iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 Issue: XI Month of publication: November 2017

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

Experimental Investigation on Modified Geo-Polymer Mortar

Dr. P. Thamilselvi[1]
[1]Associate Professor, Division of Structural Engineering, Department of Civil Engineering, College of Engineering Guindy, Anna University, Chennai-25

Abstract: The production of Portland cement of one ton approximately emits 0.98 ton of carbon dioxide (CO_2) in the atmosphere, which leads to several pollutions. Rice husk ash (RHA) is one of the agro-waste materials which can be utilized for the production of geopolymer mortar/concrete using alkaline activator. An alternate concrete material which eliminates the CO_2 emission can be used for the construction recently; rice husk ash (RHA) has become one of the most popular construction materials in geopolymer mortar/concrete which can be used in wide range of applications. RHA is rich in silica and alumina content/contain high amount of silicon dioxide. In this research RHA has been investigated with ambient and oven curing for the geopolymer mortar which was compared with the different morality ratio. The study has been carried out on strength enhancement and microstructure analysis has also been carried out using X -ray diffraction (XRD), capillary flow analysis, Elevated temperature, acid and sulfate attack etc., The activation of geopolymer mortar using sodium hydroxide (NaOH) powder/pellets with density of 2.13 g/cm³ and sodium silicate (Na_2SiO_3) solution/liquid with density of 2.4 g/cm³. The concentration of NaOH in a range of 7M to 10M was found to have similar effects on the strength and ductility. The compressive strength of the mortar ranges from 10-50MPa according to NaOH/Na_2SiO_3 ratio. The results are very excellent in comparison with different morality ratio, which promise further research for RHA.

Keywords: Geopolymer Mortar, Rice husk ash, Ultrasonic pulse velocity, Elevated temperature, Molarity concentration, X-ray Diffraction.

I. INTRODUCTION

Alkali-activated binders are using solid aluminosilicate powders like fly ash or blast furnace slag with alkaline activated solution. The reaction will be similar to organic thermo set polymers and such binders are known as "inorganic polymers" or "geopolymers". The waste or by-product from industry like fly ash or blast furnace slag is utilized as the alkali-activated binder for the geopolymer mortar/concrete. These materials substituting as alkali-activated binders for the ordinary Portland cement which reduces the carbon dioxide emission upto 80% [1].

Si/Al and raw material from industry is the main factor which controls the compressive strength of concrete for inorganic polymer concrete. In recent years Fly ash (FA) is a by-product from coal-fired electric power stations, one of the emerging materials which have the chemical composition (SiO_2, Al_2O_3 and Fe_2O_3) along with suitable size and shape which can be utilized for the geopolymer concrete products. The quality of the FA mainly depends on the source which may be difficult to control the chemical composition. High silica material can be blended in order to achieve the suitable chemical composition [2].

In the production of rice or paddy from agriculture, an agro-waste material rich husk is removed from farming process. The rich husk is burnt in kilns or power plant to generate the heat and the rich husk ash is produced which has the high silica content can be utilized for the cement replacement or admixture of cement. It is one of the environmental friendly by-products which can be used for sustainable concrete production. Several researches have been conducted on enhancement of compressive strength using RHA [3-5]. RHA doesn't suit directly to geopolymer concrete because it is lack in SiO_2/Al_2O_3 ratio, since it is mixed with another alumina-rich material like pozzolanic fly ashes.

Several factors affect the compressive strength of ash based geopolymer concrete such as particle size, curing temperature & time, source of ash and concentration of NaOH etc. From the previous investigation the effects of finer particle size of ash has better performance in geopolymer concrete production [6-8]. Many research work was carried out and the high strength geopolymers with different fine ashes has been accepted to achieve high compressive strength [2,9-11]. The concentration of high NaOH have increased the strength was reported by several research [2,6-8,12] and other showed negative impact of the high concentration of NaOH [13,14].

