Processed Flyash Geopolymer Concrete and Effects of MIRHA (Microwave Incinerated Rice Husk Ash) on Processed Flyash Geopolymer Concrete and its Comparison with Different Geopolymer Concrete & Cement Concrete

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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 & 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 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 less will be flyash to alkali activator ratio, but there will be decrease in strength.*

Keywords: MIRHA, geopolymer, fly ash, concrete, rice husk ash, curing, alkaline activator.

1. INTRODUCTION

Production of cement causes a large volume of carbon dioxide CO2 emission causing temperature rise, global warming. It is estimated that one tonne of cement approximately requires about 2 tonnes of raw materials (Limestone and Shale) and release about 0.87 tonne of carbon dioxide and about 3 kg of nitrogen oxide. Production of cement causes greater impact in environment causing changes in land-use patterns and local water contamination as well as air pollution. Fugitive CO2 emissions also pose huge threat to the environment. The cement industry does not fit in sustainable development due to raw materials used for the production does not recycle and are non-renewable. The waste material or by-product from the industry which can be utilized for reduction of carbon dioxide CO2 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.

2. EXPERIMENTAL INVESTIGATION

2.1 Experimental Investigations from Literature reviewed

The base mix for the experimental study is taken from the paper R. Anuradha, et.al; 2012

Table-1 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

2.2 EXPERIMENTAL SETUP

Fig-1 Mechanical Shaker with 45µ I.S. sieve with lid and receiver.

Fig-2 Pycnometer Bottle filled with Rice Husk Ash and Water.

2.3 MATERIALS USED

Coarse Aggregates:

Fine Aggregates:

Processed Flyash (P63):

Table -2 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)

2.4 Unprocessed Fly ash:

Locally available unprocessed flyash from flyash bricks manufacturing plant will be 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 as follows:

Table -3 Properties of Unprocessed flyash.

Specification	Unprocessed fly ash
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 Un Processed Flyash

Fig-7 Rice Husk Ash

3. ALKALI ACTIVATORS:

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

3.1 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:

3.2 Testing:

The compressive testing is carried out for 3 days, 7days, 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 Oven Curing

Fig-12 Ambient Curing

Compressive Strength Testing

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

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

3.4 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 which is (600+200) = 800gms. 11.25% of 800gms is 90gms. The quantity of water need for 1 mould mix is 90gms.

Similarly 90gms of alkali solution will be used for 1 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 same manner in that of processed geopolymer concrete.

3.5 Procedure:

In all 6 moulds will be casted, which will be tested on 3days and 7days of curing.

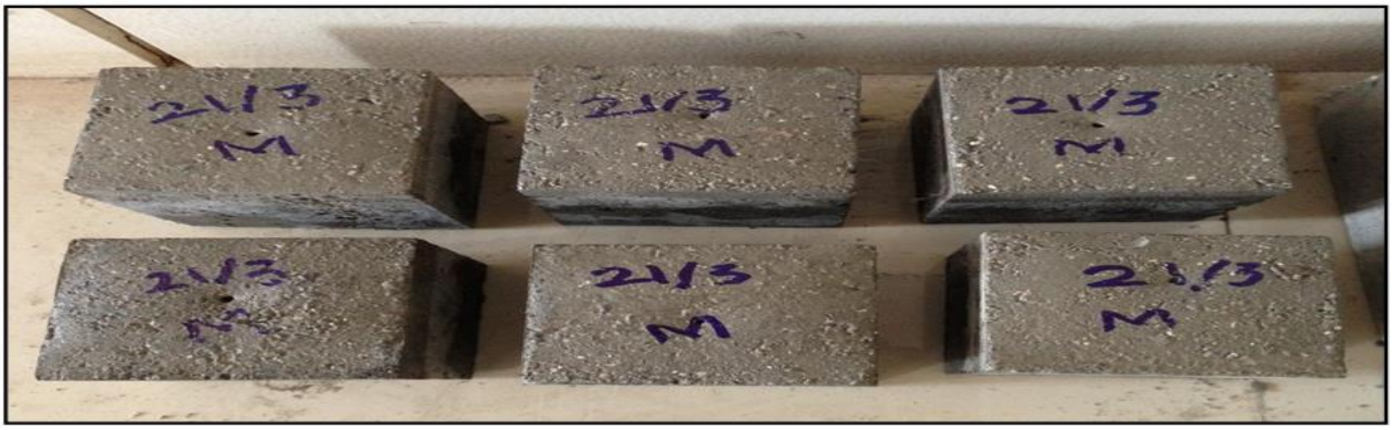


Fig-13 Processed geopolymer mortar cubes of 70x70x70mm

Fig-14 Bonding of Processed geopolymer mortar

4. Test Results of Compressive testing of Processed fly ash (P63)

At 3 days of curing:

Table 4 Compressive strength of processed flyash at 3 days of curing.

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

At 7 days of curing:

Table-5 Compressive strength of processed flyash at 7 days of curing.

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

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

4.1 Actual Test Program

As the testing is 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 shall be casted. The different mixes for the experimentation are as follows-

Table-6 Notations of Mixes.

Sr. 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 Concrete	Mix 7
8.	Plain Cement Concrete	Mix 8
9.	Base Mix (R. Anuradha, et al. 2012)	Mix M6

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

The actual mix design for the 8 mixes as per the base mix design is as follows:

Table-7 Actual Mix Design for Mix 1-8.

Mix	Fly Ash kg/m³	RHA kg/m³	Fine Agg. kg/m³	Coarse Agg. kg/m³	Flyash to Alkali ratio	Na_2SiO_3 kg/m³	NaOH kg/m³	Water kg/m³
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			

4.2 Material Quantities

Estimated material requirement for each mix of 12 moulds is given in Table no: 10. Volume of 12 moulds (0.1m x 0.1m x 0.1m) x 12 = 0.012 m³

Table-8 Quantity of material for each mix

Mix	Fly Ash kg	RHA Kg	Fine Agg. Kg	Coarse Agg. 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		

4.3 Total Quantities required:

Table-9 Total material quantities

Sr. 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

5. TEST RESULTS

The Crushing strength of the geopolymer concrete mixes at 3, 7, 14, and 28 days of curing are as follows:

Table-10 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

5.1 RESULT INTERPRETATION AND DISCUSSION

General Observations

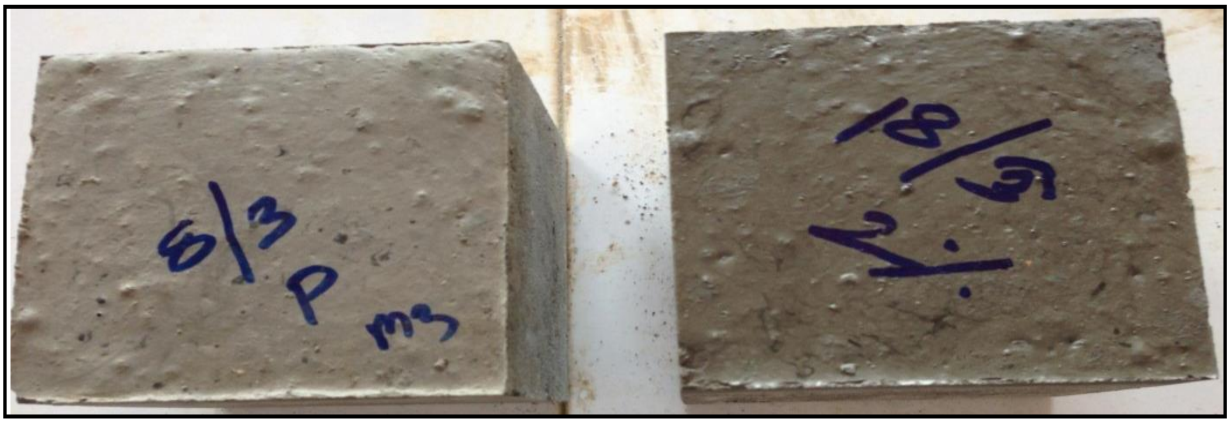


Fig-15 Colour differentiations between Processed geopolymer concrete and 2% Ricehusk ash replaced geopolymer concrete

Fig-16 A distinct 12 to 15 mm thickness dark grey layer is observed from top of Rice husk ash replaced processed geopolymer concrete.

