Durability Performance of Metakaolin Redmud Geopolymer Mortar Under Various Exposure Condition

R. Srinivasan[1], Dr M. Logesh Kumar[2]
Author 1: M.E Construction Engineering and Management, Sona College of Technology,Salem, Tamil Nadu, India
Author 2: Assistant Professor, Sona College of Technology, Salem, Tamil Nadu, India.

***Abstract*-Approximately 7% of all human-caused CO2 emissions originates from the cement sector. Hence, in order to support sustainable material, another material must be found. A different approach is to use materials other than cement, such as red mud and metakaolin. Alkaline activator must be added together with red mud and metakaolin as binders in the form of sodium silicate (Na2SiO3) and sodium hydroxide (NaOH). The goal of this study is to quantify compressive strength and examine how activator liquid content affects the characteristics of geopolymer mortar. To achieve a low molarity ratio, NaOH has a range of molarities of 8,12,14, and 16 M with liquid to binder (l/b) ratios of 0.48, 0.5, 0.52 and 0.54. The 100 x 100 x 100 mm cube-shaped specimen is steam cured for 24 to 48 hours at a temperature of 25 to 28o C. According to the experimental findings of a new mortar, the molarity of NaOH affects the flow of the slump and the time it takes for it to set. The greater the concentration of NaOH, the smaller the slump value and the quicker the setting time. Based on the experiment's results, the specific gravity increased as NaOH molarity increased. Testing for durability was done using the highest strength possible with MK and RM proportions. This study aims to investigate the corrosion behaviour of geopolymer mortar. In this study, a quick review of the1, 3, 6 and 9 month long studies on accelerated corrosion, acid resistance, chloride resistance, and sulphate resistance is provided.**

***Index Terms*- Metakaolin, RedMud, Durability**

I. INTRODUCTION

One of the most often utilised building materials is concrete. Human activities that release greenhouse gases into the atmosphere, such as carbon dioxide, are what lead to global warming. Carbon dioxide makes up roughly 65% of the greenhouse gases that cause global warming. To lessen the amount of Portland cement used in concrete, numerous efforts are being explored. Using additional cementing ingredients like metakaolin, red mud, geopolymer, and alkaline activators like sodium hydroxide and sodium silicate, as well as looking for substitutes for Portland cement, are some of these initiatives. They could be organic minerals, like clays and kaolinite. The selection of the raw materials used to create geopolymer is influenced by a number of variables, including cost, kind of application, and end-user demand. The soluble alkali metals that are used to make the alkaline liquids are typically sodium or potassium based. A mixture of sodium hydroxide (NaOH) and sodium silicate is the most popular alkaline liquid used in geo polymerization (Na2SiO3).

An alkaline solid waste by product of the bauxite-to-alumina conversion process is known as red mud. While its usage is very low, 1 to 1.5 tonnes of red mud are typically produced from 1 tonne of alumina production. The currently known treatments for red mud involve recovering important elements from it, including Fe, Al, Ca, Ti and others. In addition, red mud is rich in silicate elements like Si, Al, Fe, and Ca that may be utilised to make building materials like cement and concrete. Modified red mud is used as an adsorbent to absorb pollutants in air and water and enhance the soil. Red mud usage can typically be most significantly increased by use in building materials. Iron is abundant in red mud, which can be used to create high-iron aluminium cement. Sulfur aluminate cement was made using fly ash and Bayer red mud. Red mud can help lower the clinker's burning temperature. Moreover, the development of C4A3S and the enhancement of compressive strength were helped by the right quantity of red mud.

II. MATERIALS USED

A. Metakaolin:

The clay mineral kaolinite has been de-hydroxylated to generate metakaolin. Metakaolin's particles are not as fine as silica fume but are smaller than cement particles. Metakaolin's quality and reactivity are highly influenced by the properties of the raw material. By raising the temperature of kaolin natural clay to 650–900°C, metakaolin is created. It has greater longevity, excellent performance, high strength, and increased resistance to chemical attack.

