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Green Concrete Initiative by Replacing Cement With More Than 50% Mineral Admixtures For Substructure Concrete

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Abstract: As India is a developing nation, construction activity have expanded over the past few decades. There are large-scale infrastructure projects underway all around the country, including the development of airports, dams, sea link bridges, river bridges, metro, rail, expressways and flyover projects. The need for concrete and fossil fuels surged due to the development and expansion of the building industry, which dramatically boosted CO2 emissions into the atmosphere. The development of concrete technology can lessen the burden of toxins on the environment and the consumption of natural resources and energy sources. Cement and industrial waste exhibit chemical similarities. Utilizing GGBS as a partial replacement for cement will lower the cost of concrete while also assisting in a slower rate of cement consumption. This study reviews the use of GGBS -ground granulated blast furnace slag which is the waste product of the steel manufacturing industry, as an additive to concrete that can replace cement to the extent of more than 50%. By reducing energy consumption (the energy needed to create cement) and preventing the depletion of natural resources, materials like GGBS and others generate concrete that is more "GREEN". In this study, an experiment was conducted to examine the mechanical and durability properties of concrete when a mineral admixture, such as GGBS, was employed to partially substitute ordinary Portland cement in M45 Grade Substructure Concrete. Concrete's compressive strength was compared experimentally after 7, 14, and 28 days of curing. Concrete durability tests such as the RCPT-Rapid Chloride Permeability Test, WPT-Water Permeability Test at 28 days & RCMT-Chloride Migration Test at 56 Days are performed on it. Other tests include cylindrical compressive strength, flexural strength, split tensile strength, and strength after 28 days.

***Index Terms* - Ground Granulated Blast Furnace Slag; Green Concrete, Compressive Strength, Split Tensile Strength, Flexural Strength, Durability Tests**

I. INTRODUCTION

In the construction sector, concrete plays a significant role. Civil engineering has reached the pinnacle of technology with the introduction of concrete. The most widely utilized and versatile building material, concrete is often used to withstand compressive stresses. Sand, aggregates, and cement are some of the key components of concrete. In addition to being expensive and energy-intensive, the manufacture of Portland cement emits a significant amount of carbon dioxide into the atmosphere. Use of mineral admixtures as a partial cement substitute in both concrete and mortar is one efficient strategy to lessen the impact on the environment. This will likely result in cost savings, energy savings, the preservation of natural resources, and a reduction in waste emissions [02]. GGBS-ground granulated blast furnace slag, FA-fly ash, rice husk ash, recycled glass, construction debris, etc. are examples of natural pozzolanic materials or industrial by-products/wastes that are frequently used in concrete to replace some of the cement. When special performance is required, it is sometimes known as "Supplementary Cementing Materials": Strengthening, impenetrability, low heat of hydration, increased durability, addressing deficiencies in aggregate gradation (as fillers), and other properties. Cement mains replacement is expensive; processing these materials also uses far less energy than cement does. These wastes and byproducts reduce environmental harm and contamination [07]. In this study we are replacing cement with GGBS more than 50% to make concrete GREEN.

GREEN is now used to describe more than just a color. It serves as a representation of our surroundings, or environment. "Green concrete" is a term used to describe concrete that is manufactured from concrete waste, industrial waste, or other environmentally beneficial materials. Dr. WG from Denmark developed the idea of green concrete in 1998. Green concrete is characterized as having at least one component made of waste, a manufacturing technique that does not harm the environment, excellent performance, and long-term sustainability. Reduce, reuse, and recycle principles, or any two other concrete technology procedures should guide the production of green concrete. The three main goals of the green concept in concrete are to reduce greenhouse gas emissions (from the cement industry's carbon dioxide emissions), to reduce the consumption of natural resources—such as limestone, shale, clay, natural river sand, and natural rocks—that are used for human development but aren't returned to the environment, and to reduce the use of waste materials in concrete that contribute to pollution of the air, land, and water. Nowadays, it's important to promote the use of green concrete since it may reduce waste overall, not only carbon dioxide emissions, and has a number of mechanical and long-lasting advantages.

