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Strength Studies on Geo-Polymer Concrete by Using Fly Ash and Quarry Dust

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ABSTRACT
The major problem the world is facing today is environmental pollution. In the construction industry mainly the production of Portland cement will cause the emission of pollutants results in environmental pollution. The alkaline liquids used in this study for the polymerization are the solutions of Sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). Different molarities of sodium hydroxide solution i.e. 8M, 10M and 12M are taken to prepare different mixes. And the compressive strength is calculated for each of the mix. The cube specimens are taken of size 150mm x 150mm x 150mm.The Geo polymer concrete specimens are tested for their compressive strength at the age of 7days, mixes of varying sodium hydroxide molarities i.e.8M,10M and 12M are prepared and they are cured by direct sun-light and strengths are calculated for 7 days. The result shows that the strength of Geo polymer concrete is increasing with the increase of the molarity of sodium hydroxide.
Keywords: *compressive strength Geo-polymer concrete, physical properties, fly ash, quarry dust.*

I. INTRODUCTION

For the construction of any structure, Concrete is the main material. Concrete usage around the world is second only to water. The main ingredient to produce concrete is Portland cement. On the other side global warming and environmental pollution are the biggest menace to the human race on this planet today. The production of cement means the production of pollution because of the emission of CO_2 during its production. There are two different sources of CO_2 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 calcimine Lime stone into lime in the cement kiln also produces CO_2. In India about 2411.7 million of metric tons of CO_2 are emitted in the year of 2021. The cement industry contributes about 5% of total global carbon dioxide emissions. And also, the cement is manufactured by using the raw materials such as lime stone, clay and other minerals. Quarrying of these raw materials is also causes environmental degradation. To produce 1 ton of cement, about 1.7 tons of raw materials are required and the time taken to form the lime stone is much longer than the rate at which humans use it. But the demand of concrete is increasing day by day for its ease of preparing and fabricating in all sorts of convenient shapes. So to overcome this problem, the concrete to be used should be environmental friendly.

II. MATERIAL AND METHODS

FLY ASH:

Fly ash is manufactured by the burning of coal in an electrostatic precipitator, a by product of industrial coal. The cementations properties of fly ash were discovered in late 19th century and it has been widely used in cement manufacture for over 100 years. In fly ash is supplied as a separate component for concrete and is added at the concrete at the mixer. It generally replaces between 20 and 80 per cent of the normal Portland cement. Fly ash is taken from **METTUR THERMAL POWER STATION, METTUR** in Tamilnadu.

PHYSICAL AND CHEMICAL PROPERTIES OF FLY ASH:

Description	Fly Ash	IS:3812-1981 Specifications
Specific Gravity	2.23	-
Fineness	430 m^2/kg	Shall not be less than 320m^2/kg
SiO_2	60.21%	35% min.
Al_2O_3	24.10%	-
Fe_2O_3	4.2%	-

$SiO_2 + Al_2O_3 + Fe_2O_3$	88.51%	70% min.
Al_2O_3	1.31%	5%max.
Fe_2O_3	2.72%	-
SO_3	2.96	3% max.
Alkali	2.78%	1.5%
LOI	1.34%	5%max.

QUARRY DUST:

Now-a-days the natural river sand has become scarce and very costly. Hence we are forced to think of alternative materials. The Quarry dust may be used in the place of river sand fully. To overcome the stress and demand for river fine aggregate, researchers and practitioners in the construction industries have identified some alternative materials such as fly ash, slag, limestone powder and siliceous stone powder. It is proposed to study the possibility of replacing sand with locally available crusher waste without sacrificing the strength and workability of concrete. Coarse aggregate of 20mm maximum size is used in Reinforced cement concrete work of all types of structures. This is obtained by crushing the stone boulders of size 100 to 150mm in the stone crushers. Then it is sieved and the particles passing through 20 mm and retained on 10mm sieve known as course aggregate. The particles passing through 4.75mm sieve are called as quarry dust. Based on this experimental investigation, it is found that quarry dust can be used as an alternative material to the natural river sand. The physical and chemical properties of quarry dust satisfy the requirements of fine aggregate. It is found that quarry dust improves its mechanical property of concrete if used along with super plasticizer. Usage of quarry dust it will also reduce the cost of concrete.

