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INVESTIGATION ON GEOPOLYMER CONCRETE FOR DIFFERENT PROPORTIONS OF ALKALINE ACTIVATOR

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Abstract: The major problem world is facing is environmental pollution. Mainly in the construction industry, the production of Portland cement causes the emission of pollution that causes a serious threat to the environment. The pollution effects on the environment can be reduced by increasing the usage of industrial by-product materials in our construction industry. Currently, Geopolymer is a new developing material in the world of concrete, in which cement is totally replaced by fly ash and activated by the alkaline solution to act as a binder in the concrete mix. The study was mainly carried out on strength analysis of geopolymer concrete with different activator ratios. For selecting suitable ingredients of geopolymer concrete to achieved desire strength at required workability, an experiment experimental has been carried out on gradation of geopolymer concrete and as per Indian standard code, a mix design is a procedure to proposed on the basis of quantity and fineness of fly ash, the quantity of water or alkaline liquid, W/C ratio or SF ratio, grade of fine aggregate, fine to total aggregate ratio, super plasticizer. The laboratory-grade Sodium silicate solution with Na2O=14.28%, SiO2=36.38% and water = 49.43%. The concentration of (NaOH) solution was maintained at 5 Molarity. The main objectives of the present research work on first to prepare geopolymer concrete by using waste industrial material fly ash in replace of cement and Compare with conventional concrete and its cost and Second to identify appropriate dosage of SS/SH for better performance of geopolymer concrete. The experimental investigation was carried out on M30 grade concrete. In this study, the SF ratio is 0.30,0.35,0.40 and the dosage of activator ratio is 0.5,1.0 and 2.0 is a combination of sodium silicate and sodium hydroxide ratio by weight of fly ash is considered for studying. The geopolymer concrete is cast at normal temperature, thus this method is used for mixed the concrete by hand mixing and the temperature of oven heat curing was maintained at 80°c for 24 hours after keep in normal room temperature duration (20 to 23°c), and tested 7,14,21,28 days after heating. The test was carried out on fresh concrete and hardened concrete. For fresh concrete, workability and density are tested and for hardened concrete compressive strength test on CTM. The optimum test results of geopolymer concrete after 28 days compressive strength is 42.81 MPa, workability 71 mm, Dry density 2530.74 Kg/m^3, Wet density 2620.72kg/m^3.

Keywords: Geopolymer Concrete, Fly Ash, Activator Ratio, SF Ratio.

1. INTRODUCTION

In recent times the emission of (CO_2) into the air is being increased day by day. Due to the issue of energy consumption and CO_2 emission raised about the cement industry, it is now introducing new material like fly ash is completely replaced by OPC in concrete production. The development new material other the Portland cements using a large amount of waste as raw material. These waste materials contain a sufficient amount of silicon- aluminium oxides, which react with alkaline solution to form a binder similar to OPC. This innovative binder material is called Geopolymer concrete. From an environmental point of view, the main benefit of geopolymers cement could reduce approximately 80-90% of CO_2 emission rate to the atmosphere from geopolymer production compare to OPC. The production of OPC leads to release a significant amount of carbon footprint and other greenhouse gas to the atmosphere. In contrast, the production of fly ash for geopolymer doesn't require high-level energy, this significantly reduces the energy consumption and CO2 emission. Geopolymer concrete offers several economic benefits over Portland cement concrete, heat-cured low calcium fly ash-based geopolymer concrete also show some excellent resistance to sulphate attack, fire resist and good acid resist, undergoes low creep, and suffer very little drying shrinkage. These unique properties make GPC a strong candidate as a substitute for Portland cement concrete. Thus, the use of geopolymer technology not only substantially reduces the CO_2 emission by the cement industry but also utilizes the industrial wastes alumino-silicate composition to produce added value to construction material

Geopolymer : The term Geopolymer originally formed by French professor Joseph Davidovits in (1991) proposed that an alkaline liquid could be used to react with the silicon (SI) and the aluminium (Al) in a source material of geological origin or in by –product materials such as fly ash and rice husk ash to produce binders. Because the chemical reaction that takes place in this case is polymerization process coined the term 'Geopolymers' to represent these binders. Geopolymer belong to the family of inorganic polymer and chain structure formed on a backbone of AL and SI ions. The geopolymer consist of polymeric Si-O-Al framework, with SiO_4 and AlO_4 tretrahedrally interlink alternately by sharing all the oxygen atoms. Geopolymers consist of silico-alumina with Si^{4+} and Al^{3+} in 4-fold coordination with oxygen and ranges from amorphous to semicrystalline, based on the chemical reaction under alkaline condition on Si-Al minerals, results is three-dimensional polymeric chain a ring structure consisting of Si-O-Al bonds. These three basic units are polysialate, polysialate-siloxo, and polysialate-disiloxo is defined. (Where "sialate" is an abbreviation for silicon-oxo-aluminate)**.**

Apart from the coarse aggregate and fine aggregate used as in conventional concrete. The two main constituent of geopolymer namely the source materials and alkaline medium. The source material for geopolymer based on alumina-silicate should be rich in silica (Si) and alumina (Al).This could be natural raw material like kaolinite, clays, etc. alternatively, by product material such as coal Fly ash, ground granulated blast- furnace slag (GGBS), silica fume, rice hunk ash, red mud, etc used as source materials, were Si-Al source material and the alkaline activator have direct effect on final product of geopolymer. The choice of the source material for making geopolymer depend on many factor such as availability, cost, type of application and specific demand of end used. The alkaline medium is form soluble metals that are usually sodium or potassium based.The most common alkaline solution used in geopolymerization is a combination of sodium silicate and sodium hydroxide.

