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EXPERIMENTAL STUDIES OF GEOPOLYMER CONCRETE FULLY REPLACING CEMENT

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ABSTRACT

These days the demand for eco-friendly products has increased in our daily life, with increased awareness on pollution, therefore, helping the environment for being healthy. The demand for cement in construction has been rapidly increased with increase in demand for heavy constructions and due to population explosion.

In manufacturing of cement the emission of CO_2 contributes about 5% of CO_2 in the world pollution. Therefore it is necessary to find an alternative product to cement and hence decrease the emission of CO_2 in atmosphere. However, there are many products which have been partially replacing cement, but not fully and they doesn't makeup to the properties of conventional concrete, increasing in demand in research for eco-friendly, strong and durable product replacing cement.

This research contains preparation of geo-polymer concrete which undergoes certain tests compared to conventional concrete, which results in being better than conventional concrete.

Keywords:- Geo-Polymer, Metakaolin, Ambient curing.

I. INTRODUCTION

1 Geo-polymer Concrete

'Geo-polymer cement concrete' (GPCC) is an Inorganic polymer composite, which is a prospective concrete with the potential to form a substantial element of an environmentally sustainable construction by replacing/supplementing the conventional concrete. GPCC have high strength, with good resistance to chloride penetration, acid attack, etc. These are commonly formed by alkali activation of industrial alumino-silicate waste materials such as FA and GGBS, and have a very small Greenhouse footprint when compared to traditional concretes.

1.1 Basics of Geo-polymers

The term 'geo-polymer' was first introduced by Davidovits in 1978 to describe a family of mineral binders with chemical composition similar to zeolites but with an amorphous microstructure. Unlike ordinary Portland/Pozzolanic cements, geo-polymers do not form calcium- silicate-hydrates (CSHs) for matrix formation and strength, but utilize the poly-condensation of silica and alumina precursors to attain structural strength. Two main constituents of geo-polymers are: source materials and alkaline liquids. The source materials on alumino-silicate should be rich in silicon (Si) and aluminum (Al). They could be by-product materials such as fly ash, silica fume, slag, rice-husk ash, red mud, etc. Geo-polymers are also unique in comparison to other alumino-silicate materials (e.g. alumino-silicate gels, glasses, and zeolites). The concentration of solids in geo-polymerization is higher than in alumino-silicate gel or zeolite synthesis.

1.2 Composition of Geo-polymer Cement Concrete Mixes

Following materials are generally used to produce GPCCs:
Fly ash,
GGBS,
Fine aggregates and
Coarse aggregates

Catalytic liquid system (CLS): It is an alkaline activator solution (AAS) for GPCC. It is a combination of solutions of alkali silicates and hydroxides, besides distilled water. The role of AAS is to activate the geo-polymeric source materials (containing Si and Al) such as fly ash and GGBS.

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1.3 Formulating the GPCC Mixes

Unlike conventional cement concretes, GPCCs are a new class of materials and hence, conventional mix design approaches are applicable. The formulation of the GPCC mixtures requires systematic numerous investigations on the materials available.

1.4 Mechanical Properties

Compressive Strength: With proper formulation of mix ingredients, 24 hour compressive strengths of 25 to 35 MPa can be easily achieved without any need for any special curing. Such mixes can be considered as self-curing. However, GPCC mixes with 28 day strengths up to about 60-70 MPa have been developed at SERC.
Modulus of Elasticity the Young's modulus or modulus of elasticity (ME), Ec of GPCC is taken as tangent modulus measured at the stress level equal to 40 percent of the average compressive strength of concrete cylinders. The MEs of GPCCs are marginally lower than that of conventional cement concretes (CCs), at similar strength levels.

Stress Strain Curves the stress-strain relationship depends upon the ingredients of GPCCs and the curing period.

Rate of Development of Strength This is generally faster in GPCCs, as compared to CCs.

Figure 1: Metakaolin

Table 1: Chemical Properties of Cementitious materials

Chemical composition %	Cementitious materials		
	Cement	Metakaolin	Silica fume
SiO2	20.1	51.34	93.6
Al2O3	4.51	41.95	0.06
Fe2O3	2.50	0.52	0.45
CaO	61.3	0.34	0.50
Loss of ignition	2.41	0.72	2.26

Zang & Malhotra(1995)

1.5 Preparation of Geo-Polymer Concrete (GPC) Mixes

The mixing of ingredients of GPC can be carried out in mixers used for conventional cement concretes – such as pan mixer, drum mixer, etc

II. ALKALINE SOLUTION

The most common alkaline liquid used in geo-polymerization is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate. Liquid plays an important role in the polymerization process. Reactions occur at a high rate when the alkaline liquid contains soluble silicate, either sodium or potassium silicate, compared to the use of only alkaline hydroxides. Xu and van Deventer confirmed that the addition of sodium silicate solution to the sodium hydroxide solution as the alkaline liquid enhanced the reaction between the source material and the solution. Furthermore, after a study of the geo-polymerization of sixteen natural Al-Si minerals, they found that generally the NaOH solution caused a higher extent of dissolution of minerals than the KOH solution.

The alkaline liquid is soluble alkali metals usually sodium or potassium based. The sodium based liquid has more reactivity and it is easily soluble than potassium based solution. A combination of sodium silicate solution and sodium hydroxide solution was chosen as the alkaline liquid. The sodium hydroxide solids were a technical grade in flakes form with a specific gravity of 2.13 with 98% purity. The chemical composition of sodium silicate solution was Na2O is 23.3%, SiO2 is 20.8% and water 55.9% by mass.

