An Experiment Study on Geopolymer Concrete Incorporating Metakaolin and GGBS with 10m Alkali Activator

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Abstract— Geopolymer concrete is the other source of producing concrete in which GGBS prove like a binding material which is obtained from an iron manufacturing industries like a waste. conventionally cement is used as a binding material which produce nuisance regards to pollution. We have to avoid this introduction of GGBS which is no pollution content and has no environmental pollution also the quality of concrete is improved compared to normal concrete.
Key words: GGBS, Metakaolin, Activator

I. Introduction

The term geopolymer was first introduced to the world by davidovits of France resulting a new field of research and technology. Geopolymer is an inorganic polymer resulting from the reaction of amorphous aluminosilicates with alkali hydroxide and silicate solutions. Synthesis of a geopolymer usually involves mixing of source materials containing aluminosilicates, such as metakaolin, fly ash, ggbs, rice husk etc. with alkaline solution. for the binding of materials the silica and alumina present in the source material are induced by alkaline activators and the chemical reaction that takes place in this case is a polymerization process. the most common alkaline liquid used in the geo-polymerization is the combination of sodium hydroxide and sodium silicate/ potassium silicate. alkaline solution is prepared by mixing sodium hydroxide in form of flakes with sodium silicate solution of definite proportion. the mass of naoh flakes in a solution vary depending on the concentration of the solution expressed in terms of molar, m. the sodium hydroxide solution is mixed with sodium silicate solution to get the desired alkaline solution one day before making the geopolymer concrete. After solution is prepared the composition is weighed and mixed in concrete mixture as conventional concrete and transferred into moulds. Aggregates are inert granular materials such as sand, gravel, orcrushed stone that, along with water and portland cement, are an essential ingredient in concrete. Aggregate is mined from earth, either dug out of pits or blasted out of quarries. However, continuous quarrying activities will result in the eventual depletion of the aggregates. the cost of concrete materials will increase if, owing to the continuous decline of the local granite aggregate production, there is increased dependence on the supply of imported material. therefore, introduction of other materials as partial coarse aggregates in concrete making should reduce the high consumption of local granite. here the study is based on partial replacement of course aggregate with laterites in geopolymer concrete. the strength of the concrete is examined by the replacement of coarse aggregate with laterite, using ground granulated blast furnace slag (ggbs) [23].

A. Literature Survey

Davidovits Proposed That An Alkaline Liquid Could Be Used To React With Aluminosilicate In A Source Material Of Geological Origin Or In By-Product Materials Such As Fly Ash To Make A Binder. Geopolymer Is Synthesized By Mixing Aluminosilicate-Reactive Material With Strong Alkaline Solutions, Such as Sodium Hydroxide (Naoh), Sodium Silicate or Potassium Silicate. The Mixture Can Be Cured At Room Temperature or Temperature Cured. The Most Commonly Used Alkaline Activators Are Naoh [2]. Concrete Is The Most Widely Used Man Made Construction Material In The World And Is Second Only To Water As The Most Utilized Substance On The Planet. It Is Obtained By Mixing Cementitious Materials, Water And Aggregates (And Sometimes Admixtures) In Required Proportions. When Mixture When Placed In Forms And Allowed To Cure, Hardens Into A Rock Like Mass Known As Concrete [1].

II. Related Work

A. Materials used

Following materials were used for laboratory tests.

In this chapter varies materials and method of conducting the test was discussed in detail and detailed methodology of the work was presented

- Metakaolin
- Ground granulated blast furnace slag (GGBS)
- Chemicals
  Sodium hydroxide -Sodium silicate
- Aggregates
  Fine aggregate - Coarse aggregate

B. Metakaolin

1) General

The raw material in the manufacture of Metakaoline is kaolin clay. Kaolin is a fine, white, clay mineral that has been traditionally used in the manufacture of porcelain. Kaolins are classifications of clay minerals, which like all clays, are phyllosilicates, i.e. a layer silicate mineral. The Meta prefix in the term is used to denote change. In case of Metakaolin, the change that is taking place is de-hydroxylation, brought on by the application of heat over a defined period of time. De-hydroxylation is a reaction of decomposition of kaolinite crystals to a partially disordered structure. The results of isothermal firing shows that the de-hydroxylation begins at 420^0C at about 100-200^0C clay minerals lose most of their adsorbed water. The temperature at which Metakaolite loses water by de-hydroxylation is in the range 500-800 ^{0}C. This thermal activation of a mineral is also referred to as calcining. Beyond the temperature of de-hydroxylation, kaolinite retains two dimensional orders in the crystal structure and the product is termed Metakaolin. Pozzolanic materials including silica fumes, MK and GGBS, slag, Rice Husk Ash and Metakaolin have been used in recent years as cement replacement material for developing HSC with improved workability, strength and durability with reduced permeability. Metakaolin,