The effect of oven curing such as temperature and time still is not clear on compressive strength. Pan et al. [15] investigated the oven curing time upto 96 hours at a temperature of 80ºC, the results was quite impressive for higher compressive strength using fly ash based geopolymer concrete. Rangan and his group worked extensive on the fly ash based geopolymer concrete [16-19]. The geopolymer concrete can be manufactured using fly ash combined with sodium silicate pellet/powder and sodium hydroxide solution [18]. Optimum geopolymer concrete engineering properties occurred after oven curing at 60ºC for 24 hours [19].
Several research works was carried out on the effects on compressive strength of ash-based geopolymer concrete with same parameters [20-22]. There is a variety of factors affects the compressive strength of geopolymer concrete. To overcome the discrepancy of such affects a suitable experimental investigation can be helpful to reduce the experimental investigation with different parameters. Taguchi have investigated with oven curing time and temperature together to evaluate the effects with different NAOH concentration on fine ash-based geopolymer concrete in different three levels of parameters. He investigated nine series of experiments for water curing and other with oven curing. From the investigation is concluded that ANOVA method was the optimum level for factors affecting the compressive strength.

II. MATERIALS AND EXPERIMENTAL PROCEDURES

A. Rice Husk Ash (RHA)

Rice husk (RH) is an agro-waste which is processed from production of rice about 20% of a dried rice paddy is made upof Rice husk ash (RHA)by burning rice husk. RHA is rice husk ash contains large proportion of 80-90% of amorphous silica which enhances the strength of concrete. Depending on the burning conduction of RH can achieve amorphous silicate, which may be burnt at controlled temperature to yield maximum. Particular sample of RHA collected for the experimental investigation is necessary to evaluate the performance and uniformity of deleterious as silt obtaining in RHA for the geopolymer concrete investigation.

Table I
PHYSICAL PROPERTIES of RHA

Specific Gravity	2.3
Humidity	2 % maximum
Mean particle size	25 microns
Colour	Grey
Loss on ignition at 800°C	4 % maximum

Fig. 1 Rice husk ash

Table II
CHEMICAL COMPOSITION of OPC and RHA

Compound	OPC	RHA
Silicon-di-oxide (SiO_2)%	20–21	91.77
Aluminum oxide (Al_2O_3)%	5.2–5.7	2.13
Ferric oxide (Fe_2O_3)%	4.4–4.9	0.81
Calcium oxide (CaO)%	60–63	1.28
Magnesium oxide (MgO)%	0.5–0.7	0.66
Sulphur-tri-oxide (SO_3)%	2.4–2.7	----
Loss on ignition (LOI)%	1.5–2.3	4
Sodium oxide (Na_2O), Potassium oxide (K_2O)	----	1.81

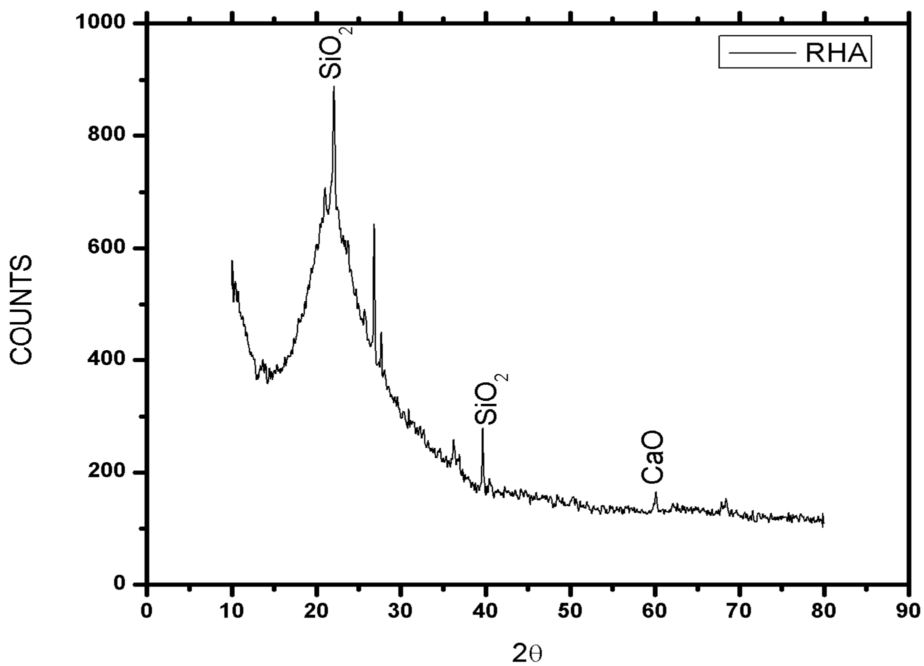


Fig. 2 X-ray diffraction spectrum of RHA

B. Mix Proportions

The binder used in this research was a mixture of Fly Ash (FA), sand and RHA for the samples in the ratio 1:2. The sodium silicate to sodium hydroxide ratios by mass is 2.5 and different concentration of $NaOH/Na_2SiO_3$is used as 7M to 10M respectively. The dry mix of fly ash, rice husk ash and fine aggregate was kept ready to cast. In order to obtain the workability 5% by mass of geopolymer paste (fly ash, $NaOH/Na_2SiO_3$) was added to base water. The different molarity solution of $NaOH/Na_2SiO_3$ was kept ready for the cast of geopolymer mortar.