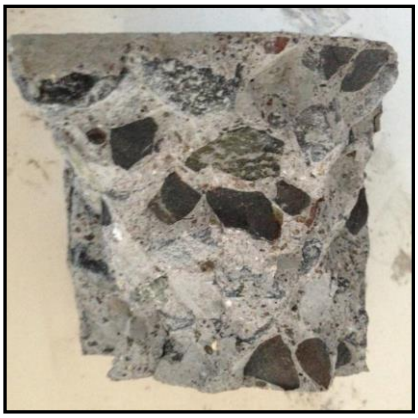


Fig-17 Bonding between Processed Geopolymer Concrete Mix

5.2 GRAPHS:

Comparison of compressive strength of processed flyash geopolymer concrete with previous results from paper. (Andri Kushiantoro et al.2012).

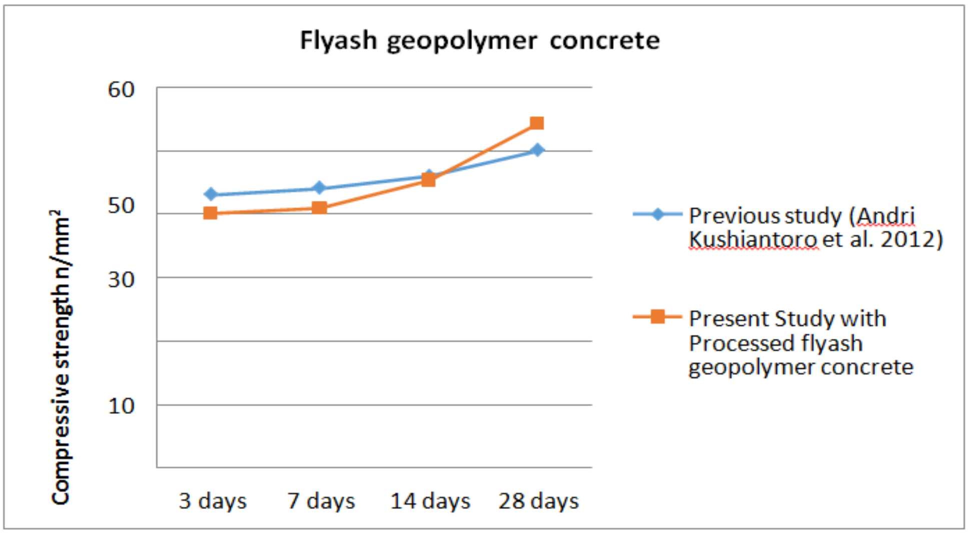


Chart-1 Comparison of flyash geopolymer concrete on oven curing

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 3 | Mar 2019 www.irjet.net p-ISSN: 2395-0072

The graph states that the initial strength at 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 at 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 paper. (Andri Kushiantoro et al.2012).