Balaji Subbramanian V et al. [02] have reported that mineral admixtures are similarly reactive binder elements to cement. They discovered that partial substitution of OPC increases with mineral admixtures such FA and GGBS results in a reduction in the compressive strength of concrete. **Ardra Mohan et al. [01]** have reported that SCM-Supplementary Cementitious Material boosts the mechanical characteristics of concrete compared to concrete without SCM. Their research demonstrated that adding SCM to concrete reduces the amount of voids, as demonstrated by Tests for Water Absorption and Sorptivity. **Meghal Dewangan et al. [05]** showed that the consistency, compressive strength, mechanical, and durability qualities of concrete were boosted when silica fume was used to replace 25% of the cement.

P. Vipul Naidu et al. [09] have shown that use of mineral admixtures like FA, GGBS etc. reduces the expenses on Cement. The use of mineral admixtures in concrete, make concrete structure denser and thus improves their durability further workability of concrete gets increased. Green Concrete Technology, which has low direct and/or indirect emissions of CO2 and CO, is created when GGBS, FA, and lime are used in place of cement. **Manik Goyal et al. [06]** concluded that the amount of waste or by-product substitution has a significant impact on the characteristics of concrete.They discovered that the mechanical and durability attributes of concrete that included by-product waste such as FA, SF, and GGBS were improved. They evaluated that Green Concrete was cost-effective & environment friendly. It promotes sustainability by lowering trash production and carbon emissions. Additionally, it reduced landfill area and helped to save natural resources. **Ernst Worrel et al. [04]** reported that increasing the process' energy efficiency and switching out high-carbon fossil fuels for low-carbon ones can minimize CO2 emissions. The best ways to reduce CO2 emissions are to improve energy efficiency, build efficient new kilns, increase the production of mixed cement, and increase the utilization of waste fuels. **Mohammed S. Imbabi et al. [07]** concluded that most effective producing method of green, environmentally & economical sustainable cement are A) use of substitute i.e., low carbon fuel B) development of novel cement invention & manufacture method.

The use of mineral admixture gives improved quality to the concrete. In terms of concrete's strength and durability properties, using GGBS enhances the quality of hardened concrete. By using a mineral admixture like GGBS, less natural resources and energy are consumed, and less pollution is released into the environment.

Therefore, it is proposed to have look into determining the impact of replacing 51% of the cement in M45 Grade Concrete Mix-A with a mineral additive such GGBS as opposed to M45 Grade Concrete Mix-B, which contains no GGBS.

II. OBJECTIVE

- To analyze strength as well as durability characteristics of GGBS concrete against plain Concrete.
- To reduce more than 50% cement by using mineral admixture like GGBS in concrete & making concrete environment friendly.

III. METHODS AND MATERIALS

3.1 MATERIALS: -

In this test O.P.C. 53 grade cement having specific gravity 3.14 was used. 10 mm, 20 mm, and crushed sand aggregates with specific gravities of 2.71, 2.73, and 2.63, respectively, were employed. As a substitute, GGBS was used. GGBS is a commercial by-product of the Iron manufacturing process. The specific gravity of GGBS was 2.9. GGBS is Off-white in color. Alco fine having specific gravity 2.87 also used. Additionally, a Super plasticizer, named Fosroc Auramix 400, based on polycarboxylic ether polymer was used. The water which was accessible to the lab was used.

3.2 SPECIMEN PREPARATION: -

Concrete mix of M45 was used to cast the samples. The w/c ratio was kept low 0.235. Table 1 displays specifics regarding the proportion of the concrete mix. Surface saturated dry (SSD) before moisture correction is the mix proportion stated in Table 1. It is shown that mineral admixtures like GGBS was used to replace cement. The concrete mix was identified as CMD-A (With GGBS).

With similar manner Concrete mix of M45 used to cast samples which was without GGBS. Table 2 displays specifics regarding the SSD weights and concrete mix proportion. The concrete mix was identified as CMD-B (Without GGBS). The codes IS 456, IS 383, IS 10262:2009 and IRC 112:2011 were followed to conduct the experiment.