C. X –Ray Diffraction(XRD)

XRD analysis is a rapid analytical technique which is used to find out the primarily phase identification of crystalline materials (e.g. minerals, inorganic components) provides information on unit cell dimensions. It collects the data using angle2θfrom 5º-70ºand rotation of sample in terms of goniometry. Such textural measurement by the orientation of grains and other polycrystalline identified using XRD analysis.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

D. Ultrasonic Pulse Velocity Test

UPV testing is one of the non-destructive to identify the strength and quality of concrete, natural rocks. The oscillation frequency is in the range of 40 kHz to 50 kHz and it assesses the velocity of ultrasonic pulse passing through the concrete structure or natural bed rock formation. Comparatively higher velocity indicates good concrete quality is good in terms of density, uniformity, homogeneity, while less velocity may indicate that the concrete has many cracks or voids etc...

E. Compression Test

The compressive strength of mortar specimens of size 50 x 50 x50 mm cubes cast with geopolymer using different concentration of NaOH. The specimens were subjected to two types of curing namely ambient and oven. After 7, 14 and 28 days of curing compression test were conducted for each concentration system for which three specimens were cast. The cubes are tested in the compression-testing machine (1000kN) capacity at the rate of 140 kN/min of loading. The ultimate load at which the cube fails was noted and the test set up is shown in Figure 3.

Fig. 3 Compression test in progress

Table III

COMPRESSIVE STRENGTH of GEO-POLYMER & CONTROL MORTAR CUBE 7, 14 & 28 DAYS

Days	Compressive Strength (MPa)								
	Rice Husk Ask								Control
	7M		8M		9M		10M		
	Air	Temp	Air	Temp	Air	Temp	Air	Temp	
7Days	9	19	13	21	16	22	17	23	25
14 Days	19	27	19	28	22	30	23	31	29
28Days	39	40	40	41	41	43	44	45	38

III. RESULTS AND DISCUSSION

A. X-RAY Diffraction (XRD)

In accordance with Joint Committee on Powder Diffraction Standards (JCPDS) the XRD peaks were identified. XRD patterns of OPC control mortar and different concentrated morality of geopolymer mortar are shown in Figure 4. The control system was arranged in a high intensity crystal phase ranges from 25^{o}-30^{o} to identify the Calcium aluminum silicate hydrate(C-Al-H)

($Ca.Al_2.Si_2O_8.4H_2O$), low high intensity crystal phase range of 29º to identify the calcium silicate (Ca_3SiO_5) and calcium hydroxide ($Ca(OH)_2$)at 34º peaks were observed. From the Figure 4 it is inferred the high crystal phase of Sodium aluminum silicate hydrate ($Si_7.Al_5.O_{24}.Na._{7.4}$ (H2O) $_{5.2}$) were gradually increased in the intensity for different molarity concentration.

