Effect of FLYASH and GGBS on the Mechanical Properties of Green Concrete

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Abstract:

Concrete is a fundamental material in construction, demanding high strength and workability for modern engineering structures. However, conventional cement production contributes significantly to CO2 emissions, prompting the exploration of eco-friendly alternatives. Several industrial by-products, such as fly ash, ground granulated blast furnace slag (GGBS), silica fume, and metakaolin, have cementitious qualities and can be used as binding agents in concrete. In our research, we aim to find ways to substitute cement for these by-products, particularly fly ash and GGBS, in concrete production in order to reduce cement consumption. Blast furnaces produce GGBS, a fine powder that is subsequently ground into fine powder as a byproduct. Fly ash has pozzolanic qualities, but it also provides pozzolanic materials that can be utilized to make cement. Industrial by-products like fly ash and ground granulated blast furnace slag (GGBS) offer promising substitutes for traditional cement. This study investigates the incorporation of 20% fly ash and 30% GGBS into concrete, evaluating its mechanical properties over 7, 14, and 28 days. Results show that green concrete exhibits comparable or superior compressive, flexural, and split tensile strengths to conventional concrete, with lower carbon emissions and cost. The study underscores green concrete's potential as an environmentally sustainable and cost-effective alternative in construction.
Keywords: Concrete, green concrete, ground granulated blast furnace slag (GGBS), sustainability, compressive strength, flexural strength, split tensile strength, carbon emissions

Introduction

Concrete, a fundamental material in construction, faces increasing demands as engineers tackle more complex projects. With its indispensable role, concrete must exhibit both strength and workability. However, traditional cement production contributes significantly to CO2 emissions, urging the exploration of eco-friendly alternatives. Industrial waste materials like fly ash and ground granulated blast furnace slag (GGBS) offer promising solutions. In our study, we investigated substituting cement with these by-products in concrete production, aiming to reduce environmental impact. Our research involved creating concrete samples with varying ratios of fly ash and GGBS in lieu of cement. Testing revealed that concrete containing 20% fly ash and 30% GGBS exhibited superior compressive strength and workability compared to conventional concrete. Moreover, this "green" concrete demonstrated improved flexural and splitting tensile strength. Our findings highlight the potential of fly ash and GGBS to enhance concrete's mechanical properties in an environmentally and cost-effective manner, paving the way for a more sustainable construction industry.

Components of Green Concrete

A wind turbine consists of several key components:

- **Fly Ash**: Produced from coal combustion, fly ash possesses pozzolanic properties, improving concrete workability, reducing water demand, and enhancing long-term strength.

- **Ground Granulated Blast Furnace Slag (GGBS)**: A byproduct of iron and steel production, GGBS acts as a cementitious material, lowering heat of hydration, enhancing performance, and improving resistance to chemical degradation.

- **Silica Fume**: Also known as micro-silica, silica fume, a byproduct of silicon metal or ferrosilicon alloys manufacturing, enhances concrete durability, abrasion resistance, and compressive strength.

- **Metakaolin**: Produced by calcining kaolinite clay, metakaolin strengthens concrete durability, refines pore structure, and increases resistance to chemical attack.
• Recycled Aggregates: Obtained from crushed concrete and masonry waste, recycled aggregates reduce reliance on natural aggregates, aiding waste management and contributing to sustainability.
• Rice Husk Ash: A byproduct of rice milling, rice husk ash improves concrete workability, strength, and durability while managing agricultural waste.
• Volcanic Ash: A natural pozzolan, volcanic ash enhances concrete resilience against alkali-silica reaction and sulphate attack, as well as improving strength and durability.
• Other Additives: Various materials like slag, calcined shale, and natural pozzolans contribute to concrete sustainability and performance by enhancing properties and reducing reliance on traditional cement.

Environmental Impact of Conventional Concrete

Despite its benefits, conventional concrete production has significant environmental drawbacks:

• Cement production is a major source of carbon dioxide emissions, representing about 8% of the world's CO2 emissions. This is mostly because making cement requires a lot of energy during the calcination process.
• The extraction of raw materials like limestone, clay, sand, and gravel leads to landscape alteration, habitat destruction, and resource depletion.
• Cement production requires substantial energy, contributing to its environmental footprint. The high-temperature kilns used in the production process are energy-intensive.