2. LITERATURE REVIEW

Effect of alkaline liquid ratio on the compressive strength of geopolymer concrete was carried out by **Annapurna, Ravande Kishore.** [1] The study was on geopolymer concrete, in replace of cement by fly ash is one of the efforts to produce more environmentally friendly concrete. No cement is used in Geopolymer concrete, but fly ash and alkaline solutions, i.e, sodium hydroxide (Na OH) and sodium silicate (Na2O, SiO2) are used to make the binder necessary to manufacture the concrete. For 2.5 m^3 of high quality Geopolymer concrete, 1 tone of fly ash is used. In this study investigations are made to see the effect of AL to FA ratio on compressive strength of Geopolymer concrete in ambient conditions as well as oven dry conditions at 90^0C for 4 hours. Alkaline liquid ratio is varied from 0.5, 0.45, 0.40, 0.35, 0.30 and compressive strengths are detected after 7 and 28 days. The study was on mathematical model is prepared by using the Fuzzy logic to predict the compressive strength of Geopolymer concrete for different chemical ratios using the experimental results. The alkaline liquid ratio is used as input and 7 days, 28 days and oven dried samples compressive strengths are used as output while developing Fuzzy logic model. Compressive strength of Geopolymer concrete depends on proportioning of ingredient of mix design.

- The author study, increase the alkaline solution ratio from 0.3 to 0.50, 28 days oven compressive strength increases 21.3 Mpa to 31.52 Mpa.
- The 7 days strength is observed to increase by 63.058% of 28 days strength of geopolymer concrete.
- The oven strength to be 102.75% of 28 days strength of geopolymer concrete

The study on effect of duration and temperature curing on compressive strength of fly ash based of geopolymer concrete carried out by **Manesh Satpute B et al** [2] Geopolymer concrete replaced cement by low calcium fly ash and activated by alkaline solution. Cubes of size 150mm were made at solution to fly ash ratio of 0.35 with 16 Mole concentrated sodium hydroxide solution. All the specimens were cured in oven at 60ºC, 90^OC and 120^OC for 6, 12, 16, 20 and 24 hour's duration. Curing temperature and its duration are also important in the activation of geopolymer concrete. Curing time in the range of 6 to 24 hours, produce higher compressive strength. However, the increase in strength beyond 20 hours is not significant. Strength is slow at 60°C compared to strength at 120°C. Compression strength of GPC of 16 to 24 is not much significant, so, minimizes to 16 hours for saving of consumption of energy. 60 MPa strength gain of GPC in 24 h duration

The Study was conduct on different type of curing method for geopolymer concrete and evaluates best method of curing study by **Varsha v. Yewale et al** [3] the research paper different type of curing is done on geopolymer, mix design grade are chosen M-30 and M-40, and alkaline solution liquid used was a combination of sodium silicate and sodium hydroxide solution. Sodium Hydroxide in flakes form with 98% purity and Sodium hydroxide solution purchased from local chemical supplier and molarity of NaOH is 16M. First test carried out on oven heating, heat curing of specimen is done in oven as increase the temperature of curing for optimum time the compressive strength goes in increasing up to optimum temperature after that it decrease. In this type of curing, we get 28 day strength of the

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concrete in 7 days of rest period at 80°c temperature. Second test, in the steam curing as increase the temperature of curing for optimum time the compression strength goes on increasing. In this type of curing, we get 28 day strength of concrete in 7 days of rest period at 100°c temperature. Third test in water curing, as increase the rest period of curing compression strength goes on increasing. In this type of curing compression strength of geopolymer concrete is increase but the strength is not up to the characteristics strength at 28 days.

Shankar H. Sanni, et al [4] Experiment study on performance of geopolymer concrete subjected to severe environment conditions. The study research paper with different grade chosen M-30, M-40, M-50 and M-60, the mixes were designed for morality of 8M and 12M. The alkaline solution used for present study is the combination of sodium silicate and sodium hydroxide solution with the ratio of 2.50 and 3.50. The cubes size is 150 mm and 100x200 mm cylinders heat-cured at 60°c in oven**.** In this paper two test are conduct on geopolymer concrete compressive strength and split tensile strength with two different chemical reaction like sulphate acid and magnesium sulphate, molarity exposed for the period of 15, 30,and 45 days to sulpheric acid. The test results indicate that the heat-cured fly ash based geopolymer concrete has an excellent resistance to acid and sulphate attack where compare with conventional concrete. Thus the production of geopolymer concrete has high strength, excellent volume stability, and better durability**.**

Experimental investigation on Production of lightweight Geopolymer concrete using artificial local lightweight aggregate **Abbas Weeled [5]** the main focus of this research is to produce lightweight geopolymer concrete using artificial coarse lightweight aggregate which produced from locally available bentonite clays. In this investigation, the binder is low calcium fly ash and the alkali activator is sodium hydroxide and sodium silicate in different molarities. The experimental tests including workability, fresh density, also, the compressive strength, splitting tensile strength, flexural strength, water absorption and ultrasonic pulse velocity at the age of 7, 28 and 56 days were studied. The oven dry density and thermal conductivity at 28 days age are investigated. The results show that it is possible to produce high strength lightweight geopolymer concrete successfully used as insulated structural lightweight concrete. The 28-day compressive strength, tensile strength is 35.8 MPa, flexural strength 2.6 Mpa, dry density 1853 Kg/m^3

Experimental study on optimum mix for fly ash geopolymer concrete binder based ion workability and compressive strength is carried out b**y Arafa S .A et al.[6]** To prepare geopolymer paste with different mix of A/FA is (0.4, 0.45,0.60,0.5) is used and the sodium hydroxide concentration (6M, 8M, 10M, 12M) and sodium silicate to sodium hydroxide ratio was constant 2.5 and cube size is 150mm. The mixing process used for geopolymer paste is similar to conventional concrete. Thus, paper describes the experiment work conduct by casting 40 geopolymer paste mixes, was cured at 80°c for 24 h duration to evaluate the effect of various parameters affecting on workability and compression strength. Alkaline solution to fly ash ratio and sodium hydroxide concentration are chosen as key parameter of strength and workability. The study with different percent of NaOH concentration and different A/FA revel that optimum ratio are 10M A/FA=0.5. It is generally found that the workability decrease and the compressive strength increase with an increase in concentration of sodium hydroxide solution. However, workability was increase and the compressive strength was decrease with the increase in the ratio of fly ash to alkaline solution. The author study that compressive strength and workability with different percentage of NaOH were found to be 78.2 MPa and 3.92 for control specimen respectively at 10 Molar and 0.5 of AL/FA ratio, workability of geopolymer concrete, in fresh state increase with the increase AL/FA ratio but decrease with the increase of sodium hydroxide ratio.

