sand passed through 4.75mm IS sieve is applied as fine aggregate conforming to the requirements of IS 383:1970.

Coarse Aggregate

The crushed aggregates used were of 20mm nominal maximum size. Aggregate most of which is retained on 4.75-mmIS Sieve and containing only so much finer material as is permitted for the various types described in this standard.

Copper Slag

Copper slag is an individual by product material produce by copper smetting and refining processes. Copper slag is a by-product material produced from the process of manufacturing copper. The disposal of this material is already inflicting environmental issues round factories.

Ground granulated blast-furnace slag

Ground Granulated Blast Furnace Slag (GGBS) is a byproduct of the steel industry. Blast furnace slag is defined as "the non-metallic product consisting essentially of calcium silicates and other bases that is developed in a molten condition simultaneously with iron ina blast furnace.", blast furnaces are loaded with iron ore, fluxing agents, and coke. When the iron ore, which is made up of iron oxides, silica, and alumina, comes together with the fluxing agents, molten slag and iron are produced.

The molten slag then goes through a particular process depending on what type of slag it will become. Air cooled slag has a rough finish and larger surface area when compared to aggregates of that volume which allows it to bind well with Portland cements as well as asphalt mixtures.

GGBS is produced when molten slag is quenched rapidly using water jets. For the present work GGBS is collected from Sri Vishnu SaiSarvana Enterprises, Visakhapatnam.

Superplasticizer

Naphthalene based super plasticizer namely Fosroc Conplast SP430 is a chloride free, super plasticizing admixture based on sulphonated naphthalene polymer is used to upgrade or boost the workability as well as strength of geopolymer concrete. The dosage is raging from 1.00 to 3.00 litres per 100 kg of cementitious material such as fly ash, GGBS and alccofine etc.

IV. MIX DESIGN

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance. Percentage dosage of super plasticizer was fixed as per the mix design method described in IS 10262- 2009. Mix proportion was arrived through various trial mixes. The grade of concrete prepared for the experimental study was M30.

V. TESTS ON FRESH CONCRETE

5.1 WORKABILITY OF CONCRETE

Workability of conventional and geopolymer concrete with variable proportions is determined utilizing slump cone. It is seen that decline in the slump an incentive as expansion in both molarity of alkaline solution and proportion of GGBS and copper slag are flaky in nature and high molar solution has greater viscosity when contrasted with water. Naphthalene based synthetic admixture i.e., super plasticizer is vital for redesign workability of GPC while mixing the various ingredients. Slump test was carried out to measure the workability of various mixes. The workability of various mixes was assessed as per the IS 1199:1959 specification.

TABLE 5.1 shows the Variation of Slump Values

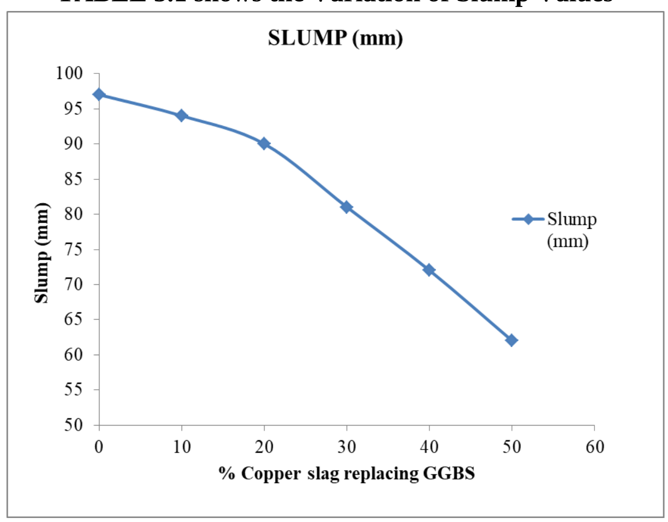
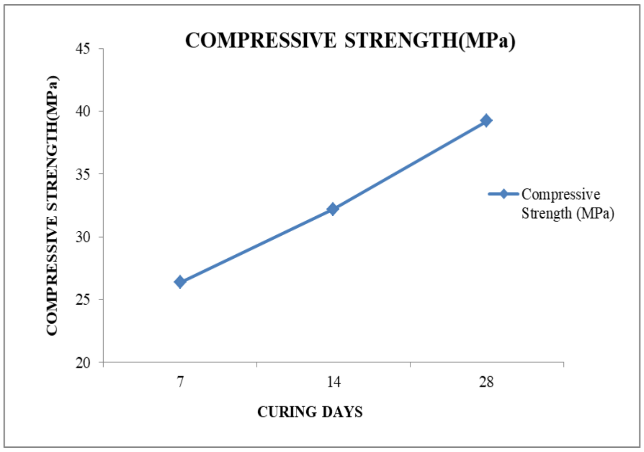


