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Green Concrete for Better Sustainable Environment

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Abstract

The increasing demand for infrastructure has led to a significant rise in cement usage, contributing to environmental degradation due to high CO_2 emissions. Green concrete is an innovative alternative that incorporates industrial waste materials to reduce the environmental footprint of construction while maintaining structural integrity. This research investigates the use of supplementary cementitious materials (SCMs) such as fly ash, blast furnace slag, glass powder, gypsum, demolished aggregates, and plastic waste in M25 grade concrete. The properties of green concrete, including compressive strength and workability, were evaluated through standardized tests. The results show that green concrete demonstrates comparable strength and improved sustainability features when compared with conventional concrete. This study reinforces the potential of green concrete as a practical, durable, and eco-friendly construction material.

Keywords

Green Concrete, Fly Ash, Sustainability, Blast Furnace Slag, Supplementary Cementitious Materials, Compressive Strength

1. Introduction

Concrete is the most widely consumed construction material globally, forming the backbone of modern infrastructure, including buildings, bridges, roads, and dams. Despite its indispensable role in development, the production of concrete, particularly the manufacturing of its key ingredient cement has significant adverse environmental effects. Cement production is responsible for a considerable percentage of global carbon dioxide (CO_2) emissions, primarily due to the energy intensive processes involved and the chemical decomposition of limestone. As a result, the concrete industry faces increasing scrutiny for its contribution to climate change and environmental degradation. In an effort to address these challenges, the concept of green concrete was first introduced in Denmark. Green concrete focuses on replacing conventional concrete components with more sustainable alternatives, including industrial by-products such as fly ash, slag, silica fume, and recycled aggregates. These substitutions not only reduce the demand for natural raw materials but also help in managing industrial waste, thus minimizing the overall environmental footprint. This project is dedicated to the development, formulation, and testing of green concrete utilizing an M25 mix, a standard grade commonly used in general construction. The study aims to evaluate the mechanical properties, durability, workability, and overall performance of green concrete, while also quantifying its potential to significantly reduce CO_2 emissions. Ultimately, the project seeks to promote sustainable construction practices and demonstrate that green concrete can be a viable alternative to traditional concrete without compromising on quality or strength.

Green Concrete Cubes

2. Literature Review

Previous studies have consistently demonstrated that the incorporation of supplementary cementitious materials (SCMs) such as fly ash, ground granulated blast furnace slag (GGBS), and various recycled materials can significantly enhance the durability, mechanical performance, and sustainability of concrete. Research by Yu et al. (2016) revealed the mechanical efficiency and strength development of ultra-high volume fly ash concrete, showcasing its potential for structural applications while substantially lowering the carbon footprint associated with cement use. Similarly, Turk et al. (2015) provided strong evidence supporting the utilization of industrial by-products, including foundry sand and steel slag, in concrete production. Their findings indicated that these materials not only act as effective partial replacements for natural aggregates and cement but also contribute to improved long-term strength and resistance to environmental degradation.

Additionally, Liew et al. (2017) emphasized the environmental and technical advantages associated with green concrete mixtures, noting improvements in workability, resistance to chemical attacks, and overall durability. Their study also highlighted the reduced energy consumption and emissions associated with the use of recycled and industrial waste materials. Collectively, these research efforts establish a strong foundation for the broader integration of SCMs and recycled resources into concrete technology. Building upon these findings, the present project seeks to incorporate various SCMs into an M25 grade concrete mix, aiming to optimize mechanical properties while minimizing environmental impacts. By synthesizing insights from previous studies, this work aspires to advance the practical application of green concrete in sustainable construction practices.

3. Materials and Methodology

3.1 Materials Used:

In this study, a variety of materials were utilized to develop the green concrete mix, each selected for its potential to enhance sustainability while maintaining or improving mechanical properties. The key materials and their respective proportions by weight are as follows:

Cement (Ordinary Portland Cement – OPC): 19.32%

Fly Ash: 5.80%

Blast Furnace Slag: 0.06%

Glass Powder: 2.28%

Gypsum: 8.31%

Plastic Waste: 0.01%

Recycled Aggregates: 44.19%

Natural Sand: 20.04%

Ordinary Portland Cement (OPC) was used as the primary binding material due to its widespread availability and proven performance. However, to reduce the carbon footprint, significant portions of the cementitious content were replaced with supplementary cementitious materials (SCMs) like fly ash and blast furnace slag. Fly ash, a by-product of coal combustion in thermal power plants, was incorporated to enhance the long-term strength and durability of the concrete. Blast furnace slag, a waste product from the steel industry, was added in small quantities to further improve resistance to chemical attacks.

Glass powder, produced from finely ground recycled glass, was utilized for its pozzolanic properties and ability to improve workability and surface finish. Gypsum was included primarily to regulate the setting time of the concrete mix. Additionally, plastic waste was introduced in minimal quantities to explore its potential as a

sustainable filler material. A major component of the aggregate mix consisted of recycled aggregates, derived from demolished concrete structures, contributing to 44.19% of the total mix. Natural river sand was also employed to ensure proper grading and workability, making up 20.04% of the total weight.

