A Review on Geopolymer Concrete and Its Properties

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Abstract: Geopolymer concrete is an environment- friendly construction material. Recently, many new innovative researches are being carried out in the Construction field to rectify the problems related to Pollution. Geopolymer concrete is one of the efficient innovations in Civil industry. Several mixes were developed by varying the percentage of alkaline solution, percentage of fly ash, percentage of GGBS, addition of admixtures and other aspects. Another important fact is that an exothermic reaction happens while preparing the alkaline solution. So it should be handled with care. Though geopolymer concrete has more advantages, it also has some disadvantages which should be taken care of. This review paper consolidates the properties of geopolymer concrete. The fresh and mechanical properties of geopolymer concrete and the effects of fibres and other mineral admixtures have been discussed in this paper.

Keywords: Geopolymer concrete, fibres, fly ash, GGBS, mineral admixtures.

I. INTRODUCTION

Cement has been one of the most essential materials in concrete. But manufacture of cement accounts for the release of carbon-dioxide into the atmosphere which is one of the major causes for air pollution. This may lead to deterioration of atmosphere due to the greenhouse gases. Geopolymer concrete eliminates the use of cement in its production. It employs the use of supplementary cementitious materials like Fly ash, GGBS, etc., which have the properties that are more or less similar to that of cement. These admixtures are being used as a partial replacement of cement all over the world. But in Geopolymer concrete, cement is completely being replaced by these cementitious materials. In some cases, different types of fibres are also included in the concrete mix and their effects on the properties of geopolymer concrete have been studied.

II. MATERIALS USED

Geopolymer concrete comprises of the following materials:

- Fine and Coarse aggregates
- Fly ash
- GGBS
- Alkaline activator solution

i. Fly Ash

Fly ash is a by-product that is received as a result of combustion of coal in places like thermal power plants. These are finely divided particles that are spherical in shape. The size of these particles ranges from 1 to 150 microns. Incorporation of Fly ash into concrete will help in improving the workability of concrete. It also leads to reduction in heat of hydration. Because of the fine size, permeability in concrete will also be considerably reduced.

ii. GGBS

Ground Granulated Blast Furnace Slag is obtained by grinding the slag that is a residue from iron ore industries. Molten slag is quenched with cold water until the slag dries up. After sometime, this slag is ground to a size less than 45 microns. Adding GGBS to concrete will increase its flowability, making the concrete easy to place.

iii. Alkaline Activator solution

This is an important constituent in manufacture of geopolymer concrete. As mentioned in paper [10], this solution is prepared by mixing Sodium hydroxide pellets in water. This solution is kept undisturbed for 24 hours at room temperature. This is to avoid the exothermic reaction. After preparing this solution, before casting of geopolymer concrete, the relative humidity of that environment is maintained as 65% to ensure favourable conditions while casting. This solution is added in different concentrations and the influence of this solution is studied by numerous researchers.

III. FRESH CONCRETE PROPERTIES OF GEOPOLYMER CONCRETE

i. Slump test

This test is done by filling the concrete mix into slump cones of top diameter 100mm, bottom diameter 200mm and height 300mm. This test helps in assessing the extent to which a particular concrete mix is capable of being workable or easy to handle. It is an essential property of concrete which will play an important role while placing the concrete. According to paper [11] which studied the effects of sodium hydroxide solution in self- compacting geopolymer concrete, a maximum value of 700mm was achieved. This paper also summarized that when the concentration of NaOH solution was raised, a decrease in slump flow value was observed. Paper [6] speaks about the effect of short steel fibres in fresh properties of geopolymer concrete. Slump value of 175mm was recorded for the mix with lower amount of steel fibres whereas a slump of 25mm was achieved for the mix with higher amount of short steel fibres. The authors of paper [4] have compared the results of ordinary Portland cement concrete and geopolymer concrete which showed that both the mixes had similar slump values.

