

# Utilizing rice husk ash as a bio-waste material in geopolymer composites with aluminium oxide

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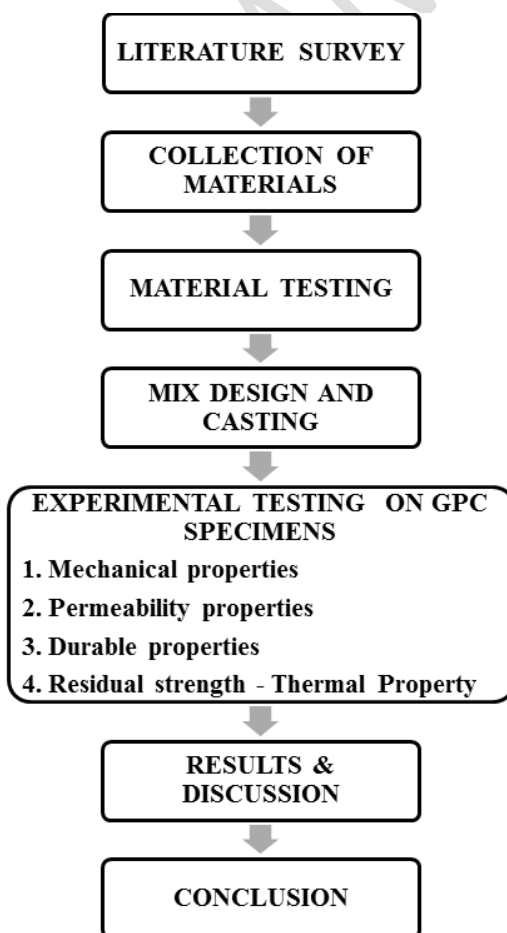
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## GRAPHICAL ABSTRACT:



## ABSTRACT

Permanent damages and spalling occur in conventional concrete due to hightemperature. Also concrete loses its compressive strength amounting to about 50 to 75% of the original strength as reported in most of the research works. As opting for high grade of concrete leads to higher costs and emits CO<sub>2</sub>, an attempt to develop thermal resistant geopolymer concrete is done. A new class of silica-alumina binders called geopolymers has the ability to withstand high temperatures. Generally geopolymer concrete (GPC) is having good strength and durability properties. In this paper, the heat resistance and strength performance of geopolymer is improved by adding aluminium oxide as admixture in the doses of 1% and 2% byweight of rice husk ash. With rice husk ash, fine aggregate and coarse aggregate, thermally resistant GPC was created. As alkali activators, sodium hydroxide and silicate were employed. The molarity of NaOH solution was 12 and 14. The specimens were cast and oven cured at 60°C for 24 hours. The specimens were tested to determine strength, permeability, durability and thermal studies of geopolymer concrete.

**Key Words:** Bio-waste (rice husk ash), Compressive Strength, CO<sub>2</sub>, silica-alumina binders, thermal resistant, geopolymer concrete, etc.

## 1. INTRODUCTION

Flame retardants are used in building materials and products to meet important fire safety standards and codes. According to reports, one of the most significant fire-resistant building materials is geopolymer concrete. Materials that are fire resistant have the capacity to sustain high temperatures without being destroyed. Due to its amorphous and ceramic-like characteristics, geopolymer cement has a potential for enhanced fire resistance. The more porous structure of the geopolymer concrete specimen makes it easier for the internal steam pressure to be released during heating. As a result, the geopolymer concrete undergoes less tensile stress and becomes more fire resistant. Geopolymers, in particular Ca(OH)<sub>2</sub>, lack the hydrate phase. When Portland cement is exposed to high temperatures (>400°C), internal tensions are caused by structural water. The Ca (OH)<sub>2</sub> dehydroxylate to CaO process also

CaO rehydrates with a volume change when it cools on its own, damaging matrices in the process. On the other hand, geopolymers re-crystallize into more heat-resistant anhydrous alumino-silicate solids. Geopolymers based on rice husk ash are considered in this section. One of the most chemically stable oxides known, aluminium oxide has a melting point of 2070°C and exceptional hardness, strength, and spalling resistance.. In this project aluminium oxide was as an additive. The final objective of this study, comparison between the mechanical properties and the residual compressive strength at elevated temperature of Thermal Resistant Geopolymer Concrete (TRGPC). Also, to conduct the permeability and durability tests on Geopolymer concrete and study their effects on the compressive strength of TRGPC.

## 2. LITERATURE REVIEW

**E.P. Ayswarya, Ajalesh B. Nair et al., (2021),** In this research, the reinforcement effects of nanosilica (NS), modified rice husk ash (MRHA), and epoxy resin are studied, including the mechanical, dynamic mechanical, and thermal properties of composites. Smaller size and more fillers are needed to improve the characteristics. The mechanical and impact properties of composite are improved by the addition of fillers and an increase in specific surface area. Silica makes up roughly 90% of RHA. As a result, it can be used as a source for making nanosilica. In relation to filler loading, density and specific gravity exhibit an ascending trend. This is because adding fillers with nanoparticle sizes gives the composites a high density. Reduced particle size is what gives NS filled composites their increased tensile strength. Flexural modulus of polymer composites is dependent on filler nature, and aspect ratio of the filler particles. Enhancement of thermal stability of RHA, MRHA and NS composites is due to the organic/inorganic interaction between the polymer and filler where inorganic filler delays the volatilization of the products generated at the temperature of carbon-carbon bond scission of the polymer matrix.

**RattaponSomna, TeeraponSaowapunet al., (2022),** This work discusses the use of rice husk ash (RHA) to create hollow geopolymer blocks based on NaOH activation using both rice husk ash and fly ash (FA). For 15, 30, 60, and 90 minutes, RHA was

grounded. Using 14 molar sodium hydroxide, the RHA to FA ratios of 10:90, 20:80, 30:70, 40:60, and 50:50 by weight were applied. At 7, 28, and 60 days, the compressive strengths of geopolymer paste were evaluated. The geopolymer blocks' compressive strengths and water absorption rates were evaluated after 7 and 28 days. The findings demonstrated that the geopolymer's compressive strength rose as RHA content did. Amorphous silica was present in the RHA, which also improved strength and the  $\text{SiO}_2/\text{Al}_2\text{O}_3$  ratio. With an increase in RHA fineness, geopolymer's compressive strength rose. The carbon footprint of a geopolymer hollow block made of rice husk ash and fly ash was roughly two thirds that of a Portland cement system. The outcome demonstrates that the rice husk ash and fly ash geopolymer hollow block could be employed while maintaining standard compressive strength and water absorption. Geopolymer hollow blocks manufactured from rice husk and fly ash have a lower carbon footprint than cement-based ones. As a result, the community and environment benefit from this product's use of environmentally friendly materials.

**Herwani, Ivindra Pane et al. (2018)**, the purpose of this study was to determine the impact of alkaline activator solution (AAS) molarity on the compressive strength of geopolymer concrete made from fly ash with a variable sodium hydroxide (NaOH) solution molarity. As a test variable, sodium hydroxide solution was selected as the activator solution. The sodium hydroxide solution concentrations utilised for ambient curing were 10M, 12M, and 14M. According to test results, raising the content of sodium hydroxide (NaOH) solution increases the compressive strength of geopolymer concrete. Geopolymer concrete's ideal compressive strength was attained at a sodium hydroxide solution (NaOH) concentration of 12M. Geopolymer concretes compressive strength only achieves around 50-60% of the planned. On a 12M molar NaOH solution, geopolymer concrete attained its maximum compressive strength. Only 50–60% of the required compressive strength was really reached. The geopolymer concrete shrank the least when the NaOH solution had a 14M molarity. On a molarity of 12M, the compressive strength increased by 32.56% the most, whereas on a molarity of 14M, it increased by just 8.51%. The geopolymer concrete also demonstrated a high initial compressive strength.

