International Journal of Scientific Research & Engineering Trends
Volume 9, Issue 3, May-Jun-2023, ISSN (Online): 2395-566X

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

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Abstract- Supplementary cementitious materials (SCMs) and chemical additives (CA) are incorporated to modify the properties of concrete. In this paper, SCMs such as fly ash (FA), ground granulated blast furnace slag (GGBS), silica fume (SF), rice husk ash (RHA), sugarcane bagasse ash (SBA), and tire-derived fuel ash (TDFA) admixed concretes are reviewed. FA (25–30%), GGBS (50–55%), RHA (15–20%), and SBA (15%) are safely used to replace Portland cement. FA requires activation, while GGBS has undergone in situ activation, with other alkalis present in it. The reactive silica in RHA and SBA readily reacts with free Ca(OH)2 in cement matrix, which produces the secondary C-S-H gel and gives strength to the concrete. SF addition involves both physical contribution and chemical action in concrete. TDFA contains 25–30% SiO2 and 30–35% CaO, and is considered a suitable secondary pozzolanic material. In this review, special emphasis is given to the various chemical additives and their role in protecting rebar from corrosion. Specialized concrete for novel applications, namely self-curing, self-healing, superhydrophobic, electromagnetic (EM) wave shielding and self-temperature adjusting concretes, are also discussed.

Keywords- supplementary cementitious materials, chemical additives, corrosion inhibition, special concretes, reinforcement corrosion

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. The replacement material should not only reduce the cement content but also enhances the competitiveness of this with cement both in terms of strength and durability. A concrete is called durable only when it performs acceptably for the occupants or users of that structure in any extreme exposure conditions throughout its service life. Since the concrete is a material used for a variety of construction activities, it has been used in various categories with respect to its strength and performance.

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. In Ready Mixed Concretes the dosage of these chemical admixtures is comparatively higher in high grades of concrete. The vast research activities happening in this advanced generation in concrete industry had introduced advanced admixtures for any modification and the performance requirement. The adoptability of six concrete ingredients such as cement, fine aggregate, coarse aggregate, water in place of fundamental four ingredient of concrete have paved the way for a concept of sustainable concrete.

III.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. The cooling process of molten slag is done rapidly to avoid the formation of particle size not more than 5mm. Due to rapid smoothening process, the most of the slag particles will attain granular shape. The formed ash particle mostly consists of non-crystalline calcium-alumina silicates. After the cooling process completed, the granulated slag is sent into the final processing unit, in which, the granulated slag is allowed to dry. After the moisture content is left, the granulated slag is allowed into grinding process to get the particle shape similar to the cementing materials. The final product after grinding the granulated slag in rotating ball mills is called as ground granulated blast furnace slag. The GGBS contains about 30-50% of Calcium Oxide, 28-38% of Silicon Dioxide, 8-24% of Aluminium Oxide and 1-18% of Magnesium Oxide.

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. As per ASTM standards, the slag activity index is defined as the ratio of the average compressive strength of slag cement mortar cubes to the average compressive strength of control cement mortar cubes at a designated age in percentage. It classifies GGBS cement as Grade 80, Grade 100 and Grade 120, based on the relative compressive strength. The quantity of fines retained on a 45- when wet screened. In mix design the choice of cementitious materials and admixture is the most important to achieve definite properties of concrete.