PROPERTY QUARRY	ROCK DUST	TEST METHOD
Specific Gravity	2.60	IS 2386 (Part III) 1963
Bulk relative density (kg/m^3)	1700	IS 2386 (Part III) 1963
Absorption (%)	1.30	IS 2386 (Part III) 1963
Moisture Content (%)	Nil	IS 2386 (Part III) 1963
Fine particles less than 0.075mm (%)	14	IS 2386 (Part I) 1963
Sieve Analysis	Zone III	IS 383-1970

PHYSICAL PROPERTIES OF QUARRY DUST:

IS Sieve	Weight retained (gm)	Cumulative Weight retained (gm)	% Cumulative Weight retained	% Passing	Grading Limit (Zone III)
4.75 mm	91	91	9.1	90.9	90-100
2.36 mm	68	159	15.9	84.1	85-100
1.18 mm	92	251	25.1	74.9	75-100
600 micron	196	447	44.7	55.3	60-79
300 micron	401	848	84.8	15.2	12-40
150 micron	129	977	97.7	2.3	0-10
Pan	23	1000	100	0	-

CHEMICAL COMPOSITION OF QUARRY DUST:

CONSTITUENT	QUARRY ROCK DUST (%)	TEST METHOD
SiO_2	62.48	IS: 4032 - 1968
Al_2O_3	18.72	
Fe_2O_3	06.54	
Cao	04.83	
Mgo	02.56	
Na_2O	Nil	
K_2O	03.18	

PREPARATION OF ALKALINE LIQUIDS:

NOTE: **Molarity = moles of solute / liter of solution**

In this paper the compressive strength of geo-polymer concrete is examined for the mixes of varying molarities of Sodium hydroxide (8M, 10M, and 12M). The molecular weight of sodium hydroxide is 40. To

prepare 8M i.e. 8 molar sodium hydroxide solutions, 320 g of sodium hydroxide flakes are weighed and they can be dissolved in distilled water to form 1 liters solution. For this, a volumetric flask of 1 litre capacity is taken, sodium hydroxide flakes are added slowly to distilled water to prepare 1liter solution.

Required Molarity	**Weight in g. of Sodium hydroxide flakes**
8M	320
10M	400
12M	480

ALKALINE SOLUTIONS:

The solutions of Sodium hydroxide and Sodium Silicate are used as alkaline solutions in the present study. Sodium hydroxide is available in market in various forms as flakes, pellets and in powder forms. In the study, Commercial grade Sodium Hydroxide in flakes form (97%-100% purity) is used. Sodium silicate is available in powder form. By using sodium silicate we may prepare solution of required molarity. In this study, sodium silicate used in solution from having the following chemical proportion is used.

Na2O - 7.5%-8.5%
Sio2 - 25% -28%
Water - 67.5%-63.5%

SUPER PLASTICIZER:

In order to improve the workability of fresh concrete, Super plasticizer Cornplast SP 430, of colour brown based on sulphonated naphthalene polymers, complies with IS 9103-1999, BS: 5075 part 3 and ASTM C-494, Type F was used.

The mix proportions given by taken as a reference one, several trial mixes are prepared with flyash and constant molarity of NaOH as 12M. The mix which gives high workability is taken as final one and the project continues with the final one. The trial mixes are as follows.

The trial mixture proportion is as follow: combined aggregates = 1848 kg/m^3, GGBS = 408 kg/m^3, sodium silicate solution = 103 kg /m^3, and sodium hydroxide solution = 41 kg/m^3 (12M solution). 20 mm aggregates = 910 kg/m^3, fine sand = 554 kg/m^3 .The geo-polymer concrete is wet-mixed for four minutes and cured at 60oC for 24 hours in hot air oven after casting. Commercially available super plasticizer of about 0.75% of mass of GGBS, i.e. 5 kg/m^3 is added to the mixture to facilitate ease of placement of fresh concrete. In this manner, by changing the quantities of aggregates and by increasing the fines in the mixture the final mix is as follows. The total volume occupied by the aggregates (Coarse and fine aggregates) is assumed to be 65%. The alkaline liquid to GGBS ratio is taken as 0.30. The quantities of all ingredients are kept constant as given in except the molarity of NaOH is changed in the each mix.

