Experimental studies on durability properties of Sustainable and Eco-friendly materials of GGBS and Fly ash in reinforced cement concrete

Velpuri Venkata Sekhar Babu a, Jyothishya Bramha Chari Kanneganti b, Vinod Y c

a Post-Graduate student, Department of civil engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur Andhra Pradesh, India – 522502. (Email: sekhbarbabuv999@gmail.com)

b Assistant professor, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh, India – 522502. (Email: chari.k285@kluniversity.in). Orcid id: 0000-0002-3340-8307

Assistant professor, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh, India – 522502. (Email: yadlapallivinod2@gmail.com), Orcid id: 0000-0002-2116-8406

Abstract

This paper represents the use of supplementary cementitious material (SCM) with the blend of Portland cement in producing the corrosion resistive concrete. Fly ash and GGBS are partially replaced in three different ratios by the weight of cement. Compressive strength, chloride penetration, corrosion, sorptivity of (FA-GGBS) were determined. The test revealed the confrontation by chloride ions through the infiltration of concrete improves substantially by replacement coal by-product Fly ash, GGBS, and improvement increase with increases in the replacement level. The corrosion resistance of SCM-Proportional Mixes was better than the Control mix concrete. Besides, test results indicated that reduction of permeability of chlorides ion as a reduction in porosity in the concrete, that associates with increases in the compressive strength. It significantly affects the durability of the Supplementary Cementitious Materials. On the same proportional mixes, we have gone with microstructural analysis of Scanning Electron Microscopy (SEM) and (EDX), X-Ray Diffraction and non-Destructive tests are following method. The work is suggested that the higher replacement of cement with SCM shows more satisfactory results in the durability properties of proportional grades of SCM.

Keywords: Chemical composition; corrosion resistance; Fly ash; Ground Granulated blast furnace Slag; Microstructural analysis; Sustainable materials; Waste minimization; Water absorption.

1. Introduction

Concrete is the premier material in the world that is widely used on the earth after the water. Today’s construction industry facing a major problem in service life prediction of a construction. Hence durability plays an effective role in the reinforced cement concrete structures requires an extended life to serve requirements. It depends on the environment that concrete resistances to the physical impacts and chemical attacks, the potential in concrete toward safeguard by reinforcing passive layer around steel in rebars against corrosion[1]. In previous studies of the work, most of the researchers are work conducted on the concrete materials that effects of pozzolanic materials on physical and mechanicals on normal concrete[2]. In the world and especially Asia countries the ground granulated blast furnace slag is made to be used as an additive to cement and concrete, such that utilization of waste that is a byproduct of quenching iron, and in connection with the production of fly ash that is the byproduct of a thermal power plant, whereas it is not fully utilized. Since the world change from the ancient stage to the modern stage to fulfill the needs of people the production of fly ash has increased rapidly that is harmful to the environment, as it is kept like waste product per year 88 million tons are generated by every year in India, that too generally Class-F (low calcium), it remains used fully by 10 % by generation, in b/w to 15 % by generation.[3]. The GGBS can reduction in flexural and compressive strength with the high replacement[4]. While the replacement with the GGBS in concrete gives us
adequate strength and flexural strength in adding 15-45%. Another mineral admixture that a good method in part replacement of OPC by the fly ash, which is generated from the coal-based electricity generation plant by pulverized coal burning[4,5].

Non-Destructive testing that implies the strength parameter by the part changes in the strength variances in the mix by taking the different percentages in the of addition of coal-based pulverized by-product ash in (5%-45%). The outcome of the strength-wise improvements in Strength parameters lateral stages has been shown [6]. Amongst the seven-mixes of coal-based pulverized, fly ash which is made a mortar mixed Proportions of (0%-60%). The 40% by weight we took a part replacement in OPC by mortar provides of 13% in strength parameter of compression and by the 9% in the strength of HT accompanying by the OPC. The effect demonstrations and growth in the strength through a rise of a coal-based by-product that is fly ash. The growth of coal-based pulverised by-product that of fly ash will effecting the durability of construction and also the decrease in environment like emission of co2[7]. Fly ash is found that usually improves workability and hence it is an effective component to the concrete, and also widely used in cement with replacement from normal concrete to high strength grade of concrete, so that to cut the heat of generation and to attain the improved in durability properties[8].

