Prediction of Optimum Geopolymer Concrete Mix With Various Methods

Aleena Alan , Arathi S ,
Bikku Biju , Febina V Shaji
B.Tech Students
Department of Civil Engineering
Mangalam College of Engineering
Kottayam India

Dr. K Arunkumar
Associate Professor
Department of Civil Engineering
Mangalam College of Engineering
Kottayam India

***Abstract*— By chemically activating industrial waste byproducts including Bottom Ash, Flyash, GGBS, Wood Ash, Metakaolin, and others using alkali activator solutions, Geopolymer Concrete (GPC) has been created. It should be noted that the binding substance contains a suitable amount of aluminium silicate. The potential for the geopolymer concrete to replace OPC concrete is greater. The binders, such as GGBS and wood ash, are employed for the geopolymer mix at varied ratios from 0% to 100% as part of this experimental inquiry. Alkali-binder ratio, alkali activator component ratio, and concentrations are just a few of the GPC factors that are used in different combinations. According to the findings, the mixture should contain 0.55 alkali to every 70 percent GGBS and 30 percent wood ash at a 14M concentration for achieving maximum values for strength properties. We may infer that GGBS has a significant role in the higher values of the strength characteristics of the geopolymer mix.Due to the low cost of these byproducts, geopolymer concrete's widespread use will result in a very lucrative construction material that is also environmentally friendly.**

Keywords:Geopolymer concrete, Sodium silicate, Sodium hydroxide, Wood ash , Ground Granulated Blast Furnace Slag , varying parameters

1.INTRODUCTION

The cement acquires the position of being the most utilized product in widespread in all over the world. When combined with water, fine and coarse aggregate, and other binder materials, liquid cement is primarily used as the binding agent in concrete. This is so that the cement, when mixed with other concrete ingredients, may function very effectively as a binder material. The cement may provide the structural component formed of cement concrete with high workability, fresh concrete qualities, and mechanical properties.When producing clinker, an intermediary product in the cement manufacturing process, carbon dioxide emissions are released into the environment. Carbon dioxide is released into the atmosphere as a result of the excessive production of cement in every corner of the globe, which may speed up the greenhouse effect and eventually result in global warming. According to research and publications, it is clear that the manufacture of cement on a global scale contributes significantly to the increased rate of CO_2 in the atmosphere. In other words, excessive cement production is to blame for 8% of the world's CO_2 emissions. Therefore, finding an alternative to cement as a binder ingredient is important. As an equivalent for Portland cement concrete, geopolymer concrete is now popular in the construction sector in general. Making applications for precursor materials with an alumina silicate composition as well as an alkali activator solution allows for the production of geopolymer concrete.This study focus attention on green approach that can be implemented by exchanging any current materials with a different option materials that might deliver the same efficient functions.

2.OBJECTIVE

For achieving the optimum proportional mix of GGBS - Wood ash geopolymer concrete at varying percentage proportions of binders , varying molar concentrations of activator solution with varying ratios and at varying ratios of activator to binder ratios by means of mechanical properties.

3.MATERIALS

1.Ground Granulated Blast Furnace Slag: Ground Granulated Blast Furnace Slag (GGBS) which is a byproduct that is obtained during the steel and iron manufacturing process. It is used as a major binding material which consist of silica and alumina content.

Figure1 : GGBS

Table 1: Properties of GGBS

No	Properties	Value
1	Colour	Off white
2	Specific gravity	2.83
3	Fineness	7%
4	Bulk Density	1220 Kg/m^3

2.Wood Ash : Wood ash is obtained as waste product when a quantity of woods are subjected to fire.Here, wood ash is collected and used as binder material substituting the GGBS.

Figure 2 : Wood Ash

Table 2: Properties of Wood ash

No	Tests	Result
1	Average Particle Diameter (mm)	0.23
2	Bulk Density (kg/m^3)	853
3	Specific Surface Area (m^2/kg)	7800

2. **Alkali activator solution:** The NaOH- Na_2SiO_3 solution is used s activator solution for the present geopolymer concrete mix.