Ground Granulated Blast Furnace Slag (GGBS)

A by-product of producing iron in a blast furnace is ground granulated blast furnace slag. Melting iron ore, coke, and limestone at high temperatures results in the formation of molten slag, a non-metallic residue. This slag is quickly cooled by quenching it in water, forming a glassy, granular substance that is subsequently dried and ground into GGBS, a fine powder. Figure 1 shows that GGBS is a great supplementary cementitious material (SCM) because it possesses cementitious properties, which allow it to react with water and calcium hydroxide, a byproduct of Portland cement hydration, to form cementitious compounds. Concrete treated with GGBS has better workability, increased durability, and resistance to chemical attacks (like sulphate and chloride). In addition, because GGBS requires less energy and emits fewer greenhouse gases than Portland cement, it lowers the heat of hydration and prevents thermal cracking in large concrete pours.

Objectives of the Present Investigation

• In this Present study the comparison between conventional concrete and green concrete with 20% Fly Ash and 30% GGBS for Compressive strength, Splitting Tensile strength test and Flexural strength test.
• To investigate the mix proportions of conventional concrete and green concrete using concrete grade M25 and M30 with different age 7, 14 and 28 days
• Determine the workability of using Slump Cone Test.
• Also find Cost of conventional concrete and green concrete.
Literature Review

Al-Mansour et al. (2019): Concrete's widespread use has left a huge carbon footprint on our surroundings due to horrendous consumption patterns. As well as the depletion of natural resources, a large amount of carbon dioxide (CO2) is released into the atmosphere during the fabrication of natural materials. A sustainable solution involves recycling or replacing ordinary Portland cement (OPC) and natural aggregates, the key components of concrete. The carbon footprint here is being reduced by using by-products like fly ash, rice husk ash, and silica fume, recycled coarse aggregate, pulverized granular blast furnace slag, scrap glass, and plastic.

Chandio et al. (2020): Explored the use of fly ash and demolition debris in green concrete mixes, finding that a combination of 50% recycled aggregate and 5% fly ash yielded superior results in terms of compressive. In green concrete that has been partially replaced by demolition debris, fly ash is used as a replacement for some of the traditional coarse aggregates. Research on green concrete, which is made from waste materials, is ongoing because it can help with environmental protection and waste management problems. Six concrete mixes were made with a 1:2:4 ratio; fly ash was added in increments of 2.5% from 0% to 10% of the conventional aggregates, while demolition debris was utilised in equal amounts with them.

Bakhous et al. (2023): Investigated the integration of green concrete and artificial intelligence for sustainable construction. Developed prediction models using artificial neural networks and multiple linear regressions to optimize concrete mix designs, considering factors like compressive strength, CO2 emissions, and cost. Recommended optimal ranges of fly ash and cement kiln dust for sustainable concrete production.

Hashmi et al. (2023): Discussed the sustainability benefits of green concrete, emphasizing the use of alternative materials like fly ash, slag, and recycled aggregates to reduce CO2 emissions and resource consumption in concrete production. Identified knowledge gaps regarding the long-term behavior of green concrete.

Sivakrishna et al. (2024): Addressed the sustainability crisis in the concrete industry due to CO2 emissions and depletion of natural resources. Highlighted the importance of incorporating novel materials like alkali-activated binders and recycled concrete to enhance the durability and sustainability of concrete.

Tural et al. (2024) According to the study, the ideal replacement percentages for GGBS, fly ash, and silica fume in concrete mixtures are 15–50%, 10–35%, and 5–15%, respectively. The study also showed that using these replacements resulted in a significant decrease in carbon emissions, which were between 13% and 43% for GGBS, 9–31% for fly ash, and 4–13% for silica fume. The study offers a cleaner disposal route for pozzolans, primarily when compared to traditional waste management alternatives, and makes a significant contribution to the development of greener construction materials.

Qu et al. (2024) By this study examined the functions of wood waste biochar in augmenting the chloride immobilization capacity (CIC) of GGBS-blended cement (PG) composites. The findings showed that the chloride immobilization ratio (CIR) of PG composites increased initially before declining as the dosage of biochar increased. With 2.0 weight percent biochar, PGBC2 had the highest CIR. The addition of biochar enhanced the production of Friedel's salts, which in turn enhanced the chemical chloride immobilization in the PG composites, according to microscale characterization. These results provide new understandings of how to use wood waste biochar to strengthen the longevity of concrete structures mixed with GGBS in environments high in chloride.

