Parametric study of concrete by using agricultural waste and ground granulated blast -furnace (GGBFS): A Review

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Abstract-

This study explores the feasibility of incorporating agricultural waste and Ground Granulated Blast Furnace Slag (GGBFS) in M-25 grade concrete to enhance sustainability and mechanical properties. Agricultural waste materials, such as coconut shell and powdered glass, are used as partial replacements for conventional aggregates and cement. GGBFS, a pozzolanic material, improves concrete strength and durability through a secondary hydration reaction. The research includes material characterization, mix design, and testing of fresh and hardened concrete for compressive, split tensile, and flexural strengths. By analyzing various replacement proportions, the study aims to determine the optimal mix for enhanced performance. The findings contribute to cost-effective, eco-friendly concrete solutions while promoting waste utilization in construction.

Keywords: *Ground Granulated Blast Furnace Slag (GGBFS), Agricultural Waste Concrete, Sustainable Construction, Coconut Shell Aggregate, Pozzolanic Reaction etc.*

1. Introduction

Concrete is the most widely used construction material globally due to its high strength, durability, and versatility. However, the production of conventional concrete requires significant amounts of natural resources and contributes to environmental issues such as carbon emissions and resource depletion. Cement production alone is responsible for nearly 8% of global CO_2 emissions. In response to these environmental concerns, researchers have been exploring the use of alternative materials in concrete to reduce its ecological footprint. One such approach is the incorporation of industrial by-products and agricultural waste as partial replacements for cement and natural aggregates. This study focuses on utilizing Ground Granulated Blast Furnace Slag (GGBFS) and agricultural waste, such as coconut shell and powdered glass, in concrete production [1].

GGBFS is a by-product of the iron and steel industry, obtained by rapidly cooling molten slag from a blast furnace. When finely ground, GGBFS exhibits cementitious properties, making it a valuable supplementary material in concrete. It enhances concrete strength, durability, and resistance to chemical attacks due to its pozzolanic reaction, which contributes to secondary hydration. The use of GGBFS not only improves the performance of concrete but also helps in reducing the reliance on ordinary Portland cement (OPC), thereby lowering greenhouse gas emissions [2].

Agricultural waste, on the other hand, is an abundant and underutilized resource in the construction industry. Large amounts of waste are generated from farming activities, including plant residues such as stems, leaves, and shells. In particular, coconut shells are a significant agricultural waste product in tropical regions. Due to their hardness, lightweight nature, and availability, coconut shells can be processed into aggregates for concrete, providing an eco-friendly alternative to conventional coarse aggregates. Additionally, waste glass, when finely ground, acts as a pozzolanic material, improving the mechanical and durability properties of concrete [2][3].

The combination of GGBFS and agricultural waste in concrete has the potential to enhance sustainability, reduce construction costs, and minimize waste disposal issues. However, the impact of these materials on concrete properties, including workability, strength, and durability, requires thorough investigation. This study aims to assess the feasibility of using GGBFS and agricultural waste in M-25 grade concrete by evaluating material properties, mix design, and mechanical performance [3].

The research involves casting and testing different concrete mixes, including conventional concrete and mixes with varying proportions of GGBFS and agricultural waste. The tests will include compressive strength, split tensile strength, and flexural strength of hardened concrete, along with fresh concrete properties such as slump and workability. By analyzing the results, the study will determine the optimal mix proportion that balances strength, durability, and sustainability [4].

Incorporating GGBFS and agricultural waste in concrete presents an innovative solution for sustainable construction. This study contributes to the growing body of research on green building materials by exploring practical applications of industrial and agricultural by-products. If proven effective, this approach could reduce the environmental impact of concrete production while providing economic benefits through the utilization of waste materials. The findings of this research will help in developing eco-friendly concrete solutions that support sustainable infrastructure development [5].

Fig.1 Sustainability of Composites Reinforced with Natural Fibres

2. Problem Statements

- Environmental Impact of Cement Production – The high carbon emissions and energy-intensive nature of cement production contribute significantly to global warming and resource depletion.
- Agricultural Waste Disposal Issues – Large quantities of agricultural waste, such as coconut shells and glass waste, are generated annually, leading to environmental pollution and disposal challenges.
- Depletion of Natural Aggregates – Excessive use of natural coarse aggregates in concrete results in resource depletion, increasing construction costs and environmental degradation.
- Waste Utilization Challenges – Agricultural and industrial by-products are often underutilized, leading to waste accumulation without sustainable applications.
- Need for Sustainable Concrete Alternatives – The construction industry requires innovative solutions that reduce dependence on conventional materials while maintaining concrete’s strength and durability.
- Lack of Research on Optimal Mix Proportions – Limited studies exist on the combined use of GGBFS and agricultural waste in concrete, necessitating further investigation into their effects on mechanical properties.

