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Experimental Analysis on Mechanical Properties of Geopolymer Concrete

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Abstract: ***A major environmental issue is pollution in production of cement throughout the world. Large number of carbon-dioxide emissions are released in manufacturing of cement which leads to global warming. Geopolymer concrete (GPC) is an alternate to the cement and environmental- friendly material in construction fields because of zero emission of greenhouse gases. In this study ground granulated blast furnace slag (GGBS) and fly ash as blenders and sodium silicate & sodium hydroxide as combined alkaline activator used making of GPC. The 40% of GGBS is replaced with fly ash. In this study 8M (molarity) of NaoH solution is used. Manufactured sand (stone dust) because of bankrupting natural resources posed threat to the environment. In this study mechanical properties and durability properties of geopolymer concrete are done. Mechanical properties are compression strength test, tensile test and flexural test and durability studies are absorption test, sulphate test.***
Keywords: Fly ash, GGBS, Geopolymer concrete, Sodium silicate, Sodium hydroxide.

I. INTRODUCTION

Now-a-days use of the cement concrete is increased day by day, concrete is one of the most widely used in the construction field. Concrete is allied with the ordinary Portland cement has the main material for making of concrete. In production of cement approximately 5-7% of total greenhouse gas emission are released which effects the environment and human health. Manufacture of one ton cement releases one ton of CO_2 which pollutes the environment. Manufacturing of cement is increasing as urbanization increasing to overcome this problem, we have to use the environmental friendly concrete for environmental friendly concrete we have to use another binder material instead of cement. Industrial by-production also have the environmental impact the use of by-products has the binder material which leads to reduce the CO_2 emission in the atmosphere which are released by cement and aggregate industries. Geopolymer concrete is a eco-friendly concrete. Geopolymer name was given by Daidovits [1,2] in 1978 to material which are characterized by in organic molecules. Geopolymer has low impact on environment and ultra-high performance. In geopolymer concrete flyash, GGBS along with alkali solutions are used as binders. Geopolymer concrete has more strength than normal cement concrete. 40% of fly ash is replaced with ground granulated blast furnace slag (GGBS) and sodium silicate (Na_2sio_3) to sodium hydroxide (NaOH) ratio is 2.5

II. MATERIALS USED

1) Fly ash: - It is the byproduct generated from thermal power plant. Class F flyash Is usedFly ash constituents are:

Parameter	Content (%)
Sio_2	59.02
Al_2O_3	
Cao	39.02
MgO	
Na_2o_3	0.94
Kao	
	0.28
	0.47
	0.22

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2) Ground granulated blast furnace slag (GGBS): GGBS is generated as waste material in steel plant
GGBS Constituent are:

Parameter	Content (%)
CaO	37.04
Al_2O_3	
Fe_2O_3	14.02
SiO_2	
MgO	1.11
MnO	
Sulphide sulphur	37.79
	8.71
	0.02
	0.39

3) Manufactured Sand: - Stone dust is a by product of crushing stone it can be obtained from crusher plants
4) Coarse aggregate: - 20mm size of Coarse aggregate is used. the density of coarse aggregate is 2680kg/m. the specific gravity 2.680
5) Alkaline activators: - Alkaline activators are NaOH and Na_2SiO_3 solutions are prepared 24hours before casting the concrete specimens, to activate the fly ash and GGBS. In geopolymerization alkaline solutions plays a major role.
6) Fly ash and GGBS are usually mixed with alkali solution to obtain alumina and silica precursors when it comes in to contact with alkali solution, dissolution of silicate species starts. Mass of Na_2sio_3 to NaOH ratio 2.5
7) Alkaline binder ratio: - the alkaline binder ratio is taken as 0.4 for preparation of geopolymer concrete.
8) Molarity: - 8 Molarity of NaOH is used for geopolymer concrete
9) Super plasticizer: - Super plasticizer is a high-range water reducer. It improves the workability of the concrete and reduce the water. It is a chemical admixture which enhance the workability, improve the finish ability and consistent performance.

III. EXPERIMENTAL INVESTIGATION

In this section describes the production of geopolymer concrete and the testing of the specimen and the test procedure is explained.