The aim of this project is to study the durability properties of a normal grade of concrete and a high-performance grade of concrete by replacing the OPC with supplementary cementitious materials. Studies are conducted by using the Fly ash and GGBS.

The work which we are going to deal with the finding out the durability properties that corrosion of steel in concrete. To find out the durability properties the tests that we are conducting are RCPT – Rapid chloride permeability test ASTM C 1202, ACT – Accelerated corrosion test, and sorptivity ASTM C 1585 – 20.

1.1 Mechanisms of chloride ion Diffusion

Chloride ions penetrate concrete is through capillary action, diffusion, and hydrostatic pressure. Method that is most commonly attain the chloride ion diffusion process is hydrostatic pressure, when H2O holding the anion that is based of chlorine which is negatively that of chloride ions in a charged part of it, which been drawn obsessed by the concrete by divergent pressures from one side to the other side. Usually, a bit of little concern that continuous water effects the concrete structures of bridge decks, the mechanism that major for the marine environments. The capillary action is another most common form of chloride attack. Concrete contains very small voids, which are essential to concrete that was the ability to safely extend and contract during the time of freezing and thawing that are referred to as capillaries. These capillary void spaces are filled with water, when the concrete becomes wet, surface tension force by drawing the water into voids. Over time the concrete structures are going to face a problem that the flow of water and negatively charged ions into concrete.

The most and common method for chloride that is (-ve) ions infiltration by the mechanism is through diffusion, which is a key concept to concern that when it is evaluating the different methods by measuring the parameters by (-ve) charged chloride ions. The dispersal method is determined by the existence of a absorption gradient and occurs of the movement of chloride ions from an area of elevated absorption to low concentration, to become an unchanging attentiveness to equilibrium. From bridge bottom levels to the decks, the gradient basically occurs because of the use in de-icing salts during the months of winter. Though Chloride (i.e., acid) that is (-ve) charged ions, currently in the mix of molten snowflake, softened salt.

In concrete chloride ions mostly crumble to rust the superficial of the bar, it was degrading and fat the life span of embedded reinforcing the bar by significantly. Besides, corrosion of the steel bar external compromises the tie that exists in a mong the blended mixes of reinforcement in steel. But compared with the outcomes that of blended concrete mix which may be spalling to separate the reinforced bar, again and again subsequently through rapid weakening of the outer layer of the bridge layer of the decks to dominant exclusive repairs. Inflow of (-ve) charged ion that are anions by mix through concrete structures can also create extreme cracking in the blended concrete. Since the cracks form and subterranean of blended mix concrete to develops by visible to the environment, increasingly vulnerable by further (-ve charged anions) penetration and reinforced bar degradation and cracking[10]. Deterioration of strengthening bar while immersed in proportion mix an electrochemical process of anode, and a cathode an electrolyte, and an electrical connection between the anode and cathode for the transfer of electrons. The 2 cathodic and anodic actions are taking place in the form of reactions by the reinforcing steel surface. Here mix is poured by water acts as an electrolyte and the build the reinforced bar offers the electrical linking in amid the anode and cathode. Whereas
anode and cathodes are may to supposed to place on the same rebar than on bars and electrically related through metallic draws or chairs.

The anode and cathode are called half-cell reactions which is by corrosion and drop reactions. At the anode, iron is oxidized and goes into liquid as electrons are forms like ferrous ions.

which is added impervious and powerfully adherent to the bar. In highly alkaline mix the solution in environments, that forms the ferrous hydroxide ions can also oxidize to gamma Fe₂O₃[11].

2. Materials and Methodology

In this study, we have used a commercial Type I Portland cement. And the cementitious materials are re Fly ash and GGBS are used. OPC 53 grade cement confirming to IS: 12269-1987[12] in this study the specification was used. Physical parameters and chemical compositions of cement is characterised in Table 1 and Table 2. This is as per the manufacture report and test certificate. Fly ash has been used as a supplementary material in cement, which is gathered from Vijayawada, Thermal power station (VTPS), Vijayawada, Andhra Pradesh[13]. The chemical compositions and physical parameters are represented in Table 1 and Table 2. GGBS brought in HYDERABD. It went find the the properties like SG and fineness which is found to be 2.9 and 3500 cm²/gm respectively, which is explained in Table 1 as per the manufacture report. The river sand which is obtainable in a nearby place and is utilized as the fine aggregate in this following study. The river sand which is free from silt, organic impurities, and clay. Coarse aggregate were as 10 mm and 20 mm nominal size of aggregates are used that are free from impurities like clay elements, organic substance and powder etc[14]. Characterization of these materials was accomplished by preliminary studies.