III. AMBIENT CURING

Curing of concrete is very important to maintain the hydration levels. Temperature variations are not a major problem, provided the concrete temperature is maintained above 5 degrees Celsius. Curing can therefore be achieved either through maintaining mixing water in the concrete during early hardening or by preventing moisture loss from the surface by sealing.

In ambient curing the concrete blocks or beams or cylinders are kept at room temperature and the curing is done for 3,7 and 28 days , getting the moisture content from atmosphere itself.

IV. RESULTS

The mix was design for M25 for conventional concrete and Percentages of Flyash, SilicaFume and Metakaolin were changed with the mix.

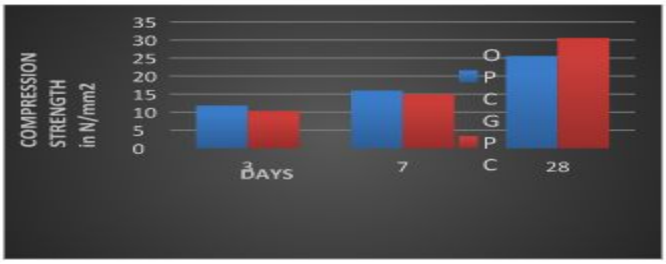
Eg: if 90% flyash is used then 10% of silica fume is added to it with 20% Metakaolin to weight of Flyash. Therefore, the highest strength value is obtained from the mix is taken and compared with M25 mix conventional concrete.

The GPC is Ambient cured and Conventional concrete has been normally cured.

Compressive Strength

Comparison between compressive strength of Ordinary Portland Concrete (OPC) and Geo-polymer concrete (GPC).

Specimen	**Average compressive strength test at 3 Days in N/mm^2**	**Average compressive strength test at 7 Days in N/mm^2**	**Average compressive strength test at 28 Days in N/mm^2**
OPC	11.82	15.97	25.57
GPC	10.32	14.92	30.55



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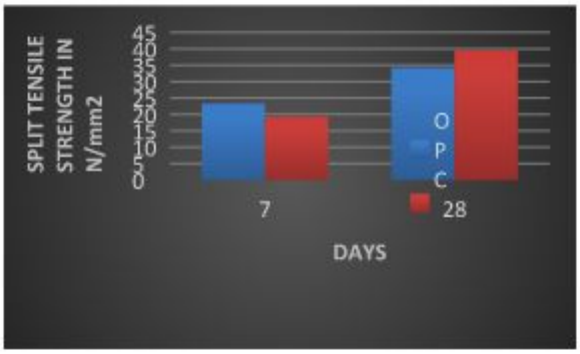
Split Tensile Strength

Comparison between Split Tensile strength of Ordinary Portland Concrete (OPC) and Geo-polymer concrete (GPC)

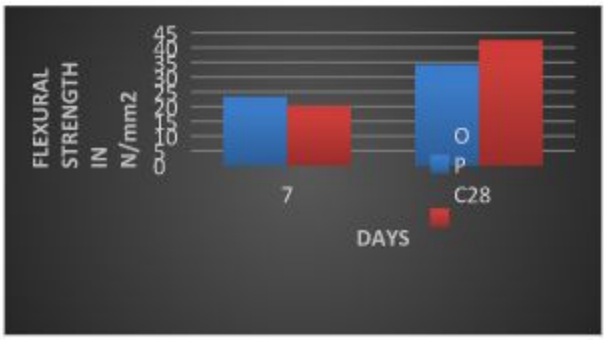
Specimen	Average split tensile strength test at 7 Days in N/mm^2	Average split tensile strength test at 28 Days N/mm^2
OPC	23.3	34.2
GPC	19.2	39.5



Flexure Strength

Comparison between flexure strength of Ordinary Portland Concrete (OPC) and Geo-polymer concrete (GPC).

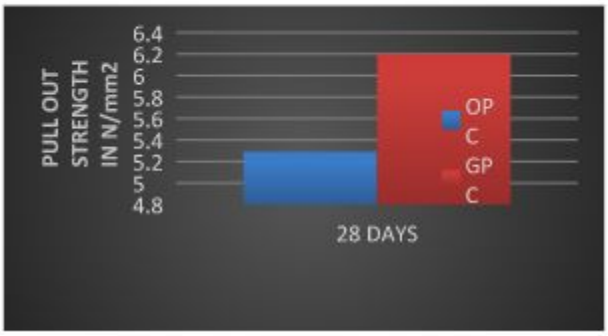
Specimen	Average split flexure strength test at 7 Days in N/mm^2	Average split flexure strength test at 28 Days in N/mm^2
OPC	23.3	34.2
GPC	20.2	42.5



Pull Out Test

Comparison between Split Tensile strength of Ordinary Portland Concrete (OPC) and Geo-polymer concrete (GPC)

Specimens	Average Pull out test strength test at 28 Days in N/mm^2
OPC	5.29
GPC	5.40



V. CONCLUSION

1. From the above test performed the results reveals that the GPC doesn't attains early strength than conventional concrete at 7 days of ambient curing. After 7 days of ambient curing the strength at all tests has been raised and therefore, from this it is concluded that Geo-polymer concrete gives good strength at 28 days.
2. It can be concluded that use of cement can be reduced 100% and use of GPC can be used to reduce the pollution caused by manufacturing process.
3. Using Ambient Curing water usage also can be reduced for curing.

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