Table I. Chemical Composition of Metakaolin

Parameter	Experimental Value Sample 1	Experimental Value Sample 2	Method
Loss on Ignition(LOI)	0.09%	1.30%	Weight Loss Method
Silica	57.25%	54.45%	Gravimetric Method
Calcium Oxide (CaO)	0.20%	0.15%	EDTA Method
Magnisium Oxide (MgO)	0.11%	0.10%	EDTA Method
Iron Oxide (Fe2O3)	2.56%	0.95%	EDTA Method
Aluminium Oxide (Al2O3)	38.37%	41.60%	EDTA Method
Sodium Oxide (Na2O)	0.10%	0.10%	Acid Base Titration
Potassium Oxide (K2O)	0.75%	0.50%	Acid Base Titration

B. Red Mud

The Iron oxides are a mixture of solid and metallic oxides that give red mud its red colour and can account for as much as 60% of the volume. The pH of the red dirt ranges from 10 to13, making it very acidic. The other primary components, besides iron, are silica, residual aluminium compounds, and titanium oxide. With the exception of a fraction of the silicon component, the residue's makeup often matches that of the non-aluminum components. While part of the existing silica, which is usually referred to as reactive silica, will react under the extraction conditions to form sodium aluminium silicate as well as other related compounds, crystalline silica (quartz) will not.

Table II. Chemical Composition of Red Mud

Parameter	Experimental Value	Method
Loss on Ignition(LOI)	15.98%	Weight Loss Method
Silica	20.80%	Gravimetric Method
Calcium Oxide (CaO)	6.10%	EDTA Method
Magnisium Oxide (MgO)	1.68%	EDTA Method
Iron Oxide (Fe_2O_3)	34.25%	EDTA Method
Aluminium Oxide (Al_2O_3)	15.50%	EDTA Method
Sodium Oxide (Na_2O)	4.50%	Acid Base Titration
Potassium Oxide (K_2O)	0.30%	Acid Base Titration

C. Fine Aggregate

Sand from a local river was used as the fine aggregate in this project. According to BIS 2386-1963 (reaffirmed2002), river sand's physical characteristics were examined, and the findings are provided. As per BIS383-1970, river sand conforms to grading zone III (reaffirmed 2011).

Table III. Physical Properties of Sand

S. No	Tests	Result
1	Specific Gravity	2.63
2	Bilk Density	1738 kg/m^3
3	Fineness Modulus	2.28
4	Water Absorption	1.444%
5	Grading Zone	III

C. Alkali Activator

Alkaline solutions are always important for synthesis in geopolymerization. The soluble alkali metals that are used to make the alkaline solutions are probably sodium-based in nature. Sodium hydroxide is the alkaline solution that is most usually employed in the geopolymerization process. Bulk sodium hydroxide flakes with a purity of 95 to 97% were bought from a nearby supplier. By dissolving flakes in water, a solution of sodium hydroxide was created. The mass of NaOH solids in a solution changes with the solution's molarity-expressed concentration (M). Bulk sodium silicate in liquid gel form was obtained from a nearby vendor.

III.METAKAOLIN AND RED MUD BLEND GEOPOLYMER MORTAR(MK-RM GPM)

An attempt has been made to find out the optimum mix composition of MK-MK GPM. The optimum mix proportion of geopolymer mortar was arrived based on the compressive strength of the mortar.

A. Mix Proportion of MK-RM GPM

Metakaolin, Red Mud, fine aggregate, sodium silicate, and sodium hydroxide are employed to create MK-RM GPM in the current work. For this work, a total of twenty mixes have been created. For a 25% interval, the amount of MK and BA varied from 0% to 100% of the total weight of the source material. The liquid to binder ratio was changed in steps of 0.02 from 0.48 to 0.52. Moreover, a range of 1.6 to 2.2 sodium silicate to sodium hydroxide ratios were used. Moreover, the geopolymerization process was activated using 8M sodium hydroxide. The following mix codes are used in this work to comprehend the mix composition. The capital characters in the mix code, such M and R, stand for red mud and metakaolin, respectively.

