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EXPERIMENTAL STUDY ON CONCRETE USING MARBLE POWDER, RICE HUSK ASH, AND STEEL SLAG AS ALTERNATIVE CONSTRUCTION MATERIALS

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ABSTRACT

The present study investigates the mechanical and durability properties of concrete incorporating sustainable industrial and agricultural by-products as partial replacements of conventional constituents. Fine aggregate was partially replaced with marble powder to utilize waste from the marble industry, thereby reducing disposal hazards and improving particle packing. Rice husk ash was used as a supplementary cementitious material, replacing cement due to its pozzolanic reactivity and ability to enhance long-term strength and durability. Additionally, steel slag was employed as a partial replacement of coarse aggregate to improve the toughness and load-bearing capacity of concrete. Experimental work involved casting and testing concrete specimens with varying replacement levels, and results were compared with control mixes. Parameters such as compressive strength and split tensile strength were evaluated at 7 and 28 days of curing. The findings demonstrated that optimized proportions of marble powder, rice husk ash, and steel slag improved mechanical performance, reduced porosity, and enhanced durability. Moreover, the combined use of these materials contributed to sustainable construction practices by reducing natural resource consumption and lowering environmental impact. The study concludes that this eco-friendly composite concrete has significant potential for structural applications.

KEYWORDS: Marble powder, Rice husk ash, Steel slag, Sustainable concrete, Waste utilization, Compressive strength, Partial replacement, Durability.

1. INTRODUCTION

Concrete is the most widely used construction material across the globe due to its versatility, strength, and durability. It is a composite material made up of cement, fine aggregate, coarse aggregate, and water, which when combined undergoes hydration to form a hard, stone-like mass. The demand for concrete has steadily increased with rapid urbanization and infrastructure development. However, the large-scale use of natural aggregates and cement in concrete production has raised concerns regarding depletion of natural resources and environmental

impacts such as carbon emissions and waste generation. Therefore, it has become essential to explore sustainable alternatives to conventional raw materials without compromising the performance of concrete.

One of the effective strategies to achieve sustainable construction is the partial replacement of concrete constituents with industrial and agricultural by-products. This not only minimizes environmental hazards associated with waste disposal but also conserves natural resources and reduces the overall cost of construction. Marble powder, generated as waste from the marble industry, is rich in calcium carbonate and has a very fine particle size that makes it suitable as a partial replacement for fine aggregate. Its addition improves particle packing and reduces voids in the concrete mix, thereby enhancing strength and durability when used in optimal proportions.

Similarly, rice husk ash, an agricultural residue obtained from burning rice husks, has gained attention as a supplementary cementitious material. It contains a high amount of amorphous silica, which exhibits pozzolanic properties. When used as a partial replacement of cement, rice husk ash reacts with the calcium hydroxide released during hydration, forming additional calcium silicate hydrate (C-S-H) gel, which contributes to strength development and long-term durability. Incorporating rice husk ash not only reduces cement consumption but also provides an effective solution for managing agricultural waste.

Steel slag, a by-product from steel industries, offers another sustainable alternative by replacing natural coarse aggregates. It is a dense, hard material with good mechanical strength, making it suitable for structural concrete. The use of steel slag in concrete improves toughness, abrasion resistance, and load-bearing capacity. By integrating marble powder, rice husk ash, and steel slag into concrete, a composite eco-friendly material can be produced that addresses both environmental and engineering concerns. This approach supports the development of green concrete with reduced ecological footprint, paving the way for sustainable infrastructure.

2. OBJECTIVES

1. **To evaluate the effect of partial replacement of fine aggregate with marble powder** on the mechanical properties of concrete, focusing on compressive and split tensile strength.
2. **To study the performance of rice husk ash as a partial replacement of cement** and its contribution to strength development and durability of concrete.
3. **To investigate the influence of steel slag as a partial replacement of coarse aggregate** on the toughness and load-bearing capacity of concrete mixes.
4. **To determine the optimum combination of marble powder, rice husk ash, and steel slag** that yields the best compressive and split tensile strengths at 7 and 28 days compared to conventional concrete.

3. MATERIALS

3.1 Cement:- A fine binding material, typically composed of limestone and clay, that hardens when mixed with water. It is the main ingredient responsible for strength in concrete through the hydration process.

3.2 Fine Aggregate:- Naturally occurring sand or crushed stone passing through a 4.75 mm sieve. It fills voids between coarse aggregates and improves workability of concrete.

3.3 Coarse Aggregate:- Gravel or crushed stone retained on a 4.75 mm sieve. It provides bulk, strength, and stability to concrete mixtures.

3.4 Water:- A key ingredient in concrete that reacts chemically with cement to form hydration products. It also provides the necessary workability for placing and compaction.

3.5 Marble Powder:- A waste by-product obtained during cutting and polishing of marble stones. It is rich in calcium carbonate and can partially replace fine aggregate in concrete.

3.6 Rice Husk Ash:- A by-product from controlled burning of rice husks, containing high amorphous silica. It exhibits pozzolanic properties and can replace a portion of cement in concrete.

3.7 Steel slag :- A by-product generated during steel manufacturing in blast furnaces. It is a dense, durable material suitable as a partial replacement for coarse aggregate.