Fig. 1: Metakaolin

2) *Physical and Chemical Properties of Metakaolin*

Specific gravity	2.40 to 2.60
Color	Off white, Gray to buff
Physical form	Powder
Average plastic size	<2.5 µm
Brightness	80-82 Hunter L
BET	15 m^2/g
Specific surface	8-15 m^2/g

Table 1: Physical properties of MK

Chemical composition	Weight %
SiO_2+AlO_3+TiO_2+Fe_2O_3	>97
Sulphur Trioxide (SO_3)	<0.50
Alkalies (as Na_2O,K_2O)	<0.50
Loss on ignition	<1.00
Moisture content	<1.00

Table 2: Chemical Composition of MK

C. Advantages

High Strength Concrete with Metakaolin as admixtures offers many advantages. Some of these are as follows

1) Facilitate finishing concrete surfaces by rubbing and smoothing due to the lack of stickiness of concrete to the tool and good thixotropy.
2) It reduces the amount of cement in the formation of concrete, especially in concrete with high requirements for water resistance.
3) Can significantly increase the residual strength of refractory concrete after firing, typically lose 50% of its strength after heating to 800^0C.
4) The strength and durability of concrete increases.
5) Use of Metakaolin accelerates the initial set time of concrete.
6) Compressive strength of concrete increases @ 20 % with metakaolin.
7) The cross sectional areas of structural members can be reduced safely, so saving in concrete and can be economically used for high rise buildings, dams, bridges etc.
8) It imparts improved water-tightness, so safely used for water retaining structure, off shore structure etc.
9) Confers high early strength, allows a quicker reuse of formwork, and thus enhances the production rate.
10) j) Ecofriendly.
11) Metakaoline increases resistance to chemical attack and prevention of Alkali Silica Reaction.
12) Metakaolin reduces autogenously shrinkage in concrete.
13) Metakaolin disperse more easily in the mixer with less dusting.
14) Being second to Diamond in hardness on Mho Scale, Metakaolin offers high abrasion resistance concrete so used for industrial flooring, Warehouses, Container Depots, Roads etc. [11].

D. Applications

High Strength Concrete with Metakaolin as admixtures offers many advantages as mentioned above. So it can be used for

- Dams,
- Bridges
- Water Retaining Structures
- High Rise Buildings
- Off Shore Structures
- Industrial Flooring
- Warehouses
- Container Depots
- Roads
- Lining
- Mass Concreting
- Aqueducts
- Nuclear Power Stations
- Structural members where cross section required to be small etc.].

III. METHODOLOGY

A. General

The study work is to analyze strength properties of partially replaced GGBS concrete. The tests on concretes are carried out as per IS code for this proposed investigation work. For successful investigation, tests have to be performed on normal concrete and on GGBS concrete with proportion 50%, 60%, 70%, 80%, 90%, 100% cement replacement. The comparative report prepare before arriving at the final conclusion of plain concrete and GGBS concrete with crush sand and natural sand

Following methodology will be followed for proposed work:

- Collection of review of journals and articles to get idea of research work conducted on proposed subject of work.
- Studying the properties of cement with GGBS by conducting tests as per BIS such as standard consistency test, initial and final setting time test.
- Mix design of concrete is done for preparation of concrete as per IS10262:1983.
- Tests on fresh concrete conducted at the time of casting work of different specimens required for proposed work.
- Test procedure used as per IS 516.
    1) Compression test- For this test cubes of standard size of 150mm x 150mm x 150 mm used.
    2) Flexural tensile strength- It is measured by testing beams under central point load of size 100mm x 100mm x 150mm.
- Analysis is carried out with test result comparison of GGBS concrete with normal concrete.