Parth S. et al. [7] the research paper was study on behaviour of fly ash geopolymer concrete with 20 molar NaOH activators. Thus, different test are conducted to find properties such as compressive strength, flexure strength and split tensile strength for 3, 7, and 28 days, the mix design for 20 molarity geopolymer mix 3 different proportion sodium silicate were prepared 1:2, 1:2.5, 1:3 and the solution to fly ash ratio is 0.45. In this paper 3 tested is conduct for geopolymer concrete compression strength, flexure strength test, split tensile strength test. Results of sodium silicate to sodium hydroxide ratio by mass to 1:3 is higher strength as compare to 1:2 and 1:2.5 geopolymer concrete ratio, in this compression strength of concrete increase 30% for 7 days, flexure strength of concrete increase 40 % for 7 days and split tensile strength 50% for 7 days when compare to 3 days strength.

Mix design of fly ash based geopolymer concrete carries out by **Subhash v. Patankar et al. [8].** In this research paper, proposed the guide line for design of fly ash based geopolymer concrete of ordinary and standard grade with suitable ingredient materials by maintaining solution-to-fly ash ratio 0.35 and sodium silicate- to- sodium hydroxide ratio of 1 with concentration of sodium hydroxide as 13 M. workability of geopolymer concrete was measure by flow table apparatus and cube size 150 mm were Heat curing was done at 60°c for duration of 24 h and tested after 7 days after oven heating. Experimental results of M20, M25, M30, M35 and M40 grades of geopolymer concrete mixes proposed method of mix design show promising result of workability and compressive strength, so this guideline help in design of fly ash based geopolymer concrete of ordinary and standard grades as mention in Indian standard code.

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Abhisek C Ayuchiti, et al. [9] The author suggest guidelines for the mix design of fly ash based geopolymer concrete of ordinary and standard grade on the basis of quantity and fineness of fly ash, quantity of water and grading of fine aggregate by maintaining water- to-geopolymer binder ratio of 0.40, solution-to-fly ash ratio of 0.35, and sodium silicate-to-sodium hydroxide ratio of 2 with concentration of sodium hydroxide as 13 M. Heat curing was done at 60 °C for duration for 24 h and tested after 7 days after oven heating. Experimental results of M20, M25, M30, M35 and M40 grades of geopolymer concrete mixes using proposed method of mix design shows promising results of workability and compressive strength. So, these guidelines help in design of fly ash based geopolymer concrete of Ordinary and Standard Grades as mentioned in IS (456: 2000).

As per the study development of geopolymer concrete is carried out by **Pallavi Vivek Dongre et al.** [10] The geopolymer paste is formed by activating by-product materials, such as low-calcium (Class F) fly ash, that are rich in silicon and aluminium. A solution with a $NaOH/Na_2SiO_2$ ratio by mass is 2, and NaOH = 14.7%, SiO2 = 29.4%, and water = 55.9%) is required. Sodium hydroxide purity is 98%, aggregate to fly ash ratio is 0.35 Casting 7 cubes of Fly ash Geopolymer concrete cubes heat cured at 60ºC on oven for 24 hours. The fly ash used from local power generation plant. A combination of sodium silicate solution and sodium hydroxide solution was used as the activator. This research paper reviews experimental investigations on ordinary Portland cement cubes and fly ash based geopolymer concrete cubes that are Strength of Geopolymer concrete with different water/geopolymer ratio, Comparison of Compressive strength between OPC and GPC with respect to curing temperature as well as Compressive strength of fly ash based geopolymer concrete cubes in different curing time. Higher concentration of sodium hydroxide solution results in a higher compressive strength of geopolymer concrete.
The author suggestion was Curing temperature in the range of 30 to 90°C increases, the compressive strength of geopolymer concrete also increases, Longer curing time, in the range of 6 to 96 h (4 days), produces larger compressive strength of geopolymer concrete.

3. MATERIALS AND SPECIFICATIONS

3.1 MATERIALS

For the development of fly ash based geopolymer concrete mix design method, a detail investigation have been carried out by analysis of results

3.1.1 Fly Ash

In this research work, as per (ASTM C 618) low -calcium (class F fly ash) from dirk Indian private limited used was named Dirk Pozzocerete 63. Fly ash is fine grey powder that is a by-product material of pulverized bituminous coal blown into a fire furnace which is produces in electricity generating thermal power station. Specific gravity of the Fly Ash used is 2.26. The fineness of the Flash by Blaine's method is 360m^2/kg.

Table No. 1: chemical composition of class F fly ash

Sr. no	Composition	Typical Test Results	R Requirement as per IS 3812-2003
1	SiO2 +Al2O3 + fe2O3	93.00%	Max 70
2	Silicon dioxide (SiO_2)	85.00%	Min 35
3	Calcium oxide(CaO)	1.22%	Not specified
4	Iron oxide (Fe_2O_3)	1.41%	Not specified
5	Aluminum oxide (Al_2O_3)	6.50%	Not specified
6	Loss of ignition (LOI)	0.60%	Max 5
7	Total sulphur as sulphur trioxide (SO_3)	NIL	Max 3.0
8	Magnesium oxide (Mgo)	0.20%	Max 5
9	Chloride (Cl)	0.01%	Max 5

3.1.2 ALKALINE ACTIVATOR: The alkaline liquid was used was a combination of sodium hydroxide and sodium silicate solution. Sodium hydroxide is flakes form with 97-98% purity and sodium silicate purched from local chemical supplier used as alkaline liquid. Molarity of NaOH solution was 5M.