Yuanliang et al. (2024) This study looks at how fly ash and Portland cement pore formation impacts the functionality of hybrid alkali-activated foamed concrete (HAAFC). According to the results of the experiments, adding Portland cement speeds up the hydration process, shortens the time it takes for bubbles to
become pores, and prevents defoaming. Additionally, because of the increased matrix yield stress, the Portland cement in HAAFC improves foam stability and reduces bubble diameters. HAAFC's drying shrinkage can be moderated by adding Portland cement and fly ash, which can increase the crystalline phases and decrease the percentage of mesopores (2 nm \(\leq r \leq 50\) nm). Alkali activated foamed concrete may eventually be replaced by the 20% cement, 60% GGBS, and 20% FA HAAFC, which has low drying shrinkage, high foam stability, and a slightly lower compressive strength.

Dinh et al. (2024) This study looked into the use of ground granulated blast-furnace slag (GGBFS) as a binder and waste glass cullet (WGC) as fine aggregate in fly ash (FA) based geopolymer concrete. The intrinsic properties of WGP, WGC, FA, and GGBFS can be considerably changed by a number of variables, including impurity level, sources, combustion temperatures, and particle size.

The paper shows at ten different groups: five groups used WG in place of fly ash at different percentages (0, 10, 20, 30, 40%); five groups used WG in place of sand with different fly ash to slag ratios (20, 40, 60, 80%). Leaching tests show that while Si only shows activity in high-temperature environments, Ca from WGP, WGC, FA, and GGBFS readily leaches out and reacts in both ambient and oven curing conditions. Overall, compressive strength and water absorption showed improvements in the reactivity of Ca from GGBFS and WG of up to 50% and 30%, respectively. Furthermore, the most efficient molar ratios (Si/Al=3.5–4) showed the highest compressive strength (60–70 MPa) based on the alkali leaching test, and this was thoroughly confirmed using scanning electron microscopy–energy-dispersive spectroscopy (SEM-EDS). Finally, this study showed that a considerable amount of Ca was also leached out of WGC as fine aggregate with a size of 20 µm during the geopolymerization process.

Venkitasamy et al. (2024) This study examines the mechanical and durability characteristics of heavy weight concrete (HWC) with a strength grade of M50. Fly ash and slag are used in place of cement at percentages of 15%, 25%, and 35%, and 40%, 50%, and 60%, respectively. Compressive strength, elastic modulus, flexural and split tensile strengths are among the mechanical properties that were examined. Water permeability, drying shrinkage, and carbonation behavior are examples of durability properties. While longer curing increases the mechanical strength and water permeability of fly ash and slag blended HWCs, fly ash replacement somewhat lowers the HWC's modulus of elasticity. Fly ash and slag-based HWCs' elastic modulus was calculated using a straightforward relationship based on their density and compressive strength, and the estimated values closely matched the outcomes of the experiment. According to experimental research, all fly ash-based HWCs (15–35%) have shorter long-term drying shrinkage strains than all slag- and ordinary Portland cement (OPC)-based HWCs (100%). Estimating the shielding thickness of HWC members can be done using the hardened density variations of fly ash and slag blended concretes exposed to a long-term controlled environment that are covered in this paper. According to estimated accelerated carbonation coefficients (kacc) for all varieties of HWCs, the carbonation resistance of HWC made with 40% slag and 15% fly ash is similar. The rate at which fly ash and slag are replaced rises in proportion to the accelerated carbonation of HWCs. Apart from the increased rate of carbonation, the calcium carbonate content, as determined by micro analytical studies, also indicates that a higher replacement level of slag considerably lowers the carbonation resistance of HWC. The use of geopolymer concrete in industry is growing. Nevertheless, the performance of the blended geopolymer concrete is frequently severely constrained by the characteristics of the single percussion instrument. Therefore, using several percussors to create geopolymer concrete is preferred. The residual micro- and macro-mechanical properties of the steel-fibre reinforced geopolymer concrete blended with fly ash, salic fume, and ground granulated blast ash, salic fume, and ground granulated blast-furnace slag are the subject of an experimental study reported in this paper.
Pan et al. (2024) In this study, fly ash, ground granulated blast-furnace slag (GGBS), and steel slag were used as the primary matrix materials for the preparation of low-carbon, environmentally friendly NSC. Cement was used as a binder, and water glass and dihydrate gypsum were added as alkali activators. The performance of NSC was investigated and examined through the comparison of the single factor experiment and the orthogonal experiment, and the NSC's best preparation plan yielded outstanding results. In order to investigate and validate the functionality of NSC, the composition and structural mechanism of NSC were seen and examined using scanning electron microscopy (SEM) and X-ray diffraction (XRD). After taking into account the cylinder compressive strength, bulk density, specific surface area, and one-hour water absorption, it was found that the prepared NSC performs best when the water consumption is 35%, the cement dosage is 10%, and the steel slag: GGBS and fly ash: GGBS = 1:1. The NSC cylinders had compressive strengths of 4.2 MPa and 12.4 MPa, respectively, and a water absorption rate of 13% after one hour. This suggests that the NSC prepared using fly ash and GGBS as the matrix material had superior overall performance. The development of NSC strength is better served by the steam curing method. Controlling the steam curing time at 12 hours makes more sense in light of the current circumstances. By using an orthogonal test analysis, the ideal alkali activator dosage for NSC was found to be 3% for water glasses and 5% for dihydrate gypsum. Additionally, the ideal steam curing temperature was found to be 60 °C. This study made use of high doping and low activity steel slag, which allowed for a thorough examination and comprehension of the recycling of solid waste, and to some extent resolved the issue of steel slag's difficulty in being used and treated for an extended period of time.

