Effects on Processed Geopolymer Concrete With Respect to Different Strength Parameters

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Abstract

The objective of this study is to study the effects of partial replacement of MIRHA on processed fly ash as a geopolymer concrete, and it is compared with the unprocessed fly ash and plain cement concrete. The strength of plain cement concrete increases gradually from 3 to 28 days of water curing. The strength of processed and rice husk ash processed flyash geopolymer concrete mixes gains early strength within 3 days of curing and later increases only by 20 to 25% at the end of 28 days of curing. The strength of rice husk ash processed flyash geopolymer concrete mixes increases from 2% to 3% replacement, and beyond 5% replacement, the strength starts decreasing. 3% rice husk ash processed flyash geopolymer concrete gives the maximum value of compressive strength as compared to other mixes. As the percentage of rice husk ash is changed from 2% to 10%, the flyash to alkaline activator ratio goes on decreasing from 0.66 to 0.43. The more the rice husk is replaced, less will be flyash to alkali activator ratio, but there will be decrease in strength.

Keywords: **Alkaline activator, concrete, curing, fly ash, geopolymer, MIRHA, rice husk ash**

I. INTRODUCTION

Production of cement causes a large volume of carbon dioxide (CO_2) emission causing temperature rise and global warming. It is estimated that one tonne of cement approximately requires about 2 tonnes of raw materials (Limestone and Shale), and releases about 0.87 tonne of carbon dioxide, and about 3 kg of nitrogen oxide. Production of cement causes greater impact on environment causing changes in land-use patterns, and local water contamination, as well as air pollution. Fugitive CO_2 emissions also pose huge threat to the environment. The cement industry does not fit in sustainable development as the raw materials used for production are not recycled and are non-renewable. The waste material or by-product from the industry can be utilized for reduction of carbon dioxide CO_2 emission. Emphasis on energy conservation and environmental protection has been increased in recent times, which have led to the investigation of alternatives to customary building materials and technologies. Thus, the material or by product of an industry could be used in cement production thereby, lessening carbon foot print. Inorganic polymer or organic polymer composites possess the potential to form a substantial element to form an environment friendly and sustainable constructional building material which produces lower greenhouse footprint when compared to the traditional concrete.

II. EXPERIMENTAL INVESTIGATION

A. Preamble

The testing program was decided based on the literature survey and objective of the proposed work. In the present study, a total of 96 cubes having different combinations of mix, material specification test program, compressive strength, and materials were used.

B. Experimental Investigations From Literature Reviewed

The details of the mix design are given in Table I denoted by M6, which gives a compressive strength of 33N/mm^2 and tensile strength of 2.865 N/mm^2.
The details of mix design M6 are as follows:

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TABLE I.
MIX DESIGN OF MIX M6

Material	Content kg/m^3
Fly Ash	483.7
Coarse Aggregates	882.2
Fine Aggregates	652.1
Na_2SiO^3	224.6
NaOH	89.8
Water	14.2

III. EXPERIMENTAL SETUP

The flyash used for further experiment of the project is of Dirk India's (Pozzocrete 63) flyash. This is an ISI certified flyash. Pozzocrete 63 is a high efficiency class F pozzolanic material confirming to BS 3892 obtained by selection, and processing of power station fly ashes resulting from the combustion of pulverized coal. Microwave Incinerated Rice Husk Ash (MIRHA) of different particle size has been used as a partial replacement in flyash based Geopolymer concrete. In our experimentation study, rice husk ash of specific fineness was used, whose particle size was less than 45µ I.S. sieve.

Rice husk ash passing through 45µ I.S. sieve will be used, as it will partially replace the same processed flyash (P63) by its same particle size. Residue on sieve (R.O.S.) on 45µ sieve of P63 is 10%. Densification of geopolymer framework is obtained due to finer particle size.

4.75mm, 2mm, 1mm, 500µ, 90µ & 45µ I.S. sieve with receiver and lid are used to sieve different raw materials. 20mm and 10mm I.S. sieve with receiver and lid are used to sieve the coarse aggregate. Mechanical shaker is used for sieving rice husk ash. 100 x 100 x 100 mm concrete cube casting moulds, which confirms to I.S. 10086-1982 are used. 70 x 70 x 70 mm mortar casting moulds are used to cast the processed flyash geopolymer mortar cubes which confirms to I.S. 10086-1982.

Vibratory Table (Table Vibrator) is used for proper compaction purpose. Microwave Temperature Controlled Oven is used for curing the cubes at 600 ^oC for 24 hrs. Compressive Testing Machine (CTM) having a least count of 10 kN is used to find the compressive strength of casted cubes at 3, 7, 14, and 28 days. Compacting (Tamping) Rod, 25 mm in diameter, confirming to I.S. 10086-1982 is used to compact the geopolymer mix filled in three layers. Weighing balance of 100kg capacity is used to weigh the required material. Oiling is done for good finishing and easy demoulding of cubes. Pycnometer bottle (Fig. 2) is used to find specific gravity of different materials.

Fig. 1. Mechanical Shaker With 45µ I.S. Sieve With Lid and Receiver

Fig. 2. Pycnometer Bottle Filled With Rice Husk Ash and Water

IV. MATERIALS USED

A. Coarse Aggregates

Locally available crushed stone aggregates of size passing through 20mm were retained on 10mm I.S. sieve, whose specific gravity was 2.9 were used.

B. Fine Aggregates

Locally available natural river sand of size passing through 4.75mm I.S. sieve, whose specific gravity was 2.6 was used.

C. Processed Flyash (P63)

Processed flyash of Dirk India's P63 grade was used to prepare processed flyash based geopolymer concrete, whose specific gravity was 2.12. It had Bulk density of $900kg/m^3$. The properties of P63 are given in Table II.

TABLE II.
PROPERTIES OF PROCESSED FLYASH P63

Specification	Value
Fineness as per Blaine's Permeability	400 m^2/kg
R.O.S. on 45µ sieve	10%
Loss on ignition (max)	2.5%
Moisture content (max)	0.50%
$SiO_2+Al_2O_3+FeO_3$	90% (min)
SiO_2	50% (min)
CaO	5% (max)
MgO	4% (max)
SO_3	2% (max)
Na_2O	1.5% (max)
Total Chlorides	0.05% (max)

D. Unprocessed Fly Ash

Locally available unprocessed flyash from flyash bricks manufacturing plant was used to prepare unprocessed flyash based geopolymer concrete which confirms to I.S. 3812. The specific gravity of unprocessed fly ash was 1.7. Its recommendations are given in Table III.

TABLE III.
PROPERTIES OF UNPROCESSED FLYASH

Specification	Unprocessed Flyash
Fineness as per Blaine's Permeability m^2/kg	320
R.O.S on 45µ sieve (max %)	34
Loss on Ignition (max %)	5
$SiO_2+Al_2O_2+Fe_2O_3$ (%)	70
SiO_2 (%)	35
Moisture Content (max %)	2

Fig. 3. Coarse Aggregate

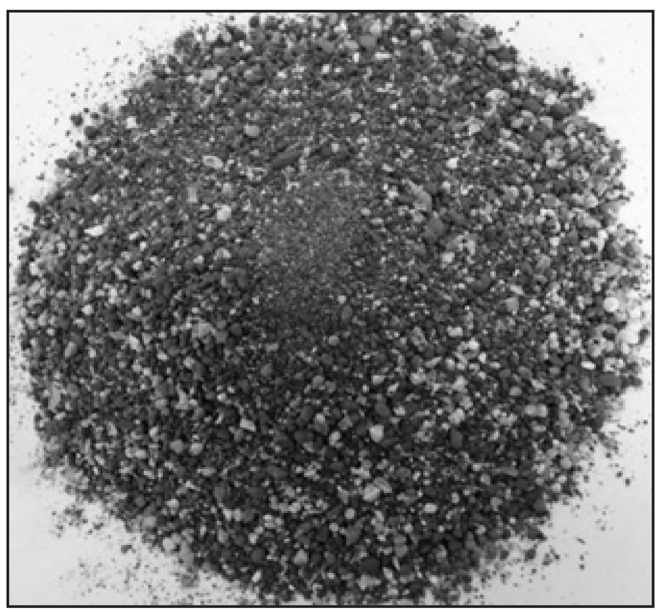


Fig. 4. Fine Aggregate

Fig. 5. Processed Flyash (P63)

