iJRASET
International Journal For Research in Applied Science and Engineering Technology



# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

**Volume:** 14 **Issue:** V **Month of publication:** May 2026

**DOI:** https://doi.org/10.22214/ijraset.2026.82426

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538*
*Volume 14 Issue V May 2026- Available at www.ijraset.com*

# Study on Partial Replacement of Fine and Coarse Aggregates by Ceramic Waste in Concrete

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***Abstract:*** ***Concrete is one of the most widely used construction materials in the world, but its production depends heavily on natural aggregates such as sand and crushed stone. Continuous extraction of these materials has created environmental concerns including depletion of riverbeds, habitat destruction, and increasing construction waste. Ceramic waste generated from broken tiles, sanitary ware, and construction debris has emerged as a sustainable alternative material for concrete production. This review paper examines the use of ceramic waste as a partial replacement for fine and coarse aggregates in concrete.***
***The study reviews research papers published between 2015 and 2025 and compares the influence of ceramic waste on compressive strength, split tensile strength, flexural strength, workability, and durability properties of concrete. The findings from the reviewed literature indicate that replacement levels between 20% and 30% generally provide optimum performance. Within this range, concrete exhibits improved mechanical properties while maintaining acceptable workability and durability. In addition, the use of ceramic waste helps reduce landfill disposal and conserves natural aggregate resources.***
***This review highlights the practical potential of ceramic waste in sustainable construction and identifies important areas for future research including long-term durability studies, large-scale implementation, and development of standard guidelines.***

## I. INTRODUCTION

Concrete plays a major role in modern infrastructure development and is extensively used in buildings, bridges, pavements, dams, and industrial structures. Aggregates constitute nearly 70–75% of the total volume of concrete and therefore large quantities of natural resources are consumed every year for construction activities. Rapid urbanization and infrastructure growth have significantly increased the demand for natural aggregates such as sand and crushed stone.

At the same time, the construction industry produces a large amount of waste materials. Ceramic waste generated from broken tiles, sanitary ware, rejected products, transportation damage, and demolition activities contributes significantly to landfill accumulation. Since ceramic materials are non-biodegradable, improper disposal creates environmental and land management problems.

Researchers have therefore explored the possibility of using ceramic waste as a replacement for natural aggregates in concrete. Ceramic materials possess good hardness, abrasion resistance, and chemical stability, making them suitable for concrete applications. Several experimental studies have shown that partial replacement of aggregates with ceramic waste can improve concrete strength and durability at certain replacement levels.

Although many studies are available on ceramic waste concrete, the reported results vary depending on material source, particle size, mix proportion, and curing conditions. Hence, a consolidated review is necessary to summarize existing findings and identify optimum replacement ranges.

The main objectives of this review paper are:

*1)* To study the physical and chemical properties of ceramic waste.
*2)* To review the effect of ceramic waste on fresh and hardened concrete properties.
*3)* To identify optimum replacement levels for fine and coarse aggregates.
*4)* To evaluate the environmental benefits of ceramic waste utilization.
*5)* To discuss future research opportunities in sustainable concrete technology.

## II. REVIEW METHODOLOGY

### *A. Literature Selection*

A structured review approach was followed for collecting relevant research articles. Research papers were selected from databases including Google Scholar, ScienceDirect, Scopus, and ResearchGate using keywords such as:

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- Ceramic waste concrete
- Ceramic tile aggregate
- Recycled ceramic aggregate
- Fine aggregate replacement
- Coarse aggregate replacement
- Sustainable concrete

The review mainly considered papers published between 2015 and 2025. However, a few important earlier studies were also included because of their foundational contribution to ceramic waste concrete research.

### *B. Inclusion Criteria*

The following studies were included in the review:

- Experimental studies involving ceramic waste as fine or coarse aggregate.
- Studies reporting compressive strength, workability, or durability properties.
- Studies clearly mentioning replacement percentage and curing period.

Studies without experimental results or without proper material characterization were excluded.

### *C. Research Gap*

Several previous review papers have discussed ceramic waste in concrete. However, many of them focus only on strength properties or only on fine aggregate replacement. This review combines findings related to both fine and coarse aggregate replacement and compares their mechanical, durability, and sustainability performance in a single study. The paper also highlights practical replacement limits and implementation challenges relevant to developing countries such as India.