3. Objectives

- **Material Characterization:** Study the physical and chemical properties of GGBFS, coconut shell aggregates, and glass powder as per relevant codes.
- **Concrete Mix Design:** Develop M-25 grade concrete with partial replacement of cement and aggregates using agricultural waste and GGBFS.
- **Strength Assessment:** Evaluate the compressive, tensile, and flexural strength of modified concrete compared to conventional concrete.
- **Durability Analysis:** Investigate water absorption, chloride penetration, and sulfate resistance of the modified concrete.
- **Optimization & Sustainability:** Identify the best combination of replacements for enhanced mechanical properties and eco-friendliness.

4. Literature Review

Patel, P., & Shah, B. (2018), This study examines the impact of GGBFS as a partial replacement for cement in concrete. The findings indicate that replacing cement with 30–50% GGBFS improves compressive strength, reduces permeability, and enhances durability. The pozzolanic reaction of GGBFS increases long-term strength and resistance to chemical attacks. The study concludes that GGBFS is an effective sustainable material for eco-friendly concrete, reducing carbon emissions and improving structural performance.

Gunasekaran, K., Kumar, P. S., & Lakshmipathy, M. (2011), This research investigates the feasibility of using coconut shells as coarse aggregates in concrete. The study finds that coconut shell concrete has lower density, making it suitable for lightweight structural applications. Although the compressive strength is slightly lower than conventional concrete, the flexural and tensile strengths remain satisfactory. The authors recommend using coconut shell aggregate in non-load-bearing structures to reduce waste disposal issues and promote sustainable construction.

Sharma, R., & Bansal, P. (2016), This paper explores the potential of finely ground glass powder as a supplementary cementitious material. The study reports that replacing up to 20% of cement with glass powder enhances early-age strength due to the pozzolanic reaction. It also improves durability by reducing alkali-silica reaction (ASR) effects. The research supports the use of waste glass in concrete to enhance sustainability while maintaining mechanical performance.

Ramesh, T., & Kumar, A. (2020), This study evaluates the combined effect of GGBFS and agricultural waste, such as rice husk ash and coconut shell, in concrete mixtures. The results demonstrate that a 40% replacement of cement with GGBFS and 20% replacement of coarse aggregates with coconut shell improves durability while maintaining strength. The research highlights the economic and environmental benefits of using industrial and agricultural waste in concrete.

Mehta, P. K., & Monteiro, P. J. (2014), This research emphasizes the role of supplementary materials like GGBFS, fly ash, and agricultural waste in reducing the environmental impact of concrete. The study highlights that GGBFS improves long-term strength and reduces permeability, while agricultural waste, such as coconut shells and rice husk ash, contributes to sustainability. The authors advocate for integrating alternative materials into concrete to lower carbon emissions and enhance durability.

Wang, H., & Meyer, C. (2012), This study investigates the effect of GGBFS as a partial replacement for cement in concrete. It finds that incorporating up to 50% GGBFS significantly enhances resistance to sulfate attack, reduces chloride permeability, and improves durability. The pozzolanic reaction of GGBFS contributes to strength gain over time. The research concludes that GGBFS is an effective material for producing durable, eco-friendly concrete with improved long-term performance.

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Maninder, K., & Singh, S. P. (2014), This study evaluates the potential of using coconut shells as a replacement for coarse aggregates in concrete. It finds that coconut shell concrete is lightweight, with a lower density compared to conventional concrete. The compressive strength decreases slightly but remains within acceptable limits. The study suggests that coconut shell concrete can be used in non-load-bearing structures, reducing the environmental impact of waste disposal while lowering construction costs.

Ali, E. E., & Al-Tersawy, S. H. (2013, This study investigates the pozzolanic activity of finely ground waste glass in concrete. It finds that replacing 15-25% of cement with glass powder enhances compressive and flexural strength. Additionally, the study highlights that glass powder improves resistance to sulfate attack and reduces the alkali-silica reaction (ASR). The findings support the use of glass powder as a sustainable alternative in cementitious materials.

