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Experimental Studies on Mechanical Properties of GEO Polymer Concrete with Fly-Ash and Metakoalin

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ABSTRACT: Over 2.5 billion tons production every year, Concrete is one of the mainly used construction material globally[1].This can be taken as a bench mark that use of cement in concrete has reached its threshold limit producing Carbon di-oxide contributing to 6% of total CO_2 around the globe.Geo-Polymer concrete is an emerging technology replacing waste by-products with cement[2].Lot of materials are available as by products such as Fly-Ash, Ground Granulated Blast Furnace Slag,Copper Slag,Meakoalin etc.. But the effective and optimized one to be selected based on experimental investigation. Of these metakoalin and Fly-Ash can be used as an effective replacement,[3].In this expeimetal study, tests were carried on concrete specimens with percentage replacement of Fly-Ash with Buff Metakaolin in variable percentages of 20,40,60,80.Alkali Solutions were used instead of water for better bonding and mixing. Sodium Hydroxide with 10M&12M and Sodium Sulphate solutions were used in the ratio of 1:2.Grade of concrete proposed was M50.Compressive strength Test and Split Tensile Strength Tests were performed and was compared with control mix results.

KEYWORDS: Geo-Polymer Concrete GPC, Fly Ash, Metakoalin, Sodium Hydroxide (NaOH), Sodium Silicate (Na2SiO3)

I. INTODUCTION

As Cement industries emits large amounts of greenhouse gases to produce cement from raw materials,different types of waste byproducts such as Fly-Ash, Ground Granulated Blast Furnace Slag,Copper Slag,Meakoalin etc are under study in replacing the cement.

When cement is replaced by waste by-products the demand of water also becomes reduces.As 20% Fly-Ash replacement in cement reduces around 10% of the water demand.In Metakaolin also replacement with cement reduces the water demand which shows almost no effect on long term effects in concrete such as Shrinkage or Cracking.As metakaolin in highly reactive alumino-silicate source material,It can be used an effective replacement for cement to enhance the mechanical and durability charecteristics of concrete.

All the above said waste by-products are fine and glassy materials which reduce the water content and increases the workability of concrete,which in turn reduces the concrete cost and also in producing an eco friendly material.

II. LITERATURE REVIEW

Veerabhadyatta.M,Vijay.S[3] has conducted tests on concrete specimens replacing fly-ash with 10%,20%,30%,40% and 50% for M40 grade concrete. The prepared moulds are heated at 60°C for 24 hours and placed it for sunlight curing. The results has shown that workability, compressive strength and split tensile strength of concrete has increased with 30% replacement of fly ash with metakaolin.

Chien-Chung Chen, ivan Diaz, kathleen Menozzi, luis Murillo[4] has studied the properties of concrete by replacing cement with GGBS and Fly-Ash.Variable Percentages of 50/50,75/25,85/15 as Slag/Fly-Ash were mixed and the cured

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concrete specimens were tested for Mechanical Properties. The studies has shown that the mixes used in this study has higher unit weight than that of control mix. Compressive strength and Flexural strength of the mix with higher slag/Flyash ratio has been increased compared to that of other mixes and conventional concrete also.

K. Srinivasan and A. Sivakumar has studied the effect of lime and alkali activator (sodium hydroxide) on the geopolymerisation of bentonite systematically. The experimental results showed that the initial and final setting time of binary mixtures containing bentonite and silica fume (5%) with alkali activator (NaOH) showed early setting time of 30 minutes compared to other geopolymer mixtures. It was also noted that compressive strength of ternary mixtures containing 40% bentonite, 30% flyash and 30% lime (M16) attained the maximum strength of 24.74 MPa at 28 days. The highest rate of strength gain was observed at early curing period (7 days) for the ternary mixtures (M14) consisting of 80% bentonite, 10% flyash and 10% lime compared to other mixtures. It can be realized from the experimental study that, geopolymerisation reaction was effective for the specimens cured at 100°C hot air oven.