1) Mix design: - In this study mix design of geopolymer concrete is done based on the conventional concrete, there is no any specific design procedure or codal provision for geopolymer concrete. Mix proportion for 8 M of NaOH is mass of fly ash is 255kg/m^3, GGBS is 170kg/m3 (Fly ash + GGBS = 425kg/m3) mass of Na2sio3 is 90.99kg/m^3, mass of NaOH is 36.4kg/m^3, stone dust is 613kg/m^3 and 1.5% of mass binder of super plasticizer is used. Based on this proportions test samples are prepared.
2) Preparation of alkaline activator: - alkaline activator are prepared 24hours before casting preparation of NaOH solution the molecular weight of sodium hydroxide is 40 for 8m of NaOH Solution we have to take 32og of NaOH pellets and the pellets are dissolved in one Liter of dissolved water the Na2sio3 solution and NaOH Solution are mixed together.
3) Preparation of samples and curing: - For compressive strength test total cubes are prepared for the test on the age 7 days, 14 days and 28 days. For split tensile test 6 cylinders are prepared for the test on the age of 7 days, 14 days and 28 days. Specimens size of cube is 150mmx150mmx150mm, size of cylinder is 150mmx300mm and size of beam is 750mmx150mmx150mm. All these samples are cured under the ambient curing at roomtemperature.
4) Tests on hardened concrete: - Mechanical properties are compressive strength test split tensile test and flexural strength test are done.
5) Compressive strength test: -This test is tested on hydraulic compressive testing machine as per the code book IS516:1969. The compressive strength of the ability of the concrete to withstand specific compressive forces depends on water to binder ratio, binder strength quality of concrete material and quality control during production of concrete. Concrete is prepared according to the mix proportion oil is applied to the inner surface of the mould.

For each layer 25 blows are done by using tamping rod level the surface of the mould after one day specimen is removed from mould and cured under the ambient curing at room temperature after 7days.

The specimen is placed the compression testing machine instruction is adjusted such that plate surface touches the top surface of specimen the load is applied up to the specimen fails. Note down the readings at which load specimen fails. Test is done for 7days, 14days, and 28days.

6) *Split tensile test:* - tensile strength of concrete is obtained by applying a compressive force along the length of the cylinder specimen. This test is tested on hydraulic compressive testing machine as per the code book IS516:1969. Fresh concrete is prepared according to the mix proportion. Cylinder specimen is used for this test oil is applied to the inner surface of the cylinder concrete is poured into the cylinder mould into 3 layers each is tamped 25times by tamping rod. Level the surface of the specimen. Remove the specimen fro after 24hours the cylinder specimen is tested under hydraulic compressive machine at the age of 7days, 14days and 28days.

7) *Flexural strength test:* - flexural strength of concrete is the indirect calculation of tensile strength of concrete. This test is tested on flexural strength test machine as per the code book IS516:1969. Fresh geopolymer concrete is prepared as per mix proportion. The standard size of the beam is 750mmx150mmx150mm. the inner surface of the beam mould is applied by oil. The concrete is poured into the beam mould into 3layers each layer is tamped by 25 times by using tamping rod. Level the surface of mould, remove from the mould after 24hours the beam is test for 7days, 14days and 28days. The beam is placed at the surface of flexural testingmachine and load is applied up to the failure of specimen.

8) *Water Absorption Test:* - Water absorption test is conducted on Cubes which are dried in oven up to 110^{o}C for 24 hours until constant mass is observed and that cubes are immersed in water for 24 hours as per the code book BS 1881:2011.

9) *Sulphate resistance Test:* - In this study sodium sulphate and magnesium sulphate test are conducted. In this Specimens are immersed in the solution of 5% of sodium sulphate and magnesium sulphate separately for 28 days.

IV. MICROSTRUCTURE ANALYSIS

SEM, XRD and EDS analysis is done. SEM analysis captured the information of electron interact with the Geopolymer concrete sample atoms on surface topography, EDS analysis is done to find atomic percentage of various elements. The SEM and EDS analysis is done on the specimens are cured at 28 days. XRD analysis is done by using xray diffraction method to identify the crystalline phases in solid manner and the amorphous nature of GPC.

V. RESULTS AND DISCUSSIONS

Table 1

Results of Compressive strength, Split Tensile strength and Flexural strength of GPC for 7 days, 14 days and 28 days

S.No	Concrete Type	Days	Compressive Strength (MPa)	Split Tensile Strength (MPa)	Flexural Strength (MPa)
1	GPC	7	35.6	4.8	3.9
		14	39.8	5.2	4.0
		28	42.6	5.7	4.1
2	Conventional Concrete	7	31.2	2.1	2.2
		14	34.6	2.3	2.4
		28	38.5	2.68	2.93

Table 2

Water Absorption test after 24 hours

Dry wt. of specimen (W1)kg	Wet wt. of the specimen(W2)kg	% of water absorption	Level
8.110	8.330	2.67	Excellent

Table 3
Change in weight for 8M GPC immersed in Na_2SO_4 for various durations.

