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AN EXPERIMENTAL INVESTIGATION ON PARTIAL REPLACEMENT OF CEMENT WITH SUGARCANE BAGASSE ASH AND REPLACEMENT OF FINE AGGREGATE WITH COPPER SLAG

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Abstract:

The increasing demand for sustainable construction materials has driven research towards the utilization of industrial by-products as substitutes in conventional concrete. This study investigates the potential of sugarcane bagasse ash (SCBA) as a partial replacement for cement, and copper slag as a replacement for fine aggregate, in concrete production. SCBA, a residue from sugar industries, is rich in silica and offers a promising alternative to traditional cement, contributing to environmental sustainability by reducing carbon emissions. Copper slag, an industrial by-product of copper production, exhibits favourable mechanical properties, making it suitable for replacing fine aggregate in concrete.

Keywords — **REPLACEMENT OF CEMENT, SUGARCANE BAGASSE ASH, REPLACEMENT OF FINE AGGREGATE, COPPER SLAG**

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INTRODUCTION

We are conducting an experimental investigation on concrete by partially replacing cement with sugarcane bagasse ash and replacing fine aggregate with copper in this experimental investigation, the design and development of concrete with partial replacement of cement by Sugarcane. The experimental investigation explores various replacement levels of cement with SCBA and fine aggregate slag. Concrete is a mixture of cement, fine Bagasse Ash (SBA) and fine aggregate by Copper Slag involved a meticulous selection with copper slag, aiming to evaluate their effects on the mechanical properties of concrete, including aggregate, coarse aggregate, and water. In of materials, mix proportions, and compressive strength, tensile strength, and durability. Results indicate that the optimal combination of SCBA

DESIGN and DEVELOPMENT / CONSTRUCTION

our project, we are using Ordinary Portland construction procedures. The primary and copper slag not only enhances the strength characteristics of concrete but also reduces the environmental Cement of grade 53. M-sand is used as fine footprint associated with construction materials. aggregate and hard broken stone of size 12 to 20 mm is used as coarse aggregate. The use of sugarcane bagasse ash as a partial materials used in the mix were Ordinary Portland Cement (OPC),

SBA as a cement replacement, Copper Slag as a replacement for natural sand, coarse aggregate (crushed This study demonstrates that the integration of SCBA and copper slag in concrete can lead to a more replacement for cement contributes to granite), and potable water. SBA was sourced from sugar factories, processed by sustainable, cost-effective, and high-performance material, contributing to the advancement of green sustainability and reduces cement construction practices.
consumption. Meanwhile, copper slag, being a durable material, improves the compressive strength of concrete. In this project, we are replacing cement with sugarcane bagasse ash and fine aggregate with copper slag at varying percentages to study their effect on the overall properties of concrete.
burning at controlled temperatures to enhance its pozzolanic properties, and then sieved through a 90-micron sieve to ensure a fine particle size. Copper slag, a by-product of copper refining, was obtained from industrial sources, processed, and sieved to match the gradation of fine aggregates. The mix design was based on M25 grade concrete, with varying percentages of SBA (10%, 15%, 20%) and Copper Slag (20%, 30%, 40%) to assess their influence on the concrete's mechanical properties. The water-cement ratio was maintained at 0.45 for consistency. ensure uniform compaction. Once the moulds were filled and the top surface smoothed, the specimens were left to set for 24 hours. After demoulding, the concrete specimens were placed in water for curing, with tests conducted at 7, 14, and 28 days to evaluate compressive and tensile strength.

The development phase focused on optimizing the performance of the concrete mix by balancing the replacement levels of SBA and Copper Slag. SBA contributed to the pozzolanic reaction in the cement matrix, improving the long-term strength and durability of the concrete. Meanwhile, Copper Slag enhanced the density and mechanical strength of the concrete, particularly in terms of compressive and tensile strength. The combination of SBA and Copper Slag resulted in a concrete mix that not only demonstrated improved mechanical properties but also contributed to sustainable construction practices by utilizing waste materials, thereby reducing the environmental impact of cement and sand production. The overall construction process followed standard procedures for batching, mixing, casting, and curing, ensuring the reliability and reproducibility of the experimental results.

WORKING PRINCIPLE

The working principle behind this experimental investigation is based on the utilization of Sugarcane Bagasse Ash (SBA) as a partial replacement for cement and Copper Slag as a partial replacement for fine aggregate in concrete. Both materials are selected for their potential to enhance the sustainability and mechanical properties of concrete.