Table 2: Properties of NaOH

No	Properties	Values
1	Colour/appearance	White/pellets
2	Boiling point	102°C
3	Specific gravity	2.13
4	Molecular weight	1.5
5	Solubility	Soluble in water, ethanol and glycerol; insoluble in acetone and ether

Table 3 : Properties of Na_2SiO_3

No	Properties	Value
1	Na_2O	16%
2	SiO_2	32.30%
3	H_2O	51.70%
4	Appearance	Liquid
5	Colour	Light yellow
6	Molecular weight	184
7	Specific gravity	1.6
8	Boiling point	102^0 C

3. **Fine aggregate :** The sand which confirms with IS 383:2016 are selected as the fine aggregate for the present work.

Figure 3 : Natural sand

Table 4 : Properties of fine aggregates

No	Properties	Value
1	Specific gravity	2.63
2	Grain size analysis	Grading Zone : Zone III Fineness : 3.01%

4. **Coarse aggregate :** Coarse particles of nominal size 10mm are selected. The coarse aggregate confirms with IS 383:2016.

Figure 4:Coarse aggregate

Table 5 : Properties of Coarse aggregates

No	Properties	Values
1	Specific gravity	2.8
2	Fineness	6%

4.MIX DESIGN

The mix design for the geopolymer concrete mix is adopted from the journal named 'Modified Guidelines Geopolymer concrete mix design using Indian Standard'. The GGBS - Wood ash binder percentage varies from 0 to 100%. The activator solution to binding material ratio is selected at a range of 0.40 to 0.70 at 0.5 increasing rate. The alkali activator component ratio varies at 1 , 1.5 , 2 , 2.5. The molar concentration ranges at 8M to 14M at 1M increasing rate.

Table 6: Proportions of different parameters for Geopolymer concrete mix

No	Parameters	Range
1	GGBS to Wood Ash	0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100
2	A/B Ratio	0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.7
3	Sodium hydroxide to Sodium silicate Ratio	1, 1.5, 2, 2.5
4	Molar Concentration	8, 9, 10, 11, 12, 13, 14

5.METHODOLOGY

For the present work , GGBS , Wood ash , natural sand and coarse aggregate , $NaOH-Na_2SiO_3$ solution are used .The physical properties of GGBS and Wood ash has been collected from the factories. The physical properties of aggregates has been determined by performing test as per IS 383:2016. The Geopolymer concrete at varying parameters has been casted and cured by means of ambient curing. The strength properties such as compressive strength , split tensile strength and flexural strength has obtained at 3, 14 and 28 days of curing.

Figure 5: Casting of specimens

Figure 6 : Testing of specimens

6.RESULT AND DISCUSSION

6.1 Compressive strength test

Compressive strength test has been performed on Geopolymer concrete cube consisting varying parameters at 3, 14 and 28 days of curing.The investigation has been executed as per IS 516:1959.

Table 7: Compressive strength of GPC

Mix IDs	Compressive Strength in MPa		
	3 days	14 days	28 days
GW30D4M8	19.8	23.5	24.1
GW30D4M9	20.6	24.3	25.4
GW30D4M10	21.3	25.4	26.5
GW30D4M11	22.8	26.0	27.8
GW30D4M12	23.5	26.8	29.3
GW30D4M13	24.3	28.3	30.2
GW30D4M14	25.8	30.2	33
GW40D4M8	18.8	21.5	22.5
GW40D4M9	19.5	22.1	23.1
GW40D4M10	20.0	22.8	23.9
GW40D4M11	20.8	23.5	24.8
GW40D4M12	21.5	24.6	25.5
GW40D4M13	22.4	25.8	26.3
GW40D4M14	23.1	26.3	27.5
GW50D4M8	17.6	18.5	20.5
GW50D4M9	18.4	19.6	21.6
GW50D4M10	19.8	20.4	22.0
GW50D4M11	20.5	21.6	22.8
GW50D4M12	21.2	22.9	23.4
GW50D4M13	21.8	23.8	24.6
GW50D4M14	22.5	24.6	25.1