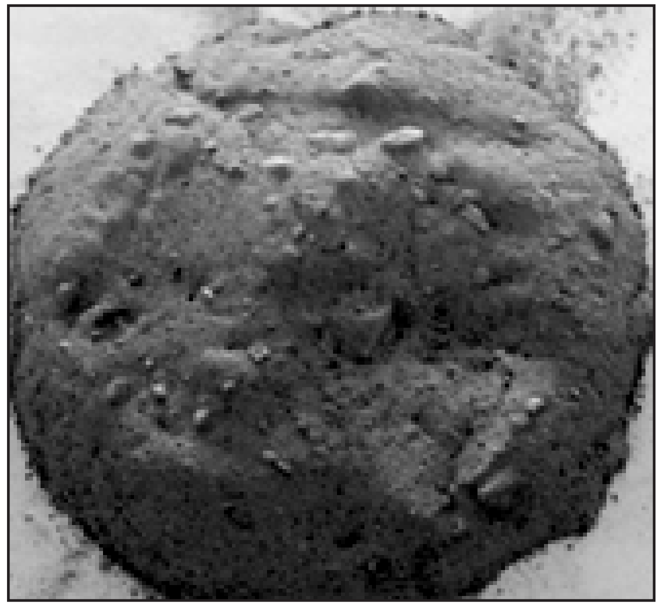


Fig. 6. Unprocessed Flyash

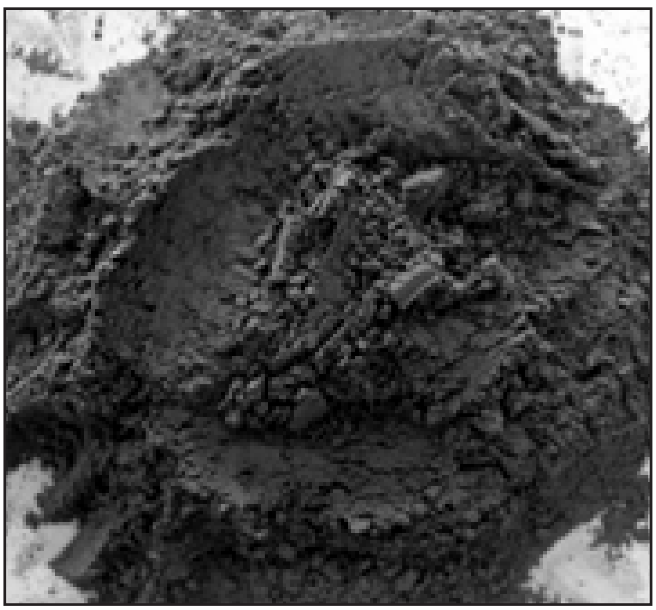


Fig. 7. Rice Husk Ash

E. Alkali Activators

1. Sodium Hydroxide (NaOH)
2. Sodium Silicate (Na_2SiO_3)

V. TEST PROCEDURE

- Compressive strength of geopolymer concrete
- Weighing the materials as per mix design
- Dry mixing
- Wet mixing
- Filling up test moulds and compaction
- Rest period
- Curing
- Demoulding

A. Testing

The compressive testing is carried out for 3 days, 7 days, 14 days, and 28 days of curing. As per I.S. 456-2007, the compressive strength of concrete is found out of average of 3 values of similar concrete cubes.

Fig. 8. Dry Mixing


Fig. 9. Wet Mixing


Fig. 10. Filling up of Moulds


Fig. 11. Compaction by Table Vibrator

Fig 12. Oven Curing

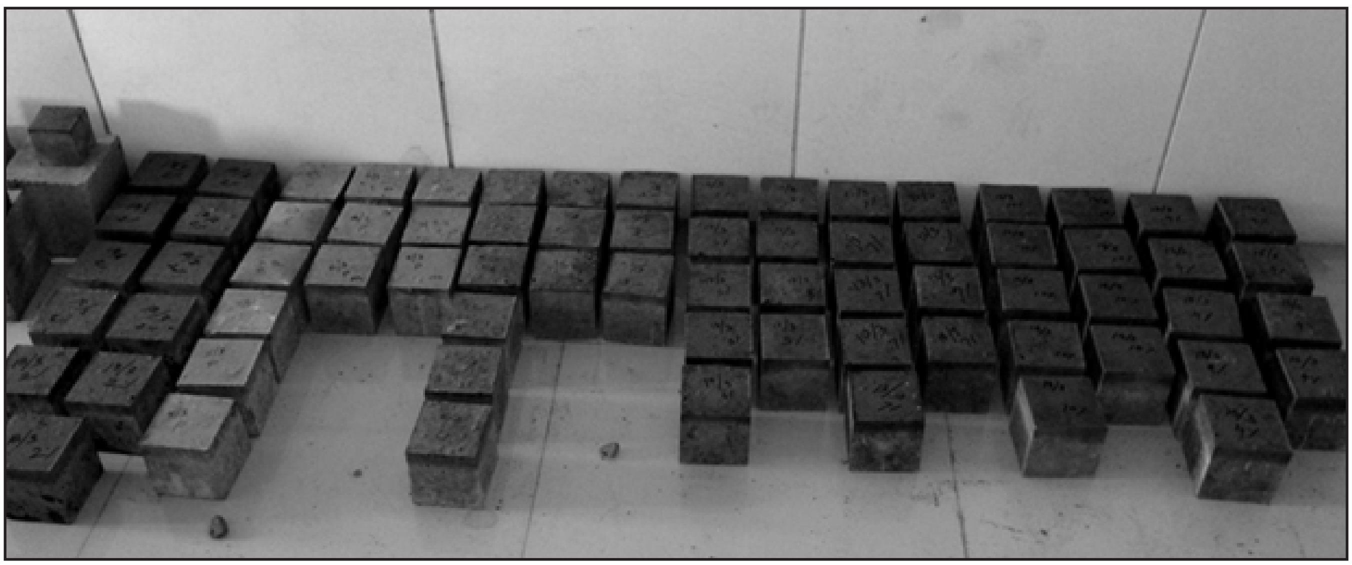


Fig. 13. Ambient Curing

Fig. 14. Compressive Strength Testing

Material for 1 mould of size 70mm x 70mm x 70mm:

1. Weight of Processed fly ash (P63) = 200 g
2. Weight of natural sand – (3x200) = 600 g

B. Calculation of Alkali Solution for Processed Geopolymer Mortar

For cement testing, (Pn/4 + 3) % of total mass of both materials is taken as quantity of water, where Pn is the standard consistency of cement, which is normally 33%. Where (33/4 + 3) % = 11.25

11.25% of total weight of sand and cement is (600+200) = 800 g. 11.25% of 800g is 90g. The quantity of water needed for 1 mould mix is 90 g.

Similarly, 90g of alkali solution is used for one mould of processed flyash geopolymer mortar, where standard sand is replaced by natural sand; cement by processed flyash; and water by alkali solution. The alkali solution for this test will be prepared in the same manner in that of processed geopolymer concrete.

C. Procedure

All 6 moulds were casted and were tested on 3 days and 7 days of curing (Fig. 15).

