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Compressive Strength of Flyash Geopolymer Mortar Having Silica Fume as A Partial Replacement

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Abstract: Geopolymer is an innovative, environmental friendly construction material for the sustainable development, using the combination of fly ash and alkali as a binding agent in place of Ordinary Portland Cement. It is one of the promising alternative binder technologies to reduce CO_2 emissions in the atmosphere. This paper presents the experimental study performed to investigate the effect of low-calcium fly ash based geopolymer mortar incorporating Silica powder. The mixture of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) is used as an alkaline activator in the ratio of 1:2.5 and the concentration of sodium hydroxide are 8M, 10M and 12M. The silica powder was replaced in place of fly ash by varying percentages of 2%, 4%, 6%, 8% and 10% and studied for its compressive strength and compared with the control geopolymer mortar cubes.
Keywords: Geopolymer, Fly ash, Silica Fume, Compressive Strength.

I. INTRODUCTION

Ever since the introduction of geopolymer binders by Davidivits in 1978, it has generated a lot of interest among engineers as well as in the field of construction. Geopolymer is one of the promising technology to reduce CO_2 emissions in the environment. For every ton of OPC manufactured nearly 1 ton of CO_2 is produced. Cement plants have been reported to emit upto 1.5 billion tons of CO_2 into the atmosphere annually. Geopolymers are a class of new binder manufactured from an alumino-silicate source material such as flyash, silicafume, blast furnace slag, etc, by activating with a highly alkaline solution with moderate thermal curing. The polymerization process involves a substantially fast chemical reaction under highly alkaline condition on Si-Al minerals that result in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds. The most common alkaline liquid used in geopolymerization is a combination of sodium hydroxide(NaOH) or potassium hydroxide(KOH) and sodium silicate or potassium silicate.

Silica fume , also known as micro silica, is an amorphous (non-crystalline) polymorph of silicon dioxide. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production. The main field of application is as pozzolanic material for high performance concrete. Silica fume consists of spherical particles less than 1µm in diameter, the average being about 0.1µm. This makes it approximately 100 times smaller than the average cement particle. Silica fume increases concrete strengths producing financial benefits to builders, developers and property owners.

Previous researches have stated that the compressive strength increases as the flyash content and activator solution increases. The use of Na2SiO3/NaOH ratio of 2.5 gives higher compressive strength. The curing temperature is the most important factor for the geopolymer. When the curing temperature increases, the setting time of the concrete decreases. During the curing process the geopolymer concrete experiences the polymerization process. Due to the increased temperature, polymerization becomes more rapid, and the concrete gain 70% of its strength within 3 to 4 hours of curing.

II. EXPERIMENTAL INVESTIGATION

A. Materials2.1.1 Fly Ash

Cementitious material used in this Experimental programme was Low calcim Flyash(ASTM type F) Tuticorin thermal power station, TN, India. Fly ash (FA) class F, known also as pulverized- fuel ash, is the byproduct obtained by electrostatic and mechanical means from flue gases of power station furnaces fired with pulverized coal. The class F is characterized by high silicon and aluminum contents and low calcium content.the Physical properties are presented in table 1

Table 1. Physical properties of fly ash

Physical Properties	
Specific gravity	2.3
Sieve analysis	36.1% < 300µ

B. Fine Aggregate

In this study, natural river sand is used as a fine aggregate. The sand passing through 4.75mm sieve was used. The sand conforms to grading Zone II as per IS:383-1970(Reaffirmed 2011). The specific gravity of sand is 2.73.

C. Sodium Hydroxide

Generally the sodium hydroxide are available in solid state by means of pellets and flakes. Since our geopolymer concrete is a homogenous material and its main process to activate the sodium silicate, so it is recommended to use the lowest cost (i.e) upto 94% to 96% purity. In this study sodium hydroxide with a varyinf molarites of 8M, 10M and 12M was used

D. Sodium Silicate

Sodium silicate is also known as liquid glass or water glass or liquid glass, available in liquid form. In present investigation sodium silicate 2.0(ratio between Na_2O & Sio_2) is used.