B. Mix Proportion with Liquid Binder Ratio

Table IV. Mix Proportion of Red Mud and Metakaolin GPM

MIX	MK	RM	FA	NA_2SiO_3	NaOH
L/B = 0.48					
R 100 M 0	0	568	1705	181.8	92.2
R 75 M 25	142	426	1705	181.8	92.2
R 50 M 50	284	284	1705	181.8	92.2
R 25 M 75	426	142	1705	181.8	92.2
R 0 M 100	568	0	1705	181.8	92.2
L/B = 0.50					
R 100 M 0	0	568	1705	189	95
R 75 M 25	142	426	1705	189	95
R 50 M 50	284	284	1705	189	95
R 25 M 75	426	142	1705	189	95
R 0 M 100	568	0	1705	189	95
L/B = 0.52					
R 100 M 0	0	568	1705	196.9	99.4
R 75 M 25	142	426	1705	196.9	99.4
R 50 M 50	284	284	1705	196.9	99.4
R 25 M 75	426	142	1705	196.9	99.4
R 0 M 100	568	0	1705	196.9	99.4
L/B = 0.54					
R 100 M 0	0	568	1705	204.5	103.8
R 75 M 25	142	426	1705	204.5	103.8
R 50 M 50	284	284	1705	204.5	103.8
R 25 M 75	426	142	1705	204.5	103.8
R 0 M 100	568	0	1705	204.5	103.8

V. DURABILITY METHODS

A. Acid Attack

After 28 days of curing, the concrete cubes were subjected to an acid attack test by being submerged in acidic water for 90 days. The water in which the concrete cubes were held received 5% weight of hydrochloric acid (HCL) with a pH of about 2. Throughout the 90-day period, the pH was maintained.

B. Chloride Attack

The passive layer defending the steel reinforcement can be attacked by the chloride ions that permeate through concrete pores in solution and cause corrosion. To determine the corrosion on the reinforcing steel in chloride-contaminated concrete, the chloride concentration is measured at various depths.

C. Sulfate Attack

Sulfate attack on concrete is a complicated process that comprises chemical sulphate assault by sulphates from soil, ground water, or seawater as well as physical salt attack caused by salt crystallisation. Sulfate attack can cause the concrete to expand, crack, lose strength, and disintegrate.

D. Accelerated Corrosion

The accelerated corrosion test, which involves partially submerging the concrete specimen, was used to carry out this experiment. contains 17 cm long, 6 mm thick CA-60 Steel bars suspended in a saline solution containing 35 grammes of sodium chloride per litre of water.

V. RESULT AND DISCUSSION

A. Result

The compressive strength of geopolymer cement is increased by the sodium oxide and sodium silicate alkaline solution mixture. They generate a gel-like structure when combined with red mud and metakaolin. It is where the effective chemical connection occurs in them. the activators used, the fineness of the material, and the chemical make-up of the source materials, and the length of the curing process are all controlling factors that impact how strong geopolymer mortar is. Moreover, the reactive silica in metakaolin and red mud has a high adhesion to other materials.

B. Discussion

With an equal mixture of RM and MK and a liquid to binder ratio of0.50, the maximum compressive strength was attained at 28 days old. It might be caused by the fast dissolution of Si and Al atoms from the original material by hydroxide ions. Compressive strengths were significantly increased by a mortar made of red mud and metakaolin geopolymer with a molar ratio of

8. A notably higher rate of early strength development of geopolymer mortar is present in almost all mixed mixes. Yet, the early strength growth in combinations made from a single material source isn't very good. All of the RM-only combinations with various liquid to binder ratios displayed weak compressive strengths. Also, RM geopolymer mortar blends were significantly outperformed by metakaolin-only geopolymer mortar in terms of compressive strength. The current investigation's findings unambiguously demonstrate that the geopolymer mortar built from RM-MK has developed a promising compressive strength at ambient curing temperature.

V. CONCLUSION

The current effort attempted to evaluate the potential of employing RM and MK as a source material for geopolymer mortar. The results are as follows.

[1]. The best liquid to binder ratio to influence maximum compressive strength is 0.50 for RM and MK manufactured with equal parts RM and MK.

