A Survey Paper on Experimental Analysis of Fly-Ash mix Nano-Silica in Geopolymer Concrete for Economical Behavior of the Structure

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Abstract— This work focuses on studying the effect of fly-ash mix Nano-Silica and their combinations in Geopolymer concrete on compressive strength characteristics of high performance concrete. This work primarily deals with the compressive strength characteristics such as water absorption super plasticizer used in high performance Geopolymer concrete a set of 4 different concrete mixture were cast and tested with different cement replacement levels of Fly-ash with Nano-Silica as Geopolymer concrete addition by wt of Cement and each trial super plasticizer has been added at constant values to achieve a constant range of slump for desired work ability with a constant water-binder (w/b) ratio of 0.30. The materials used to design the mix for M20 & M30 grade of concrete are cement, sand, coarse aggregate, water, Fly-Ash and SiO2 as for Geopolymer concrete. Three specimens are tested for typical category and the mean compressive strength of three specimens is considered as the compressive strength of the specified category of concrete.

Keywords: Concrete, Fly-Ash, Nano-Silica, compressive strength, tensile strength, Portland Cement, Variability

I. INTRODUCTION

Geopolymer Concrete is the material of present as well as future. The wide use of it in structures, from buildings to factories, from bridges to airports, makes it one of the most investigated material of the 21st century. Due to the rapid population explosion and the technology boom to cater to these needs, there is an urgent need to improve the strength and durability of concrete. Out of the various materials used in the production of concrete, cement plays a major role due its size and adhesive property. So, to produce concrete with improved properties, the mechanism of cement hydration has to be studied properly and better substitutes to it have to be suggested. Different materials known as supplementary cementitious materials or SCMs are added to concrete improve its properties. Some of these are fly ash, blast furnace slag, rice husk, Nano-Silica fumes and even bacteria in Geopolymer Concrete of the various technologies in use, Fly-Ash-technology looks to be a promising approach in improving the properties of concrete.

- Nano-Silica: C-S-H gel refers to calcium Nano-Silica te hydrates, making up about 60 % of the volume of solids in a completely hydrated cement paste. It has a structure of short fibres which vary from crystalline to amorphous form. Owing to its gelatinous structure it can bound various inert materials by virtue of Van der Waal forces. It is the primary strength giving phase in cement concrete.
- A by-product of the thermal power plant industry fly-ash is generally of two types one is the coal ash that is captured from coal-fired power plant's chimneys and second one is bottom ash which is collected from bottom of the coal furnaces. Its main constituents are silicon dioxide (SiO_2) (amorphous as well as crystalline also) and calcium oxide (CaO). Class F and Class C are two main classes of the fly-ash. The utilization of fly-ash in concrete production was mainly performed to remove the Greenhouse gases of the concrete as one tone of Portland cement produces one tone of CO_2 while zero CO_2 is being produced by the fly-ash.

II. LITERATURE REVIEW

The review of a number of literatures shows the importance of this field of research. The findings shows that a number of Fly-Ash materials like SiO2, TiO2, Al2O3, colloidal Fly-AshNano-Silica, metakaolin and others can be incorporated to improve the properties of concrete.

[Yanqun Sun, Peng Zhang, Weina Guo, Jiuwen Bao, and Chengping Qu (2020)] the first phase, nine concrete mixtures were prepared with three water-to-binder ratios (0.4, 0.5, and 0.6), three fly ash contents (15%, 20%, and 25% replacement of the cement weight), and three nano-$CaCO_3$ contents (1%, 2%, and 3% replacement of the cement weight) has suggested a new solution called component modification in-process was introduced to the results show that the fly ash added into the molten steel slag before air quenching can more effectively improve the slag's grindability than mill tailings, which is the other modification agent tested under the same conditions.

[Young, Mindness et al. (2019)] Polymer is a class of materials made from large molecules that are composed of a large number of repeating units (monomers). The molecular structure of the unit that makes up the large molecules controls the properties of the material. The noncrystalline or amorphous state is the state when the regularity of atomic packing is completely absent. The most familiar kind of an amorphous solid is glass.

[Van Deventer (2019)] Geopolymers are a member of the family of inorganic polymers, and are a chain structures formed on a backbone of Al and Si ions. The chemical composition of this geopolymer material is similar to natural zeolitic materials, but they have amorphous microstructure instead of crystalline. The polymerisation process involves a substantially fast chemical reaction under highly alkaline condition.

[G. Dhinakaran et. al. (2018)] analyzed the microstructure and strength properties of concrete with Fly-Ash SiO2. The Nano-Silica was ground in the planetary ball mill till Fly-Ash size reached and it was blended in concrete with 5%, 10% and 15% b.w.c.. The experimental results showed gain in compressive strength with maximum strength for 10% replacement.

[J.Comiletti et.al. (2018)] investigated the effect of micro and Fly-Ash CaCO3 on the early age properties of ultra-high performance concrete (UHPC) cured in cold and normal field conditions. The micro CaCO3 was added from 0

to 15% b.w.c. and Fly-Ash CaCO3 was added at the rate of 0, 2.5 and 5% b.w.c. Results show that by incorporating Fly-Ash and micro CaCO3 the flow ability of UHPC is higher than the control mix which increases the cement replacement level. The mixture containing 5% Fly-Ash CaCO3 and 15% micro CaCO3 gives shortest setting time at 10 °C and at 20°C the highest 24 hrs compressive strength is achieved by replacing cement with 2.5% Fly-Ash and 5% micro CaCO3 and highest compressive strength at 26 days was achieved at 0% Fly-Ash and 2.5% micro CaCO3.

