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"Effect of Ultra-Fine Fly Ash and GGBFS on Strength and Durability of Concrete"

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Abstract: This study investigates the combined effect of ultra-fine fly ash (UFFA) and ground granulated blast furnace slag (GGBFS) on the mechanical strength and durability properties of concrete. As sustainable alternatives to ordinary Portland cement, UFFA and GGBFS not only reduce environmental impact but also enhance long-term performance. Various concrete mixes were prepared by partially replacing cement with different proportions of UFFA and GGBFS. The compressive strength, split tensile strength, and flexural strength were evaluated at 7, 28, and 90 days. Durability was assessed through tests on water absorption, rapid chloride permeability, and resistance to sulphate attack. Results indicated that optimal replacement levels significantly improved strength characteristics and demonstrated enhanced durability compared to conventional concrete. The synergistic effect of UFFA and GGBFS contributed to densified microstructure and reduced permeability, making the blended cementitious system a promising approach for high-performance and sustainable concrete.

I. Introduction:

Concrete is the most widely used construction material globally, prized for its versatility, strength, and durability. However, the production of ordinary Portland cement (OPC), a key ingredient in concrete, is responsible for a significant portion of global CO_2 emissions. To address both environmental concerns and the need for high-performance construction materials, researchers and engineers are increasingly turning to supplementary cementitious materials (SCMs) such as fly ash and ground granulated blast furnace slag (GGBFS).

Fly ash, a byproduct of coal combustion, and GGBFS, a byproduct of the steel manufacturing industry, are known to enhance various properties of concrete when used as partial cement replacements. Ultra-fine fly ash (UFFA), due to its smaller particle size and higher pozzolanic reactivity compared to regular fly ash, offers superior performance in terms of strength development and durability. Similarly, GGBFS contributes to long-term strength gain and improved resistance to chemical attack by promoting a denser microstructure and reducing the permeability of concrete.

The synergistic use of UFFA and GGBFS has the potential to further enhance the mechanical and durability characteristics of concrete. However, the combined effects of these materials, particularly in ultra-fine form, have not been extensively studied. Understanding how UFFA and GGBFS interact in a blended cementitious system is essential for optimizing mix designs aimed at achieving both environmental sustainability and structural performance.

This study aims to evaluate the influence of varying proportions of UFFA and GGBFS on the compressive, tensile, and flexural strengths of concrete, as well as its durability characteristics such as water absorption, sulphate resistance, and chloride ion penetration. The research provides insights into the potential of these materials to produce high-performance, durable, and eco-friendly concrete suitable for modern construction applications.

II. Background of sustainable concrete

II.I Concrete is the most widely used construction material worldwide, primarily due to its availability, versatility, and structural performance. However, the production of its key ingredient—Ordinary Portland Cement (OPC)—is a major contributor to global carbon dioxide (CO_2) emissions, accounting for approximately 7–8% of total anthropogenic CO_2 emissions. This significant environmental impact, combined with the depletion of natural resources and increasing construction demands, has led to a growing interest in sustainable alternatives within the construction industry.

Sustainable concrete aims to reduce the environmental footprint of traditional concrete without compromising its performance. This involves strategies such as reducing the clinker content in cement, using recycled or industrial byproducts, and improving the durability and longevity of concrete structures to minimize maintenance and replacement needs. Supplementary cementitious materials (SCMs) such as fly ash, silica fume, metakaolin, and ground granulated blast furnace slag (GGBFS) are commonly used to replace a portion of cement in concrete. These materials, often industrial waste products, help reduce greenhouse gas emissions while enhancing certain mechanical and durability properties of concrete.

Ultra-fine fly ash (UFFA) and GGBFS are particularly promising SCMs due to their high pozzolanic activity and latent hydraulic properties, respectively. UFFA, due to its finer particle size, provides better packing density and reactivity, leading to denser concrete with improved strength and durability. GGBFS contributes to long-term strength gain and enhanced resistance to chemical attacks, such as sulphate and chloride ingress.

