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# Geopolymer concrete based on metakaolin and GGBS durability research

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***Abstract***
*The objective of this research work was to produce a carbon dioxide emission free cementious material. The geopolymer concrete is such a vital and promising one. In this study, geopolymer is prepared from 'Ground Granulated Blast Furnace Slag' (GGBS) a powder from grinding the by- product of slag waste from blast furnace of steel plants and metakaolin from industry. The Alkaline liquids used in this study for the polymerization process are the solutions of sodium hydroxide (NaoH) and sodium silicate ($Na_2Sio_3$).A 8 Molarity and 10 Molarity solutions was taken to prepare the mix. The cube compressive strength was calculated for different mixes. The cube specimens are taken of size 150 mm x 150 mm x 150 mm. Ambient curing of concrete at room temperature was adopted. In total 180 cubes were casted for their compressive strength at age of 28 days respectively. The test data indicate that on exposure to 5% Sodium Sulphate, Sulphuric Acid and Sodium Chloride, the losses in weight, and strength of geopolymer concrete (GPC) are significantly much less than those for cement concrete. Thus the geopolymer concrete is considered to be an environmentally pollution free construction material.*

***Keywords:*** *Geopolymer concrete, GGBS, Metakaolin, Alkali Activators, Ambient curing, Sodium Sulphate, Sulphuric Acid, Sodium Chloride.*

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## I. INTRODUCTION

Concrete is the most widely used construction material in the world due to its low cost, excellent durability, easy availability of its constituent materials, easy formability to any shape, etc. Among all constituents of concrete ordinary Portland cement (OPC) is the main ingredient which binds the aggregates together. However, the manufacturing of OPC is an energy intensive process and the production of OPC is responsible for almost 5% of total global $CO_2$ emissions, which is the main cause of global warming. In another estimate it was found that the production of one tone of OPC releases approximately one tone of carbon dioxide to the atmosphere. Due to an increase in global population and urbanization the increasing use of concrete in construction is unavoidable in near future. This concern has led to the use of new sustainable OPC less binder for concrete and supplementary cementations materials (SCMs) as a partial replacement of a large amount of OPC in the concrete. [1-2]

Geopolymer is emerging cement less binder purported to provide a sustainable and environmentally friendly alternative to OPC. The term geopolymer was initially introduced by Davidovits (1991) [3]. Geopolymer is synthesized from materials of geological origin (e.g., metakaolin) or industrial by-products, such as fly ash and slag, which are rich in silica and alumina with alkaline activators. In one estimate it was found that the production of fly ash-based geopolymer requires approximately 60% less energy and has at least 80% less CO2 emissions compared to the manufacture of OPC. [4] So far, extensive research and development on geopolymer concrete and composites have been undertaken worldwide with hopes to promote geopolymer as an ultimate sustainable construction material for the future [5,6,7].

GPC being a new material of construction, requires to be assessed for both strength and durability characteristics. The GPC utilizes industrial by-product of blast furnace slag from steel plants. The test data in this paper is expected to enable the engineers to examine the durability aspects of the GPC from GGBS which is obtained after grinding the slag and Metakaolin .The new concrete produced from the industrial by-product slag would not only have low carbon footprint with low 'embodied energy' and 'low carbon dioxide emission', but also it is more durable material with higher and faster strength development capability.

## II. MATERIALS

Ground Granulated Blast Furnace Slag (GGBS) and Metakaolin were used in this investigation. Commercially available GGBS and Metakaolin used during the experiments.

The Properties of GGBS and Metakaolin are given in Table 1, 2 and 3. Coarse aggregates of sizes 10 mm and river sand as fine aggregate were used. Physical properties of gravels and sand are given in Table 4 and 5. Distilled water was used in all the experiments. Master Gienium Sky 8233 from BASF India, super plasticizer were used as admixtures are given in Table 6. The alkali activators used were solutions of sodium hydroxide, potassium hydroxide and sodium silicate.