III. MIX PROPORTION

Unit weight of geopolymer mortar = 2200 kg/m^3
Aggregate to fly ash ratio = 2:1
Mass of fly ash = 2150/3
= 733.33 kg/m^3
Mass of fine aggeregate = 2150 -733.33
= 1466.67 kg/m^3
Assume, Alkaline liquid/ flyash = 0.45
Alkaline liquid = 329.99 kg/^{m3}
Assume $NaOH/Na_2SiO_3$ = 2.5
Mass of NaOH = 94.285 kg/m^3
Mass of Na_2SiO_3 = 235.70 kg/m^3

In the above mix proportion the Fly ash is partially replaced with silica fume by weight percentages of 2%, 4%, 6%, 8% and 10%

A. Mixing and Casting

Initially the source material and aggregates were mixed in dry condition as per the predetermined calculation and then pre mixed alkaline solution was added and mixed thoroughly with hand until uniform mix is obtained. The prepared mortar poured in mortar cubes of size 70.5mm x 70.5mm x70.5mm in three layer and compacted. The casted specimen is left for a day and then it is transferred to the oven at 60˚C for 24 hours and then demolded.

IV. RESULTS AND DISCUSSION

The compressive strength test was performed for the mortar cubes cured at 60˚C with varying molarities and replacement levels of silica fume. The strengths of the cubes specimens are presented in the figure. It was observed that as the molarity of the NaOH increases the strength of mix without silica fume increases. The mix with 6% silica fume and 8M NaOH concertation reaches maximum compressive strength in 8M serious mixes while in 10M serious mixes the control concrete attains the maximum compressive strength, also as the percentage of silica fume increases the strength of the mortar also starts to decrease.

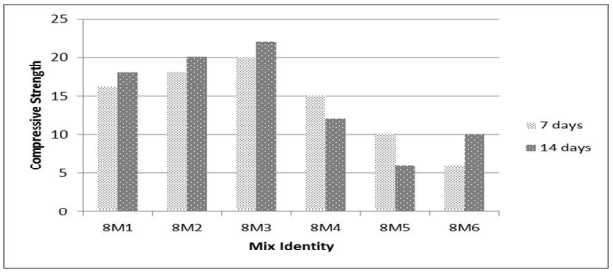

Figure 1 – Compressive Stregnth of 8M Mortar

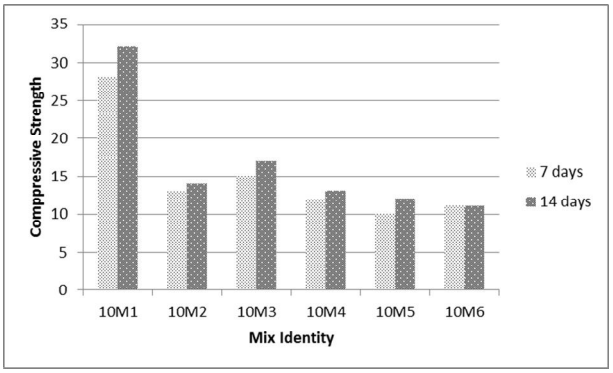

Figure 2 Compressive strength of 10M Mortar

V. CONCLUSION

A. From the above study the following are concluded

1) Fly ash based geopolymer possess the scope of replacing the cement mortar as a binder material and promising future in sustainable development in the field of construction materials.

2) As the concentration of the NaOH increases strength of the concrete also increases

3) Geopolymer is well-suited to manufacture precast products which can be utilized in infrastructure applications, marine construction, etc,. as its high strength gain at elevated curing temperature lends geopolymer to precast structural applications.

4) Further Study The strength of the geopolymer mortar at variour NaOH Molarity are yet to be studied.

