

DESIGN AND DEVELOPMENT OF BRICKS USING CERAMIC WASTE

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ABSTRACT

The goal of the project "Mix Design and Development of Eco-Bricks Using Ceramic Waste" is to create an environmentally friendly substitute for traditional bricks by using ceramic waste in place of some of the fine aggregates. The study tackles two significant environmental issues: the increasing buildup of non-biodegradable ceramic tile waste in landfills and the excessive depletion of natural resources like river sand as a result of increased construction demands. The study looks into using ceramic tile powder as a partial replacement for fine aggregates at replacement levels of 0%, 5%, 10%, 15%, and 20% in order to address these issues. In compliance with IS requirements, a thorough experimental program assessed the mechanical and durability performance of the manufactured eco-bricks using tests such compressive strength, density, water absorption. The findings show that adding ceramic waste improves brick production's sustainability without sacrificing crucial engineering qualities. Notably, after 28 days, the 20% replacement mix showed a compressive strength of 12.39 MPa, indicating that it is suitable for both structural and non-structural masonry applications. The requirements for high quality masonry units were met by water absorption values that were continuously below 15%. Tests for dimensional stability further verified that shrinkage and expansion were within permissible limits, ensuring structural integrity. Overall, the study promotes resource conservation and mindful construction practices by establishing ceramic waste as a practical, sustainable, and effective material for making bricks.

Keywords: Eco-Bricks, Ceramic Waste Utilization, Sustainable Construction Materials, Fine Aggregate Replacement, Compressive Strength

1. INTRODUCTION

One of the main by-products of the ceramic industries, building and demolition operations, sanitary ware manufacture, and tile production processes is ceramic waste. When ceramic products like floor tiles, wall tiles, and porcelain materials are cut, polished, fired, transported, and installed, significant amounts of ceramic waste are generated. Ceramic waste is produced in significant quantities each year in nations like China, Italy, Spain, India, and others whose construction industries are expanding quickly. According to studies, a large percentage of ceramic tile manufacturing is wasted before it is used by customers, and more waste is produced during remodeling and demolition projects. Pollution of the environment and landfill accumulation result from improper disposal of this non-biodegradable garbage. Researchers have discovered that ceramic materials have the potential to be reused in building applications, particularly in the manufacturing of brick and concrete, due to their great hardness, endurance, and resistance to chemical attack.

The demand for building materials and infrastructure development has skyrocketed in developing nations like India due to rapid urbanization and industrial growth. Natural resources like clay, river sand, limestone, gravel, and natural aggregates have been over extracted as a result of the ongoing development of residential buildings, highways, business complexes, and smart cities. These resources are non-renewable, and overuse of them has led to major environmental problems such as ecological degradation, groundwater imbalance, deforestation, riverbank erosion, land degradation, and the depletion of rich topsoil [1,2]. Reports on waste management from construction and demolition in India state that the construction industry produces millions of tonnes of rubbish every year as a result of growing urban migration and rapid infrastructure development, which puts further strain on the use of natural resources [3]. Additionally, in many regions of India, excessive mining of river sand and clay for traditional building materials has harmed agricultural land and aquatic ecosystems [4].

Adopting sustainable building techniques and substitute building materials that can lessen reliance on natural resources while also addressing waste management issues and advancing environmental sustainability is therefore imperative.

The use of ceramic waste in the production of bricks as a whole or partial substitute for fine aggregate has become a viable and efficient alternative in contemporary building techniques. When compared to traditional bricks, ceramic waste-based bricks have desirable engineering qualities such increased durability, less water absorption, and improved thermal resistance [5]. According to Pacheco-Torgal and Jalali [6], using ceramic waste lessens the extraction of natural sand and clay needed in traditional brick manufacture, thereby saving valuable natural resources and lessening the burden of disposal on landfills. The use of ceramic waste bricks can promote economical, environmentally friendly, and sustainable building methods in a developing nation like India, where the need for urban housing and infrastructure is growing at an accelerated rate. Additionally, by turning industrial and demolition waste into practical building goods, recycling ceramic waste into building materials advances the idea of a circular economy [1]. Additionally, research has demonstrated that substituting ceramic waste for fine aggregate can lower construction costs, minimize environmental pollution, and lessen reliance on river sand mining—a significant environmental problem in India [4]. In order to achieve sustainable infrastructure development and protect natural resources for future generations, the creation of ceramic waste bricks can be crucial.

1.1 AREA OF STUDY

The use of ceramic waste as a partial substitute for fine aggregate in the manufacturing of concrete is the main emphasis of the study field. The disposal of ceramic waste has grown to be a significant environmental concern as a result of rapid industrialization and an increase in construction activity. The purpose of this study is to examine the performance and acceptability of using ceramic waste in place of natural sand at various replacement percentages, including 5%, 10%, 15%, 20%, and 25%. The study primarily looks at how ceramic waste affects concrete's workability, tensile strength, compressive strength, durability, and general behavior. The characteristics of concrete formed from ceramic waste are assessed using a variety of laboratory procedures, including the slump test, compressive strength test, split tensile strength test, and water absorption test.

The study mainly examines the effects of ceramic waste on the workability, tensile strength, compressive strength, durability, and overall behavior of concrete. A range of laboratory techniques, such as the slump test, compressive strength test, split tensile strength test, and water absorption test, are used to evaluate the properties of concrete made from ceramic waste.