Green Concrete Materials

3.2 Mix Design and Testing:

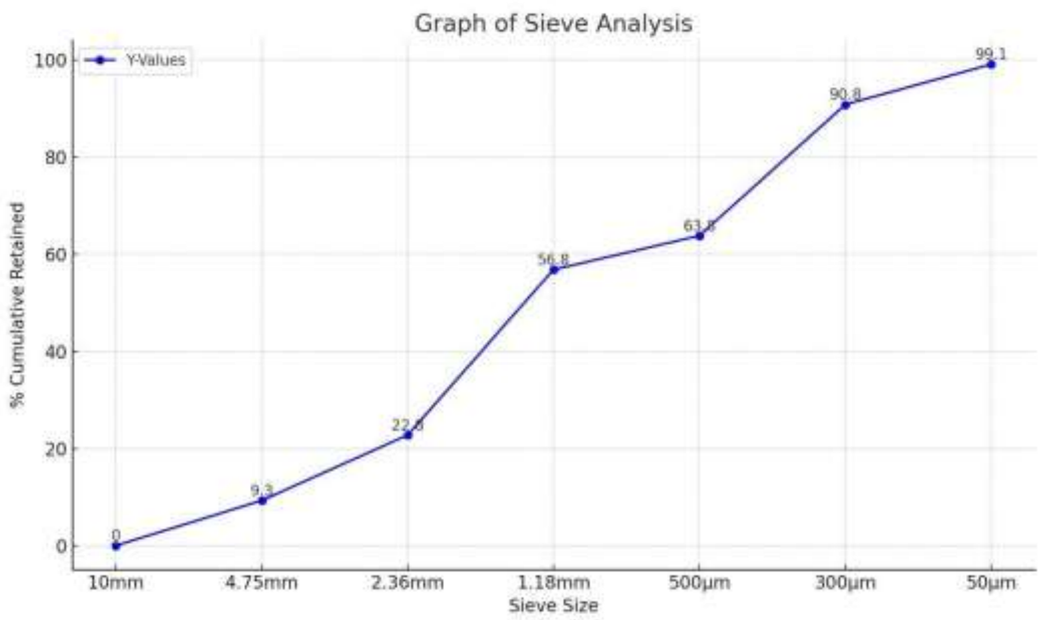
The green concrete mix was designed based on the specifications for an M25 grade, targeting a characteristic compressive strength of 25 MPa at 28 days. The mix design involved partial replacement of conventional cement and aggregates with the aforementioned SCMs and recycled materials, following standard procedures outlined in IS 10262:2019 guidelines. Appropriate adjustments were made to maintain the required workability, durability, and strength characteristics of the concrete.

Concrete specimens were prepared in the form of standard cubes measuring 150 mm × 150 mm × 150 mm. These cubes were cast using a mechanical mixer to ensure uniform distribution of materials and proper consistency. After demolding, the specimens were subjected to curing in clean water at ambient temperature conditions, and compressive strength tests were conducted at different curing intervals—namely 7, 14, and 28 days—using a calibrated compression testing machine (CTM). In addition to strength testing, the workability of the fresh concrete mix was assessed using the slump cone test, in accordance with IS 1199:1959 standards. The slump test provided valuable insights into the mix's ease of handling, placing, and compaction. Observations were recorded to evaluate how the inclusion of SCMs and recycled materials influenced the flow characteristics and cohesiveness of the concrete. The combined testing of compressive strength and workability helped to ensure that the green concrete mix met the structural and practical requirements for sustainable construction applications.

4. Results and Discussion

4.1 Sieve Analysis:

Sr. No	IS Sieve Size	Wt. Retained (gm)	Cumm. Wt. Retained	%cumulative retained	% passing
1	10 mm	0	0	0	100
2	4.75mm	93	93	9.3	90.7
3	2.36mm	135	228	22.8	77.2
4	1.18mm	340	568	56.8	43.2
5	500(micron)	70	638	63.8	36.2
6	300(micron)	270	908	90.8	9.2
7	50(micron)	83	991	99.1	0.9



Sieve analysis was conducted on the sand used in the concrete mix to evaluate its particle size distribution and overall grading. The results indicated that the sand was well-graded, with a calculated fineness modulus (FM) of 3.426. According to IS 383:2016 standards, a fineness modulus in this range suggests that the sand falls within the classification of coarse sand. Well-graded sand contributes positively to the workability, strength, and durability of concrete by ensuring a dense packing of particles, minimizing voids, and reducing the need for excessive cement paste. The proper grading of fine aggregates in the mix thus played an important role in achieving the desired consistency and strength properties of the green concrete.

