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Concept Validation of Cementless Geopolymer Mortar with Experimental Study for Partial Substitution of Natural Sand by Foundry Sand

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Abstract-: ***It's a renowned fact that concrete used around the globe is second only to water. The production of ordinary Portland cement contributes 5-7% of total green house gas emission & also consumes large amount of energy. Hence it is crucial to discover substitute to cement. Geopolymer is an organic alumino-silicate compound, synthesized from fly ash, where fly ash is a waste residual coal obtained from thermal power plant. It is also one of the source material for geopolymer binders, which is chiefly obtainable in India. Till date numerous options have been evolved regarding use of fly ash in construction but this utilization is still limited, hence it is essential to make the efforts to utilize this byproduct in concrete manufacturing by 'Geopolymer Technology' in order to make concrete environment friendly. Another additional alternative to make concrete eco-friendly is partial use of foundry sand in concrete as a replacement for fine aggregate, however, foundry sand is also waste non-decomposable industrial material. This paper describes an experimental work conducted for finding the several effects of use of fly ash & foundry sand on Geopolymer Mortar, especially on its compressive strength. Various parameters i. e. ratio of alkaline solution to fly ash, concentration of sodium hydroxide, ratio of sodium silicate to sodium hydroxide, curing time, curing temperature, resting period, additional water content in the mix of mortar have been investigated and found to be largely influencing the results. However, this research proposes the efficient use of Geopolymer Technology without a single particle of cement and also favors certain partial replacement of natural fine aggregate with foundry sand.***

Keywords: ***Geopolymer Concrete, Alkaline Solution, Fly Ash, Foundry Sand, Temperature Curing, Compressive Strength.***

I. INTRODUCTION

The demand of concrete is increasing day by day for the need of development of infrastructure facilities. Concrete is one of the most essential materials used in construction field. Ordinary Portland Cement (OPC) is used as the primary binder to produce the concrete. However, it is well known that the production of cement (OPC) not only consume huge amount of natural resources but also releases substantial quantity of carbon dioxide to the atmosphere. On the other hand, already huge volume of fly ash is generated around the world; most of the fly ash is not effectively used, and a large part of it is disposed in landfills. As the need for power increases, the volume of fly ash around the world would increase. Hence it has become necessary and significant to use fly ash material to produce concrete without Portland cement.

The global cement industry contributes around 2.8 billion tons of the greenhouse gas emissions annually, or about 7% of the total man made greenhouse gas emissions to the earth's atmosphere. It is essential to find alternatives to make environment friendly concrete. One of the alternatives to produce more environment friendly concrete is to replace the amount of Portland cement in concrete with by-product material such as fly ash. Fly ash possesses excellent mechanical properties with enhanced durability performance.

Substantial to the awareness regarding environmental unbalance due to production of cement, a new notion has been emerged to produce concrete and mortar devoid of cement, famed as geopolymer, which is the development of inorganic alumina-silicate polymer. The mass of geopolymer solids in the mixture is the sum of the mass of fly ash, the mass of sodium hydroxide flakes and the mass of solids in sodium silicate solution. Geopolymer concrete which are ideal for building and repairing infrastructures and for casting units, because they retain high early strength and their setting times can be controlled by adding super plasticizer. The production of geopolymer concrete is carried out using the conventional concrete technology methods. The fly ash based geopolymer concrete consists 75% to 80% by mass of aggregate, which is bound by a geopolymer paste formed by the reaction of silicon and aluminum with the fly ash and the alkaline solution with the addition of super plasticizer.

The next non-decomposable industrial waste material proposed in this research is foundry sand. Metal foundries use large amounts of sand as part of the metal casting process. Foundries successfully recycle and reuse the sand many times in a foundry. When the sand can no longer be reused in the foundry, it is removed from the foundry and is termed 'foundry sand'. Foundry sand production is nearly 6 to 10 million tons annually. Like many waste products, foundry sand has beneficial applications to other industries. This consists of 85-95% silica, 0-12% clay, 2-10% carbonaceous additives such as sea coal and 2-5% water. Foundry sand is the most commonly used molding media by foundries. This silica sand is the bulk medium that resists high temperatures while the coating of clay binds the sand together.

II. METHODOLOGY

Research consist preparation of geopolymer mortar cubes with partial replacement of natural sand with foundry sand. Geopolymer mortar consisted the ingredients namely Sodium Hydroxide (flakes form), Sodium Silicate (powder form), flyash, natural sand, foundry sand and mixing water. All the ingredients are used pertaining to their required standards in terms of mechanical properties, physical properties, chemical properties, shape & size, texture & source, etc. The ingredients of conventional mortar viz. fine aggregate, fly ash and water are used of identical specification in cement mortar. Only the new material i.e. Foundry sand is selected on the basis of specifications published in earlier studies by Foundry Industry Recycling Starts Today (FIRST) and is procured from Satpur MIDC, Nashik. Further the mortar mix was designed for proportions by '*Indian Standard method for Concrete Mix Design'* considering the substitution of foundry sand by 10%, 15%, and 20% by weight in place of conventional fine aggregate making considerations with respect to the specific gravities of material. The fly ash used in this study was Low-Calcium Class F processed fly ash from Pozzocrete, near Eklahare Power Plant, Nashik (Product Code: POZZOCRETE60). The chemical composition of fly ash used along with the specifications are given in Table-I.