### **3. MATERIALS INVESTIGATION**

All the constituent materials used in this research work and their properties are stated below.

#### **3.1. Rice husk ash**

Rice husk ash also improves concrete permeability through lowering the water-to-cement ratio, which reduces the volume of remaining capillary pores in the mass. Rice husk ash's spherical shape improves concrete consolidation even while reducing permeability. The rice husk ash emerged from agricultural waste in India.

#### **3.2. Fine aggregate**

Fine aggregate (river sand) used in this study was passing through 4.75 mm IS sieve, conforming to grading zone-I of IS 383 - 1997. The specific gravity of the fine aggregate was 2.6.

#### **3.3. Coarse aggregate**

Gravel particles that passed a 16 mm sieve, were retained on a 12.5 mm sieve, and were retained on a 10mm sieve were used as coarse aggregate in concrete production in accordance with IS 383 - 1997. The coarse aggregate had a specific gravity of 2.9. The coarse aggregate was washed and used to improve workability.

#### **3.4. Alkaline solution**

The alkaline solution as a binding material was a mixture of sodium hydroxide and sodium silicate. We used commercial grade sodium hydroxide pellets (97% - 100% purity) and sodium silicate solution with a composition of 14.7% Na<sub>2</sub>O, 29.4% SiO<sub>2</sub> (total solids = 45.4%) and 55.6% water by mass. The alkaline solution is used to activate silica and alumina for improving bond and involves polymerization process. After several experiments with conformance to workability and strength, the alkaline liquid to binder ratio was determined at 0.4 and the sodium silicate to sodium hydroxide ratio was set at 1:1. The preliminary survey has been conducted using various molarities. The sodiumhydroxide content was fixed at 12 M and 14 M for all tests, and two different NaOH concentrations were used.

#### **3.5. Aluminium oxide powder**

Aluminium oxide, often known as  $\text{Al}_2\text{O}_3$ , is a chemical compound composed of aluminium and oxygen. It is the most frequent of numerous aluminium oxides and has been designated as aluminium (III) oxide. It is widely recognized as alumina, however it can also be referred to as aloxide, aloxite, or alundum depending on its form or application. Because of its high melting point,  $\text{Al}_2\text{O}_3$  is crucial in the production of aluminium metal and as a refractory material. Although  $\text{Al}_2\text{O}_3$  is an electrical insulator, it has a reasonably high thermal conductivity for a ceramic material ( $30\text{Wm}^{-1}\text{K}^{-1}$ ). Water does not dissolve aluminium oxide. Aluminium oxide is important for metallic aluminum's resistance to weathering. It has a density of  $3.95\text{g/cm}^3$ . It has a boiling point of  $5391^\circ\text{F}$  ( $2977^\circ\text{C}$ ) and a melting point of  $3762^\circ\text{F}$  ( $2072^\circ\text{C}$ ).

#### 4. MIX PROPORTION AND CASTING

##### 4.1. Mix proportion

MATERIALS	12 MOLARITY			14 MOLARITY		
	Without $\text{Al}_2\text{O}_3$  $\text{Kg/m}^3$	With 1% of $\text{Al}_2\text{O}_3$  $\text{Kg/m}^3$	With 2% of $\text{Al}_2\text{O}_3$  $\text{Kg/m}^3$	Without $\text{Al}_2\text{O}_3$  $\text{Kg/m}^3$	With 1% of $\text{Al}_2\text{O}_3$  $\text{Kg/m}^3$	With 2% of $\text{Al}_2\text{O}_3$  $\text{Kg/m}^3$
Rice husk ash	394.29	394.29	394.29	394.29	394.29	394.29
Fine aggregate	554.4	554.4	554.4	554.4	554.4	554.4
Coarse aggregate	1293.6	1293.6	1293.6	1293.6	1293.6	1293.6
Sodium hydroxide solution	78.857	78.857	78.857	78.857	78.857	78.857
Sodium silicate	78.857	78.857	78.857	78.857	78.857	78.857
Aluminium oxide	-	3.943	7.886	-	3.943	7.886

##### 4.2. Preparation of test specimens and casting

The constituents for the mixes were weighed and blended for 3-4 minutes in dry environment. To enhance workability, the coarse aggregate was rinsed in tap water and filtered. The needed alkaline activator solution, a combination of sodium hydroxide and sodium silicate solutions, as well as aluminium oxide, is then added to the dry mix. In a concrete mixture machine, the mixing was maintained for around 6-8 minutes. Following the mixing, the concrete was poured in steel moulds with suitable compaction. Precautions were made to ensure that the ingredients were mixed evenly. The casted specimens healed in two days under the warm conditions depicted in fig. 4.1. The geopolymers are used to cure in sun light, steam and oven. The specimens were de-moulded and placed in a 60°C oven curing for 24 hours shown in fig.: 4.2. Then they were taken out shown in fig.: 4.3 and allowed to cure in the room temperature till the required day of testing.



**Fig.: 4.1 Casted Specimens**



**Fig.: 4.3 Cured Specimens**



**Fig.: 4.2 Oven curing**

## 5. RESULTS & DISCUSSION

To test the mechanical and thermal properties of TRGPC produced with  $\text{Al}_2\text{O}_3$ , more than 150 specimens were cast and put through various tests. Tests were performed on TRGPC using two distinct NaOH molarities and three different types of mixtures, including none, 1%, and 2% of  $\text{Al}_2\text{O}_3$ . The findings demonstrate how the percentage of admixture and the concentration of NaOH have an impact on the variation in compressive strength of TRGPC. Additionally, tests were conducted on the GPC specimens' flexural strength and splitting tensile strength. The permeability, durability and thermal studies of TRGPC were evaluated. The differences in the aforementioned parameters of the TRGPC specimen are shown in charts. Below are some discussions of the test findings.

