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STRENGTH STUDIES ON SILICA FUME BASED GEOPOLYMER MORTAR WITH COIR FIBRE

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Abstract – *Geo-polymer mortar is a product of fly-ash which when mixed with alkaline solution undergoes geopolymerisation. In this study, fly-ash is blended with Silica fume which is the byproduct from silicon and coir- fibre which is obtained from agricultural waste. Silica fume enhances the durability and coir fibre improves the shear property of geopolymer mortar. Silica fume is varied between 0 to 10% and coir fiber is added between 0 to 1%. Coir fibre has an aspect ratio (L/D) of 125. Alkaline solution was prepared by mixing sodium silicate and sodium hydroxide with a ratio of 2.5 and binder ratio kept as 0.34. Specimens were casted with 2.5 %, 5 %, 7.5 % and 10 % of silica fume as partial replacement of fly-ash and 0.25 %, 0.5 %, 0.75 % and 1 % of coir fibre was added. These samples attained 28 days strength of 44.3N/mm², 49.9N/mm², 51.23N/mm², 41.53N/mm² respectively. Thus results showed that silica fume of 7.5% and coir fiber 0.75% recorded higher strength.*

Keywords: Geopolymer, fly-ash, silica fume, alkaline solution, coir fibre.

1. INTRODUCTION

To meet the infrastructure development, concrete is a huge requirement in which cement plays an important role as an ingredient, which is causing an impact on the environmental issues due to its over production. In accordance to this issue various researches are going on to find a perfect replacement to cement. Few such replacing products are silica fume, egg shell powder, GGBS, bagasse, fly ash, rice husk ash, blast furnace slag, by product gypsum etc. Among these, Fly Ash & Silica Fume are known to have properties similar to cement and are also products which are eco-friendly, and easily & locally available thus forming an effective replacement.

Cement is a fundamental raw material used in construction. It used as a binder in concrete and cement mortar. The manufacturing of OPC releases large amount of carbon dioxide (CO_2) contributing to the greenhouse gas emissions. For every one ton of cement produced, one ton of carbon dioxide is released. Currently the world annual OPC production is 1.6 billion tons or about 7% in global loading of CO_2 into the atmosphere. To add, one ton of OPC requires calcinations of 1.5 ton of limestone and considerable amount of fossil fuel and electrical energy thereby not only contributing towards the global warming but also consuming significant amount of natural resources and energy. Hence an alternate source as a substitute for cement is the need of the hour.

As a greener alternative, calculated percentage of cement can be replaced by other materials such as fly ash, rice husk ash, metakaolin, silica fume etc. Fly ash is one of the most normally preferred substitutes for cement because concrete workability and durability are enhanced by fly ash by their small size and round shape. Silica fume as a blender to fly ash enhance the strengthening property of the mortar. Geopolymer fits into an emerging class of cementitious materials that utilize 'fly ash', one of the most abundant industrial by-products on earth, as a substitute for Portland cement. The development of geopolymer material is an important step towards the production of eco-friendly materials.

Geopolymer is an inorganic alumino-silicate compound, synthesized from materials of geological origin or from by-product materials such as fly ash, rice husk ash, etc., that are rich in silicon and aluminium. Fly ash is one of the residues generated from the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants.

Consumption of fly ash in the manufacture of geopolymer is an important strategy in making materials more environment friendly. For this reason, fly ash has been chosen as a base material for this project in order to utilize this industrial waste in a better way.

Coir fibres are found between the hard, internal shell and the outer coat of a coconut. The individual fibre cells are narrow and hollow, with thick walls made of cellulose.

They are pale when immature, but later of lignin is deposited on their walls. Each cell is about 1mm (0.04 in) long and 10 to 20 µm (0.0004 to 0.0008in) in diameters. Fibres are typically 10 to 30 centimetres (4 to 12 in) long.

Coir is high in sodium potassium, it is treated use as a growth medium for plants or fungi by soaking in calcium buffering solution. Coir is naturally reach in potassium, which can lead to magnesium efficiencies in soil less horticultural media.

For this reason the present project aims at replacing cement with fly ash using geopolymer technology and also blending silica fume so that the consumption of OPC is reduced and hence reduced CO_2emissions.

2. OBJETIVES

The objectives of the present research is to evaluate the comparative performance of geopolymer mortar manufactured using locally available low calcium Fly ash blended with Silica Fume . The current research utilizes low calcium fly ash obtained from Mettur Thermal Power Plant (MTPP) blended with another waste material silica fume. A comprehensive experimental program has been undertaken to appreciate some of the hardened properties of this low calcium fly ash based blended Geopolymer mortar at ambient temperatures beside the evaluation of some of the synthesizing parameters of the blended fly ash geopolymer mortar. The broad areas include:

- To produce geopolymer (GP) mortar with fly ash and silica fume and coir fibre.
- Study on the effect of synthesizing parameters on the hardened properties of
- Geopolymer mortar.
- Thus to reduce the pollution produced due to cement production and to bring a safer environment for future generation.

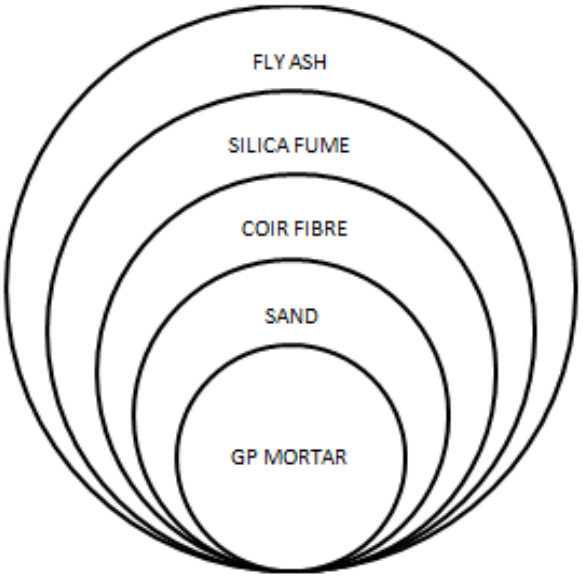
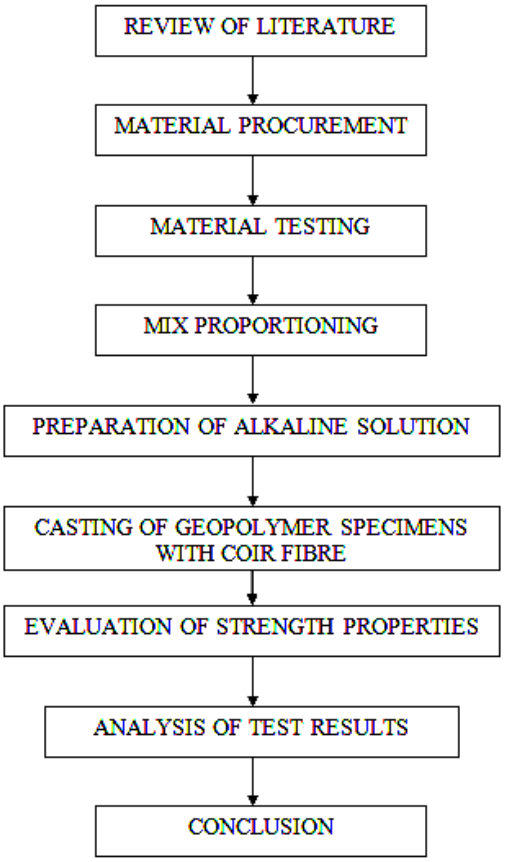


Fig. 1 Schematic Representation of Objective of Research

3. METHODOLOGY

Following preparation process was observed for preparing geopolymer mortar specimens.



- The required materials are procured and tested for basic properties.
- Mix proportioning is achieved and mixes are designated.
- Mix sodium silicate solution, sodium hydroxide pellets and water according to mix proportion, to make alkaline activator, at least one day prior to its use in manufacturing geopolymer.
- For preparing geopolymer mix hand mixings, were used throughout the work. Fly ash and Silica Fume is blended in dry state vigorously wherever required.
- Coir is prepared by cutting the size of 2.5cm with an aspect ratio (l\d) of125.
- Alkaline activator is mixed with the dry blend for about ten to fifteen minutes to make homogeneous paste.
- Next sand in saturated surface dry condition is slowly added to geopolymer paste while wet mixing in progress and continue wet mixing for another 10-15 minutes after adding the sand for preparing the Geopolymer mortar specimens.
- Transfer geopolymer mix and coir to the molds which are greased properly.

- Vibrate fresh geopolymer mix and coir in the molds on vibration table for 2-3minutes to remove entrapped air in the mix.
- Rest period of 60 minutes is given to fresh specimens prior to placing them in the oven for thermal curing for 24 hours at 85*°C.* The rate of heating oven is 0.5°C to 1°Cper minute starting from room temperature and Jar controlled depending on temperature level.
- Removed specimen from molds at room temperature air drying at room temperature until tested or exposed to elevated temperature.
- The specimens are evaluated for their strength properties at 14 & 28 days.
- The results are analyzed and discussed.

3.1 Mix Proportion

A mixture of flyash, sand and alkaline solution is called Geopolymer mortar. Flyash and silica fume in its original form acts just as a filler material and hence cannot function as binder. Hence, to activate both flyash and silica fume a strong alkali solution of sodium hydroxide and sodium silicate is used. The activated flyash-silica fume blend is rich in silica and aluminum which function as a binder.

Table 1 Mix Ratio

Mix	Mix Constituents				Binder-Blend Ratio	$Na_2SiO_3/NaOH$
	FA	SF	Coir Fibre	Sand		
Con Mix(CM)	1	0	0	2	0.34	2.5
Mix 1(M_1)	0.975	0.025	0.0025	2	0.34	2.5
Mix 2(M_2)	0.950	0.050	0.0050	2	0.34	2.5
Mix 3(M_3)	0.925	0.075	0.0075	2	0.34	2.5
Mix 4(M_4)	0.900	0.100	0.0100	2	0.34	2.5

Binder - Alkaline solution (Sodium Hydroxide & Sodium Silicate)
Blend - Flyash (FA) & Silica fume (SF)
NaOH = 9.6% of binder
Na_2SiO_3 = 2.5 times of NaOH = 24% of binder
Control Mix (CM) = 100% Flyash + 0% Silica fume + 0%Coir fibre
Mix 1(M_1) = 97.5% Flyash + 2.5% Silica fume +0.25 %Coir fibre
Mix 2(M_2) = 95% Flyash + 5% Silica fume + 0.5%Coir fibre
Mix 3(M_3) = 92.5% Flyash + 7.5% Silica fume + 0.75%Coir fibre
Mix 4(M_4) = 90% Flyash + 10% Silica fume + 1.0%Coir fibre

Table 2 Mix Proportion

MIX ID	FLYASH Kg/m³	SILICA FUME Kg/m³	COIR FIBRE Kg/m³	ASPECT RATIO (l/d)	SAND Kg/m³	ALKALINE SOLUTION lit/m³
CM	700	-	1.75 3.5 5.25 7	125	1400	245
M1	682.5	17.5	1.75 3.5 5.25 7	125	1400	245
M2	665	35	1.75 3.5 5.25 7	125	1400	245
M3	647.5	52.5	1.75 3.5 5.25 7	125	1400	245
M4	630	70	1.75 3.5 5.25 7	125	1400	245

3.2 Preparation of Alkaline Liquid

- Sodium hydroxide (40M) pellets are generally used to prepare alkaline liquid.
- In this research NaOH solution of 16 Molar concentration were used which consists of 16x40=640 grams of NaOH pellets per liter of solution, where 40 is the molecular weight of NaOH.
- To make the solution, a mass of 444 grams of NaOH solids are measured and dissolved in 556 ml of water.
- Once the pellets gets dissolved sodium silicate solution of 2.5times of NaOH solution is mixed to prepare the alkaline liquid.
- It is to be noted that the solution is prepared at least one day prior to casting.

Fig. 2 Preparation of alkaline solution

3.3 Preparation of Specimens

- For the study of compressive strength, split tensile strength and for which cube and cylinder specimens were casted.
- Cube size of 70 x70 x70 mm
- Cylinder size of 50mm dia x 100mm

Fig. 3 Specimens casted for testing

4. EXPERIMENTAL INVESTIGATONS

Specimens were casted and heat cured and prepared for experimental test. All the tests were carried out based on IS codal provisions.

4.1 Compressive Strength Test

- Compression loading tests on mortar cubes were carried out on a compression testing machine of capacity 2000KN.
- Loading rate is 2.5KN/s as per IS:516:1959 is applied.
- Test is performed on 14 & 28 days.
- Compressive strength = Maximum load/c/s area of the cube Expressed in N/mm2

Fig. 4 Compressive strength test

4.2 SPLIT TENSILE STRENGTH TEST

- Expressed as the minimum tensile stress needed to split the material apart.
- Splitting strength gives about 5-12% higher value than the direct tensile strength.
- Test is performed on 14 & 28 days.

Fig. 5 Split tensile strength test

5. RESULTS AND CONCLUSIONS

Table 3 Compressive Strength Test Results

MIX	AVERAGE COMPRESSIVE STRENGTH (N/mm²)	
	14 Days	28 Days
CM	27.7	45.5
M_1	39.4	44.3
M_2	41.4	49.9
M_3	41.8	51.2
M_4	36.3	41.5

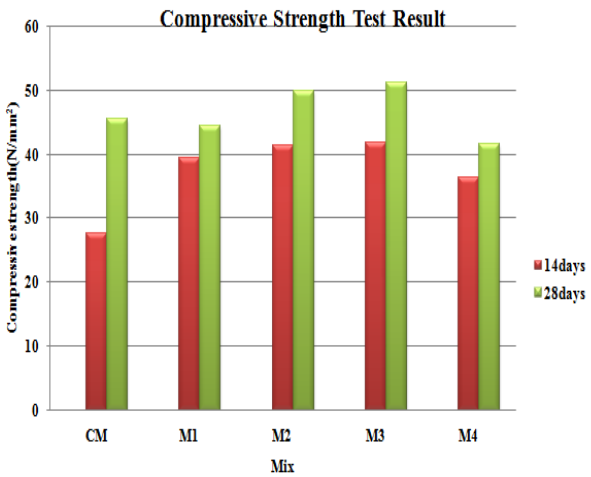


Fig. 6 Compressive Strength

Table 4 Split Tensile Strength Test Results

MIX	AVERAGE SPLIT TENSILE STRENGTH (N/mm²)	
	14days	28days
RM	3.78	5.00
M_1	4.25	5.74
M_2	4.50	5.98
M_3	4.72	6.05
M_4	3.25	4.48

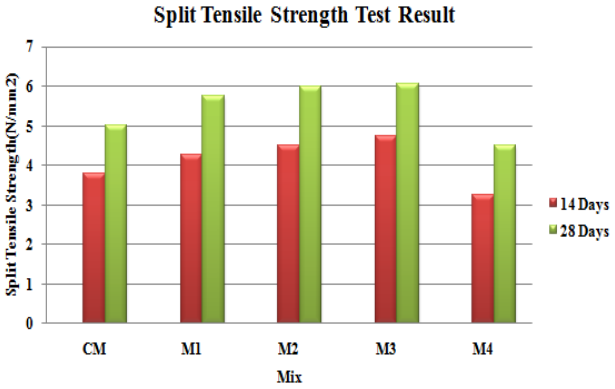


Fig. 7 Split Tensile Strength

The tests results clearly describes that Mix 3(M_3) shows satisfactory result when compared to others mixes and the reference mix. It shows that as the percentage of silica fume and coir fibre increases it gradually increases the compressive and split tensile strength, which beyond 7.5% decreases gradually.

7. FUTHER INVESTIGATIONS

- The working ease of the geopolymer mortar prepared by blending silica fume with flyash was found to be good.
- Better results are obtained for compressive strength and split tensile strength of cubes and cylinders on heat curing at 60ºC
- It is found that strength of blended geopolymer increases with age.
- Silica fume enhances the overall property on limited addition of about 7.5% and coir fibre inhibits the durability nature to the specimens with a percentage of 0.75%.
- On increasing the addition of silica fume beyond 7.5% and coir ratio beyond 0.75%and (l/d) ratio beyond 125 it reduces the working texture of the mortar.
- Blending silica fume with flyash increases the serviceability and coir improves the crack resisting capacity on the mortar.
- Coir improves the crack resisting capacity of the mortar
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