Investigation on Mechanical Properties of Fly Ash Based Steel Fibers Reinforced Geopolymer Concrete

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Abstract- *This study is for societal technologies. Production of cement results in heavy environmental pollution due to emission of CO_2 gas. Also it consumes large amount of natural resources. Hence it is essential to find alternative to cement. Geopolymer concrete is an innovative material in which the binder is produced but the reaction of an alkaline liquid with a source material that is rich in silica alumina. The study analyses the effect of steel fiber on compressive strength & split tensile strength. Geopolymer concrete mixes were prepared using low calcium fly ash & activated by alkaline solution (NaOH & Na_2SiO_3) with alkaline liquid to fly ash ratio of 0.4. Alkaline solution. The specimens was kept in oven for 24 hrs of curing time and also this curing time was same for temperature variation like 40^0C to 110^0C. After specified period of heating at particular temperature, the oven was switched off. To avoid sudden variation in temperature, the concrete cubes were allowed to cool down up to room temperature in an oven. After 24 hr, specimens were removed from oven and go for the basic mechanical properties.*

Keywords- Geopolymer, Fly ash , steel fibres.

I. INTRODUCTION

The abundant availability of fly ash worldwide creates opportunity to utilise this by-product of burning coal, as a substitute for OPC to manufacture concrete. When used as a partial replacement of OPC, in the presence of water and in ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process of OPC to form the OPC up to 60% by mass (Malhotra 2002 calcium silicate hydrate (C-S-H) gel. The development and application of high volume fly ash concrete, which enabled the replacement of Malhotra and Mehta 2002), is a significant development.

Geopolymer are members of the family of inorganic polymers. The chemical composition of the geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous instead of crystalline (Palomo et al. 1999; Xu andvan Deventer 2000). The polymerisation process involves a substantially fast chemical reaction under alkaline condition on Si-Al minerals, which result in a three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds.

Geopolymerization is the process of combining many small molecules known as oligomers into a covalently bonded network. The geo-chemical syntheses are carried out through oligomers which provide the actual unit structures of the three dimensional macromolecular edifice. In 2000, T.W. Swaddle and his team proved the existence of soluble isolated alumino-silicate molecules in solution in relatively high concentrations and high pH. One major improvement in their research was that their study was carried out at very low temperatures, as low as −9 °C. Indeed, it was discovered that the polymerization at room temperature of oligo-sialates was taking place on a time scale of around 100 milliseconds, i.e. 100 to 1000 times faster than the polymerization of ortho-silicate, oligo-siloxo units. At room temperature or higher, the reaction is so fast that it cannot be detected with conventional analytical equipment.

Currently geopolymer can be considered as the materials still in their embryonic stage, but these materials are developing very fast. Although the geopolymer technology was developed more than 30 years ago, patents and licences closely guarded it. Also, Geopolymeric materials were developed as technology rather than science; hence there is a very little fundamental understanding of these materials. Only within the last decade the interest in these materials was revived after the classified information was open to public.

II. LITERATURE REVIEW

Nisha Jain et.al (Aug 2016) investigated that, the compressive strength goes on increasing with the increase in the rest period of geopolymer concrete with addition of 10% of Lime and it’s cured at normal room temperature. The maximum compressive strength was achieved at the completion of 28 days of rest period thereby giving it a wide scope. The compressive strength achieved by grade M30 of geopolymer concrete cured at normal room temperature at a rest period of 7 days is higher than the compressive strength achieved by ordinary concrete for similar rest period.

Nisha Jain et.al (Aug 2016) studied that Compressive strength can be achieved for both the grade of GPC by replacing Fly ash with Cement for various percentages i.e. 5% & 10% by opting wet curing. The compressive strength goes on increasing with the increase in replacement percentage with cement in M30 grade of GPC by opting wet curing where maximum can be achieved by replacing 10% with cement.

Sandeep Hake, et al (May 2015), the oven heat curing of geopolymer concrete has been attempted by various researchers, but for curing of geopolymer concrete is quit difficult on site by using oven, so there is scope on types of curing which makes geopolymer concrete cure easily. The oven heat curing for geopolymer concrete is mostly used. The researchers studied only for different curing temperature in oven curing, but only few of them work on steam, membrane curing and no one work on accelerated curing, as well as comparison on steam, accelerated, membrane, natural and oven curing. So there is scope on method of curing of geo-polymer concrete. Also researchers studied for different curing time like 6,12,18,24 and the optimum strength obtained at 18 Hrs of Curing. The different curing temperatures like 60^0 C, 90^0 C, 120^0C and 150^0C. The different type of curing like Oven, Accelerated, Membrane and Steam curing are needed to be Study. The effect on compressive strength of Geopolymer concrete by using these parameter need to be study.

