Investigation on the mechanical characteristics and productivity of GGBS based geopolymer mortars

T Bhavani chowdary [1], AV Rao[2]*

[1]Assistant Professor, VNR Vignana Jyothi Institute of Engineering and Technology, Department of Civil, Hyderabad-500090,Telangana.

[1]Research Scholar,Koneru lakshmaiah Education Foundation, Department of Civil Engineering, Guntur-522502, AP, India.

[2]Professor, Koneru Lakshmaiah Education Foundation, Department of Civil Engineering, Guntur-522502, AP, India.

Abstract

It has been known for decades that geopolymer will significantly replace cement's function in construction industry. Geopolymer has low creep and shrinkage and a peak compressive strength. That is as per a recent study, geopolymer mortar is made by Fly ash and GGBS. The composition includes (100-60%) GGBS with a 10% substitution of fly ash. Alkali activators used in the research are sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). In the investigation, Na_2Sio3 is employed in two different molarities of 4 and 8. The utilised ratios of sodium hydroxide (NaOH) to sodium silicate (Na_2SiO_3) were 1.5, 2, 2.5, and 3. Investigation and research are done for mortars. Alkali activators' effects on the molarities of their setting times and characteristics. The 28-day compressive strength varied from 60 to 85 MPa, suggesting that high-calcium fly ash should be used to produce early, high-strength geopolymer concrete. The results revealed that the variables being studied significantly influenced the properties of the geopolymer mortars produced. Increasing either the NaOH concentration or the Na_2SiO_3/NaOH ratio led to a decrease in workability and setting time.

Keywords: ***Alkaline activator, Workability, Compressive Strength, Molarities, and Geopolymer.***

****Author for Correspondence*** E-mail: bhavanitalasila971@gmail.com

INTRODUCTION

Construction business is growing day by day as a result of significant industrial growth, and it will soon overtake other industries as the top investment. The need for raw materials has increased as a result to fulfill the demand for the construction businesses Due to its widespread use as a construction material; concrete is also the nation's biggest user of natural resources. Due to the widespread use of concrete, the manufacturing of cement is thought to be between 4 and 5 billion tones annually. Recent statistics information. Since cement production produces approximately 5-7% of the world's carbon Dioxide emission, it is well known that this will cause the greenhouse effect. It was anticipated that cement output would increase dramatically as a result of the enormous advancement and modernisation occurring in both the industrial and developing globe, including India, China, and Latin America. Natural resource depletion and issues with the disposal of construction wastes motivate us to look into viable choices for building materials that are durable, eco-friendly, and affordable.

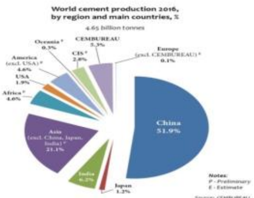

Fig 1 *Production of cement*

Source:https://cembureau.eu/cement-101/key-facts-figures/

BACKGROUND STUDY:

Utilize the early stage of great strength achievement to your advantage. In the precast assembly plant, Geopolymer Concrete can be successfully used to reach high production rates quickly and with little breakage. For the intersection of RCC beam columns, GPC may be used[1]. Given that precast structures may be heated up during treatment and that fly soot geopolymer concrete is employed in a variety of engineering applications[7], such as railway sleepers and remodelling, precast buildings should use geopolymer among others[2]. Since Geopolymerization occurs when materials are exposed to a high temperature curing, geopolymers become stronger [3]. A higher ratio of sodium silicate to sodium hydroxide results in an increase in the compressive strength of fly ash-based Geopolymer concrete[4]. Strength development is caused by sodium hydroxide concentration, and curing temperature affects strength development[5]. When the amount of NaOH is raised, a decline in the strength and longevity of Geopolymer concrete is observed. Super plasticizers including naphthalene, melamine, and other additives have improved the properties of Geopolymer paste [6]. The workability of GGBS-based Geopolymer has also increased by mixing it with fly ash-based Geopolymer. In outdoor conditions, geopolymer has sufficient mechanical properties[8]. OPC exhibits lower compressive strength when combined with GGBS than when combined with fly ash. About a percent of the strength is diminished. Fly ash-based geopolymers exhibit reduced water absorption and minimal mass loss during acidic curing (H_2SO4), according to [9, 10].