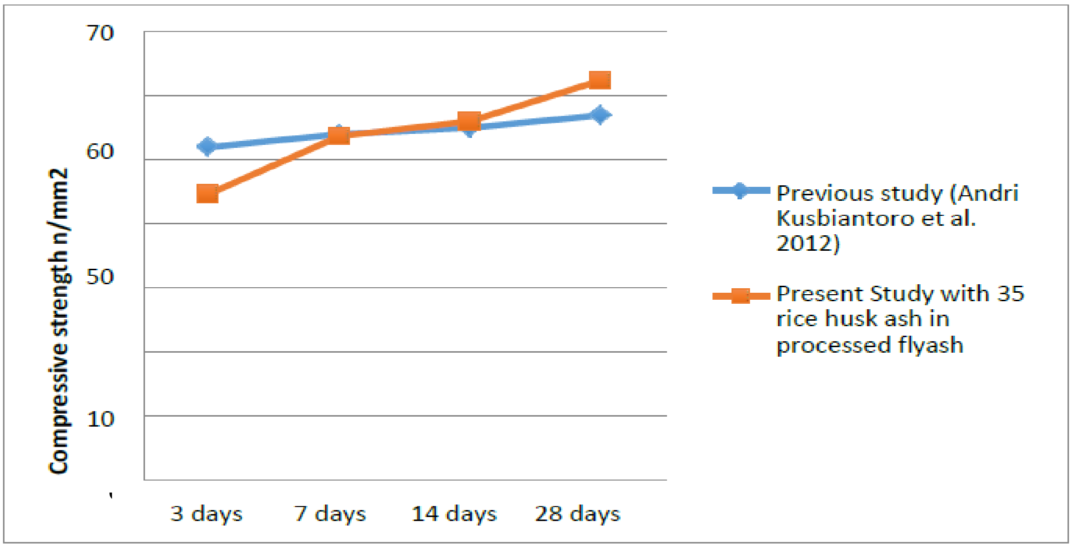


Chart-2 Comparison of 3% rice husk ash replacement in fly ash geopolymer concrete on oven curing.

The graph states that the 3% rice husk ash in replacement of processed geopolymer concrete at 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 of the present study at 28 days of curing compared to previous study. (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).

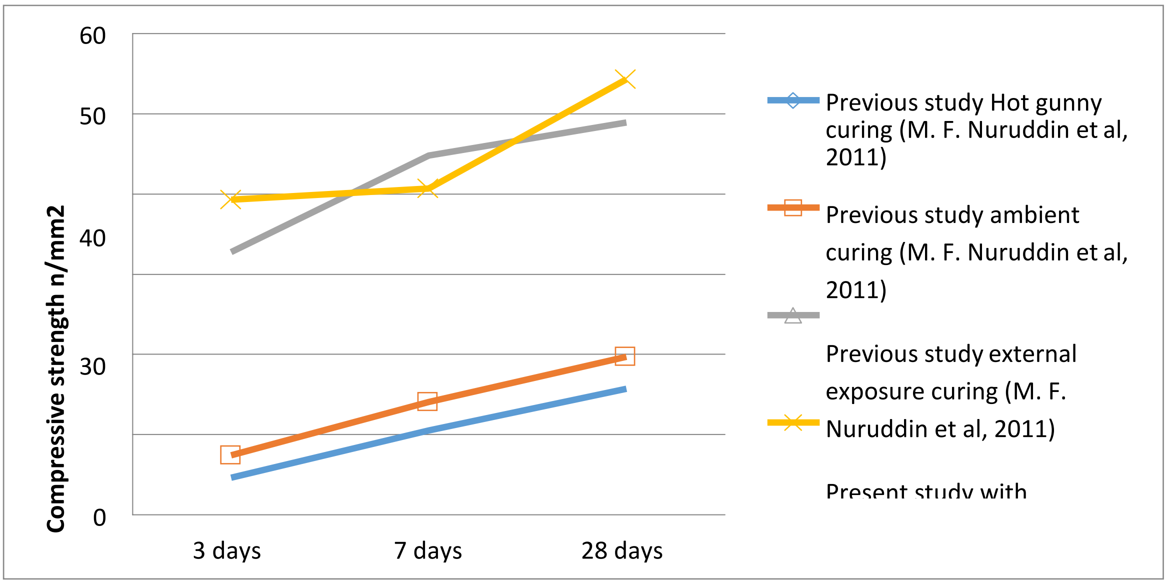


Chart-3 Comparison of geopolymer concrete at different curing conditions

As per the present study, oven curing of processed flyash geopolymer concrete drastically increases the compressive strength at 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).