Assume the density of geo-polymer concrete as 2500 kg/m^3. Assume the volume of combined aggregates occupied 70% of the mass of concrete, i.e. 0.70x2500= 1750 kg/m^3.

In this,

The mass of fine aggregates + coarse aggregates = 1750kg/m^3.
Coarse Aggregate = 60% of 1750
= 1050 kg/m^3
Quarry dust = 40% of 1750
= 700 kg/m^3
Mass of Alkaline liquid and Fly ash = 2500-1750
= 750 kg/m^3

Assume,

Mass of fly ash = 60% of 750
= 450 kg/m^3
Mass of alkaline liquid = 40% of 750 kg/m^3
=300 kg/m^3

Take the ratio of sodium silicate solution-to-sodium hydroxide solution by mass as 2;

The mass of sodium hydroxide solution = 100kg/m^3
The mass of sodium silicate solution = 200 kg/m^3
The mass of super-plasticizer = 0.75X450
=3.375 kg/m^3

MIXING PROPORTIONS OF THE GEO-POLYMER CONCRETE

Name Of The Mixture	Fly Ash (kg/m^3)	Quarry Dust (kg/m^3)	Coarse Aggregate (kg/m^3)	Sodium Silicate Solution (kg/m^3)	Sodium Hydroxide Solution (kg/m^3)	Super-Plasticizer (kg/m^3)
			20mm			
GP1	450	700	400	200	100 (8M)	3.375
GP2	450	700	400	200	100 (10M)	3.375
GP3	450	700	400	200	100 (12M)	3.375

III. RESULTS AND DISCUSSION

Compressive strength is the capacity of a material or structure to withstand axially directed pushing forces. Cubes of 150mm×150mm×150mm were casted and a compressive strength test was conducted on specimens at 7 days. To conduct the test the specimens are placed in a compression testing machine and the load is applied to the cube and the load at failure is noted as failure load. The compressive strength is calculated by using the formula