1. Pozzolanic Reaction of Sugarcane Bagasse Ash (SBA)

When cement is partially replaced with SBA, the pozzolanic reaction occurs, which improves the overall strength and durability of the concrete. SBA contains amorphous silica, which reacts with calcium hydroxide ($Ca(OH)_2$) released during the hydration of cement. This secondary reaction forms additional calcium silicate hydrate (C-S-H) gel, the primary binding agent in concrete, which contributes to long-term strength gain and durability.

The pozzolanic reaction can be represented by the following chemical equation:

$SiO2 + Ca(OH)2 \rightarrow$ C-S-H (Calcium Silicate Hydrate)

• Effect: The addition of SBA enhances the strength of the concrete over time, reduces porosity, and improves resistance to chemical attacks such as sulphate and chloride attack.

2. Copper Slag as a Fine Aggregate

Copper slag, a by-product of copper refining, is used as a partial replacement for natural sand. Its angular shape and rough texture provide better interlocking with cement paste, leading to improved bonding and mechanical properties. Additionally, copper slag has a higher specific gravity compared to natural sand, which improves the density and stability of the concrete.

• Effect: The inclusion of copper slag improves the compressive strength and tensile strength of the concrete by enhancing the internal structure and increasing the density. The higher density also improves resistance to abrasion and impacts.

3. Combined Effect

The combination of SBA and copper slag results in a synergistic effect:

• SBA contributes to the long term strength development through the pozzolanic reaction.

• Copper slag improves the workability (up to a certain limit) and mechanical properties by enhancing the internal structure of the concrete.

MANUFACTURING/FABRICATION A. Material Selection

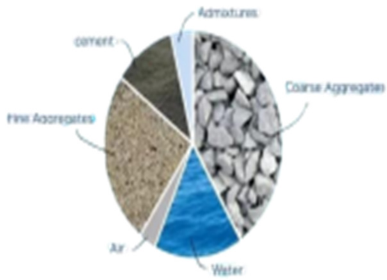
• Cement: Ordinary Portland Cement (OPC) will be partially replaced by Sugarcane Bagasse Ash (SBA). SBA is obtained by burning bagasse (a by-product of sugarcane).

• Fine Aggregate: Copper Slag will be used as a partial replacement for fine aggregate (sand). Copper slag is an industrial by-product from the smelting of copper.

• Coarse Aggregate: Use coarse aggregate with a density of 1500 kg/m³ as preferred.

• Water: Clean potable water.

• Admixtures: Based on the workability requirements, use chemical admixtures like plasticizers or superplasticizers if needed.



B. Mix Design

• Cement Content: Design the mix with different percentages of SBA replacement (e.g., 10%, 15%, 20%) to assess the optimum level of replacement.

• Fine Aggregate: Replace sand with copper slag at various levels (e.g., 20%, 30%, 40%) and evaluate the strength and workability.

• Water-Cement Ratio: Maintain a consistent water-cement ratio (e.g., 0.45–0.5) depending on the workability and strength required.

• Admixture Content: Use admixtures based on the concrete's properties, particularly if SBA significantly affects the workability.

• Target Strength: Design for a specific compressive strength (e.g., M25 grade).

C. Structural Design

The mix design should ensure:

• Adequate compressive strength (focus on the contribution of SBA).

• Improved tensile strength with recycled carbon fiber (optional if you plan to incorporate this innovative material for tensile strength).

• Enhanced durability and resistance to chloride attack, alkali-silica reaction (ASR), or other environmental factors.

2. Development/Construction Phase A. Material Procurement and Preparation

• Collect Sugarcane Bagasse Ash after burning bagasse under controlled conditions and sieving it through a 90- micron sieve.

• Obtain Copper Slag from local industrial sources and ensure it meets the required gradation for fine aggregate.

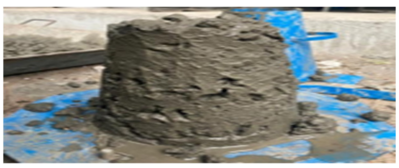
• Ensure proper curing time for concrete mixes with SBA, as it might impact the setting time.

B. Concrete Batching and Mixing

• Batching: Weigh the materials carefully according to the mix design proportions.

• Mixing: Use a concrete mixer to ensure homogeneous mixing of cement, SBA, fine aggregate, copper slag, coarse aggregate, water, and any admixtures.

• Workability Test: Perform a slump test to assess the concrete's workability, adjusting the water content or admixtures if necessary.



strength tests (standard cube and cylinder moulds).

• Curing: Cure the concrete samples under controlled conditions for 7, 14, and 28 days.