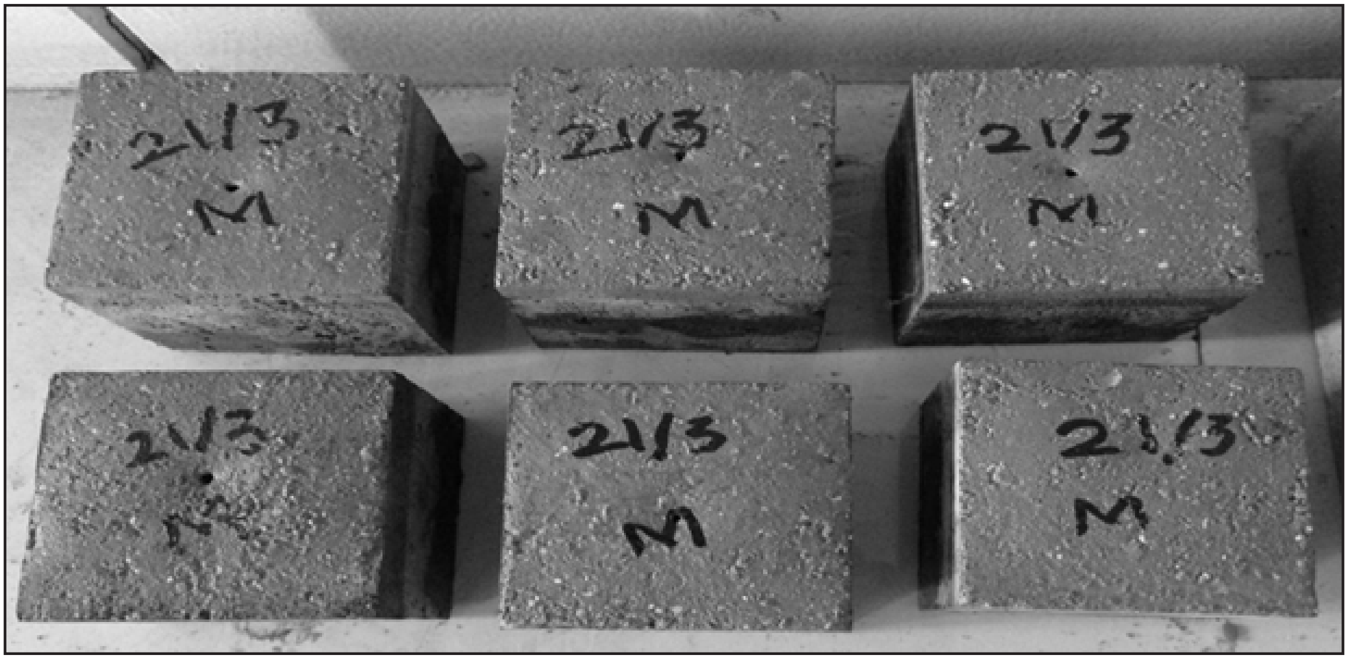


Fig. 15. Processed Geopolymer Mortar Cubes of 70x70x70mm

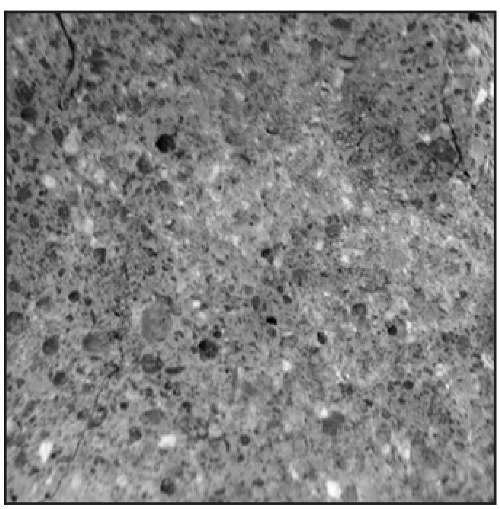


Fig. 16.Bonding of Processed Geopolymer Mortar

Test results of compressive testing of processed fly ash (P63) are given as follows:

(a) After 3 days of curing (Table IV):

**TABLE IV.
COMPRESSIVE STRENGTH OF PROCESSED FLYASH AFTER 3 DAYS OF CURING**

S. No.	Crushing Strength N/mm^2	Average Crushing Strength N/mm^2
1.	46.9	
2.	57.14	51.07 N/mm^2
3.	59.18	

(b) After 7 days of curing (Table V):

**TABLE V.
COMPRESSIVE STRENGTH OF PROCESSED FLYASH AFTER 7 DAYS OF CURING**

S. No.	Crushing Strength N/mm2	Average Crushing Strength N/mm^2
1.	47.82	
2.	49.63	52.08 N/mm^2
3.	58.78	

The compressive strength of processed fly ash (P63) after 3 days of curing was 51.07 $N/mm^{2,}$ and after 7 days of curing it was 52.08 N/mm^2. This shows that geopolymer mortar gains early strength after 3 days of curing. However, there is not much increase in the compressive strength of processed flyash geopolymer mortar from 3 to 7 days of curing.

D. Actual Test Program

As the testing was carried out for 3 days, 7 days, 14 days, and 28 days of curing, for 1 mix minimum (3 moulds x 4 days of testing), 12 moulds were casted. The different mixes for the experimentation are given in Table VI.

In all (12 x 8) = 96 moulds were of size 100 x 100 x 100 mm to be casted.

The actual mix design for the 8 mixes as per the base mix design is shown in Table VII.

**TABLE VI.
NOTATIONS OF MIXES**

S. No.	Mix	Notation
1.	Unprocessed flyash based geopolymer concrete	Mix 1
2.	Processed flyash (P63) based geopolymer concrete	Mix 2
3.	2% Rice husk ash - Processed flyash (P63) based geopolymer concrete	Mix 3
4.	3% Rice husk ash- Processed flyash (P63) based geopolymer concrete	Mix 4
5.	5% Rice husk ash - Processed flyash (P63) based geopolymer concrete	Mix 5
6.	7% Rice husk ash - Processed flyash (P63) based geopolymer concrete	Mix 6
7.	10% Rice husk ash - Processed flyash (P63) based geopolymer c concrete	Mix 7
8.	Plain cement concrete	Mix 8
9.	Base mix (R. Anuradha et al. 2012)	Mix M6

**TABLE VII.
ACTUAL MIX DESIGN FOR MIX 1-8**

Mix	Fly Ash kg/m^3	RHA kg/m^3	Fine Aggregate kg/m^3	Coarse Agagregate kg/m^3	Flyash to Alkali Ratio	Na_2SiO_3 kg/m^3	NaOH kg/m^3	Water kg/m^3
Mix 1	483.7 (unprocessed)	-	652.1	882.2	0.65	224.6	89.8	14.2
Mix 2	483.7 (processed)	-	652.1	882.2	0.65	224.6	89.8	14.2
Mix 3	474.026 (processed)	9.674	652.1	882.2	0.65	224.6	89.8	14.2
Mix 4	469.189 (processed)	14.511	652.1	8882.2	0.65	224.6	89.8	14.2
Mix 5	459.515 (processed)	24.185	652.1	882.2	0.65	224.6	89.8	142.
Mix 6	449.841 (processed)	33.859	652.1	882.2	0.65	224.6	89.8	14.2
Mix 7	435.330 (processed)	48.370	652.1	882.2	0.65	224.6	89.8	14.2
Mix 8	483.7 (Cement)		652.1	882.2	Water /Cement Ratio = 0.43			

E. Material Quantities

Estimated material requirement for each mix of 12 moulds is given in Table VIII. Volume of 12 moulds (0.1m x 0.1m x 0.1m) x 12 = 0.012m^3.

VI. TEST RESULTS

The crushing strength of the geopolymer concrete mixes at 3, 7, 14, and 28 days of curing are given in Table X.

TABLE VIII.
QUANTITY OF MATERIAL FOR EACH MIX

Mix	Fly Ash kg	RHA Kg	Fine Aggregate Kg	Coarse Aggregate kg	Na_2SiO_3 Kg	NaOH kg	Water Ml
Mix 1	5.80 (unprocessed)	-	7.82	10.58	2.695	1.077	170
Mix 2	5.80 (processed)	-	7.82	10.58	2.695	1.077	170
Mix 3	5.684 (processed)	0.116	7.82	10.58	2.695	1.077	170
Mix 4	5.626 (processed)	0.174	7.82	10.58	2.695	1.077	170
Mix 5	5.510 (processed)	0.290	7.82	10.58	2.695	1.077	170
Mix 6	5.394 (processed)	0.406	7.82	10.58	2.695	1.077	170
Mix 7	5.22 (processed)	0.580	7.82	10.58	2.695	1.077	170
Mix 8	5.80 (Cement)		7.82	10.58		Water - 2.494 Liters	

TABLE IX.
TOTAL MATERIAL QUANTITIES REQUIRED

S. No.	Material	Quantity (kg)
1.	Unprocessed Flyash	5.80
2.	Processed Flyash (P63)	33.23
3.	Cement	5.80
4.	Fine Aggregates	62.56
5.	Coarse Aggregates	84.64
6.	Na_2SiO_3	21.56
7.	NaOH	8.616

TABLE X.
COMPRESSIVE STRENGTH OF GEOPOLYMER CONCRETE

Sr. No.	Name of the mix	3 days Crushing Strength (N/mm^2)	7 days Crushing Strength (N/mm^2)	14 days Crushing Strength (N/mm^2)	28 days Crushing Strength (N/mm^2)
1.	Mix 1	8	8.3	10.67	13.36
2.	Mix 2	40.1	41	45.33	54.3
3.	Mix 3	39.3	40.67	43.3	45
4.	Mix 4	44.67	53.67	56	62.41
5.	Mix 5	38.33	39.33	41	45
6.	Mix 6	31	34	34	35.33
7.	Mix 7	16.33	17	22.67	23.23
8.	Mix 8	23	30	36.33	52.58

VII. RESULT INTERPRETATION AND DISCUSSION

A. General Observations

1) During Casting : While preparing 12 M NaOH solution, it was observed that strong vapours are generated which should be taken care of. Also, the temperature of the solution increases, which should be taken care of. If the alkali solution ($NaOH+Na_2SiO_3$) mix is kept for a long time, that is, for more than 5 - 6 hours, it becomes more viscous. The wet mix of unprocessed flyash did not possess the bonding property (stickiness) which the processed flyash showed. Replacement of 2% fly ash by rice husk ash changes the mixture colour from light grey to dark grey. As the percentage of rice husk ash increases, the colour of the mix becomes darker. There is a remarkable reduction in flyash to alkaline solution ratio when the flyash is replaced by rice husk ash passing through 45 microns without affecting workability. No additional water is required for geopolymer concrete where flyash was replaced with rice husk ash. For processed flyash geopolymer concrete, additional water was required, which was about 14.2 kg/m^3. The processed geopolymer concrete is self-compactable concrete. Hence, the moulds are kept on the table vibrator for a very short time, just to achieve surface finish.