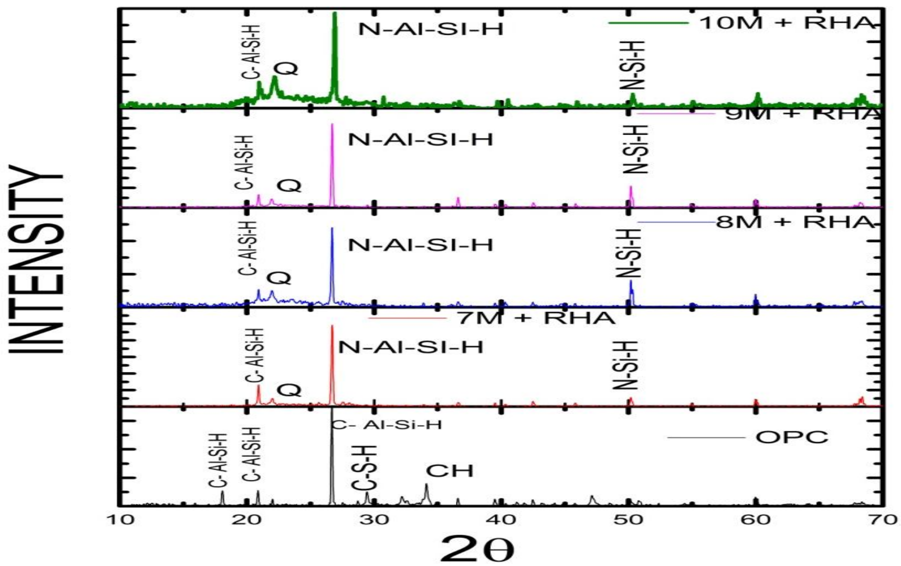


Fig.4X-ray diffraction patterns

B. Ultrasonic Pulse Velocity Test

An Ultrasonic Pulse Velocity Test measurement was performed for H_2SO_4 and sulfate exposure. From Figure 5 it also confirms that, higher velocity reduction observed for H_2SO_4 and sulfate exposure. The geopolymer mortar has less velocity in H_2SO_4 and sulfate exposure when compared to conventional control mortar. Geopolymer mortar with 10 molarity oven cured has less velocity reduction factor and its performance is better when compared to other mortar.

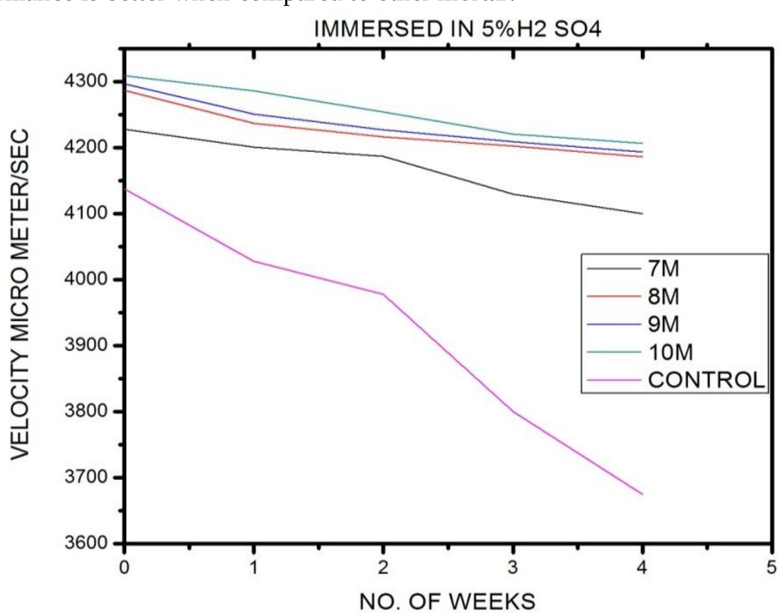


Fig. 5UPV for sulfuric acid

The compressive strength of oven cured geopolymer mortar is higher than ambient curing geopolymer mortar. Among all the other mortar 10 molarity geopolymer mortars has higher compressive strength. The strength increase is due to the Si-O-Si bond formation with increase in temperature.