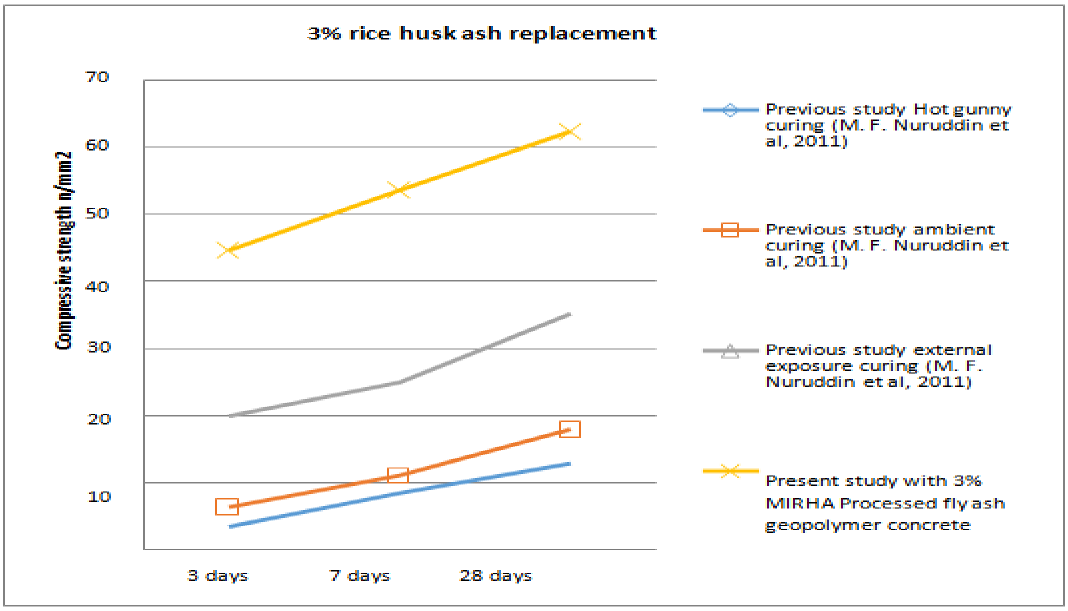
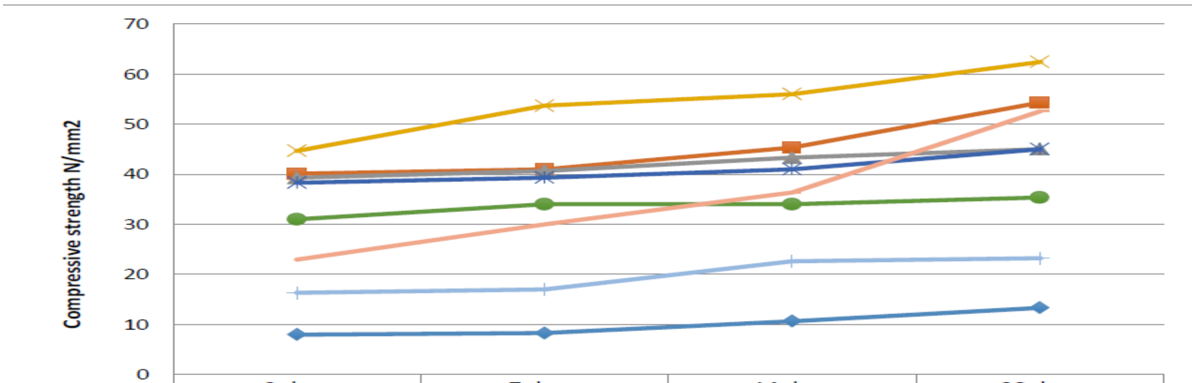


Chart-4 Comparison of 3% rice husk replacement geopolymer concrete at different curing conditions.

The graph shows that the present 3% rice husk ash replaced in processed geopolymer concrete has a higher strength as compared to 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.