2) After Casting : A glossy layer is observed on the geopolymer concrete cubes after curing. A distinct 12 to 15 mm thick dark grey layer is observed on top after de-moulding of the cubes. The density of unprocessed flyash geopolymer concrete was 2, 298 kg/m^3 and that of processed geopolymer concrete was 2, 424 kg/m^3, and plain cement concrete was 2,400 kg/m^3. Oven curing at minimum 60° C for 24 hours is necessary for geopolymer concrete. If ambient curing is done, the concrete becomes hard after 4 - 5 days and then demoulding is done, but it does not possess good strength. Replacement of the fly ash by rice husk ash by 5%, and more of particle size less than 45 microns curing makes the concrete very hard. Comparison of compressive strength of processed flyash

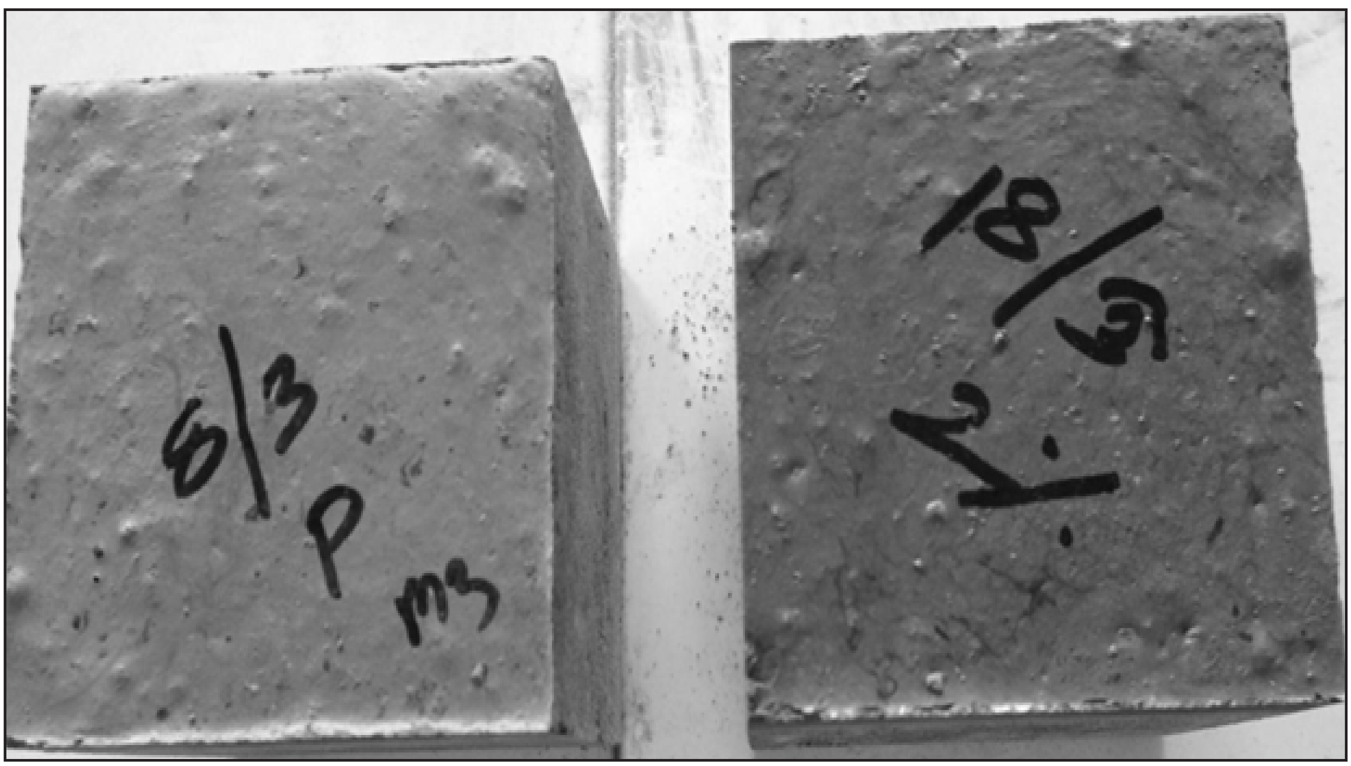


Fig. 17. Colour Differentiation Between Processed Geopolymer Concrete and 2% Ricehusk Ash Replaced Geopolymer Concrete

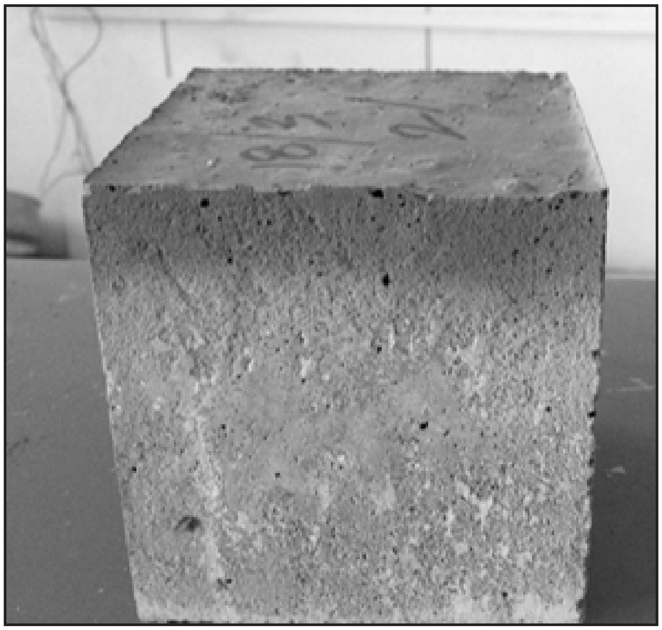


Fig. 18. A Distinct 12 To 15 mm Thick Dark Grey Layer is Observed on Top of Rice Husk Ash Replaced Processed Geopolymer Concrete