2.1. Physical and chemical properties of Cement and Composite materials

Ordinary Portland cement of 53 grade, fly ash and GGBS was used for this research. The physical and chemical properties and non-destructive testing of the cement and cementitious materials were tested are given in Table 1, Table 2, and Table 3. The OPC content used here for all the mixes is 450 kg/m³.

Table 1. Physical properties of cement and cementitious materials.

| Physical properties          | Cement | Coal-based pulverised | GGGBS |
|------------------------------|--------|------------------------|-------|
| SG                           | 3.14   | 2.51                   | 2.9   |
| Colour off                   | Grey   | Greenish               | White |
| Bulk density                 | 1440 kg/m³ | 1120 to 1500 kg/m³   | 1200 kg/m³ |
| Specific surface (Air permeability test) | 270.80 m²/kg | -                  | 425-470 m²/kg |
| Initial setting time         | 65 minutes | 55 minutes           | 75 minutes |
| Final setting time           | 285 minutes | 295 minutes         | 315 minutes |
| Soundness (Le-Chatelier test) | 1 mm   | -                      | -     |
| Consistency                  | 33%    | 35%                    | 33.5% |

Table 2. Chemical composition of OPC and cementitious composite materials.

| Composition | Fly Ash. % | Blast fume slag. % | Cement clinker. % |
|-------------|------------|-------------------|-------------------|
| Si O₂       | 52.40      | 31.70             | 21.04             |
| Al₂O₃       | 20.8       | 12.50             | 5.06              |
| Ca O        | 6.43       | 45.20             | 64.15             |
| Fe₂O₃       | 5.80       | 0.48              | 2.86              |
| Si O₂/Al₂O₃ | 2.61       | 2.61              | -                 |
| TiO₂        | 1.22       | 0.51              | -                 |
| Na₂O        | 0.92       | 0.15              | 0.23              |
| Mg O        | 0.84       | 1.00              | 1.67              |
| S O₃        | 0.83       | -                 | 2.42              |
Normal water and new consumable water, which was liberated from a corrosive and natural substance, were utilized for blending the concrete. The synthetic response among water and concrete is vital to achieving a solidifying property subsequently, water utilized must not be stained[15]. Superplasticizer is utilized to build its usefulness. Also, valuable establishing materials, for example, fly debris and silica smolder are broadly utilized as pozzolanic materials in high-strength concrete. They are regularly used to make additional strength by pozzolanic responses, to decreases the porousness, and to improve the toughness of the concrete. The reason for the superplasticizer is to influence the new solid properties by expanding the functionality in concrete. The type of superplasticizer utilized in this investigation is ECMAS[16].

Table 3. Mix proportional Details.

| Mix ID        | Portable Water kg/m³ | Cement kg/m³ | CA-20 mm kg/m³ | CA-10 mm kg/m³ | Fine aggregate kg/m³ | Admixture kg/m³ | Flyash kg/m³ | GGBS kg/m³ |
|---------------|----------------------|--------------|----------------|----------------|-----------------------|-----------------|--------------|-------------|
| W/B-0.55-0%   | 197                  | 358.18       | 644.72         | 429.81         | 537.27                | 0               | 0            | 0           |
| W/B-0.55-20%  | 197                  | 214.90       | 658.92         | 440.90         | 712.32                | 0               | 71.63        | 71.63       |
| W/B-0.55-25%  | 197                  | 179.09       | 655.60         | 438            | 715.92                | 0               | 89.54        | 89.54       |
| W/B-0.55-30%  | 197                  | 143.27       | 652.18         | 436.39         | 708.61                | 0               | 107.45       | 107.45      |
| W/B-0.28-0%   | 171.2                | 450          | 604.8          | 404.7          | 657.2                 | 4.6-4.9         | 208          | 0           |
| W/B-0.28-20%  | 171.2                | 394.8        | 580.48         | 388.41         | 630.7                 | 4.6-4.9         | 131.6        | 131.6       |
| W/B-0.28-25%  | 171.2                | 329          | 574            | 384            | 623.9                 | 4.6-4.9         | 164.5        | 164.5       |
| W/B-0.28-30%  | 171.2                | 263.22       | 567.5          | 379.73         | 677                   | 4.6-4.9         | 197.42       | 197.42      |

2.2. Experimental program and methodology

The objectives of the present study were given below:
- To study the durability properties of fly ash and GGBS.
- To study alternate materials of OPC, and to identify the potential use of SCM’s.
- To study the water absorption of SCM’s.
- To reduce the rate of carbon footprint using SCM’s.