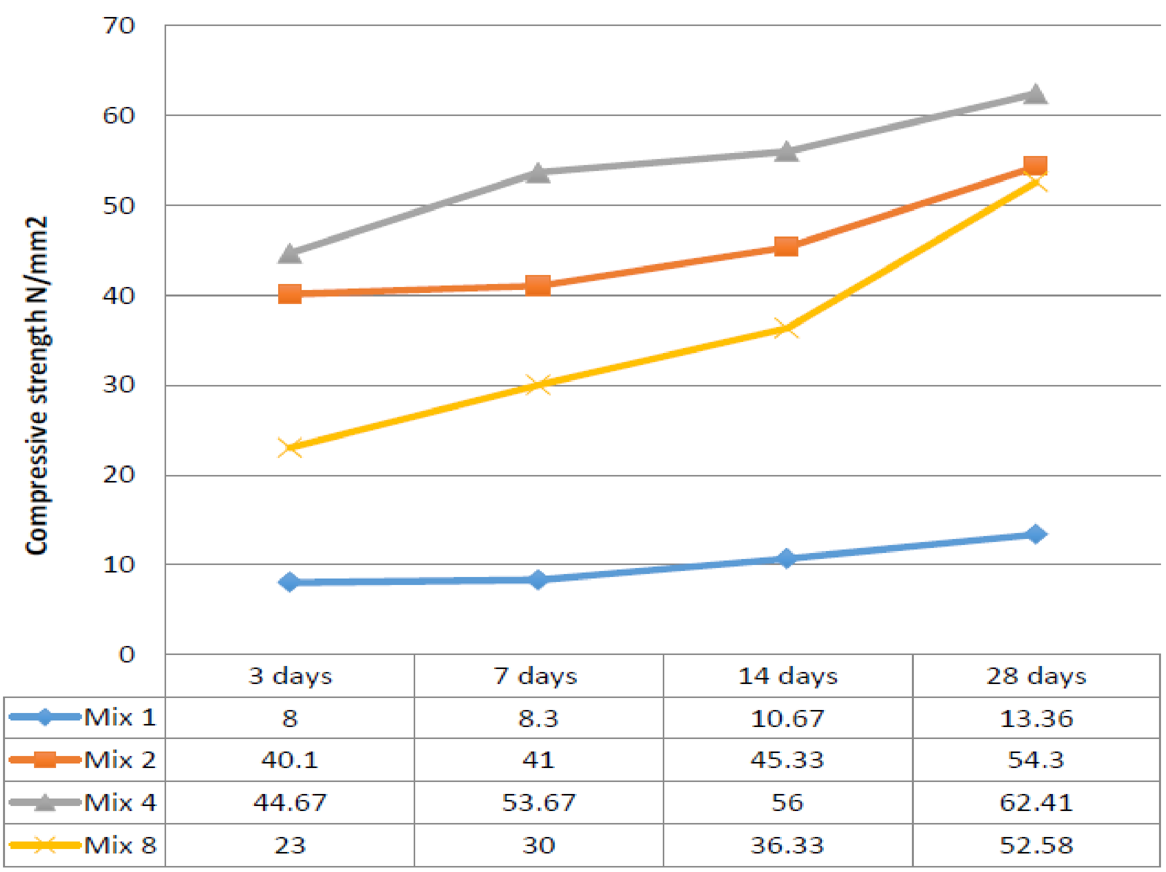
	3 days	7 days	14 days	28 days
Mix 1	8	8.3	10.67	13.36
Mix 2	40.1	41	45.33	54.3
Mix 3	39.3	40.67	43.3	45
Mix 4	44.67	53.67	56	62.41
Mix 5	38.33	39.33	41	45
Mix 6	31	34	34	35.33
Mix 7	16.33	17	22.67	23.23
Mix 8	23	30	36.33	52.58

Chart-5 Compressive strength of mix designs at 3, 7, 14 and 28 days of curing

Table-11 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

The comparison of Unprocessed flyash geopolymer concrete, Processed flyash geopolymer concrete, 3% Rice husk ash processed geopolymer concrete and Plain cement concrete.