III. MATERIALS AND METHODOLOGY

Binder Production**:** The cement is completely replaced with Silica and Alumina rich natural materials like *Metakaolin, Fly-Ash, Silica Fume, Rice husk Ash and Ground Granulated Blast Furnace Slag* to produce binders. These binders mixed with typical coarse and fine aggregate and alkaline activated solution in proportions produce Geo-Polymer Concrete

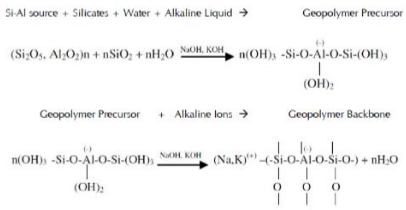

Fig.1 Binder Production

A. MATERIALS USED:

A.1 *Aggregates:* *C*oarse aggregate obtained in crushed rock form and fine aggregate in uncrushed form were used to prepare concrete in the laboratory.
A.2 *Cement:* Cement was used to prepare normal concrete for the comparison with fly ash based geopolymer concrete.
A.3 *Metakaolin:* Metakaolin can be obtained commercially for which it should be tested and ensured for use. They are two types of metakaolin are supplying

- White Metakaolin
- Grey to Buff Metakaolin
  Buff Metakaolin wa used in this study.

Fig.2 Buff Metakaolin

A.4 Fly-Ash*:* Fly ash can be obtained commercially for which it should be tested and ensured that the Fly-ash should be Class F type.

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Fig.3 Fly-Ash

A.5 Alkaline Liquid:

- In the present experimental work, a combination of sodium silicate (Na2SiO3) and sodium hydroxide (NaOH) solutions with molarity range 10M & 12M was proposed as the alkaline liquid.
- The sodium silicate solution is available commercially in liquid/powdered form where as Sodium Hydroxide solution is available commercially in pellet form for which we have to make liquid depending on the molarity of the pellets.
-

Fig.4 Sodium Silicate Solution

A.6 Superplasticizer:

Superplasticizers are water reducers which are capable of reducing water contents by about 30 percent. However it is to be noted that full efficiency of superplasticizer can be got only when it is added to a mix that has an initial slump of 20 to 30mm. Addition of super-plasticizer to stiff concrete mix reduces its water reducing efficiency. Depending on the solid content of the mixture, a dosage of
1 to 3 percent by weight of cement is advisable. In this present investigation, a super-plasticizer namely CONPLAST SP 430 has been used for obtaining workable concrete at low w/c ratio. CONPLAST SP 430 is based upon NSF condensates used for this study. The mechanism consists of very large molecules (colloidal size) which dissolve in water to produce ions with high negative charge (anions).

C. METHODOLOGY:

In this experimental study. Mechanical properties like compressive strength, split tensile strength of conventional concrete and geopolymer concrete with mix proportions as 100 % Fly Ash(M1) 100% buff MK (M2) 80%buff MK+ 20% fly ash (M3) 60% buff MK+ 40% fly ash (M4) 40% buff MK+ 60% fly ash (M5) 20% buff MK+ 80% fly ash (M6) for M50 grade was studies.

1. Materials were collected and their respective physical and chemical properties were studies.
2. As per IS: 10262-2009,Mix design for M50 grade concrete was carried out.
3. Specimens were prepared as per the above said mixes and cured at room temperature.
4. Control Mix concrete specimens were also prepared and cured in water.
5. The compressive strength test and split tensile strength tests were carried out for 7 days and 28 days in hydraulic compression testing machine.
6. Based on the comparative results conclusions were drawn.