Table 3.1 Concrete Mix Proportion for Mix-A (Kg/m3) (With GGBS)

Ingredients	CMD-A (SSD Weights in Kgs/Cum)
Cement	260
GGBS	305
Alcofines	30
20mm	628
10mm	450
Crushed Sand	677
Water	145
Admixture	3
W/C ratio	0.235

Table 3.2 Concrete Mix Proportion for Mix-B (Kg/m3) (Without GGBS)

Ingredients	CMD-B (SSD Weights in Kgs/Cum)
Cement	435
GGBS	Nil
Alcofines	20
20mm	682
10mm	489
Crushed Sand	736
Water	140
Admixture	3.48
W/C ratio	0.307

The concrete specimen was constructed using convectional steel moulds. For this study, concrete specimen cubes measuring 150 x 150 x 150 mm, beams measuring 700 x 150 mm, and cylinders measuring 100 mm in diameter and 300 mm in height were cast.

Molds were removed after 24 hours, and specimens were then cured for 3, 7, and 28 days in a water tank.

3.3 TEST METHODS: -

A series of tests were performed. Testing was done for compressive strength at three different time intervals: three days, seven days, and 28 days; cylindrical compressive strength at 28 days; flexural strength at 28 days; rapid chloride penetration test (RCPT) at 28 days; rapid chloride migration test (RCMT) at 49 and 52 days; and water permeability test (WPT).

IS-516 (1969), IS-5816, ASTM C-1202, NT Build 492, BS EN 12390-8, BS-1881 were followed for said tests.

IV. RESULTS AND DISCUSSION: -

Abstract of M45 Grade Concrete and Test Results comparison of CMD-A (With GGBS) & CMD-B (Without GGBS) are as follows,

Table 4.1 Abstract of M45 Grade Concrete and Test Results Comparison

Sr. No.	Description of Test	IS Standard/ Specification	Test Results Achieved for CMD-B (Without GGBS)	Test Results Achieved for CMD-A (With GGBS)	Specification Limits
1	3 Days Compressive Strength	Specification/IS: 516	13.1	32.25	-
2	7 Days Compressive Strength	Specification/IS: 516	37.4	42.99	-
3	28 Days Compressive Strength	Specification/IS: 516	62.10	55.29	> 53.25 Mpa
4	Cylinder Compressive Strength	Specification/IS: 516	74.02	68.36	> 53.25 Mpa
5	Flexural Strength	Specification/IS: 516	6.47	7.71	> 4.69 Mpa
6	Split Tensile Strength	Specification/IS: 5816	3.43	3.77	> 2.76 Mpa
7	Rapid Chloride Permeability Test	ASTM C 1202/ AASHTO T277	1541	783	< 1000 Coulombs
8	Chloride Migration	NT Build 492	13.140	1.670	< 2 x 10-12 m2/s
9	Water Permeability Test	BS EN 12390-8:2000 /DIN1048 Part 5:1996	8.98	4.55	< 10 mm

Cubic samples were tested for compressive strength at 3-, 7-, and 28-days age, respectively. For concrete mix proportion CMD-A & CMD-B, it is observed that the average compressive strength at 3 days for cubic specimens was 13.1 Mpa and 32 Mpa respectively; At 7 Days, it was 42.99 Mpa and 37.4 Mpa respectively. And for 28 days it was 55.29 Mpa and 62.10 Mpa, respectively. Table 4.1 displays the outcomes of the compressive strength test.