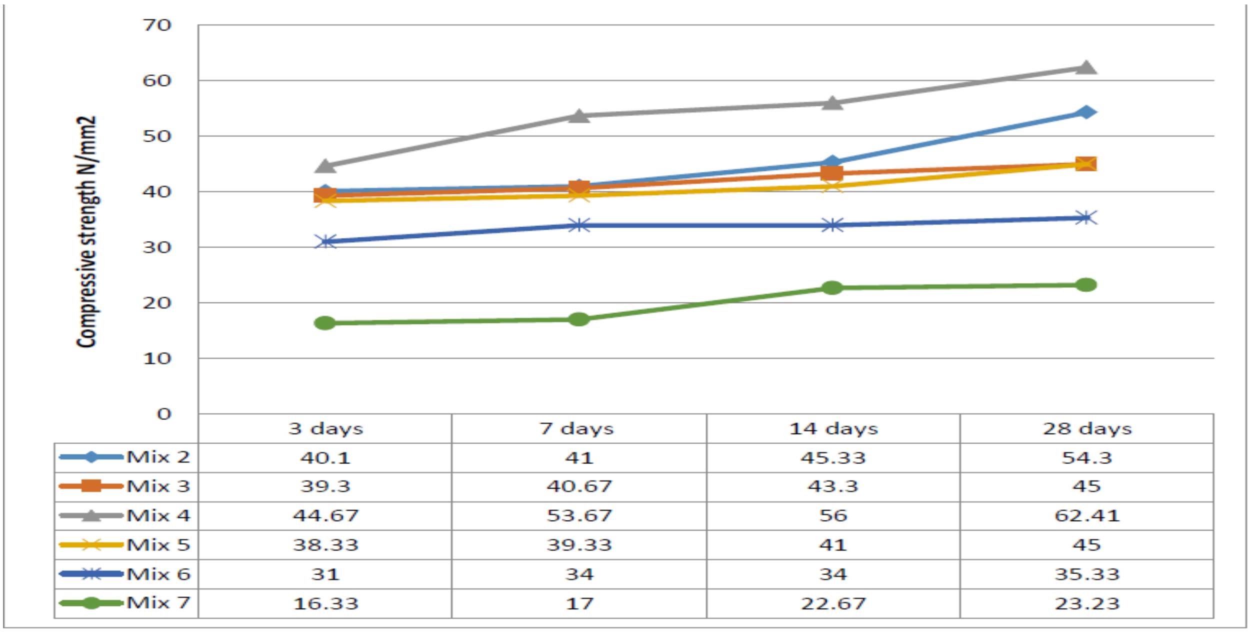


	3 days	7 days	14 days	28 days
Mix 1	8	8.3	10.67	13.36
Mix 2	40.1	41	45.33	54.3
Mix 4	44.67	53.67	56	62.41
Mix 8	23	30	36.33	52.58

Chart-6 Compressive strength of Processed, Unprocessed, 3% rice husk processed flyash geopolymer concrete and plain cement concrete.

The above graphs states that, 3% rice husk ash processed geopolymer showed the maximum value of compressive strength at 3, 7, 14 and 28 days of curing. The unprocessed flyash geopolymer concrete showed the least compressive strength at 3, 7, 14 and 28 days of curing. The strength of Processed and 3% rice husk ash geopolymer concrete achieves early strength at 3 days of curing and also the strength of these mixes are greater than the 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.

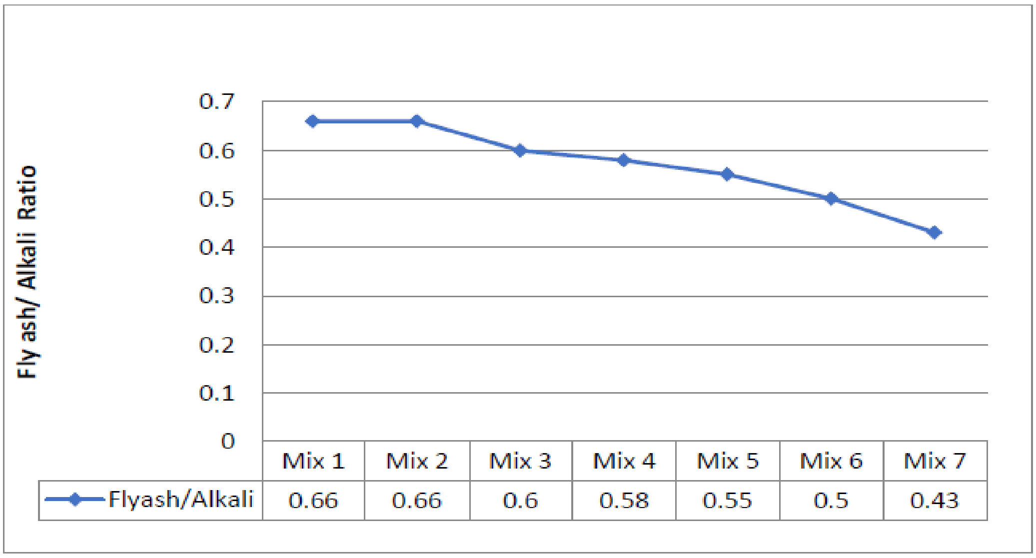


	3 days	7 days	14 days	28 days
Mix 2	40.1	41	45.33	54.3
Mix 3	39.3	40.67	43.3	45
Mix 4	44.67	53.67	56	62.41
Mix 5	38.33	39.33	41	45
Mix 6	31	34	34	35.33
Mix 7	16.33	17	22.67	23.23

Chart-7 Compressive strength of Processed, 2%, 3%, 5%, 7%, 10% rice husk ash processed geopolymer concrete.