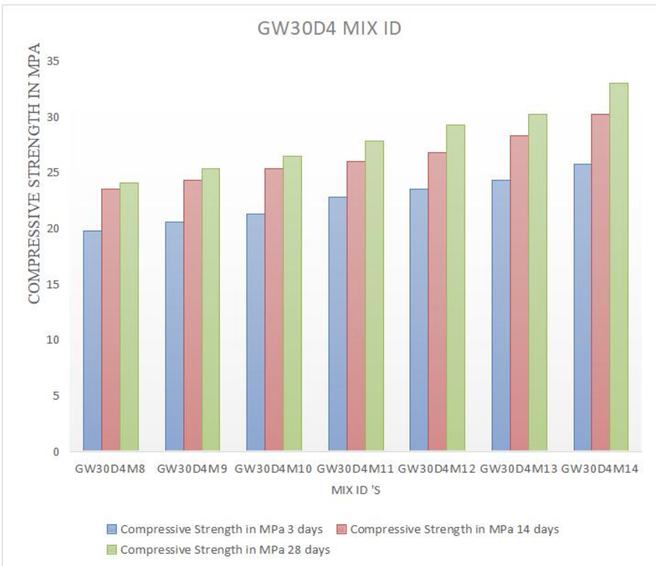

Figure 7: Compressive strength for Category GW30D4

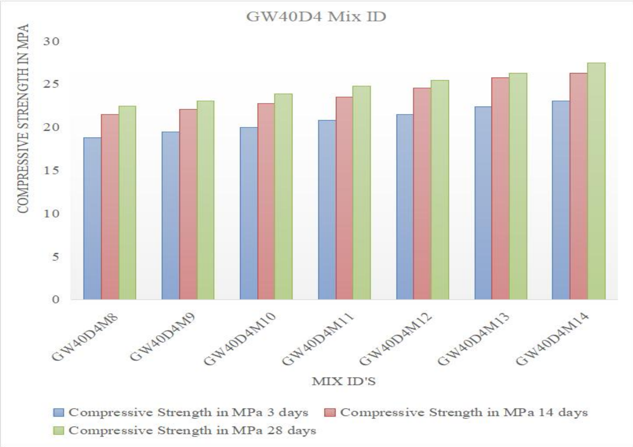

Figure 8: Compressive strength for Category GW40D4

Figure 9:Compressive strength for Category GW50D4

The Mix GW30D4M14 has maximum compressive strength of 33 MPa at 28 days of curing. The mix consist of alkali-binder ratio of 0.55 , alkali activator solution ratio of 2.5 with 14M molarity.

6.2 Split tensile strength test

Split tensile strength test has been executed for Geopolymer concrete cylinders consisting varying parameters at 3 , 14 and 28 days of curing.The test is conducted as peer IS 5186:1999.

Table 8: Split tensile strength of GPC

Mix IDs	Tensile Strength in MPa		
	3 days	14 days	28 days
GW30D4M8	2.50	5.30	5.40
GW30D4M9	2.60	5.50	5.80
GW30D4M10	2.90	5.60	6.10
GW30D4M11	3.40	5.80	6.70
GW30D4M12	4.20	5.80	7.80
GW30D4M13	4.80	6.50	8.80
GW30D4M14	5.30	7.30	9.30
GW40D4M8	2.10	4.80	5.00
GW40D4M9	2.50	5.00	6.10
GW40D4M10	3.30	5.20	6.80
GW40D4M11	3.70	5.50	7.50
GW40D4M12	4.10	5.80	7.90
GW40D4M13	4.40	6.20	8.30
GW40D4M14	4.70	6.50	8.60
GW50D4M8	1.80	4.50	4.60
GW50D4M9	2.50	4.70	5.50
GW50D4M10	3.00	4.90	6.20
GW50D4M11	3.50	5.20	6.70
GW50D4M12	3.90	5.50	7.10
GW50D4M13	4.20	5.80	7.40
GW50D4M14	4.40	6.10	7.80