MATERIAL & EXPERMIENTAL DATA:

Flyash

One of the by-products of combustion of coal is fly ash, also known as "crushed fuel ash," which is comprised of fine constituent parts that are expelled from boilers via flues. An accumulation of ash at the bottom is referred to as "bottom ash." In more modern energy plants, fly ash is captured by distillation columns, which sit at the bottom of the boiler and produce what is thought to be coal ash[11,12]. The source asserts that there will be significant volumes of fly ash constituents of SiO_2, Al_2O_3, CaO, etc.

GGBS

Similar to pozzolans, it is non-crystalline and finely divided. Supplies adequate calcium to build new teeth substances that develop cementitious qualities after reaction with fluids that are alkaline, like sodium hydroxide or some other potent alkaline substance. Grounded granulated blast furnace slag, or GGBS, was obtained for this inquiry. utilising components sourced out from Andhra Cements base material in Andhra Pradesh.

Alkaline liquids

Sodium silicate

Na_2O and sodium oxide (Na_2O) are merged to produce sodium silicate. Water with silica sand (SiO_2). Silicate of sodium is usually termed as a water glass. the table presenting below are the Na_2O and SiO_2 proportions.

Table 1 Sodium Silicate(Na_2SiO_3) Chemical Composition

Oxides	Percentage of Composition
SiO_2	29.37
Na_2O	14.69
H_2O	54.6

Sodium hydroxide

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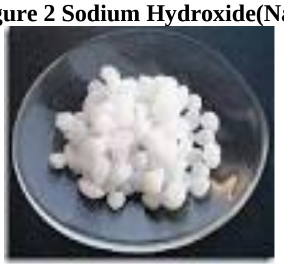
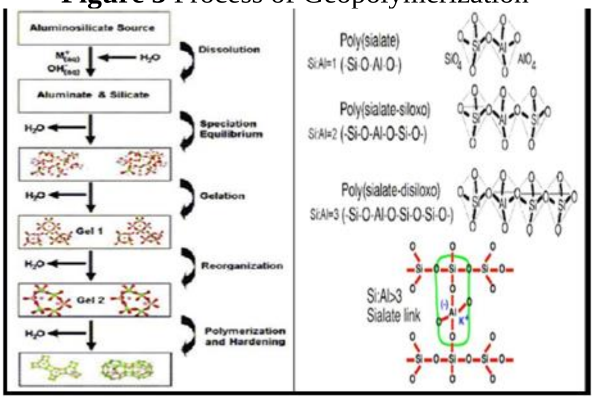
Caustic soda, also called sodium hydroxide (NaOH), is made up of white solid that come in pellet, flakes, and granular forms.

Figure 2 Sodium Hydroxide(NaOH) Pellets



Pellets of sodium hydroxide were used in the most recent analysis. NaOH and Na_2SiO_3 concentrations were utilised in the experiment because they work well to link these pozzolanic materials together (Flyash&GGBS). Since these sodium hydroxide pellets are 97% pure, reactions are carried out fairly, producing good strengths. When preparing sodium hydroxide (NaOH) solution, pellets are dissolved in deionized water. The mass of NaOH in a solution can be changed based on the required solution concentration, which is stated in molar, or M. The most common way to measure molarity is in moles of solute per liter of solution. The molecular weight of NaOH is 40, hence a litre of a solution with a 4M concentration of it included 4 x 40 = 160 grams of solid NaOH (in granules). In a kilogramme of 4M solution NaOH solution, 121 grams of NaOH solids was discovered.

