INVESTIGATING THE STRENGTH OF CONCRETE USING COPPER SLAG, BAGASSE ASH AND RICE HUSK ASH

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Abstract — This study looks at the strength qualities of concrete that contains industrial and agricultural waste materials, notably copper slag, bagasse ash, and rice husk ash, as partial substitutes for traditional cement and fine aggregates. The major goal is to assess the feasibility and efficacy of these materials in improving concrete performance and encouraging sustainable construction practices. Copper slag, a byproduct of the copper industry, is utilized as a partial substitute for fine aggregate, while bagasse ash and rice husk ash, obtained from the sugarcane and rice processing industries, respectively, are used as partial cement replacements. The results indicate that the blended use of bagasse ash and rice husk ash as partial cement replacements, along with copper slag as partial fine aggregate replacement, can produce concrete with acceptable strength and improved workability. Although the early-age strength may be slightly reduced due to the slower pozzolanic reaction of the ashes, the 28-day

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I. INTRODUCTION

A. General

Concrete is the most widely used construction material in the world due to its strength, durability, and versatility. However, the production of its key ingredient cement is highly energy-intensive and contributes significantly to global carbon dioxide (CO_2) emissions. Additionally, the continuous extraction of natural sand for use as fine aggregate in concrete has led to the depletion of riverbeds and adverse environmental impacts. In response to these challenges, researchers and engineers are increasingly exploring sustainable alternatives by incorporating industrial and agricultural waste products into concrete. This study focused on the use of bagasse ash (BA), rice husk ash (RHA), and copper slag (CS) as partial replacements for conventional cement and fine aggregate in the casting of concrete cubes. Bagasse ash is a byproduct of sugarcane processing, while rice husk ash results from the combustion of rice husks—both are rich in reactive silica and possess pozzolanic properties. These materials can partially replace cement, contributing to strength development through secondary hydration reactions. Copper slag, a waste material from copper refining processes, has excellent physical properties such as high specific gravity and angular particle shape, making it suitable as a partial replacement for sand.

B. Availability of Natural Sand as Fine Aggregate

In the last 15 years, it has become clear that the availability of good quality natural sand is decreasing. Crushed aggregate, bottom ash, foundry sand and various by-products are replacing natural sand and gravel in most countries.
The research emphasizes on the use of material to be replaced by natural sand which will give new dimension in concrete mix design and if applied on large scale would revolutionize the construction industry by economizing the construction cost and enable us to conserve natural resources

C .Production Of Copper Slag

In the separation of copper, the slag is a by-product obtained during the matte smelting and refining of copper has been reported by Bis was and Davenport in 2002. The major constituent of a smelting charge are sulphides and oxides of iron and copper. The charge also contains oxides such as silica oxide(SiO2), Aluminium oxides (Al2O3), Calcium oxide (CaO) and Magnesium oxide (MgO), which are either present in original concentration or added as a flux. It is Iron, Copper, Sulphur, Oxygen and their oxides which largely control the chemistry and physical constitution of smelting system. A further important factor is the oxidation or reduction potential of the gases which are used to heat and melt the charge stated by Goran et al in 2002.

D .Production of Bagasse ash:

Bagasse ash is produced as a by-product during the combustion of bagasse, which is the fibrous residue left after juice is extracted from sugarcane in sugar mills. In many sugar-producing regions, bagasse is not treated as waste;

instead, it is used as a renewable fuel source to generate heat and electricity. This is commonly done in cogeneration plants, where bagasse is burned in boilers to produce steam, which drives turbines for electricity generation. During this combustion process, the organic material in bagasse is burned off, and the inorganic minerals remain behind as ash—this is known as bagasse ash.

The quality and chemical composition of bagasse ash largely depend on how the bagasse is burned. Controlled combustion at moderate temperatures (typically between 500°C and 700°C) tends to produce ash with higher pozzolanic activity, particularly when the silica remains in an amorphous, or non-crystalline, state. However, if the combustion temperature is too high or inconsistent, the ash may contain unburned carbon or form crystalline silica, which reduces its effectiveness in applications such as cement replacement. After combustion, the ash is collected either from the bottom of the boiler (bottom ash) or from the flue gases (fly ash), depending on the type of boiler system. The collected ash may be processed further—such as sieving, grinding, or even chemical treatment—to enhance its suitability for industrial use.

E. **Production of Rice husk ash**

Rice husk ash (RHA) is produced by burning rice husks, which are the hard outer shells that protect rice grains during growth. These husks are a by-product of rice milling and are generated in large quantities, especially in rice-producing countries. Instead of being discarded or left to decompose, rice husks are often used as a source of bioenergy in industrial boilers, particularly in rice mills. When rice husks are burned under controlled conditions, the organic matter is oxidized, and the inorganic components mainly silica remain as ash, known as rice husk ash. The method and conditions of combustion play a crucial role in determining the quality of the rice husk ash. For RHA to be suitable for use as a pozzolanic material in concrete or cement, the silica it contains must be in an amorphous (non-crystalline) form, which is reactive with lime. This is best achieved when rice husks are burned at moderate temperatures, typically between 500°C and 700°C. If the temperature is too low, incomplete combustion occurs, resulting in ash with high carbon content. Conversely, if the temperature is too high above 800°C the silica can become crystalline, reducing its reactivity and usefulness in construction.

