Effect of Precursor and their Proportions on the Compressive Strength of Geopolymer Mortars

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Abstract : The critical element for sustainable growth in the construction industry is the development of alternative cements. A new technological process called geopolymerization provides an innovative solution, and the presence of aluminum and silicon oxides in fly ash has encouraged its use as a source material. Use of Geopolymer can reduce CO_2 emission from the manufacture of concrete since geopolymer binders are produced using industrial by-products, such as fly ash and blast furnace slag instead of Portland cement. This study provides new insight into the strength development and the effect of the molarity and particle size of the fine aggregate in the geopolymer mortars. The results are mainly influenced by the amount of precursors and alkaline activators. While increase of the quantity of additives in GGBS based geopolymer mixtures enhances compressive strength. Hence the proportion of additives to GGBS plays the major role in achievement of acceptable strength with curing condition. Suitable mixtures were found for ambient curing conditions that contained GGBS and lower proportions of RHA.

***IndexTerms* – Alkali-activation, ground granulated blast furnace slag, silica fume, compressive strength.**

I. Introduction

Concrete is the most widely used construction material in the world. With hundreds of millions of tons used annually, it is second only to water as the most consumed resource (Seal et al., 2011). The principal component and binder in concrete is ordinary Portland cement (OPC). The production of OPC is consequently one of the largest global sources of combustion and chemical process-related carbon dioxide (CO_2) emissions (Hanle et al., 2011). The emissions are created by burning fossil fuels to heat limestone to 2640°F and by the conversion of calcium carbonate ($CaCO_3$) to calcium oxide (CaO). The production of 1 ton of OPC directly generates 0.6 tons of chemical CO_2, and the required combustion of carbon-based fuel generates an additional 0.4 tons. This process results in the emission of approximately 1 ton of CO_2 for every ton of OPC produced, accounting for 5% of global CO_2 production or approximately 1.7 trillion tons per year (Pearce, 1997; PCA, 2012). The current trend in the construction industry is leaning more towards sustainable practices every year, making research valuable by providing a means to limit waste and recycle material. The use of recycled materials and byproducts has ecological effects that benefit the environment by lowering energy consumption and saving valuable landfill to space. The use of recycled materials in concrete research has been limited to recycled admixtures, recycled reinforcement fibers and recycled aggregates. The critical element for sustainable growth, however, is the development of alternative cements to replace OPC (Davidovits, 1989).

An alternative method of reducing the use of OPC is by incorporating precursor (like fly ash) into a new technological process called geopolymerization (Silverstrim et al., 1999). Geopolymers are formed when aluminum and silicon oxides (Al_2SiO_5) dissolve in a strong alkaline solution, reorganize and polycondense into a hardened state. Due to its similarity to natural sources of Al_2SiO_5, fly ash can be combined with an alkaline solution to produce new geopolymer binders (Jiang & Roy, 1992). Consequently, geopolymer mortar (GPM) and geopolymer concrete (GPC) have the potential to become low-cost and low-emission structural building materials (Seal et al., 2011). By applying this new 3 technology, byproducts such as rice husk ash (RHA), ground granulated blast furnace slag (GGBS) and silica fume can be transformed into useful construction materials, and the CO_2 from OPC production can be reduced by as much as 90% (Davidovits, 1994). Like many innovative materials, however, the appropriate practices, properties and applications of geopolymers have not yet been fully determined.

II. Methodology

2.1 Materials

The materials used in the experimental investigation were i) Ennor sand, (ii) Ground granulated blast furnace slag (GGBS), (iii) Rice husk ash (RHA), (iv) Silica fume and (v) Alkali activated solution, which is a mixture of sodium silicate gel (Na_2SiO_3) and sodium hydroxide pallets (NaOH).

In this study the NaOH concentration molarity (M) was varied as 7M, 11M and 14M. The ratio of Na_2SiO_3/NaOH maintained as 2.5.