## III. PROPERTIES OF CERAMIC WASTE

### *A. Physical Properties*

Ceramic waste obtained from tiles and sanitary ware generally possesses good hardness and abrasion resistance. The specific gravity of ceramic aggregates is slightly lower than conventional natural aggregates but remains suitable for structural concrete.

| Property | Ceramic Waste | Natural Aggregate |
|---|---|---|
| Specific Gravity | 2.20 – 2.50 | 2.55 – 2.70 |
| Water Absorption (%) | 0.5 – 0.3 | 1.0 – 4.5 |
| Abrasion Value (%) | 20 – 30 | 25 – 40 |
| Bulk Density (kg/m3) | 1300 - 1600 | 1400 - 1700 |

### *B. Chemical Composition*

Ceramic waste mainly contains silica ($SiO_2$) and alumina ($Al_2O_3$). The presence of silica contributes to limited pozzolanic activity and may improve bonding between cement paste and aggregate.

### *C. Environmental Concerns*

Improper disposal of ceramic waste creates landfill problems because ceramic materials do not decompose naturally. Recycling ceramic waste in concrete helps reduce environmental pollution and minimizes the extraction of natural aggregates.

## IV. LITERATURE REVIEW

### *A. Ceramic Waste as Fine Aggregate Replacement*

Several researchers have investigated ceramic waste as a replacement for natural sand.

Lincy et al. reported that 20% replacement of fine aggregate with ceramic tile powder produced higher compressive strength than conventional concrete. The increase in strength was mainly attributed to better particle packing and filler action.

Awoyera et al. observed that compressive strength improved up to 25% replacement, while higher replacement levels reduced workability because of the angular shape of ceramic particles. Vieira et al. found that replacement levels up to 50% did not significantly affect compressive strength, although slump decreased gradually with increasing ceramic content.

The reviewed studies collectively indicate that fine aggregate replacement between 20% and 30% provides satisfactory mechanical performance.

*B. Ceramic Waste as Coarse Aggregate Replacement*

Research studies also support the use of ceramic waste as coarse aggregate.
Subramani and Rajan observed improved compressive, split tensile, and flexural strength up to 15% replacement of coarse aggregate.
Sofri et al. reported optimum compressive strength at 20% replacement of coarse aggregate using crushed ceramic tiles.
Raval et al. concluded that replacement levels beyond 40% reduced workability and compressive strength significantly.
Patel and Shah studied simultaneous replacement of fine and coarse aggregates and observed improved performance at moderate replacement levels.

## V. RESULT AND DISCUSSION

*A. Effect on Compressive Strength*

Most studies indicate that ceramic waste improves compressive strength at low to moderate replacement levels. Strength improvement is generally observed between 10% and 30% replacement.
The increase in strength can be attributed to:

- Better aggregate interlocking
- Filler effect of ceramic particles
- Dense microstructure formation
- Improved bonding at the interfacial transition zone

Beyond 30% replacement, compressive strength generally decreases because of poor workability and reduced particle packing efficiency.

*B. Effect on Workability*

Workability decreases with increasing ceramic waste content because ceramic particles are angular and rough in texture. Several studies reported slump reductions between 10% and 35% at higher replacement levels.
The use of superplasticizers can help restore workability without increasing the water-cement ratio.

*C. Effect on Durability*

Concrete containing ceramic waste has shown satisfactory durability performance in terms of:

- Reduced water absorption
- Improved sulphate resistance
- Lower chloride permeability
- Reduced porosity

The denser concrete matrix developed due to ceramic particles contributes to improved durability.

*D. Optimum Replacement Level*

Based on the reviewed literature, the optimum replacement range for ceramic waste generally lies between 20% and 30% for both fine and coarse aggregates.

| Replacement Level (%) | Performance |
|---|---|
| 0 - 10 | Slight improvement |
| 15 – 30 | Optimum strength and durability |
| 30 – 40 | Strength reduction begins |
| Above 40 | Significant loss in workability |

## VI. SUSTAINABILITY BENEFITS

The use of ceramic waste in concrete offers several environmental benefits:

*1)* Reduction in landfill waste
*2)* Conservation of natural aggregates
*3)* Lower environmental impact from quarrying
*4)* Support for circular economy practices
*5)* Reduced transportation and disposal costs

Utilization of ceramic waste also contributes to sustainable construction practices and resource conservation.

## VII. LIMITATIONS OF PRESENT VIEW

The findings reported in this review are based on experimental studies conducted under different conditions. Variations in ceramic waste source, particle size, curing method, and mix design may influence the reported results.

Long-term field performance data are still limited, and most studies are laboratory-based. Therefore, further practical implementation studies are required before large-scale commercial adoption.

## VIII. FUTURE SCOPE

Future research on ceramic waste concrete can focus on:

*1)* Use of ceramic waste in high-performance concrete.
*2)* Long-term durability studies under field conditions.
*3)* Development of standard guidelines for ceramic waste utilization.
*4)* Combination of ceramic waste with fly ash, GGBS, and silica fume.
*5)* Economic feasibility analysis for industrial-scale implementation.
*6)* Investigation of ceramic powder as supplementary cementitious material.