Fig 5.1: Plot shows the Variation of Slump Values for different proportions of Copper Slag + GGBS

VI. TESTS ON HARDENED CONCRETE

6.1 COMPRESSIVE STRENGTH OF CONVENTIONAL CONCRETE

To find the compressive strength of conventional concrete 150x150x150 mm size mould is used for the casting of compressive test specimen, after the 24 hours of casting of specimens remove the cubes from moulds and the cubes are placed in curing tank up to one day before the testing. The specimen's ultimate load is defined as the load at which it fails. At the ages of seven and twenty-eight days, this test was conducted. The average load of three specimens is used to calculate strength for each mix.



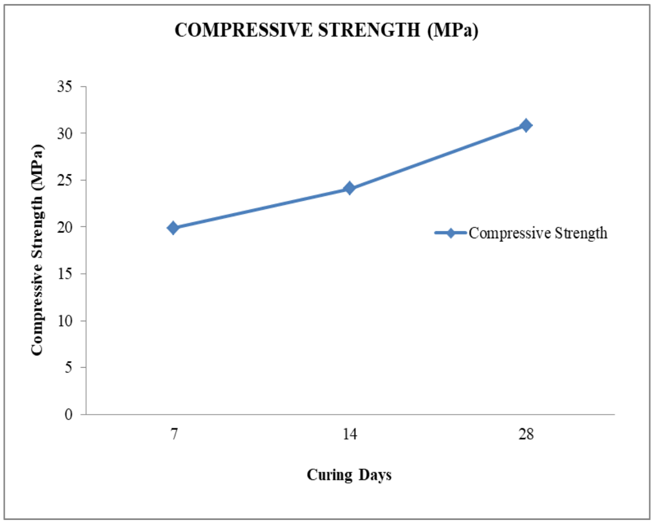


Fig 6.1: Plot shows the Variation of Compressive strength of conventional concrete

6.1.1 COMPRESSIVE STRENGTH OF GEOPOLYMER CONCRETE

This test is the important to direct and the relative investigations have done consolidating GGBS and copper slag. It is noticed that Na2SiO3/NaOH proportion of 2.5 the outcomes acquired are generally more.

Cube specimens of size 150mm were cast for compressive strength as per Indian standard specifications BIS: 516-1959. Immediately after finishing, the specimens were covered with sheets to minimize the moisture loss from them. Specimens were demoulded after 24-hours at approximately room temperature till testing. Compressive strength tests for cubes were carried out at 7, 14 and 28 days.

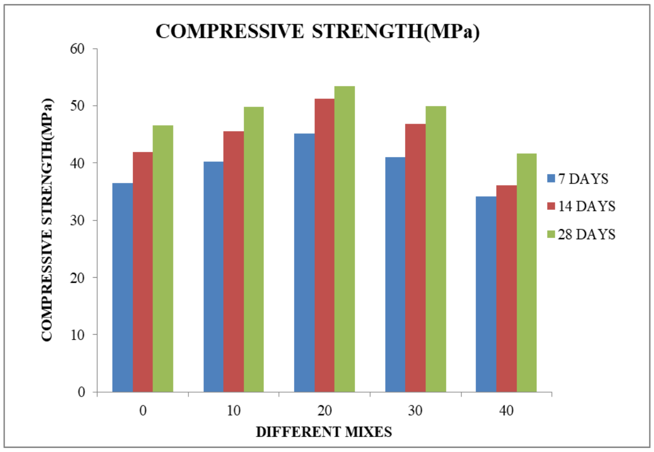
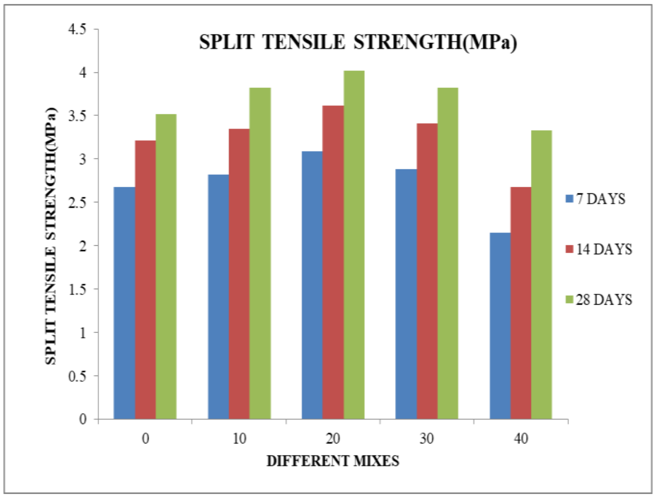