The present test technique is detailed by ASTM and the valuation of the infiltration of (-ve) charged anions ions in concrete is ASTM C 1202. This test is the “Standard Process for Electrical Indication of Concrete’s Capability to Resist Chloride Ion Dispersion. Methodology for research exists given below flowchart.
This test technique involves observing the quantity of current approved to pass through 50-mm thick slices of 100-mm nominal diameter core specimens or cylinders period a 6-hrs. The total charge excessively passed, in coulombs, is related to the resistance of the concrete test specimen to chloride ion infiltration\[17\]. Above stated that is the summary of the RCP method, in the following test, the actual practice is the concrete discs which are cast and cured for the required time after that the concrete disc are kept in a vacuum desiccator for 18 \pm 2 hr, after that, the discs are placed in the two applied voltage cells in that one disc is filled with 3% concentration of NaCl Solution and one more thing 0.3 N of NaOH solution. It relates to the negative terminal 60 V dc has applied to NaCl solution so that the process beings.

Concrete normally has an alkaline environment that protects embedded steel from corrosion. This environment can be destroyed by carbonation or by chloride attack. As already mentioned, it may take some years for sufficient chlorides to ingress cover concrete and de-passify steel. To hurriedly depassify it, we as part of the research opted for a mix concrete with two W/B ratio of 0.55 and 0.28, and the proportional mixes of 4 we have opted with the replacement of fly ash and GGBS with 0%, 20%, 25%, 30%. In that, we embedded steel rebar of 12 mm diameter and later the specimens are cured in the portable water under the controlled condition for 56 days as we have used supplementary cementitious materials, so must hydrate the cementitious materials the curing time has to be more than the 28 days of curing. After that, the specimens are 150mm*150mm*150mm are (W*B*D) cubes. Are kept under the accelerated corrosion test. The Accelerated corrosion test setup has had the procedure a specimen is immersed in 5% concentration of NaCl solution by weight of water.

This technique involves of applying a consistent DC from a source to the rebar inserted in blended concrete mix to encourage significant rust in a least time. Subsequently applying the current, the grade of tempted decomposition can be resolute apparently by means of Faraday’s law, the percentage of the definite amount of steel vanished in corrosion can be calculated by gravimetric test method directed on the extracted reinforced steel after subjecting them to accelerated corrosion. The actual amount of steel mislaid, by an comparable corrosion with current mass can be determined.
The above-shown Figure 1 which is the test specimen is kept in a bucket and then fill with 5% concentration NaCl solution up to the top level of the cube by taking a gap of 10 to 20 mm from the top surface. A stainless-steel bar is kept in the 5% NaCl solution. which is called the cathode is connected to negative terminal which is DC stabilized power supply and from a positive terminal that is anode is connected to the test bar which is immersed in the concrete specimen. The entire test setup is kept in power supply for 15V DC. Actual the power supply is kept in under process for an entire test complete that which may be taken a long time also like 56, 90, 180, 365 days and long more days. Because the power gets corroded by electrically conductive by the NaCl solution is immersed in the concrete specimen which will attack passive layer around the rebar which is acts as a protective layer which is gets vanished by carbonation or chloride attack.

The experimental work made on the concrete was made by replacing the 0%, 20%, 25%, 30% in cement with Fly ash and GGBS for a W/B ratio of 0.55 & 0.28. The sorptivity test is performed by concrete dices, the dimensions are 10cm diameter*5cm rise. The Dices were oven-dried for 7 days period at 50°c, then the weight of the dices was taken. The assessment of capillary intensification of waterlogged Ca (OH)$_2$ solution on dices was institute. The dice are sealed with the plaster round the dice and it is not absorbed the Ca (OH)$_2$ with a height of 3+-5mm from the bottom engaged in water[18].

