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AN EXPERIMENTAL STUDY ON GEO-POLYMER CONCRETE INCORPORATING GGBS (GROUND GRANULATED BLAST FURNANCE SLAG) AND METAKAOLIN

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Abstract - The major problem the world is facing today is the environmental pollution. In the construction industry mainly the production of Portland cement will causes the emission of pollutants results in environmental pollution. We can reduce the pollution effect on environment, by increasing the usage of industrial by-products in our construction industry. Geo-polymer concrete is such a one and in the present study, to produce the geo-polymer concrete the Portland cement is fully replaced with GGBS (Ground granulated blast furnace slag) and Metakaolin and alkaline liquids are used for the binding of materials. The alkaline liquids used in this study for the polymerization are the solutions of Sodium hydroxide (NaOH) and sodium silicate (Na_2Sio_3) of A53 which consists of SiO_2 = 29.4%, Na_2O = 14.7%, and water = 55.9% by mass is used. 10Molar Sodium hydroxide is taken for the preparation of different mixes by varying the percentages of GGBS (Ground granulated blast furnace slag) and Metakaolin. The cube specimens are taken of size 150mm x 150mm x 150mm for compression test. The curing was done directly by placing the specimens to direct sunlight. The geo-polymer concrete specimens are tested for their compressive strength at the age of 3, 7 and 28days and compared with conventional concrete. For this study M30 concrete mix was used for experimental work. The result shows that there is an increase in the strength of Geopolymer concrete up to 40%GGBS content and then it is decreasing. Therefore it is preferable to use 40%GGBS with Metakaolin to get high strength. Metakaolin and GGBS can be used as a replacement material for cement gives an excellent result in strength aspect and quality aspect since it is better than the control concrete.

***Key Words*:** Geopolymer concrete, GGBS, Metakaolin, Alkaline solutions, curing, compressive strength.

1.INTRODUCTION

Concrete usage around the world is second only to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The environmental issues associated with the production of OPC are well known. The amount of the carbon dioxide released during the manufacture of OPC due to the calcination of limestone and combustionof fossil fuel is in the order of one ton for every ton of OPC produced. In addition, the extent of energy required to produce OPC is only next to steel and aluminum. In the construction industry, mainly the production of Portland cement will cause the emission of pollutants, results in environmental pollution. The need to reduce the global anthropogenic carbon dioxide has encouraged researchers to search for sustainable building materials. **Bennet Jose Mathew** explained that the demand for cement is increasing with the increase in the development of infrastructure taking place all over the world. The process of producing cement is not only highly internal energy intensive, but is also responsible for large emissions of carbon dioxide (CO_2), which is green house gas causing global warming. According to one of the studies in the past the worldwide cement production accounts for almost 7% of the total world CO_2 emissions. The control of such green house gas emission is a major issue for sustainable concrete. In addition to this, about 3 billion tons of the raw materials are needed every year for cement manufacturing, which consumes considerable energy and adversely affect the ecology of the planet. At the same time, the ordinary Portland cement concretes are less durable under certain environmental conditions. On this backdrop, there is an urgent need to find an alternate binder to cement in order to make the construction industry eco friendly and sustainable. In order to reduce the emissions of carbon dioxide, cement in concrete is replaced by materials like fly ash, GGBS (Ground granulated blast-furnace slag) and metakaolin is considered as a more eco- friendly alternative to Ordinary Portland Cement (OPC) based concrete. It is termed as Geopolymer concrete. The advancement of concrete technology can reduce the consumption of natural resources and energy sources and lessen the burden of pollutants on environment. Presently large amounts of Metakaolin, a dehydroxylated form of the clay mineral kaolinite came into existence. This project describes the feasibility of using GGBS (Ground granulated blast-furnace slag) and metakaolin in concrete production as replacement of cement.

Geopolymer materials represent an innovative technology that is generating considerable interest in the construction industry, particularly in light of the ongoing emphasis on sustainability. In contrast to the Portland cement, the most Geopolymer systems rely on minimally processed natural materials or industrial byproducts to provide the binding agents. Since Portland cement is responsible for upward of 85 percent of the energy and 90 percentof the carbon dioxide (CO_2) attributed to a typical ready-mixed concrete, the savings of the potential energy and carbon dioxide through the use of Geopolymer can be considerable. Consequently, there is growing interest in Geopolymer application in construction industry. Also due to high transportation costs of these raw materials, demand, environmental restrictions, it is essential to find functional substitutes for conventional building materials in the construction industry. Growth of population, increasing urbanization, rising standards of living due to technological innovations have contributed to an increase both in the quantity and variety of solid wastes generated by industrial, mining, domestic and agricultural activities. Metakaolin and GGBS process industries are the most promising business areas of the mining sector, with a mean growth in the world production of approximately 6% per year in the last 10 years.