Fig 6.2: Plot shows the Variation in compressive strength for different proportions of CS+GGBS

6.2 SPLIT TENSILE STRENGTH OF GEOPOLYMER CONCRETE

Split tensile test is also used to determine the tensile stress in concrete; this method is also called as Brazilin test. In this we place the cylindrical specimen of size 300 mm height and 150 mm diameter is placed in horizontal between the loading surfaces of compression test machine and load is applied until the failure of the specimen along the vertical diameter. This test is performed as per IS: 5816 code.



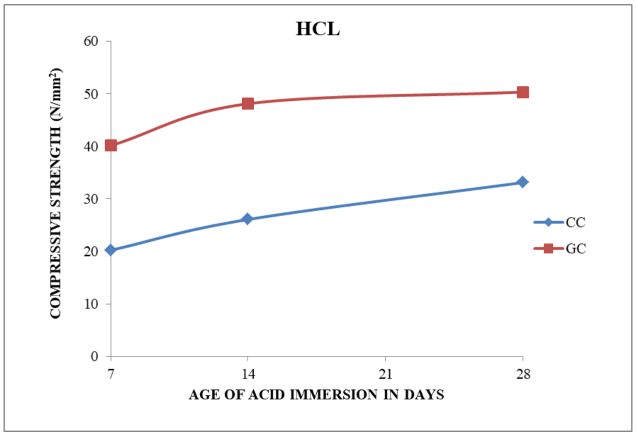
Graph 6.13: Plot shows the Variation in split tensile strength for different proportions of CS+GGBS at ambient curing

6.3 COMPRESSIVE STRENGTH ON ACID IMMERSION

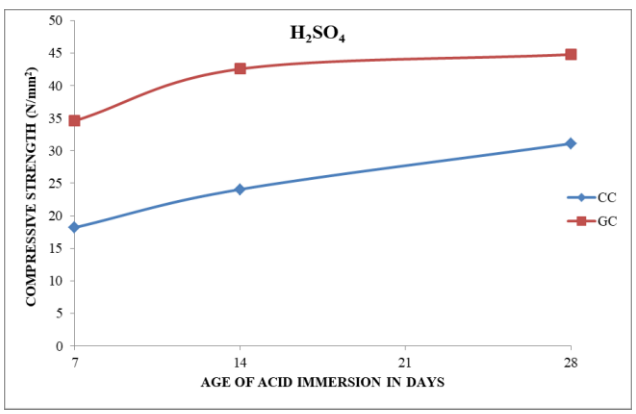
Based on the compressive strength results of geopolymer concrete it is observed that at 20% replacement of copper slag the compressive strength is more pronounced. These mix cubes were cured under ambient curing for 7 days, 14 days and 28 days. These specimens were immersed in 5%

of acid solutions i.e HCL, H2SO4, MgSO4 solutions for a period of 7 days, 14 days and 28 days. After completion of immersion period, concrete specimens were taken out and allowed for drying for a period of 1 day and weight of concrete cubes were determined.

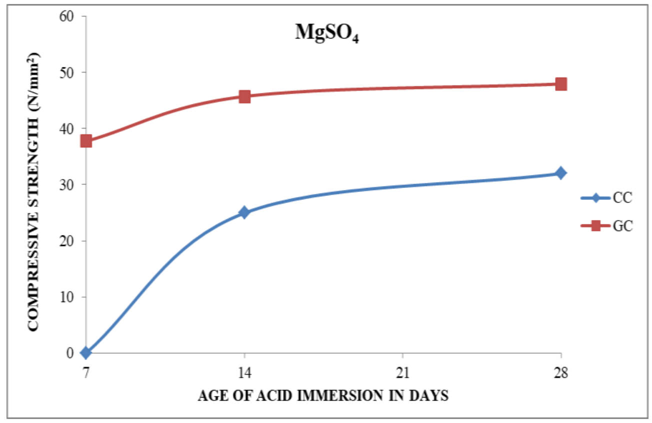
And also, the compressive strength of concrete cubes after acid immersion was determined by using U.T.M. Residual compressive strength and percentage weight loss of geopolymer and conventional concrete cubes after acid immersion have been studied and compared.