2.1 Geopolymer mortars mix design

A new class of concentration materials is geopolymers, synthesized by alkali activation of alumina silicate material the ingredients used for preparation of geopolymer are alumina silicate material ,alkaline activator, aggregate and water. It is essential to select proper ingredients and their proportions for optimum usage. The suitable ingredients of geopolymers and their related proportion are selected with objective of high compressive strength. There are number of factors influences the mechanical microscopic and durability properties of geopolymers, that are

- Alkaline activator to binding ratio
- Alkaline activator to sand ratio
- Water to solid ratio
- Type of alkaline activator
- Concentration of Alkaline activator
- Temperature used for curing

2.3 Preparation of the alkaline solution

The compressive strength of geo-polymer concrete is examined for the mixes of varying molarities of Sodium hydroxide (8M, 11M and 14M). The molecular weight of sodium hydroxide is 40. To prepare 14M i.e. 14 molar sodium hydroxide solution, 560g of sodium hydroxide flakes are weighed and they can be dissolved in distilled water to form 1 liter solution. For this, volumetric flask of 1 liter capacity is taken, sodium hydroxide flakes are added slowly to distilled water to prepare 1liter solution.

III. RESULTS AND DISCUSSION

In this study the different precursors such as rice husk ash, silica fume and ground granulated blast furnace slag were used. Rice husk ash collected from a brick factory located in Kallakuru, Andhra Pradesh. Silica fume and GGBS were collected from the commercial market Vespra Pvt. Lmtd. Vijayawada, Andhra Pradesh.

The compressive strength of all the mixes was examined at the age of 28 days ambient curing with varying precursor content for fine aggregates for Grade-1, Grade-2, Grade-3 and all grades in equal proportions. The values of average compressive strength for different replacement levels of precursors such as GGBS, silica fume and rice husk ash (as aforementioned) and prepared with different concentration of alkaline activator (8M, 11M and 14M).

Table 3.1 Test results for geopolymer mortars for Grade-1 specimens

Grade -1 mixes	28 days at ambient curing		
	8M	11M	14M
G11	41.34	46.14	50.24
G12	38.66	42.44	46.15
G13	31.24	39.88	41.34
G14	28.65	29.56	35.66
G15	23.15	26.15	30.18
G16	21.34	26.15	27.64
G17	20.15	21.34	21.45
G18	16.55	19.85	18.65
G19	8.86	6.15	6.1