The development of sustainable concrete is not only a step toward reducing the environmental impact of construction but also a means of producing high-performance, durable structures that require less frequent maintenance. The integration of SCMs like UFFA and GGBFS into concrete aligns with global goals for sustainable development, resource conservation, and carbon footprint reduction.

III. Methodology of Sustainable Concrete

This study investigates the effect of ultra-fine fly ash (UFFA) and ground granulated blast furnace slag (GGBFS) as supplementary cementitious materials on the strength and durability of concrete. The experimental methodology consists of the following phases: material selection, mix design, sample preparation, curing, and testing for mechanical and durability properties.

III.I Materials Used

Cement: Ordinary Portland Cement (OPC) 43 or 53 grade, conforming to IS 8112/IS 12269.

Ultra-Fine Fly Ash (UFFA**):** Collected from a thermal power plant and processed to achieve a fineness less than 10 µm.

Ground Granulated Blast Furnace Slag (GGBFS): Obtained from a steel manufacturing plant, conforming to IS 12089.

Fine Aggregates**:** River sand passing through 4.75 mm sieve.

Coarse Aggregates: Crushed granite with 20 mm maximum size.

Water: Potable water, free from impurities.

Superplasticizer (if required**):** To improve workability without increasing water-cement ratio.

III.II Mix Design

Concrete mixes were prepared with varying percentages of cement replacement by UFFA and GGBFS. A control mix (without any SCMs) was used for comparison. The replacement levels were as follows:

Control Mix (CM): 100% OPC
Mix A**:** 10% UFFA + 20% GGBFS.
Mix B**:** 15% UFFA + 25% GGBFS.
Mix C: 20% UFFA + 30% GGBFS.

The water-to-binder ratio was kept constant at 0.4 across all mixes. Superplasticizer was added as needed to maintain consistent workability (slump 75–100 mm).

III.IIII Sample Preparation and Curing

Concrete was mixed using a pan mixer.
Standard cubes (150 × 150 × 150 mm), cylinders (150 × 300 mm), and prisms (100 × 100 × 500 mm) were cast.
Specimens were demoulded after 24 hours and cured in water at 27±2°C until testing at 7, 28, and 90 days.

III.V Testing Procedures

a. Mechanical Properties:

Compressive Strength: As per IS 516, tested on 150 mm cubes.
Split Tensile Strength: As per IS 5816, tested on 150 × 300 mm cylinders.
Flexural Strength: As per IS 516, tested on 100 × 100 × 500 mm prisms.

b. Durability Tests:

Water Absorption Test: To evaluate permeability, as per ASTM C642.
Rapid Chloride Permeability Test (RCPT): As per ASTM C1202.
Sulphate Resistance: Immersion of specimens in 5% Na_2SO_4 solution for 90 days and comparison of mass loss and strength retention.

III.IV Data Analysis

The results were statistically analysed and compared across all mixes. The effect of UFFA and GGBFS on strength gain, permeability reduction, and chemical resistance was evaluated to identify the optimal blend for sustainable and durable concrete.

IV. Applications of Sustainable Concrete

sustainable concrete, incorporating supplementary cementitious materials such as ultra-fine fly ash (UFFA) and ground granulated blast furnace slag (GGBFS), is increasingly used in modern construction due to its improved performance and reduced environmental impact. Its enhanced strength, durability, and lower carbon footprint make it suitable for a wide range of structural and non-structural applications.

1. Green Buildings and Infrastructure

Sustainable concrete is a key material in green construction and LEED-certified projects. Its low embodied carbon and energy-efficient performance support sustainable building practices. It is commonly used in:

Residential and commercial buildings Schools, hospitals, and government buildings Low-energy housing and smart city projects

2. Pavements and Transportation Infrastructure

Due to its durability and resistance to environmental stressors (e.g., freeze-thaw, chloride attack), sustainable concrete is ideal for:

Roads and highways
Bridge decks and abutments, Airport, runways and taxiways, Railway platforms and tracks

3. Marine and Coastal Structures

UFFA and GGBFS enhance resistance to chloride and sulphate attacks, making sustainable concrete suitable for aggressive marine environments:

Ports and harbours
Offshore platforms
Sea walls and breakwaters
Coastal piers and jetties

4. Water Retaining and Waste Management Structures

The reduced permeability of blended concrete makes it effective in water-related applications:

Dams and spillways
Water tanks and reservoirs
Sewage treatment plants
Landfill liners and waste containment systems.