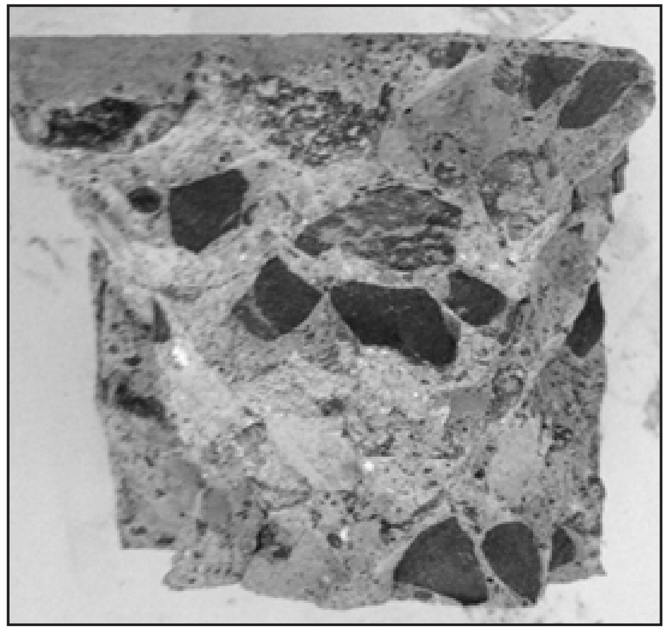


Fig. 19. Bonding Between Processed Geopolymer Concrete Mix

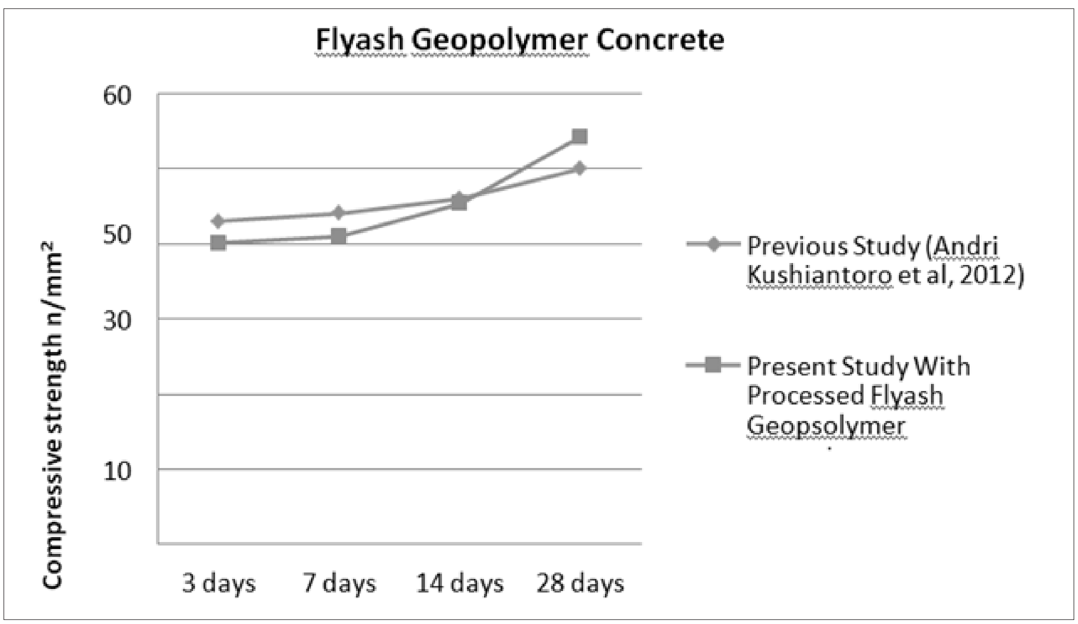


Fig. 20. Comparison of Flyash Geopolymer Concrete on Oven Curing

geopolymer concrete with previous results from Andri Kushiantoro et al. (2012) as shown in Fig. 20 reveals that the initial strength after 3 days of curing of processed flyash geopolymer is less than that of flyash geopolymer concrete of previous study (Andri Kushiantoro et al., 2012), but the gain in strength of processed flyash geopolymer concrete after 28 days of curing is higher than that of the previous study on fly ash geopolymer concrete (Andri Kushiantoro et al., 2012).

Comparison of compressive strength of 3% rice husk processed flyash geopolymer concrete with previous results from Andri Kushiantoro et al. (2012) is shown in Fig. 21. The graph shows that the 3% rice husk ash in replacement of processed geopolymer concrete after 3 days of curing is less at the early stage as compared to previous study (Andri Kushiantoro et al., 2012), but there is increase in the strength in case of the present study after 28 days of curing compared to Andri Kushiantoro et al. (2012).

Comparison of compressive strength of processed flyash geopolymer concrete with previous results from paper (M. F. Nuruddin et al., 2011) is shown in Fig. 22. As per the present study, oven curing of processed flyash geopolymer concrete drastically increases the compressive strength after 3 days of curing as compared to previous study on flyash geopolymer concrete at different curing conditions (M. F. Nuruddin et al., 2011).

Comparison of compressive strength of 3% rice husk ash processed flyash geopolymer concrete with precious results of unprocessed flyash geopolymer concrete paper (M. F. Nuruddin et al., 2011) is shown in Fig. 23.

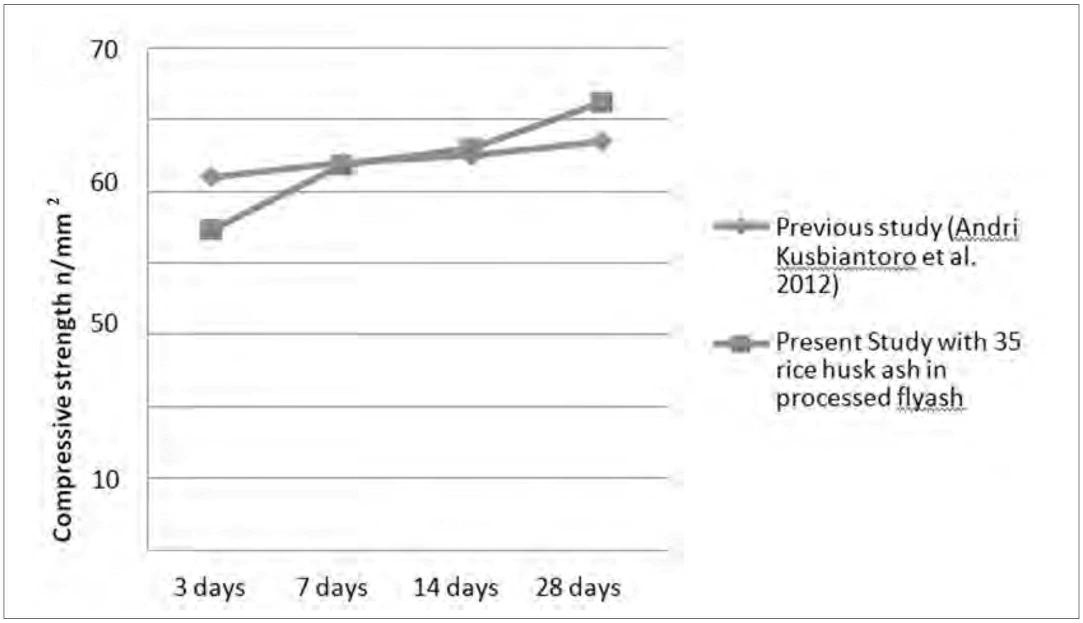


Fig. 21. Comparison of 3% Rice Husk Ash Replacement in Fly Ash Geopolymer Concrete on Oven Curing

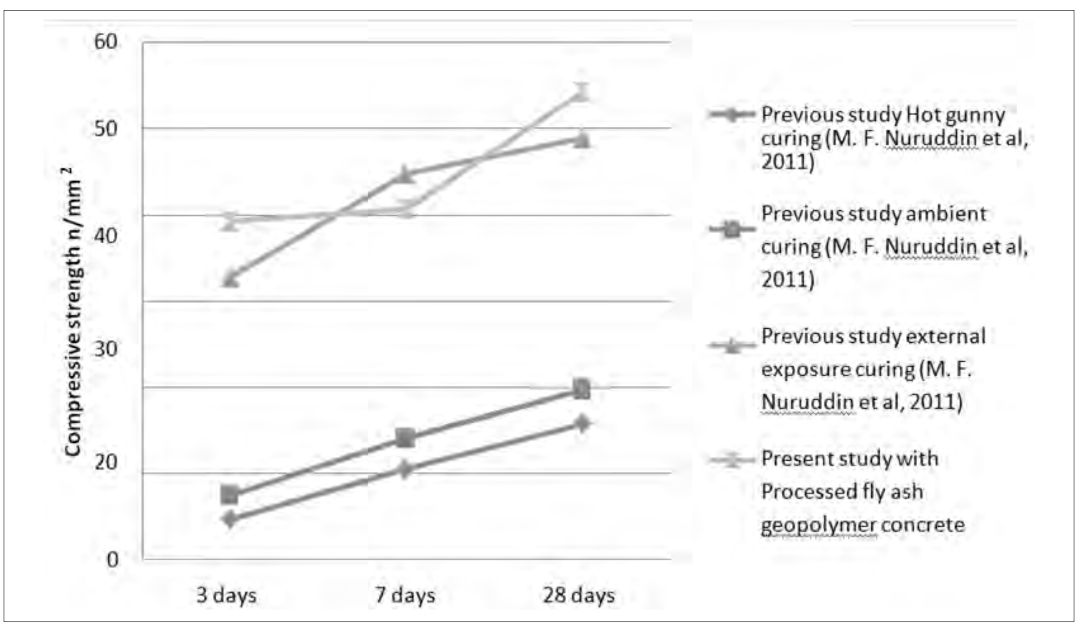


Fig. 22. Comparison of Geopolymer Concrete at Different Curing Conditions

The graph shows that the present 3% rice husk ash replaced in processed geopolymer concrete has a higher strength as compared to the other 3% rice husk ash mixes which are cured different curing conditions in the previous study (M. F. Nuruddin et al., 2011). Oven curing carried out in the present study shows a good effect in terms of compressive strength. The Comparison of Compressive Strength of all the Mixes at 3, 7, 14, and 28 days of curing is shown in Fig. 24.