Sikder et al. (2024) An industrial waste product of the cupola furnaces used to produce cast iron is called cupola slag. The casting industry's manufacturers have the burden of disposing of cupola slag. Using cupola furnace slag (CFS) for repurposing in the building industry is the purpose of this experimental study. CFS is used as coarse aggregate (CA) in concrete of the M20 grade in a gradual replacement of 0–50 wt.% by 10 wt.% step by step. After the required number of days for curing, the CFS-based concrete was assessed for durability and mechanical properties. Experimental results showed that the dry density of concrete decreased as the weight percentage of CFS in concrete increased. For the M20 grade of concrete, cast samples with a partial replacement of CFS of up to 40 weight percent satisfy the specifications in terms of compressive strength. As with the compressive strength, the split tensile strength showed a comparable trend. Concrete's depth of water penetration increases as its CFS weight percentage increases, according to durability tests. A rapid chloride penetration test, on the other hand, shows that the penetration of chloride ions decreases as CFS percentage increases in the concrete. A FESEM, EDS, and an XRD analysis were performed on the CFS-based concrete to investigate its microstructure, elemental composition, and phase characteristics. The analysis shows that CFS is a good substitute for natural CA in concrete and is a sustainable material.

Methodology

Mix designs are performed according to IS: 10262-2019. In the M25 grade, the proportions are 1:1:2 with a w/c of 0.45. In the M30 grade, the proportions are 1:0.75:1.5 with a w/c of 0.45. Total 28 samples of mixes for each grade are adopted in the laboratory.

Requirements Material for Compressive Strength

A concrete’s Compressive Strength Characteristics refers to the strength under which not more than 5% of the test’s results will fail. Concrete structures are designed and quality controlled based on this parameter. Materials used in concrete mix must meet specific requirements to achieve the desired compressive strength. These materials typically include cement, aggregates, water, and admixtures. In table 1. the materials and specifications for the
concrete mix include Grade M25 and M30, OPC (43 grade) cement, 20mm maximum size of aggregate, 80mm slump for workability, good quality control measures, severe exposure conditions, and the use of super plasticizer as the chemical admixture.

