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Optimizing Concrete Properties Utilizing Marble Waste Powder with Fine Aggregate and Coconut Shell with Coarse Aggregate

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Abstract -The study delves into the innovative utilization of marble waste powder and coconut shell as potential additives in concrete production, aiming to enhance its mechanical and physical properties. By replacing 20% of coarse aggregate with coconut shell and varying the proportion of marble waste powder as replacements for fine aggregate at 25%, 50%, 75%, and 100%, a series of experimental mixes were formulated. Ordinary Portland cement of grade 53 served as the binding agent. Results indicated significant improvements in various engineering properties of the concrete, particularly in cube compressive strength, split tensile strength, and flexural strength. The study underscores the economic and ecological viability of incorporating these waste materials, highlighting their role in augmenting concrete performance while reducing environmental impact. This research contributes to advancing sustainable practices within the construction industry by optimizing material usage and enhancing concrete properties through innovative means.

Key Words: Marble waste powder (MWP), Coconut shell (CS), Concrete.

1. INTRODUCTION

Concrete, a cornerstone of construction, relies on ingredients like cement, sand, aggregates, water, and admixtures. However, in countries like India, natural resources such as river sand and coarse aggregate are depleting rapidly, necessitating alternative materials. Coconut shells, abundant and non-biodegradable, offer a solution as a potential coarse aggregate, mitigating solid waste generation. Meanwhile, marble dust, a byproduct of marble production, poses environmental challenges when disposed of improperly. However, it can be repurposed as an admixture in concrete, enhancing its strength and sustainability. This experiment aims to explore the partial replacement of coconut shell for coarse aggregate and marble waste powder for fine aggregate. Such initiatives address the urgent need for sustainable construction practices, given the escalating environmental impact of traditional concrete production methods and the depletion of natural resources.

Vigneshpandian et al.[1] analyzed waste marble dust as a fine aggregate substitute, demonstrating improved concrete performance at 50% replacement. Ashish[2] found that substituting 20% of sand with marble powder improves concrete properties, suggesting cost-effective and sustainable solutions. Harle[3] explored coconut shell aggregates in M20, M35, and M50 concrete mixes, finding that up to 15% replacement maintained compressive strength. Tangadagi et al.[4] studied coconut shell (CS) as a partial replacement for coarse aggregate in M20 concrete, finding a viable substitution of up to 20%. Gopi et al.[5] investigated marble powder as a partial cement replacement, noting a 15% increase in compactor factor and a 14.53% increase in compressive strength. Tensile strength rose by 14.25%, and concrete modulus by 7.1%. Vardhan et al.[6] studied marble waste as a partial replacement for river sand, finding improved concrete strength and reduced drying shrinkage, with optimal results at 40% replacement. Kanojia et al.[7] investigated the partial replacement of conventional coarse aggregate with coconut shell in concrete, observing decreased compressive strength with higher coconut shell proportions. Mathew et al.[8] examined the thermal properties of coconut shell aggregate concrete (CSAC) and found that 40% replacement met criteria for thermal insulating concrete.

2. METHODOLOGY

Cement: A fine material with adhesive properties, binds aggregates to form concrete. It is produced from calcinated raw materials and is available in various grades for construction. In this research, Sagar cement OPC53 grade is utilized.

Table -1: Physical properties of Cement

S.No	Properties	Results
1	Fineness of cement	4%
2	Specific gravity of cement	3.15
3	Normal consistency of cement	32
4	Initial and final setting time	35 min and 10 hrs
5	Density of cement	1440 kg/m^3

Marble waste powder, generated in the marble stone industry, originates from crushed marble, formed by limestone crystallization. It features a fine powdery texture with a shimmer, varying in color due to impurities. Specific gravity is 2.56.

Fig -1: Marble waste powder

Coconut shells, abundant but underutilized, present an opportunity as an alternative coarse aggregate, addressing environmental concerns in concrete production. Specific gravity is 2.49.

Fig -2: Coconut Shell

Fine aggregate, In this research, Chitravathi river sand is utilized as the fine aggregate, characterized by its ability to pass through a 4.75 mm sieve. The specific gravity of the river sand is 2.65

Coarse aggregate, exceeding 4.75 mm in size, exert a considerable influence on concrete properties. In this research, graded aggregates with nominal sizes of 20 mm and 10 mm are frequently employed. The specific gravity is 2.81

Water, in concrete research, serves as a crucial component for hydration, facilitating the binding of cement with aggregates to form a durable composite material for construction.

