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Enhancement Of Performance Potential Use Of Ggbs As A Supplementary Cementitious Material Based Geopolymer Concrete And Its Application

Jitendra Malakar, Assistance Prof. Piyush Mahajan, Assistance Prof. Jitendra Chauhan
Jawaharlal Institute of Technology,
VidhyaVihar, Borawan, District Khargone Madhya pradesh 451228

Abstract- Environmental issues resulted from cement production have become a major concern today. To develop a sustainable future it is encouraged to limit the use of this construction material that can affect the environment. Cement replacement material was proposed to partially replace cement portion in concrete. Geo polymer is the best solution to reduce the use of cement in concrete. Geopolymer is a hardened cementitious paste made from fly ash, alkaline solution and geological source material. In the present study, the physical properties of Ground Granulated Blast furnace Slag (GGBS) in geopolymer concrete were discussed. The results revealed that the GGBS more environmental and ecofriendly by product used in the cement industry. Also these analyses optimized GGBC compressive strength using Curve fitting algorithm. These analysis used secondary data set related to GGBC concrete.

Keywords- Fly ash, GGBS, Geopolymer.

I. INTRODUCTION

Concrete is a building material which is a most commonly applied construction material on earth. The main ingredient of this material concrete is cement and hence contributing more than 5% for the air pollution through carbon emission. The general statistics on this material says that cement production has even crossed approximately 2.6 billion tons per year throughout the world.

And also, it is gradually raising 5% annually. The Portland cement Production is exceeding 2.6 billion tons per year worldwide. This has made annual 5% growth. The production of each ton of cement contributes equally for carbon dioxide emission by ejecting one ton to the environment [1]. The annual cement consumption in 2016 was 4.13 Giga tones and can be expected to raise to 4.68 Giga tones per year by 2050 [2]. The need of the hour is a sustainable concrete constriction where the impact of this material to the living beings by pollution is rectified and revised by replacing the fundamental raw materials by supplementary cementitious materials in remarkable proportion. There by reducing the cement content reduces the carbon dioxide emission.

II. ADMIXTURES

This generation concrete always moves beyond the normal ingredient system to various additives based on their construction demand. These additives may either be in chemical or mineral form. Mineral admixtures such as GGBS, fly ash, silica fumes etc. Chemical admixtures such as super plasticizers, water reducers, accelerators, retarders etc, are most commonly applied to vary the concrete fresh and hardened properties. The application of these various admixtures is purely based on the specific task to which it is applied. The property of concrete can be altered by applying these admixtures by varying the dosage of admixtures in chemical admixtures and by proportion replacement in case of mineral admixtures. Unlimited number of admixtures are available in market these days to add as an additive to standard ingredients.

II.GROUND GRANULATED BLAST FURNACE SLAG

GGBS Iron and steel are the important materials used for construction industries. It is produced by processing hematite, calcium carbonate and coke substances in furnace by increasing the heat up to 1500°C. The GGBS is a byproduct of iron. It is the most commonly used mineral admixture for manufacturing of concrete to obtain the high strength. In the industries, there is a step by step procedure for the manufacturing of iron using raw materials. The raw materials are converted into following two stages, such as,

1. Molten slag and
2. Molten iron

The density of the molten iron is high. Further process is necessary to obtain the required shape and size of products as per the requirement. Molten slag is the product which is mostly referred as the bottom product in evolution of GGBS. The GGBS has lesser density than a molten iron, therefore, a slag particle tends to float on the surface over the molten iron in blast furnace. The slag which is formed on the molten iron has rich amount of silicates and alumina, because the raw products are produced by the combination of silica and other oxides. Processing of slag formed over the molten iron is also an important process, in which the temperature of molten slag is reduced by injecting water with high pressure through jets.

Benefits of GGBS

1. It improves workability of fresh concrete to make work easy during the placement of concrete.
2. It reduces the permeability of concrete due to fill up the pore structure of concrete.
3. It increases the resistance against sulphate attack.
4. It enhances the strength of concrete and improves the durability performance and therefore the life span of the concrete structure made by GGBS is high.
5. The chloride penetration is less.
6. The liberation of heat during the hydration process is less.
7. It is chemically more stable.
8. It contains less amount of calcium; hence the efflorescence at the surface of concrete is less.
9. The cost of the concrete product made by GGBS is very cheap.
10. There is no emission of harmful gases, such as CO2, SO2 and NO2during the manufacturing of GGBS and does not affect the environment.