4. EXPERIMENTAL RESULTS

4.1 Compressive strength:-In this test, standard concrete cubes measuring 150 mm × 150 mm × 150 mm are cast and properly cured. After 7 or 28 days of curing, the cubes are placed in a compression testing machine, where a gradually increasing load is applied until failure occurs. The maximum load at failure is then used to calculate the compressive strength of the concrete.

Table 1: Compressive strength results of concrete marble powder as partial replacement offline aggregate.

Sl.no	% of marble powder	Compressive Strength Results, N/mm ²	
		7 days	28 days
1	0%	19.51	27.88
2	5%	19.68	28.99
3	10%	20.75	30.12
4	15%	22.02	31.51
5	20%	21.07	30.45

Table 2: Compressive strength results of concrete rice husk ashes partial replacement of cement.

Sl.no	% of rice husk ash	Compressive Strength Results, N/mm ²	
		7 days	28 days
1	0%	19.51	27.88
2	2.5%	19.39	28.17
3	5%	19.98	28.48
4	7.5%	19.86	28.42

Table 3: Compressive strength results of concrete steel slag as partial replacement of coarse aggregate

Sl.no	% of steel slag	Compressive Strength Results, N/mm ²	
		7 days	28 days
1	0%	19.51	27.88
2	20%	21.49	30.75
3	40%	23.64	32.62
4	60%	21.07	30.11

Table 4: Compressive strength results of Combined replacement of % of MP+% of RHA+% of SG in concrete.

Sl.no	% of MP+% of RHA+% of SG	Compressive Strength Results, N/mm ²	
		7 days	28 days
1	0%	19.51	27.88
2	% of MP+% of RHA+% of SG	24.28	34.74

4.2 Split tensile strength: - Split tensile strength is an indirect method used to assess the tensile capacity of concrete, as concrete is naturally weak in direct tension. In this test, a cylindrical specimen is positioned horizontally, and a compressive load is applied along its diameter. The applied load generates tensile stresses within the cylinder, causing it to split along the line of loading. Tests are performed at 7 and 28 days of curing to evaluate the development of tensile strength and observe the cracking behavior of the concrete.

Table 5: Split tensile strength results of concrete marble powder as partial replacement of fine aggregate.

Sl.no	% of marble powder	Split tensile Strength Results, N/mm ²	
		7 days	28 days
1	0%	1.89	2.75
2	5%	1.94	2.83
3	10%	2.04	2.97
4	15%	2.82	3.18
5	20%	2.08	3.02

Table 6: Split tensile strength results of concrete rice husk ash as partial replacement of cement.

Sl.no	% of rice husk ash	Split tensile Strength Results, N/mm ²	
		7 days	28 days
1	0%	1.89	2.75
2	2.5%	1.97	2.89
3	5%	2.09	3.01
4	7.5%	1.95	2.82

Table 7: Split tensile strength results of concrete steel slag as partial replacement of coarse aggregate

Sl.no	% of steel slag	Split tensile Strength Results, N/mm ²	
		7 days	28 days
1	0%	1.89	2.75
2	20%	2.11	3.05
3	40%	2.36	3.29
4	60%	2.08	3.01

Table 8: Split tensile strength results of combined replacement of % of MP+% of RHA+% of SG in concrete.

Sl.no	% of MP+% of RHA+% of SG	Split tensile Strength Results, N/mm ²	
		7 days	28 days
1	0%	1.89	2.75
2	% of MP+% of RHA+% of SG	2.56	3.63

5. CONCLUSION

1. The **normal concrete without any replacement** achieved a compressive strength of 19.51 N/mm² at 7 days and 27.88 N/mm² at 28 days.
2. **Marble powder replacement** showed an increase in compressive strength up to 15% replacement, where the concrete achieved 22.02 N/mm² at 7 days and 31.51 N/mm² at 28 days. Beyond 15%, strength slightly decreased.
3. **Rice husk ash replacement** exhibited a marginal improvement at 5% replacement, with compressive strengths of 19.98 N/mm² at 7 days and 28.48 N/mm² at 28 days.
4. **Steel slag replacement** improved strength significantly at 40% replacement, achieving 23.64 N/mm² at 7 days and 32.62 N/mm² at 28 days.
5. **Combined replacement of MP, RHA, and SG** resulted in the highest compressive strength, with 24.28 N/mm² at 7 days and 34.74 N/mm² at 28 days.
6. **The normal concrete without any replacement** achieved a split tensile strength of 1.89 N/mm² at 7 days and 2.75 N/mm² at 28 days.
7. **Marble powder replacement** showed an increase in split tensile strength up to 15% replacement, achieving 2.82 N/mm² at 7 days and 3.18 N/mm² at 28 days. Beyond 15%, the strength slightly decreased.
8. **Rice husk ash replacement** improved tensile strength at 5% replacement, with values of 2.09 N/mm² at 7 days and 3.01 N/mm² at 28 days.
9. **Steel slag replacement** enhanced tensile strength significantly at 40% replacement, achieving 2.36 N/mm² at 7 days and 3.29 N/mm² at 28 days.
10. **Combined replacement of MP, RHA, and SG** produced the highest split tensile strength, with 2.56 N/mm² at 7 days and 3.63 N/mm² at 28 days.

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