An Experimental Study on Mechanical Properties of Geo-Polymer Concrete Incorporating Waste Brick Powder as Fine Aggregate

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Abstract: - The Geo-polymer concrete is the mixture of Binder and addition material with fully replacement of cement constituent in concrete mixture. The Durability and Strength of Geo-Polymer Concrete is the important point of discussion to making it ready for construction industry use. The Research and development work of Geo-Polymer concrete have been running from last 15 years vigorously to make it user friendly. It has been seen that incorporation of various materials into Geo polymer concrete as a replacement of cement and sand gave good results but few issues could not be resolved. Geo polymer concrete is used as an alternative material of Conventional Concrete. Many waste materials are also incorporating into this concrete to check the feasibility of using this material with some addition property. Geopolymer material is an eco-friendly material with low emission of Carbon dioxide. The reuse of Waste Material can reduce the overall cost of concrete and protect the environment as well.

Keywords:- *Geo-Polymer; Compressive Strength; Ground Granulated Blast Furnace Slag; Fly Ash; Waste Brick Powder etc.*

I. INTRODUCTION

The concrete material is the most powerful material used in construction industry among all the civil engineering material. The demand of concrete material has been rising continuously because of its versatile properties. Along with the increasing demand there is some challenges of improving stability and strength of the concrete with fulfilling eco-friendly aspect of the concrete is expected more in present time. The main binding material of the concrete, Cement emits great carbon dioxide during manufacturing process which is very harmful for environment and living organisms. As a replacement of cement many researchers have used ground granulated blast furnace slag, microfine and fly-ash. To protect the environment, it is appropriate demand to preserve the nature for future generation. The geopolymer concrete is an alternative eco-friendly material which possess low carbon dioxide and protect the environment from these toxic gases.

The alternative material is mainly divided into three parts: Agriculture waste, industrial byproduct, and municipal waste. The industrial byproduct includes fly ash, silica fume, cement kiln dust and Slag etc. The agriculture waste contains rice husk ash, palm oil fuel ash, natural fiber and corn cob ash etc. The municipal waste contains water glass, solid waste ash and construction waste etc. In the geopolymer, Geostands for the source material which is rich in silicon and aluminum content with geological origin. The rich silicon and aluminum are present in fly ash and ground granulated blast furnace slag. The polymer stands for a long chain of molecule with silicon and alumina using alkali activator. This chain making process is called polymerization. The term Polymer first used by scientist Joseph Davidovits in year 1978. He briefed this word with an inorganic composition. The major concept of geopolymer concrete is a fully replacement of cement material by other waste material or cementitious material with proper mix design. This is the need of an hour to develop geopolymer concrete in such a way to use by construction industry on full scale. The researchers have been continuously working to enhance the physical and chemical properties of geopolymer concrete to make this ready for industry purpose. The geopolymer concrete can be used in construction industry for making pavements retaining wall water tank precast members if could have developed properly.

II. MATERIALS

A. *Materials*

a. Ground Granulated Blast Furnace Slag (GGBS) andFly ash:

As a fully replacement of cement, Ground granulated Blast Furnace Slag (GGBS) and Fly ash have used in combination. The GGBS used in this study due to rich mechanical and chemical properties of this material. Fly ash is also used as a combination with GGBS material.

- GGBS Physical Composition:
  Material Color: WhiteSpecific Gravity: 2.78
  Bulk Density: 1260-1360kg/m^3Fineness: > 325 m^2/kg

- Fly Ash Physical Composition:
  Class: F
  Color: Dark Grey Specific Gravity: 2.65
  Size of Particles: between 10 to 100 Micron

b. Alkali Activator:

The Geopolymer Concrete are prepared using alkali activators reacting with other ingredients in the concrete. The Alkali activators are prepared by concentrated solutions of alkaline hydroxide, Silicon, Calcium or Sulphate etc. The Solution named aluminosilicate is generally available in powder as an industrial by product or similar low-cost material. The Alkali activated material are also known as Geo-Polymer Concrete. These Alkali activators are used in the binder waste material like Fly ash and GGBS to form into geo-polymer concrete materials. In this study, the alkaline liquid such as Sodium Hydroxide (NaOH) and Sodium Silicate (Na_2SiO_3) are used. The silica Fume and Metakaolin can be used to prepare geopolymer concrete. In this process when we add sodium hydroxide and silica oxide to fly ash and Ground Granulated Blast Furnace Slag to the ingredient of concrete then it requires more silicate and aluminate monomers to get the process done. The Sodium containing activators are selected because these are less expensive than potassium- based activators. The flags and pallets are dissolved into the water during manufacturing process of hydroxide solution. The ratio of alkali materials is very important in mix design. In this study, the ratio is kept 0.3 of alkali activators.