3) After 3 Days of Curing

The compressive strength of processed flyash based geopolymer concrete (Mix 2) is 40 N/mm^2, which is 1.74 times the strength of plain cement concrete (Mix 8) which is 23 N/mm^2, and 5.01 times the strength of unprocessed flyash based geopolymer concrete (Mix 1) which is 8 N/mm^2.The compressive strength of 3% rice husk ash (Mix 4) replaced in processed fly ash

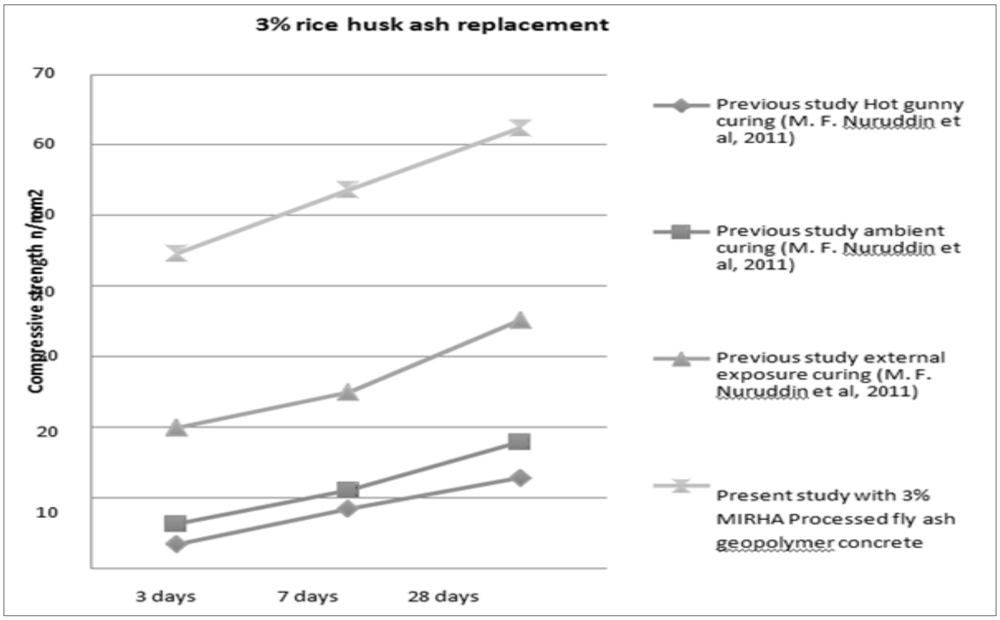
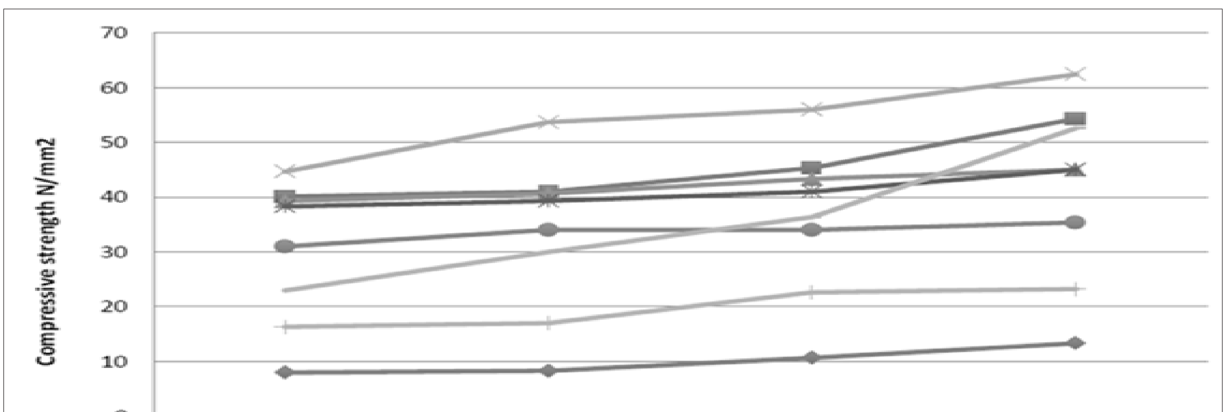


Fig. 23. Comparison of 3% Rice Husk Replacement Geopolymer Concrete at Different Curing Conditions



	3 days	7 days	14 days	28 days
Mix 1	8	8.3	10.67	13.36
Mix 2	40.1	41	45.33	54.3
Mix 3	39.3	40.67	43.3	45
Mix 4	44.67	53.67	56	62.41
Mix 5	38.33	39.33	41	45
Mix 6	31	34	34	35.33
Mix 7	16.33	17	22.67	23.23
Mix 8	23	30	36.33	52.58

Fig. 24. Compressive Strength of Mix Designs at 3, 7, 14, and 28 Days of Curing

TABLE XI.
NOTATIONS OF MIXES

Mix	Notation
Unprocessed Flyash based Geopolymer Concrete	Mix 1
Processed Flyash (P63) based Geopolymer Concrete	Mix 2
2% Rice Husk Ash - Processed Flyash (P63) based Geopolymer Concrete	Mix 3
3% Rice Husk Ash- Processed Flyash (P63) based Geopolymer Concrete	Mix 4
5% Rice Husk Ash - Processed Flyash (P63) based Geopolymer Concrete	Mix 5
7% Rice Husk Ash - Processed Flyash (P63) based Geopolymer Concrete	Mix 6
10% Rice Husk Ash - Processed Flyash (P63) based Geopolymer Concrete	Mix 7
Plain Cement Concrete	Mix 8
Base Mix Design	Mix M6

geopolymer concrete is 44.67 N/mm^2, which is 1.94 times the strength of plain cement concrete (Mix 8) which is 23 N/mm^2, and 1.11 times the strength of geopolymer concrete (Mix 2) which is 40.1 N/mm^2, and also 5.58 times the strength of unprocessed flyash geopolymer concrete (Mix 1) which is 8 N/mm^2. At the end of 3 days of curing, 3% rice husk ash processed geopolymer concrete (Mix 4) gives the maximum strength as compared to other mixes of 2%, 5%, 7%, and 10% rice husk ash processed geopolymer concrete (Mix 3, Mix 5, Mix 6, and Mix 7).

4) After 7 Days of Curing

The compressive strength of plain cement concrete (Mix 8) increased by 23.33% from 23 N/mm^2 to 30 N/mm^2 during 3 days to 7 days of curing. The compressive strength of unprocessed, processed flyash geopolymer concrete (Mix 1, Mix 2), 2%, 5%, and 10% ricehusk ash processed geopolymer concrete (Mix 3, Mix 5, Mix 6, Mix 7) increased from 5 to 8 % during 3 to 7 days of curing. The strength of 3% rice husk processed fly ash geopolymer concrete (Mix 4) increased by 16.67% from 44.67 N/mm^2 to 53.67 N/mm^{2}in 3 to 7 days of curing.

5) After 14 Days of Curing

The strength of unprocessed flyash geopolymer concrete (Mix 1) increased by 22.22% from 8.3 N/mm^2 to 10.67 N/mm^2 during 7 to 14 days of curing. The strength of plain cement concrete (Mix 8) increased by 17.42% from 30 to 36.33 N/mm^2 during 7 to 14 days of curing. The strength of processed fly ash geopolymer (Mix 2), and rice husk ash processed flyash geopolymer concrete (Mix 3, Mix 4, Mix 5, Mix 6, Mix 7) increased only by 5% to 10% during 7 to 14 days of curing.