Figure 3 Process of Geopolymerization



EXPERIMENTAL PROCEDURE

Mix Design:

This laboratory experiment explores the geopolymer mortar's strength adjusting the molarities and fly ash to alkaline solution ratio trial &error approach.

Table 2 Mix Specifications

S.No	**SPECIFICATIONS OF THE MIXES**								
1	Concentration of Sodium hydroxide	**8M**				**4M**			
2	Sodium silicate /Sodium hydroxide	1.5	2	2.5	3	1.5	2	2.5	3
3	GGBS to fly ash ratio	M1(100GGBS)				M1(100GGBS)			
		M2(90 GGBS +10 FA)				M2(90 GGBS +10 FA)			
		M3(80 GGBS +20 FA)				M3(80 GGBS +20 FA)			
		M4(70 GGBS +30 FA)				M4(70 GGBS +30 FA)			
		M5(60 GGBS +40 FA)				M5(60 GGBS +40 FA)			
4	Curing Regime	oven and Ambient				oven and Ambient			
5	Period of Curing	24hours,7&28 days				24hours,7&28 days			

Preparation of Geopolymer mortar

Mortar Density = 2200 kg/m^3

Mix Design = 1:3:0.55

Fly ash is substituted in the specified mix proportion by GGBS in the following percentages: 10%, 20%, 30%, and 40%.

Mixing and casting:

The composition and aggregate were first mixed in dry form. If the calculated results are accurate, the alkaline solution was added and mixed properly until a consistent mixture was obtained by hand. Three layers of mortar cubes measuring 100 mm x 100 mm x 100 mm were crushed. The cast specimen is allowed a day to rest before ever being demolded. After being placed inside an oven at a temperature at 110 °C for twenty-four hours to accomplish oven curing, the specimen is then transported outside to cure for 7 & 28 days.

Fig 5*:* cast mortar cubes

Fig 6*:* Ambient & Oven cured mortar cubes

Testing:

All materials must have compressive strength, which is also influenced by the curing temperature and time. Compressive strength rises in direct proportion to temperature and hardening time. Concrete can have a compressive strength of 400 to 500 kg/cm^2 at curing temperatures between 105 and 110 °C and a curing time of 24 h. Moreover, the quantity of fine fly ash dust (particles smaller than 43 micrometers) in the geopolymer exerted a notable influence on its compressive strength. Greater fineness in the fly ash led to a greater enhancement in compressive strength. Consequently, the type and quantity of activators played a pivotal role in the alkali activation reaction.

F = P/A (MPa or N/mm^2)

Where,

Fc is the compressive strength,

P is the peak load that was applied to the specimen, and

A is the specimen's area.

Three specimens are used for the compressive test, and each mix's average compressive strength is determined.

RESULTS AND DISCUSSION:

Because fly ash, a byproduct, is used in the Geopolymer mortar and cement is completely replaced, less greenhouse gas is released into the atmosphere. For two different molarities of alkaline solution—1.5, 2, 2.5, and 3—a total of 480 cubes were cast, and their compressive strength was determined. Different molarities improved the Geopolymer specimen's strength. The outcomes are displayed below.

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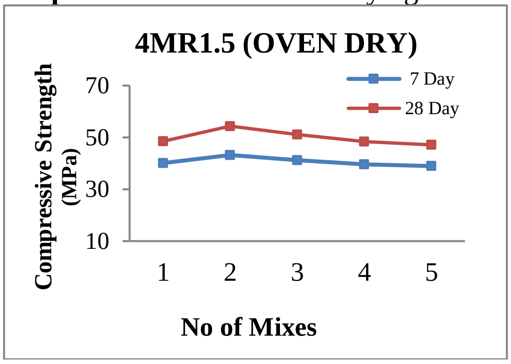
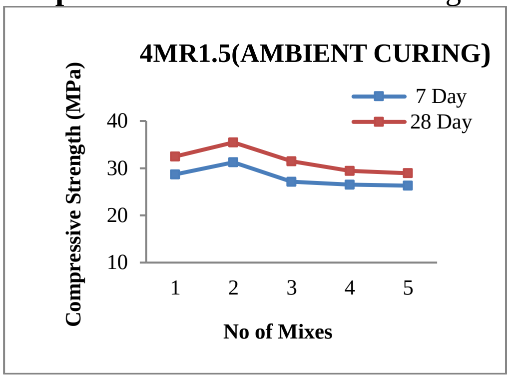
Graph 1 4M R1.5 oven drying values