D. Testing and Analysis

• Compressive Strength: Test the concrete cubes at 7, 14, and 28 days to monitor the strength development.

• Tensile Strength: If applicable, test the tensile strength of concrete reinforced with recycled carbon fiber.

• Workability: Record slump values and assess the ease of concrete placement.

• Durability Tests: If the project extends to durability analysis, conduct tests for water absorption, chloride penetration, etc.

C. Casting and Curing

• Moulding: Cast the concrete into moulds for compressive and tensile

3. Expected Outcomes

• Strength Development: Determine the optimum percentage of SBA and copper slag replacements to achieve desired compressive and tensile strengths.

• Sustainability: This project aims to reduce the environmental impact by using SBA (an agricultural waste) and copper slag (an industrial waste), thus promoting sustainable construction.

• Cost Efficiency: Evaluate the cost savings compared to traditional materials, given the lower cost of SBA and copper slag.

Testing/Result/Evaluation

Testing Procedures

The following tests were conducted on concrete specimens to evaluate the effects of partial replacement of cement with Sugarcane Bagasse Ash (SBA) and fine aggregate with Copper Slag on the mechanical properties of concrete:

• Workability Test (Slump Test): The workability of fresh concrete was evaluated using a slump cone test to determine the ease of placement and compaction. This test helped assess how the inclusion of SBA and Copper Slag affected the fluidity and handling of the concrete mix.

• Compressive Strength Test: Compressive strength tests were conducted on cube specimens of dimensions 150mm x 150mm x 150mm at 7, 14, and 28 days of curing. The specimens were tested using a compression testing machine, and the results were recorded in megapascals (MPa). This test was critical in determining the load-bearing capacity of the concrete and how the inclusion of SBA and Copper Slag impacted the overall strength.

• Tensile Strength Test (Split Tensile Test): Cylindrical specimens (150mm diameter, 300mm height) were subjected to a split tensile strength test to evaluate the tensile capacity of the concrete. This test provided insights into the concrete's ability to resist tension, which is important for structural applications where tensile stresses are involved.

Results

The results of the tests conducted on the concrete mixes containing varying percentages of SBA and Copper Slag showed the following trends:

• Workability: The slump test indicated a reduction in workability as the percentage of SBA increased. This reduction was expected due to the fine and porous nature of SBA, which tends to absorb more water. However, the inclusion of Copper Slag improved workability slightly, particularly at lower replacement levels, due to its angular shape and particle distribution.

• Compressive Strength: The compressive strength of concrete increased with the inclusion of SBA and Copper Slag up to an optimum percentage. For mixes with 10-15% SBA and 30% Copper Slag, the 28- day compressive strength was higher than that of the control mix. Beyond this range, a slight decrease in strength was observed due to excessive replacement, which affected the binding properties of the cement matrix.

• Tensile Strength: The tensile strength of concrete followed a similar trend, with the inclusion of Copper Slag enhancing the tensile strength due to its strong interlocking characteristics. Mixes containing 20-30% Copper Slag and 10-15% SBA demonstrated better tensile strength compared to the control mix, indicating that these replacement levels are optimal for maintaining both compressive and tensile strength.

Evaluation

The results of the testing demonstrated that partial replacement of cement with SBA and fine aggregate with Copper Slag is feasible for improving the mechanical properties of concrete, especially at moderate replacement levels. The pozzolanic reaction of SBA contributed to long-term strength gain, while Copper Slag enhanced the density and mechanical strength. However, care must be taken not to exceed optimal replacement levels, as excessive use of either material can lead to reduced workability and strength. The study suggests that an ideal mix for achieving high compressive and tensile strength includes 10-15% SBA and 20-30% Copper Slag. This mix design not only meets the required strength parameters but also contributes to sustainable construction by reducing the consumption of natural resources and minimizing waste.
when used in combination with copper slag, which yielded synergistic benefits

CONCLUSION

We have designed a concrete of grade M20, Sugarcane Bagasse Ash have been replaced 10%,15%,20% of cement and Copper Slag have been replaced 20%,40%,60% of fine aggregate. Pozzolanic materials, such as sugarcane bagasse ash (SCBA), fly ash, and silica fume, do not have cementitious properties on their own and Copper slag is coarser than fine aggregate which may affect the workability of the concrete The increase in SCBA and Copper Slag has reduced the strength in concrete. From investigation of this project we conclude that the optimum percentage of materials like SCBA should be added 5% to 15% and Copper Slag should be added 20% to 40% increasing further than this can reduce the strength of the concrete.

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