### 5.2 MECHANICAL PROPERTIES

#### 5.2.1 Compressive strength

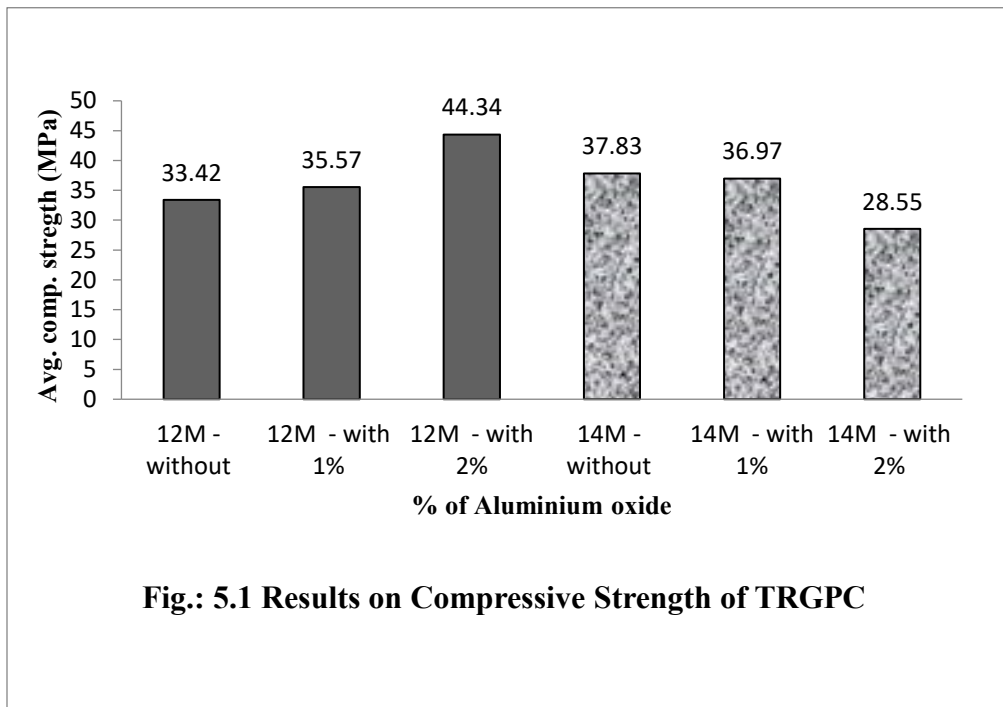
The strength attained during 24 hours oven cured on Geopolymer concrete cubes were experimentally tested for 2 specimens on each average and their average results. The result influences that molarity of sodium hydroxide (NaOH) solution and admixture of  $\text{Al}_2\text{O}_3$  on the compressive strength of TRGPC was studied for two different molar concentrations of NaOH viz., 12M and 14 M. At 60°C, the oven was used to cure each specimen. The compressive strength results are presented in Table 5.1, and Figures 5.1 , respectively, show the variations in compressive strength of TRGPC specimens corresponding to the two different molar concentrations of NaOH and % of  $\text{Al}_2\text{O}_3$ .

**Table 5.1 Results on Compressive strength of TRGPC**

Sl.No.	NaOH Concentration	Percentage of $\text{Al}_2\text{O}_3$	Trial 1 (MPa)	Trial 2 (MPa)	Average Compressive strength (MPa)
1	12M	-	35.39	31.44	33.42
2		1%	36.73	34.40	35.57
3		2%	44.07	44.61	44.34
4	14M	-	38.60	37.06	37.83
5		1%	36.92	37.01	36.97



6		2%	29.23	27.86	28.55
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The results show that when the concentration of NaOH increased, the compressive strength of TRGPC also increased. The strength increase of the  $\text{Al}_2\text{O}_3$ -free specimen (GP) after 24 hours in the oven ranged from 5 to 10% for the equivalent rise in molarity starting at 12 M and 14M. The increase in compressive strength could have been caused by a faster rate of silica and alumina ions dissolving in the alkaline solution due to the rise in NaOH concentration. The 12M-2% of  $\text{Al}_2\text{O}_3$  gives high compressive strength compared to remaining mixes of specimen. When the 14M - 2% of  $\text{Al}_2\text{O}_3$  gives low strength because of high molar concentration and increases the percentage of  $\text{Al}_2\text{O}_3$  might be reduces the strength.

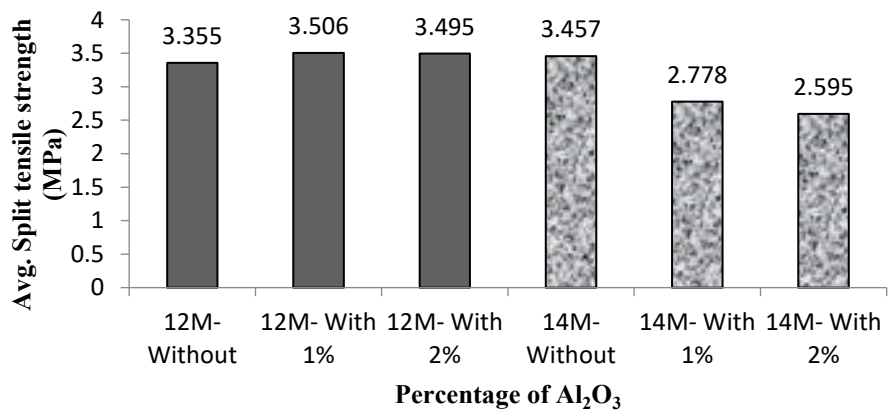
### 5.2.2 Split tensile strength

The split tensile strength test for the mixes was carried out on cylindrical specimens after 24 hours of curing and their results are presented. The split tensile strength of the 12M & 14M GPC mixes was noted of 3.355 and 3.457 MPa, and that of adding  $\text{Al}_2\text{O}_3$  were found to be in the range of 2.595 to 3.506 MPa. The effects of

NaOH concentration and % of  $\text{Al}_2\text{O}_3$  on the split tensile strength of the TRGPC mixes are discussed in the subsequent table.

**Table 5.2 Results on split tensile strength of TRGPC**

Sl.No.	NaOH Concentration	Percentage of $\text{Al}_2\text{O}_3$	Trial 1 (kN)	Trial 2 (kN)	Average load (kN)	Average Split tensile strength (MPa)
1	12M	-	95.7	115.1	105.40	3.355
2		1%	106.1	114.2	110.15	3.506
3		2%	110.4	109.2	109.80	3.495
4	14M	-	98.7	118.5	108.60	3.457
5		1%	84.1	89.8	86.95	2.778
6		2%	83.4	79.1	81.25	2.595



**Fig.: 5.2 Results on Split tensile strength of TRGPC**

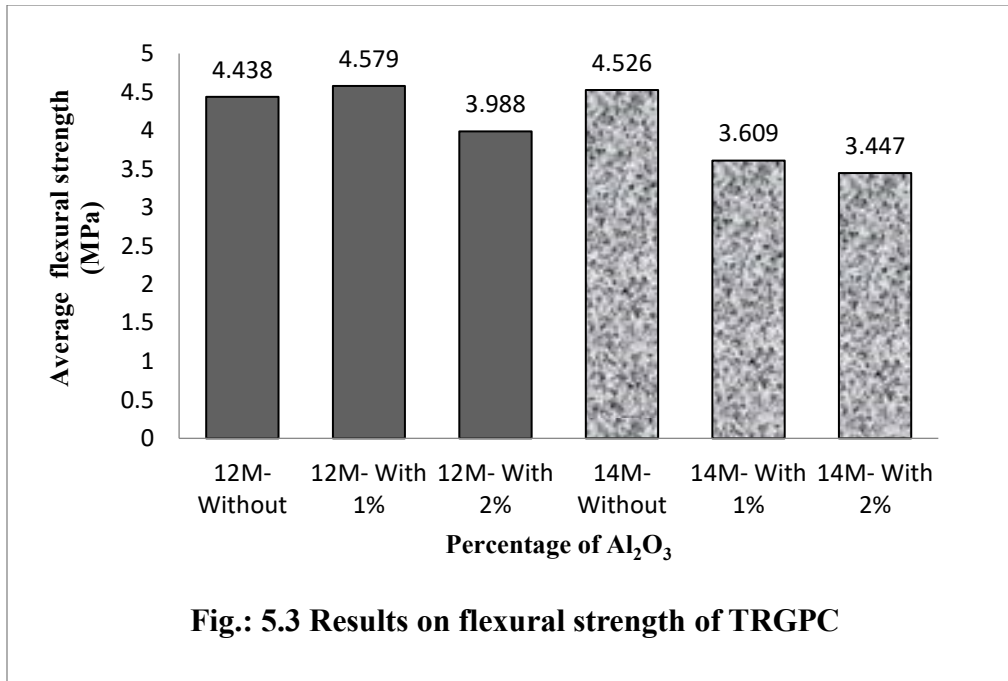
Without adding of  $\text{Al}_2\text{O}_3$  gives promising results compared to research papers. When comparing the 12M - 1% of  $\text{Al}_2\text{O}_3$  mix with 12M - 2% of  $\text{Al}_2\text{O}_3$  there was a slight improvement in split tensile strength. But the split tensile strength seems to be reduced with additional increases in molar concentration with percentage of  $\text{Al}_2\text{O}_3$ .