In this chapter mix design of Geo-polymer concrete and the experimental investigation carried out on the test specimen to study the strength related properties of geopolymer concrete was discussed in detail. The experimental test for strength properties of concrete are compressive strength, split tensile strength, Flexural strength test of concrete. Based on the test procedure given in IS 516-1959 code tests were conducted on specimens

IV. EXPERIMENTAL STUDY

A. Storage

The materials were procured from respective places as mentioned above. Further the task ahead was the storage of these materials. The materials had to be stored in dry place, which is free from moisture, as these materials have tendency to deteriorate and lose their properties. Therefore extra care should be taken in this regard. The materials were stored in the laboratory. Hence, sufficient care was needed to keep these materials intact without any wastage at the same time attaining the optimum usage of the materials.

B. Materials

In the present study, ground granulated blast furnace slag (GGBS) was used as a source material for the synthesis of alkali activated blast furnace slag paste (AAGGBS). GGBS was obtained from the Tata Metaliks Ltd. Kharagpur, India. The slag obtained was ground to fineness less than 45 microns. In order to overcome the high evolution of heat during the preparation of NaOH solution, this has been prepared a day before the casting. Then the Na_2SiO_3 solution was mixed the NaOH solution for the required ratio of AAS. In order to achieve the required workability of GPC, chemical admixture in the form of Superplasticizer (Glenium B233) was added to the AAS. Glenium was available in the form of Light Brown Liquid with pH of 6. Excess water has been restricted which may leads to the development of pores, which could be the cause of reduction in the strength and durability of GPC.

Fig. 2: Cubes for using testing

The Geopolymer mixes were prepared by taking Sodium Hydroxide solution with concentration of 10M.The ratio of alkaline solution was varied as 2.5 varying the liquid binder ratio to get an acceptable workability of concrete. The detailed mix proportioning is listed in table 2. The mixtures were casted in 100mm size cube specimens and vibrated using table vibration technique. The curing of the specimens was done at ambient temperature condition as there is no significant increase in the strength at elevated temperature. The Alkaline activator Solution (AAS) was prepared by mixing the commercially available Sodium Hydroxide Solution, Sodium Silicate Solution (Water Glass), and Distilled Water (DW) in the required proportions.

1) 3 Test Specimens and Test Procedure

150 mm concrete cubes and cylinders of 150 mm diameter and 300 mm length were used as test specimens to determine the compressive strength of concrete and split tensile strength of concrete for both cases (i.e., normal concrete and GGBS concrete). The ingredients of concrete were thoroughly mixed till uniform consistency was achieved. The cubes and cylinders were properly compacted. All the concrete cubes and cylinders were de-molded within 24 hours after casting. The de-molded test specimens were properly cured in water available in the laboratory at an age of 28 days.

V. RESULTS AND DISCUSSION

A. Compressive Strength

Cubes of specimen of the size 150 mm x 150 mm x 150 mm were prepared for each mix. it can be observed that the compressive strength of geopolymer concrete increases enormously with increase in percentage of GGBS. The result shows that the maximum compressive strength was obtained for 90% GGBS and 10% Metakaolin. The variation of compressive strength at the age of 7th and 28th days with optimum percentage of GGBS and MK from the test results.