Selection of GGBS

Among the above discussed industrial by-product waste materials, the GGBS have chosen as another supplementary cementing material since it is also having good pozzolanic properties. Many researchers found that the consumption of GGBS up to 50% could be beneficial effect in the production of structural concrete (Pathan et al. 2012, Awasara& Nagendra 2014 and Karri et al. 2015). When the GGBS is reacted with water and CH forms CSH paste and produces denser micro-structure of the concrete matrix. It helps to enhance the strength and durability of concrete and increase the performance of concrete structure beyond the estimated service life (Shi & Qian 2000 and Binici et al. 2007).

GGBS is the material in granular form. It is obtained when quenching rapidly the molten iron blast furnace slag using water immersion. It has a very limited crystal formation having granular form. It is highly cementitious in nature and ground to cement fineness, and hydrates like Portland cement. IS 16714:2018 [3] defines the GGBS in a technical context. The process of GGBS formation happens at an approximate temperature of 15000C by feeding iron ore, coke and limestone mixture at a proper proportion. The iron ore get reduced to iron. The residual materials of iron ore form a slag that suspend on top of the iron. The slag so obtained is tapped off as a molten liquid at regular intervals and during the manufacture of GGBS it has to be rapidly cooled by water in large quantity.

The cooling condenses the cementitious properties and arrives at granules. The obtained granulated slag is then dried and ground to a fine powder. The application of this by-product otherwise would have become a reason for unnecessary land filling. The replacement of this slag by cement in concrete will result in reduced embodied energy for the cement and also reduces the green gas emissions by concrete construction.

The main chemical content of GGBS is oxides of calcium, aluminium, silicon and magnesium. This may also vary considerably based on the raw materials composition in the iron manufacturing process. To reduce the viscosity of the slag, impurities of Silicate and aluminate from the ore and coke are added in the blast furnace with a flux. Concrete based on GGBS cement exhibits remarkable ultimate strength than with normal cement-based concrete. It can arrive at ample Calcium silicate hydrates responsible for strength properties. It can also reduce the free lime. It gives better workability, by making placing and compaction easier. It can reduce the risk of thermal cracking in large pouring and also the shrinkage cracks thereby reduce voids and permeability in concrete. Generally, the heat of hydration in this GGBS based concrete is less compared to conventional mix hydration.

III. POLYCARBOXYLATE ETHER AS CHEMICAL ADMIXTURE

The most effective high range water reducing admixtures are Polycarboxylateetherbased chemicals. They act as a good water reducer up to 40% [4]. Hence used in most of the ultra-high strength concretes. They can reduce the water to cement ratio as low as 0.20 [5]. Generally, they perform well at excellent slump retention features and exhibits good gain of strength of the concrete without any delay.

This study focuses on Ready Mix concrete Industry adopting GGBS. GGBS and poly carboxylic ether-based admixtures is used to reduce the cement content in the production of concrete. The aim of the proposal is to study concrete mixes with high volume GGBFS cement replaced of OPC. The study provides on the mix design parameter and cost analysis for each concrete type. The fresh, hardened and durability properties of each mix will be studied.

Significance Of The Study

Thesis has been carried out to optimize the cost of concrete mix by replacing GGBS and the locally available materials. The present study focuses on the usage of GGBS in Ready Mix concrete Industry. GGBS and poly carboxylic ether-based admixtures will be used to reduce the cement content in the production of concrete. This research mainly focusses on different concrete mixes prepared using high volume of GGBS cement in replacement with OPC. The study explores the mix design parameter and the cost reduction for each concrete mix.