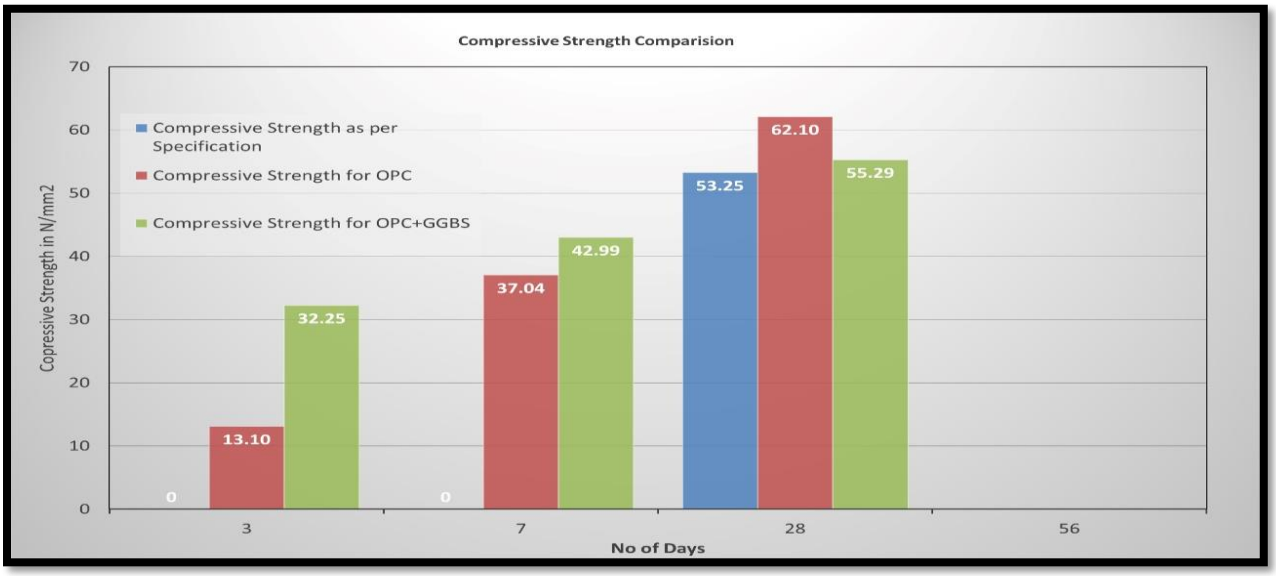


Fig. 1 Compressive Strength vs Age Test Results

It was discovered that the compressive strength of CMD-A (With GGBS) increased at age of 03 & 07 days compared to CMD-B (Without GGBS) however compressive strength of CMD-B increased at age of 28 Days compared to CMD-A.

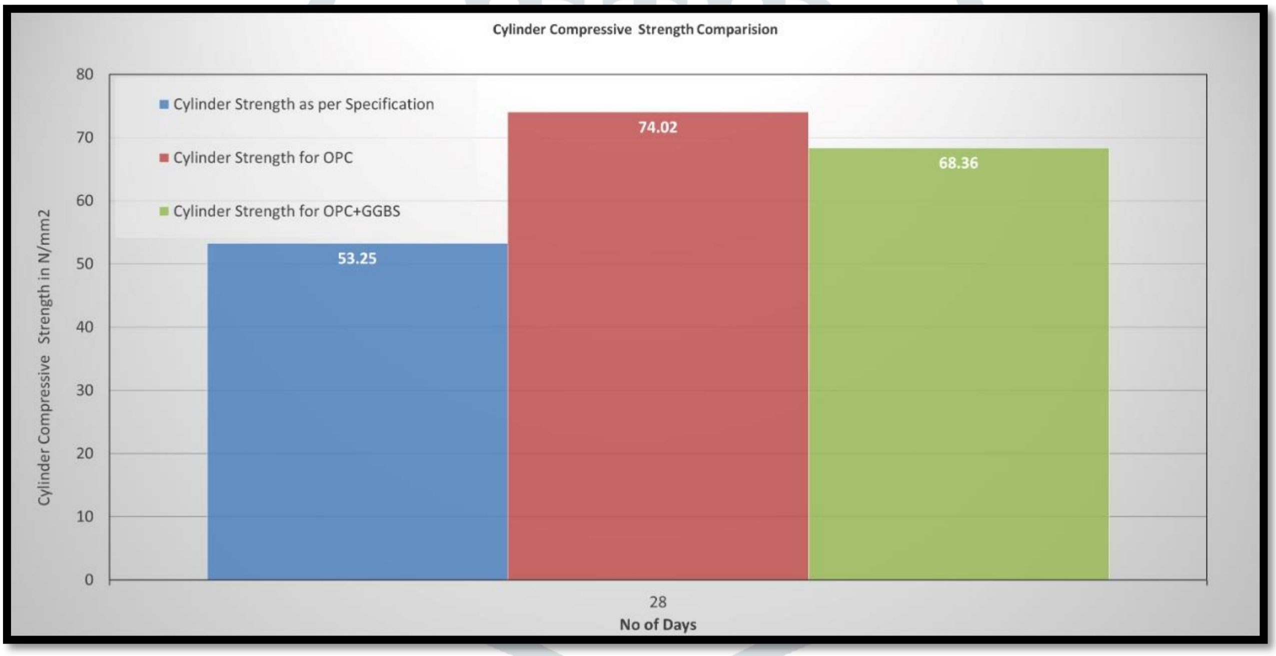
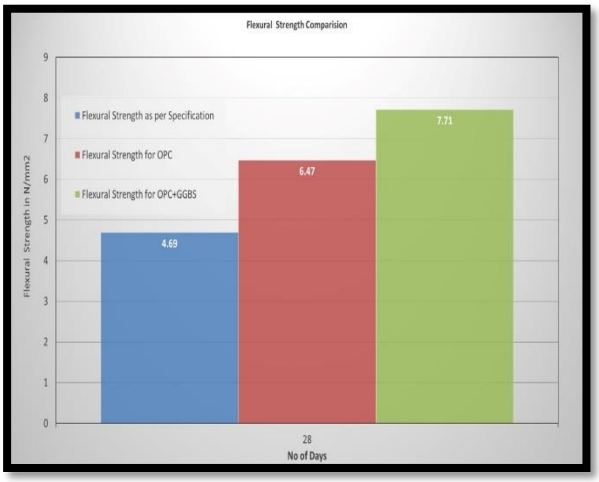


