Mechanical Properties of Geopolymer Concrete By Using Processed Fly Ash

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Abstract- *In this experiment we are aiming to minimize the use of cement as it is a major contributor in this global warming. Hence by total replacement of cement with substitute material that is fly ash is thus the hot topic which is still under research. In this experiment we have evaluated the properties of processed fly ash based geopolymer concrete within its fineness of fly ash like Pozzocrete60(P60), Pozzocrete63(P63) and Pozzocrete100(P100) by performing the compression test, split tensile test and flexural strength test with fully replacement of cement by fly ash. To achieve these results, we have prepared mix design of M30 by using chemicals like Sodium Hydroxide (NaOH) 13M and Sodium Silicate (Na_2SiO_3) combinely called alkaline solution. Solution to fly ash ratio 0.35 is taken for mix designs of each type of processed fly ash which is obtained from Dirk India Pvt. Ltd. Nashik Plant. This experiment shows that initiallyas fineness of the fly ash increases strength of geopolymer concrete increases. But we observe that, after certain fineness of fly ash there is decreasein the compressive strength and the same pattern for result is observed for split tensile test also.*

Keywords- Geopolymer concrete, processed fly ash, fineness, compressive strength,split tensile strength.

I. INTRODUCTION

Concrete industry is one of the most widely spreading industries in the world and production of cement is increasing every year. This production consumes a huge amount of energy which affects the Global environment. Production of one ton of Portland cement releases approximately one ton of carbon dioxide during its manufacturing process which have contribution around 8% of global CO_2emission. Thus a new technology based on the environmental impact is developing a low emission of CO_2 requiring an alternate sustainable source like fly ash, blast furnace slag for Cement industry. Coal-based thermal power installations in India contribute about 65% of the total installed capacity for electricity generation. As a consequence, a huge amount of fly ash is generated in thermal power plants, causing several disposal-related problems. One potential alternative to Portland cement based concrete is fly ash based geopolymer concrete, which may have the potential to reduce Portland cement usage while acquiring the similar compressive strength and durability characteristics of Portland cement concrete. A significant number of research studies have been conducted on fly ash based geopolymers and that had concluded many beneficial properties of fly ash based geopolymer concrete.

The term 'geopolymer' is coined by French researcher Davidovits in 1978 that given to describe the amorphous alkali aluminosilicate forms and also commonly used for the inorganic polymers. In this work, low calcium fly ash based geopolymer is used as the binder, instead of Portland or other hydrated cement paste, to produce concrete. The fly ash based geopolymer paste binds the loose course aggregates, fine aggregates and other unreacted materials together to form geopolymer concrete, with or without admixtures.The main concept behind this geopolymer is the polymerization of Si-O-Al-O bond which develops when Al-Si source materials like fly ash is mixed with alkaline activating solution (NaOH with Na_2SiO_3)

Geopolymer reduces Greenhouse emission, increasing fire and chemical resistance and industrial waste utilization. Geopolymers are also used for fire and heat resistant coatings and adhesives, high temperature ceramics, new binders for fire resistant fiber composites, medical applications, toxic and radioactive waste encapsulation and new cements for concrete [2]. Hence we are trying to minimize the use of cement by partial or total replacement by any of its substitute cement replacement materials like fly ash and waste chemicals like NaOH and Na_2SiO_3. In practice, highest replacements OPC by 60 to 68% of fly ash in high volume concrete are achieved. But more research should be done to achieve 100% replacement of cement by fly ash.In this context of geopolymer concrete we have done total replacement of cement which has the good impact on environmental conditions and reduces the effect of pollution and waste disposal problem to a large extent. It is thus the hot topic which is still under research.

II. LITERATURE SURVEY

Properties of geopolymer concrete, **Prof.Joseph Davidovits**Geopolymer Institute (1994). Joseph Davidovits Investigate that the behavior of geopolymeric cements and their unique properties which include high early strength, low shrinkage, freeze-thaw resistance, sulphate resistance and corrosion resistance for long term containment in surface disposal facilities.