Mix	Initial Weight kg	Final weight of the specimen		% change in weight after exposure	
		28days	60days	28days	60days
GPC	8.04	8.06	8.12	0.02	0.08

Table 4
Change in weight for 8M GPC immersed in $MgSO_4$ for various durations.

Mix	Initial Weight kg	Final weight of the specimen		% change in weight after exposure	
		28days	60days	28days	60days
GPC	8.035	8.040	8.046	0.05	0.13

Table 5
Loss of compressive strength for 8M GPC immersed in $MgSO_4$ for various durations.

Mix	Initial compressive strength MPa	compressive strength MPa		% loss in compressive strength after exposure	
		28days	60days	28days	60days
GPC	42. 6	41.55	41	-1.98	-3.54

Table 6
Loss of compressive strength for 8M GPC immersed in Na_2SO_4 for various durations.

Mix	Initial compressive strength	compressive strength MPa		Loss of compressive strength after exposure %	
		28days	60days	28days	60days
GPC	53.10	41.53	38.55	-2.02	-7.58

Table 1: - Shows the results of the hardened concrete test results of compressive strength, split tensile test and flexural test.
Test 2: - Shows the results of the water absorption test.
Table 3-4: - Shows the results of the durability tests of change in weight of GPC for 8M when immersed in sodium sulphate and magnesium sulphate.
Table 5-6: -Shows the results for loss in compressive strength of GPC for 8M when immersed in sodium sulphate and magnesium sulphate.

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VI. MICRO STRUCTURE ANALYSIS

A. SEM and EDAX/EDS Analysis

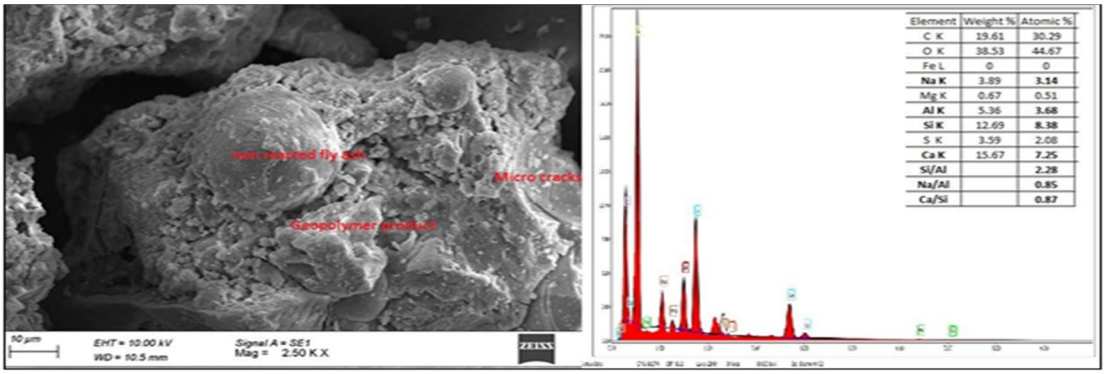


Figure4.57: SEM and EDX analysis of 8M GPC30

From Figure 4.57 it is seen that the SEM analysis indicates the formation of alumino- silicates which are homogeneous matrices of continuous and less porous in visualization. Due to the presence of unreacted fly ash particles, the setting of GPC is of slow rate and the curing has incurred much time. The micro structure reveals the presence of C-S-H gel due to the reaction of silica, alumina and calcium. The unreacted fly ash particles are visible near the C-S-H gel and geopolymer product and contributed towards medium densification. The unreacted particles such as quartz in continuous crystalline form, iron oxide in stoichiometric and crystalline form, magnesium oxide in the white hygroscopic solid mineral and sulfur oxide in crystalline form are visible in microstructure that affects the compressive strength of GPC.