Fig. 2 Cylindrical Compressive Strength vs Age Test Results

Further it was discovered that Cylindrical compressive strength of CMD-B (74.02 Mpa) increased at age of 28 Days as opposite to CMD-A (68.36 Mpa).

At the age of 28 days, tests for flexural strength and split tensile strength were performed. For concrete mix proportion CMD-A & CMD-B, it is detected that Flexural strength was 6.47 Mpa and 7.71 Mpa respectively as well as 3.77 Mpa and 3.43 Mpa respectively.



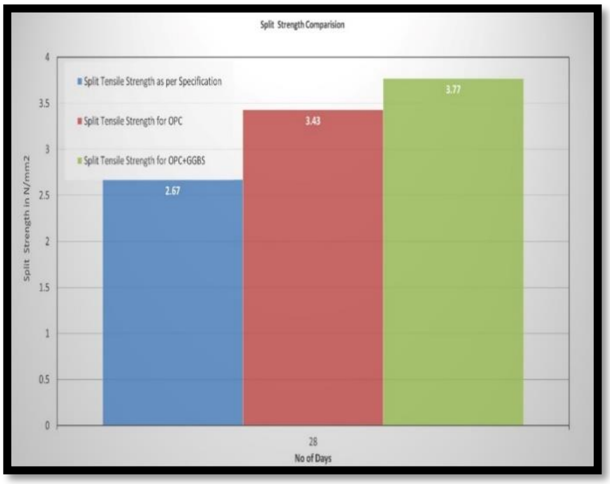


Fig. 3 & 4 Flexural Strength vs Age Test & Split Tensile Strength vs Age Test Results

It was discovered that CMD-A (With GGBS) had higher split tensile and flexural strengths at age 28 days than CMD-B (Without GGBS).

After 28 days of curing, an RCPT (rapid chloride penetration test) was performed. Table 4.2 demonstrates that the barrier to chloride penetration increases with decreasing charge passed.

Table 4.2 Performance of Chloride Permeability Based Totally on Charge Passed.[03]

Chloride Permeability	Charges Passed (coulombs)
High	> 4000
Moderate	2000 - 4000
Low	1000 - 2000
Very low	100 - 1000
Negligible	< 100

For CMD-A, specimens cast with GGBS shows 49.18% reduction in charge passed than CMD-B which specimens cast without GGBS. That clearly shows the use of GGBS as mineral admixture is effective. GGBS reduces the permeability of the chlorides by creating strong, dense, and impermeable structural surfaces.