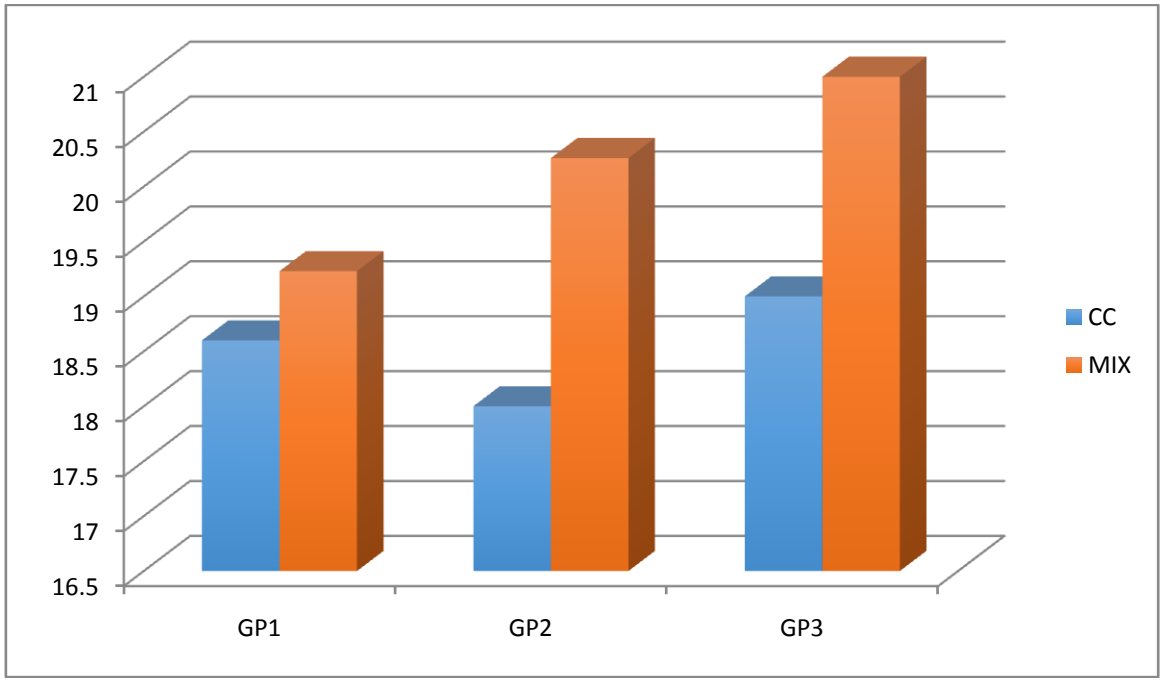
$$\mathbf{F_{ck} = P_c/A}$$

Where, P_c = load at failure in N, A = loaded area of cube in mm^2

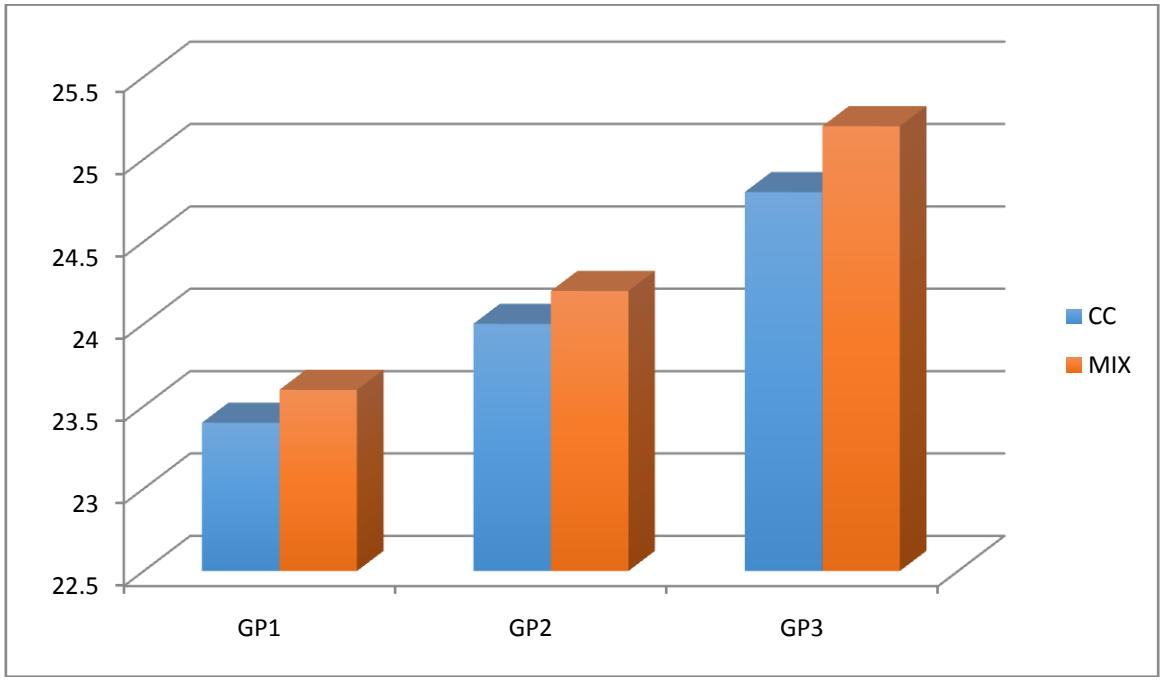
Fig .1 GEO - POLYMER CONCRETE CUBES AFTER COMPRESSION TEST

COMPRESSIVE STRENGTH:

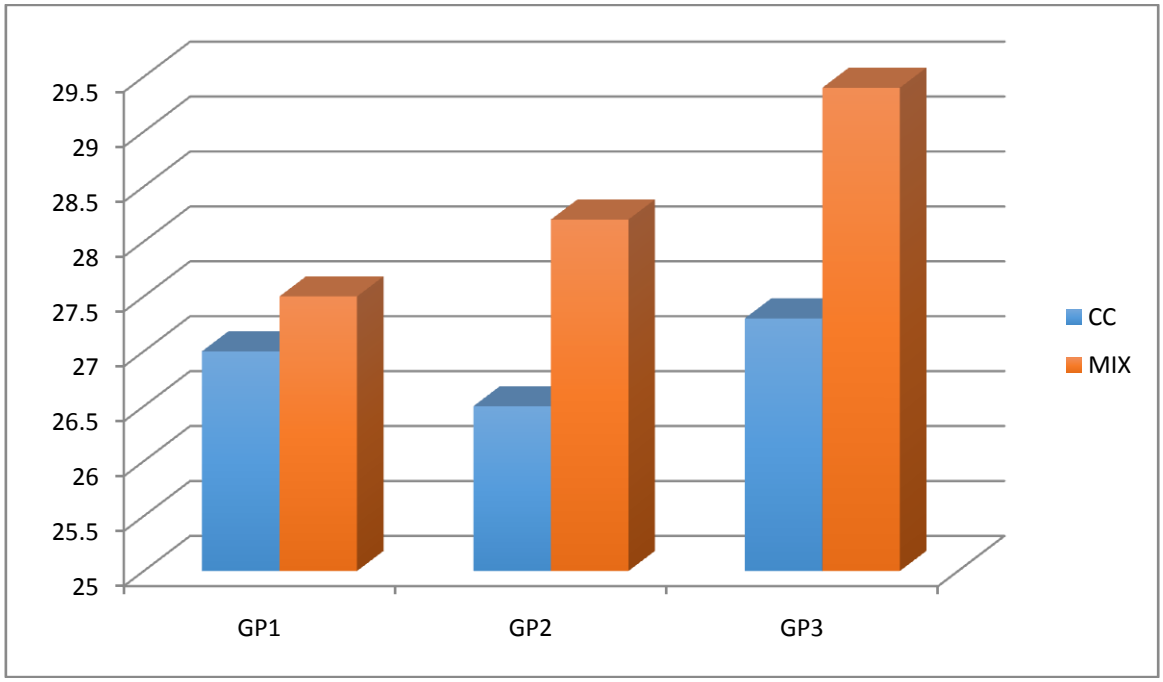
Name of the mix	Compressive strength in N/mm^2 of specimens Cured by		
	7 days	14 days	28 days
CC	18.6	23.4	27
GP1	19.23	23.6	27.5
GP2	20.26	24.2	28.2
GP3	21	25.2	29.4



COMPRESSIVE STRENGTH OF SPECIMENS AT THE AGE OF 7 DAYS



COMPRESSIVE STRENGTH OF SPECIMENS AT THE AGE OF 14 DAYS



COMPRESSIVE STRENGTH OF SPECIMENS AT THE AGE OF 28 DAYS

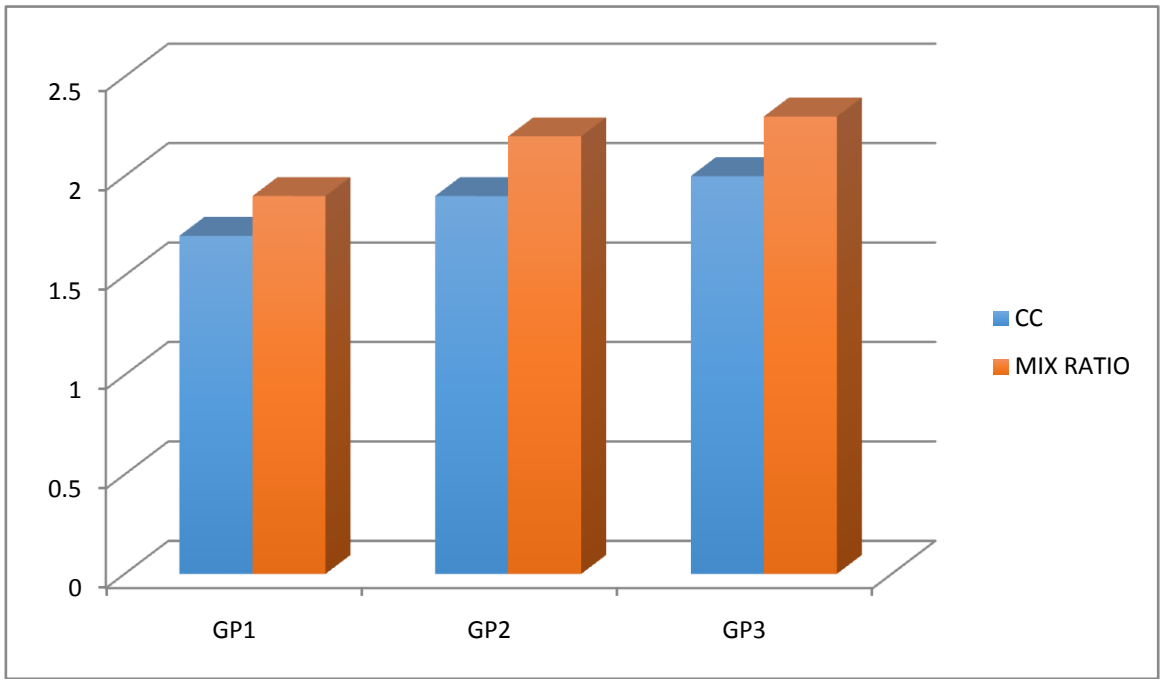
By showing the above graph the compressive strength increase the strength by 40% in 7 days. The other one shows the increase of the strength by 60% it reflects that by increase the days limit the strength of the mixture can be increased .The last one shows the increase of the strength by 75%.