c. Natural Sand:

The Quality of Fine aggregate makes direct impact on fresh concrete properties such as strength and workability. The Particles of natural sand must have a particular shape so that it can be used into the concrete and gives good results as expected. The Spherical shape of sand particles helps in reduction of percentage of voids in the concrete mixture. This can be helpful in no requirement of additional chemical or paste for mixture. This Sand is prepared using crushing of larger size aggregate. For Getting good results, the spherical size particles are considered as ideal for concrete mixture.

d. Waste Brick Powder:

The Waste brick powder is a powder which is made up of waste brick during manufacturing process of bricks in the kilns. The Waste Brick powder is a kind of waste and having no further use. The Waste baked Powder is also known as surkhi or burnt clay. It can be used as a fine aggregate. As a waste material it has no further use but researchers have been trying to use this into the concrete mixture as a replacement of sand. The Feasibility must be checked properly before adding it into the concrete mixture.

e. Coarse Aggregate:

The Workability and Strength of concrete mix depends on quality and gradation of coarse aggregate. It also depends upon the dispersion of aggregate into the mix. If the aggregate sizes are more than 4.75 mm, it is categorized as coarse aggregate. The Larger volume of the concrete covers by coarse aggregate. The Initial and ultimate strengths are depending upon the quality of coarse aggregate.

f. Admixture:

In this study, the high strength and water reducer admixtures have been used. The Perma Plast PC-405 admixture have used as per mix design. The Doses are finalized by mix design of target strength. Although the amount of admixture must be in between the range of0.3 to 1.5% by the weight of cement. It must be very precise to avoid the problem related to strength and workability.

III. METHODS AND EXPERIMENTAL DATA

a. Trial for Mix Design Proportion (Coarse to FineAggregate)

Table 1: Coarse to fine Aggregate ratio for different mixes

Mix Design	Binder Content (Kg/m3)	CA:FA	CA: FA	CA: FA	CA: FA	S/B
MD-1	325	50:50	55:45	60:40	65:35	0.50
MD-2	350					
MD-3	375					

b. Compressive Strength Results on 3rd day

The Compressive Test were conducted on different mixes as per mix design and comparative analysis was done. These results were very important for this study to move ahead of another tests. The results found best on the proportion of 60:40 of Coarse Aggregate and Fine Aggregate. The results are mentioned below with average value of those tests to get exact comparison.

Table 2: Compressive Strength Value at 3rd Day Trial Mix

CA: FA → Binder ↓ (kg/m3)	50:50	55:45	60:40	65:35
	Compressive Strength in N/mm2			
325	10.47	15.99	16.01	17.75
	10.65	15.75	15.85	17.45
	10.55	15.55	15.05	17.17
Avg. Value	**10.56**	**15.76**	**15.63**	**17.45**
350	11.45	17.16	18.75	16.76
	11.42	17.05	18.65	16.85
	11.38	17.35	18.45	16.85
Avg. Value	**11.41**	**17.18**	**18.62**	**16.82**
375	15.98	16.09	16.47	18.58
	15.85	16.65	16.06	18.25
	15.80	16.25	16.15	18.16
Avg. Value	**15.88**	**16.33**	**16.22**	**18.33**

c. Material Proportion of Mix Design-2 (350 Kg/m³)

Table 3: Proportion of Ingredient as per MD-2

Mix Design	CA: FA (%)	Waste Brick Powder (%)	Natural Sand (%)	S/B
MD-2	60:40	0	100	0.50
		50	50	
		100	0	

Table 4: Mix Design Proportion

Binder Content (Kg/m3)	Coarse Aggregate (Kg/m3)	Fine Aggregate (Kg/m3)	Alkali Solution (Kg/m3)	Additional water req.
350	1055.20	668.58	185	4% of the Alkali Solution
1:1.75:2.75				