The work represents the study of an experimental program by a laboratory on the durability aspect of the tertiary blended mix on the electro-chemical possessions of U.H.P.C. The assessment on the concrete dices is made by the two methods that is time-related various on the experimental work which will be taken by the performance-related
significance on the mechanical parameters. The experimental work was testing Rapid chloride permeability test, Accelerated corrosion test, and sorptivity. The results showed that the combination of fly ash and blast furnace slag can expand the attributes of concrete in a time-dependent term, while concrete with HV coal-based pulverised by-product fly ash and steel slag requires lengthy stages for the useful outcome. Sorptivity test technique is one of the main to determine the water demand of the concrete specimen or structural element. Actual the procedure for the sorptivity related test specimens is taken by the cubes, as supplementary cementitious materials are taken in the present study the 56 days curing is needed to get the performance in the theme of water absorption.

Sorptivity specimens are taken by the core cutting machine from the cubes which is 100 mm dia. * 50 mm thick. The required sized specimens are kept in oven for about 7 days in 50°C temperature, and after that the discs are coated with the epoxy around the discs, so that the water will not allow from sides of the specimen and top surface which is covered with any soft and smooth like thing which is allow to take weights without any error, after the discs are taken out from the oven the discs are kept in room temperature for about 24 hours, then the discs are placed in a flat bucket on it a 2 mm L-shape strips are laid and on it, the test specimens are kept and pour the water, that the discs should be merge about 2-5 mm, and the bottom surface should be contact with water, it is kept like that for about 30 minutes. Before the sample weight as the dry sample as W1 and after the saturated weight of specimen as W2.

The extent of solution poured in container weighs 0.1 mg the dice for every half one hour. Sorptivity technique is that water demand by the material which is the property by that water can be absorbed and transmitted by capillary action. Sorptivity (S) is calculated by.

\[ S = \frac{(W_2 - W_1)}{(Area \times density \times time^{0.5})} \]

Where 
- \( W_1 \) = Dry weight of the cylinder in grams
- \( W_2 \) = Weight of the cylinder after capillary suction in grams
- Area = Surface area of the dices uncovered to water infiltration by capillary action in mm\(^2\)
- Density = Density of water
- Time = Time in minutes

3. Results and Discussion

3.1. Non-Destructive testing

As per the code IS 13311-1 (1992): Method of NDT on concrete. The assessment was conducted on cubes after the curing of specimens for 56 days in portable water under controlled conditions which is shown in Table 4. The NDT of the structural member of concrete is fixed out by using the rebound (Schmitz) hammer. The test was based on the principle of the rebound hammer of an elastic mass that was the hardness of the exposed surface of cube against the mass impinges. The rebound (Schmitz) hammer weighs around 1.8kg and is suitable for use in both the laboratory and the field. It is using to test concrete at hardened stage of every curing period. This test would ten repetitions on each and very cube within a specific location on the specimen, and a total of ten readings were noted as stated by ASTM C 805-1997 [19].

| Sample Id | Non-Destructive Test |
|-----------|----------------------|
| A1        | 22.53                |
| A2        | 22.89                |
| A3        | 27.84                |
| A4        | 28.92                |
| B1        | 46.80                |
| B2        | 48.20                |
| B3        | 49.56                |
| B4        | 49.98                |

3.2. Rapid Chloride permeability test

After conducting RCP test on different W/B ratio by taking different proportions, at the end of 56 days, the rate of chloride penetration is observed.
Figure 4. Coulombs versus (%) Replacement of FA-GGBS.

From Figure 4 the reduction of chloride ion permeability which will be noticed here, as we can that the W/B ratio 0.55 with 0% replacement shows the high range of permeability with respect to the PRSCM’s. The value which taken in coulombs are 4742 in 28 days were as for 56 days 3872 it is not very low but it is in moderate range of permeability. In all the PRSCM’s the replacement of 30% shows the low and very low ranges of permeability i.e., 1445 to 987. But comparatively the strength wise parameters also 25% PRSCM shows effectively results. As the supplementary cementitious material of fly ash and ggbs are not given early strength but later stage the was high and the porous structure in the mix is also filled and hydrated, in later stages. The chloride penetration itself is showing the differences between stages and time period curing.

Figure 5. Coulombs versus (%) Replacement of FA-GGBS.