Dr.Patankar (2015) A mix design procedure is proposed on the basis of quantity and fineness of fly ash, quantity of water, grading of fine aggregate and fine to total aggregate ratio. Sodium silicate solution with Na_2O= 16.37%, SiO_2= 34.35%, H_2O= 49.28% and Sodium hydroxide solution having 13M concentration were maintained constant throughout the experiment. Water to geopolymer binder ratio of 0.35, alkaline solution to fly ash ratio of 0.35 and sodium silicate to sodium hydroxide ratio of 1.0 by mass were fixed on the basis of workability and cube compressive strength.

Modified guidelines for mix design of geopolymer concrete which was relevant to IS 10262-2009 was presented by **Anuradha R. (2012)** Also authors examined the applicability of existing mix design with the geopolymer concrete. In this study 100% cement was replaced by class F fly ash and 100% sand was replaced by M-sand.

P. K. Jamdadeand **U. R.Kawade (2014)[5]** studied the strength of Geopolymer concrete by using oven curing. It was observed that higher curing temperature resulted in larger compressive strength of Geopolymer concrete, even though an increase in the curing temperature beyond 60^{0}C did not increase the compressive strength substantially.

III. MATERIAL AND METHODOLOGY

3.1 MATERIALS USED:

3.1.1 Fly Ash

Locally available fly ash confirming to IS 3812-2003
3.1.1: Pozzocrete 60(P60) has 82% particles finer than 45 micron sieve
3.1.2: Pozzocrete 63(P63) has 90% particles finer than 45 micron sieve
3.1.3: Pozzocrete 100(P100) has 95% particles finer than 25 micron sieve

3.1.2 Fine Aggregates

Locally available sand passing through IS 4.75 mm sieve and free from silt is used.

Table 1: Physical properties of fine aggregate as per IS 383(1970)

Sr. No.	Characteristics	Results
1.	Type	Uncrushed
2.	Particle shape and size	Round, 4.75 mm down
3.	Specific Gravity	2.59
4.	Fineness Modulus	2.76
5.	Bulking of Sand	5.88%
6.	Surface Moisture	Nil

3.1.3 Coarse Aggregates

Aggregates passing through IS 20 mm sieve are used.

Table 2: Physical properties of coarse aggregate as per IS 383(1970)

Sr. No.	Characteristics	Results
1.	Specific gravity	2.86
2.	Impact value (%)	12.10
3.	Crushing value (%)	23.30
4.	Water absorption (%)	0.20
5.	Fineness Modulus	7.00

3.1.4 Sodium Hydroxide (NaOH)

The Sodium Hydroxide (97% pure) is available in solid state by means of pellets and flakes. 13 M concentration is used.

3.1.5 Sodium Silicate (Na_2SiO_3)

Sodium silicate in fluid gel form having arrangement Na_2=14.7% SiO_2=29.4% and water 55.9% by mass is used.

3.1.6 Water

Potable tap water available in laboratory is used for mixing.

3.2 METHODOLOGY:

3.2.1 Mix design of M 30

Table 3: Quantity of Materials Required Per Cubic Meter for M30 Grade of Geopolymer Concrete

Ingredients	Fly Ash	NaOH	Na2SiO3	Sand	Coarse Aggregate	Total Water	Extra Water
Quantity (kg/m^3.)	405	47.25	94.5	674.03	1927.25	120	54.34

3.2.2 Preparation of Specimen

The Sodium Hydroxide was beard by dissolving sodium Hydroxide flakes in water. The flakes are commercial grade with 97% purity; thus 13M solution was prepared one day before concrete batching. The Sodium silicate and sodium hydroxide solution mixed just prior to concrete. The ingredients are thoroughly mixed over a GI sheet. The sand, fly ash, coarse aggregate are measured accurately on digital balance and are mixed set of normal concrete.Alkaline solution is spread over the concrete mix with two stages and mixed for 5 minutes.The fresh concrete was placed in the moulds of size 150 x 150 x 150mm and 150 mm diameter x 300 mm height by trowel. All the moulds are then vibrated on vibrating table. The vibration is continued till fly ash slurry just ooze out on surface of moulds. The specimens were demoulded after 24 hours of casting and immediately stored in the oven for 1 day at 60^0C temperature. in the oven for 1 day at 60^0C temperature.