### 5.2.3 Flexural strength

All of the prism specimens were oven-cured at  $60^\circ\text{C}$ , and the flexural strength of the cured specimens was assessed. This circumstance (a 133 mm but  $> 110$  mm for 100mm specimen) results in the breaking point. The findings are listed in Table 5.3, and Figure 5.3 displays the variations in compressive strength of TRGPC specimens at the two different molar concentrations of NaOH and %  $\text{Al}_2\text{O}_3$  respectively. The flexural strength of the 12M & 14M GPC mixes was noted of 4.438MPa and 4.526MPa, and that of adding  $\text{Al}_2\text{O}_3$  were found to be in the range of 3.447Mpa to 4.579MPa.

**Table 5.3 Results on flexural strength of TRGPC**

Sl.No.	NaOH Concentration	Percentage of $\text{Al}_2\text{O}_3$	Trial 1 (kN)	Trial 2 (kN)	Average load (kN)	Average flexural strength (MPa)
1	12M	-	37	35	36	4.438
2		1%	27.5	28	27.75	4.579
3		2%	20	26	23	3.988
4	14M	-	32	39	35.5	4.526
5		1%	29	26	27.5	3.609
6		2%	27	24	25.5	3.447



The variation in the flexural strength of the TRGPC mixes with respect to NaOH concentration. While increasing NaOH concentration increases the flexural strength of the GPC mixes. The improved performance with the increase in the NaOH concentration is primarily because of the increasing amount of leaching of Si and Al at higher concentration of NaOH. In 12M - 1% of  $\text{Al}_2\text{O}_3$  gives slightly high strength compared to 12M- 2% of  $\text{Al}_2\text{O}_3$ . The rate of decreasing the strength is low in 14M mixes compared to 12M mixes.

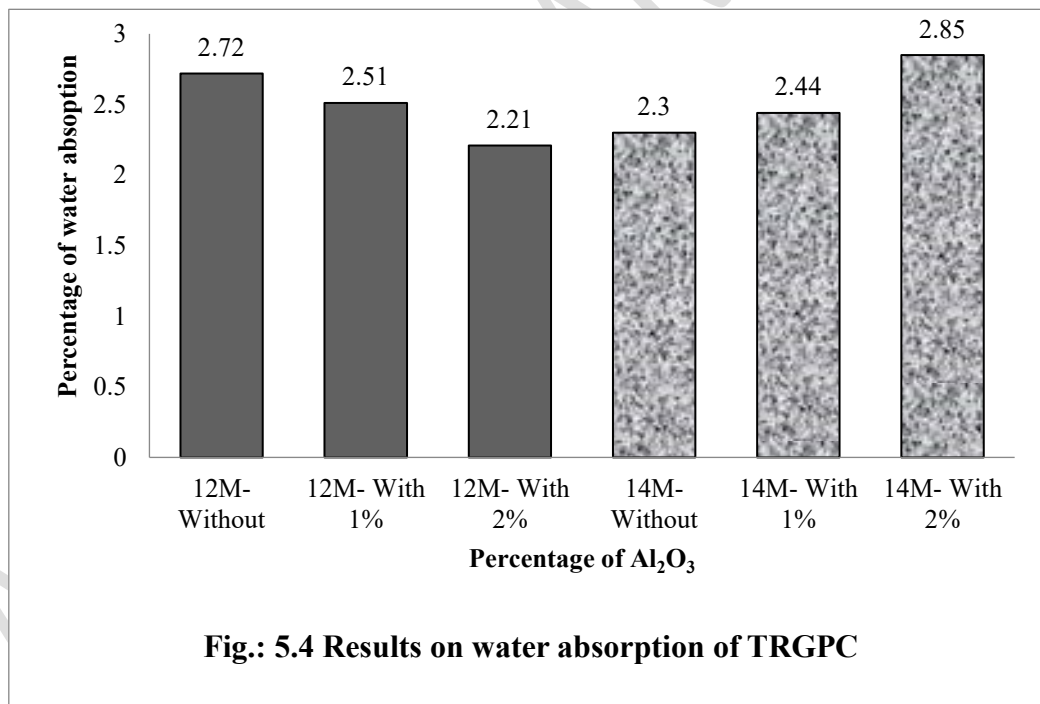
### 5.3 PERMEABILITY PROPERTIES

#### 5.3.1 Water absorption

The water absorption after 24 hours of immersion of 14M - 2% of  $\text{Al}_2\text{O}_3$  specimens was found to be 2.85% and 12M - 2% of  $\text{Al}_2\text{O}_3$  specimens recorded water absorption of 2.21%. For 12M – without  $\text{Al}_2\text{O}_3$ , it was 2.72% and 14M – without  $\text{Al}_2\text{O}_3$ , recorded a value of 2.30%. This shows the decrease in water absorption in Geopolymer concrete when the NaOH concentration is high. The water absorption in percentage is shown in Figure 5.4.

**Table 5.4 Results on water absorption of TRGPC**

Sl.No.	NaOH Concentration	Percentage of $\text{Al}_2\text{O}_3$	Dried weight (g)	Saturated weight (g)	Percentage of Water absorption
1	12M	-	668.7	686.9	2.72
2		1%	694.2	711.6	2.51
3		2%	691.2	706.5	2.21
4	14M	-	644.7	659.5	2.30
5		1%	730.9	748.7	2.44
6		2%	746.2	767.5	2.85



While comparing the 12M and 14M mixes from table 5.3.1 shows that 12M adding the  $\text{Al}_2\text{O}_3$  gives less absorption because of aluminium oxide able to fills pores and created an additional bond with existing aluminium oxide in GPC. The combination of higher molarity with increasing percentage of  $\text{Al}_2\text{O}_3$  might be increases the absorption

capacity because of  $\text{Al}_2\text{O}_3$  is insoluble in water. The presence of higher silica content formed higher quantity of aluminosilicate gel and provides very good particle bonding. Hence, the silicate occupies the void spaces between the Rice husk ash particles resulted in lower water absorption,