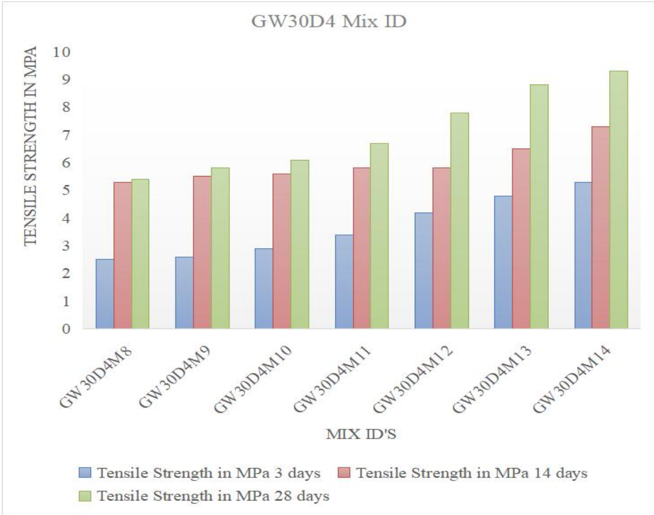

Figure 10: Split tensile strength for Category GW30D4

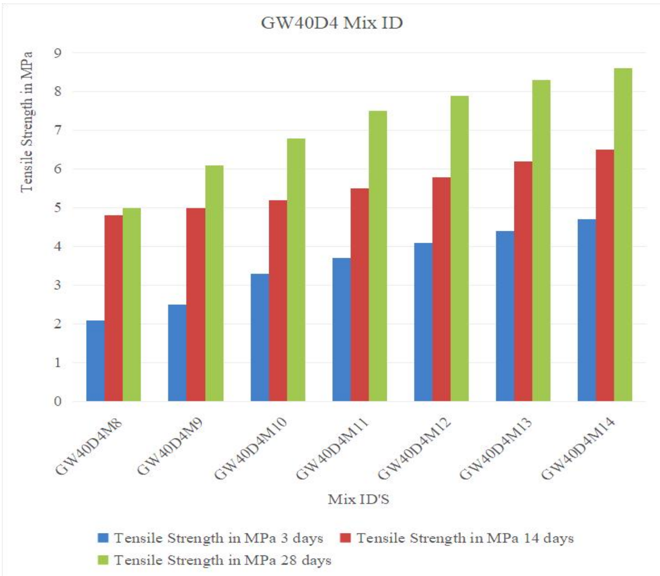

Figure 11 :Split tensile strength for Category GW40D4

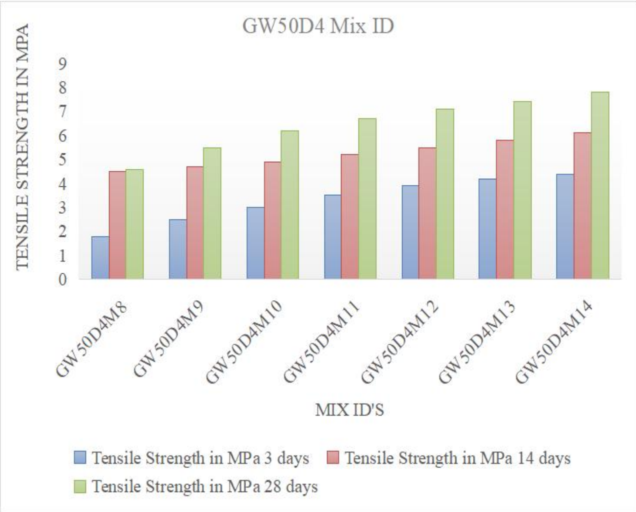

Figure 12 :Split tensile strength for Category GW50D4

The Mix GW30D4M14 has maximum split tensile strength of 9.30 MPa at 28 days of curing. The mix consist of alkali-binder ratio of 0.55 , alkali activator solution ratio of 2.5 with 14M molarity.

6.3Flexural strength test

The Flexural strength test has been executed for Geopolymer concrete beams consisting varying parameters at 3 , 14 and 28 days of curing.The test has been executed as per IS 516:1959.

Table 9 : Flexural strength test results

Mix ID	Flexural Strength in MPa		
	3 days	14 days	28 days
GW30D4M8	2.5	5.35	6.10
GW30D4M9	2.6	5.50	6.30
GW30D4M10	2.9	5.60	7.20
GW30D4M11	3.4	5.70	7.10
GW30D4M12	4.31	5.80	8.10
GW30D4M13	4.26	6.50	8.80
GW30D4M14	4.80	7.30	9.30
GW40D4M8	2.20	5.05	5.60
GW40D4M9	3.90	5.70	6.50
GW40D4M10	3.20	5.25	7.10
GW40D4M11	3.80	6.05	7.80
GW40D4M12	4.10	6.60	8.10
GW40D4M13	4.35	6.95	8.45
GW40D4M14	4.50	7.10	8.70
GW50D4M8	1.90	4.60	5.10
GW50D4M9	2.45	4.20	5.55
GW50D4M10	2.85	5.05	6.05
GW50D4M11	3.10	5.45	6.50
GW50D4M12	3.45	5.90	6.90
GW50D4M13	3.80	6.15	7.30
GW50D4M14	4.10	6.50	7.80