After demoulding the concrete specimen are allowed to become air dry in laboratory until the day of testing.This schedule will be followed for GPC of P-60, P-63and P-100 fly ash each for M30 grade designs. Total 72 test specimens required to perform these testswhich include 45 cubes of and 27 cylinders.

3.2.3 Compression Strength Test

These specimens are tested by compression testing machine after 7 days, 14 days and 28 days curing. Load applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails.

The compressive strength of specimen was calculated by formula

$$Fck = P/A$$

Where, P = failure load in compression in N

A = Loaded Area of cube in mm^2
F_{ck}=Compressive strength in N/mm^2

Fig 3.1: Compressive Testing

3.2.4 Split Tensile Test

The cylindrical specimens were taken out from the water after 7 days, 14 days and 28 days of curing.The tensile strength of specimen was calculated by formula

$$Fsp = (2P)/(\pi L d)$$

Where, f_{sp} =Split tensile strength in N/mm.
P = Maximum applied load in N
L = Length of cylinder in mm
d = Diameter of cylinder in mm

Fig 3.2: Split Tensile Testing

IV. RESULTS

4.1 Compression Test Results:

Table 4: 7TH Day Compressive Strength

Type of Fly ash	Cube Name	Test Result (N/mm²)	Average value (N/mm²)
P60	P60-1	14.40	15.23
	P60-2	14.88	
	P60-3	16.00	
	P60-4	15.33	
	P60-5	15.55	
P63	P63-1	16.88	16.88
	P63-2	17.55	
	P63-3	17.11	
	P63-4	16.22	
	P63-5	16.66	
P100	P100-1	14.88	14.43
	P100-2	13.77	
	P100-3	14.4	
	P100-4	14.00	
	P100-5	15.11	

Table 5: 14TH Day Compressive Strength

Type of Fly ash	Cube Name	Test Result (N/mm²)	Average value (N/mm²)
P60	P60-6	22.00	22.97
	P60-7	22.88	
	P60-8	23.55	
	P60-9	23.11	
	P60-10	23.33	
P63	P63-6	31.33	31.32
	P63-7	30.66	
	P63-8	31.55	
	P63-9	30.66	
	P63-10	32.44	
P100	P100-6	19.77	19.68
	P100-7	20.22	
	P100-8	20.00	
	P100-9	19.33	
	P100-10	19.11	

Table 6: 28TH Day Compressive Strength

Type of Fly ash	Cube Name	Test Result (N/mm²)	Average value (N/mm²)
P60	P60-11	28.22	28.29
	P60-12	30.22	
	P60-13	26.22	
	P60-14	28.88	
	P60-15	28.44	
P63	P63-11	32.22	34.53
	P63-12	34.00	
	P63-13	36.22	
	P63-14	35.55	
	P63-15	34.66	
P100	P100-11	28.0	26.62
	P100-12	26.22	
	P100-13	24.88	
	P100-14	27.55	
	P100-15	26.44	

4.2 Split Tensile Test Results:

Table 7: 7TH Day Split Tensile Strength

Type of Fly ash	Cylinder Name	Test Result (N/mm²)	Average value (N/mm²)
P60	P60-1	2.22	2.26
	P60-2	2.44	
	P60-3	2.12	
P63	P63-1	2.75	2.74
	P63-2	2.88	
	P63-3	2.61	
P100	P100-1	2.28	2.56
	P100-2	2.78	
	P100-3	2.68	