II. REVIEW OF LITERATURE

Dhanshree Patil et al. (2023)[1]. Rice husk ash (RHA) is a valuable substitute for cement in modern concrete due to its pozzolanic reactivity and economic production. Derived as a by-product from rice plants and paddy industries, RHA enhances concrete strength and durability while offering an environmentally friendly disposal method for agricultural waste. This study examines the properties and performance of concrete with 5%, 10%, 15%, and 20% RHA replacement, comparing it to normal concrete at 7, 14, and 28 days. Results indicate that a 10% RHA replacement optimizes compressive strength and durability. RHA's high silica content (90% SiO_2) gives it excellent pozzolanic properties. This research underscores the positive effects of incorporating RHA into concrete.

Reza Sedghi et al. (2023) [2]. In this research, the mechanical and hydraulic characteristics of pervious concrete incorporating copper slag coarse aggregate were investigated. Generally, seven main mixes including 0%, 20%, 40%, 50%, 60%, 80%, and 100% replacement of dolomite aggregate with copper slag were considered in this study. The results of mechanical strength tests revealed that the highest increase in strength compared to the control mix was related to 60% replacement, in which compressive strength, flexural strength, and splitting tensile strength increased 31%, 19% and 18%, respectively.

III. OBJECTIVES AND METHODOLOGY

A. *Objective of the Project*

1. To reduce cement consumption by incorporating agro-waste materials, thereby minimizing the depletion of limestone and clay.
2. To evaluate the strength of concrete with copper slag as fine aggregate.
3. To analyze the effects of bagasse ash & rice husk ash as cement replacements

B. *Materials Involved*

- Concrete
- M-sand
- Coarse aggregate
- Copper slag

Copper slag is a waste product created during the smelting and refining of copper. It is a mixture of iron and silica oxides, and also contains small amounts of other elements.

Figure 1. Copper slag

- Bagasse ash

Bagasse ash is a waste product from the sugar industry that's created when sugarcane bagasse is burned.

Bagasse ash is used in the construction industry as a supplementary cementitious material to improve the performance of concrete and mortar

Figure 2. Bagasse ash

- Rice husk ash

Rice husk is an agricultural byproduct obtained from rice milling, and when burnt it produces Rice Husk Ash. Rice Husk Ash is a sustainable, cost-effective, and environmentally friendly alternative to cement, offering improved strength, durability, and resistance to aggressive environments

Figure 3. Rice husk ash

C. *Mix proportioning*

Concrete mix designs are prepared with varying replacement levels of copper slag, bagasse ash and rice husk ash to study their effects on strength and durability.

Mix	Cement replacement %	Fine replacement %
	Bagasse ash (BA)+Rice husk ash (RHA)	Copper slag (CS)
M1 (Control)	0%+0%	0%
M2	0%+0%	30%
M3	15%(BA)+15%(RHA)	30%
M4	20%(BA)+20%(RHA)	30%
M5	25%(BA)+25%(RHA)	30%

D. *Compressive strength testing*

- The compressive strength test of a concrete cube is one of the most fundamental and essential tests to assess the load-bearing capacity of hardened concrete. It is performed using a Compression Testing Machine (CTM), typically of 2000 kN capacity. The concrete cubes used for this test are generally cast in moulds of standard dimensions, usually 150 mm × 150 mm × 150 mm.
- These moulds are filled with fresh concrete in three equal layers. Each layer is thoroughly compacted using a tamping rod with 25 strokes to eliminate air voids and ensure uniformity.
- After casting, the cubes are allowed to set for 24 hours in a controlled environment. They are then removed from the moulds and placed in a water-curing tank or moist room at a temperature of 27 ± 2°C. The curing period typically lasts for 7, 14, or 28 days, depending on the testing requirement. Proper curing is vital as it ensures complete hydration and strength development of the concrete.
- The cube is then placed in the CTM such that the load is applied perpendicular to the direction of casting. This ensures that the load is evenly distributed across the cube surface
- The CTM applies a gradually increasing compressive load at a uniform rate of 140 kg/cm² per minute (approximately 1.2 kN/sec) until the cube fails. The maximum load at the point of failure is noted.

E. *Split tensile tests*

- The tensile strength of concrete is a critical property that influences its cracking resistance and overall structural behavior. Since concrete is weak and brittle in direct tension, it is not practical to test it using direct tensile methods, especially on cube specimens
- In this test, a 150 mm × 150 mm × 150 mm concrete cube is subjected to a compressive load along its vertical edges using a Compression Testing Machine (CTM). This setup induces tensile stresses perpendicular to the applied load, causing the cube to split vertically along its center.
- Before testing, the cube is cured for a standard period (usually 7 or 28 days), then removed from the curing tank and surface dried. To ensure uniform stress distribution, two narrow strips of plywood or rubber padding (about 3 mm thick and 25 mm wide) are placed between the cube and the CTM platens, aligning with the line of load application .
- The cube is then positioned in the CTM so that the load is applied along one set of opposite vertical faces, and the machine is operated to apply the load gradually at a uniform rate of about 1.2 kN/sec.