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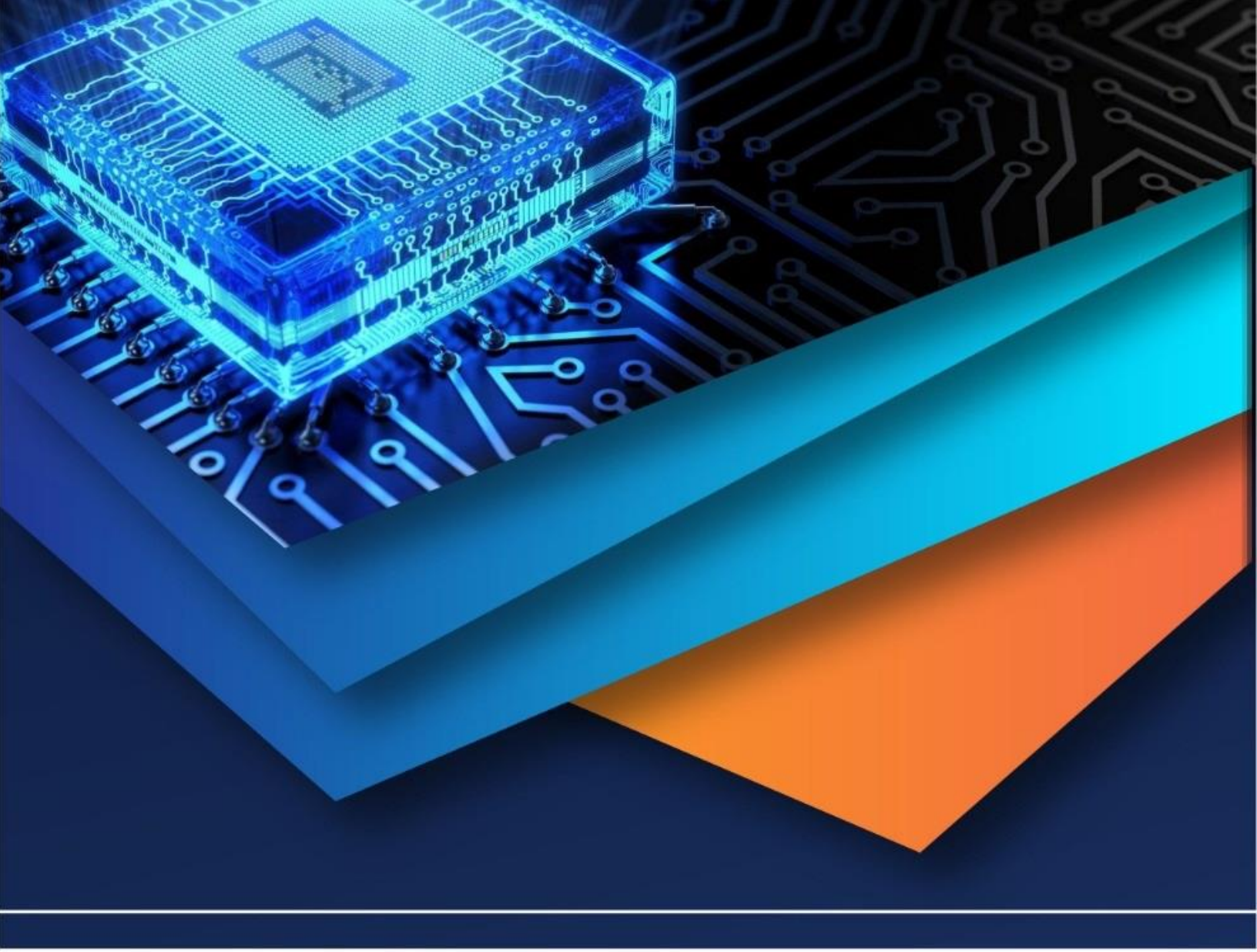

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