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Table No. 2: properties of sodium silicate solution (Na_2SiO_3)

Sodium Silicate Solution	**(Na_2SiO_3)**
PH value	11.04
Specific gravity	1.44 g/cm^3
Total solids	50.66 %
H_2O	49.44%
Total alkalinity (Na_2O)	14.28%
Total soluble silica (SiO_2)	36.38%

Table No. 3: properties of sodium hydroxide solution (NaOH)

Sodium Hydroxide Solution	**(NaOH)**
PH value	Strong base > 14
Specific gravity	1.44 g/cm^3
Molecular weight	48.95 g/mol
Boiling point	145°c for 50 % solution
Carbonate as Na_2CO_3	0.4 % max
Chloride as NaCl	0.05 % max

3.1.4 ADMIXTURE

It is a chloride free super plasticizer and it's selected from synthetic polymers. This is in the form of solution which instantly disperses in water. The Master Rheobuild 8501 provides high workability, usually it is necessary in pumping the concrete for high rise structures and also provides early strength. It is available in 1, 5, 20 and 275 litre drums. This super plasticizer is non-toxic and non flammable. This Master Rheobuild 8501 it is strongly recommended to use in curing for hot weather concreting, windy and dry climate.

Table No.4: Properties of Admixture

Properties	Results as per -IS 9103(1999)
Aspect	Free from liquid (dark Brown color)
pH value	6 %
Specific Gravity	1.21 ± 0.02@ 25^{O}C
Chloride ion content	<0.2 %

3.1.5 AGGREGATE

Locally available fine aggregate with the fineness of Zone (II) and coarse aggregate with maximum size nominal size of 12mm and 20 mm were used. Specific gravity of fine aggregate to be used for Mix Design purpose was found out to be 2.60 m^2/kg whereas specific gravity of coarse aggregate was 2.84 m^2/kg.

4. EXPERIMENTAL WORK

4.1 MIXING AND CASTING

In geopolymer concrete, mixing of the all ingredients is done by hand mix as per conventional method. For casting of geopolymer concrete, a sodium hydroxide is to be prepared as per ratio of Na_2SiO_3 to NaOH i.e. alkaline solution ratio, amount of Na_2SiO_3 to NaOH is calculated and mixed together an hour before the casting with water or super-plasticizer.

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Prepare geopolymer concrete, as per the convention method of mixing firstly dry mix of fine aggregates, coarse aggregate and fly ash is done by hand mix and then add prepared mixture like sodium hydroxide and sodium silicate solution along with extra water or super plasticizer based on solution-to-geopolymer concrete ratio and hand mix thoroughly for 5-10 min to give homogeneous mix. After proper mixing of all ingredient fresh fly ash based geopolymer concrete was viscous, cohesive and dark grey in colour**.** After mixing concrete, cube size 150mm fill each mould in three approximately equal layers and consolidate each layer with 25 strokes of the appropriate tamping rod, using the rounded end and finish final layer of top surface each mould is levelled with trowel. After 24 or 48 hour of casting, all specimens demoulded.

4.2 CURING

The specimen demould after 24 or 48 of casting, the concrete specimen cured at 80ºC for 24 h duration to sets polymerization chemical process of geopolymer concrete. After 24 h duration of heating curing, concrete specimen are removed from oven dry heating and then heat cured specimen left to Ambient curing (23-24ºC) till the tests conducted for 7,14,21,28 days.

4.3 MIX DESIGN

The Mix Design for M30 grade of Geopolymer Concrete with SF ratio 0.30, 0.35, 0.40,was carried by the modified guidelines help to design fly ash geopolymer concrete of ordinary and standard grades as mention in (IS -10262:2009) and (IS -456-2000).

Table NO.5: Mix proportion of GPC Concrete (per cu.m)

SF ratio or W/C ratio	Fly Ash (F)	Na_2SiO_3	NaOH	C.A	F.A	Admixture	Extra water	Dry Density (GPC)
0.30	460	99.70	99..70	1220.26	574.104	8.28	15.14	2477.18
0.35	395	99.54	99.54	1256.73	618.05	7.11	15.86	2492.49
0.40	345	99.89	99.89	1275.28	655.14	6.21	16.37	2497.78

Table No.6: Nomenclature of different Concrete Mix

GPC30N05	Geopolymer concrete of 0.30 SF and 0.5 Activator ratio
GPC35N10	Geopolymer concrete of 0.35 SF and 1.0 Activator ratio
GPC40N20	Geopolymer concrete of 0.40 SF and 2.0 Activator ratio
CCW30	Conventional concrete of 0.30 W/C ratio
CCW35	Conventional concrete of 0.35 W/C ratio
CCW40	Conventional concrete of 0.40 W/C ratio
AR RATIO	$Na_2SiO_3/NaOH$

Table NO.7: Mix Proportions of M-30 grade Fly Ash Geopolymer Concrete for 5 Molarity (per cu.m)

Mix ratio	Solution to Fly Ash ratio	Fly Ash Kg/m^3	Coarse Aggregate Kg/m^3	Fine Aggregate Kg/m^3	$Na2SiO_3$ Kg/m^3	NaoH Kg/m^3	Admixture kg/m^3	Extra water
GPC30N05	0.30	460	1220.26	574.104	66.47	132.94	8.28	15.14
GPC30N10		460	1220.26	574.104	99.7	99.7	8.28	15.14
GPC30N20		460	1220.26	574.104	132.94	66.47	8.28	15.14

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GPC35N05	0.35	395	1256.736	618.05	66.59	133.18	7.11	15.86
GPC35N10		395	1256.736	618.05	99.59	99.59	7.11	15.86
GPC35N20		395	1256.736	618.05	133.18	66.59	7.11	15.86
GPC40N05	0.40	345	1275.28	655.142	66.59	133.18	6.21	16.37
GPC40N10		345	1275.28	655.412	99.59	99.59	6.21	16.37
GPC40N20		345	1275.28	655.412	133.18	66.59	6.21	16.37

Table No.8: Mix proportions of M-30 grade for ordinary Portland cement concrete (per cu.m)

Mix ratio	Cement in Kg/m^3	Coarse aggregate Kg/m^3	Fine aggregate Kg/m^3	Water Kg/m^3	Admixture Kg/m^3	Extra water	Dry Density Kg/m^3
CCW30	460	1220.26	574.104	138	8.28	15.14	2415.78
CCW35	395	1256.738	618.05	138	7.11	15.86	2430.75
CCW40	345	1275.28	655.412	138	6.21	16.37	2436.27

5. RESULTS AND DISCUSSIONS

The results discussed below mainly consist of comparison between Geopolymer M30 grade concrete with conventional concrete. The test results of fresh and harden concrete are discuss below. The table and graph consist test results of comparative study of fresh concrete like Slump Test, Dry Density & Wet Density and with 7, 14, 21 and 28 days Compressive Strength. After tabulating the results, graphs were plotted to give a clear idea about average results of comparative analysis. The discussion was made because of obtained results and Figures.

Table No.7: Average Slump Values in (mm) for Various Mix concrete

Grade of concrete	W/C or SF ratio	Concrete Mix	Slump Value In (mm)
M30	0.30	CCW30	87
		GPC30N05	110
		GPC30N10	90
		GPC30N20	76
	0.35	CCW35	85
		GPC35N05	100
		GPC35N10	90
		GPC35N20	71
	0.40	CCW40	80
		GPC40N05	105
		GPC40N10	87
		GPC40N20	70

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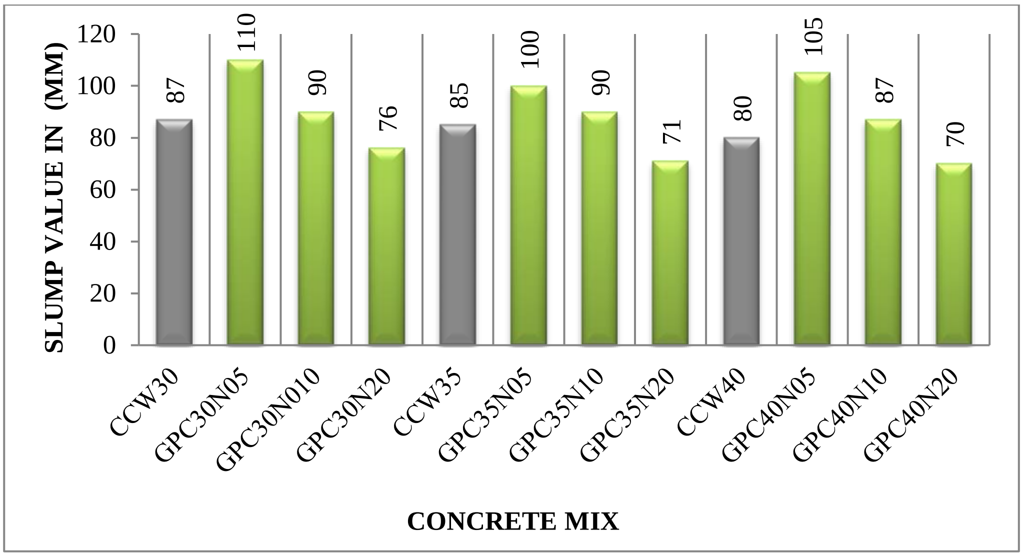

Figure No.1: Average slump value in (mm) compared GPC with CC

Above shown in the graph, it is seen that geopolymer concrete have much higher slump value and slight less in conventional OPC concrete. Its observed that as the dosage of sodium hydroxide is increase and sodium silicate decrease the concrete gets more cohesive fluidity and more flowable, but on another hand dosage of sodium silicate increase and sodium hydroxide is decrease it become more workable. Average slump value of geopolymer concrete compare with conventional, it is observed that SF ratio of 0.30, 0.35, 0.40 with activator ratio 0.5, 1.0 the average result is little beat higher than conventional concrete. Therefore Slump test result, it is observed that when SF ratio of 0.30, 0.35, and 0.40 with activator ratio 2.0 is much better as compare to conventional concrete.

Table No.8: Average Dry Density value in (kg/m^3) for various mixes concrete

Grade of concrete	W/C of SF ratio	Concrete Mix	Dry density CC/GPC Kg/m^3
M30	0.30	CCW30	2499.03
		GPC30N05	2460.40
		GPC30N010	2470.30
		GPC30N20	2540.70
	0.35	CCW35	2488.88
		GPC30N05	2501.48
		GPC30N10	2518.51
		GPC30N20	2530.74
	0.4	CCW40	2450.51
		GPC30N05	2465.10
		GPC30N10	2477.44
		GPC30N20	2490.75

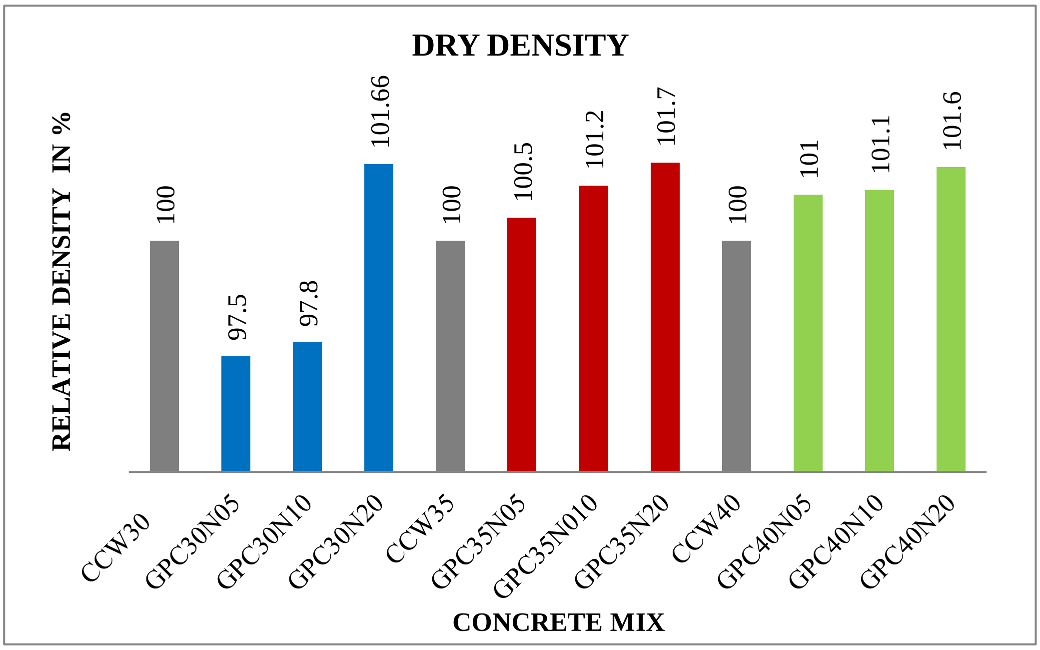

Figure No.1: Average Dry Density compared GPC with CC

Table No 8 (a) indicates the average value of dry density of geopolymer concrete compared with conventional concrete which is shown in figure No.1 As shown in the graph, for SF ratio of 0.30 average dry density of geopolymer concrete is decrease by 2.2 to 2.5%, and increase by 1.66% as compared to conventional concrete. When SF ratio of 0.35 dry density of all activator ratios is showing good results and well matches, as compare to conventional concrete. For SF ratio of 0.40 average dry density of geopolymer concrete are showing increase results 1.0%, to 1.6% as compared to conventional concrete. As compare the above results, geopolymer concrete with SF ratio 0.35 shows 0.5% to 1.7% higher dry density as compare to conventional concrete.

Table No.9: Average wet density value (kg/m^3) for various mixes concrete

W/C of SF ratio	Concrete mix	Wet density CC/GPC Kg/m^3
0.30	CCW30	2517.03
	GPC30N05	2595.23
	GPC30N10	2579.23
	GPC30N20	2601.26
0.35	CCW35	2488.88
	GPC30N05	2575.74
	GPC30N10	2588.51
	GPC30N20	2620.72
0.4	CCW40	2450.51
	GPC30N05	2518.51
	GPC30N10	2499.44
	GPC30N20	2521.75

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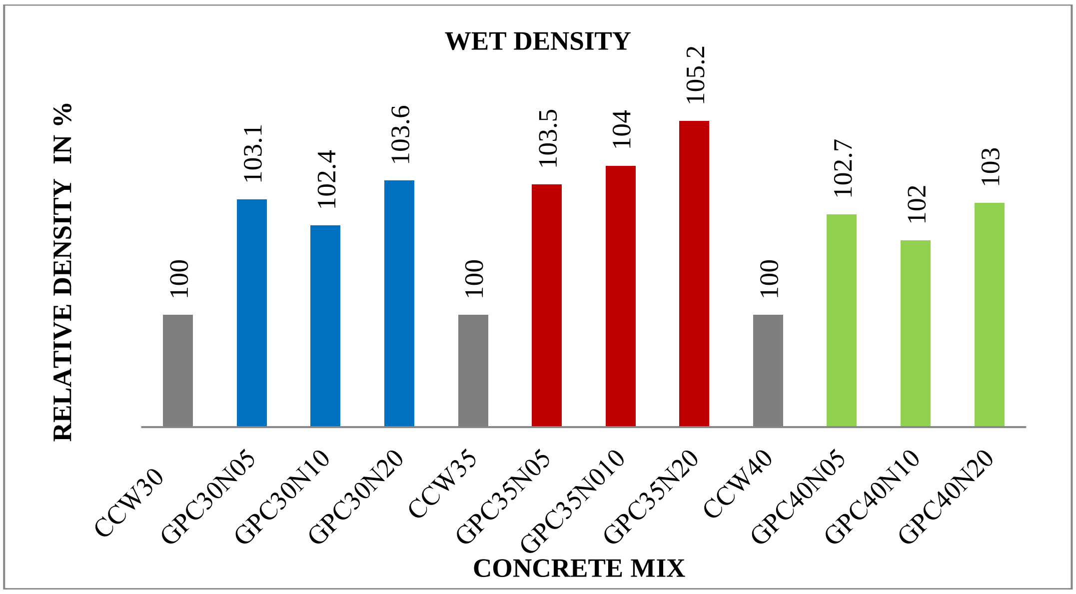

Figure No.2: Average Wet Density Compared GPC with CC

As the dosage of activator ratio increase its results formation increase in wet density of geopolymer concrete in different solution to fly ash ratio. As shown in the graph, for SF ratio 0.30 average wet density of geopolymer concrete is increase by 1.3% to 3.6% as compared to conventional concrete. When SF ratio 0.35 dry density of all activator ratios is showing good results and well matches as compared to conventional concrete. For SF ratio 0.40 average dry density of geopolymer concrete is showing increase results of 2.7% to 3.0% as compared to conventional concrete. As compare to above results, geopolymer concrete with SF ratio 0.35 shows 3.5 to 5.2% higher dry density as compare to conventional concrete.

Table No.10: Average Compressive Strength of M30 Grade Concrete containing with various Dosage of Alkaline Activator

W/C or S/F ratio	Mix proportion	7 day Average Comp. strength N/mm^2	14 day Average Comp. strength N/mm^2	21 day Average Comp. strength N/mm^2	28 day Average Comp. strength N/mm^2
0.30	CCW30	26.73	29.85	34.10	38.68
	GPC30N05	24.38	30.63	34.70	38.45
	GPC30N10	26.30	31.15	32.80	38.57
	GPC30N20	26.39	31.50	39.13	40.61
0.35	CCW35	25.01	30.88	34.13	38.71
	GPC35N05	23.50	27.18	31.01	37.50
	GPC35N10	24.10	27.90	29.52	37.79
	GPC35N20	36.48	38.62	41.76	42.81

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0.40	CCW40	26.80	31.38	35.15	38.87
	GPC35N05	22.95	31.50	34.31	38.47
	GPC35N10	25.87	32.14	33.59	37.82
	GPC35N20	23.97	29.95	39.84	40.47

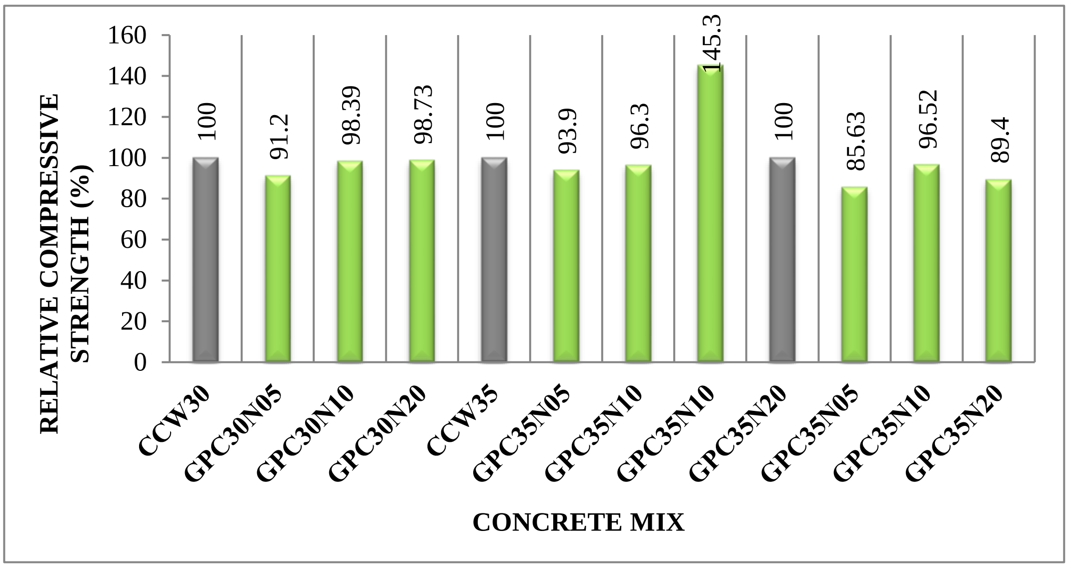

Figure No.3: 7 days Average Compressive Strength compared GPC with CC

Figure No.3 indicates 7 days compressive strength of various concrete samples with different mix proportions. As shown in the graph, for SF ratio of 0.30 the average compressive strength of geopolymer concrete decreases 1.27% to 8.8% as compared to conventional concrete. When SF ratio of 0.35 we can achieve higher compressive strength of geopolymer concrete increase by 45.3% as compared to conventional concrete. For SF ratio 0.40 average compressive strength of geopolymer concrete has decreased by 3.48% to 14.37% as compared to conventional concrete. As compare above results SF ratio of 0.35 showing much better compressive strength of geopolymer concrete as compared to 0.30 and 0.40 SF ratios. As we observed the above results, geopolymer concrete with SF ratio of 0.35 shows 45.3% higher compressive strength after 7 days of curing as compared to conventional concrete.

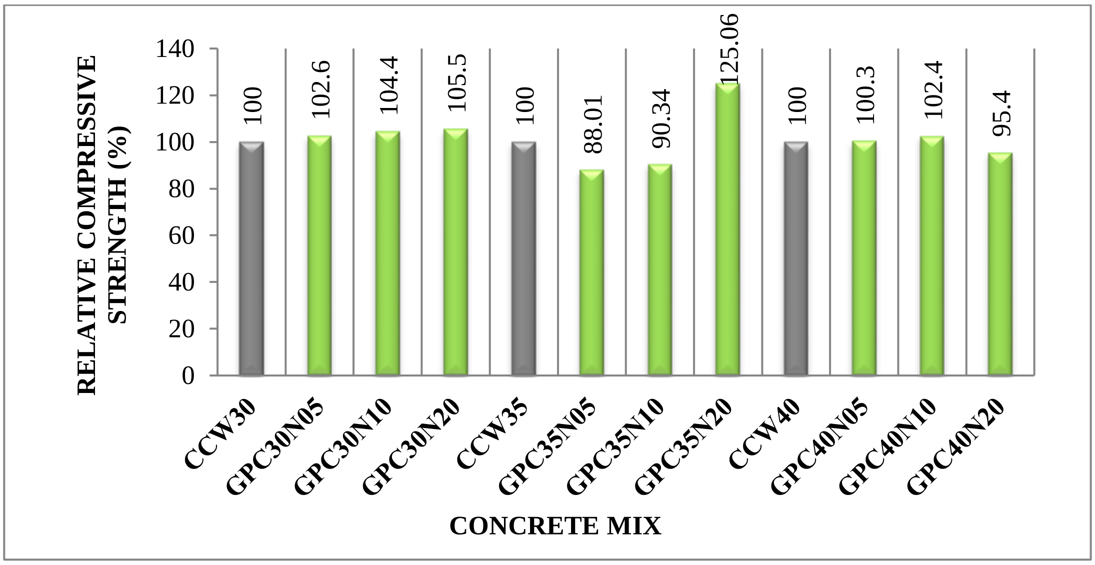

Figure No.4: 14 days Average Compressive Strength compared GPC with CC

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Figure No.4 indicates 14 days compressive strength of various concrete samples with different mix proportions. As shown in the graph for SF ratio of 0.30 the average compressive strength of geopolymer concrete increases by 2.6% to 5.5% as compared to conventional concrete. when SF ratio of 0.35 we can achieve higher compressive strength of geopolymer concrete increase by 25.06% as compared to conventional concrete. For SF ratio of 0.40 average compressive strength of geopolymer concrete increase by 0.3% to 2.4% and strength decrease by 4.6% as compared to conventional concrete. As compare the above results SF ratio of 0.35 is showing much better compressive strength of geopolymer concrete as compared to 0.30 and 0.40 SF ratios. As we observed the above results, Geopolymer concrete with SF ratio of 0.35 shows 25.06% higher compressive strength after 14 days of curing as compared to conventional concrete.

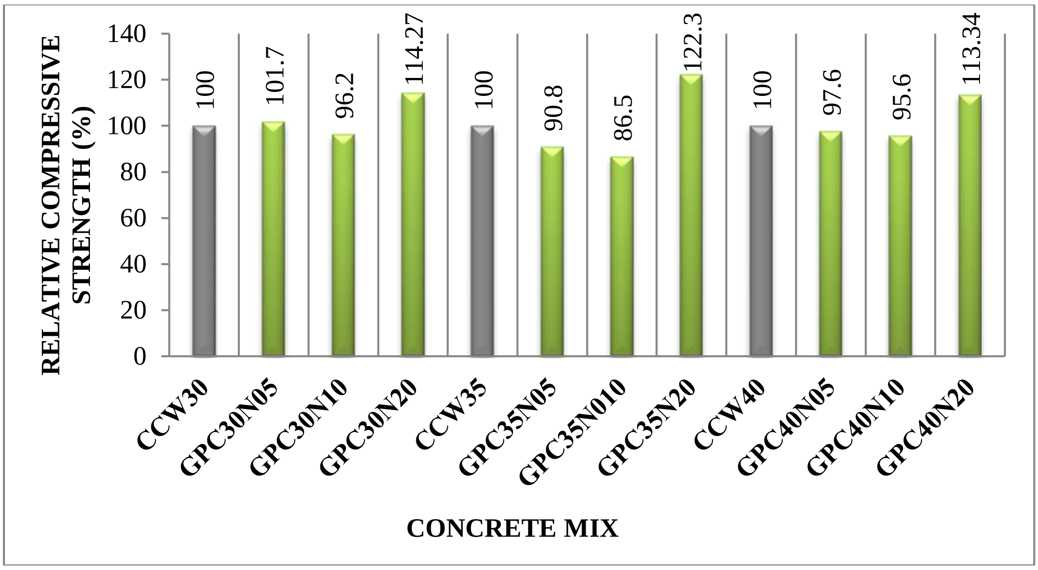

Figure No.5: 21 days Average Compressive Strength compared GPC with CC

Figure No. 5 indicates 21 days compressive strength of various concrete samples with different mix proportions. As shown in the graph, for SF ratio of 0.30 the average compressive strength of geopolymer concrete is increase by 1.7% to14.27% and reduces by 3.8% as compared to conventional concrete. When SF ratio of 0.35 we can achieve higher compressive strength of geopolymer concrete increase by 22.30% as compared to conventional concrete. For SF ratio 0.40 average compressive strength of geopolymer concrete is increase by 13.34% and strength decrease by 2.4% to 4.4% as compared to conventional concrete. As compare above results ratio of 0.35 showing much better compressive strength of geopolymer concrete as compared to 0.30 and 0.40 SF ratio. As we observed the above results, geopolymer concrete with SF ratio of 0.35 shows 22.30% higher compressive strength after 21 days of curing as compared with conventional concrete.

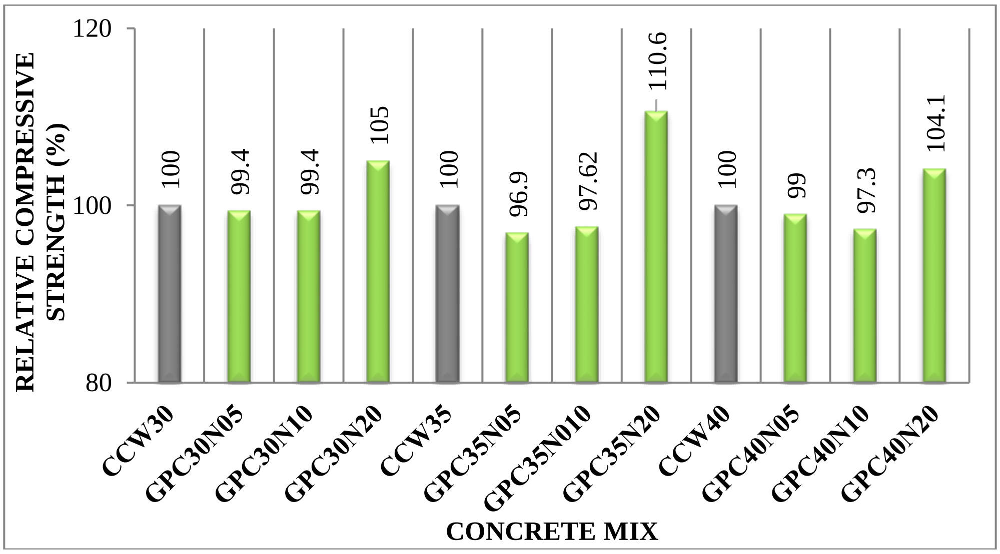

Figure No.6: 28 days Average Compressive Strength compared GPC with CC

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Figure No.6 indicates 28 days compressive strength of various concrete samples with different mix proportions. As shown in the graph, for an SF ratio of 0.30 the average compressive strength of geopolymer concrete increase by 5% and strength reduce by 0.6% as compared to conventional concrete. when SF ratio 0.35 we can achieve higher compressive strength of geopolymer concrete increase by 10.6% as compared to conventional concrete. For SF ratio 0.40 average compressive strength of geopolymer concrete is increase by 4.1% and strength decrease by 1.0% to 2.7% as compared to conventional concrete. As compare above results 0.35 SF ratio showing much better compressive strength of geopolymer concrete as compare to 0.30 and 0.40 SF ratio. As we observed the above results, Geopolymer concrete with SF ratio 0.35 shows 10.60% higher compressive strength after 28 days of curing as compared to conventional concrete.

6. CONCULSIONS

On the basis of results obtained during the experimental investigation, following conclusion was drawn:

- Workability of geopolymer concrete for SF ratio of 0.35 shows much better results than 0.30 and 0.40 when compare with conventional concrete.
- Dry density of geopolymer concrete for SF ratio of 0.35 shows a much better result than 0.30 and 0.40 of SF ratio when compared to conventional concrete.
- Wet density of geopolymer concrete for SF ratio of 0.35 shows a much better result than 0.30 and 0.40 of SF ratio when compared to conventional concrete.
- The Compressive strength of geopolymer concrete with SF ratio of 0.35, shows the result of 45.3%, and 10.6% increase after 7 days and 28 days when compared to conventional concrete.
- After 7 days compressive strength of geopolymer concrete with SF ratio of 0.35 is showing good results compare with conventional concrete as well as further when we go for activator ratio under 0.35 SF ratio, 2.0 is much better than other activator ratio 0.5,1.0.
- Fly ash Geopolymer concrete is 3.307% saving cost as compare to ordinary conventional concrete.

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