<table>
<thead>
<tr>
<th>S. no</th>
<th>Materials</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Grade of Concrete</td>
<td>M25 and M30</td>
</tr>
<tr>
<td>2</td>
<td>Type of cement</td>
<td>OPC (43 grade)</td>
</tr>
<tr>
<td>3</td>
<td>Max size of aggregate</td>
<td>20mm</td>
</tr>
<tr>
<td>4</td>
<td>Degree of workability</td>
<td>80mm (slump)</td>
</tr>
<tr>
<td>5</td>
<td>Degree of quality control</td>
<td>Good</td>
</tr>
<tr>
<td>6</td>
<td>Type of exposure</td>
<td>Severe</td>
</tr>
<tr>
<td>7</td>
<td>chemical admixture type</td>
<td>Super plasticizer</td>
</tr>
</tbody>
</table>

**Table 1. Requirements Material**

A concrete's workability determines the ease with which it can be mixed, placed, compacted, and cured. There are several standard tests that can be used to assess the workability of conventional concrete and green concrete. This section discusses the tests and their relevance for conventional concrete and green concrete containing 20% fly ash and 30% GGBS.

**Figure 2. Flow Chart of Fresh Concrete**
a) Acceptance Criteria of Workability

Fresh concrete can be tested for workability using the slump cone test. Placement, compacting, and finishing concrete without segregation or excessive effort requires workability. The acceptance criteria for workability using the slump cone test vary depending on the type of construction, environmental conditions, and specific requirements of the project.

<table>
<thead>
<tr>
<th>Acceptance Criteria</th>
<th>M25 Conventional Concrete</th>
<th>M25 Green Concrete</th>
<th>M30 Conventional Concrete</th>
<th>M30 Green Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slump Flow (mm)</td>
<td>75</td>
<td>80</td>
<td>70</td>
<td>80</td>
</tr>
<tr>
<td>Admixture (%)</td>
<td>0.55%</td>
<td>0.5%</td>
<td>0.55%</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

Table 2. Acceptance Criteria of Workability of M25 and M30

For M25 grade conventional concrete, the slump flow should be 75mm, while for green concrete, it's slightly higher at 80mm. The admixture percentage for conventional concrete is 0.55%, whereas for green concrete, it's slightly lower at 0.5%. For M30 grade conventional concrete, the slump flow requirement is 70mm, while for green concrete, it matches M25 at 80mm that shows in table 2. The admixture percentage remains the same for both at 0.55% for conventional and 0.5% for green concrete.

b) Procedure of Compressive Strength Test of Concrete Cubes

- In this study, M-25 and M-30 concrete grades were used. According to IS: 10262 specifications, the mix design was carried out. A concrete mixer was used to mix the concrete.

- A concrete cube of 150mm by 150mm by 150mm was cast. Afterwards, the specimen was demoulded for 24 hours and immersed in a curing tank filled with water, where it was cured for 7, 14 and 28 days.

- Tests were conducted on each concrete grade of M-25 and M-30 after seven, fourteen, and 28 days of curing.

c) Shape and Size of Specimen

Cube-shaped specimens are commonly used for compressive strength testing. Figure 3 shows that specimens have flat and parallel faces to ensure accurate measurement of compressive strength. Standard sizes for these cubes are typically 150 mm x 150 mm x 150 mm.

![Figure 3. Making Cube in the Laboratory for Present Investigation](image-url)
**Hardened Concrete Test**

Hardened concrete refers to the state of concrete after it has undergone the chemical process of hydration and has set and developed sufficient strength to perform its intended structural function. This stage typically occurs after the initial setting phase, which can range from a few hours to several days after placement, depending on the mix design, ambient conditions, and curing process.

- **Compressive strength test**

Most hardened concrete tests are conducted on its compressive strength because it is straightforward and many of its desirable properties are closely related to it. A cubical or cylindrical specimen is tested for this test. The most common method of measuring compressive strength is to use cube specimens that have dimensions of 150 x 150 x 150 mm that can fit inside a cube box.

![Figure 4. Cube Testing in the Laboratory for Present Investigation](image)

- **Split tensile strength Test**

The Split Tensile Strength Test is used to test the tensile strength of concrete specimens. Since these properties affect cracking and tensile strength, it is very important to determine the capability of a material. The specimen is compressed under a diametric load until it fractures. Typically, 150 x 150 x 150 mm cubes are used for this purpose.