From Figure 5 Coulombs versus (%) Replacement of FA-GGBS, here in this the reduction in dispersion of (+ve) charges chloride anions of ions, from rapid chloride ion permeability test, the diffusion of chloride ion can be evaluated through the electrical conductivity by measured in coulombs. In the W/B ratio of 0.28 the 0% replacement of fly ash and ggbs shown less penetration that low range as per the code ASTM C 1202, in which It is stated. In this mix the
The electrical current reading is taken from a digital analog meter. To measure the corrosion rate, we have conducted an accelerated corrosion test by giving a 15V DC to the rebar which is embedded in the concrete by taking cover from the surface of the specimen i.e., 40 mm cover. Which is testing on different proportions of concrete with replacement in the fly ash and GGBS in the OPC. The percentages which are changed in OPC is 0%, 20%, 25%, 30% respectively. Actual the change of supplementary cementitious materials in the 2 water-binder ratios so that we can difference in that mix proportions which is shown in Table 5.

Table 5. Corrosion Initiation of rebar and Cracking time (in days) of rebar.

| Cube Sample Id | Corrosion initiation time (days) | Cracking time (days) |
|----------------|----------------------------------|----------------------|
| G2-40-A1       | 2                                | 4                    |
| G2-40-A2       | 2                                | 5                    |
| G2-40-A3       | 3                                | 7                    |
| G2-40-A4       | 5                                | 8                    |
| G6-40-A1       | 8                                | 11                   |
| G6-40-A2       | 12                               | 15                   |
| G6-40-A3       | 16                               | 22                   |
| G6-40-A4       | 21                               | 31                   |

3.4. Sorptivity

As increases in the replacement of fly ash and GGBS with OPC, the sorptivity, that is the absorption water for the mix with W/B-0.55, 0.28, are decreased as shown in Figure 6. The Supplementary cementitious materials (100% CEM + 0% F.A + 0% G.B.S) show a high demand in water absorption whereas (40% CEM + 30% F.A + 30% G.B.S) as low demand in water absorption in both the W/B ratios of 0.55, 0.28. The pores are minimum in the high replacement of SCM with OPC as compared with the data from the experimental work that we have done as per the ASTM C 1585 – 20.
3.5. SEM Analysis:

The formation and distribution of hydration of blended concrete glue with different percentages which is shown in Figure 7, Figure 9, and Figure 11, respectively. The rheology elements are of different mix proportions were studied and equated with nominal mix. The interfacial properties and durability parameters of proportioned composite mixes which is compared with based on dampen particles or products after 13 weeks, were it is immersed in NaCl solution for 28 before that 56 days for normal curing with portable water. The various parameters are analysed based on the growth of hydration products in the microstructure of concrete mixes.

MIX ID-1. W/B-0.55 (50% C + 25% F.A + 25% G.B.S)

![SEM Micrograph of Mix (50% C + 25% F.A + 25% G.B.S)](image)

Figure 7. SEM Micrograph of Mix (50% C + 25% F.A + 25% G.B.S), a)100 μm; b)50 μm.

![EDX Analysis of Mix (50% C + 25% F.A + 25% G.B.S).](image)

Figure 8. EDX Analysis of Mix (50% C + 25% F.A + 25% G.B.S).

In above picture stated that SEM morphology of hydrated cement matrix of mix 1. The formation of minimum amounts of CH crystals that are observed on shells of hydrated concrete glue particles. In above pictures the round portion are the particle replacement were the hydration process is slow and it shows that cementitious materials which are surrounded by the cement paste and were the water reacts with the SCM was slow, initially the durability properties is showing low but the increases in time of hydration the sc materials was fully hydrated. The microstructure of hydrated cement concrete paste of mix with 0.55 W/B ratio EDX analysis in the above Figure 8, Figure 10, and
**Figure 12.** respectively, which is considerable strength and durability in the present mix as of pozzolanic movement with coal based pulverised fly ash and ggbs. As of chemical reaction with fly ash and ggbs creation of extra C-S-H gel by Ca (OH)$_2$ [20].

**MIX ID-2. W/B-0.28 (60% C+20% F.A+20% G.B.S)**

![SEM Micrograph of Mix (60% C+20% F.A+20% G.B.S)](image)

Figure 9. SEM Micrograph of Mix (60% C+20% F.A+20% G.B.S), a)100 μm; b)50 μm.