2. Materials

Cement

Ordinary Portland Cement of "BHARATHI" brand 53 GRADE confirming to Indian standards is used in the present investigation. The cement is tested for its various properties as per IS: 4031-1988 and found to be confirming to the requirements as per IS: 8122-1989.

Fine aggregate

The sand obtained from Krishna River near Vijayawada is used as fine aggregate in this project investigation. The sand is free from clayey matter, silt and organic impurities etc. The sand is tested for specific gravity, in accordance with IS: 2386-1963 and it is 2.719, where as its fineness modulus is 2.31. The sieve analysis results are presented in table. The sand confirms to zone-II.

Coarse aggregate

Machine crushed angular Basalt metal used as coarse aggregate. The coarse aggregate is free from clayey matter, silt and organic impurities etc. The coarse aggregate is also tested for specific gravity and it is 2.68. Fineness modulus of coarse aggregate is 4.20. Aggregate of nominal size 20mm and 10mm is used in the experimental work, which is acceptable according to IS: 383-1970.

3.1.1 Coarse aggregate

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S.No	PARAMETER	RESULTS	
1	Organic	46 mg/lit	200 mg/lit
2	In organic	86 ng/lit	3000 mg/lit
3	Sulphates	40.32 mg/lit	400 mg/lit
4	Chloride	51.77 mg/lit	2000 mg/lit Fire concrete not containing R.C.C For R.C.C 500mg/lit
5	Suspended matter	183 mg/lit	2000 mg/lit

Metakaolin

Metakaolin is obtained from the Kaomine industries PVT LTD at Vadodara on Gujarat state. The specific gravity of Metakaolin is 2.6 and the size of particle is less than 90 microns. The colour of metakaolin is pink.

Chemicals	Percentage (%)
SiO_2	62.62
Al_2O_3	28.63
Fe_2O_3	1.07
MgO	0.15
CaO	0.06
Na_2O	1.57
K_2O	3.46
TiO_2	0.36
LOI	2.00

Table -1: Sample Table format

Ground granulated blast furnace slag (GGBS)

GGBS is obtained from jindal steel and power ltd.,Vijayawada office . The specific gravity of GGBS is 2.9. Bulk density is 1200 kg/m3 and Fineness is >350m2/kg. The colour of GGBS is off-white.

Alkaline Solution

The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). It is recommended that the alkaline liquid is prepared by mixing both the solutions together at least 24 hours prior to use. The sodium silicate solution is commercially available in different grades. The sodium silicate solutionA53 with SiO2-to-Na2O ratio by mass of approximately 2, i.e., SiO2 = 29.4%, Na2O = 14.7%, and water = 55.9% by mass is used. The sodium hydroxide with 97-98% purity, in flake or pellet form, is commercially available. The solids must be dissolved in water to make a solution with the required concentration. The concentration of sodium hydroxide solution can vary in the range between 8 Molar and 16 Molar. In this investigation 10M is adopted.

3. EXPERIMENTAL PROGRAM

An experimental study is conducted on "Metakaolin and GGBS" as a full replacement of cement concrete. Normal strength grade concrete of M30 Design mix with various percentages of Metakaolin and GGBS replacing cement has been made use in the investigation. The test program consists of carrying out compressive strength test on cubes. Experimental study is carried out to investigate the compressive strength of concrete.

Fineness of cement

Brand of Cement: Bharathi Opc grade53.

Trail No.	1	2	3
Weight in cement (g)	100	100	100

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Quantity of Cement Retained (%)	3	2.4	2.4