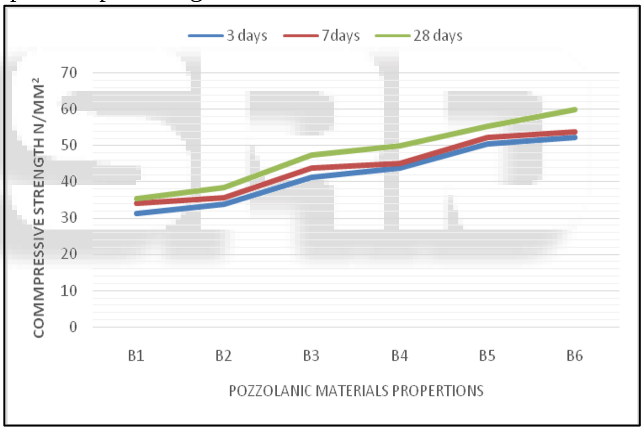

Fig. 3: Compressive strength vs Pozzolanic materials proportions

1) Compressive strength graph for 3days

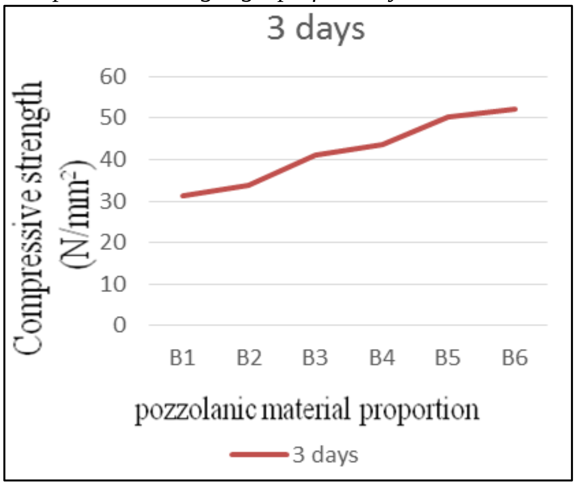

Fig. 4: Compressive Strength vs Pozzolanic Proportions (3days)

The compressive strength of concrete with different proportions are casted of age 3 and a graph is plotted between pozzolanic proportion (x-axis) and compressive strength (y-axis).From the figure we can say, as the GGBS increases compressive strength increases. 100% GGBSgives compressive strength of 52.12 N/mm² which is the maximum strength obtained than other proportions. The strength variation between one proportion to other is in slight manner.

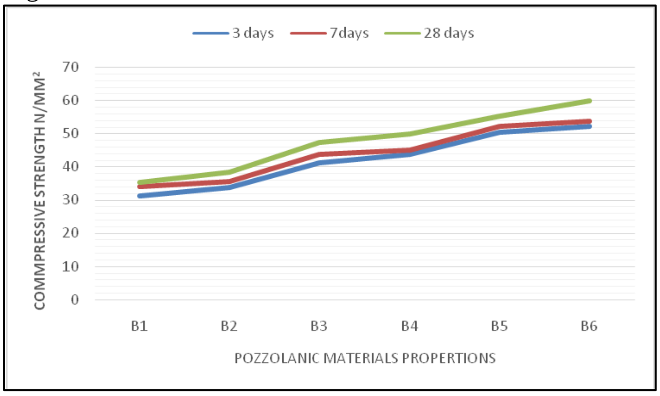

Fig. 5: Compressive strength vs Pozzolanic materials proportions

VI. CONCLUSION

To evaluate an alternative binder instead of Cement for concrete to reduce Co2 emissions. To develop a concrete with 100% replacement of cement. To develop a Multi-benficial concrete in the aspects of compressive strength and ecofriendly. To work out and enhance the concrete for durability to study the different strength properties of geo-polymer concrete with percentage replacement of Mk and GGBS. This experimental programme consist of following step

The test was performed to study the effect of Na_2SO_4on geopolymer concrete and its comparison with control concrete.

- Test specimens
- Test procedure
- Change in compressive strength
- Change in mass

The preparation of solution is done by dissolving sodium hydroxide in water. The concentration of sodium hydroxide changes with molarity. The quantity of sodium hydroxide solution with a concentration of 10M is calculated. The mass of NaOH solids in solution varied depending on the concentration of the solution expressed in terms of molar, M. The NaOH solution with concentration of 10M consisted of 10*40 = 400gm of NaOH solids per liter of the solution, where 40 is the molecular weight of NaOH. The mass of NaOH solids was measured as 306gm per kg of NaOH solution of 10M concentration. The sodium hydroxide is added to the water and stirred about fifteen minutes to get cool down. Then the sodium silicate is added to solution. This solution is used after 24 hours of its preparation.It is understood from the earlier studies that good scientific information is available on the evaluation of strength and durability properties of geopolymer concrete. Also, very few works has been reported on the effect of different proportions of geopolymer concrete. Further studies are needed to investigate the sulphate resistance of GPC. The addition of alkali solutions can exhibit a reasonable improvement on the strength properties of geopolymer concrete. The concentration and type of alkali need to be investigated extensively to choose the combination and dosage of alkali for metakaolin and GGBS. The effect of alkali activators on the rate of hardening of geopolymers at ambient curing regimes needs to be well documented. Curing regime on the hardening properties ofgeopolymeric concrete needs special attention to improve the strength properties. The weight loss due to immersion of specimens in solution can be evaluated after a period of time.

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