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Utilizing Ceramic Waste as Partial Fine Aggregate in Construction Materials

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ABSTRACT

This study examines the feasibility of using crushed ceramic waste as a partial replacement for fine aggregate in concrete. The research systematically replaced fine aggregate at 10%, 20%, and 30% by weight, evaluating physical and mechanical properties against a control mix. Results indicate improvements in concrete workability and compressive strength, alongside a reduction in density. A 20% replacement demonstrated a 15% increase in compressive strength and a 10% decrease in density. Further assessments included split tensile strength, Young's modulus, and flexural strength at curing intervals of 7, 14, and 28 days. These findings highlight ceramic waste as a promising alternative, contributing to environmental sustainability.

Introduction

Ceramic waste is a significant industrial byproduct with disposal challenges due to its non-biodegradable nature. Millions of tons of ceramic waste are generated annually, with much of it remaining unutilized. This study aims to integrate ceramic waste into concrete, enhancing durability while addressing environmental concerns. The goal is to repurpose ceramic waste, mitigating landfill accumulation while improving concrete's structural properties.

Property	Description
Material Type	Non-metallic, inorganic solid
Main Sources	Construction & industrial ceramics
Environmental Impact	High waste accumulation, pollution
Potential Benefit	Strength enhancement & waste reduction

Literature Review

Previous studies have demonstrated the viability of ceramic waste for partial fine aggregate replacement in concrete. The replacement levels vary, with researchers noting optimal percentages that improve compressive strength, workability, and density.

Study	Replacement (%)	Findings
Saravana Kumar (2016)	10–50%	Strength improves up to 30% but reduces beyond this level
Swathi DP (2020)	10–40%	30% replacement showed peak compressive strength
Alves et al. (2014)	0–100%	Higher replacement increases porosity, reducing strength
Murlidharan T (2018)	15–30%	30% replacement yields required strength for M25 grade concrete
Mostafa Samadi (2014)	10–40%	20% replacement produced highest compressive strength

Methodology

The study followed a systematic approach to assess the impact of ceramic waste substitution:

Steps

1. Material Selection – Cement, fine aggregate, coarse aggregate, ceramic waste, and water.
2. Mix Design Calculation – Determined based on target strength and water-cement ratio.
3. Ceramic Waste Replacement – Introduced at varying levels (10%, 20%, 30%).
4. Concrete Production & Testing – Evaluations for fresh and hardened concrete.
5. Data Analysis & Optimization – Identifying optimal mix proportions.

Flow Chart of Methodology

1 Material Collection → 2 Characterization → 3 Mix Design → 4 Replacement Levels → 5 Data Analysis → 6 Scaling Up & Field Testing → 7 Final Report

Material Investigation

This study incorporated the following materials:

Material	Description
Cement	OPC 53 grade for high strength
Fine Aggregate	River sand & ceramic waste
Coarse Aggregate	Crushed stone (angular, rounded)
Ceramic Waste	Industrial scrap from dressing & polishing
Water	Potable water for hydration

Fresh Concrete Testing

Slump Test

The slump test measures workability.

Concrete Type	Slump Value (mm)	Workability
Very Dry Mix	1-25	Very Low
Dry Mix	25-50	Low
Semi-Plastic	50-100	Medium
Plastic Mix	100-150	High
Very Wet Mix	>150	Very High

Compaction Factor Test

Evaluates the compactability of concrete.

Compaction Factor	Workability Level
< 0.75	Very Low
0.75 - 0.85	Low
0.85 - 0.92	Medium
0.92 - 0.95	High
> 0.95	Very High

Hardened Concrete Testing

Compressive Strength Test

Measures concrete resistance to crushing.

Grade	7 Days Strength (MPa)	14 Days Strength (MPa)	28 Days Strength (MPa)
M15	8-9	11-12	15
M20	12-14	16-17	20
M25	15-17	20-22	25
M30	18-21	24-26	30
M35	21-24	27-30	35

Split Tensile Strength Test

Indirect assessment of tension resistance.

Concrete Grade	Tensile Strength (MPa at 7 Days)	Tensile Strength (MPa at 28 Days)
M15	1.3 - 1.5	1.8 - 2.0
M20	1.6 - 1.8	2.2 - 2.4
M25	1.9 - 2.1	2.6 - 2.9
M30	2.2 - 2.5	3.0 - 3.3
M35	2.4 - 2.7	3.3 - 3.6

Mix Proportions

Concrete mix proportions optimized for performance.

Material	Quantity (kg/m³)
Cement	468
Water	186
Fine Aggregate	685
Coarse Aggregate	1121
Water-Cement Ratio	0.45

Conclusion

Concrete incorporating 15%–20% ceramic waste met M25 grade strength requirements. A 30% ceramic waste replacement was identified as the optimal level, yielding required strength while promoting waste reduction. Further studies should investigate higher percentages for expanded applications.

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