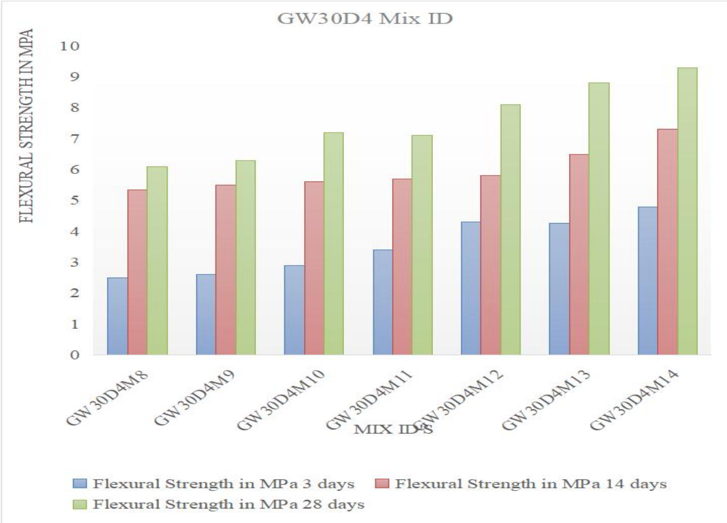

Figure 13 : Flexural strength for Category GW30D4

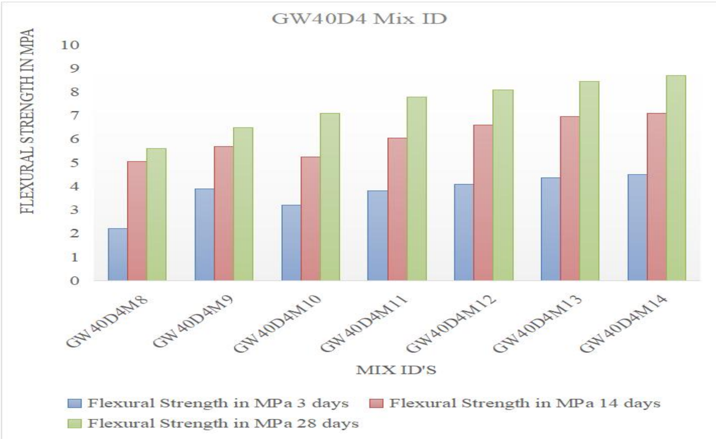

Figure 14 : Flexural strength for Category GW40D4

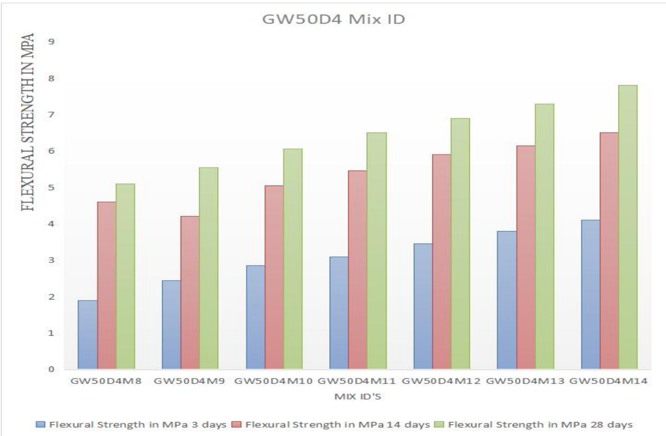

Figure 15 : Flexural strength test for Category GW50D4

The Mix GW30D4M14 has maximum flexural strength of 9.30 MPa at 28 days of curing. The mix consist of alkali-binder ratio of 0.55 , alkali activator solution ratio of 2.5 with 14M molarity.

7. CONCLUSIONS

- According to the findings, the mix ID GW30D4M14 containing 0.55 alkali to every 70% GGBS and 30% wood ash at a 14M concentration has been achieved maximum values for strength properties.
- When compared with the other mix categories, The mix category GW50D4 has achieved strength in every aspect at a lower rate.
- Strength characteristics fall as the dosage of wood ash goes up.
- Due to the low cost of these byproducts, geopolymer concrete's widespread use will result in a very lucrative construction material that is also environmentally friendly.

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