Kumar, R., & Gupta, P. (2019), This research examines the effects of replacing cement with agricultural waste such as rice husk ash, coconut shell, and sawdust ash in concrete. It finds that a combination of 30% GGBFS and 10% agricultural waste results in improved durability while maintaining strength. The study concludes that incorporating agricultural waste in concrete enhances sustainability and reduces dependence on natural resources.

Senapati, D., & Patel, R. (2021), This study explores the optimal mix proportion of GGBFS and agricultural waste for sustainable concrete production. It finds that a combination of 40% GGBFS and 20% coconut shell as coarse aggregate replacement produces concrete with comparable strength to conventional mixtures. The research highlights the economic and environmental benefits of replacing cement and aggregates with sustainable alternatives.

Research gap –

Despite extensive studies on incorporating Ground Granulated Blast Furnace Slag (GGBFS) and agricultural waste in concrete, gaps remain in optimizing their combined effects on mechanical and durability properties. Most research focuses on individual replacements, but limited studies explore the synergetic impact of GGBFS with coconut shell aggregates and glass powder. Additionally, variations in mix design, curing conditions, and long-term performance assessments are not well-documented. The impact on sustainability, economic feasibility, and large-scale implementation also requires further exploration. This study aims to bridge these gaps by evaluating optimal replacement percentages and their influence on the strength, durability, and eco-friendliness of concrete.

5. Research Methodology

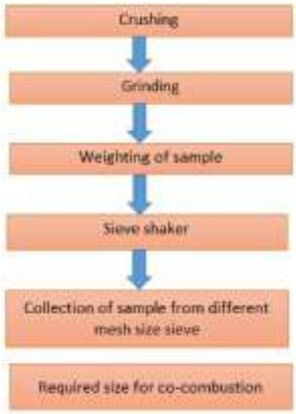

Fig1. Schematic Diagram

- Preparation: Calculate the proportions of Portland cement, aggregates, water, Fly ash, polypropylene fiber, coconut coir needed for the desired concrete mix. Consult engineering guidelines for appropriate ratios.
- Mixing: Start by mixing the dry ingredients: cement, aggregates, Fly ash, polypropylene fiber, coconut coir Mix these components until they are evenly distributed.
- Gradually add water while continuing to mix. Adjust the water content to achieve the desired consistency; the mix should be workable but not too wet. Continue mixing until all the ingredients are thoroughly combined. The materials should be evenly dispersed throughout the mixture.
- Placement: Transfer the mixed concrete into molds or forms, shaping them according to your project's requirements. Ensure that the mixture is evenly spread and compacted.
- Compaction: Use a vibrator or other suitable equipment to eliminate air pockets and ensure proper compaction of the concrete mix.
- Curing: Cover the placed concrete with plastic sheeting or wet burlap to prevent rapid moisture loss. This will aid in the curing process, promoting strength development.
- Keep the concrete moist for an appropriate curing period (usually 7 days or more), ensuring that it doesn't dry out too quickly.
- Testing and Quality Control:

After the curing period, perform tests to evaluate the properties of the porous concrete. This may include tests for compressive strength, permeability, and other relevant factors.

6. Selection Required

Limit state plan strategies empower the potential methods of disappointment of a construction to be recognized and examined so a specific untimely type of disappointment might be forestalled. Limit state might be extreme' or 'functionality'. The, limit state configuration has been utilized effectively for north of 20 years for the plan of fluid holding structures. Flexible plan is a less complex cycle, yet with the broad utilization of PC offices, there is no trouble in getting ready breaking point state plans. There are two significant variables to be noted in the plan of an

Preventing cracks caused by shrinkage in the tank walls is essential to guaranteeing the water tank's structural integrity and impermeability. The WSM gives more area of support steel consequently in WSM there is compelling reason need to actually look at the break width. Yet, the LSM gives less area of support of steel and consequently the check for break width must be finished and the most extreme cutoff is 0.2mm.Under no conditions will the utilization of permeable totals, like slag. squashed over consumed block or tile, swelled earth totals and sintered f1yash totals, be considered pieces of design either in touch with the fluids on any face or encasing the space over the fluid. Joint turners, joint fixing mixtures, and water bars will adjust to the necessities of pertinent Indian Principles. Other jointing materials, for example, polyurethane and silicone based sealants may likewise be utilized given there are agreeable information on their appropriateness. The jointing materials utilized will not affect the nature of fluid to be put away.