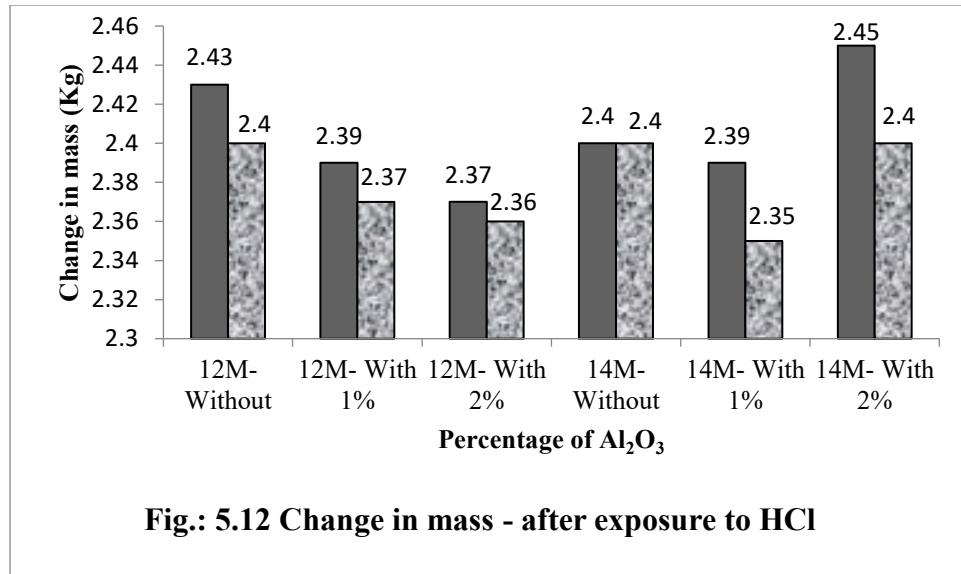
## 5.4 Durability studies

### 5.4.1 Acid attack

For the purpose of assessing initial corrosion behaviour, the weight and compressive strength losses of TRGPC after exposure to a 5% solution of HCl were measured at 1, 7, and 14 days after immersion. In Table 5.6 and Fig. 5.12, the weight (actual mass and change in mass) are displayed. The strength variations are depicted in Table 5.7 and Fig. 5.13.

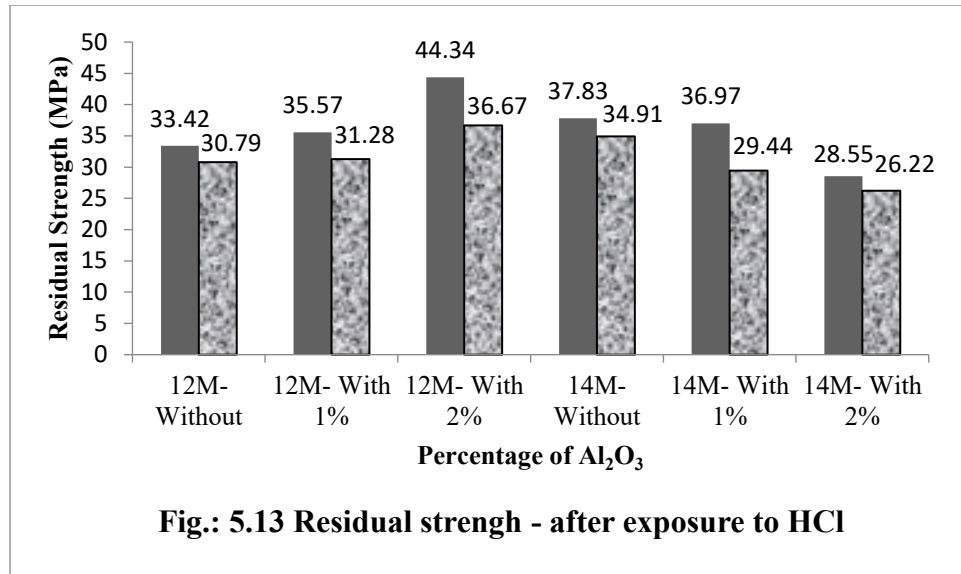
**Table 5.6 Change in mass of TRGPC after exposure of HCl**

Sl.No.	NaOH Concentration	Percentage of $\text{Al}_2\text{O}_3$	Actual Mass (Kg)	Change in mass (Kg)		
				7 days	14 days	30 days
1	12M	-	2.43	2.44	2.47	2.40
2		1%	2.39	2.41	2.43	2.37
3		2%	2.37	2.38	2.39	2.36
4	14M	-	2.40	2.42	2.43	2.40
5		1%	2.39	2.40	2.43	2.35
6		2%	2.45	2.46	2.49	2.40



**Table 5.7 Residual strength of TRGPC after exposure of HCl**

Sl.No.	NaOH Concentration	Percentage of $\text{Al}_2\text{O}_3$	Actual Compressive strength (MPa)	Residual Compressive strength (MPa)
1	12M	-	33.42	30.79
2		1%	35.57	31.28
3		2%	44.34	36.67
4	14M	-	37.83	34.91
5		1%	36.97	29.44
6		2%	28.55	26.22



The acid resistance of 12M-1% and 2% specimens revealed lower losses than other specimens after the addition of  $Al_2O_3$  had a positive effect. Weight first rose up to 14 days after exposure. After 30 days of exposure to 5% HCl, the percentage strength losses ranged from 3 to 7% (corresponding weight losses ranged from 0.1% to 4.5%). It is evident from the current study that the performances of  $Al_2O_3$  added TRGPC samples are comparable to those of the Rice husk ash based GPC even when exposed to a comparably higher concentration of HCl, while they have performed significantly better than the conventional concrete from the aforementioned literature. However, the 14M-2% of  $Al_2O_3$  specimens did not provide much resistance against HCl due to their poor structural compatibility and they showed larger weight and compressive strength losses at the conclusion of the 30 day exposure period.

The visual examination concludes the 12M, 14M, and 2% of  $Al_2O_3$  mixes obtain colour changes in bottom centered.





**Fig.: 5.14**After exposure of HCl

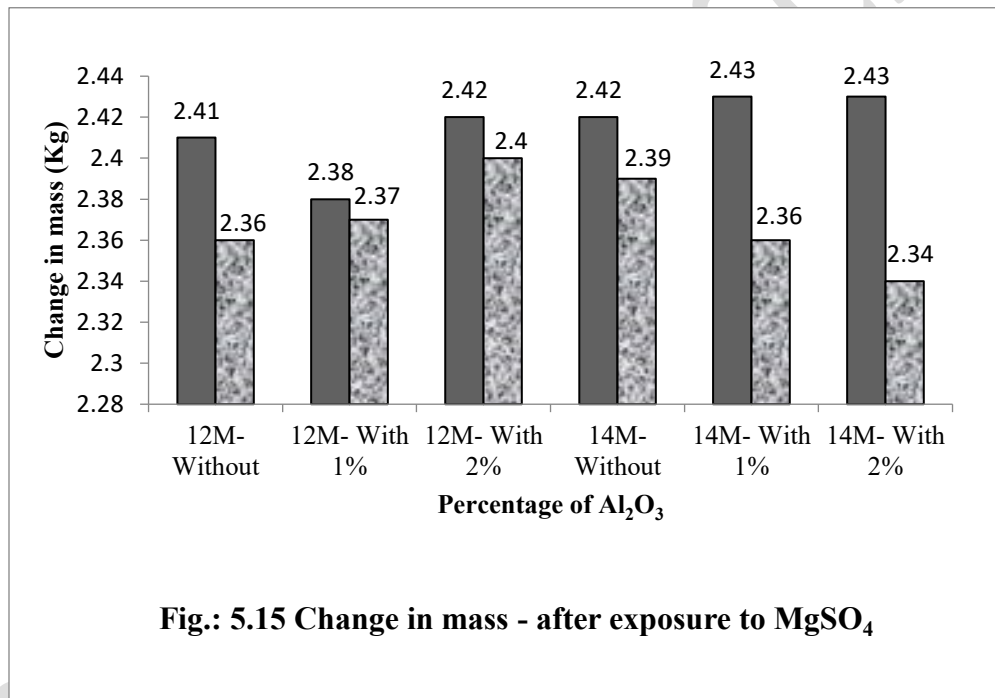
#### 5.4.2 Sulphate attack

To determine the first corrosion behaviour, weight and compressive strength losses of TRGPC were measured at 1, 7, and 30 days after exposure to a 5% solution of  $\text{MgSO}_4$ . In Table 5.8 and Fig. 5.15, the weight (actual mass and change in mass) are displayed. Strength variations are depicted in Table 5.9 and Figure 5.16.