S. S. Jamkar et al (April 2013) have studied the effect of fly ash fineness on the compressive strength of geopolymer concrete. Geopolymer concrete was produced by activating fly ash with a highly alkaline solution of sodium silicate containing 16.45% Na2O, 34.35% SiO2 and 49.20% H2O and 13 molar sodium hydroxide solutions. Concrete cubes of 150 mm were cast using five samples of fly ash with Blaine fineness of 542, 430, 367, 327, 265m2/kg and solution to fly ash ratio of 0.35. The specimens were cured in an oven for 4, 8, 12, 16, 20 and 24 hours at 90°C. The compressive strength results show that the fly ash fineness plays a vital role in the activation of geopolymer concrete. An increase in the fineness increased both workability and Compressive strength. It was also observed that finer particles resulted in increasing the rate of reaction needing less heating time to achieve a given strength.

A. S. Sayyad and S. V. Patankar (2013) investigated the effect of steel fiber and low calcium fly ash on mechanical and elastic properties of geopolymer concrete composite. Tests were conducted on fresh concrete like flow table test, wet density and dry density. And they also analyzed the effect of steel fiber and low calcium fly ash on hard concrete like compressive strength, flexural split tensile strength and bond strength of geopolymer concrete composite. The test result shows that the workability of geopolymer concrete including steel fibres reduces with increases in fibre content and inclusion of steel fibre increases the density of geopolymer concrete. Also Authors reported that optimal fibre content for maximum value of various strength of geopolymer concrete is 0.2%.

III. EXPERIMENTAL METHODOLOGY

3.1 Material Used:

The ingredients of Geopolymer concrete i.e. flyash, alkaline solution, fine aggregate & coarse aggregate are tested before producing the concrete. The relevant Indian standard codes were followed for conducting various tests on the concrete.

3.1.1. Fly Ash

According to the American Concrete Institute (ACI) Committee 116R, fly ash is defined as 'the finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gasses from the combustion zone to the particle removal system' (ACI Committee 232 2004)(24). Fly ash is removed from the combustion gases by the dust collection system, either mechanically or by using electrostatic precipitators, before they are discharged to the atmosphere. Fly ash particles are typically spherical, finer than Portland cement and lime, ranging in diameter from less than 1 μm to no more than 150 μm. The types and relative amounts of incombustible matter in the coal determine the chemical composition of fly ash. The chemical composition is mainly composed of the oxides of silicon (SiO_2), aluminium (Al_2O_3), iron (Fe_2O_3), and calcium (CaO), whereas magnesium, potassium, sodium, titanium, and sulphur are also present in a lesser amount.

3.1.2. Alkaline Liquid

A combination of sodium silicate solution and sodium hydroxide solution was chosen as the alkaline liquid. Sodium-based solutions were chosen because they were cheaper than Potassium-based solutions. The sodium hydroxide solids were either a technical grade in flakes form (3 mm), with a specific gravity of 2.130, 97% purity.

The sodium hydroxide (NaOH) solution was prepared by dissolving either the flakes or the pellets in water. 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 8M consisted of 8x40 = 320 grams of NaOH solids (in flake or pellet form) per litre of the solution, where 40 is the molecular weight of NaOH. The chemical composition of the sodium silicate solution was Na2O=16.37%, SiO2=34.31%, and water 49.32% by mass. The other characteristics of the sodium silicate solution were specific gravity=1.53 g/cc and viscosity at 20^{o}C=400 cp.

The ratio of sodium silicate to sodium hydroxide is kept 2.5.

3.1.3 Fine Aggregate: (Natural Sand):

Concrete is an assemblage of individual pieces of aggregate bound together by cementing material, its properties are based primarily on the quality of cement paste. This strength is dependant also on the bond between the cement paste and aggregate. If either the strength of the paste or the bond between the paste and aggregate is low a concrete of poor quality will be obtained irrespective of strength of the aggregate, for making strong concrete, strong aggregate are an essential requirement. For which naturally available aggregate are strong enough for making normal strength concrete.

3.1.4 Coarse Aggregate:

The nominal maximum size of coarse aggregate should as large as possible within the specified limits but in no case greater than one fourth of the minimum thickness of the member, provided that the concrete can be placed without difficulty so as to surround all reinforcement thoroughly and fill the corners of the form.

3.1.5 Different types of Fibres

The end hook steel fibres of length 30mm and diameter 0.5mm were used. The steel fibres having aspect ratio (L/D) 0.55 and 0.75 with volume fraction of 0.0% to 2.8% at an interval of 0.4% by volume of geopolymer concrete were used. Other types of fibres (Carbon, Basalt, and Natural Fibres) were used similarly with same percentage of addition of geopolymer concrete.

3.2 Preparations of Specimen

The conventional concrete the cement is most important ingredient for binding the fine aggregate, coarse aggregate &sand etc. Like that for making the geopolymer concrete fly ash is most important ingredient to for binding the all material used in GPC. The fly ash may be of processed and unprocessed type. The processed fly ash contain the silicon and aluminum oxides in the low-calcium fly ash reacts with the alkaline liquid to form the geopolymer paste that binds the loose coarse aggregates, fine aggregates, and other un-reacted materials together to form the geopolymer concrete. As in the case of Portland cement concrete, the coarse and fine aggregates occupy about 75 to 80% of the mass of geopolymer concrete. This component of geopolymer concrete mixtures can be designed using the tools currently available for Portland cement concrete. The compressive strength and the workability of geopolymer concrete are influenced by the proportions and properties of the constituent materials that make the geopolymer paste. Higher concentration (in terms of molar) of sodium hydroxide solution results in higher compressive strength of geopolymer concrete. Higher the ratio of sodium silicate solution-to sodium hydroxide solution ratio by mass, higher is the compressive strength of geopolymer concrete. The slump value of the fresh geopolymer concrete increases when the water content of the mixture increases.

