Comparison of geopolymer & Ferrocement mortar with varying volume percentage and Specific surface of mesh

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Abstract— The major factors in the global warming is Production of cement which releases CO2 in atmosphere. Efforts are needed to make concrete more environmental friendly by reducing or replacing the cement by other cementitious material or industrial waste like fly ash. Geopolymer is a new development in the world of mortar in which cement is totally replaced by fly ash and activated by alkaline solutions to act as a binder in the concrete mix. Experimental investigation has been carried out to study the effect of different volume fraction % of steel mesh on compressive strength and split tensile strength of Ferrocement and geopolymer mortar . Activated liquid to fly ash ratio of 0.6 by mass was maintained in the experimental work on the basis of past research. Sodium silicate solution with Na2O = 16.37%, SiO2 = 34.35% and H2O = 49.28% and sodium hydroxide solution having 13M concentration were maintained throughout the experiment. Geopolymer mortar cylinders of 150*300 mm size were cast. The temperature of heating was maintained at 90^0C for 8 hours duration after demoulding. Test results show that compressive strength and split tensile strength of geopolymer mortar increases with increase in volume fraction percentage and specific surface of steel mesh as compare to ferrocement mortar.

Keywords - Fly ash, steel mesh, Sodium silicate, sodium hydroxide, Volume fraction, Specific surface, Compression test, Tensile test.

1. INTRODUCTION

World production of hydraulic cements is close to one thousand million tons per year. Every year the production of Portland cement is increasing with the increasing demand of construction industries[1,2]. The worldwide, near about 3% annual increase in production of Portland cement [6,9]. Therefore the rate of release of carbon dioxide into the atmosphere during the production of Portland cement is also increasing[3]. Among the greenhouse gases, CO2 contributes about 65% of global warming [7, 8]. The green house gas emission from the production of Portland cement is about 1.35 billion tons annually, which is about 7% of the total greenhouse gas emissions [9]. Portland cement production is under critical review due to high amount of carbon dioxide gas released to the atmosphere. The climatic change due to global warming is one of the major issues concerning with the environmental pollution. So there must be an alternative to OPC. fly. In the past few decades , it has emerged as one of the possible alternative to OPC binders due to their reported high early strength and resistance against acid and sulphate attack apart from its environmental friendliness. Davidovits [4] was developed amorphous to semi-crystalline three dimensional silico-aluminate materials in 1979 called as geopolymer. Geopolymer mortar is a new material in which cement is totally replace by low calcium fly ash and activated by alkaline solutions. Low-calcium fly ash based geopolymer concrete possess high compressive strength [6,9], undergoes very little drying shrinkage and moderately low creep [10], and shows excellent resistance to sulphate and acid attack [7, 8]. They are not suffering from alkali-aggregate reaction and possess excellent fire resistant [6]. Geopolymer is produced by a polymeric reaction of alkaline liquid with source material of geological origin or byproduct material such as fly ash. In terms of reducing global warming, geopolymer technology could reduce approximately 80% of CO_2 emission to the atmosphere caused by cement and aggregate industry. This favorable behavior can be attributed to the type of matrix formation in geopolymer mortar. It has been reported that the stress strain relationship of fly ash based geopolymer mortar is almost similar to that of ordinary Portland cement mortar. The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide or potassium hydroxide and sodium silicate or potassium silicate. Davidovits found that geopolymer cements has very low mass loss of 5%-8% when samples were immersed in 5% sulphuric acid and hydrochloric acid solutions.

1.2.1 Salient feature of geopolymer

Geopolymers can meet a “zero waste” objective because they can be produced from materials that are themselves waste products, such as fly ash, blast furnace slag, rice husk ash, metakaoline etc. The properties of alkali-activated fly ash are influenced, by a set of factors related to the proportioning of ingredients of the mixture and the curing conditions. Also, the earlier studies have manifested the high potential of these materials that could be used in the near future in the construction industry, especially in the pre-cast industry. The development of fly ash-based geopolymer mortar is one of the needs to the ‘greener’ mortar for sustainable development. Fly ash based geopolymer mortar has excellent compressive strength and is suitable for structural applications. The elastic properties of hardened mortar and the behavior and strength of structural members are similar to those of Portland cement mortar. The scope of the present study is to check suitability of geopolymer mortar as a substitute to cement mortar on the basis of compressive strength and split tension test on cylinder. It is expected that the final outcome of the research will have beneficial effect on generalizing the use of geopolymer mortar in the field of civil engineering construction in general and pre-cast construction in particular.

MATERIALS USED

i)* Fly ash*: Low calcium processed fly ash procured from Dirk India Private Limited, Nashik under the tread name Pozzocrete-83 is used in the present investigation.

***ii)* Sand: -** Locally available sand confirming to zone II with specific gravity 2.74, water absorption 3.41% and fineness modulus 3.039.

iii) Alkaline activator : . In this case the mixture of Sodium Hydroxide (NaOH) and Sodium Silicate (Na_2SiO_3) is used as alkaline Solution. Sodium hydroxide in pellets form.

iv) Water : The fresh drinking water should be used in the mortar

v) steel mesh: The steel mesh of 1.5 mm diameter, 15 mm spacing (with galvanized coating) with tensile strength of 512 N/mm^2 and yield strength of 406 N/mm^2 has been used as reinforcement

Table No. 2.1 : Details of Steel Mesh

%of steel	Specific surface area (mm^2)	Weight of required steel (gm)	Size of steel mesh (mm X mm)
0.5	1.33	208	280 X 383
1	2.67	416	280 X 766
1.5	4.00	624	280 X 1149
2	5.33	832	280 X 1532

2.2 Preparation of sodium hydroxide solution

The sodium hydroxide (NaOH) solids were dissolved in water to make the solution. The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. For instance, NaOH solution with a concentration of 13M consisted of 13x40 = 520 grams of NaOH solids (in flake or pellet form) per liter of the solution, where 40 is the molecular weight of NaOH. The mass of NaOH solids was measured as 361.11 grams per kg of NaOH solution of 13M concentration. The sodium silicate solution and the sodium hydroxide solution were mixed together at least one day prior to use to prepare the alkaline liquid. On the day of casting of the specimens, the alkaline liquid was mixed together with the extra water (if any) to prepare the liquid component of the mixture.

III. Experimental program

In the present investigation, solution-to-fly ash ratio is considered as 0.60 which gives comparatively cohesive and workable mixes. Following parameters are fixed to study the effect of activators(NaOH and Na_2SiO_3).

1. Mix proportion 1:3
2. Molarity... 13
3. Solution to fly ash ratio............ .... 0.6
4. Type of curing .... Oven
5. curing Temperature .... 90^0C

6. Curing time (duration) 8hours
7. Test Period 3days

3.1 Mixing, Casting, Compaction and Curing

Mixture of fly ash and graded sand is taken in a bowl of capacity 6 kg. Homogeneous mix was made in the bowl-using trowel. Then the dry mix was spread on the non-absorbent steel plate in thick layer. Then prepared solution was added and thoroughly mixed for 3 to 4 minutes so as to give uniform colour. It was found that the fresh fly ash-based geopolymer mortar was viscous, cohesive and dark in colour. The amount of water in the mixture played an important role on the behavior of fresh mortar.

After making the homogeneous mix, workability of fresh geopolymer mortar was measured by flow table apparatus. Then 48 cylinders of size 150 mm X 300 mm were cast in three layers with placing 0.5%, 1%,1.5% & 2% steel mesh (V_f) and 12 cylinders were cast with geopolymer mortar and ferrocement mortar without mesh. As per the percentage of volume fraction ,mesh was placed in cylindrical form in cylinder mould as shown in fig. Each layer of mortar was well compacted by tamping rod of diameter 20 mm and vibrator machine. After compaction of mortar, the top surface was leveled by using trowel and also struck the sides of mould by using hammer so as to expel air if any present inside the mortar. After 24 hours of casting, all cylinders were demoulded and then placed in an oven for thermal curing (heating) at (90^0C) temperature and for 8 hrs duration. For GPM, After specified period of heating at required temperature, oven was switched off. To avoid the sudden variation in temperature, the mortar cylinders were allowed to cool down up to room temperature in an oven. After 24 hours, specimens were removed from oven and weight of each specimen was taken for determination of mass density and then tested for compressive strength and split tensile strength. 60cylinders were cast and tested 30 for compressive strength & 30 for split tensile strength after specified curing period.

IV. Tests and Results :

4.1 Compressive strength : Compressive strength of mortar cylinders was tested after curing and tested after three days of casting. Testing procedure of GPM is similar to that of cement mortar.

4.2 Split tensile test: The split tensile strength at an age 3 & 28 days has been evaluated for mortar GPC and OPC mix are reported in Table . Average split tensile strength of 3cylinders (150mmx300mm) for all concrete mixes are given in table.

4.3 Specific Surface of Reinforcement : The specific surface of reinforcement is the total surface area of reinforcement divided by the volume of composite that is, the surface area of bonded reinforcement per unit volume of composite.

Fig 4.1 & 4.2 Specimen at Testing & mesh in cylinder mould.

Table 4.1: : Experimental Results

Sr.No.	Steel %	Ferrocement Mortar		Geopolymer Mortar	
		Average Compressive Strength (N/mm^2)	Average Split Tensile strength (N/mm^2)	Average Compressive Strength (N/mm^2)	Average Split Tensile strength (N/mm^2)
1	0	21.71	1.55	24.58	2.55
2	0.5	23.43	1.84	28.94	2.96
3	1.0	26.47	2.8	33.41	4.74
4	1.5	27.58	3.09	36.32	5.39
5	2.0	27.82	3.27	39.1	5.58

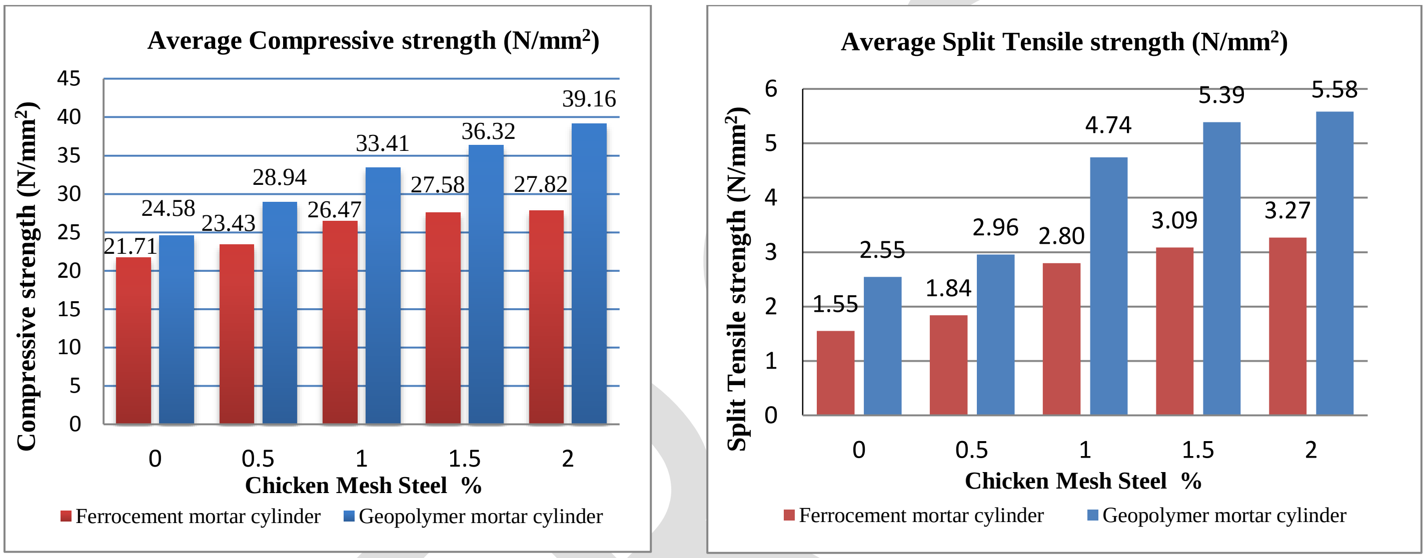

Fig. 4.3 & 4.4 strength comparison of FCM & GPM

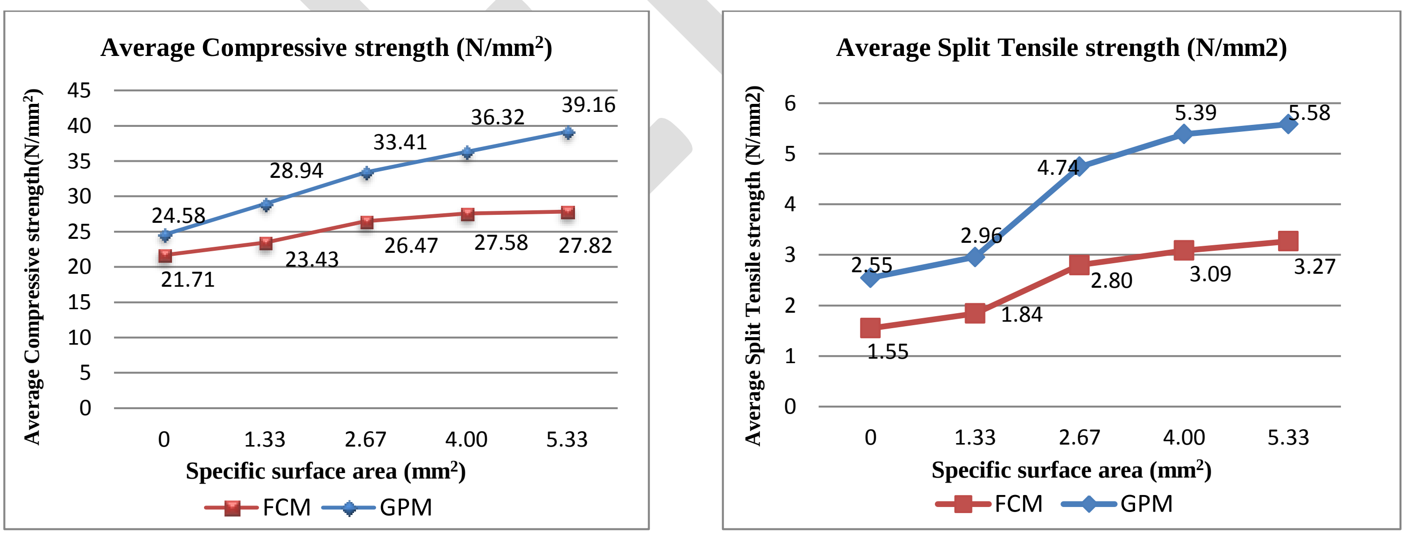

Fig. 4.5 & 4.6 : Average Compressive & Split tensile strength w.r.t. Specific surface For GPM

VI. CONCLUSION

On the basis of results obtained during the experimental investigations, following conclusions were drawn:.

- Compressive and split tensile strength increases by increasing volume fraction % (0.5,1,1.5,2)of steel mesh.

- In o.5% steel mesh, It gives 13.21% and 60.86% more compressive strength and split strength in GPM than FCM respectively.
- It is concluded that if we doubles the volume fraction (1%) of same size mesh with the specific surface of specimen increased by 100% and therefore increased in compressive Strength is observed to be 26% . Further using 1.5% V_f i.e. increases specific surface by 200% increase compressive Strength around by 32%. Further if specific surface is increased by 300% i. e. using 2% V_f , the corresponding compressive Strength of GPM increased by41% than FCM.
- It is concluded that if we doubles the volume fraction (1%) of same size mesh with the specific surface of specimen increased by 100% and therefore increased in split tensile strength is observed to be 69% . Further using 1.5% V_f i.e. increases specific surface by 200% increase tensile strength around by 74%. Further if specific surface is increased by 300% i. e. using 2% V_f , the corresponding tensile strength of GPM increased by 70% than FCM.
- Different percentage of volume fraction also affecting specific surface. From experiment it is noted that the specific surface is increases in multiples of % of wire mesh.

GPC utilizes the industrial waste for producing the binding material in concrete, hence it can be considered as eco-friendly material and gives more strength than FCM. The environmental issues associated with the production of OPC are too many, responsible for some of the CO2 emissions, So there must be an alternative to OPC. The reduced CO2 emissions of GPC make them a good alternative to OPC.

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