**Table 5.8**Change in mass of TRGPC after exposure of  $\text{MgSO}_4$

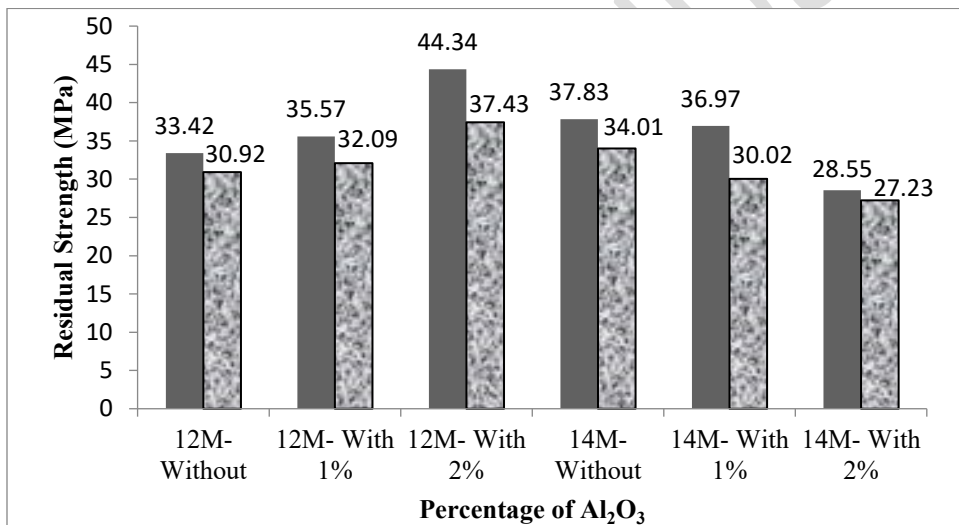
Sl.No.	NaOH	Percentage	Actual	Change in mass (Kg)
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	Concentration	of $\text{Al}_2\text{O}_3$	Mass (Kg)	7 days	14 days	30 days
1	12M	-	2.41	2.43	2.45	2.36
2		1%	2.38	2.40	2.41	2.37
3		2%	2.42	2.43	2.44	2.40
4	14M	-	2.42	2.43	2.44	2.39
5		1%	2.43	2.45	2.49	2.36
6		2%	2.43	2.46	2.50	2.34



**Table 5.9 Residual strength of TRGPC after exposure of  $\text{MgSO}_4$**

Sl.No.	NaOH Concentration	Percentage of $\text{Al}_2\text{O}_3$	Actual Compressive strength (MPa)	Residual Compressive strength (MPa)
1	12M	-	33.42	30.92
2		1%	35.57	32.09
3		2%	44.34	37.43
4	14M	-	37.83	34.01
5		1%	36.97	30.02
6		2%	28.55	27.23

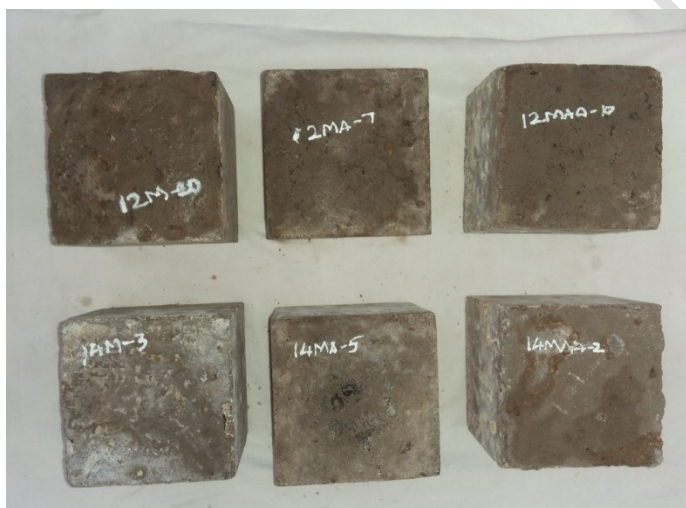


**Fig.: 5.16 Residual strength - after exposure to  $\text{MgSO}_4$**

Initially the weight gets increased upto 14 days of exposure to  $\text{MgSO}_4$  because of the specimens are oven cured under dry condition. So it absorbed and fill the pores laterally it get affects the specimen losses the weight in 30 days.  $\text{Al}_2\text{O}_3$  was added, and it improved the acid resistance of the 12M-2% and 14M-1% specimens, resulting in smaller losses than the other specimen. After 30 days of exposure to 5%  $\text{MgSO}_4$ , the percentage

strength losses ranged from 2 to 5% (corresponding weight losses ranged from 0.2% to 3%). It is evident from the current investigation that the 14M-2%  $\text{Al}_2\text{O}_3$  specimens did not provide much resistance against  $\text{MgSO}_4$ , and at the conclusion of the 30 day exposure period, they showed increased weight and compressive strength losses due to their poor structural compatibility.

The visual examination concludes the 12M, 14M, and 2% of  $\text{Al}_2\text{O}_3$  mixes obtain colour changed in side faces.