TABLE I
Composition of Class F Fly Ash (POZZOCRETE60)

Sio_3	Al_2O_3	Fe_2O_3	MgO	SO_3	NgO	CaO	LOI
57.30%	27.13%	8.06%	2.13%	1.06%	0.73%	0.03%	1.60%

The alkaline solution used was a combination of sodium hydroxide and sodium silicate. Sodium hydroxide (NaOH) in flakes form with 98% purity purchased from local chemical supplier was used and sodium silicate solution. (Na_2O = 16.37%, SiO_2 = 34.85% and water = 49.28% by mass) was used as alkaline solution. Sodium hydroxide solution is prepared by dissolving the flakes in distilled water. The activator solution was prepared one day prior to use. Locally available river sand is used as fine aggregate in the mortar mix. The detailed proportions of different ingredients of mortar are shown in Table II below.

TABLE II
Ingredients for Geopolymer Mortar Mix-1 to Mix-4

Ingredients	Unit	Mix-1 (0%)	Mix-2 (10%)	Mix-3 (15%)	Mix-4 (20%)
Fly Ash	gm	750	750	750	750
Fine Aggregate	gm	2250	2025	1912.5	1800
Foundry Sand	gm	-	225	337.5	450
Na_2Sio_3 (Powder)	gm	56	56	56	56
Mixing Water	gm	98.5	98.5	98.5	98.5
NaOH (Flakes)	gm	199	199	199	199
Mixing Water	ml	189.125	189.125	189.125	189.125
Curing Temperature	^0C	100	100	100	100
Curing Period	Hours	24	24	24	24
	Hours	48	48	48	48
Additional water	Kg/m^3	158	158	158	158
Rest period for 24 Hrs	Days	2	2	2	2
Rest period for 48 Hrs	Days	1	1	1	1
No. of cubes	-	4	4	4	4

III. RESULTS AND DISCUSSIONS

A. Results

Each proportion was tested for compressive strength at the age of 3 days and 7 days having heat cured for 24 hours and 48 hours. Likewise four cubes of each proportion were casted and tested at their respective schedules. Hereby the results of all the variations are mentioned in Table III.

TABLE III
Compressive Strength of Mortar by Partial Replacement

Sr. No.	Partial Replacement of Foundry sand	3 days Avg. Compressive Strength of Mortar in (N/mm^2)		7 days Avg. compressive Strength of Mortar in(N/mm^2)		Average Weight of Cube in (gms)	
		24 Hrs	48 Hrs	24 Hrs	48 Hrs	24 Hrs	48 Hrs
1.	0%	4.07	4.31	4.93	5.25	782	710
2.	10%	4.22	4.48	5.18	5.36	744	655
3.	15%	3.92	4.28	4.51	4.81	637.5	601
4.	20%	3.53	3.85	4.01	4.09	568	513