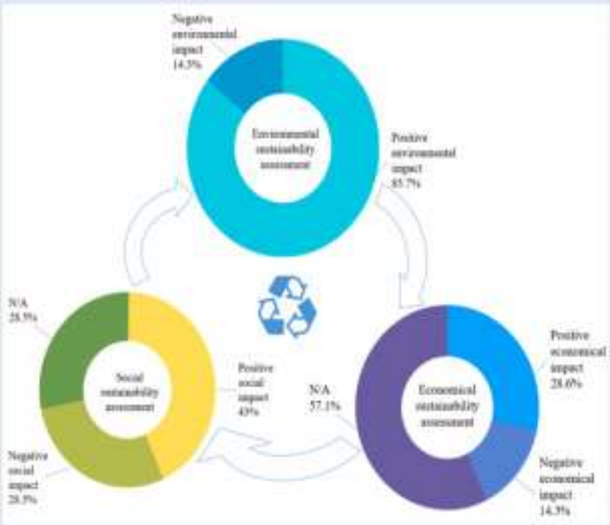

Figure 3: Recent developments on natural fiber concrete

Two phases of substantial blends were created to assess the impact of PP strands on asphalt quality cement's mechanical characteristics PQC. The base grade of cement for PQC is M35. In this way, M35-grade PQC was thought of. Stage I was utilized to foster the WGP-mixed control PQC example, and stage II was the advancement of the M35-grade fiber-built up PQC example. The arrangements were followed for accomplishing blend proportioning with the designated trademark flexural strength of 4.5 MPa following a 28-day restoring period. The base and greatest concrete bits were chosen as 350 kg/m3 and 425 kg/m3, separately. The blend proportioning of the control PQC examples is introduced in Table 4. Subsequent to doing different preliminaries, the OPC part of M35-grade PQC without WGP was chosen as 400 kg/m3. The WGP substitution levels of 5, 10, 15, 20, and 25% were picked for finding the ideal dose level in stage I. As per the substitution levels, PQC was assigned. Blend proportioning of the WGP-mixed PPFRPQC examples with the fiber items in 0.25, 0.5, 0.75, 1.0, and 1.25% by weight of cement.

7. Advantages and Application

A. Advantages

- Eco-Friendly & Sustainable: Utilizes industrial and agricultural waste, reducing environmental pollution and carbon footprint.
- Cost-Effective: Lowers construction costs by replacing conventional materials with waste products.
- Improved Durability: Enhances concrete strength, reduces permeability, and increases resistance to sulfate and chloride attacks.
- Lightweight Structure: Coconut shell aggregates reduce the density of concrete, making it suitable for lightweight construction.
- Enhanced Workability: GGBFS improves workability and reduces heat of hydration, minimizing thermal cracks.
- Waste Management: Provides an effective solution for disposing of agricultural and industrial waste.
- Energy Efficient: Reduces reliance on energy-intensive cement production, conserving natural resources.

B. Application

- Residential & Commercial Construction: Used in walls, slabs, and non-load-bearing structures.
- Road & Pavement Construction: Ideal for low-traffic roads and sidewalks.
- Precast Concrete Products: Suitable for blocks, tiles, and lightweight precast panels.
- Marine & Coastal Structures: Increased sulfate resistance makes it ideal for bridges, ports, and dams.
- Eco-Friendly Building Projects: Used in green buildings and sustainable infrastructure.
- Rural & Low-Cost Housing: Provides affordable housing solutions in developing regions.
- Industrial Flooring & Foundations: Suitable for factories and warehouses due to enhanced durability.

8. Conclusion

The study of concrete incorporating Ground Granulated Blast Furnace Slag (GGBFS) and agricultural waste, such as coconut shell aggregates and glass powder, presents a sustainable and cost-effective alternative to conventional concrete. The experimental analysis highlights that GGBFS enhances strength and durability due to its pozzolanic reaction, while coconut shell aggregates reduce density, making the concrete lightweight. Additionally, glass powder contributes to improved mechanical properties and durability. By replacing traditional materials with industrial and agricultural waste, this research promotes eco-friendly construction while addressing waste disposal challenges. The optimized mix design offers an effective balance between strength, workability, and sustainability. The results indicate that with proper proportioning, this modified concrete can be used in various structural applications, including residential buildings, pavements, and precast elements. Future studies should focus on long-term durability and large-scale implementation to further validate its viability in modern construction.

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