![Figure 5. Cylinder Testing in the Laboratory for Present Investigation](image)

- **Flexural strength Test**

The modulus of rupture measures how hard a material will become under bending or flexure. In the realm of concrete, flexural strength signifies the material's capacity to withstand deformation or cracking under bending loads. This property holds particular significance in scenarios where concrete elements like beams or slabs encounter bending forces. In order to determine flexural strength, a standardized test called the flexural or modulus of rupture is typically conducted. Tests consist of bending concrete specimens resembling prismatic beams until failure occurs. Flexural strength is measured at the point of failure after the maximum stress has been observed. It is more common to test flexural strength using prismatic beam specimens instead of 150 x 150 x 150 mm cube specimens.
Result and Discussions

Compared to conventional concrete, green concrete containing 20% Fly Ash and 30% GGBS showed higher compressive strength, splitting tensile strength, and flexural strength. The experimental procedure involved using a compression testing machine to evaluate the performance of the concrete samples. Standard concrete cubes were prepared with different mix proportions to achieve the target strengths of M25 and M30 MPa. We tested the compressive strength, split tensile strength, and flexural strength of these cubes. There were differences in mechanical properties between conventional concrete and green concrete.

Graph: 1 showing for conventional and green concrete, compressive strength results were analyzed at intervals of 7, 14, and 28 days. According to tests done on conventional concrete, the compressive strength was 21.2 MPa at 7 days, 26.9 MPa at 14 days, and 32 MPa at 28 days. At 7 days, 16.7 MPa was observed in green concrete that contains 20% fly ash and 30% GGBS as replacements. At 14 days, 28.1 MPa was observed in green concrete, and at 28 days, 33.4 MPa was observed in green concrete. These results indicate that while the initial strength of green concrete is lower at 7 days, it surpasses the conventional concrete by the 28-day mark, demonstrating its effectiveness and potential for sustainable construction.

Graph: 2 showing both conventional and green concrete were measured for compressive strength at 7, 14, and 28 days for M30 grade concrete. During the first seven days of compression, conventional concrete had a compressive strength of 23.9 MPa, 25.5 MPa, and 37.9 MPa, while after 28 days it had a compressive strength of 37.9 MPa. At 7 days, 21.7 MPa was the compressive strength of the green concrete containing 20% fly ash and 30% GGBS. After 14 days, it reached 27.7 MPa and 39.2 MPa. These results indicate that while the green concrete has slightly lower strength at 7 days compared to the conventional concrete, it
achieves higher strength by 14 and 28 days. This demonstrates the green concrete's potential for achieving superior long-term performance while contributing to sustainable construction practices.

Graph 1. Comparatively Results of Compressive Strength for Conventional and Green Concrete with 7, 14 and 28 Days for M25

Graph 2. Comparison of the Compressive Strength of Conventional Concrete and Green Concrete with 7 Days, 14 Days, and 28 Days for M30
Graph 3. For M25 Concrete, a Comparison of Flexural Strength of Conventional Concrete and Green Concrete after 7, 14 and 28 Days is Presented

Graph: 3 Showing that Both conventional and green concrete were tested for flexural strength at 7, 14, and 28 days. Flexural strength values for conventional concrete were 3.3 MPa after 7 days, 4.2 MPa after 14 days, and 4.8 MPa after 28 days. During the following periods, the flexural strength values of the green concrete were 2.4 MPa per 7 days, 3.4 MPa per 14 days, and 4.2 MPa per 28 days. The green concrete includes 20% fly ash and 30% GGBS as replacements. These results indicate that while the initial flexural strength of green concrete is lower than that of conventional concrete, it improves significantly over time, nearly matching the conventional concrete's performance by the 28-day mark.

Graph: 4 showing that the flexural strength results for M30 grade concrete were measured at

Graph 4. A Comparative Study of the Flexural Strength of Conventional and Green Concrete Built over 7 Days, 14 Days, and 28 Days
7, 14, and 28 days for both conventional and green concrete. For conventional concrete, the flexural strength values were recorded as 3.7 MPa at 7 days, 4.8 MPa at 14 days, and 5.9 MPa at 28 days. In comparison, the green concrete, which incorporates 20% fly ash and 30% GGBS as replacements, showed flexural strength values of 3.2 MPa at 7 days, 4.4 MPa at 14 days, and 5.3 MPa at 28 days. These results indicate that while the green concrete has slightly lower flexural strength at each testing interval compared to conventional concrete, it still achieves comparable performance by the 28-day mark. This suggests that green concrete, with its sustainable composition, can effectively reach a satisfactory level of flexural strength over time, making it a suitable alternative for environmentally friendly construction projects.