3. RESULTS AND DISCUSSION

The study on Optimizing Concrete Properties Utilizing Marble Waste Powder with Fine Aggregate and Coconut Shell with Coarse Aggregate" in M20 grade concrete, focused on various mix proportions. Testing at the age of 28 days included assessing compressive strength using cube molds sized 150 mm × 150 mm × 150 mm, split tensile strength with cylindrical specimens measuring 100mm x 200 mm, and flexural strength utilizing beam molds sized 500 mm × 100 mm × 100 mm. Results were tabulated and graphically depicted to enhance clarity and facilitate comprehensive analysis.

Table -2: Compressive strength results for 28 days

S.No	Mix Details	Compressive strength (MPa)
M0	C+FA+CA(100%)	31.4
M1	C+(MWP25%+FA75%)+(CS20% +CA80%)	33.79
M2	C+(MWP50%+FA50%)+(CS20% +CA80%)	38.93
M3	C+(MWP75%+FA25%)+(CS20% +CA80%)	30.96
M4	C+(MWP100%+FA0%)+(CS20% +CA80%)	27.79

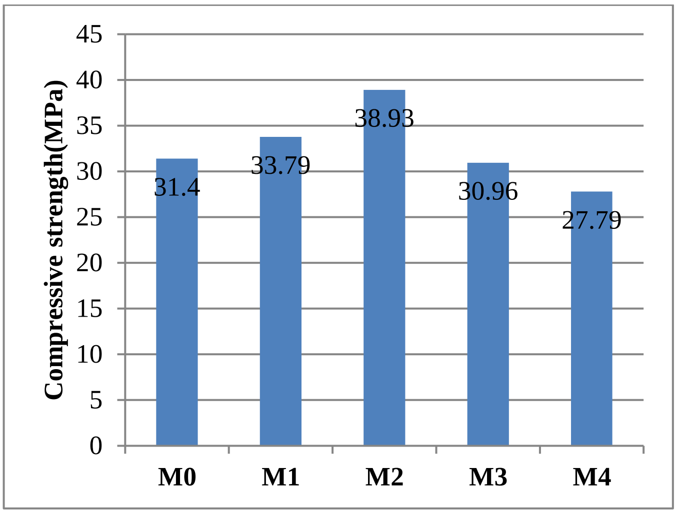

Fig -3: Compressive strength results for 28 days

The graph shows the values of compressive strength for different concrete mixes at 28 days of curing. Comparing the compressive strength results of M0 with the other mixes indicates that while the control mix achieved the highest strength at 31.4 MPa, the experimental mixes displayed varying degrees of reduction in strength. Among the experimental mixes, M1 showed the highest strength at 28.79 MPa, with subsequent decreases observed in M2, M3, and M4. This suggests that the incorporation of marble waste powder and coconut shell adversely affected compressive strength, particularly as the substitution percentages increased. To optimize concrete performance, it's recommended to carefully balance the inclusion of waste materials with traditional aggregates, aiming for a mix that enhances sustainability without compromising structural integrity. Further research could explore additional admixtures or alternative proportions to achieve a more balanced blend of eco-friendliness and strength in concrete formulations.

Table - 3: Split tensile results for 28 days

S.No	Mix Details	Split tensile strength (MPa)
M0	C+FA+CA(100%)	3.95
M1	C+(MWP25%+FA75%)+(CS20 %+CA80%)	3.07
M2	C+(MWP50%+FA50%)+(CS20 %+CA80%)	2.43
M3	C+(MWP75%+FA25%)+(CS20 %+CA80%)	2.75
M4	C+(MWP100%+FA0%)+(CS20 %+CA80%)	1.46