ii. V- Funnel test for Self- compacting geopolymer concrete

This test is peculiarly conducted for a self- compacting concrete mix. As mentioned in paper [11], for the lowest concentration of NaOH solution, the time recorded was 9.5 seconds. The mix with highest concentration resulted in a flow time of 12 seconds. This

proves that the flowability of concrete reduced with an increase in the concentration of sodium hydroxide solution, since it aids in the increase of viscosity of the mix.

iii. L- Box test for Self- compacting geopolymer concrete

This fresh concrete test is also done for assessing the passing ability of self- compacting concrete mix. In paper [11], the ratio of H2/H1 was recorded for different mixes of self- compacting geopolymer concrete. A highest value of 0.96 was recorded for the mix with higher concentration and a value of 0.9 was observed for the mix with lowest concentration.

iv. Compaction factor test

In paper [4], compaction factor test was done and the results between OPC concrete and Geopolymer concrete were compared. OPC gave a compaction factor of 0.89. On the other hand, Geopolymer concrete resulted in a compaction factor of 0.87.

IV. MECHANICAL PROPERTIES OF GEOPOLYMER CONCRETE

i. Compression Strength

Cubical concrete specimens of size 150x150x150 mm are casted, cured and tested for their 7th day, 14th day and 28th day compressive strengths. Paper [1] speaks about the effects of various parameters and characteristics that influence the properties of concrete in different ways. It considers various factors like the ratio of sodium silicate solution to sodium hydroxide solution, curing time, type of superplasticizer being used in the mix, and water to geopolymer solids ratio. Paper [3] investigates the effects of varying quantities of fly ash and GGBS on the mechanical aspects. The mix with 40% cement, 30% fly ash and 30% GGBS gave a maximum compressive strength of 90 N/mm^2 after 28 days. As per the paper [11], the compressive strength of the mix increased when the concentration or molarity of sodium hydroxide solution was increased. The researchers of paper [2] have developed high strength geopolymer concrete mix along with alccofine and investigated the results. A compressive strength of 73 MPa was recorded for the mix with 10% of alccofine after 28 days.

ii. Split Tensile Strength

Cylindrical specimens of length 300mm and diameter 150mm are tested for their strengths. In paper [4], when the split tensile strengths of conventional concrete with Portland cement was compared with geopolymer concrete, it was observed that conventional mix resulted in a split tensile strength of 3.8 MPa and the latter resulted in a split tensile strength of 4.2 MPa after a period of 28 days. Paper [3] summarised that the mix with 0% of cement had a split tensile strength of 3.4 MPa and the mix with 40% cement, 30% fly ash and 30% GGBS resulted in 3.77 MPa at the 28th day. Paper [5] has tested the cylindrical specimens based on the Australian standard 1012.10-2000 (2000) and the highest recorded split tensile strength was 5.98 MPa.

iii. Flexural Strength

Prism specimens of length 500mm, breadth 100mm and thickness 100mm were tested for their flexural strengths after 7, 14 and 28 days. Paper [6], steel fibres were added to the mix and checked for their strengths. The mix with 7% of steel fibres gave a flexural strength of 5.94 MPa whereas the mix with lowest quantity of steel fibres gave a flexural strength of 1.45 MPa. As per paper [3], a higher value of 6.35 MPa was recorded.

V. LIMITATIONS

Papers [7] and [8] have enumerated some of the demerits in geopolymer concrete which are as follows:

- Preparation of alkaline solution is a costly process.
- Steam curing is a tedious method for curing geopolymer concrete
- Alkaline solution should be prepared with the suitable molarity to ensure that we get better results.
- It may lead to efflorescence in some cases.
- It can be sold only as pre-cast material or as a mix that has already been prepared.

VI. CONCLUSION

From this literature study, the following conclusions are made:

- Inclusion of fibres will affect the fresh properties, but it helps in improving the mechanical properties of geopolymer concrete which is important for a structure to stay durable.
- Cement can be replaced by materials like fly ash, GGBS, silica fume, alccofine, rice husk ash, etc.
- When the concentration of sodium hydroxide solution is altered, the fresh and hardened concrete properties may vary in a positive or negative way.
- Manufacture of geopolymer concrete should be done with care.
- Right proportion of materials may result in a mix with higher strengths.

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