The concrete mix with GGBS as a substitute to the cement is showing great reduction in chloride penetration compared to concrete mix without GGBS. (CMD-A = 783 Coulomb & CMD-B=1541 Coulomb)

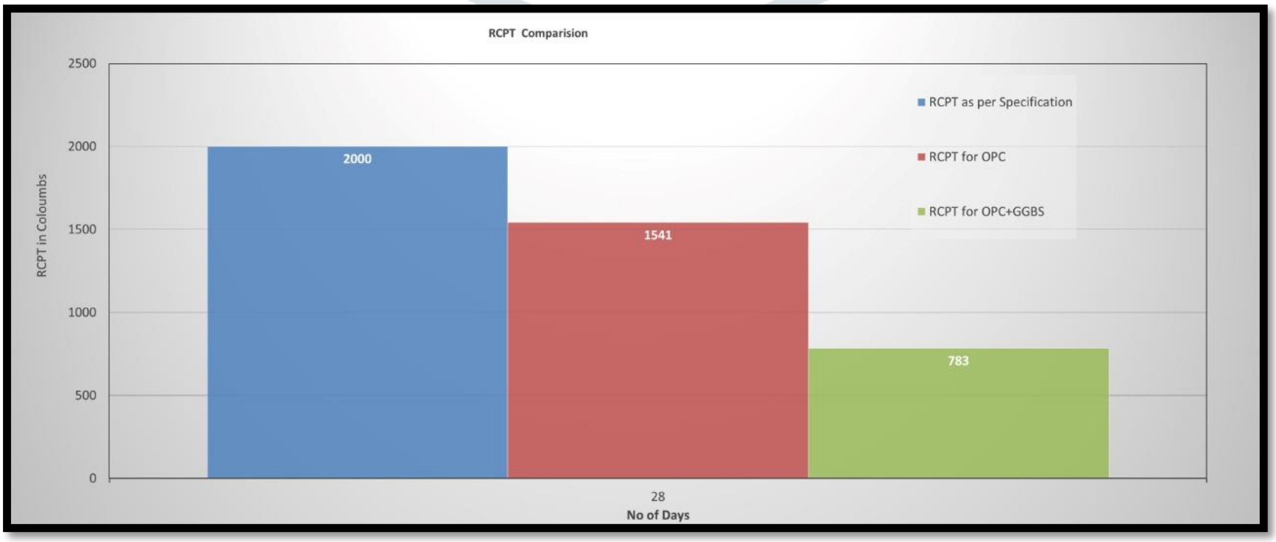


Fig. 5 RCPT Test Results - Coulombs Passed.

This shows that the use of GGBS- Ground granular blast furnace slag i.e., industrial waste/by-product from steel manufacturing industries as mineral admixture in concrete mix is helpful to reduce the chloride penetration.

After 28 days of cure, the WPT—Water Permeability Test—was performed. By using this test method, continuous hydrostatic pressure of 5 bar for 72 hours is used to assess the depth of the water penetration. For CMD-A, specimens cast with GGBS shows 49.33% reduction in water penetration than CMD-B which specimens cast without GGBS. That clearly shows the use of GGBS as a mineral admixture is effective. GGBS reduces the water permeability of the concrete by creating strong, dense, and impermeable structural surfaces.

The avg. water penetration depth for CMD-A (With GGBS) was 4.55 mm & for CMD-B (Without GGBS) was 8.98 respectively. Outcomes shows a great reduction in water penetration for concrete mix with GGBS as a substitute to the cement compared to concrete mix without GGBS which increases the durability of structures.