IV. MATERIAL CHARECTERIZATION

This chapter brings about the necessary material characterization adopted in this research work. The present research work mainly comprises of utilization of GGBS to develop high strength concrete and self-compacting concrete and a cost-effective concrete in combination with polycarboxylate ether-based admixture. Hence, in this chapter the characterization of GGBS, OPC, Fine aggregates and coarse aggregates has been carried out and also analyzed for their suitability. The characterization consists of fundamental testing on physical properties and chemical properties of the raw materials. The study also highlights the suitability of GGBS as a cementitious material in higher percentile.

Cement

The Ordinary Portland Cement [OPC] of 53 grade conforming to IS 269-2015 [3] was adopted. The standard sample of cement was subjected to various physical property examinations such as specific gravity test, fineness or specific surface test by air Blaine's permeability test, initial and final setting time test. The results of these tests are tabulated in Table 1. Specific gravity as fundamental physical test was carried out as per IS 4031 Part 6 [1988] [4] and has obtained the specific gravity of cement as 3.14 which is within the acceptable limit.

Table 1: Experimental Characterization on Physical properties of Ordinary Portland Cement.

Physical characterization	Cement
Specific gravity	3.13
Fineness specific surface by Blaine's permeability method [m^2/kg]	324
Vicat time of setting (min) Initial	140
Final	220

The chemical composition was also examined through XRF technique, and the composition obtained is as depicted in Table 3.2.

Table 2: Experimental Characterization by Chemical properties of Ordinary Portland Cement

Chemical	Percentage composition
SiO (%)	20.98
Al_2o_2 (%)	5.08
Fe_2O_2 (%)	4.19
CaO (%)	62.2
MgO (%)	1.24
SO_2 (%)	2.16
Na2(%)	0.19
K_2 O_2 (%)	0.52
LOI(%)	1.58
Other minor (%)	1.86

GGBS

The GGBS used was conforming to ASTM C 989[5] and was supplied by a reputed GGBS manufacturer. The chemical analysis of GGBS was performed using XRF technique. Table 3 presents the Chemical properties of GGBS. As obtained, GGBS confirms to ASTM C 989 standard, and Table 3 denotes the physical properties of GGBS.

Table 3: Experimental Characterization by Chemical properties of GGBS

Components in GGBS	Proportion
SiO_2 (%)	32.8
Al_2O_3 (%)	17.8
Fe_2O_3 (%)	0.96

Fine Aggregates

The fine aggregates so chosen is as per IS 383-2016 [6] standards and is categorized in zone II grade. The physical properties of fine aggregates and also the particle size distribution conducted are as given in table 3.5 and Table 3.6 respectively.

Coarse Aggregates

Table 4 represents the various physical properties of the crushed coarse aggregates are of desirable quality. The particle size distribution of the aggregates is given in Table 3.8. The coarse aggregate is characterized as per IS 383-2016 standard [6] with maximum aggregate size of 20mm.

Table 4 Experimental Characterization based on Properties of Coarse aggregates

Properties	Coarse Aggregate
Combined Flakiness Index & Elongation Index	21.74
Impact Value	23.0
Crushing Value	27.0
Specific gravity	2.67
Fineness Modulus[FM]	7.10
Water Absorption	0.40

V.PROPOSED METHODOLOGY-SUPPLEMENTARY CEMENTITIOUS MATERIAL BASED GEOPOLYMER CONCRETE

Geopolymer concrete is produced by the alkali activation of fly ash or ground granulated slag combining with aggregates. The progress in the field of geopolymer concrete up to present time has been the fruit of an empirical approach, rather than the fundamental and scientific one. And because of empirical approach, the results from different studies cannot be related to one another. Geopolymers are a group of inorganic polymer produced by the result of reaction between an alkaline solution and an aluminosilicate as a source. The microstructure of hardened geopolymer material has an amorphous, three-dimensional structure similar to that of an aluminosilicate glass. However unlike a glass, these hardened geopolymer materials are produced at low temperature and as a result can integrate an aggregate skeleton and a reinforcing system, if required, during the forming process. The reactants needed to form a geopolymer are an alkali hydroxide, alkali silicate solution and an aluminosilicate fine binder. The binder needs to have a significant proportion of silicon and aluminium ions held in amorphous phases. Commonly used binders include class-F fly ash, ground granulated slag and metakaolin, but any fine amorphous aluminosilicate material can be used [1]. All types of concrete fail under compression when tested [2].