**MIX ID-3. W/B-0.28 (50% C+25% F.A+25% G.B.S)**

![SEM Micrograph of Mix (50% C+25% F.A+25% G.B.S)](image)

Figure 11. SEM Micrograph of Mix (50% C+25% F.A+25% G.B.S), a)100 μm; b)50 μm.
3.6. XRD Analysis:

XRD analysis of cement concrete with replacement of partial replacement of SCM under controlled curing of portable water 3% NaCl solution for 28 days, which has performed in order to investigate the structural evolution as shown in Figure 13. Ettringite, portlandite, Alite, and Belite, Quartz were defined on a majority of specimen particles. Variations of peaks in elevation and development of new peaks were detected for low binder ratio. The results illustrated that, Ca\textsubscript{2}\textsubscript{(OH)}\textsubscript{2} crystal which desires to creation of C–S–H gel appears proportional mix covering Fly ash and GGBS and influence development of successive gel of C.S.H[21].

Figure 12. EDX Analysis of Mix (50% C+25% F.A+25% G.B.S).

Figure 13. XRD Analysis for replacement of Fly ash and GGBS with W/B different ratios.
4. Conclusion

The following points are concluded in this present research work.

1. The permeability of chloride ions into concrete specimen were reduced with high replacement of PRSCM in Ordinary PC that is (40% CEM+30% F.A+30% G.B.S).
2. From Accelerated corrosion test method, the initiation of corrosion to rebar which is embedded in concrete taken more time period to damage the passive layer around the rebar, with Water to Binder ratio of 0.28 given most durability then Water to Binder ratio of 0.55.
3. Water absorption or demand of concrete specimen, that both the ratio of W/B of 0.55 and 0.28, shows effective results with replacement of Fly ash and GGBS materials with 30% (F.A and G.B.S), because less porous in nature in comparative with the other proportions.
4. Experimental validation for the important cement, fly ash and ggbs chemistry aspects in XRD through a combination of SEM and EDX.
5. The durability properties of the concrete was originate to be improved on part replacement with coal based by-product fly ash and GGBS in high performed concrete related to conventional concrete of proposed grades in severe exposure condition.

Scope of work

Further research can be supported out with the deep study on the replacement with higher percentages ofFly ash and GGBS in Ordinary Portland cement (OPC) with microstructure and behaviour properties of high value Supplementary cementitious materials like FA-GGBS with combination or addition of poly-Ironite ceramic cementitious to the proposed mix to strength and further the durability properties of concrete at the site condition and to determine the real condition with the laboratory values.

Credit authorship contribution statement

V.V. Sekhar Babu: Writing - original draft, Data curation, Formal analysis, Investigation, Methodology. K.J. Bramha Chari: Funding acquisition, Writing - review & editing, Supervision, Validation. Vinod Y.: acquisition, Visualization.

Acknowledgment

The continues support with help and consolation of Koneru Lakshmaiah Educational Foundation were gratefully acknowledged. This work would not have been finished without the help of the University and we will be forever thankful. Our uncommon gratitude to the Head of Department, Civil Engineering, Project, and Laboratory in control for giving us adequate facilities, ways, and means by which we can complete this project work. Authors would like to thank Department of Science and Technology (DST), Govt. of India, for the award of DST-FIST Level-I (SR/FST/PS-1/2018/35) scheme to Department of Physics, KLEF. And thanks to Department of science and technology (DST), to Vignan’s Foundation for science, Technology and Research. We thank teaching and non-teaching members and friends of the Department of Civil Engineering for full or partial support.

References:

[1] V. Horskulthai and K. Paopongpaiboon, “Strength, chloride permeability and corrosion of coarse fly ash concrete with Bagasse-Rice Husk-Wood Ash additive,” *Am. J. Appl. Sci.*, vol. 10, no. 3, pp. 239–246, 2013, doi: 10.3844/ajassp.2013.239.246.
[2] S. Rukzon and P. Chindaprasirt, “Use of rice husk-bark ash in producing self-compacting concrete,” *Adv. Civ. Eng.*, vol. 2014, no. 325, 2014, doi: 10.1155/2014/429727.
[3] W. Aperador, A. Delgado, and J. Bautista-Ruiz, “Effect of durability and chloride ion permeability in ternary cementitious concrete with additions of fly ash and blast furnace slag,” *Int. J. Electrochem. Sci.*, vol. 11, no. 3, pp. 2297–2305, 2016.
[4] M. A. Fahad S and S. A. Sharma, “GROUND GRANULATED BLAST FURNACE SLAG (GGBS or
GGBFS) AND FLYASH IN CONCRETE,” Int. Res. J. Eng. Technol., pp. 266–270, 2018, [Online]. Available: www.irjet.net.