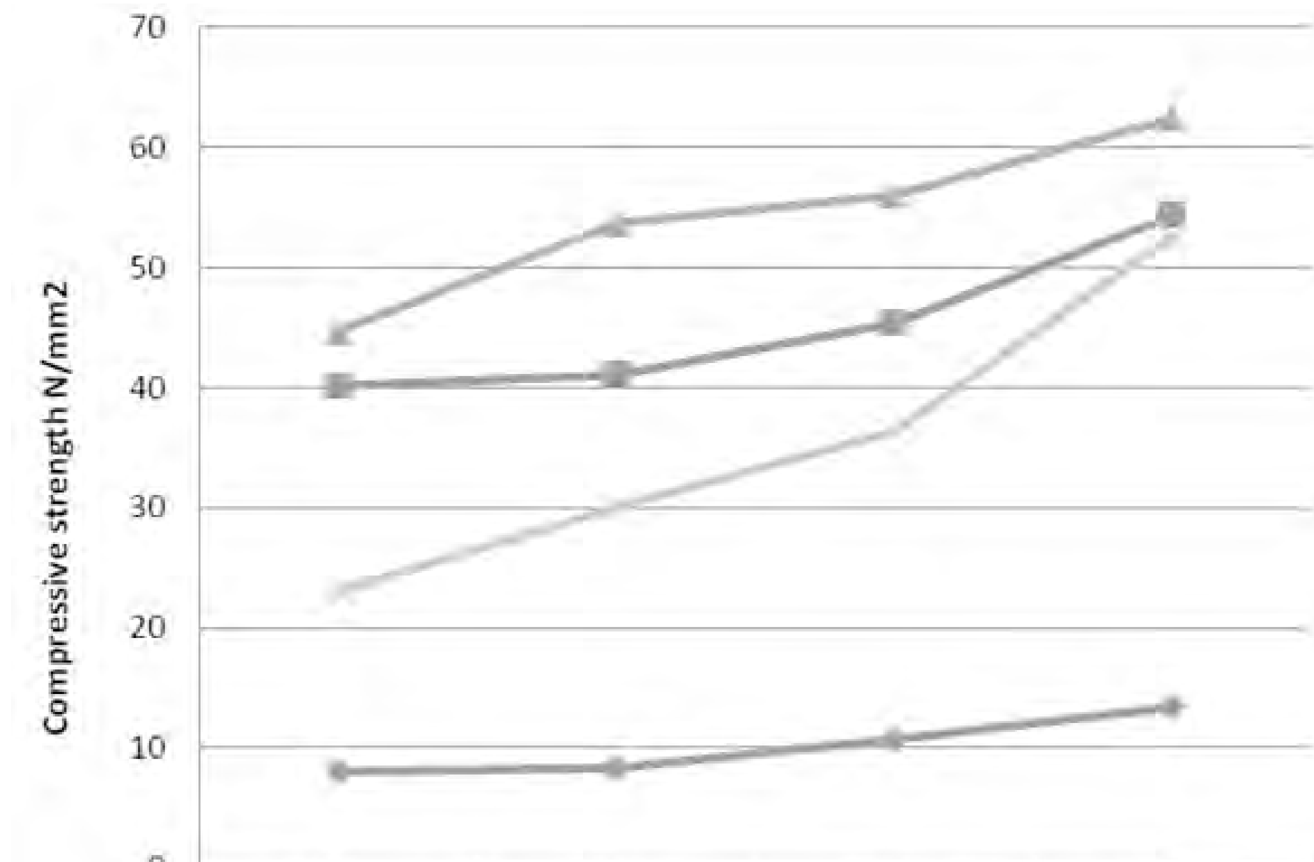
6) After 28 Days of Curing

The strength of unprocessed flyash geopolymer concrete (Mix 1) increased by 20% from 10.67 N/mm^2 to 13.36 N/mm^2 during 14 to 28 days of curing. The strength of plain cement concrete (Mix 8) increased by 30% from 36.33 N/ mm^2 to 52.58 N/mm^2 during 14 to 28 days of curing. The strength of processed fly ash geopolymer concrete (Mix 2), and rice husk ash processed flyash geopolymer concrete (Mix 3, Mix 4, Mix 5, Mix 6, and Mix 7) showed only 3% to 10% increase in strength. The strength of processed flyash geopolymer concrete (Mix 2) was 54.3N/mm^2, which is 3.93 times the strength of unprocessed fly ash geopolymer concrete (Mix 1) which was 13.36 N/mm^2. The strength of 3% rice hush ash processed flyash geopolymer concrete (Mix 4) was 62.41 N/mm^2 at the end of 28 days of curing which was 4.67 times the strength of unprocessed flyash geopolymer concrete (Mix 1) which was 13.36 N/mm^2, and 1.18 times the strength of plain cement concrete (Mix 8), which is 52.58 N/mm^2, and also 1.14 times the strength of processed flyash geopolymer concrete (Mix 2) which is 54.3 N/mm^2. 3% rice husk ash processed flyash geopolymer concrete (Mix 4) gives maximum strength after 28 days of curing among all mixes.

The comparison of unprocessed flyash geopolymer concrete, processed flyash geopolymer concrete, 3% rice husk ash processed geopolymer concrete, and plain cement concrete is shown in Fig. 25. It shows that 3% rice husk ash processed geopolymer has the maximum value of compressive strength at 3, 7, 14, and 28 days of curing. The unprocessed flyash geopolymer concrete shows the least compressive strength after 3, 7, 14 and 28 days of curing. The strength of processed, and 3% rice husk ash geopolymer concrete achieves early strength after 3 days of curing, and also the strength of these mixes is greater than that of plain cement concrete at 3, 7, 14, and 28 days of curing.

The comparison of partially replaced rice husk ash mixes in processed flyash geopolymer concrete is shown in Fig. 26. It shows that the partial replacement rice husk in processed geopolymer mixes increases compressive strength as percentage of rice husk ash is increased from 2% to 3%. Further increase in rice husk ash replacement, from 5% to 10% decreases the compressive strength. 3% rice husk ash processed geopolymer concrete gives the maximum compressive strength at 3, 7, 14, and 28 days of curing. The flyash/alkali ratio from unprocessed, processed flyash geopolymer concrete, and rice husk ash replaced processed geopolymer mixes.

Fig. 27 shows that there is a decrease in flyash/alkali

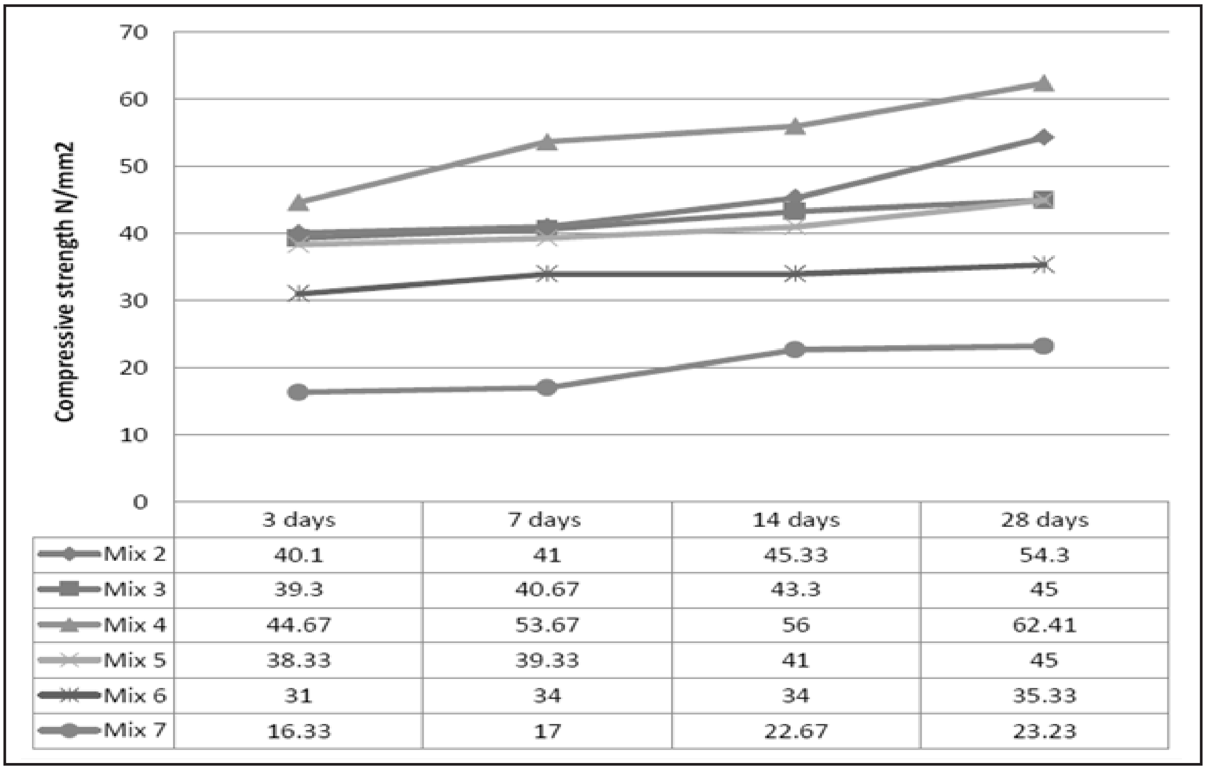


	3 days	7 days	14 days	28 days
Mix 1	8	8.3	10.67	13.36
Mix 2	40.1	41	45.33	54.3
Mix 4	44.67	53.67	56	62.41
Mix 8	23	30	36.33	52.58