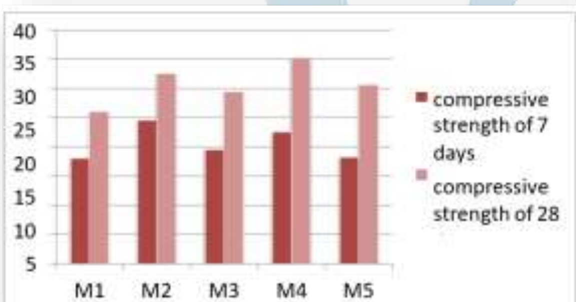
F. *Efflorescence tests*

- Efflorescence is a surface phenomenon characterized by the appearance of white, powdery deposits on the surface of concrete due to the movement of soluble salts.

- These salts, present either in the concrete mix or absorbed from the environment, dissolve in water and migrate to the surface, where they crystallize upon evaporation. While primarily an aesthetic issue, severe efflorescence can indicate deeper durability problems.
- To evaluate this, an efflorescence test is conducted on hardened concrete specimens, such as a 150 mm × 150 mm × 150 mm cube. This test is typically qualitative but can be extended to a semi-quantitative form by observing the degree of deposit formation or measuring weight changes.

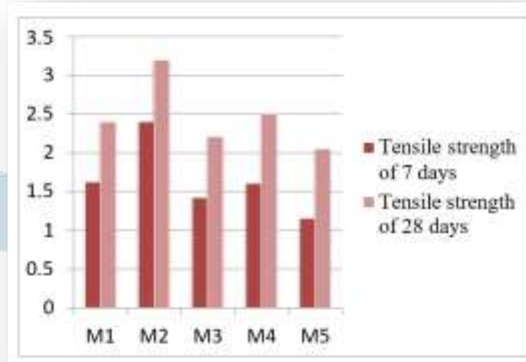
IV. *RESULTS AND DISCUSSIONS*

A . Compression strength results for 7 & 28 days



The compressive strength results reveal important trends in the performance of concrete with varying combinations of copper slag and pozzolanic materials. The control mix (M1), containing no replacements, achieved 26 MPa at 28 days. This improvement is attributed to enhanced secondary hydration and better particle packing. In contrast, further increasing the ash content to 25% each (M5) resulted in a decline in strength to 30.6 MPa, possibly due to excessive cement dilution and incomplete reaction of pozzolans. Overall, the results suggest that a 40% combined replacement of cement with RHA and BA, along with 30% copper slag, yields the most favorable compressive strength.

B. Tensile strength test results



The split tensile strength results follow a similar trend to the compressive strength outcomes, showing how the addition of copper slag and pozzolanic ashes affects the concrete's performance under tensile stress. The control mix (M1), with no replacements, exhibited a tensile strength of 2.4 MPa at 28 days. Incorporating 30% copper slag alone (M2) significantly enhanced the tensile strength to 3.2 MPa, reflecting the dense, angular texture of copper slag that contributes to improved bonding and crack resistance. However, with the inclusion of 15% rice husk ash and 15% bagasse ash in mix M3, the 28-day tensile strength dropped to 2.21 MPa, indicating the effect of reduced cement content and the relatively slower pozzolanic reaction

C. *Efflorescence test results*

The efflorescence test results provide insight into the impact of copper slag, bagasse ash (BA), and rice husk ash (RHA) on the leaching of lime compounds and surface salt deposits in concrete. The control mix (CS), which contained no replacements, showed a relatively high salt deposit of 40% and was rated as having moderate efflorescence. This is attributed to the high free lime content in ordinary Portland cement and greater permeability in conventional concrete. When 30% copper slag was added alone (with 0% RHA+BA), the salt deposit reduced significantly to 15%, receiving a slight to moderate rating. This improvement is due to copper slag's ability to reduce concrete permeability, thereby limiting moisture and salt migration.
displacement performance in the X axis, confirming steady lateral behaviour and energy dissipation.

VII. CONCLUSION

The partial substitution of copper slag, bagasse ash, and rice husk ash in concrete shows encouraging promise in improving strength characteristics and encouraging sustainability. According to the study, as compared to traditional mixes, concrete with the right replacement amounts can have better compressive strength, workability, and durability. Bagasse ash and rice husk ash's pozzolanic activity improves long-term strength growth, whereas copper slag's dense, angular particles help improve mechanical interlocking. Additionally, by lowering the need for natural raw resources and avoiding landfill disposal, the use of these industrial and agricultural wastes promotes environmental conservation. All things considered, including these additional components in concrete is consistent with sustainable building methods and offers a practical way to create environmentally friendly and structurally strong concrete.

VIII. REFERENCES

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Codes;

- **IS 2720(PART3):** To determine the specific gravity of fine materials such as bagasse ash and rice husk ash.

- **IS 2386(PART3):** Methods of test for aggregate for concrete and to fine specific gravity, density, and water absorption