[5] A. Yousuf, S. O. Manzoor, M. Youssouf, Z. A. Malik, and K. Sajjad Khawaja, “Fly Ash: Production and Utilization in India-An Overview,” J. Mater. Environ. Sci., vol. 2020, no. 6, pp. 911–921, 2020.

[6] R. Mahida et al., “International Journal of Advance Engineering and Research Development A R REVIEW OF COMPRESSIVE STRENGTH OF MORTAR USING FLYASH AS A PARTIAL REPLACEMENT OF CEMENT,” pp. 52–57, 2014.

[7] M. Islam and S. Islam, “Strength Behaviour of Mortar Using Fly Ash as Partial Replacement of Cement,” vol. 1, no. September 2010, pp. 98–106, 2012.

[8] I. Elkhadiri, A. Diouri, A. Boukhari, J. Aride, and F. Puertas, “Mechanical behaviour of various mortars made by combined fly ash and limestone in Moroccan Portland cement,” Cem. Concr. Res., vol. 32, no. 10, pp. 1597–1603, 2002, doi: 10.1016/S0008-8846(02)00834-7.

[9] B. Rajalakshmi, “Experimental Study on Optimization of Cement by Using Ground Granulated Blast Furnace Slag ( GGBS ) and M- Sand in High Performance Concrete,” vol. 6, no. 12, pp. 216–220, 2020.

[10] E. W. Ryan, “TRACE : Tennessee Research and Creative Exchange Comparison of Two Methods for the Assessment of Chloride Ion Penetration in Concrete : A Field Study,” 2011.

[11] D. Trejo, C. Halmen, and K. Reinschmidt, “Corrosion Performance Tests for Reinforcing Steel in Concrete: Technical Report,” Fhwa/Tx-09/0-4825-1, vol. 7, no. 2, 2009.

[12] IS:12089-1987, “Specification for granulated slag for the manufacture of Portland slag cement,” Bur. Indian Stand. New Delhi, pp. 1–14, 1987.

[13] IS:3812, “Specification for Pulverized fuel ash, Part-I: For Use as Pozzolana in Cement, Cement Mortar and Concrete,” Bur. Indian Stand. New Delhi, India, pp. 1–12, 2013.

[14] “IS-2386-PART-IV-1963-2 aggaregates.pdf.”

[15] IS 456, “Concrete, Plain and Reinforced,” Bur. Indian Stand. Dehli, pp. 1–114, 2000.

[16] IS 9103 : 1999, “Specification for Concrete Admixtures,” Bur. Indian Stand. Dehli, pp. 1–22, 1999.

[17] ASTM C1202, “Standard Test Method for Electrical Indication of Concrete’s Ability to Resist Chloride Ion Penetration,” Am. Soc. Test. Mater., no. C, pp. 1–8, 2012, doi: 10.1520/C1202-12.

[18] M. Jemimah Carmichael, G. Prince Arulraj, S. Elizabeth, J. K. Johnson, A. Tomy, and I. Joy, “Assessment of sorptivity and water absorption of concrete with nano sized cementitious materials,” Int. J. Eng. Adv. Technol., vol. 8, no. 3 Special Issue, pp. 847–851, 2019.

[19] IS 13311 (Part 1), “Method of Non-destructive testing of concret, Part 1: Ultrasonic pulse velocity,” Bur. Indian Satandards, pp. 1–7, 1992.

[20] A. S. A. Saran and P. Magudeswaran, “SEM Analysis on Sustainable High Performance Concrete,” Int. J. Innov. Res. Sci. Eng. Technol., vol. 6, no. 6, p. 11, 2017, doi: 10.15680/IJIRSET.2017.0606016.

[21] A. K. Mukhopadhyay, R. M. Ganesh, K.-W. Liu, and Y. Deng, “Direct Determination of Cement Composition by X-ray Diffraction,” pp. 1–89, 2019.