Table3: Fineness of cement

Result: Fineness of the given cement: **2.6 %**

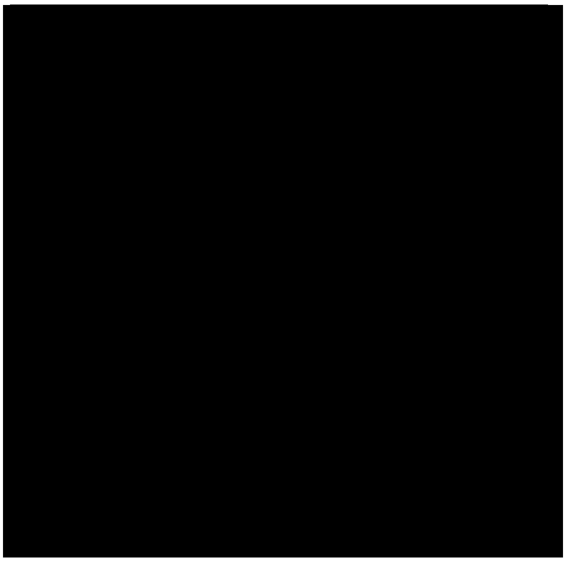
As per IS: 269 the residue of cement sampled on the sieve 90 micron after sieving should not exceed 10% and hence it is with in its limit.

The following tabular column shows the physical Tests results of Bharathi opc cement

Table 4: physical Tests results of Bharathi opc cement

Tests on aggregate:

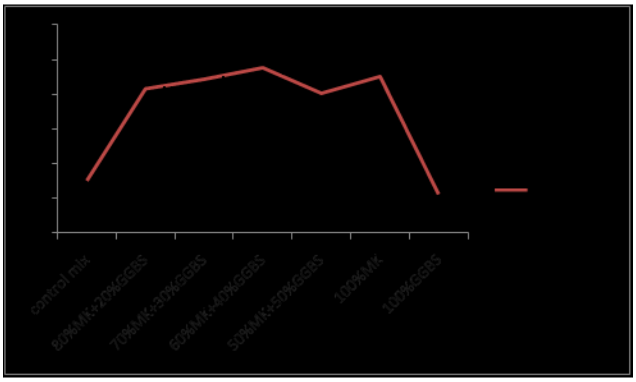
The following tabular column shows the physical Tests of Aggregates which were used in Geopolymer concrete.

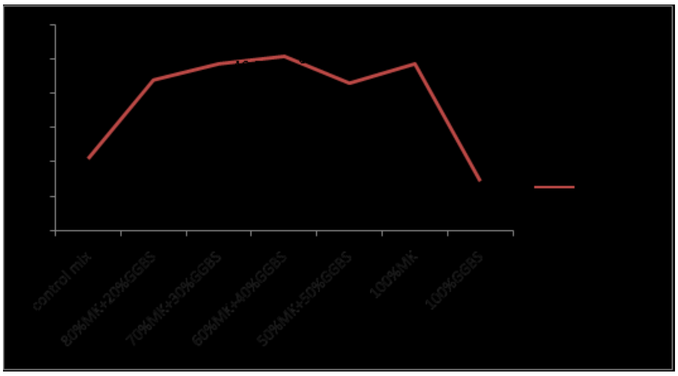


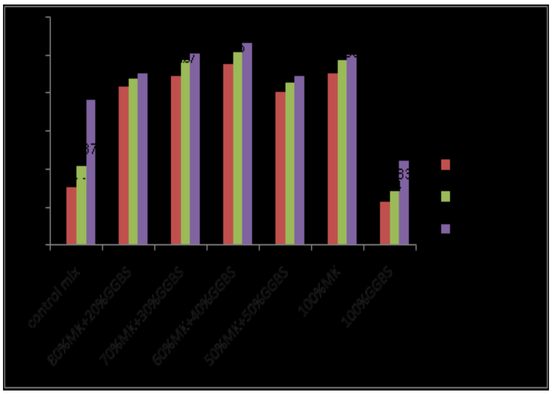
Compressive strength for conventional and geopolymer concrete mixes

The following are the various results obtained for concrete and the values are tabulated as below.

Table13: compressive strength of concrete forM30 control mix for 3,7,and 28 days







4. CONCLUSIONS

Based on limited experimental investigations conducted on concrete the followingconclusions are drawn.

- From the above results it is apparent that Geopolymer concrete based on GGBS and metakaolin has got more compressive Strength than conventional concrete.
- The strength of the Geopolymer concrete increases with the increase in GGBS content upto 50% and then reduces, so it is recommended to use GGBS up to 50% in the GPC mixes
- The strength of the Geopolymer concrete increases with 2%-4% from 3 to 7 days and 2% - 5% from 7 to 28 days that means there is no much increase in the strength after 7days.
- Alone metakaolin can perform well as it has got 45MPa compressive strength for 3days but GGBS cannot be used as the compressive strength of it is less than control mix of M30.

The results showed that the substitution of 60% Metakaolin and 40% GGBS content induced higher compressive strength.

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