Figure 4.57 illustrates the chemical analysis of fly ash–GGBS based 8M GPC30 through EDS/EDX/EDAX analysis. The chemical analysis represents the presence of each element in atomic percentage. The figure depicts the presence of sodium, aluminum, silica and calcium. The presence of these atomic elements represents C-S-H gel in coexistence with N-A-S-H identified by their morphology. As calcium is available with Ca/Si ratio of 0.87 and Si/Al ratio of 2.28 (greater than 1.65) it indicates the presence of geopolymer products in the composition. Calcium is acting as a precipitating element and its increase causes a finer microstructure. GGBS content in GPC has resulted in the formation of calcium bearing compounds which contributed towards excessive binding products of GPC. . The atomic percent of Ca/Si of 0.87 can be attributed to the presence of C-S-H in the form of slight traces. If the ratio of Si/Al is in between 1.4 to 1.65, it indicates dense particulates with large interconnected pores. It is further claimed that the dense particulates are proportional to Si/Al ratio. In the present study as the Si/Al ratio is more than 1.65 it resulted in dense structure and increase in the compressive strength.

4.5.3.2 XRD analysis

Figure 4.58 shows the crystalline phases of quartz detected as sharp peak at 27^0 and at 61^0 in the ranges of 2θ. The peaks are SiO2 in crystalline form which is unreacted material. Figure

4.59 depicts the sharp peaks of quartz along with iron oxide, magnesium oxide and sulfur oxide. Small humps are identified at 2^0 to 7^0, 34^0 to 36^0 and 81^0 to 84^0. The hump indicates that silica and alumina have higher reactivity resulting in formation of geopolymer product.