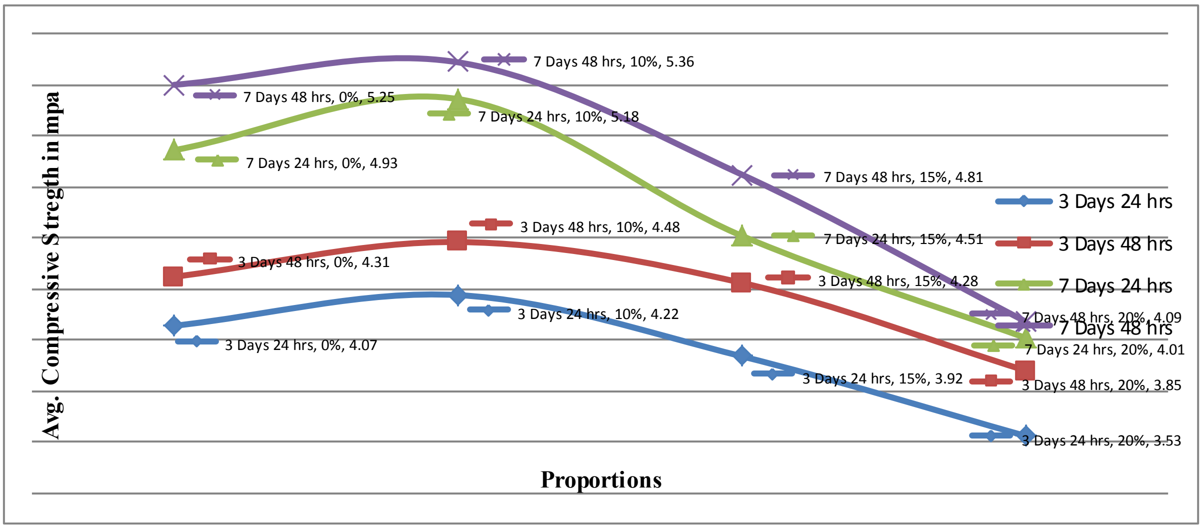

Fig. 1: Graph showing Compressive Strength comparison of all the mixes

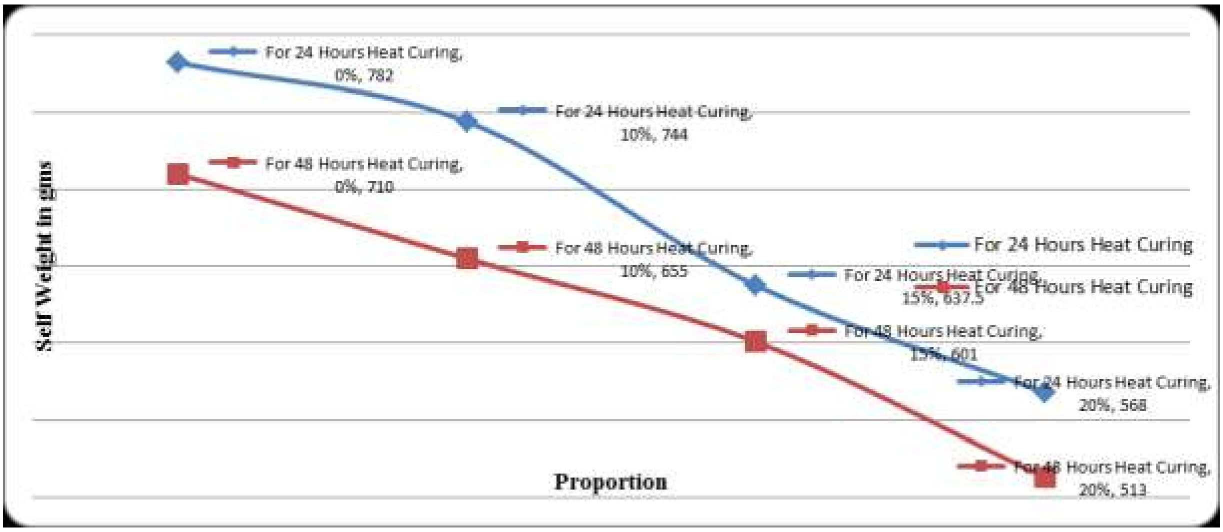

Fig.2: Graph showing Self Weights of all mixes

B. Discussion

With reference to the results above the following discussions can made

1. It is possible to replace cement fully with flyash by employing geopolymer technology.
2. It is observed that cubes with 10% replacement of natural sand with foundry sand gives more strength as compared to other proportions in both cases i.e. 24 hours heating as well as 48 hours heating.
3. Hence it is possible to replace foundry sand upto 10% with natural sand, but further more replacement will lead to reduction in strength as well as in self weight of mortar.
4. Further it is also observed that cubes heated for 48 hours gives more strength than those heated for 24 hours, however increase in strength from 24 to 48 hours is not much significant.
5. In contrast, the self weight of cubes heated for 48 hours is less than those heated for 24 hours. This means that Compressive Strength to Self Weight ratio for 48 hours is more than 24 hours.
6. Further it is also observed that compressive strength of cubes after 7 days is slightly more than those at 3 days. This means that more the rest period more will be the strength.

CONCLUSION

Research proposes the effective utilization of fly ash and foundry sand in the form of geopolymer mortar, thus eminently expressing the mode of reducing CO_2 emission and degradation of environment due to continuous increase in non-decomposable wastes. Currently increase in green house gas emission has become a global issue due to which the industries having higher carbon footprints are on the verge of trim down. Hence it has become need for today to discover and implement such notions that would lead to ecofriendlyness and sustainability in construction industry. The concept of geopolymer mortar proves to be working and effective, however the further replacement of natural sand with foundry give additional advantages like utilization of non-decomposable residues such as flyash & foundry sand and prevention of use cement and natural sand. Increase in cement production, foundry sand, flyash, etc being hazardous to nature, our concept of geopolymer mortar with foundry sand demonstrates to be an ecofriendly option for construction industry.

FUTURISTIC SCOPE

The present study of geopolymer mortar shows the significant potential to be a material for the future, because it is not only environment friendly but also possesses the required strength and durability. However, on the present study further research can be carried out to know the chemical reactions between foundry sand and geopolymer concrete. Also the changes in properties due to variations in curing temperature, alkaline content, mixing water, etc needs to be explored. Further it is also necessary to find certain steps to reduce the cost of production of geopolymer concrete or mortar.

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