Table 8: 14TH Day Split Tensile Strength

Type of Fly ash	Cylinder Name	Test Result (N/mm²)	Average value (N/mm²)
P60	P60-4	3.20	2.94
	P60-5	3.02	
	P60-6	2.62	
P63	P63-4	2.86	3.10
	P63-5	3.33	
	P63-6	3.12	
P100	P100-4	2.72	2.62
	P100-5	2.72	
	P100-6	2.36	

Table 9: 28TH Day Split Tensile Strength

Type of Fly ash	Cylinder Name	Test Result (N/mm²)	Average value (N/mm²)
P60	P60-7	3.41	3.17
	P60-8	2.96	
	P60-9	3.14	
P63	P63-7	3.54	3.35
	P63-8	3.31	
	P63-9	3.22	
P100	P100-7	2.61	2.79
	P100-8	2.88	
	P100-9	2.90	

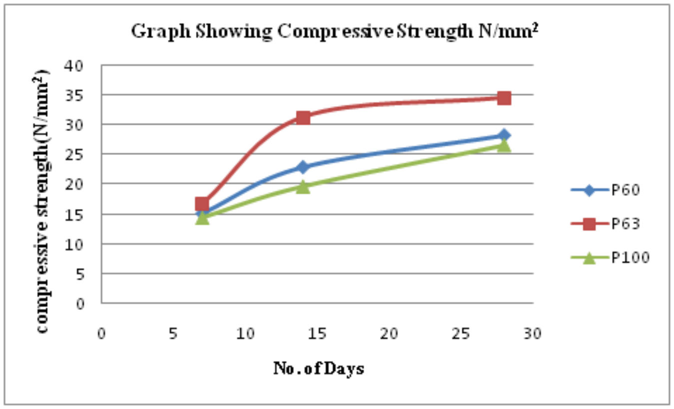

Fig 4.1: Compressive Strength of M30 for P60, P63 & P100

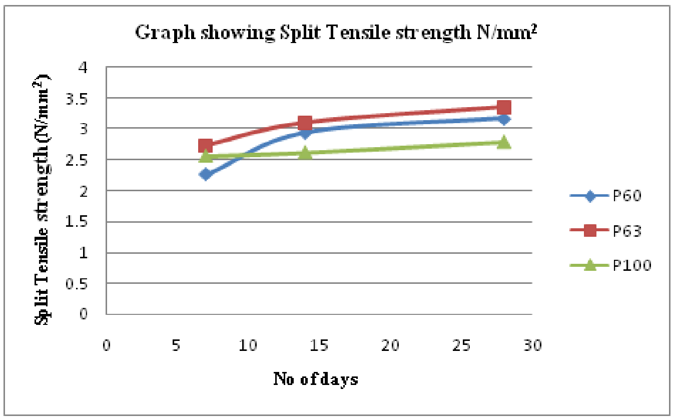

Fig 4.2: Split Tensile Strength of M30 for P60, P63 & P100

V. CONCLUSION

From the research work carried, the following conclusions were made,

1. The compressive strength and split tensile strength of geopolymer concrete increases with increase in fineness of fly ash up to P63 and then decreases with further increase in fineness of fly ash i.e. for P100.
2. For P63 type of fly ash rate of gain in strength of concrete for compressive strength and split tensile strength is higher than P60 and P100 fly ash.
3. The Compressive strength achieved for P63 concrete is 15.10% higher than desired strength of M30 concrete.
4. The Compressive strength achieved for P60 and P100 concrete is lower than desired strength of M30 concrete.
5. The Compressive Strength results for P63 concrete are observed greater than P60 and P100 fly ash concrete.
6. The Split Tensile Strength results for P63 concrete are observed greater than P60 and P100 fly ash Concrete.
7. Geopolymer concrete can be used as innovative construction material by saving in natural resources, sustainability and all other geopolymer concrete properties.
8. The result helps to build up faith and trust for the use of geopolymer concrete over conventional concrete.
9. Geoplymer concrete is an excellent alternative solution to the CO2 producing ordinary Portland cement concrete.

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