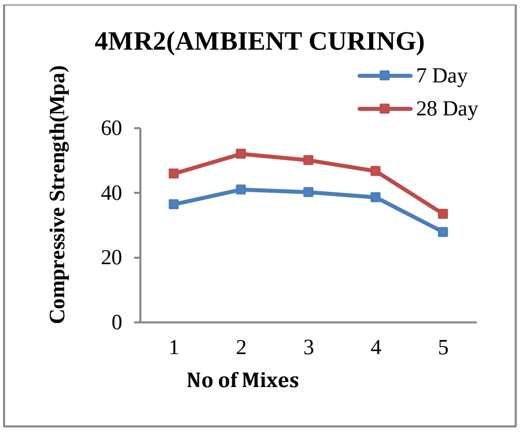


Graph 2 4M R1.5 Ambient Curing

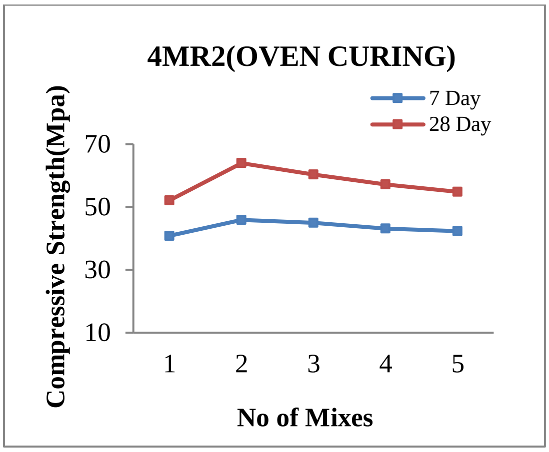


When sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) are mixed in a 4:1 molarity ratio, oven curing produces stronger results than ambient curing,therefore the geopolymerization process is considerably better at high temperatures.

Graph 3 4 Molar Ratio 2 Ambient Curing values

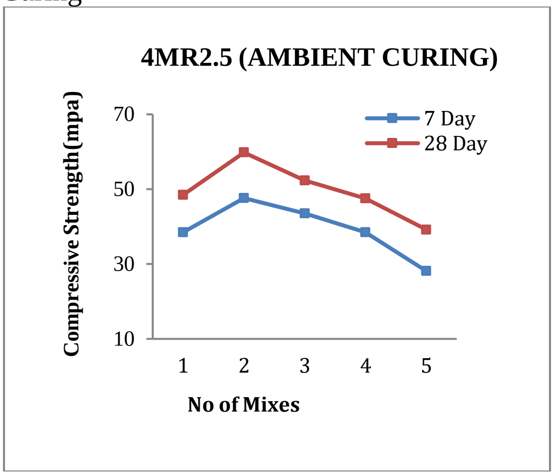


Graph 4 4 Molar Ratio 2 oven drying values

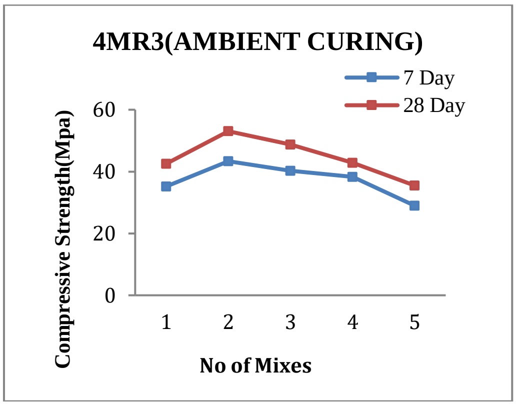


Oven curing outperforms ambient curing in a 4M Na_2Si0_3 to NaOH at 2.0 ratio because the geopolymerisation process demonstrates greater strength at higher temperatures.