D. MIX DESIGN:

A) Parameters

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- Target Strength : M50
- Type of cement : OPC 53 Grade
- Exposure condition : Mild
- Degree of supervision : Good
- Maximum Aggregate size : 20mm

B) Test Data for Materials

- Specific Gravity of cement :
- Specific Gravity of Fly-Ash
- Specific Gravity of Metakaolin:
- Specific Gravity of Coarse Aggregate:
- Specific Gravity of Fine Aggregate:
- Water absorption of Coarse Aggregate:
- Water absorption of Fine Aggregate:

C) Mix Proportions

- Cement : 420 kg/m^3
- Fine Aggregate: 773 kg/m^3
- Coarse Aggregate:773 kg/m^3
- Water : 152 kg/m^3
- Water Cement Ratio: 0.36
- Admixture: Conplast SP430(Napthalene based) at 2% of the weight of cement/Geopolymer.
- Mix Ratio: C:F.A:C.A:W/C =1:1.46:3.1:0.36

D) Tests Conducted**:**

- Compressive strength Test
- Split Tensile Strength Test

IV. RESULTS

Table:1 compressive strength results of mix with 10M solution (1:2) NaOH:Na2SiO3

COMPRESSIVE STRENGTH RESULTS OF MIX WITH 10M SOLUTION (1:2) NaOH:Na_2SiO_3			
Sl.No	**Mix Proportion**	**7 days N/mm^2**	**28 days N/mm^2**
1	C.C	31.5	49.7
2	100% F.A	FAILED	
3	100% Metakaolin	48.56	50.23
4	80%MK+20 %F.A	49.67	51.62
5	60%MK+40 %F.A	42.56	45.36
6	40%MK+60 %F.A	35.72	43.13
7	20%MK+80 %F.A	32.86	42.54

Table:2 compressive strength results of mix with 12M solution (1:2) NaOH:Na2SiO3

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Sl.No	Mix Proportion	7 days N/mm^2	28 days N/mm^2
1	C.C	31.5	49.7
2	100% F.A	FAILED	
3	100% Metakaolin	49.89	51.49
4	80%MK+20 %F.A	50.87	52.83
5	60%MK+40 %F.A	43.25	47.43
6	40%MK+60 %F.A	38.37	45.26
7	20%MK+80 %F.A	39.38	43.15

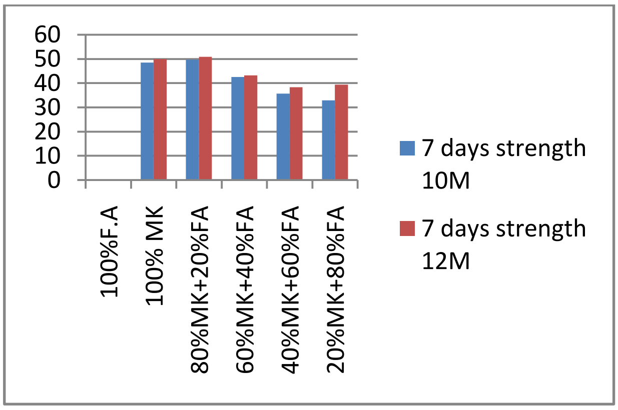

Fig.5: Variation of 7 days compressive strength with variation in % geopolymers for 10M &12M solution with 1:2 alkaline liquid ratio

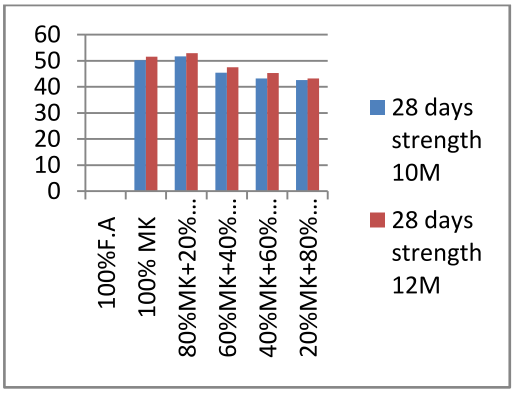

Fig.6: Variation of 28 days compressive strength with variation in % geopolymers for 10M &12M solution with 1:2 alkaline liquid ratio