**Fig.: 5.17 After exposure of  $\text{MgSO}_4$**

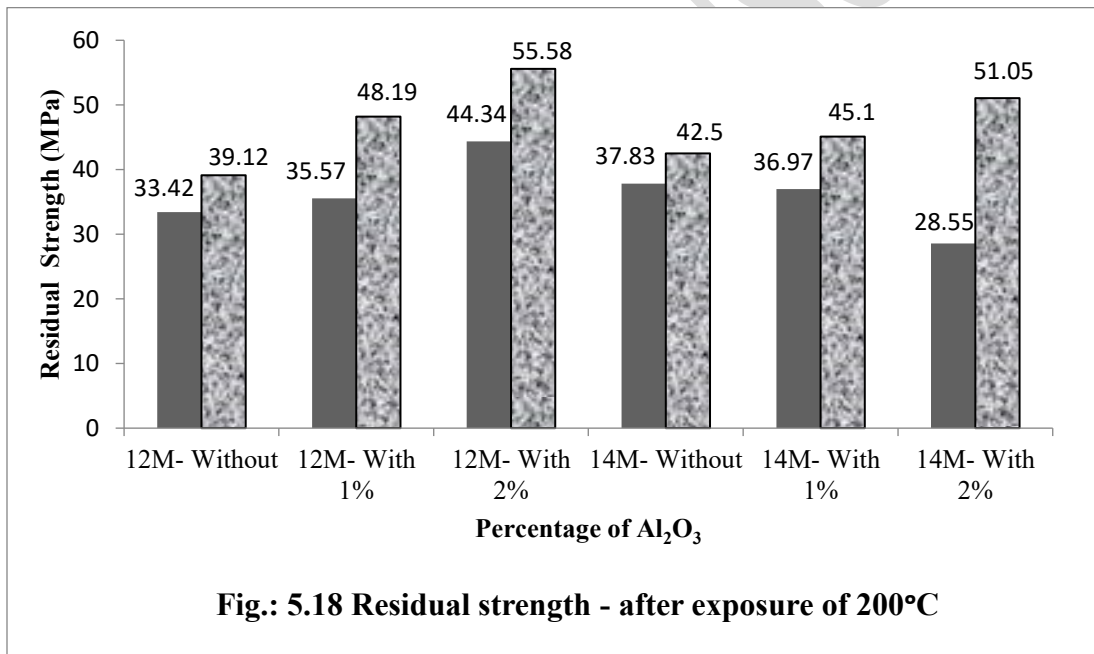
## **5.5 THERMAL PROPERTY**

### **5.5.1 Residual Compressive strength**

The cube specimens were oven cured at  $60^\circ\text{C}$  and cured specimens were exposed to high temperature  $200^\circ\text{C}$ ,  $400^\circ\text{C}$ ,  $600^\circ\text{C}$  and  $800^\circ\text{C}$  for 1 hour. Following exposure to high temperatures, the results as measured by changes in mass and residual compressive strength of TRGPC were discussed.

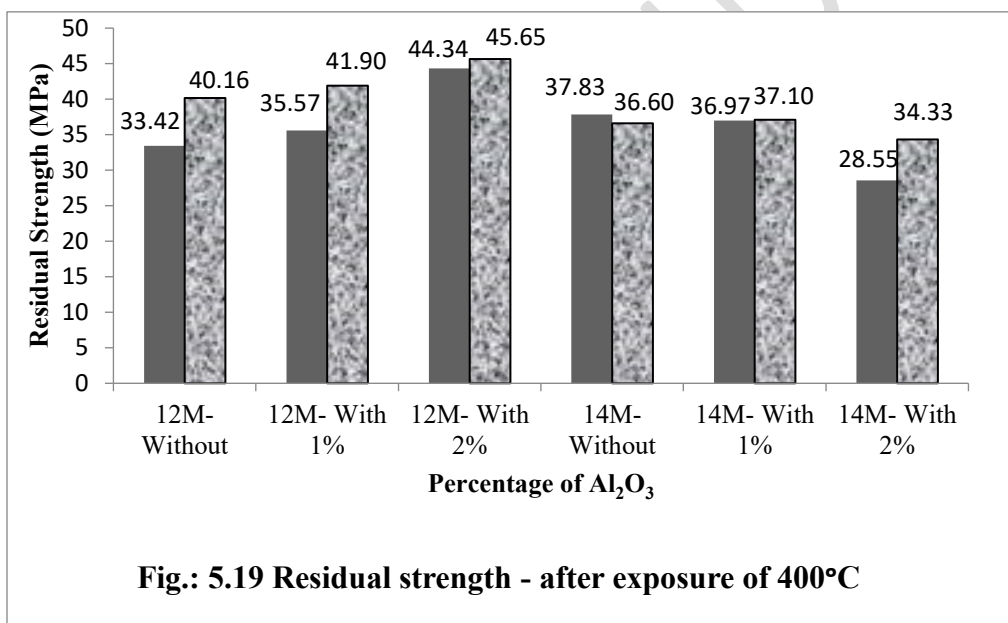
**Table 5.10 Residual strength of TRGPC after exposure of  $200^\circ\text{C}$**

Sl.No.	NaOH Concentration	Percentage of Al <sub>2</sub> O <sub>3</sub>	Actual mass (kg)	Change in mass (kg)	Residual strength (MPa)
1	12M	-	2.448	2.451	39.12
2		1%	2.339	2.342	48.19
3		2%	2.290	2.293	55.58
4	14M	-	2.349	2.353	42.50
5		1%	2.347	2.350	45.10
6		2%	2.441	2.446	51.05



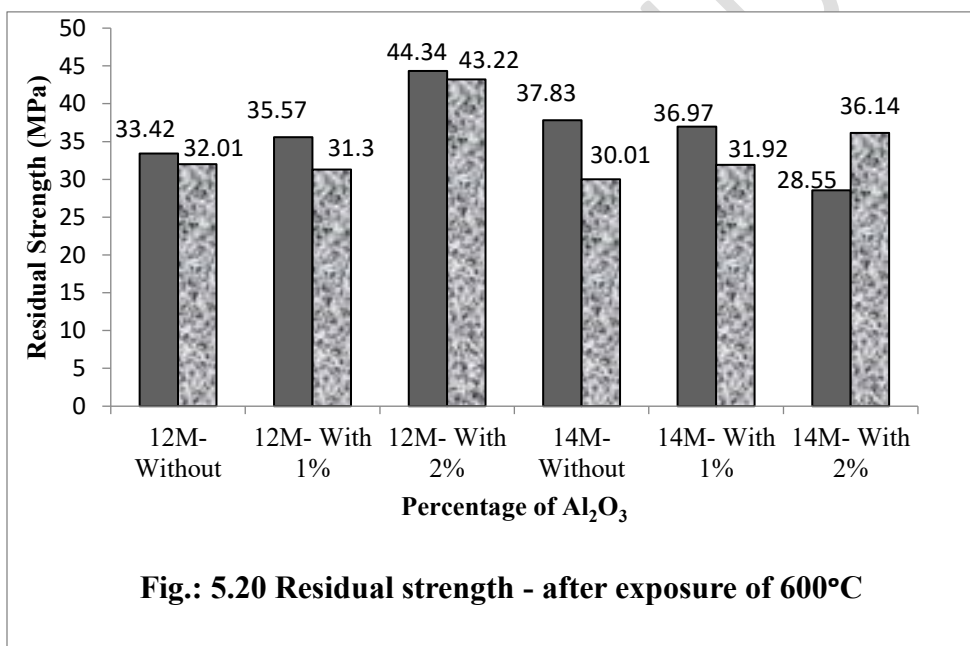
**Table 5.11 Residual strength of TRGPC after exposure of 400°C**

Sl.No.	NaOH Concentration	Percentage of Al <sub>2</sub> O <sub>3</sub>	Actual mass (kg)	Change in mass (kg)	Residual strength (MPa)
1	12M	-	2.41	2.32	40.16
2		1%	2.38	2.32	41.90
3		2%	2.39	2.31	45.65
4	14M	-	2.56	2.51	36.60
5		1%	2.42	2.36	37.10
6		2%	2.30	2.22	34.33