Plot shows the variation of Compressive Strength of Conventional concrete (CC) and Geopolymer Concrete (GC) - After Immersion in HCL acid



Plot shows the variation of Compressive Strength of Conventional concrete (CC) and Geopolymer Concrete (GC) - After Immersion in H2SO4 acid.



: Plot shows the variation of Compressive Strength of Conventional concrete (CC) and Geopolymer Concrete (GC) - After Immersion in MgSO4 acid.

Geopolymer concrete cubes and conventional concrete cubes were immersed in 5% of acid solutions i.e HCL, H2SO4, MgSO4 solutions and tested. From the results drawn graphs, based on the graphs it is observed that compared to conventional concrete, geopolymer concrete mixes resisted acid attack more. When compared to all the solutions, among all H2SO4 attack is more on concrete cubes.

Table 6.6 Percentage loss of compressive strength in Conventional concrete (CC) and Geopolymer concrete (GC) after acid immersion

S.No	**Curing**	**HCL**		**H_2SO_4**		**$MgSO_4$**	
		CC	**GC**	**CC**	**GC**	**CC**	**GC**
1	7 Days	23.23	11.1	30.92	23.34	27.51	16.34
2	14 Days	19.1	6.09	25.31	16.92	22.49	10.76
3	28 Days	15.6	5.84	20.77	16.22	18.47	10.31

Table 6.7 shows variation of split tensile Strength (N/mm2) of Conventional concrete (CC) and Geopolymer Concrete (GC) (N/mm2)-After Immersion in acids.

S.No	**Curing**	**HCL**		**H_2SO_4**		**$MgSO_4$**	
		CC	**GC**	**CC**	**GC**	**CC**	**GC**
1	7 Days	1.53	2.72	1.28	2.38	1.38	2.55
2	14 Days	2.11	3.23	1.81	2.92	1.91	3.18
3	28 Days	2.65	3.61	2.45	3.31	2.56	3.48

It is noted from the above graphs that when compared to conventional concrete, the slag based alkali activated concrete resisted the attack in a better way both in compressive strength point of view and tensile strength point of view. It is observed that the strength of concrete dependents on quantities of various oxides in the cementitious material, viz, cements and copper slag and ground granulated blast furnace slag.

It is observed With increasing in percentage of copper slag in GGBS with alkaline solution there is an increase in compressive strength up to 20% replacement of copper slag and 80% replacement of GGBS further replacement leads to decrease in strength and optimum found to be 20% + 80% replacement of copper slag and ground granulated blast furnace slag.

VII. CONCLUSIONS

Based on the experimental investigations carried out on the geopolymer concrete and conventional portland cement concrete, Following conclusions are inferred from the test results.

- It is noted that workability decreases linearly with increase of % copper slag replacing by GGBS at rate of 10 % for every 10 % replacement of GGBS with copper slag.
- It is observed that compressive strength of geopolymer concrete increases with increase in % copper slag replacing GGBS up to 20 % copper slag, and then decreases beyond / more than 20 % copper slag. Hence, it concluded that 20 % copper slag is optimum for M30 grade concrete.
- Substantial improvement in the strength properties of blended GPC mix was noticed using 20% copper slag and 80% GGBS based on highest compressive strength point of view. However, 30% of copper slag and 40 % GGBS can also be used since the strength is more than that of the control mix.
- It is noted from the above graphs that when compared to conventional concrete, the slag based alkali activated concrete resisted the attack in a better way both in compressive strength point of view and tensile strength point of view.
- With increasing in percentage of copper slag in GGBS with alkaline solution there is an increase in compressive strength about 27% and in case of split tensile strength 26% increase in strength. Further replacement leads to decrease in strength and optimum found to be 20% + 80% replacement of copper slag and GGBS.
- From the results drawn graphs, based on the graphs it is observed that compared to conventional concrete, geopolymer concrete mixes resisted acid attack more. When compared to all the solutions, among all H2SO4 attack is more on both conventional and geopolymer concrete cubes.
- From the graphs it is found that maximum loss of compressive strength is considerably high in conventional concrete when compared to geopolymer concrete.Loss of compressive strength is considerably high in H2SO4 and less in both HCL and MgSO4.

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