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Table:3 Split Tensile Strength results of mix with 10M solution (1:2) NaOH:Na2SiO3

Sl.No	Mix Proportion	7 days N/mm^2	28 days N/mm^2
1	C.C	4.22	4.87
2	100% F.A	0.23	0.36
3	100% Metakaolin	2.23	3.67
4	80%MK+20%F.A	3.23	4.94
5	60%MK+40%F.A	2.78	3.73
6	40%MK+60%F.A	2.24	2.38
7	20%MK+80%F.A	0.27	0.59

Table:4 Split Tensile Strength results of mix with 12M solution (1:2) NaOH:Na2SiO3

Sl.No	Mix Proportion	7 days N/mm^2	28 days N/mm^2
	C.C	4.22	4.87
2	100% F.A	0.55	0.74
3	100% Metakaolin	3.34	4.26
4	80%MK+20%F.A	3.86	4.97
5	60%MK+40%F.A	3.53	3.82
6	40%MK+60%F.A	3.03	3.41
7	20%MK+80%F.A	1.73	2.24

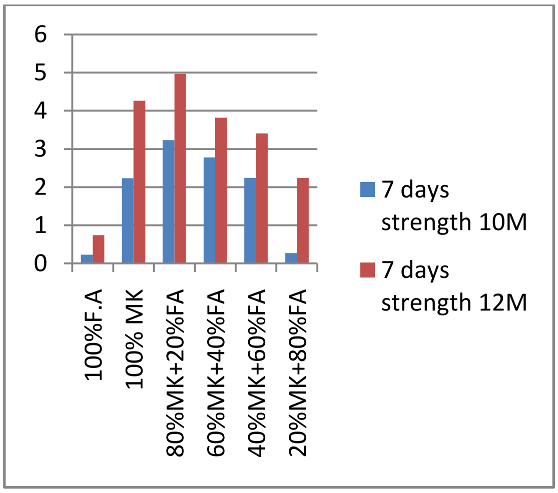

Fig.7: Variation of 7 days tensile strength with variation in % geopolymers for 10M &12M solution with 1:2 alkaline liquid ratio

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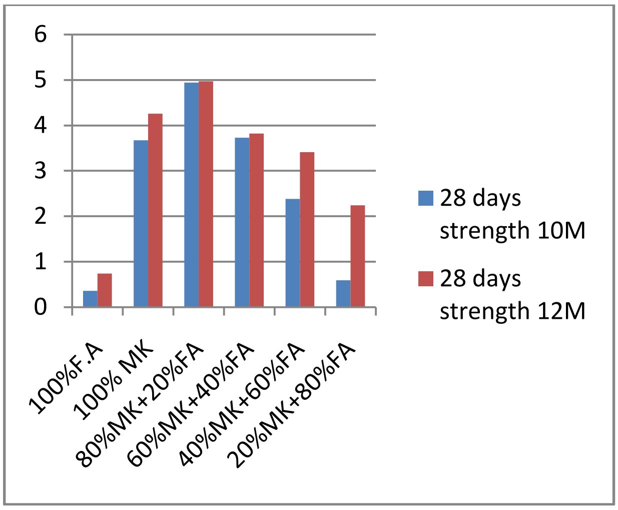

Fig.6: Variation of 28 days tensile strength with variation in % geopolymers for 10M &12M solution with 1:2 alkaline liquid ratio

V. CONCLUSION

- Workability of concrete increases with increase in percentrages of replacement of fly ash and metakaolin.At 20%F.A+80%MK,a very good enhance in workability can be observed.
- Optimum percentage of mix can be taken as 80%MK+20%FA.
- Compressive Strength of concrete has been increased by 1% for 10M and 3.5% for 12M when compared to that of conventional concrete.
- Split Tensile Strength has been increase by 1.4% for 10M and 2% for 12M compared to conventional concrete.

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