But compression strength itself is not the property of concrete to explain the performance of concrete. Concrete failure will always develop in weakest part of one of these three phases namely: aggregate zone, transition zone and hydrated cement paste. Thus, in order to increase the compressive strength of concrete, great care must be taken to strengthen all these three phases. It also depends on the microstructural features of concrete which govern the other properties like strength, elastic modulus and durability [3].

Alkali-activated materials vs. geopolymer cements.

Geo polymerization chemistry requires appropriate terminologies and notions that are evidently different from those in use by Portland cement experts. The main article geopolymer summarizes how geopolymer cements belong to the category of inorganic polymer. On this matter, the Australian GeopolymerAlliance[6] outlines on its web site the following statement: "Joseph Davidovits developed the notion of a geopolymer (a Si/Al inorganic polymer) to better explain these chemical processes and the resultant material properties. To do so required a major shift in perspective, away from the classical crystalline hydration chemistry of conventional cement chemistry. To date this shift has not been well accepted by practitioners in the field of alkali activated cements who still tend to explain such reaction chemistry in Portland cement terminology.

Analysis Method- Curve And Surface Fitting

Curve fitting is one of the most powerful and most widely used analysis tools in Origin. Curve fitting examines the relationship between one or more predictors (independent variables) and a response variable (dependent variable), with the goal of defining a "best fit" model of the relationship.

Curve fitting is the process of constructing a curve, or mathematical function, that has the best fit to a series of data points, possibly subject to constraints. Curve fitting can involve either interpolation, where an exact fit to the data is required, or smoothing, in which a "smooth" function is constructed that approximately fits the data. A related topic is regression analysis, which focuses more on questions of statistical inference such as how much uncertainty is present in a curve that is fit to data observed with random errors. Fitted curves can be used as an aid for data visualization, to infer values of a function where no data are available, and to summarize the relationships among two or more variables. Extrapolation refers to the use of a fitted curve beyond the range of the observed data, and is subject to a degree of uncertainty since it may reflect the method used to construct the curve as much as it reflects the observed data.

For linear-algebraic analysis of data, "fitting" usually means trying to find the curve that minimizes the vertical (*y*-axis) displacement of a point from the curve (e.g., ordinary least squares). However, for graphical and image applications, geometric fitting seeks to provide the best visual fit; which usually means trying to minimize the orthogonal distance to the curve (e.g., total least squares), or to otherwise include both axes of displacement of a point from the curve. Geometric fits are not popular because they usually require non-linear and/or iterative calculations, although they have the advantage of a more aesthetic and geometrically accurate result.

Fitting other functions to data points

Other types of curves, such as trigonometric functions (such as sine and cosine), may also be used, in certain cases. In spectroscopy, data may be fitted with Gaussian, Lorentzian, Voigt and related functions. In biology, ecology, demography, epidemiology, and many other disciplines, the growth of a population, the spread of infectious disease, etc. can be fitted using the logistic function. In agriculture the inverted logistic sigmoid function (S-curve) is used to describe the relation between crop yield and growth factors. The blue figure was made by a sigmoid regression of data measured in farm lands. It can be seen that initially, i.e. at low soil salinity, the crop yield reduces slowly at increasing soil salinity, while thereafter the decrease progresses faster.

Mathematical Curve Fitting Methods:

To avoid the subjective errors in graphical fitting, curve fitting is done mathematically. Three methods are available for this purpose; the method of moments, the method of least squares and the method of maximum likelihood. The last method gives the best estimates but it is usually very complicated for practical application. The method of least squares gives a better overall fit than the method of moments and involves relatively less computations and therefore is commonly adopted.

VI. RESULT AND SIMULATION

MIX DESGIN

A. Alkaline Liquids

A combination of sodium silicate solution and sodium hydroxide (NaOH) solution were used as the alkaline liquid. It is recommended that the alkaline liquid is prepared by mixing both the solutions together at least 24 hours prior to use.

B. Sodium Silicate Solution

The sodium silicate solution with SiO2-to-Na2O ratio by mass of approximately 2, SiO2 = 29.4%, Na2O = 14.7% and water = 55.9% by mass were recommended.