Fig. 25. Compressive Strength of Processed, Unprocessed, 3% Rice Husk Processed Flyash Geopolymer Concrete, and Plain Cement Concrete

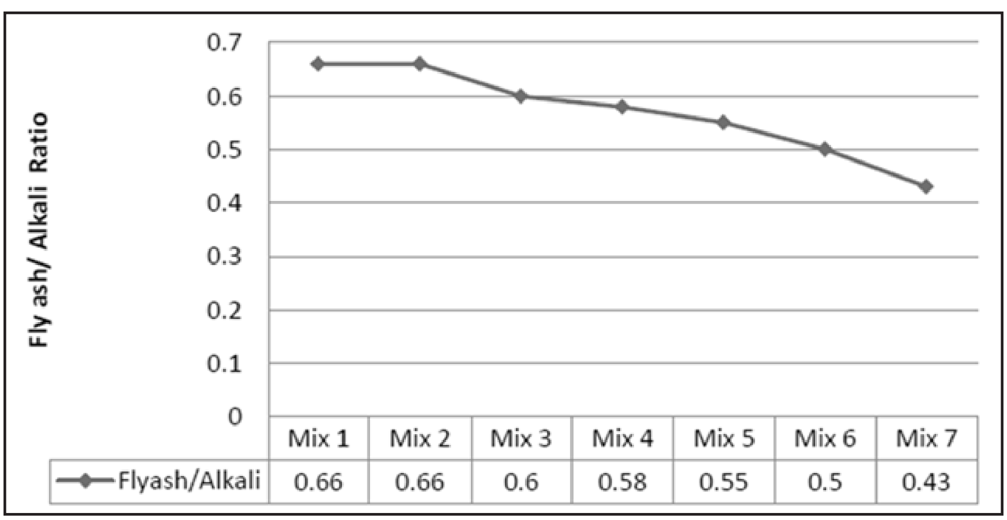
ratio when the processed flyash is partially replaced by rice husk ash. The ratio decreases as the percentage of rice ash to be replaced increases. The ratio decreases from 0.66 to 0.43 from processed flyash geopolymer concrete to 10% rice husk ash processed geopolymer concrete.

The bar chart showsthe compressive strength of base mix,unprocessed flyash geopolymer concrete, processed flyash geopolymer concrete, and plain cement concrete.



	3 days	7 days	14 days	28 days
Mix 2	40.1	41	45.33	54.3
Mix 3	39.3	40.67	43.3	45
Mix 4	44.67	53.67	56	62.41
Mix 5	38.33	39.33	41	45
Mix 6	31	34	34	35.33
Mix 7	16.33	17	22.67	23.23

Fig. 26. Compressive Strength of Processed, 2%, 3%, 5%, 7%, 10% Rice Husk Ash Processed Geopolymer Concrete



	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6	Mix 7
Flyash/Alkali	0.66	0.66	0.6	0.58	0.55	0.5	0.43

Fig. 27. Graph of Flyash / Alkali Ratios

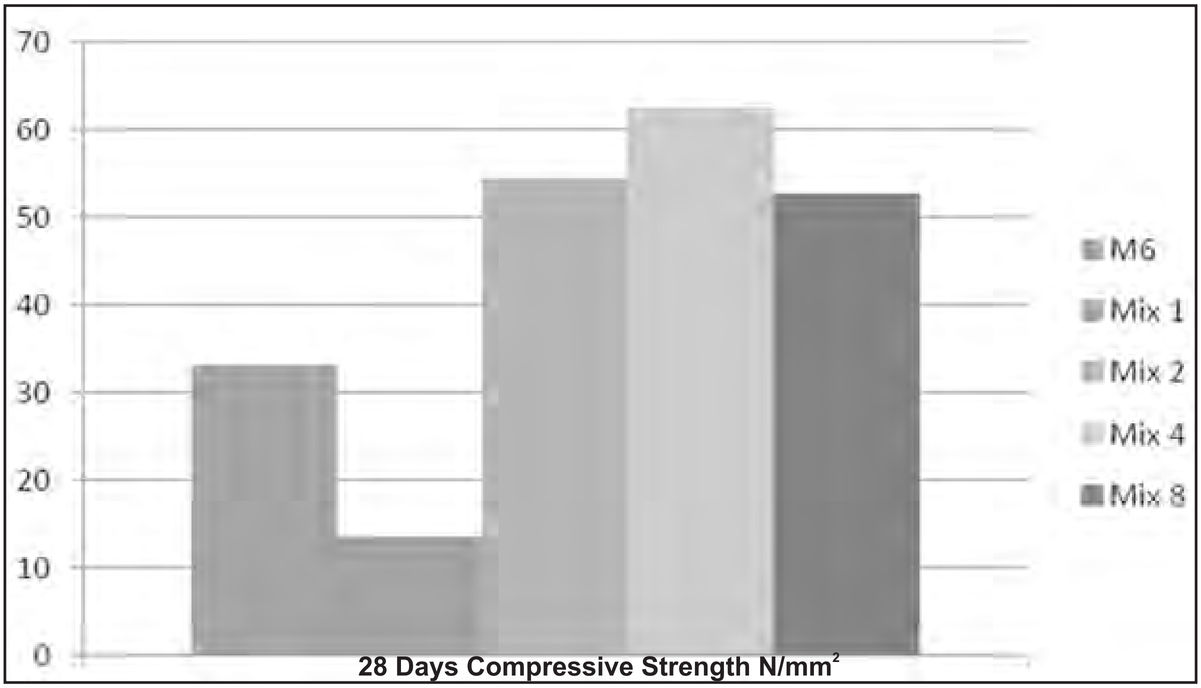


Fig. 28. Bar Chart of 28 days Compressive Strength

The compressive strength of processed flyash based The compressive strength of processed flyash based geopolymer concrete (Mix 2) at the end of 28 days of curing was 54.3 N/mm^2, which is 1.54 times the strength of the Base mix (M6), which had a strength of 33 N/mm^2. The compressive strength of unprocessed flyash based geopolymer concrete (Mix 1) after 28 days of curing was 13.363 N/mm^2, which was 60% less than that of the Base mix (M6), which had a strength of 33 N/mm^2. The compressive strength of 3% rice husk ash replaced in processed geopolymer (Mix 4) was 62.41 N/mm2 after 28 days of curing, which is 1.89 times the strength of Base mix which was 33N/mm^2. The compressive strength of plain cement concrete (Mix 8) after 28 days of curing was 52.58 N/mm^2, which is 1.59 times the strength of the Base mix (M6), which was 33 N/mm^2.

VIII. DISCUSSION

The strength of plain cement concrete increases gradually from 3 to 28 days of water curing. The strength of processed and rice hush ash processed flyash geopolymer concrete mixes gain early strength within 3 days of curing, and later increases only by 20 to 25% at the end of 28 days of curing. The strength of rice husk ash processed flyash geopolymer concrete mixes increases the strength from 2% to 3% replacement, and beyond 5% replacement, the strength starts decreasing. 3% rice husk ash processed flyash geopolymer concrete gives the maximum value of compressive strength as compared to other mixes. As the percentage of rice husk ash is replaced from 2% to 10%, the flyash to alkaline activator ratio goes on decreasing from 0.66 to 0.43. The more the rice husk is replaced, lesser will be flyash to alkali activator ratio, but there will be decrease in strength. No extra water is needed for rice husk ash geopolymer concrete mixes.

IX. CONCLUSION

- Processed geopolymer concrete gives higher compressive strength as compared to plain cement concrete for the same mix design.
- Use of processed fly ash in geopolymer concrete gives good results as compared to unprocessed fly ash due to removal of unburnt particles and crystalline substances.
- Replacement of microwave incinerated rice husk ash by 3% in processed flyash geopolymer concrete gives maximum compressive strength.
- Use of rice husk ash passing through 45µ in processed geopolymer concrete gives higher results as compared to rice husk ash of variable grain size.
- Processed flyash based geopolymer concrete with

partial replacement by rice husk ash provides a very good alternative to plain cement concrete.

- Use of rice husk ash and fly ash of the same grain size gives better strength than rice husk ash and fly ash of different grain size.

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