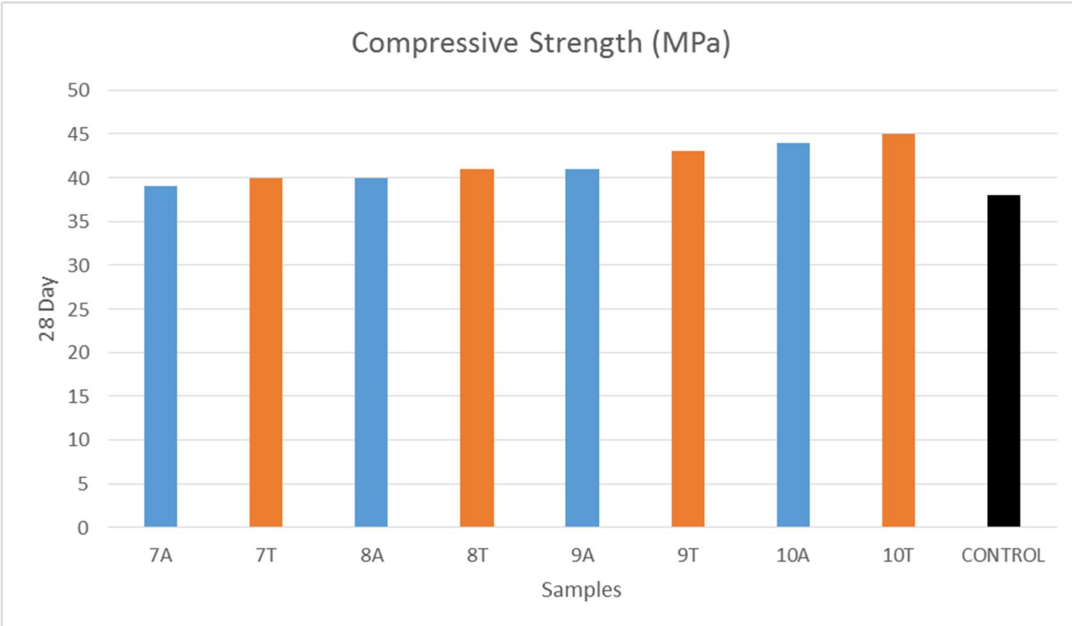


Figure 6 Compressive strength of mortar cubes at 28 days curing period

C. Elevated Temperature Study

Elevated temperature investigation was carried out for control mortar and geopolymer mortar with different molarity ratio. The temperature at which the specimens tested were 200^0C, 300^0C and 400^0C for all the systems and represented in Figure 7 (a) to (c) and Figure 8 (a) & (b) shows the different mortar such as (Control cement & Geopolymer).From the investigation the 400^0C for both control and geopolymer mortar found to be lesser strength, while 200^0C and 300^0C has showed similar performance. The geopolymer performance was high when compared to control mortar. Among all other mortar10M geopolymer mortar (both ambient and oven cured specimens) was found to have better performance.