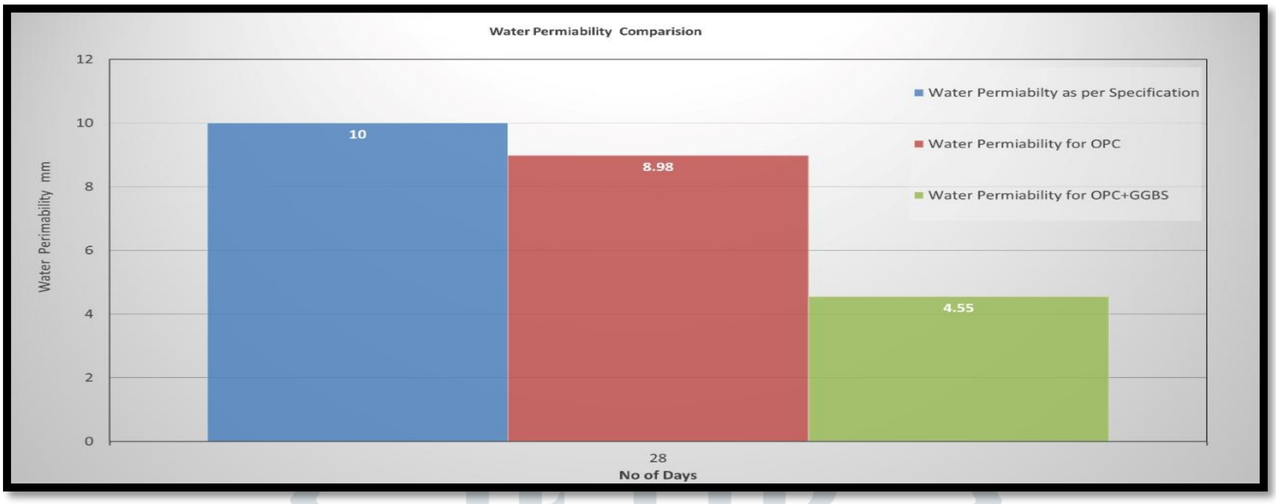


Fig.6 WPT-Water Permeabilities Results – Avg. Water Penetration Depth

This shows that the use of GGBS- Ground granular blast furnace slag i.e., industrial waste/by-product from steel manufacturing industries as mineral admixture in concrete mix is helpful to reduce the water penetration and improve the durability of structure.

RCMT- Rapid Chloride Migration Test was performed on CMD-A and CMD-B after 53 and 49 days of cure, respectively. The no-stationary chloride ions migration coefficient is supported by the NORDTEST NT BUILD 492 [11] standard. To endorse the chloride ions' entry into the concrete, an electric current is therefore generated. This test measures the material's ability to physically resist the entry of chloride and other hazardous ions into its matrix, which has to do with its penetrability and sponginess properties. The samples fit into cylinders with a 100 mm diameter and 50 mm height that are prepared in accordance with ASTM C1202 requirements. Alternate immersions in sodium hydroxide and sodium chloride solutions are used during the elucidation phase. The test was settled at 30 V recordkeeping the current. After the test was complete, the sample was split in half and given a top-down application of silver nitrate. In the presence of chloride ions, a white silver nitrate film forms. As the average of seven measurements made at the sample's breadth, the depth of chloride penetration is calculated. The sample width, exposure period, voltage, and average temperature are used to compute the migration coefficient along with the depths of the chloride ions' penetration. NT Build 492 classification of the chloride ions ingress resistance is displayed in Table 5.

Table 5 Classification of the chloride ions ingress resistance according to NT Build 492[03].

Migration coefficient (Dnssm) x 10^{-12} m^2/s	Chloride ions ingress resistance
>15	Low
10 – 15	Moderate
5 – 10	High
2.5 – 5	Very high
< 2.5	Extremely high

The avg. chloride migration value for CMD-A (With GGBS) was 1.67 x 10-12 m2/sec & for CMD-B (Without GGBS) was 13.14 x 10-12 m2/sec respectively. Outcomes shows great reduction in chloride ions ingress resistance for concrete mix with GGBS as a substitute to the cement compared to concrete mix without GGBS which increase durability of structures.