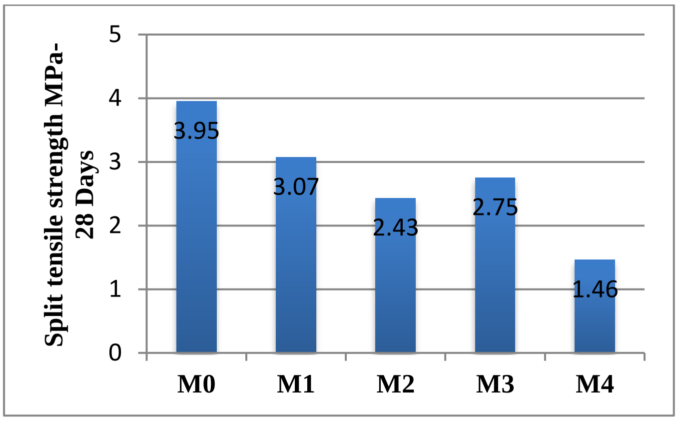

Fig -4: Split tensile results for 28 days

Comparing the split tensile strength results for 28 days reveals that while mix M0, with 100% traditional aggregates, demonstrated the highest strength at 3.95 MPa, subsequent mixes incorporating marble waste powder showed a consistent decrease in strength. Mix M1 exhibited the highest split tensile strength among the experimental mixes at 3.07 MPa, with further reductions observed in mixes M2, M3, and M4. The decline suggests the influence of waste material incorporation on concrete's tensile behavior. Balancing sustainability goals with mechanical performance considerations is crucial in concrete mix design. Future research should focus on optimizing mix proportions and investigating the long-term durability of concrete containing marble waste powder and coconut shell aggregates to ensure sustainable and resilient construction materials.

Table - 4: Flexural strength results for 28 days

S.No	Mix Details	Flexural strength (MPa)
M0	C+FA+CA(100%)	5.15
M1	C+(MWP25%+FA75%)+(CS20%+CA 80%)	4.44
M2	C+(MWP50%+FA50%)+(CS20%+CA 80%)	3.31
M3	C+(MWP75%+FA25%)+(CS20%+CA 80%)	3.1
M4	C+(MWP100%+FA0%)+(CS20%+CA 80%)	1.89

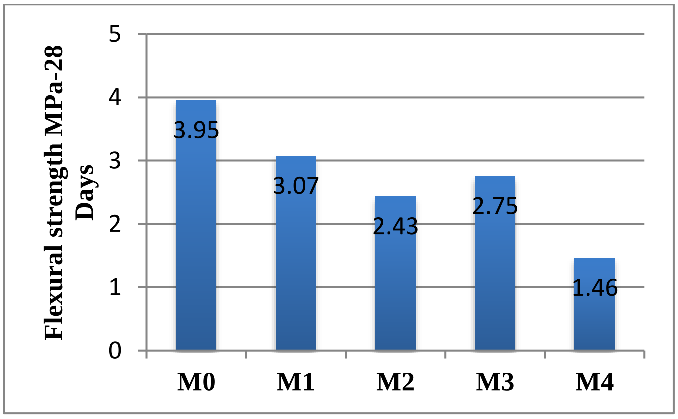

Fig -5: Flexural strength results for 28 days

The above figure shows the flexural strength results for 28 days, indicating that mix M0, with 100% traditional aggregates, achieved the highest strength at 5.15 MPa. However, as marble waste powder increased in mixes M1, M2, M3, and M4, there was a consistent decline in flexural strength. Mix M1 displayed the highest flexural strength among the experimental mixes at 4.44 MPa, with subsequent mixes showing further reductions. Notably, mix M4, featuring 100% marble waste powder substitution, demonstrated the lowest flexural strength at 1.89 MPa. These results emphasize the influence of waste material inclusion on concrete's flexural performance. Balancing sustainability objectives with mechanical properties is vital in concrete mix design. Future research should focus on refining mix proportions and assessing the long-term durability of concrete containing marble waste powder and coconut shell aggregates to ensure resilient and environmentally friendly construction materials.

4. CONCLUSIONS

This research delves into the incorporation of marble waste powder and coconut shell in concrete mixes, revealing implications for compressive, split tensile, and flexural strengths. While the control mix (M0) demonstrated superior strength, experimental mixes (M1, M2, M3, and M4) showed varying strength reductions with increasing substitution percentages. This highlights the need to carefully balance waste material inclusion with traditional aggregates to optimize concrete performance sustainably.

Future efforts should focus on refining mix proportions and exploring additional admixtures or alternative ratios to achieve an eco-friendly yet robust blend. It is essential to conduct thorough assessments of the long-term durability of concrete containing marble waste powder and coconut shell aggregates. This study significantly advances sustainable practices in construction, offering insights into material utilization and concrete enhancement, paving the way for environmentally conscious and resilient infrastructure projects.

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