C. Sodium Hydroxide

In this study, NaOH solution with a concentration of 8 Molar consists of 8x40 = 320 grams of NaOH solids per liter of the solution, where 40 is the molecular weight of NaOH.

Table 5 Mix proportions.

Materials		(kg/m^3)	In Cube	In all Samples (kg/m^3)
Coarse aggregates	20mm	277	0.935	16.83
	14 mm	370	1.249	22.48
	7 mm	647	2.184	39.31
Fine sand		554	1.870	33.66
GGBS		408	1.377	24.79
Sodium silicate solution($SiO_2/Na_2O=2$)		103	0.348	6.26
Sodiume hydroxide solution		41(8M)	0.138	2.48
Superplasticizer		6	0.020	0.36
Extra water		None		

2. Slump Test

This test is widely used in the construction site all over the world. The slump test does not measure the workability of concrete, although ACI 116R-90 describes it as a measure of consistency. The test is very useful in detecting variation in the uniformity of a mix of given nominal proportions the slump test is prescribed by ASTMC 143-90a and BS 1881: Part 102: 1984 25. Workability of Fresh Concrete using Slump Test Table 5shows the values of slump test for geopolymer concrete made of GGBS which occurred 72 mm respectively.

3. Compressive Strength Test

The study followed the design used in this research according to the British standard, BS: 1881 Part 116: 198426 and the experience of a single standard for each mixture at 7, 14 and 28 days. Cubes were tested for compressive at the ages of 7,14 and 28 days to determine the compressive resistance of concrete, taking cubes between superficial machine pressure and the load applied regularly, and then the strength (F) was calculated by the following equation:

F = P/a

Where:

F = Compressive strength (N/mm2)

P = Applied load (N).

a = Surface area (mm2).

4. Permeability Test

Permeability is the ease which liquids or gases can travel through concrete. Although the testing concrete for permeability has not been generally standardized by ASTM21 and BS but for practical purpose, it is the absorption characteristic of the outer zone of concrete which protect the reinforcement are the greatest interest for that purpose in this paper, preliminary study towards permeability through ISAT (Initiation surface absorption test) test as specified in BS: 1881 Part 5: 197027 was developed to determine the initial surface absorption. The samples testing cube have a size of 150 mm x 150 mm x 150 mm and shall be dried in a well ventilated oven at 105 ± 50 C until constant weight is achieved.

4. Effect Of Ggbs On Compressive Strength

In this section, the main concern is to study the compressive strength of geopolymer concrete made of GGBS. Concrete tests are conducted on the concrete samples at the specific ages. All the strength tests are limited in the ages of 7, 14 and 28 days. The cubes with the size of 150 mm x 150 mm x 150 mm were tested at the ages of 7, 14 and 28 days.

5.Compressive Strength

The most important properties in concrete structures are those related with strength, because the strength gives an overall picture of the quality of the concrete. Among the various strength types of concrete strength, compressive strength is the most dominant because the concrete is primarily meant to withstand compressive stress. The details of cube samples tested at the ages of 7, 14 and 28 days are shown in the Table 5

Table 6 Slump test.

N.O	Samples	Slumps(mm)
1	GGBS	72

Table 7 Compressive strength.

Material used	Age (days)	Compressive Strength (MPa)
Geopolymer concrete made of GGBS	7	54.17
	14	66.00
	28	69.43