IV. 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.

V. 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.

- To investigate the material properties, such as, Cement, GSA, GGBS, PPF, Fine Aggregate, Coarse Aggregate and Water.
- To understand the role of polypropylene fibre in concrete.
- To examine the mechanical properties of concrete, such as, cube compressive strength, cylinder splitting tensile strength and prism flexural strength.
- To utilize the optimization technique using Response Surface Methodology to predict the optimum proportions of materials to get maximum strength of concrete by establishing the relationship between the Independent variables and responses.
- To study the workability performance of fresh concrete using slump test.
  - To assess the durability performance of concrete incorporating optimum proportions of materials exposed to HCl and MgSO4concentrated solutions.
  - To study the behaviour of reinforced concrete beam to examine the load-deflection character, flexural toughness, beam ductility and crack pattern by incorporating optimum proportions of cement, GSA, GGBS and PPF and compared with conventional reinforced concrete beam. An attempt has been entertained to learn and appraise the hardened concrete tests as follows:
  - Cube compressive strength of concrete of 150mm×150mm×150mm size using Compression Testing Machine (CTM) with the capability of 200tonnes as per IS 516-1959.
  - Cylinder splitting tensile strength of concrete of 150mm in diameter and 300mm in height using CTM with capability of 200tonnes as per IS 5816-1999.
  - Prism flexural strength of concrete of 150mm×150mm×700mm size using Universal Testing Machine (UTM) with capability of 60tonnes as per IS 9399-1979.
  - Flexural behaviour of RC beam of size 150mm×150mm with an effective length of 1000mm consisting of two numbers of 10mm diameter of tensile reinforcement at the bottom of beam under static loading using flexural testing machine with capacity of 50tonnes.

VI.LITERATURE REVIEW

Chandrasekhar Bhojaraju, Fresh And Hardened properties of ggbs-contained cementitious composites using graphene and graphene oxide: the addition of nanomaterials affects the workability of cementitious composites by reducing the free water available within the mixtures. in order to address this issue, the present study intends to study the addition of ground granulated blast furnace slag (ggbs) in cementitious materials containing graphene (g) and graphene oxide (go). an experimental program is considered to measure fresh properties, compressive strength, and service life of cementitious composites. dosages of 0.03% and 0.06% (by weight of cement) of g

and go are tested in cement pastes and mortars. ggbs in three different dosages of 15%, 30%, and 45% is investigated. a constant water/cement ratio of 0.35 is used in all mixtures. results show that ggbs improves the yield stress and plastic viscosity of g- and go-modified cementitious composites. moreover, ggbs dosages of 30% and 45% compensate the reduced fluidity of 0.03 wt% of g- and go-modified cementitious composites, respectively. the thixotropy of the composite paste containing go decreases with the addition of ggbs. moreover, comparable and slightly improved compressive strengths are obtained for mixtures containing ggbs. the results from the nomogram show a promising trend for the service life of mixtures containing g, go, and ggbs.
a.e. akinwale, effects of supplementary cementitious materials on concrete reinforcement corrosion in magnesium sulphate:in this study, electrochemistry and weight loss techniques were used to investigate the effect of supplementary cementitious materials (scms) on corrosion behaviour of concrete reinforcement immersed in magnesium sulphate solution. the blend of three different scms (fly ash (fa), silica fume (sf) and ground granulated blast furnace slag (ggbs)) were used; the change in the surface morphologies of the corroded reinforced samples was physically observed.

The electrode potentials of the samples studied increased from more negative potentials to less negative potentials with the highest of 1029.6 mv recorded for blended scms sample and −1030 mv recorded for control sample. although, electrochemical noise behaviour was exhibited by all the samples throughout the exposure period. lowest corrosion rate of 0.018 mmpv was observed with 30% sf while the control sample has 0.072 mmpv corrosion rate. physical observation showed that about 25 to 60 mm from the interface between the concrete and the reinforcement to the top of the reinforcement corroded. the results obtained from the weight loss analyses showed that steel reinforcements in concrete samples containing ggbs, sf, and fa generally exhibited corrosion resistance in sulphate solution. however, increase in fa and ggbs contents in concrete resulted in decreasing corrosion resistance of steel reinforced concrete samples.