**Table 1** Physical properties of GGBS.

| **Parameter** | **GGBS** | **IS : 12089 – 1987** |
|---|---|---|
| CaO | 37.34% | --- |
| $Al_2O_3$ | 14.42% | --- |
| $Fe_2O_3$ | 1.11% | --- |
| $SiO_2$ | 37.73% | --- |
| MgO | 8.71% | Max. 17% |
| MnO | 0.02% | Max. 5.5% |
| Sulphide Sulphur | 0.39% | Max. 2% |
| Loss of Ignition | 1.41% | --- |
| Insoluble Residue | 1.59% | Max. 5% |
| Glass Content (%) | 92% | Min. 85% |

**Table 2** Physical properties of Metakaolin

| **Colour** | **Pink / Off-white** |
|---|---|
| Pozzolan Reactivity mg Ca (OH)2 / gm | 900 |
| Average Particle size | 1.4 micron |
| Brightness (ISO) | 75 ± 2 |
| Bulk Density (Gms / Ltr) | 320 to 370 |
| Specific Gravity | 2.5 |

**Table 3** Chemical Properties of Metakaolin

| | |
|---|---|
| $Al_2O_3$ | >39.0 % |
| $Fe_2O_3$ | <0.8% |

**Table 4** Sieve analysis of aggregates

| BS sieve size (mm) | Percentage passing of aggregates of different size | |
|---|---|---|
| | 10 mm (aggregate) | Fine aggregates (aggregate) |
| 20 | 100 | 100 |
| 12.5 | 100 % | 100 |
| 10 | 94.62 % | 100 |
| 4.75 | 15.40 % | 99.6 |
| 2.36 | 2.89 % | 99 |
| 1.18 | -- | 92.6 |
| 0.60 | -- | 48.6 |
| 0.3 | -- | 8.2 |
| 0.15 | -- | 2 |
| Pan | -- | 0 |

**Table 5** Physical properties of gravels and sand

| Sample | Sp. Gravity | Water absorption (%) | Fineness modulus |
|---|---|---|---|
| 10 mm aggregate | 2.74 | 0.33 | -- |
| Sand | 2.50 | 0.30 | 2.2 |

**Table 6** Properties of GLENIUM B233 Superplasticiser

| | |
|---|---|
| Specific Gravity | 1.09 |
| Chloride ion content | Less than 0.2% |
| Recommended Dosage | 0.5 to 1.5 liter per 100kg of cementations material |
| pH | 7+/-1 |
| Aspect | Yellowish free flowing liquid |

*Data taken from the product brochure of the supplier.

## III. TEST PARAMETERS

The chloride resistance of control concrete and geopolymer concrete were evaluated by measuring the residual compressive strength after chloride exposure. Cubes were immersed in solution after 28days of curing period. Sodium Chloride (Nacl) solution with 5% concentration was used as the standard exposure. The specimens were immersed in the Sodium Chloride solution in a tank. To prepare the solution of 5% concentration, for each 100 gm solution 95 gm of water and 5 gm of Sodium Chloride powder is added. After preparation of the solution pH value of the solution was measured by using digital pH meter. In order to maintain the concentration of sodium chloride throughout the test, the pH value of the solution was measured at every 7 days interval and by considering the initial pH as reference, sodium chloride powder or water is added and by trial and error initial pH value was achieved.

## IV. CONCLUSION

The test results demonstrate that ambient cured GGBS and Metakaolin based geopolymer concrete has an excellent resistance to sulphate attack. There is no damage to the surface of test specimens after exposure to sodium sulphate solution up to one month. There are no significant changes in the mass and the compressive strength of test specimens after the exposure. Exposure to sulphuric acid solution damages the surface of ambient cured geopolymer concrete test specimens and causes a mass loss after the exposure. The severity of the damage depends on the acid concentration. The sulphuric acid attack also causes degradation in the compressive strength of heat-cured geopolymer concrete; the extent of degradation depends on the concentration of the acid solution and the period of exposure. The test result of chloride attack demonstrates that geopolymer concrete has a good resistance to chloride. There are no significant change in mass and the compressive strength after exposure up to three months. The strength of geopolymer concrete was increased with increase in percentage of GGBS in a mix.

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