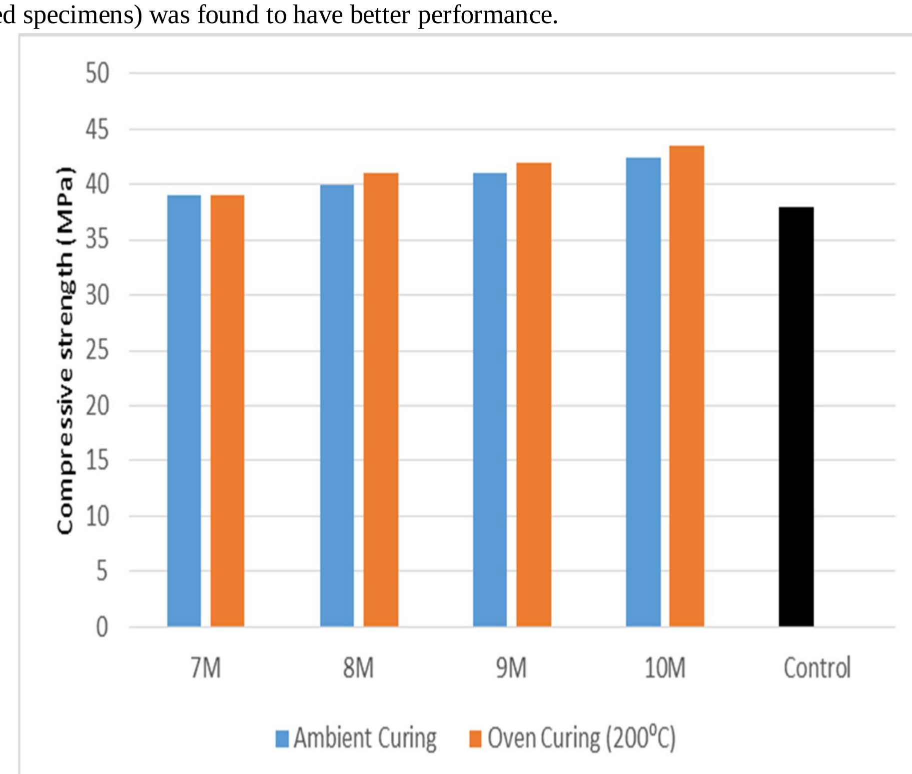


Fig.7a Compressive strength for 200^0c

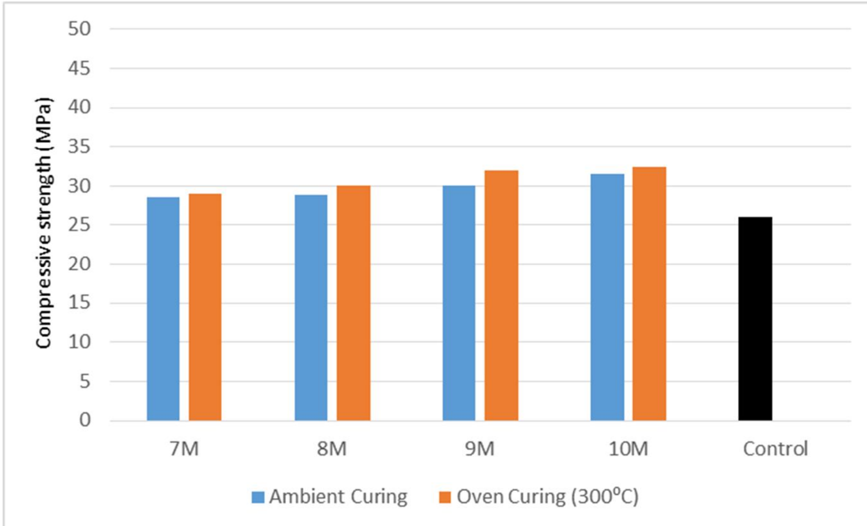


Fig.7_b Compressive strength for 300^0C

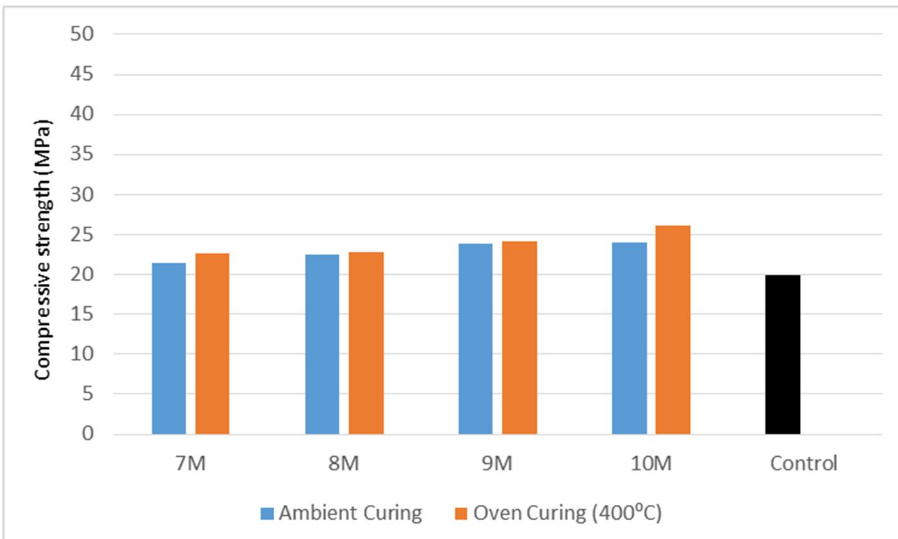


Fig.7c Compressive strength for 400^0C

Fig. 8a Visual observation of control specimen

Fig. 8b Visual observation of geopolymer specimen

IV. CONCLUSIONS

From the above investigations conclusion was drawn that 10M geopolymer mortar was found to be better among all other systems and the following broad conclusions were drawn.

A. Compressive strength test results indicated that, all the geopolymer mortars have shown better performance than the control system.
B. Geopolymer mortar with 10M oven cured has better performance and less velocity reduction factor. Among all other mortar 10M geopolymer mortar (both ambient and oven cured specimens) was found to have performed better.
C. Elevated temperature of 400^0C for both control and geopolymer mortar found to have lesser strength. The geopolymer mortar with 300^0C has more resistance to temperature.
D. The geopolymer mortar 10M has higher compressive strength due to the Si-O-Si bond formation with increase in temperature.
E. X-ray diffraction investigations revealed that, geopolymer mortars have shown additional formation of peaks responsible for the polymerization reaction.
F. It is inferred that high crystal phase of Sodium aluminum silicate hydrate (Si7.Al5.O24.Na.7.4 (H2O) 5.2)gradually increases the intensity for different molarity concentration.