[2]. Geopolymer mortar is more effective when compared to mortar made from just one of RM and MK.

[3]. The mix R25 M75 produced compressive strengths that were much higher at room temperature during all ages of curing compared to other mortar mixes. Moreover, R25 M75 acquires strength at ambient curing temperature far earlier than any other combinations than any other.

REFERENCE

[1]. Abhisek Mohapatra, Prasanta Bose, Sagar S Pandit, Sanjay Kumar, T.C. Alex “Bulk Utilization of Red Mud in Geopolymer Based Products” Advances in Sciences and Engineering, Vol-12, PP 86-91,(2020)

[2]. Alwis Deva Kirupa J. P. and Sakthieswaran N “Strength and stability characteristics of GGBS and red mud based geopolymer concrete incorporated with hybrid fibres” The Indian Concrete Journal,Vol-10, PP 66-72, (2015)

[3]. Chava Venkatesh, Madduru Sri Rama Chand, Ruben Nerella “A State of the Art on Red Mud as a substitutional Cementitious Material” International Information and Engineering Technology Association, Vol-43, PP 99-106, (2019)

[4]. Chava Venkatesh, Nerella Ruben, Madduru Sri Rama Chand “Red mud as an additive in concrete:Comprehensive aracterization” Journal of the Korean Ceramic Society, Vol-3, PP 1-8,(2019)

[5]. Chava Venkatesh, Ruben Nerella, Madduru Sri Rama Chand “Comparison of mechanical and durability properties of treated and untreated red mud concrete” Materials Today:Proceedings, Vol-27, PP 284-87,(2020)

[6]. Chunjin Lin, Wenjie Dai, Zhaofeng Li, Fei Sha “Performance and Microstructure of Alkali-Activated Red Mud- Based Grouting Materials Under Class F Fly Ash Amendment” Indian Geotech,Vol-50,PP 1048-1056, (2020)

[7]. Gabor Mucsi, Roland Szabo, Adam Racz, Ferenc Kristaly, Sanjay Kumar “Combined utilization of red mud and mechanically activated fly ash in geopolymers” The Mining- Geology-petroleum Engineering Bulletin, Vol-34, PP 1-44,(2019)

[8]. Jian He, YuxinJie, Jianhong Zhang, Yuzhen Yu, Guoping Zhang “Synthesis and characterization of red mud and rice husk ash-based geopolymer composites” Cement & Concrete Composites, Vol-37,PP 108–118,(2012)

[9]. Kardelen Kaya, Sezen Soyer-Uzun “Evolution of Structural Characteristics and Compressive Strength in Red Mud-Metakaolin Based Geopolymer Systems” Department of Chemical Engineering Turkey, Vol-43, PP 14545-14551, (2016)

[10]. Manish Mudgal, Archana Singh, R.K. Chouhan, Ankur Acharya, A.K. Srivastava “Fly ash red mud geopolymer with improved mechanical strength” Cleaner Engineering and Technology, Vol-4, PP 1-7, (2021)

[11]. M. Jothilingam, V. Preethi “Feasibility, compressive strength and utilization of redmud in geopolymer concrete for sustainable constructions” Materials Today: Proceedings, Vol-45, PP 7016-7022, (2021)

[12]. Nan Ye, Jiakuan Yang, Sha Liang, Yong Hu, Jingping Hu, Bo Xiao, Qifei Huang “Synthesis and strength optimization of one-part geopolymer

based on red mud" Construction and Building Materials, Vol-111, PP 317–325,(2016)

[13]. Nevin Koshy, Kunga Dondrob, Liming Hu, Qingbo Wen and Jay N. Meegoda "Mechanical Properties of Geopolymers Synthesized from Fly Ash and Red Mud under Ambient Conditions" Crystals,Vol-9, PP 579, (2019)

[14]. Partogi H Simatupang, Razie Hanafi, Bambang Sunendar, Iswandi Imran, Ivindra Pane "The Study of Red Mud Addition Influences in Metakaolinite-Based Geopolymer Characteristics" Advanced Materials Research, Vol 450-451,PP 281-285, (2012)