Liaqat ali qureshi, combined effects of supplementary cementitious materials (silica fume, ggbs, fly ash and rice husk ash) and steel fiber on the hardened properties of recycled aggregate **concrete:** recycled aggregate concrete (rac) is now getting much more attention than ever as a likely substitute for natural aggregate concrete, credited to the growing interest of many countries towards the sustainable environment and economy. to increase the goodwill of rac its performance in terms of strength and durability needs to be optimized. this research article presents the effects of combined incorporation of supplementary cementitious materials (scms) and hook-ended steel fibers (hsf) on compressive behavior and durability of rac. in this study, four different scms (i.e. silica fume (sf), ground granulated blast furnace slag (ggbs), fly ash (fa), and rice husk ash (rha)) were used in rac with 0% and 1% hsf, respectively. sf, ggbs, fa, and rha were respectively used as 10%, 30%, 20%, and 15% by mass replacement of ordinary portland cement (opc). studied properties included compressive strength, elastic modulus, splitting tensile strength, water absorption (wa), chloride penetration (cp), and acid attack resistance (aar). the results of testing indicate that mechanical strength and durability of rac can be improved substantially by the combined incorporation of scms and hsf reinforcement. scms show more contribution towards the development of durability properties of rac, whereas, hsf shows more contribution towards the development of mechanical properties and aar. 10%sf + 1% hsf and 15%rha + 1% hsf helped in the production of rac having superior mechanical and durability properties compared to that of the plain rac. moreover, the benefits of combined addition of hsf and scms are notably higher than the sum of the benefits achieved through individual incorporation of hsf and scms.

Qian rusheng, effects of aqueous-phase speciation on portland cement and supplementary cementitious materials as reflected using zeta potential of powder suspensions:the zeta-potential of cementitious powder suspension is significant for its cement hydration and highly depends on its soluble components. in this work, the suspension zeta-potentials of portland cement (pc), ground granulated blast-furnace slag (ggbs), fly ash (fa) and silica fume (sf) were examined in pure-water (pw) and saturated calcium-hydroxide (ch) along with 0 ~ 24 h. the corresponding ion-concentration was examined for analyzing its effects on zeta-potential.

The results manifested that the inchoative-charges of pc, ggbs, fa and sf in pw respectively were +1.50 mv, −0.28 mv, +0.48 mv and −0.27 mv while the inchoative charge-reversal occurred when their powders were dispersed in ch. the ion-strength magnitude of pc, ggbs, fa and sf in pw and ch were both in the decreasing order of pc > fa > sf > ggbs, and ch solvent improved their ion-strengths. the zeta-potential of pc suspension reduced with the increasing ion-strength while the relationships between zeta-potential and ion-strength of scms increased first and then decreased with the threshold of approximately 40 mmol/l.

haitang zhu, low carbon and high efficiency limestone-calcined clay as supplementary cementitious materials (scms): multi-indicator comparison with conventional scms: the increasing shortage of conventional supplementary cementitious materials, including fly ash (fa) and ground granulated blast furnace slag (ggbs), further obliterates the sustainability potential of portland cement. fortunately, recent studies have proved that limestone-calcined clay (lc2) is a feasible substitute. in this study, lc2 was used as scm to study the properties of blended cement, and compared with fa and ggbs, the relevant mechanisms leading to the unique properties of lc2 were also explained. the evaluation indexes related to energy consumption and carbon emission were proposed. results show that, contrary to the positive effects of fa and ggbs, lc2 has a negative effect on normal consistency and workability.

Lc2 slightly shorten the setting time at normal consistency, but at large content, the setting time was significantly prolonged due to the increase of consistency. lc2 diminished drying shrinkage and is superior to fa and ggbs. lc2 has higher cementing efficiency than fa and ggbs, and it is more obvious at early age. the environmental impact analysis also showed that lc2 reduced the relative energy consumption and carbon emission of cement, and reduces by about half at the substitution rate of 45 ~ 60%.

Weitan zhuang, the effect of supplementary cementitious material systems on dynamic compressive properties of ultra-high performance concrete paste:supplementary cementitious materials (scms) have been widely used to replace cement in uhpc, which benefits to reducing co_2 emissions and declining construction costs. however, the influence of scms on the dynamic compressive properties of ultra-high performance concrete (uhpc) paste has not been well understood.

Here, the workability, pore structure, quasi-static compressive strength and dynamic compressive properties of uhpc paste with different scm systems are comprehensively studied. the results show that the substitution of cement by ground granulated blast furnace slag (ggbs) and limestone powder (lp) increases workability. with the substitution rate of 10% lp, the microstructure of m2 becomes denser. with the further increasing replacement of ggbs and lp, the porosity increases, while the quasi-static compressive strength and dynamic compressive properties trend to decrease, but the extent is limited. the compressive properties such as dynamic compressive strength, dynamic increase factor (dif), peak strain and toughness are highly dependent on the strain rate. an applicable dif model for uhpc is established at the strain rate of 53.9 - 170.7 s^{-1}. the fractal dimension increases with the rising of ggbs and lp. additionally, a positive linear relationship is observed between the fractal dimension and the denary logarithms of the strain rate.