REFERENCES

[1] M.C.G. Juenger, F. Winnefeld, J.L. Provis, J.H. Ideker, “Advances in alternative cementitious binders”, Cem Concr Res, vol 41, pp. 1232-1243, 2011.
[2] J. Wongpa, K. Kiattikomol, C. Jaturapitakkul, P. Chindaprasirt, “Compressive strength, modulus of elasticity, and water permeability of inorganic polymer concrete”, Mater Des, vol 31, pp. 4748-4754, 2010.
[3] Naji Givi, S. Abdul Rashid, F. Nora, A. Aziz, M.A. Mohd Salleh, “Assessment of the effects of rice husk ash particle size on strength, water permeability and workability of binary blended concrete”, Constr Build Mater, vol 24 (11), pp. 2145-2150, 2010.
[4] P. Chindaprasirt, S. Rukzon, “Strength, porosity and corrosion resistance of ternary blend Portland cement, rice husk ash and fly ash mortar”, Constr Build Mater, vol 22 (8), pp. 1601-1606, 2008.
[5] G.S. Rodriguez, “Strength development of concrete with rice husk ash”, Cem Concr Compos, vol 28 (2), pp. 158-160,2006.
[6] Nazari, A. Bagheri, S. Riahi, “Properties of geopolymer with seeded fly ash and rice husk bark ash”, Mater Sci Eng A, vol 528 (24), pp. 7395-7401, 2011.
[7] Nazari, S. Riahi, A. Bagheri, “Designing water resistant lightweight geopolymers produced from waste materials”, Mater Des, vol 35, pp. 296-302,2012.
[8] Nazari, S. Riahi, “Experimental investigations and ANFIS prediction of water absorption of geopolymers produced by waste ashes”, J Non-Cryst Solids, vol 358 (1), pp. 40-46,2012.
[9] S.J. O’Connor, K.J.D. MacKenzie, “A new hydroxide-based synthesis method for inorganic polymers”, J Mater Sci, vol 45 , pp. 3284-3288,2010.
[10] E. Najafi Kani, A. Allahverdi, “Effects of curing time and temperature on strength development of inorganic polymeric binder based on natural pozzolan”, J Mater Sci, vol 44,pp. 3088-3097,2009.
[11] Zhang, K.J.D. MacKenzie, I.W.M. Brown, “Crystalline phase formation in metakaolinite geopolymers activated with NaOH and sodium silicate”, J Mater Sci, vol 44 , pp. 4668-4676,2009.
[12] Z. Zuhua, Y. Xiao, Z. Huajun, C. Yue, “Role of water in the synthesis of calcined kaolin-based geopolymer”, Appl Clay Sci, vol 43 (2) , pp. 218-223,2009.
[13] P. Chindaprasirt, T. Chareerat, V. Sircicatnanon, “Workability and strength of coarse high calcium fly ash geopolymer”, Cem Concr Compos, vol 29 , pp. 224-229,2007.
[14] , K. Somna C. Jaturapitakkul, P. Kajitvichyanukul, P. Chindaprasirt, “NaOH-activated ground fly ash geopolymer cured at ambient temperature”, Fuel, vol 90 (6), pp. 2118-2124, 2011.
[15] Z. Pan, J.G. Sanjayan, B.V. Rangan, “An investigation of the mechanisms for strength gain or loss of geopolymer mortar after exposure to elevated temperature”, J Mater Sci, vol 44, pp. 1873-1880,2009.

[16] Hardjito, S.E. Wallah, D.M.J. Sumajouw, B.V. Rangan, "On the development of fly ash-based geopolymer concrete", ACI Mater J, vol 101 (6) , pp. 467-472, 2004.

[17] D.M.J. Sumajouw, D. Hardjito, S.E. Wallah, B.V. Rangan, "Fly ash-based geopolymer concrete: study of slender reinforced columns", J Mater Sci, vol 42 (9), pp. 3124-3130, 2007.