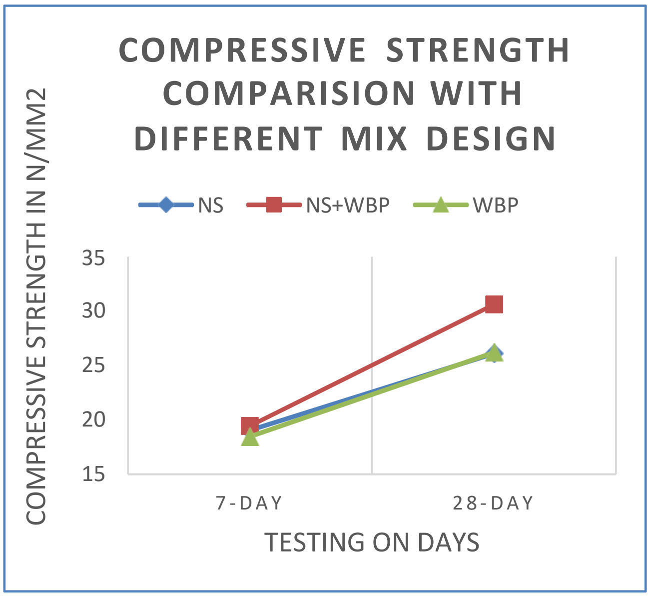
d. Compressive Strength Test Observation on Day-7 andDay-28

Table 5: Compressive Strength Observations on Day-7

Sr. No.	Natural Sand (N/mm2)	Natural Sand + Waste Brick Powder (N/mm2)	Waste Brick Powder (N/mm2)
1	19.66	19.91	18.63
2	18.42	19.41	18.05
3	19.09	19.05	18.75
Avg.	19.05	19.45	18.47

Table 6: Compressive Strength Observations on Day-28

Sr. No.	Natural Sand (N/mm²)	Natural Sand + Waste Brick Powder (N/mm²)	Waste Brick Powder (N/mm²)
1	26.67	30.71	25.30
2	25.42	31.06	26.05
3	26.18	29.95	27.10
Avg.	26.1	30.6	26.2

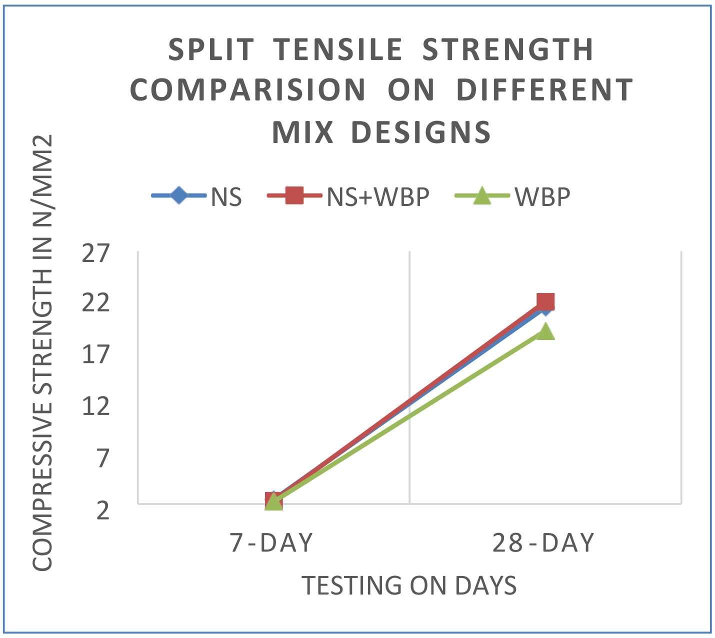


Graph 1: Compressive Strength Observation Graph

e. Split Tensile Strength Test Observations

Table 7: Split Tensile Strength Test Observation on Day-28

Sr. No.	Natural Sand (N/mm2)	Natural Sand + Waste Brick Powder (N/mm2)	Waste Brick Powder (N/mm2)
1	23.67	22.88	19.09
2	22.73	21.59	19.05
3	22.94	21.53	19.13
Avg.	21.44	22.00	19.14

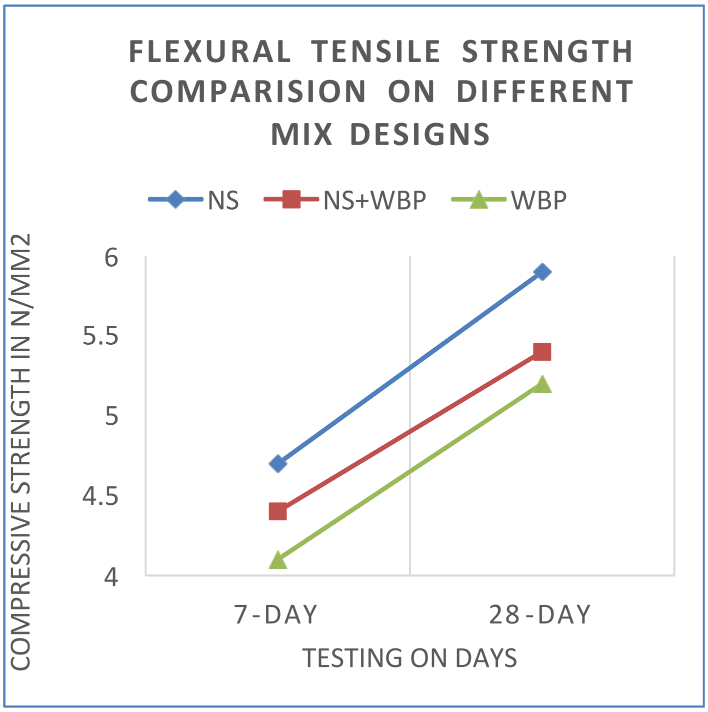


Graph 2: Split Tensile Strength Comparison graph

f. Flexural Strength Test Observations

Table 8: Flexural Strength Test Observation on Day-28

Sr. No.	Natural Sand (N/mm2)	Natural Sand + Waste Brick Powder (N/mm2)	Waste Brick Powder (N/mm2)
1	5.2	5.4	5.3
2	5.5	5.3	5.1
3	5.3	5.5	5.2
Avg.	5.3	5.4	5.2



Graph 3: Flexural Strength Comparison graph

g. Carbonation Test Observations

Table 9: Carbonation Depth Observations

Sr. No.	Mix Design	Sample	Carbonation Depth(mm)	Avg. (mm)
1	Natural Sand	1	12.4	12.37
2		2	12.7	
3		3	12	
4	Natural Sand + Waste Brick Powder	1	10.2	10.23
5		2	10	
6		3	10.5	
7	Waste Brick Powder	1	8.8	8.56
8		2	8.6	
9		3	8.3	

h. NDT (Ultrasonic Pulse Velocity Test) Observations

Table 10: Ultrasonic Pulse Velocity Observations

Specimen No.	Pulse Velocity Value in Km/Sec			
	Direct Method	Average and Grading	Semi Direct Method	Average and Grading
1	5.25	4.93 (Excellent)	4.2	4.1 (Good)
2	5.5		3.9	
3	4.2		4.3	
4	4.9		4.1	
5	4.8		4.0	

IV. CONCLUSIONS

In this experimental study, following conclusions are givenbased on all observations:

- The Proportion of Binder content with 60% Fly ash and 40% Ground Granulated blast furnace slag for mix having density 350 kg/m^3 showed best results with solution binder ratio 0.50.
- The Value of Compressive Strength found maximum

  30.6 MPa by adding 50% Natural sand with 50% of waste brick powder.
- The Observation of Split Tensile Strength was found maximum 22 MPa on 28th Day Testing.
- The Open-Air Curing have good results on polymerization.
- The Flexural Strength value was found maximum 5.5 MPa adding both Natural Sand and Waste BrickPowder.
- The Water Absorption of waste brick powder was too high therefore results could not match the expected outcome.
- The Carbonation Depth was observed low and good results found adding both waste brick powder and Natural Sand.
- The Observations found in NDT (Rebound Hammer andUltrasonic pulse velocity) was quite impressive. The uniformity and homogeneity of ingredient of concrete found good.
- Adding Waste brick powder have direct impact on the economic factor in construction industry.

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