5. Industrial Floors and Heavy-Duty Structures

Sustainable concrete provides high abrasion resistance and long-term strength, making it suitable for:

Industrial floors and warehouses
Heavy equipment foundations
Power plants and cooling towers

6. Precast Concrete Products

The early strength gain and dimensional stability of SCM-enhanced concrete make it ideal for:

Precast panels and blocks
Pipes and manholes
Railway sleepers
Architectural precast elements

7. Retrofitting and Repair Works

Due to its superior durability, sustainable concrete is used in:

Structural rehabilitation of old buildings and bridges

Jacketing and overlays for damaged concrete
Crack sealing and patch repairs using high-performance concrete.

CONCLUDING REMARKS AND FUTURE SCOPE

Remarks

The use of supplementary cementitious materials such as ultra-fine fly ash (UFFA) and ground granulated blast furnace slag (GGBFS) presents a significant advancement in the development of sustainable concrete. The experimental results from this study indicate that the incorporation of UFFA and GGBFS, in optimal proportions, not only reduces the carbon footprint of concrete but also enhances its mechanical and durability characteristics.

Concrete mixes containing these materials showed improved compressive strength, lower permeability, and higher resistance to sulphate and chloride attacks when compared to conventional concrete. These benefits are largely attributed to the densification of the microstructure, increased pozzolanic activity, and refined pore structure due to the synergistic effect of UFFA and GGBFS.

Furthermore, sustainable concrete aligns with global efforts to mitigate climate change, reduce construction waste, and promote circular economy principles by utilizing industrial by-products. It serves as a practical and environmentally responsible solution for modern infrastructure demands.

Future Scope

Despite the proven benefits, further research and development are needed to fully unlock the potential of sustainable concrete in various applications. Future work can focus on the following areas:

Long-Term Performance Studies

Monitoring the behaviour of UFFA-GGBFS concrete in real-life structures over extended periods.

Assessing performance under varying environmental conditions such as freeze-thaw cycles, marine exposure, and high temperatures.

Optimization through Ternary and Quaternary Blends

Investigating the combined effects of UFFA, GGBFS, silica fume, metakaolin, and other SCMs to achieve tailored properties for specific applications.

Life Cycle Assessment (LCA) and Cost Analysis

Conducting comprehensive LCA studies to quantify environmental benefits over the entire lifecycle of concrete structures.

Evaluating economic viability, especially in developing countries where SCM availability and processing may vary.

3D Printing and Advanced Construction Technologies

Exploring the use of UFFA and GGBFS in sustainable concrete mixes for 3D printed construction and prefabricated elements.

Standardization and Code Development

Developing specific guidelines and standards for the use of ultra-fine SCMs in structural and non-structural applications.

Waste Management Integration

Utilizing additional industrial and agricultural waste products in combination with UFFA and GGBFS to enhance sustainability.

REFERENCES

- Sujay H.M. a, Nishant A. “Experimental study on durability characteristics of Composite fiber-reinforced high-performance concrete incorporating nano-silica and ultra-fine fly ash” Naira, H. Sudarsana Rao b, V. Sairam a, (Elsevier, 2020)
- Jingjing Feng, Shuhua Liu, “Effects of ultrafine fly ash on the properties of high-strength concrete” Zhigang Wang (Springer, 2015)
- Faiz U.A. Shaikh, “Compressive strength and durability properties of high-volume fly ash (HVFA) concretes containing ultrafine fly ash (UFFA)” Steve W.M. Spit (Elsevier, 2015)
- IS 383:2016 – Specification for coarse and fine aggregates from natural sources for concrete
- IS 456:2000 Code of practice for plain and reinforced concrete.
- IS 2386(Part 3):1963 Methods of test for aggregates for concrete: Part 3 Specific gravity, density, voids, absorption, and bulking