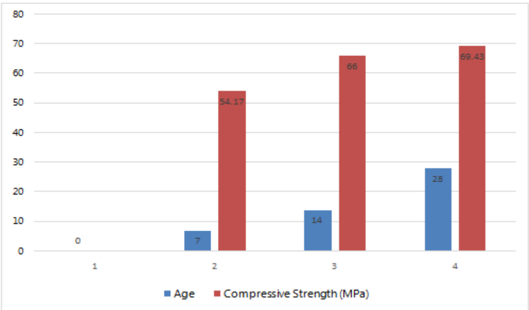

Fig.6 Compressive strength

6. Geopolymer Concrete Cube Strength. - The compressive strength test has become a part of the structural testing in construction to determine the grade of concrete, which have to comply with design standards. In this study, 12 cubes had been prepared and tested to the required strength of 7, 14 and 28 days. During the preparation of the cubes, slump tests had been done. The main concern of the study work the compressive strength of geopolymer concrete contains of the different materials. It's manufactured by sodium silicate solution with SiO_2-toNa_2O ratio by mass 2, Na_2O = 14.7%, SiO_2 = 29.4%, water = 55.9% by mass and sodium hydroxide solids (NaOH) with 97-98% purity are recommended with GGBS. For water-togeopolymer solids ratio by mass of 0.19, the design compressive strength is approximately 45 MPa. Cubes with the size of 150 mm x 150 mm x 150 mm were tested at the ages of 7, 14 and 28 days. The results of the compressive strength test are shown in Table 6

VI.COMPRESSIVE STRENGTH OF GEOPOLYMER CONCRETEAT THE AGE OF 7 DAYS

The results shows the compressive strength of specimens at a particular age as compared with the compressive strength of specimens from the same batch of the geopolymers concrete tested on the day of 7. After the curing age of 7 days the compressive strength of geopolymers concrete made of GGBS is 54.17 MPa (Mega pascal). As known, the geopolymers are members of the inorganic polymers family.

The chemical composition of the geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous. The polymerization process involves a substantially fast chemical reaction under alkaline condition on Si-Al minerals, those results in a three-dimensional polymeric chain and ring structure consists of Si-O-Al-O bonds1. The study had been used GGBS with the alkaline solution to produce geopolymers concrete. The GGBS with the following chemical composition: 35.2% SiO_2, 37.9% CaO and 10.7% Al_2O_3. The geopolymer concrete made of GGBS got good compressive strength with the early age. An overdose of CaO binds almost all the available silica to form weak linear chains, therefore insufficient silica is left to nucleate the gel.

Curve fitting

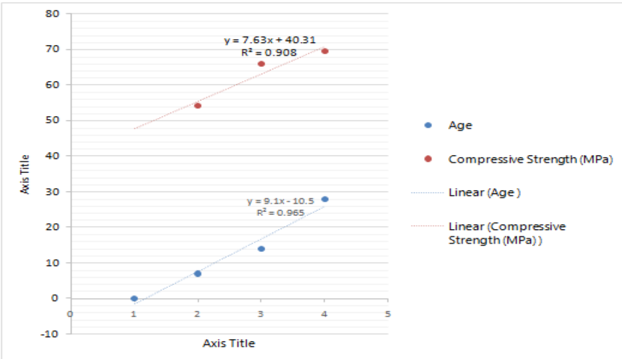

Fig.7 Curve fitting.

VII. CONCLUSION AND FUTURE SCOPE

Conclusion

In this study concluded that progress and current status on the development of Geopolymer concrete using by-products GGBS. Investigations about GGBS geopolymer have found a potential material for replacing the used of OPC in infrastructure development. However, it must be noted that different samples of GGBS may give different reactivity due to their varying chemical compositions. The current knowledge shows that the influence of NaOH molarity, alkaline activator ratio, Na2SiO /NaOH ratio, and curing temperature are essential for achieving the optimum strength of geopolymer. Moreover, the durability of the GGBS based geopolymer is better than OPC when exposed to an aggressive environment.

Considerable progress has been made during the last two decades in the investigation of geopolymer concrete and information available is summarized in this paper. Fundamental knowledge on compressive strength and microstructure of GPC has already been obtained by the research carried out so far. However, intensive research is required to get optimum mix of geopolymer concrete with and without fibers, durability and microstructure of geopolymer concrete. While a larger focus has been on investigating mix design and workability of GPC mixes, studies are still required to get a good workable GPC, durability aspects and microstructure of GPC. Authors are pursuing the research in this subject area.

FUTURE SCOPE

The following recommendations for future work are suggested to study the behavior of GGBS concrete.

1. Performance under marine and acidic environment for GGBS concrete
2. Performance under temperature effect for same GGBS concrete.
3. Performance under creep and shrinkage of GGBS concrete.

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