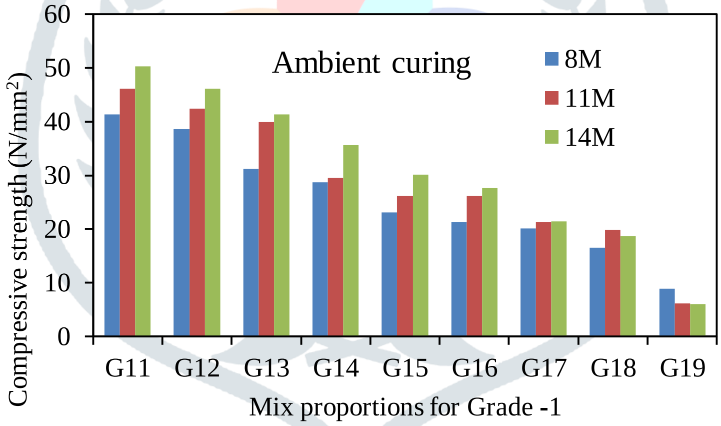

Figure 3.1 Compressive strength of mortars prepared with Grade -1 Ennore sand

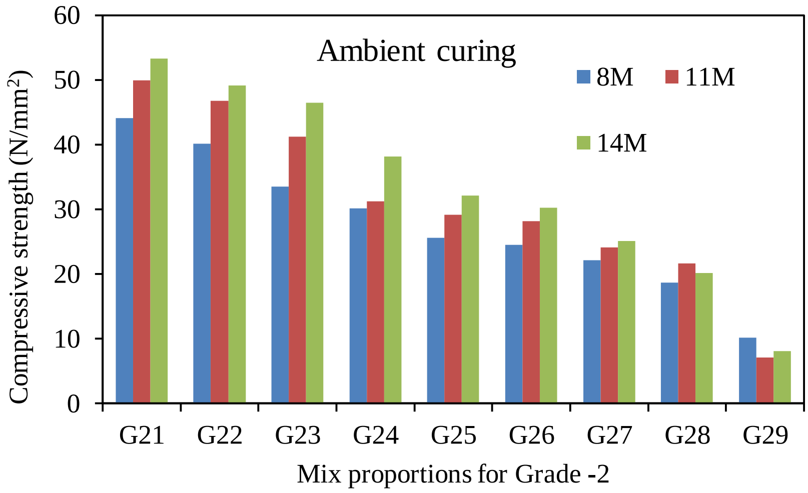

Figure 3.2 Compressive strength of mortars prepared with Grade -2 Ennore sand

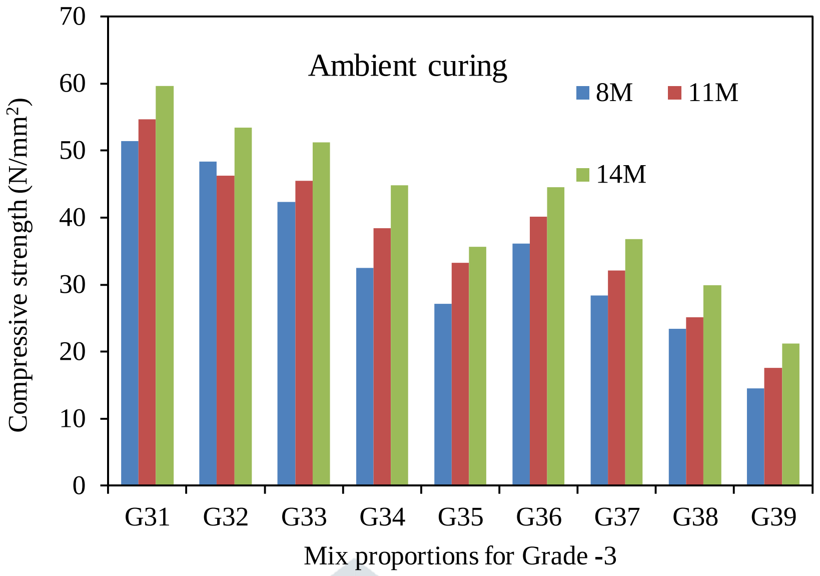

Figure 3.3 Compressive strength of mortars prepared with Grade -3 Ennore sand

Fig 3.1 shows the variation of compressive strength of mortar prepared with different precursor content as mentioned in the Table 3.1 Increasing the GGBS content increases the compressive strength of the GGBS based geopolymer blends. It can be that the compressive strength of geopolymer matrix increase with increase in the GGBS content. This can attributed due to the higher alumina content dissolved in the alkaline solution. Significant differences were noted in the compressive strength development of the geopolymers with various precursors' contents. Further mixes, when GGBS content replaced by silica fume and RHA there is a significant decrease in the strength. This can be attributed due to the random sizes of the precursors presents in the blends.

V. CONCLUSIONS

The following conclusions can be drawn from the foregoing study:

1. Geopolymer mortars can be produced at both ambient curing and by heat curing using GGBS activated by sodium silicate and sodium hydroxide solution whereas the production of GGBS-RHA-based Geopolymer mortars, using GGBS and RHA activated by sodium silicate and sodium hydroxide solution need heat curing to accelerate the setting process.
2. Na_2O dosage had a significant influence on the strength of both GGBS and RHA based geopolymer mortars. For GGBS based geopolymer binder the Na_2O is needed to maintain the alkalinity of the mixes, the condition needed to assist the dissolution of the slag and the adsorption of ions in solution on the surface of the slag. For combined GGBS-RHA-based geopolymer binder, the alkali has two roles. Firstly, to partially balance the charge of aluminates groups in the tectosilicate, and secondly to increase the solubility of the aluminosilicate.
3. The mere fact that fine aggregate occupy 66-70% of volume of mortar, their impact on various characteristics of mortar is undoubtedly considerable along with its gradation.

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