Graph 5 4 Molar Ratio 2.5 Ambient Curing



Graph 6 4Molar Ratio 3 Ambient Curing



Graph 7 4Molar Ratio 3 oven drying

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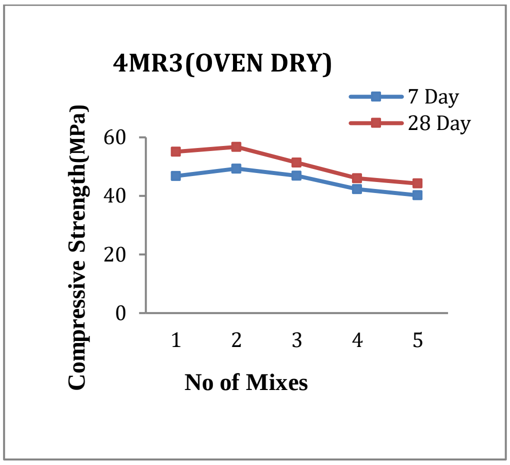
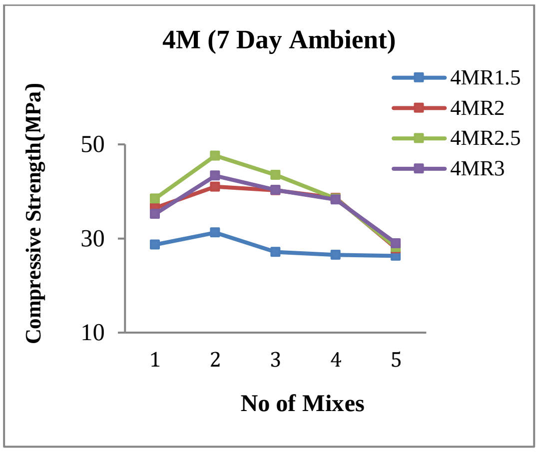
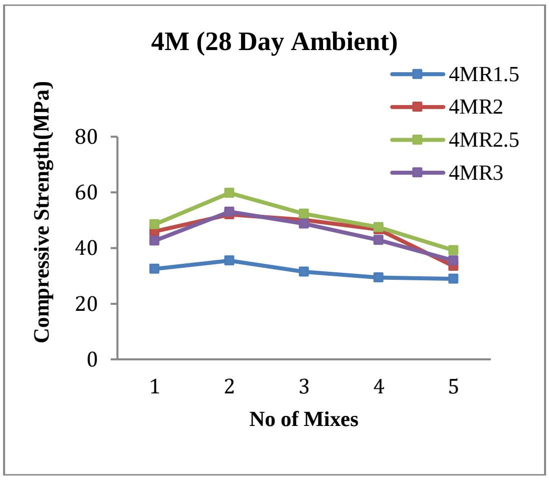


Graph 8 4Molar 7 day Ambient Curing for all ratio's



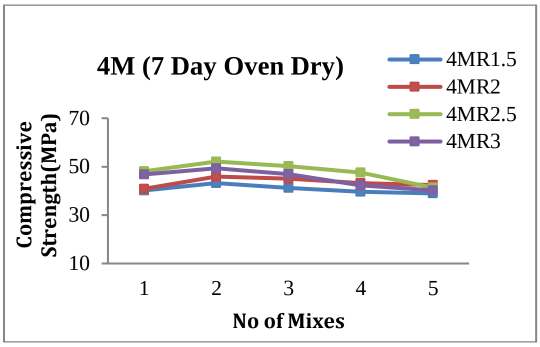
Explicit observation reveals that 4M R2.5 performs better in a 7-day ambient curing environment.