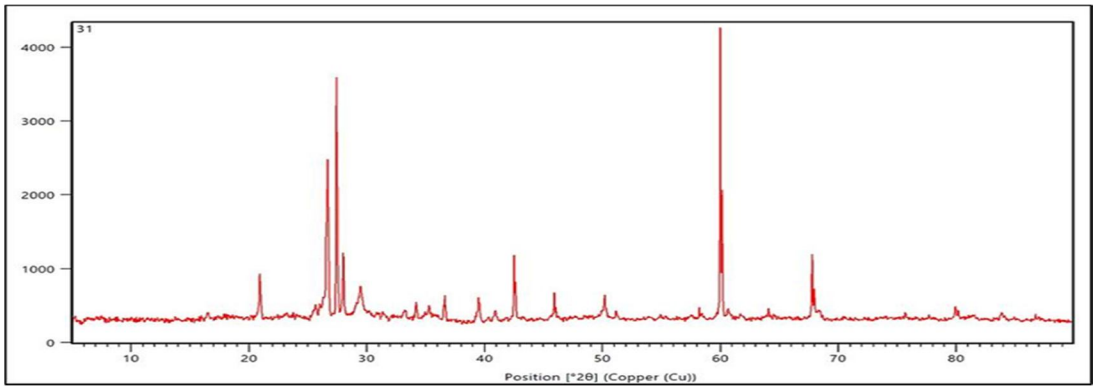


Figure 4.58: XRD analysis of 8M GPC30

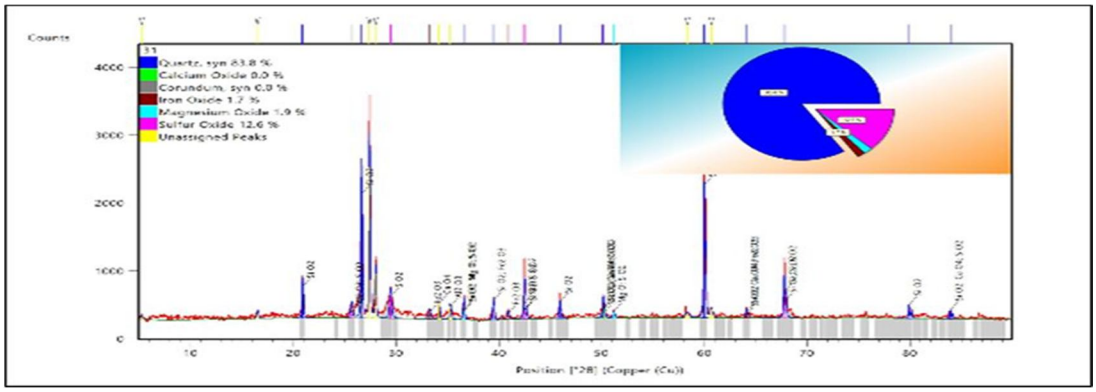


Figure 4.59: Chemical composition of 8M GPC30 using XRD analysis

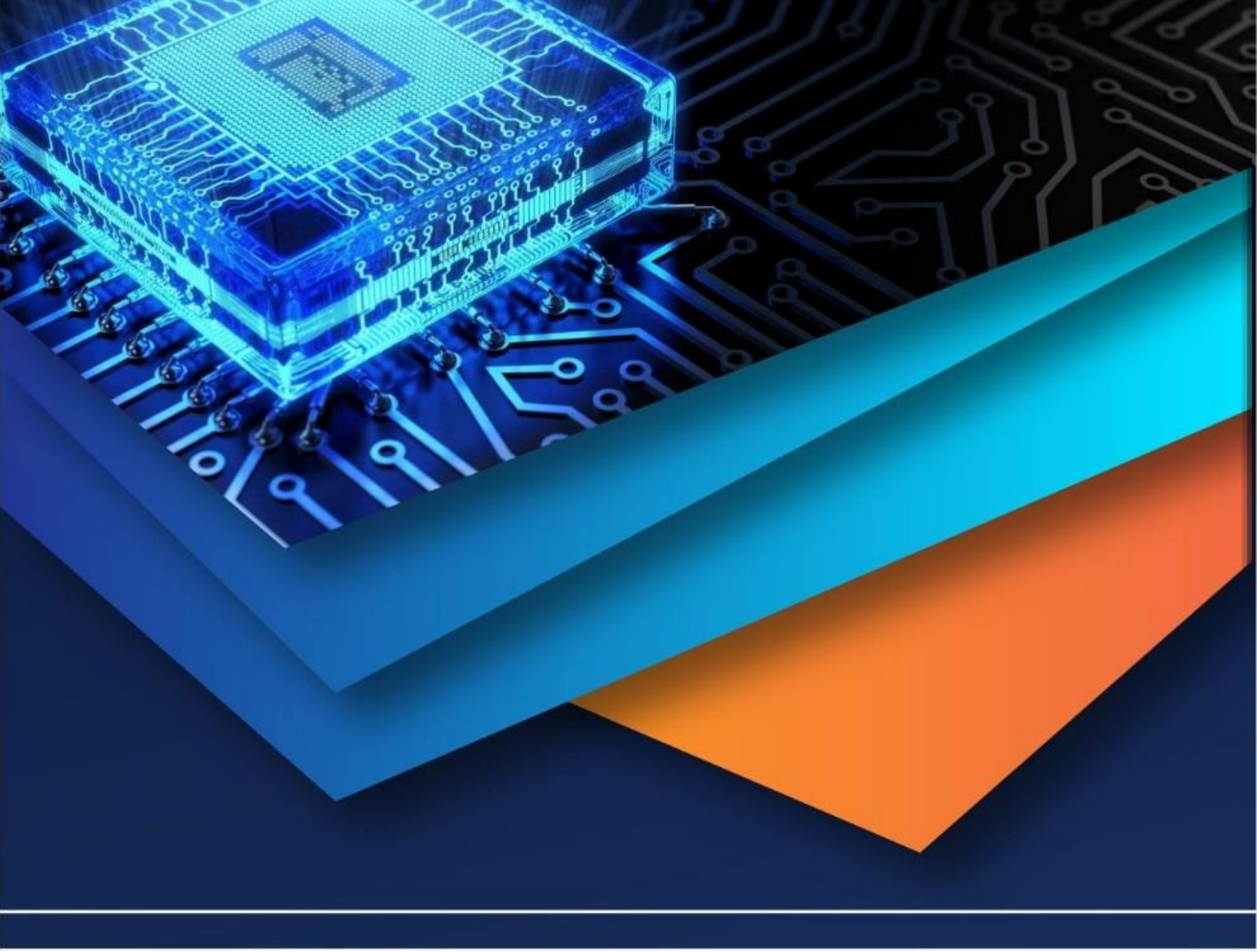
VII. CONCLUSION

The following conclusion are observed from the experimental investigation conducted ongeopolymer concrete

1) If compressive strength of the GPC has achieved good strength, is 42.63 MPa for 8molarity the compressive Strength of Conventional concrete 30MPa
2) The Split tensile strength of the GPC for 8M is 5.7MPa
3) The flexural strength of the GPC for 8M is 4.45MPa. The flexural Strength of the conventional concrete is 3.9MPa.
4) The water absorption for GPC 30 is categorized under excellent level.
5) The loss of Compressive strength of GPC for 8M Immersed in Na2SO4 is increasing as the immersion period increases.
6) The loss of Compressive strength of GPC for 8M immersed in MgSO4 increasing as the immersion period increases.
7) The Si/Al ratio is more than 1.65 it can dense structure and increase in the compressive strength.

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