IV. RESULT AND DISCUSSION

The result of the experimental programs on geopolymer concrete. The effect of temperature variation, curing time, percentage of steel fibers for compressive strength of geopolymer concrete. This study shows that the behaviour of geopolymer concrete in different temperature condition.

4.1 Mechanical Properties

4.1.1 Effect of Temperature Variation on 3 Day Testing age

The Compressive strength of cube were tested for different temperature but for the 24 hours, 3 days testing age of Geopolymer concrete. The results of compressive strength of M-30 The Compressive strength of cube were tested for different temperature but for the 24 hours , 3 days, 7 days testing age and 28 days of testing age of Geopolymer concrete. Geopolymer concrete test result and comparison graph are as follows

Fig 4.1 Effect of Degree of heating on different Testing Age of GPC.

4.1.2 Effect of Addition of Steel Fibres on GPC

The percentage addition varies from 0.4, 0.8, 1.2, 1.6, 2.0, 2.4 and 2.8 are as follows

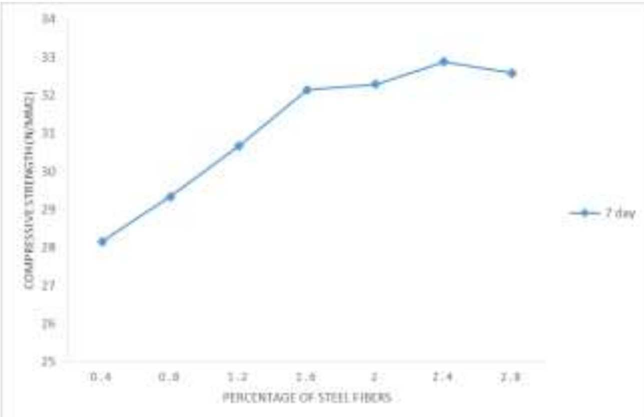

Fig 4.2 Effect of Percentage Addition of Steel Fibres for GPC.

4.1.3 Effect of Percentage addition on testing age

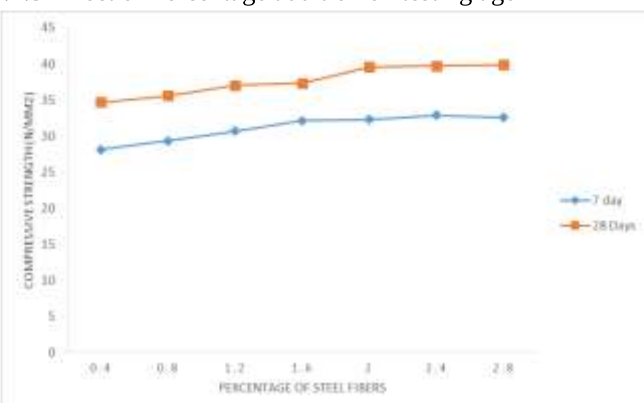

Fig 4.3 Effect of Percentage Addition of Steel Fibers for different Testing age of GPC.

4.1.4 Effect of Different Types of Fibres for 7and 28 days

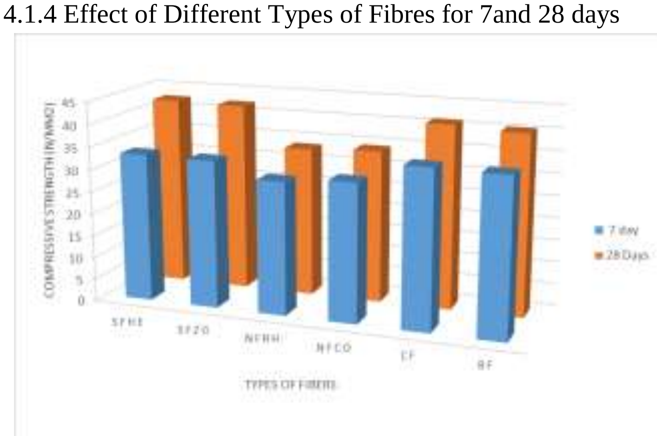

Fig 4.4 Effect of Types of fibres on GPC for different Testing age.

V. CONCLUSIONS

On the basis of result obtained during the experimental investigations, it can be concluded that:

1. The different types of fibres shows their importance with in the compressive strength of fibres added geopolymer concrete.
2. The carbon fibres and basalt fibres gives the maximum compressive strength as compare to other types of fibres but the as consideration of economical consideration the steel fibres are optimized for the further work.
3. The increase in compressive strength of steel fibre reinforced geopolymer concrete was found to be increased as compared to geopolymer concrete. The maximum compressive strength is achieved with increasing percentage volume of steel fibres by volume of geopolymer concrete.

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