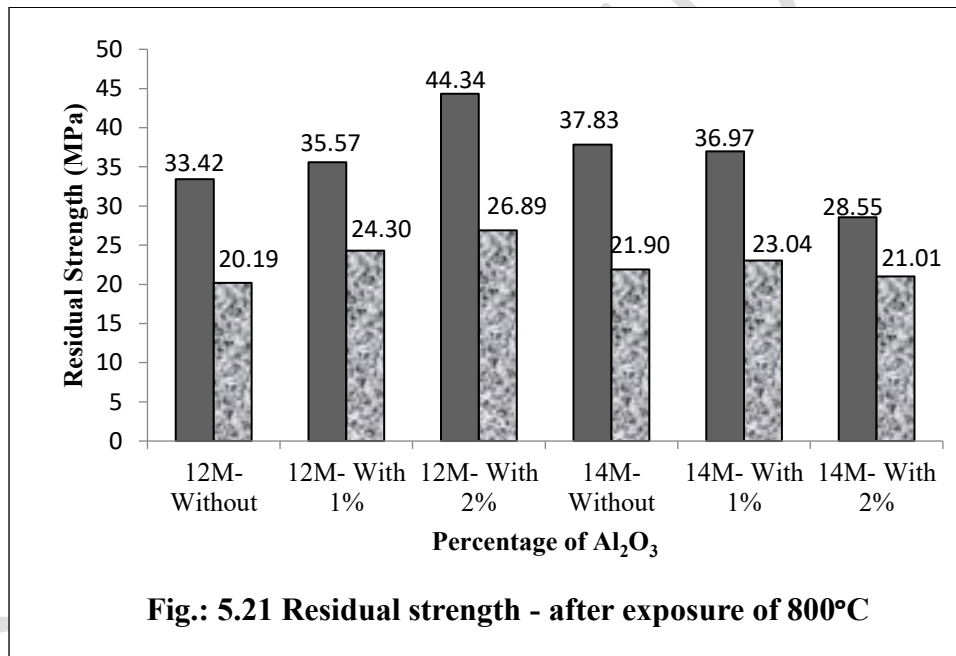
**Table 5.12 Residual strength of TRGPC after exposure of 600°C**

Sl.No.	NaOH Concentration	Percentage of Al <sub>2</sub> O <sub>3</sub>	Actual mass (kg)	Change in mass (kg)	Residual strength (MPa)
1	12M	-	2.45	2.38	32.01
2		1%	2.40	2.33	31.30
3		2%	2.34	2.27	43.22
4	14M	-	2.52	2.44	30.01
5		1%	2.37	2.30	31.92
6		2%	2.41	2.33	36.14



**Table 5.13 Residual strength of TRGPC after exposure of 800°C**

Sl.No.	NaOH Concentration	Percentage of Al <sub>2</sub> O <sub>3</sub>	Actual mass (kg)	Change in mass (kg)	Residual strength (MPa)
1	12M	-	2.39	2.27	20.19
2		1%	2.39	2.30	24.30
3		2%	2.45	2.36	26.89
4	14M	-	2.48	2.40	21.90
5		1%	2.45	2.36	23.04
6		2%	2.46	2.38	21.01



The residual strength and change in mass were drawn, according to table 5.10. The weight of the specimen decreases from 1 to 3% of the actual mass. But the residual strength is higher than the actual compressive strength. Then the 12M - addition of Al<sub>2</sub>O<sub>3</sub> gives the higher residual strength shown in fig.: 5.18. Because of the GPC get more



active upto 200 °C and yields the high strength referred in previous research work. The visual observation of after exposure at 200 °C remains no cracks.

Table 5.11 indicates that the residual strength and change in mass were taken into consideration. The weight of the specimen decreases from 2 to 7% of the actual mass. Then the residual strength is higher than the actual compressive strength. But the rate of increasing is decreased compared to 200 °C exposures. When the combination of 12M-2% of  $\text{Al}_2\text{O}_3$  is gives the optimum value shown in fig.: 5.19. The visual observation of after exposure at 400 °C remains no cracks are obtained.

The residual strength and change in mass were extracted from table 5.12. The weight of the specimen decreases from 5 to 10% of the actual mass. The residual strength is decreased because of dehydroxylation and it obtains minimal shrinkage. This 12M-2%  $\text{Al}_2\text{O}_3$  yields satisfactory results. And compared to actual compressive strength, residual strength from 14M-2%  $\text{Al}_2\text{O}_3$  is higher. 12M and 14M were visually observed to have surface edge hair line cracks following exposure to 600 °C.

The residual strength and change in mass were taken from table 5.13. The weight decreases 8 to 15% from the actual mass. The residual strength is decreased and rate of decreasing is high compared to 600 °C exposure specimen. The 12M and 14M specimens are densified by vitreous sintering compared to %  $\text{Al}_2\text{O}_3$  of specimens. The visual observation of after exposure at 800 °C, 12M and 14M having hair line cracks occurred in surface and 2% of  $\text{Al}_2\text{O}_3$  occurs crack in corners shown in fig 5.22.



**Fig: 5.22 After exposure of heat**

## 6. CONCLUSIONS

- The experimental results demonstrated that utilising rice husk ash and aluminium oxide, it is feasible to produce geopolymer concrete with significant strength and durability.
- The compressive strength increased as NaOH concentration raised.
- For the corresponding in 12 molarity and percentage of adding aluminium oxide, the strength increase varied from 5 to 10%.
- When aluminium oxide was added to Rice husk ash-based TRGPC, the mechanical qualities showed promise when compared to mixes with 14 molar concentration.
- Lower water absorption is the result of silicate and aluminium oxide filling the gaps between the rice husk ash particles. As the proportion of  $\text{Al}_2\text{O}_3$  increased at 12M, the water absorption dropped linearly.
- According to the durability experiments, specimens with a 12M-2%  $\text{Al}_2\text{O}_3$  content demonstrated good resistance to acid and sulphate assault since their weight and strength losses were lower than those of the other specimens.
- Compared to the actual compressive strength of oven curing, rice husk ash-based geopolymer concrete experiences a high strength during its early heating period (up to 200°C). Compared to other specimens, the residual strength in the 12M-2%  $\text{Al}_2\text{O}_3$  exhibited high results.
- The unreacted crystalline components of geopolymer concrete are converted to an amorphous state and go through polymerization at an exposure temperature of 600 °C. As a result, the strength loss in geopolymer is marginally reduced. Up to 600 °C, the geopolymer concrete showed no discernible cracks, and at an exposure temperature of 800 °C, only small fissures appeared.

- The experimental research leads to the conclusion that, out of six mixtures, 12M-1% and 12M-2% of  $\text{Al}_2\text{O}_3$  are the best.

#### **ENVIRONMENTAL APPLICATION:**

- In view of the environmental degradation caused by the cement industry, an attempt has been made in this work to develop geopolymer concrete using Rice husk ash which is industrial by product as replacement for cement, and to assess their strength and durability properties.
- In spite of enhancing the thermal resistant property by adding an aluminum oxide was used. Since aluminum oxide has high melting point. It induces a better performance geopolymer concrete base pad.
- The amorphous inorganic structure of the geopolymers lends itself to good thermal resistance which leads to potential applications as thermal insulation in industrial, military, molten mineral processing, Food processing units, Oven bases, chimney and domestic sectors.

#### **Scope for further research**

The paper has dealt with the experimental investigation on thermal resistant geopolymer concrete with aluminium oxide. The following suggestions are given for further research in thermal resistant geopolymer concrete:

- Further work shall be done by varying the NaOH concentration from 6M to 16M and also varying the temperature for conducting thermal test.
- Various agricultural and industrial wastes by products can be used instead of Rice husk ash.
- Increase the percentage of  $\text{Al}_2\text{O}_3$  for increase the thermal resistance and different chemicals having high melting point shall be used.
- Study will be extended to evaluate the permeability, durability and thermal properties like laser flash diffusivity, transient hot wire test etc., after exposure of heat.

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