Graph 9 4Molar 28day Ambient Curing for all ratio's



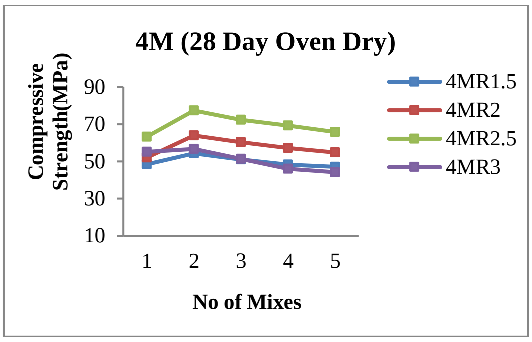
According to the results of the 28-day ambient curing regime, 4M R2.5 produces a higher yield.

Graph 10 4Molar 7day oven drying for all ratio's



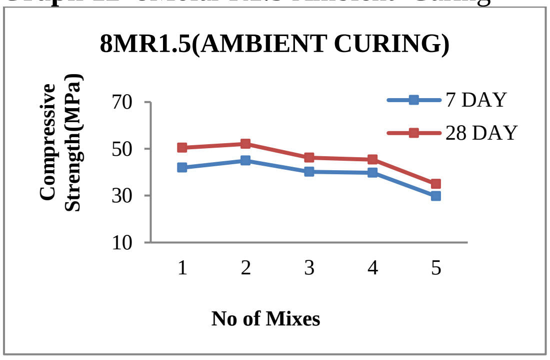
According to this graph, the 7-day oven curing regime has achieved early strength, and results for 4MR2, 4M R2.5, and 4MR2 are nearly identical, with little strength difference between them. We can determine that 4MR2.5 is performing better by closely observing this.

Graph 11 4Molar 28day oven drying for all ratios



According to this graph, 28-day oven curing, the 4MR2, 4M R2.5 are providing precise proof of a 12.5% strength variation between results. It is quite clear that 4MR2.5 is outperformed by achieving excellent performance.

Graph 12 8Molar R1.5 Ambient Curing



Graph 13 8Molar R1.5 oven drying

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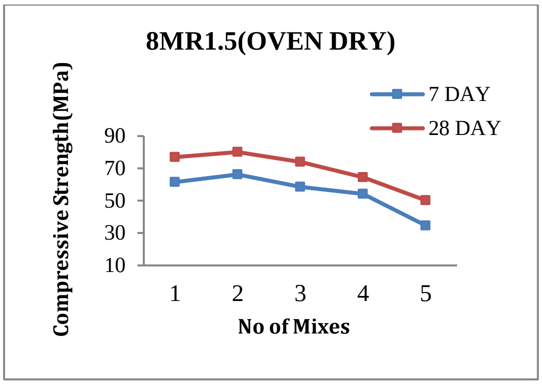
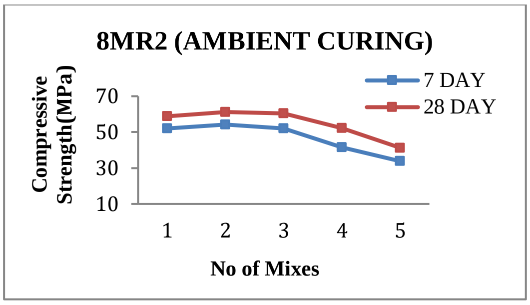
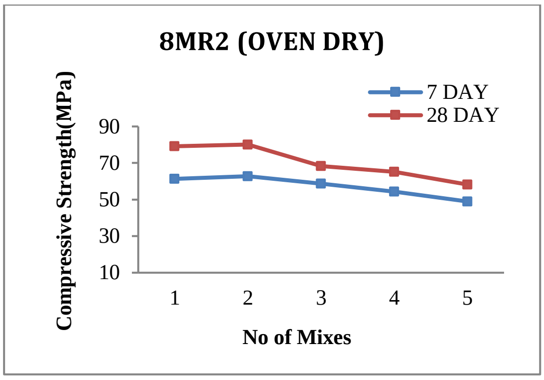