4.2 Slump Cone Test:

Result: Medium slump (25-75mm): Medium workability, suitable for general construction projects.
The workability of the fresh green concrete mix was evaluated using the slump cone test. The observed slump was in the range of 25–75 mm, which classifies the mix as having medium workability. This level of workability is generally suitable for most general construction activities such as slabs, beams, columns, and walls, where moderate ease of placement and compaction is required. Medium workability ensures that the concrete mix can be effectively placed without segregation or excessive bleeding while still being workable enough for manual handling and finishing operations. The use of supplementary materials like fly ash and glass powder appeared to contribute positively to the mix's cohesion and workability characteristics.

4.3 Compressive Strength Test:

Table: Compressive Strength without Plastic

Sr. No	Cube Number	Load (N)	Compressive Strength
1	Cube1	572	25.42
2	Cube2	590	26.22
3	Cube 3	457	20.31

4	Cube 4	567	25.20
5	Cube 5	571	25.37
6	Cube 6	565	25.18
7	Cube7	563	25.16
8	Cube 8	576	25.60
9	Cube 9	519	23.06
10	Cube 10	552	24.53

Table: Compressive Strength with Plastic

Sr. No	Cube Number	Load (N)	Compressive Strength
1	Cube11	531	23.6
2	Cube12	553	24.57
3	Cube 13	520	23.11
4	Cube 14	481	21.37
5	Cube 15	511	22.71
6	Cube 16	515	22.88
7	Cube17	525	23.33
8	Cube18	505	22.44

The compressive strength of the concrete was assessed by testing cube specimens at standard curing intervals. Two different sets of specimens were analyzed—those prepared without plastic waste and those with a small percentage of plastic waste incorporated as a filler.

Without Plastic Waste:

The compressive strength of the concrete cubes ranged from 20.31 MPa to 26.22 MPa across various curing ages. The results indicate that the mixes without plastic waste achieved strength values suitable for M25 grade requirements, particularly at 28 days of curing. The presence of SCMs such as fly ash and slag contributed to steady strength gain over time due to their pozzolanic reactions.

With Plastic Waste:

The compressive strength of concrete mixes containing plastic waste ranged from 21.37 MPa to 24.57 MPa. Although a slight reduction in maximum strength was noted compared to the control specimens, all values remained within acceptable limits for structural applications. The incorporation of plastic waste slightly altered the microstructure, possibly introducing minor voids or affecting the bonding characteristics between cement paste and aggregates. However, the extent of reduction was marginal and did not compromise the overall structural integrity.

The results demonstrated that the inclusion of plastic waste, even in small quantities, offers a promising way to recycle non-biodegradable materials into concrete without significantly affecting compressive strength. Additionally, the use of recycled aggregates and industrial by-products maintained good performance, confirming that green concrete can achieve the strength necessary for practical use while significantly contributing to sustainability goals.

5. Conclusion

1. The study on "Green Concrete for Better Sustainable Environment" demonstrates the potential of green concrete in reducing environmental impact while maintaining structural integrity. By incorporating industrial waste materials like fly ash, blast furnace slag, and glass powder, green concrete offers a sustainable alternative to traditional concrete.

2. Improved sustainability: Green concrete reduces waste, conserves natural resources, and decreases carbon emissions, making it an environmentally friendly option.

3. Enhanced durability: Green concrete exhibits improved durability and energy efficiency, reducing the need for frequent repairs and replacements.

4. Potential for large-scale adoption: With policy support and industry adoption, green concrete can become a mainstream construction material, contributing to a more sustainable built environment.

5. The study comprehensively investigated the use of supplementary cementitious materials (SCMs) in M25 concrete mix to enhance sustainability in construction. The findings demonstrate that SCMs significantly influence key properties such as compressive strength, workability, and durability of concrete.

6. The evaluation of various SCMs revealed their potential to improve concrete performance while reducing environmental impact.

7. The study identified optimal mix designs that support sustainable construction practices without compromising structural integrity.

8.Overall, the use of SCMs in M25 concrete presents a viable and eco-friendly alternative in the development of green concrete solutions for a sustainable future.

6. Future Scope

While this study successfully demonstrated the potential of green concrete as a sustainable alternative to conventional construction materials, several avenues for future research and development remain open for exploration.

Future Scope of Green Concrete:

- **Use of Alternative Materials**
  Explore agricultural waste (e.g., rice husk ash, sugarcane bagasse ash), construction/demolition waste, marble dust, and copper slag for improved sustainability and performance.
- **Nano-Materials**
  Study nano-silica and other nano-additives to enhance strength and durability at the microstructural level.

- **Real-World Applications**

Implement in large-scale projects (bridges, highways, buildings) and evaluate long-term performance, durability, and lifecycle costs.

- **Policy and Awareness**

Promote adoption through government incentives, standards, subsidies, and public awareness. Encourage collaboration among stakeholders.

- **Advanced Mix Design**

Use AI and computational tools to optimize material selection and mix design for better performance.

7. References

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