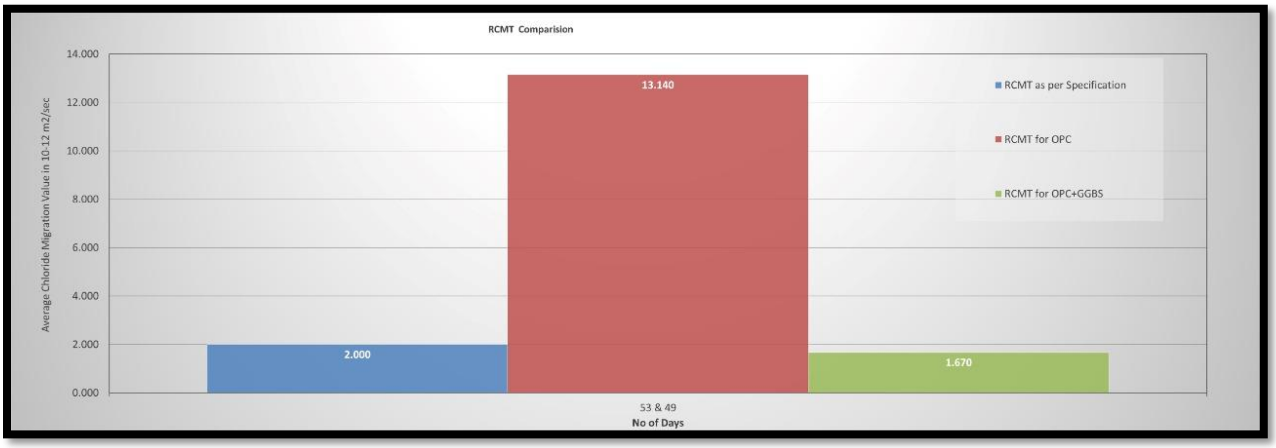


Fig. 7 RCMT-Rapid Chloride Migration Test Results – Average Chloride Migration Value

This shows that the use of GGBS- Ground granular blast furnace slag i.e., industrial waste/by-product from steel manufacturing industries as mineral admixture in concrete mix is helpful to reduce chloride iron attack over the concrete and improve the durability, life span of structure.

V. CONCLUSION: -

According to the study, mineral admixtures, such as GGBS, are reactive binder elements just like cement and can be utilized in concrete as a partial substitute.

Concrete's mechanical and durability capabilities were enhanced when it contained by-product trash like GGBS. The compressive strength of the cubic specimens cast with CMD-A (With GGBS) was higher at 3 and 7 days than that of the specimens cast with CMD-B. (Without GGBS). CMD-compressive B's strength is greater than CMD-at A's age 28 days.

The specimens cast CMD-A (With GGBS) showed 49.18% reduction in charges passed in Rapid Chloride Penetration test (RCPT). This shows reduction in chloride penetration through the surface. Results of WPT- Water Permeability Test shows great reduction i.e., 49.33% in water penetration for concrete mix with GGBS. It was clearly showing the use of GGBS as mineral admixture is effective. GGBS reduces the permeability of the chlorides by creating strong, dense, and impermeable structural surfaces. Results of RCMT-Rapid Chloride Migration Test shows great reduction in chloride ions ingress resistance for concrete mix with GGBS as a substitute to the cement compared to concrete mix without GGBS which protect structure from chloride attack, deterioration and increase durability of structures.

The experiment was carried out with Concrete Mix CMD-A by replacing cement with 51% of mineral admixture i.e., GGBS and with Concrete Mix CMD-B which was without mineral admixture like GGBS. It was crucial to keep in mind that the amount of waste or byproduct replacement significantly affected the characteristics of concrete. Using GGBS as partial replacement to cement lessens the expenses on (energy & cost) cement. It lessens consumption of overall quantity of cement in the industry which resulted into preserve natural resources and lessens landfill space. As a result, sustainability is improved by reducing overall carbon emissions and waste. Green Concrete Technology, which has low emissions of carbon dioxide and carbon monoxide into the environment directly or indirectly, is created when cement is replaced with GGBS-Ground Granulated Blast Furnace Slag.

The use of mineral admixture makes the concrete mix cohesive, dense and improves workability. Use of GGBS in concrete makes structures denser and thus improve their durability.

VI. ACKNOWLEDGMENT: -

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