## IX. CONCLUSION

This review paper evaluated the use of ceramic waste as a partial replacement for fine and coarse aggregates in concrete. Based on the reviewed literature, ceramic waste can be considered a sustainable and technically feasible material for concrete production.

The major conclusions drawn from this review are as follows:

*1)* Ceramic waste improves compressive, split tensile, and flexural strength at moderate replacement levels.
*2)* Optimum replacement levels generally range between 20% and 30%.
*3)* Workability decreases with increasing ceramic content but can be controlled using admixtures.
*4)* Durability properties such as water absorption and sulphate resistance show improvement at optimum replacement levels.
*5)* Ceramic waste utilization reduces landfill disposal and conserves natural resources.

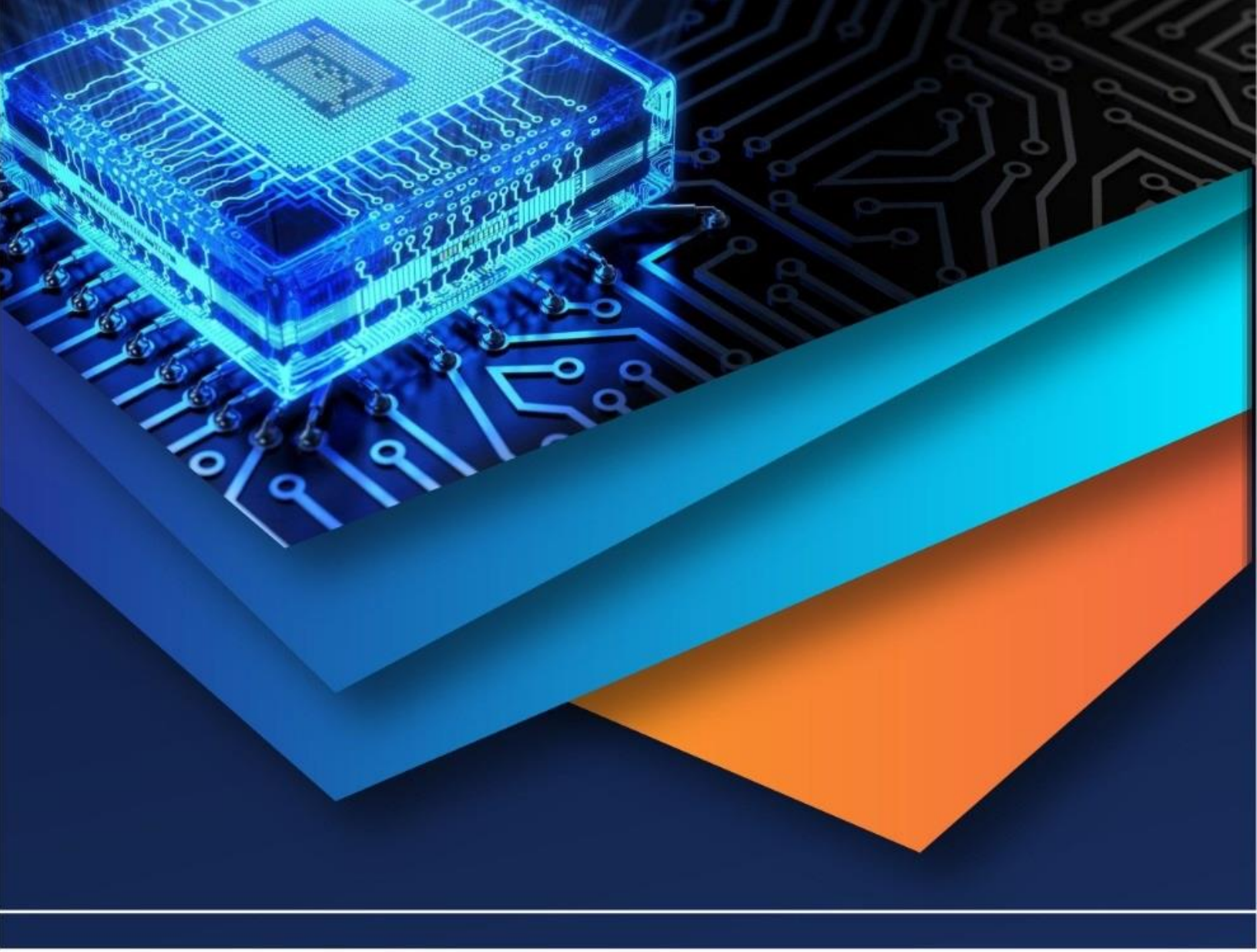
Overall, ceramic waste concrete offers a promising solution for sustainable construction and waste management.

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