Hong-joon choi, mechanical properties of high-strength strain-hardening cementitious composites (hs-shcc) with hybrid supplementary cementitious materials under various curing conditions:this study aimed to achieve improved tensile performance of strain-hardening cementitious composites (shccs) utilizing various types of supplementary cementitious materials (scms) along with polyethylene (pe) fibers. ground granulated blast-furnace slag (ggbs), silica fume (sf) and cement kiln dust (ckd) were used as scms, with at least two types of scms incorporated into shcc to improve the mechanical performance through hybrid effect of scms. additionally, reaction sensitivity and hydration products were evaluated using specimens manufactured under various curing temperatures (20 °c, 40 °c, and 90 °c) in consideration of different chemical compositions of the scms.

It was confirmed that the 40 °c curing condition has the most positive effect on the compressive and tensile strengths of shcc and strain capacity. the absence of sf led to a decrease in the strain capacity, significantly affecting the low strain energy density of the corresponding specimens. the specimen cured at a temperature of 40 °c after incorporating all three scms exhibited remarkably long-lasting strain-hardening behavior and achieved the highest strain capacity and strain energy density among all the specimens. crack investigation after a tensile test was conducted to confirm traces of strain-hardening behavior, which improved a reliability of the mechanical tests. moreover, derivative thermogravimetry analysis was performed to identify the residual amounts of hydrates affecting the performance of the cement composites. the high $ca(oh)_2$ residue was the basis for explaining insufficient hydration reactions, and the key factors for the low strength of some specimens was found in a low produced amount of $caco_3$.

Zhaoheng guo, synergistic effect of nanosilica and high-volume granulated blast furnace slag on pore structure and mechanical properties of cementitious materials:high-volume ground granulated blast furnace slag (ggbs) is often used in cementitious materials to produce environmentally friendly building materials. however, high-volume ggbs (hvs) can lead to numerous problems including low strength and loose structure of concrete at the early age. to overcome these drawbacks, nanosilica (ns) is used to compensate the early strength insufficiency of high-volume granulated blast furnace slag (hvs) cementitious material by improving the pore structure. currently, it is still a challenge to perform accurate testing of the pore structure. although mercury intrusion porosimetry is widely used to test the pore structure of cementitious materials, there is still some controversy.

In this study, the ^{1}h nmr tests are used to measure the pore structure of ns and hvs blended materials and compared with standard mip tests to comprehensive evaluate the effect of ns on the pore structure of hvs cementitious materials. results indicate that ns can significantly improve the early strength of hvs cementitious materials and the greater the volume of ggbs, the greater the degree of enhancement exhibited by ns. the compressive strength increases of 23.5% and 30.2% were presented by 3-day s6n2 and s8n2 samples while flexural strength increases of 25.3% and 68.7% was resulted. ns significantly reduces the amount of harmful pores and increases the amount of harmless pores (smaller than 100 nm) in the hvs cementitious materials, it was also found that ns had no significant effect on the reduction of the total pore volume.

Results showed that the strength of samples with high porosity was not necessarily low, the pore distribution and pore composition have a greater effect on the strength than the total porosity. the pore volume (>3 nm) obtained from the mip test was larger than the pore volume measured by ^{1}h nmr for early age samples. the difference in the porosity and pore size distribution obtained from the mip and ^{1}h nmr test was large at early age. the effect of ns on the pore structure of hvs system was investigated in more detail by ^{1}h nmr and mip techniques to provide a further theoretical basis for the application of ns in hvs cementitious materials.

VII. CONCLUDING STATEMENT

Going Through The Published Literature It Can Be Very Well Established That Hpc Can Be Prepared Through A Careful Proportioning Of Its Ingredients. The Physical And Chemical Properties Of Individual Ingredients And Their Compatibility With Each Other Are The Key Elements In Achieving A Gain In Compressive Strength Of The Concrete Mix Or The Gain In An Initial Slump.

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