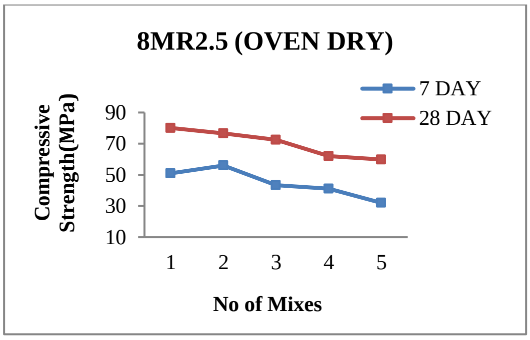
Graph 14 8Molar R2 Ambient Curing



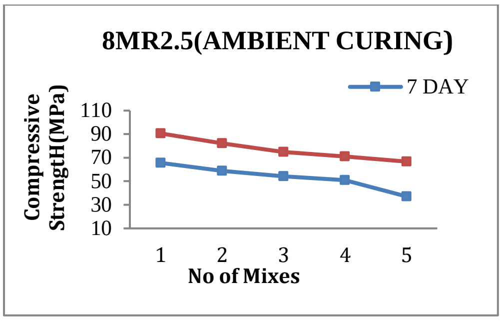
Graph 15 8Molar R2 oven drying



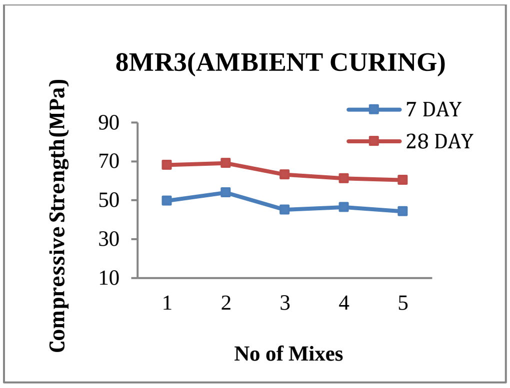
Graph 16 8Molar R2.5 oven drying



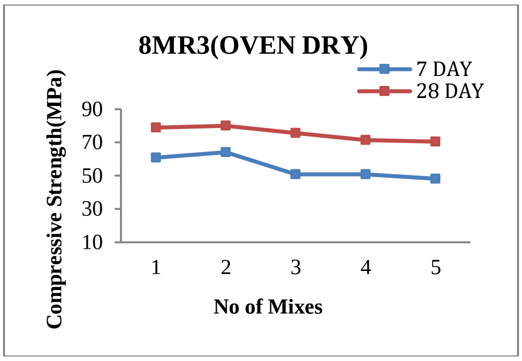
Graph 17 8Molar R2.5 Ambient Curing



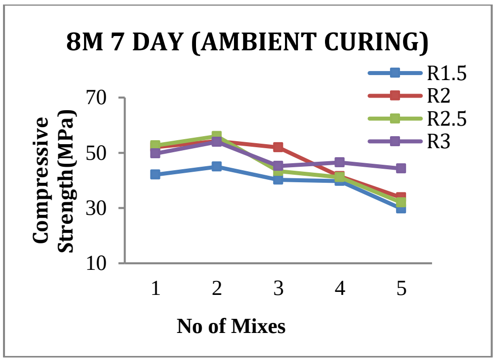
Graph 18 8Molar R3 Ambient Curing



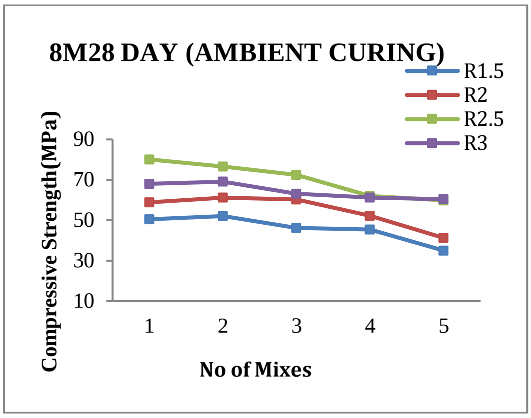
Graph 19 8Molar R3 oven drying



Graph 20 8Molar 7day Ambient Curing for all ratio's

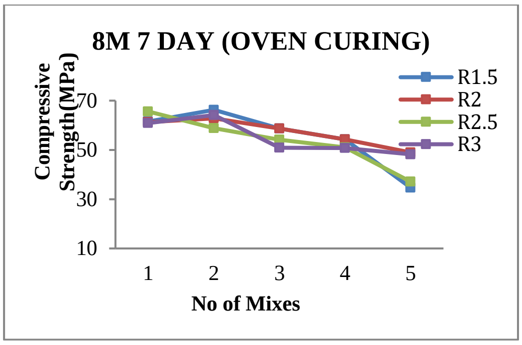


By monitoring this, we may deduce that 8M R2.5 is functioning well.



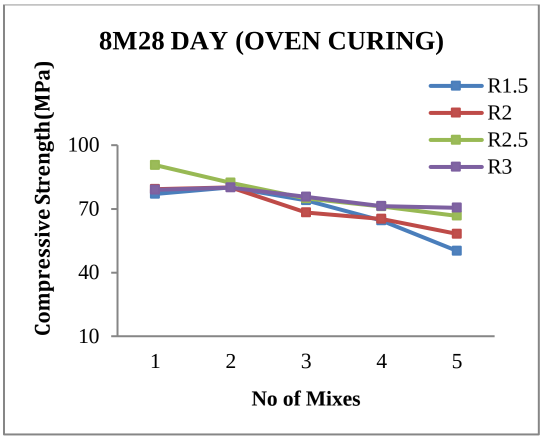
By observing this, we may conclude that 8M R2.5 is performing efficiently.

Graph 20 8Molar 7day oven drying for all ratio's



This observation enables us to conclude that 8M R2.5 is providing superior performance.

Graph 20 8Molar 28day ambient drying for all ratio's



We can infer from this graph that 8M R2.5 has a high compressive strength.

By evaluating all of the aforementioned values for every mix, including 4 and 8 molar ratios of sodium silicate (Na2SiO3) to sodium hydroxide (NaOH), each mix's values can be determined. The 8 M R 2.5 has demonstrated effective performance, yielding the optimal values.

Conclusions :

For geopolymer mortar cubes with molarities of 4 and 8, the following results were drawn from the experimental examination.

- The results show that the mix M1 (i.e.,100GGBS) has greater strength when compared to the other mixes.
- Mix M1 and M2 almost have equal strengths; but, by adding a naphthalene-based admixture, the setting time can be slashed.
- Since GGBS is a substantial component of all the mixes, setting time is very quick. Naphthalene-based admixtures can be used to reduce setting time.
- In comparision with both the 4, 8 molarities, 8 molarity yields higher strength.
- At both 4 and 8 molarities, the 2.5 sodium silicate to sodium hydroxide ratio is showing more strength.
- When compared to outdoor curing, an oven-cured sample has shown to be stronger; the highest strength observed in this investigation was 80MPa.
- The values of the ultrasonic pulse velocity for ambient curing specimens are higher than those of oven curing specimens.

- When compared to outdoor-cured specimens, the strength of oven-cured specimens had an average strength improvement of 12%–13.5%.
- As compared to 7 days, 28 days of curing resulted in an increase of around 45–50% in compressive strength. The early stage of strength gain occurs at a faster rate. The strength decreases with rate of increase of fly ash content.

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