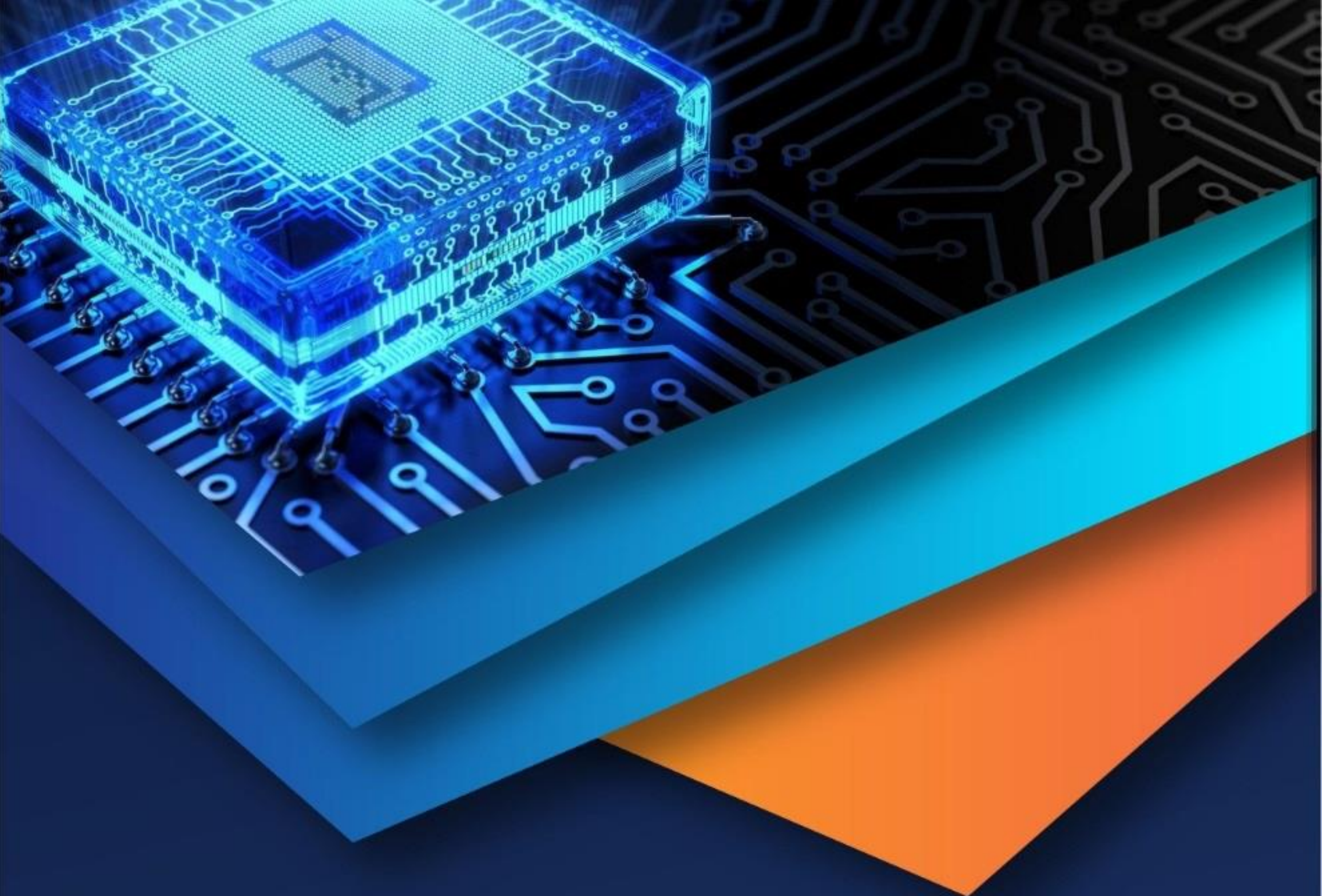
[18] Hardjito D, Wallah SE, Sumajouw DMJ, Rangan BV, "Properties of geopolymer concrete with fly ash as source material: effect of mixture composition, developments in mechanics of structures and materials", In: Deeks A, Hao H, editors. Proc 18th Australian conference on the mechanics of structure and materials, Perth, Australia,1–3 December, 2004.

[19] B.V. Rangan, S.E. Wallah, D.M.J. Sumajouw, D. Hardjito, "Heat-cured, low-calcium, fly ash-based geopolymer concrete", Indian Concr J, vol 80 (6), p. 47,2006.

[20] F. Pacheco-Togal, J. Castro-Gomes, S. Jalali, "Investigation about the effect of aggregates on strength and microstructure of geopolymeric mine waste mud binders", Cem Concr Res, vol 37 (6) , pp. 933-941,2007.

[21] Pacheco-Togal F, Castro-Gomes J, Jalali S, "Studies about mix composition of alkali-activated mortars using waste mud from Panasqueira", In: Proc of the engineering conference, University of Beira Interior, Covilha, Portugal,2005.

[22] T. Bakharev, "Geopolymeric materials prepared using Class F fly ash and elevated temperature curing", Cem Concr Res, vol 35 , pp. 1224-1232, 2005.



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY