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High Strength Fly Ash and GGBFS Based Geopolymer Mortar

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Abstract— ***Geopolymer mortar is a type of cementitious material that is made from fly ash & GGBS as an industrial waste product, with an alkaline activator. Fly ash is a pozzolanic material, which means that it can react with an alkaline solution to form a hard, cementitious material. Geopolymer mortar has several advantages over traditional cement mortar, including its high strength, durability, and low environmental impact. This study investigated the effects of fly ash, GGBFS and alkaline activator compositions on the strength of fly ash and GGBFS-based geopolymer mortar. The results showed that the use of high-calcium fly ash resulted in higher-strength mortars than the use of low-calcium fly ash. The use of a sodium hydroxide/sodium silicate activator also resulted in higher strength mortars than the use of a sodium hydroxide/potassium hydroxide activator. The highest-strength mortars were produced using high-calcium fly ash and a sodium hydroxide/sodium silicate activator. In this study, the mortars had a compressive strength of over 82 MPa, which is comparable to the strength of traditional Portland cement mortars. The results of this study suggest that high-strength fly ash and GGBFS-based geopolymer mortars can be produced using a variety of fly ash types, GGBFS and alkaline activator compositions. These mortars have the potential to be used in a variety of applications, including structural, high-performance, and durable applications.***

Keywords— ***Geopolymer mortar, Fly ash, GGBS, Sodium Hydroxide (NaOH), Sodium silicate (Na2SiO3), Compressive strength.***

I. INTRODUCTION

Using flyash, an industrial waste product, and an alkaline activator, a type of mortar called high flyash strength and GGBFS geopolymer-based mortar is created. The alkaline activator is affected by the flyash to transform it into a fresh inorganic polymer. Because of its increased strength and endurance, this polymer could replace conventional cement-based mortars. Using high strength flash-based geopolymer mortar has several benefits. First, because it employs the waste otherwise unavailable product be thrown off which can be used as sustainable material. Since the fact that flyash production lessens carbon dioxide emission than cement production which contain low-carbon material. Flyash is a sturdy substance with decent resistance to fire, chemicals, and the elements.

However, employing high strength geopolymer mortar based on mixture of flyash with GGBFS has significant drawbacks as well. The material is very new; hence its long-term performance is still somewhat unknown. Second, it can cost more than conventional mortars made of cement. Thirdly, it is less accessible than conventional cement-based mortars. High strength geopolymer mortar based on flyash has the potential and it considered as major innovation in the building sector despite these difficulties. Flyash with GGBFS is a long-lasting, low-carbon, sustainable substance that might lessen the negative effects of construction on the environment. High-strength geopolymer mortar according to flyash projected to be utilized much more frequently in the future as sustainability is necessary and low-carbon materials rise. The key to the exceptional properties of high-strength flyash with GGBS based geopolymer mortar lies in alkaline activators. Aluminosilicate-rich materials found within flyash, chemical takes the chemistry involving flyash and place with the activators, forming a three-dimensional network structure. This chemical process results in a durable and strong geopolymer binder, capable of withstanding mechanical and environmental stresses. High-strength flyash-based geopolymer mortar exhibits excellent compressive and tensile strength, making it suitable for a diverse array of construction applications. Its remarkable resistance to chemical attack, thermal stability, and low creep ensures its durability and longevity in harsh environments.

Despite its potential qualities, still there are some challenges in widespread adoption of flyash-based geopolymer mortar. Issues related to workability, long-term durability assessment, and variations in flyash properties should be investigated to ensure consistent and reliable performance. Continued research and development in this field are crucial to overcome these challenges and promote geopolymer-based materials as a viable alternative to conventional cementitious materials.

High strength: Compressive strengths of up to 82 MPa have been reported.

- Durability: Good resistance to chemicals, fire, and weathering.
- Low shrinkage: Less shrinkage than traditional cement-based mortars.

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II. MATERIALS AND METHODOLOGY

2.1 Materials

2.1.1 Fly Ash:

Class F type flyash used to cast the GPM that is produced from the Thermal Power Station, Kudagi (Karnataka).

Table 1: Composition of different chemicals used prepare Flyash (percentage by mass)

Name of Chemical	% composition by mass
SiO_2	60.11
Al_2O_3	26.53
Fe_2O_3	4.25
SO_2	0.35
CaO	4.00
MgO	1.25
Na_2O	0.22
LOI	0.88

Fig 1: Class F Fly Ash

2.1.2 GGBFS:

GGBFS is obtained by "the non-metallic product consisting essentially of calcium silicates and other bases that is developed in a molten condition simultaneously with iron in a blast furnace".

Table 2: Composition of chemicals in GGBFS (% by mass)

Chemical composition	GGBFS
SiO_2	34.06
Al_2O_3	20
Fe_2O_3	0.8
SO_3	0.9
CaO	32.6
MgO	7.89
Na_2O	NIL
LOI	NIL

Fig 2: Ground Granulated Blast Furnace Slag (GGBFS)

2.1.3 Sand:

In this experiment three types grades of sand are used to cast the geopolymer mortar specimens. Grade-1, Grade-2, and Grade-3 sand are three different grades of sand that are utilized in casting of the geopolymer mortar cubes.

Table 3: Different Grades and Particle Size of Sand

Grade	Particle Size
Grade-1	0.09 mm to 2 mm
Grade-2	0.5 mm to 1 mm
Grade-3	1 mm to 2 mm

Fig 3: Different Grades of IS Sand

Table 4: Physical properties of geopolymetric source

Properties	Units	Flyash	GGBFS
Specific gravity		2.25	2.91
Fineness	m^2/kg	330	425
Bulk Density	kg/m^3	1005	1360
Residue on 45-micron sieve	%	35	ND
Cementing efficiency factor, 28 days		0.93	0.95
LOI	%	1.4	1.8
Glass content 85(BS:6699)	%		96

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2.1.4 Alkaline Solutions:

Geopolymeric Source Materials (GSMs) require a solution with alkalinity, which is composed of sodium silicate (Na2SiO3) and sodium hydroxide (NaOH) solution to start chemical reactions.

1) Sodium Hydroxide Solution:

In this experiment, NaOH (97% pure) pellets from Shanti Chemicals in Belagavi were dissolved in water to create solutions with molarities of 8 and 12M

Table 5: Properties of Sodium Hydroxide

Amount of NaOH	**50 % (by mass)**
Density	1.5 kg/Litre
Nature	Hygroscopic
Molar mass	39.9971 mol^{-1}
Ph	13

Fig 4: Pellets of sodium hydroxide (NaOH)

2) Sodium Silicate Solution (Na2SiO3)

The solution of sodium silicate (Na2SiO3) which is used in my work was manufactured by Shanti Chemical Works (Mfrs. of Na2SiO3 and K2SiO3), Belagavi.

Table 6: Physical properties of Na2SiO3 solution

Chemical Formulae	Na2O.xSiO2
Appearance	Liquid
Colour	Light Yellow Liquid
Molecular Weight	184-254

Table 7: Chemical composition of Na2SiO3 solution

Specific Gravity	1.63 to 1.645
Be	56.5 ± 0.5° Be
Na_2O	16 to 17 %
SiO_2	35 to 36 %
Weight Ratio	1:2.1 ± 0.1

Fig 5: Sodium silicate (Na2SiO2) and Sodium Hydroxide (NaOH) solution

2.1.5 Water:

Any water satisfying drinking standards is used for the preparation of GPMs. Preferably demineralized water or distilled water may be used.

2.2 Mix Details

For preliminary studies, mortar and paste were chosen as the composite. This was made by mixing Geopolymer Source Materials (GSM) and sand in the weight ratio of 1:2 for mortar. To prepare the fresh Geopolymer mix Alkali Activator Solution (AAS) was added. The fresh mix prepared has enough workability and hence it could be easily compacted using a table vibrator when the mix was placed in molds to prepare the specimens.

Table 8: Mortar Mix Details

i) Geopolymer Mortar

GSM: SAND: AAS	1:2:0.45 (by weight)
GSM (Geopolymer Source Material)	Flyash + GGBS
Percentage of Flyash Content in GSM	0%, 25%, 50%, 75% & 100%
Composition of GSM (Flyash: GGBS)	i. 0:1.0 ii. 0.25:0.50 iii. 0.50:0.50 iv. 0.75:0.25 v. 1.0:0
Alkaline Activator Solution (AAS): **Sodium Hydroxide solid: Sodium silicate solution**	1:2.5 (by weight)

Fig 6: Mixture of Geopolymer Mortar

Table 9: Paste Mix Details

ii) Geopolymer Paste

GSM:AAS	1:2:0.45 (by weight)
GSM (Geopolymer Source Material)	Flyash + GGBS
% of Flyash Content in GSM	0%, 25%, 50%, 75% & 100%
Composition of GSM (Flyash: GGBS)	i) 0:1.0 ii) 0.25:0.50 iii) 0.50:0.50 iv) 0.75:0.25 v) 1.0:0
Alkaline Activator Solution (AAS):- Sodium Hydroxide solid: Sodium silicate solution	1:2.5 (by weight)

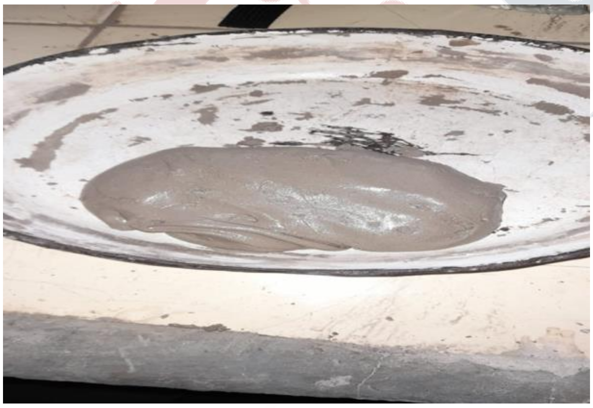

Fig 7: Mixture of Geopolymer Paste

2.3 Mixing and Curing of Geopolymer Paste and Mortar

By using the traditional methods used to create Portland cement mortar, GPM can be produced. As shown regarding mix design table above, the flyash, GGBS, and sand were first combined inside a lab on a pan for mortar and the GGBS and flyash for paste. After adding the liquid component to the dry ingredients, the mixture is stirred for an additional four minutes, on average.

NaOH pellets were dissolved in distilled water in a polypropylene container to create a NaOH solution. After the NaOH had been in contact with water for 24 hours, Na2SiO3 and NaOH were combined to create an alkaline activator. The use of sodium silicate will speed up the geopolymerization process. Na2SiO3/NaOH and flyash/alkaline activator were utilised in the current investigation in 0.45 as a ratio for each mix. Alkaline activator as well as GSMs were combined in the mixer to create a homogenous binder. 70mm (Diameter) X 70mm (Height) test specimens are created by using square molds. Three layers of freshly mixed mortar were added to the mold, and a table vibrator was used to vibrate each layer. The molds are coated with vinyl sheet for 24 hours after casting. Apart from the Geopolymer Source Material (GSM), which contains 100% flyash, all other mixes were able to reach the necessary strength in less than 24 hours. Therefore, after casting for 24 hours, that demoulding procedure could be completed. For each mixture with a distinct source material percentage composition, this mixing process can be completed in 5 minutes. Fresh geopolymer mortar made by the flyash was often cohesive. The specimens that had been demolded were stored in a hot air oven at room temperature.

Table 10: Mix proportions of geopolymer mortar

Mix ID/proportion of binders	Flyash (kg/m3)	GGBS (kg/m^3)	Fine aggregate (kg/m^3)	NaoH (kg/m^3)	Na_2SiO_3 (kg/m^3)	Alkaline liquid (kg/m^3)
Na2SiO3/NaOH=2.5						
S1	310	0	310	40	100	140
S2	305	30	335	45	110	155
S3	265	65	330	40	110	150
S4	230	100	330	40	110	150
S5	200	130	330	40	110	150
S6	170	165	335	45	105	150
S7	140	205	345	45	110	155
S8	105	240	345	45	110	155
S9	70	275	345	45	110	155
S10	35	310	345	45	105	155

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Table 10: Mix proportions of geopolymer paste

Materials	COMPOSITION IN GRAMS				
	0%FA	25%FA	50%FA	75%FA	100%FA
GGBS	300	225	150	75	0
FLYASH	0	75	150	225	300
AAS	135	135	135	135	135

2.4 Methodology

The square molds were used to cast test specimens of size 70mm (Diameter) X 70mm (Height). The fresh mortar mix was placed in three layers in the mold and each is vibrated using table vibrator. After casting the molds are covered by vinyl sheet over a period of 24 hours. Except for 100% flyash content in Geopolymer Source Material (GSM), all other mixes were able to gain sufficient strength within 24 hours. So, that demoulding operation could be done after 24 hours of casting. After demoulding, all the specimens for 3 days, 7 days, 28 days were kept in hot air oven. Then each cube which were casted are checked for increased strength in the compressive testing machine. The Results for high strength for each cubes are noted.

Fig 8: Geopolymer Mortar Specimens

III. TEST RESULTS AND DISCUSSION

- The material's compressive strength of geopolymer mortar was increased as the concentration of NaOH was increased in the solution. Maximum compressive strength that 81.63 MPa was achieved by using 12M sodium hydroxide.
- Compressive strength was affected by amount flyash used relating to the geopolymer mortar. Maximum compressive strength was gained with flyash content of 70 Kg/m3
- Curing temperature also had a beneficial impact on compressive strength of the geopolymer mortar. Maximum compressive strength was gained with a curing temperature of 65 °C.
- The geopolymer's strong compressive resistance of mortar is because of durable geopolymer matrix. The geopolymer matrix is formed by the reaction of sodium hydroxide solution with aluminosilicates among the flyash. This reaction produces a three-dimensional network of alumino silicate polymers.
- Flyash content has a beneficial impact on compressive strength of the geopolymer mortar. This is because flyash contains a high percentage of aluminosilicates. The more aluminosilicates in the flyash, the stronger the geopolymer matrix will be.
- The curing temperature also has a beneficial impact on compressive strength of the geopolymer mortar. This is because the higher curing temperature accelerates the geopolymerization reaction.
- The geopolymer mortar has good usage and better setting time. This is because the sodium hydroxide solution and flyash react to form a viscous gel. This gel gives the geopolymer mortar its good usage and setting time.

Table 11: Compressive strength test results on geopolymer mortar

Sample Name	Load (KN)	Compressive Strength (N/mm^2)
S1	250	51.92
S2	220	44.89
S3	190	38.77
S4	300	61.22
S5	290	59.18
S6	320	65.30
S7	340	69.38
S8	310	63.26
S9	340	69.38
S10	400	81.63

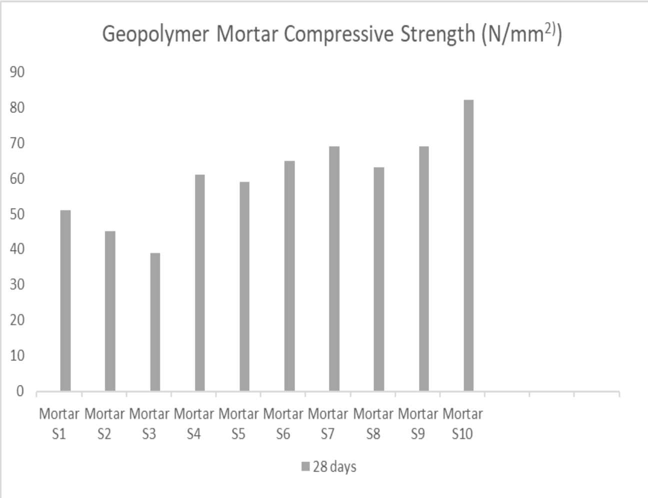

Fig 9: Compression Strength Test

Fig 10: Compressive strength test of Geopolymer Mortar Cubes.

IV. CONCLUSIONS

- When flyash with GGBS content is increased, the compressive strength of geopolymer mortar is also increased, because the combination of flyash and GGBS leads to a denser microstructure due to the filling of voids and the formation of more C-S-H and C-A-S-H gels. This results in reduced porosity and higher strength.
- When the content of GGBS is replaced or reduced by increasing the flyash content in a geopolymer mortar, the compressive strength tends to decrease, because increasing the flyash content can lead to a slower setting time due to its lower reactivity. This slower reaction delays the hardening process and can result in a decrease in early compressive strength.
- The compressive strength of geopolymer mortar was also enhanced by the oven curing temperature. In this research, a curing temperature of 65 °C were provided.
- As the concentration of sodium hydroxide solution is increased, the compressive strength of geopolymer mortar is also increased. In the work, a sodium hydroxide concentration of 12M resulted in the highest compressive strength of 81.63 N/mm2.

REFERENCES

[1] G Mallikarjuna Rao, T. D. Gunneshwara Rao "Final Setting Time and Compressive Strength of Flyash and GGBS-Based Geopolymer Paste and Mortar" 07 July 2015 Department of Civil Engineering, National Institute of Technology, Warangal, Warangal-506004, India.

[2] G Mallikarjuna Rao and C. H. Kireety "Durability Studies on Alkali Activated Flyash and GGBS-Based Geopolymer Mortars" Department of Civil Engineering, Vardhaman College of Engineering, Hyderabad, India.

[3] M Venu, G Mallikarjuna Rao, Y Anil Kumar, Sri Rama Chand Madduru "Influence of Alkaline ratios on strength properties of Fly- Ground Granulated Blast Furnace Slag Based

Geopolymer Mortars" 2020 Department of Civil Engineering, Vardhaman College of Engineering, Shamshabad, Telangana, India.

[4] Subhashree Samantasinghar and Suresh Prasad Singh "Fresh and Hardened Properties of Flyash-Slag Blended Geopolymer Paste and Mortar" 2019 Department of Civil Engineering, National Institute of Technology, Rourkela, Odisha-769008, India.

[5] Banda Rohit Rajan, K.Ramaujee "Strength & Development of Flyash and GGBS Based Geopolymer Mortar" 2015 Department of Civil Engineering VNRVJIET Hyderabad, Telangana, India.