The above graph states that the partial replacement rice husk in processed geopolymer mixes increases the compressive strength, as percentage of rice husk ash is replaced from 2% to 3%. Further increase in the 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.



	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

Chart-8 Graph of Flyash/Alkali ratios

The graph states that, there is a decrease in flyash/alkali 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 showing Compressive strength of Base Mix, Unprocessed flyash geopolymer concrete, Processed Flyash geopolymer concrete and Plain cement concrete.

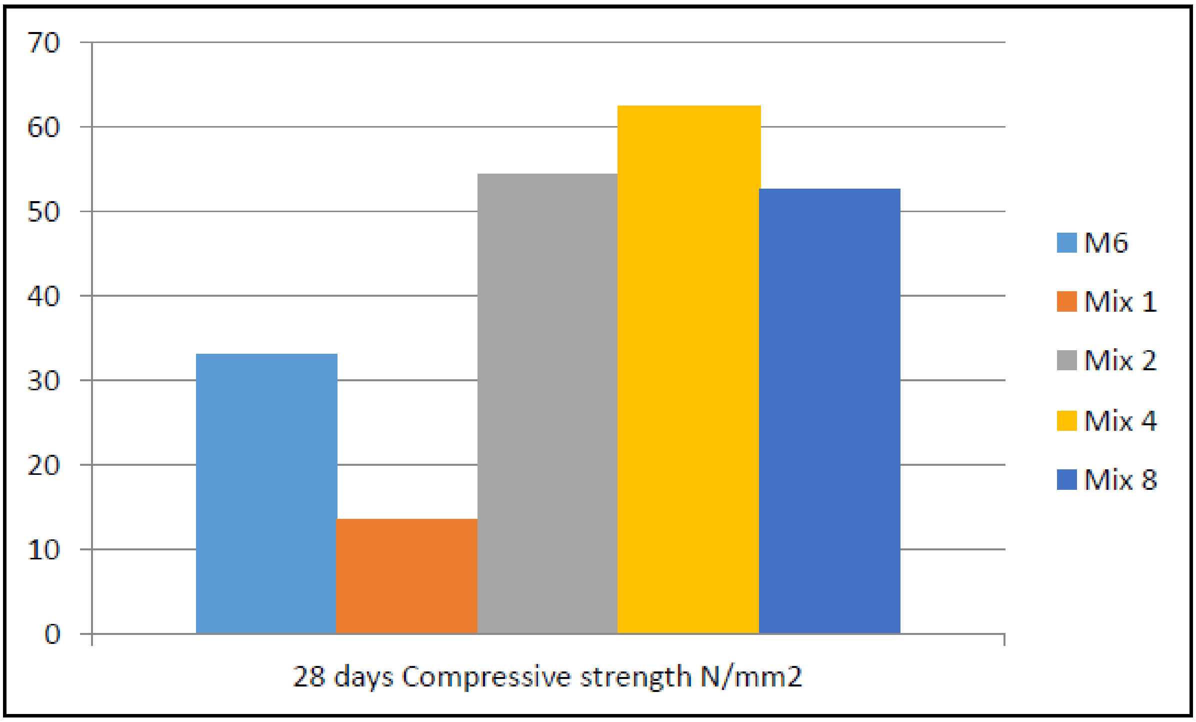


Chart-9 Bar chart of 28 days compressive strength

The compressive strength of Processed flyash based geopolymer concrete (Mix 2) at the end of 28 days of curing is 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) at the end of 28 days of curing is 13.363 N/mm^2, which is 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) is 62.41 N/mm^2 at 28 days of curing, which is 1.89 times the strength of Base mix which is 33N/mm^2. The compressive strength of Plain cement concrete (Mix 8) at the end of 28 days of curing is 52.58 N/mm^2, which is 1.59 times the strength of the Base mix (M6), which is 33 N/mm^2.

6. DISCUSSIONS

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 less 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.

7. CONCLUSIONS

- 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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