[15]. Ramamohana Reddy Bellum, Chava Venkatesh, Sri Rama Chand Madduru "Influence of red mud on performance enhancement of fly ash-based geopolymer concrete" Innovative Infrastructure Solutions, Vol-6, PP 1-9, (2021)

[16]. Rishabh Bajpai, Anshuman Shrivastava, Manpreet Singh "Properties of fly ash geopolymer modified with red mud and silica fume: a comparative study" SN Applied Sciences, Vol-2,PP 2-16, (2020)

[17]. Smita Singh, Dr. M. U. Aswath and Dr. R.V. Ranganath "Effect of curing methods on the property of red mud based geopolymer mortar" International Journal of Civil Engineering and Technology (IJCIET)Vol 8, PP 1481–1489, (2017)

[18]. Smita Singh, Dr. M. U. Aswath and Dr. R.V. Ranganath "Effect of mechanical activation of red mud on the strength of geopolymer binder" Construction and Building Materials,Vol-177, PP 91–101,(2018)

[19]. Smita Singh, M.U. Aswath, R.V. Ranganath " Performance assessment of bricks and prisms: Red mud based geopolymer composite" Journal of Building Engineering,Vol-32,PP 1-10, (2020)

[20]. Smita Singha, S.N. Basavanagowdab, M. U. Aswathc, R. V. Ranganathd "Durability of Bricks Coated with Red mud Based Geopolymer Paste" IOP Conf. Series: Materials Science and Engineering, Vol-149, PP 1-9,(2016)

[21]. Sreelekshmi S, Remya S Chandran, Sera Rachel Varghese, Naeem, Thushara Raju and Ramaswamy K P "Rheological and strength behaviour of red mud – slag geopolymer composites" Materials Science and Engineering,Vol-989, PP 2-11, (2020)

[22]. Supriya Kulkarni "Experimental Study on Red Mud, Fly Ash and GGBFS based Geopolymer Concrete" International Journal of Engineering Research & Technology, Vol-267,PP 107-111,(2021)

[23]. Tao Ai, Danni Zhong, Yao Zhang, JingshanZong, Xin Yan and YanhuiNiu "The Effect of Red Mud Content on the Compressive Strength of Geopolymers under Different Curing Systems" Buildings, Vol-7, PP 107-111,(2021)

[24]. W. Hajjaji, S. Andrejkovicova, C. Zanelli, M. Alshaaer, M. Dondi, J.A. Labrincha, F. Rocha " Composition and technological properties of geopolymers based on metakaolin and red mud" Materials and Design , Vol-52, PP 648–654 (2013)

[25]. Xiaoming Liu and Na Zhang "Utilization of red mud in cement production: a review" Waste Management and Research Vol-29, PP 1053-1063, (2011)

[26]. Xiangzhou Liang, Yongsheng Ji "Experimental study on durability of red mud-blast furnace slag geopolymer mortar" Construction and Building Materials, Vol-267, PP 1-10, (2020)

[27]. Xiangzhou Liang, Yongsheng Ji1 "Mechanical properties and permeability of red mud-blast furnace slag-based geopolymer concrete" SN Applied Sciences, Vol-23, PP 1-8, (2021)

[28]. Yuancheng Li, Xiaobo Min, Yong Ke, Degang Liu, Chongjian Tang "Preparation of red mud-based geopolymer materials from MSWI fly ash and red mud by mechanical activation" Waste Management, Vol-83,PP 202–208 (2019)

[29]. Yurdakul Aygormez "Evaluation of the red mud and quartz sand on reinforced metazeolite based geopolymer composites" Journal of Building Engineering, Vol-43, PP 1-11,(2021)

[30]. ZhaotongYan, Ryan Mocadlo, Mengxuan Zhao, Richard D. Sisson Jr, Mingjiang Tao, JianyuLiang "Preparation of a geopolymer from red mud slurry and class F fly ash and its behavior at elevated temperatures" Construction and Building Materials, Vol-221, PP 308–317(2019).