SPLIT TENSILE TEST:

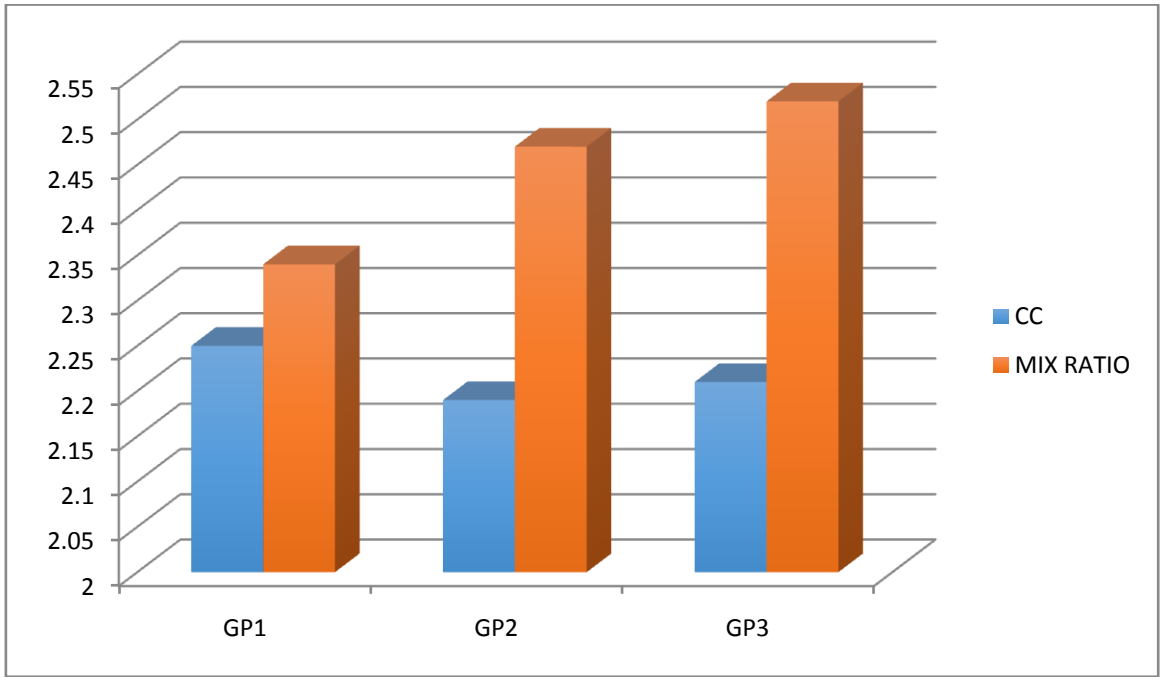
The concrete cylinders cured at room temperature are tested to find the tensile strength of the concrete using compressive Testing Machine (CTM). The same specimen is also tested on 7th and14th and 28th day to study tensile strength property of the geo-polymer concrete on ageing.

Fig .2 - GEO - POLYMER CONCRETE CYLINDER AFTER SPLIT TENSILE TEST

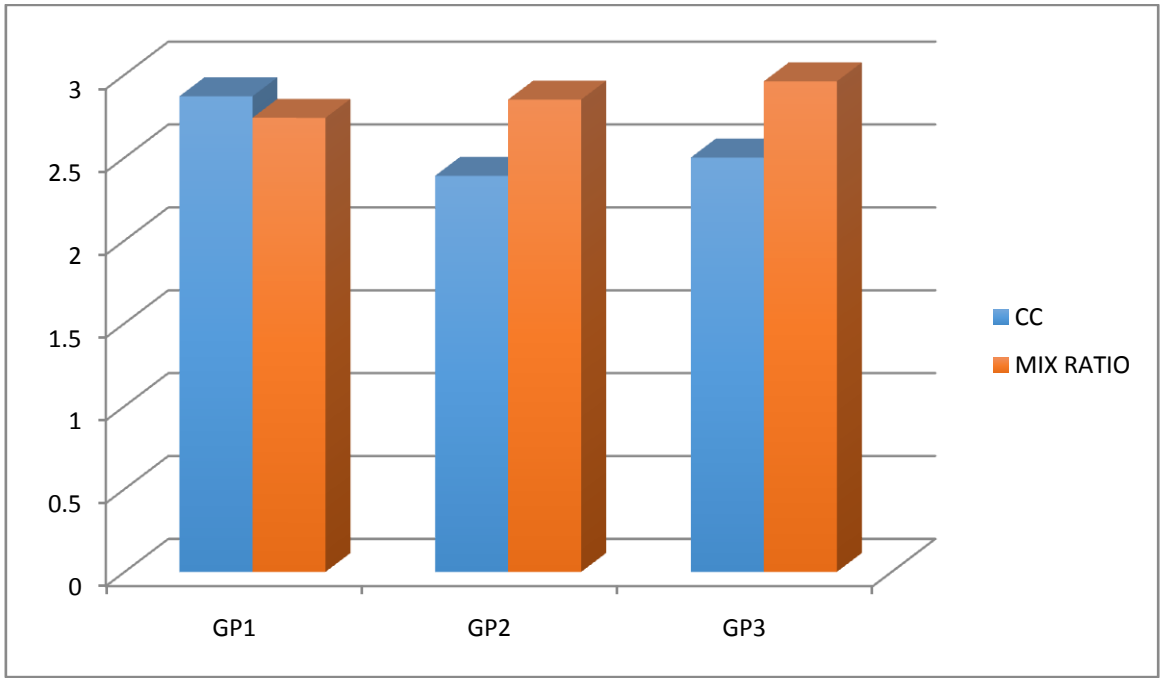
Name of the mix	Split Tensile Test in N/mm^2 of specimens Cured by		
	7 days	14 days	28 days
CC	1.7	2.25	2.87
GP1	1.9	2.34	2.74
GP2	2.2	2.47	2.85
GP3	2.3	2.52	2.96



SPLIT TENSILE TEST OF SPECIMENS AT THE AGE OF 7 DAYS



SPLIT TENSILE TEST OF SPECIMENS AT THE AGE OF 14 DAYS



SPLIT TENSILE TEST OF SPECIMENS AT THE AGE OF 28 DAYS

In case of considering the split tensile test the strength can be varied as it compares with the compressive strength. The only difference we can observe is the mixing ratio of the quantity .The graph shows an increase of composition by 40% to 80 %.

IV. CONCLUSION

This paper proposed the guidelines for the 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- geo polymer binder ratio of 0.35, solution-to-fly ash ratio of 0.35, and sodium silicate-to-sodium hydroxide ratio of 1 with concentration of sodium hydroxide as 12 M.

Heat curing was done at 60 °C for duration of 24 h and tested after 7 days after oven heating. Experimental results of M40 grades of geo polymer concrete mixes using proposed method of mix design shows promising results of workability and compressive strength.

Geo-polymer concrete shall also be used in the Infrastructure works. In addition to that fly ash shall be effectively used and hence no landfills are required to dump the fly ash. So, these guidelines help in design of fly ash based geo polymer concrete of Ordinary and Standard Grades as mentioned in IS 456: 2000.

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