**Graph 5. Comparatively Results of Split Tensile Strength for Conventional and Green Concrete with 7, 14 and 28 Days for M25**

**Graph 6. Comparatively Results of Split Tensile Strength for Conventional and Green Concrete with 7, 14 and 28 Days for M30**
Graph: 5 showing that both conventional and green concrete were tested at 7, 14, and 28 days for split tensile strength. After 7 days, conventional concrete's split tensile strength was recorded at 2.2 MPa. After 14 days, it was found to be 2.6 MPa. After 28 days, it was found to be 2.9 MPa. At 7 days, 1.9 MPa, 2.4 MPa, and 2.8 MPa were achieved for the green concrete containing 20% fly ash and 30% GGBS replacements as replacements. The results show that green concrete does have a lower split tensile strength than conventional concrete at the beginning, but that its strength develops over time is similar to conventional concrete. By the 28-day mark, the split tensile strength of green concrete nearly matches that of the conventional mix. This indicates that green concrete, despite its initial slower strength gain, can achieve comparable long-term performance in terms of split tensile strength, making it a viable sustainable alternative in concrete construction.

Table 3 showing Comparatively Results of Compressive Strength, Flexural Strength, split Strength of Conventional Concrete and Green Concrete with 20% fly ash and 30% GGBS for M25 and M30 Grade in 7, 14 and 28 Days.

<table>
<thead>
<tr>
<th>Parameters</th>
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<th>M30</th>
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<tbody>
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<td>Conventional Concrete</td>
<td>Green Concrete</td>
</tr>
<tr>
<td>Compressive Strength in N/mm²</td>
<td>21.2 26.9 32</td>
<td>16.7 28.1 33.4</td>
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<tr>
<td>Flexural Strength in N/mm²</td>
<td>3.3 4.2 4.8</td>
<td>2.4 3.4 4.2</td>
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<tr>
<td>Split Tensile Strength in N/mm²</td>
<td>2.2 2.6 2.9</td>
<td>1.9 2.4 2.8</td>
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</table>

Table 4 shows a comparatively Results of CO2 Emissions and Cost-effectiveness conventional concrete, the cost is recorded at 3600. In contrast, the cost of green concrete, which includes 20% fly ash and 30% GGBS as partial replacements for traditional cement and aggregates, is lower at 3370 for M25 grade of concrete.

Table 4. Comparatively Results of CO2 Emissions and Cost-effectiveness

<table>
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<th>Parameters</th>
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<th>M30</th>
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<tbody>
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<td></td>
<td>Conventional Concrete</td>
<td>Green Concrete</td>
</tr>
<tr>
<td>Cost in Cubic meter</td>
<td>3600 ₹</td>
<td>3370 ₹</td>
</tr>
<tr>
<td>Carbon Emission in Cubic meter</td>
<td>264 224</td>
<td>280</td>
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</table>
Conclusion

In conclusion, the study compared conventional concrete with green concrete incorporating 20% fly ash and 30% GGBS, examining their compressive, flexural, and split tensile strengths, as well as cost and carbon emissions for M25 and M30 grades over different curing periods. Green concrete initially displayed slightly lower strength at 7 days but surpassed conventional concrete by 14 and 28 days, indicating its superior long-term performance potential. Moreover, the cost-effectiveness of green concrete was evident due to the use of industrial by-products like fly ash and GGBS, resulting in lower costs compared to conventional concrete. Additionally, green concrete significantly reduced carbon emissions, highlighting its sustainability. For conventional concrete, the carbon emissions are recorded at 280 kg CO2 per cubic meter. In contrast, the green concrete, which incorporates 20% fly ash and 30% GGBS, shows lower carbon emissions at 243 kg CO2 per cubic meter for M30 grade of concrete. These findings underscore the viability of green concrete as a suitable alternative for environmentally friendly construction projects, offering enhanced performance and sustainability compared to conventional concrete. Further studies could explore additional properties and applications of green concrete, contributing to the advancement of sustainable construction practices.

References


IS 10262: 2019 Indian Standard for Concrete Mix Design.

IS 383-2016 Indian Standard for Aggregates.

IS 456-2000 Indian Standard for Plain Concrete.

IS 9103-1999 Indian Standard for Admixtures.