[Alireza Naji Givi et.al. (2018)] studied the effect of Fly-Ash SiO2 particles on water absorption of RHA blended concrete. It is concluded that cement could be replaced up to 20% by RHA in presence of Fly-Ash SiO2 particle up to 2% which improves physical and mechanical properties of concrete.

[Heidari and Tavakoli (2017)] investigated the combined effect of replacement of cement by ground ceramic powder from 10% to 40% b.w.c. and Fly-Ash SiO2 from 0.5 to 1%. A substantial decrease in water absorption capacity and increase in compressive strength was observed when 20% replacement is done with ground ceramic powder with 0.5 to 1% as the optimum dose of Fly-Ash SiO2 particles.

[A.M. Said et.al. (2017)] studied the effect of colloidal Fly-Ash Nano-Silica on concrete by blending it with class F fly ash and observed that performance of concrete with or without fly ash was significantly improved with addition of variable amounts of Fly-Ash Nano-Silica. The mixture containing 30% FA and 6% CNS provides considerable increase in strength. Porosity and threshold pore diameter was significantly lower for mixture containing Fly-Ash Nano-Silica. The RCPT test shows that passing charges and physical penetration depth significantly improved.

III. Problem Identification

The increased use of cement is essential in attaining a higher compressive strength. But, cement is a major source of pollution. The use of Geopolymer materials by replacement of a proportion of cement can lead to a rise in the compressive strength of the concrete as well as a check to pollution. Since the use of a very small proportion of Fly-Ash and Nano-Silica can affect the properties of Geopolomer concrete largely, a proper study of its microstructure is essential in understanding the reactions and the effect of the Fly-Ash particles.

IV. Objectives

The main objectives of the present study are as mentioned below:

- To study the effect of Fly-Ash & Nano Silica on the compressive strength of Geopolomer concrete.
- To study the specimen for valuable % of Fly-Ash mix Nano-Silica.
- To explain the change in properties of Geopolymer concrete, with various propagation.
- Find the impact of a Fly-Ash & Nano-Silica on the variation in strength of Geopolomer concrete.

V. Methodology

The details of the properties of the materials used, the method followed to design the experiment and the test procedures followed. The theory is supplemented with a number of pictures to have a clear idea on the methods.

Specific Gravity	Fineness by sieve analysis	Normal consistency
3.014	2.01%	33%

Table 1: Properties of Portland slag cement

Property	Coarse Aggregate	Fine Aggregate
Specific Gravity	2.72	2.65
Bulk Density (kg/L)	1.408	-
Loose Bulk Density (kg/L)	1.25	-
Water Absorption (%)	4.469	0.0651
Impact Value	26.910	-
Crushing Value	26.514	-
Fineness Modulus	3.38	2.84

Table 2: Properties of coarse aggregate and fine aggregate

Fig. 1: Image of the Fly-Ash SiO2 used

A. *Preparation of Test Specimen*

For conducting compressive strength test on concrete cubes of size 150×150×150 mm are casted. A rotary mixture is used for thorough mixing and a vibrator is used for good compaction. After succesful casting, the concrete specimens are de-moulded after 24 hours and immersed in water for 28 days maintaining 27 +/- 1 C°. Fig. 3.3 shows some concrete specimen casted in laboratory.

Fig. 2: Mixing of the Fly-Ash SiO2

B. Compressive Strength Test

The compressive strength of specimens is determined after 7 and 28 days of curing with surface dried condition as per Indian Standard IS: 516-1959. Three specimens are tested for typical category and the mean compressive strength of three specimens is considered as the compressive strength of the specified category.

VI. Discussion

The increase in compressive strength can be attributed to the filling of voids in the microstructure by the Fly-Ash Mix SiO2 particles which prevents the growth of Ca(OH)2 crystals. In addition to it the Fly-Ash Mix Nano-Silica reacts with calcium hydroxide crystals converting them into C-S-H gel. The reduction in the Ca(OH)2 content is the reason for increase in compressive strength of Geopolymer concrete.

Ca(OH)2 crystals are present in the Interfacial Transition Zone (ITZ) which is between the aggregates and the hardened cement paste. Fly-Ash Mix SiO2 reacts with these crystals and decreases their concentration, hence, strengthen the ITZ. Due to lesser concentration Fly-Ash Mix SiO2 are consumed in the reaction and hence the increase in strength is inhibited with time.

A study of relevant papers show that Geopolomer concrete blended with Fly-Ash Mix SiO2 sets quicker compared to normal concrete. Since, the mix design is carried out without the aid of supper-plasticizers, the mix dried up fast which affected the compaction of the mix using mechanical vibration. Lumps of the mix could be seen during the mixing of concrete. With increase in percentage of Fly-Ash Mix SiO2 the compaction gets tougher. This is the reason for degradation in its quality. It is advisable to use superplasticizers with Fly-Ash Mix Nano-Silica.

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