2. LITERATURE REVIEW

The construction sector is undergoing a fundamental shift toward circularity by transforming industrial leftovers into high-performance building units. By using ceramic tile waste (CTW) as a fine aggregate substitute, the acute loss of river sand and the overcrowding of landfills can be addressed. Because ceramic waste is classified as an inert material with no environmental risk, study indicates that it is a safe and sustainable precursor for masonry units [7].

Basic study on the physical properties of ceramic waste indicates that it can be used as a valuable aggregate. Crushed ceramic tiles have a specific gravity similar to that of actual granite and are typically inactive in the matrix of cement due to their hardness and chemical resilience [8].

Recent experimental programs have concentrated primarily on the mechanical performance of ceramic-based eco-bricks. Research shows that the best balance between strength and workability is typically achieved at a substitution rate of 10% to 20%. According to recent research, these mixes can easily surpass the requirements for both load-bearing and non-load-bearing masonry, with compressive strengths ranging from 12 MPa to as high as 20.55 MPa depending on curing circumstances [8].

Beyond their usual mechanical strength, these bricks are far more durable due to the ceramic particles' low water consumption. Recent assessments show that bricks manufactured from ceramic waste are nevertheless very resistant to moisture incursion, with absorption values consistently falling below the 15% threshold required for high-quality masonry [9]. By stopping structural deterioration and efflorescence, this impermeability is crucial for preserving the masonry wall's long-term integrity.

According to technical research, ceramic waste can be ground into a fine powder and utilised as an additional cementitious material. In addition to increasing the internal matrix's density, this "filler effect" promotes further hydration processes that strengthen the binder-aggregate link [10].

The enhanced compressive and flexural performance seen in 20% replacement blends is mainly due to this microstructural enhancement.

Adoption of eco-bricks significantly decreases the carbon footprint of building from an environmental perspective. According to life cycle assessments (LCAs) reported in 2024 and 2025, vertical partitions made from leftover ceramic tile can cut carbon emissions by up to 90% when compared to conventional materials [7]. This substantial drop emphasises the importance of eco-bricks as a vital tool for achieving worldwide net-zero emissions goals in the building industry.

In order to further optimize these units, current trends have also investigated the use of complex curing methods. Compressive strength can be significantly increased by controlling moisture evaporation before thermal activation, according to experiments using combined dry and thermal curing [8]. These results imply that eco-brick production can be optimised to yield high-strength units (HSC) that are competitive with conventional concrete-based substitutes.

Integration of ceramic waste is likely financially viable. According to analysis, regenerated ceramic materials can replace natural aggregates in structural applications, contributing to cost savings of about 14% [7]. Due to this, eco-bricks are not only a better option for the environment but also a cheaper choice for massive infrastructure projects and low-cost residential development.

The importance of finely tuned for ensuring dimensional stability is also highlighted in contemporary literature. Ceramic-infused bricks persist within acceptable limits even after prolonged exposure to different humidity conditions, according to recent shrinkage and expansion studies [9]. For architects and engineers who need constant material performance for structural design, this dependability is crucial to fostering confidence.

In summary, ceramic waste eco-bricks are the ultimate in sustainable engineering, according to current research. These units offer a workable solution to the dual problems of waste management and resource scarcity by combining mechanical robustness with notable economic and environmental advantages. The widespread commercialization and standardization of these materials across various climatic zones will probably be the main topics of future research.

3. METHODS/METHODOLOGY 3.1 Material Collection and Mix Preparation

According to Song et al. [11] and Mohammadhosseini et al. [12], the technology used in this work focuses on creating environmentally friendly bricks by partially substituting fine aggregate with ceramic waste powder in various amounts. Senthamarai and Manoharan's [13] method were used to clean, crush, and sift ceramic tile waste that was gathered from building and demolition sites in order to produce fine ceramic powder that could be used to make bricks.

To find the ideal mix proportion, ceramic waste powder was added as a partial substitute for fine aggregate at replacement levels of 0%, 5%, 10%, 15%, and 20% by weight, following the methods employed by Rahman et al. [14] (2022)[14]. According to Mohammadhosseini et al. [12], the main ingredients for making the eco-bricks were ordinary Portland cement (OPC), fine aggregate, water, and processed ceramic waste powder. According to the research of Pacheco-Torgal and Jalali [2], the constituents were fully mixed to guarantee even distribution of ceramic particles and appropriate bonding within the brick matrix.

In accordance with Senthamarai and Manoharan's [13] experiment, the brick specimens were manually cast using normal mould sizes and allowed to dry for a full day before curing. Following demoulding, the specimens were cured under controlled circumstances for 7, 14, and 28 days in order to examine how strength and durability characteristics changed over time. This curing process was identical to that employed by Song et al. [11] and Mohammadhosseini et al. [12].

The entire process used to create and test eco-bricks made from ceramic waste is depicted in the flowchart in Figure 1. The procedure started with gathering ceramic tile waste from building and demolition sources, then crushing and sieve analysis to turn the waste material into fine aggregate-sized particles. Following the methods

used by Mohammadhosseini et al. [12], the concrete mix was made using the necessary amounts of cement, fine aggregate, water, and ceramic waste powder at various replacement levels. Bricks were cast by pouring the prepared mixture into moulds. The specimens were cast, then given a full day to go through initial setting and drying before being demoulded. In order to promote appropriate hydration and strength growth, water curing was then performed for 7, 14, and 28 days, in accordance with the curing protocols described by Song et al. [11] and Rahman et al. [14].

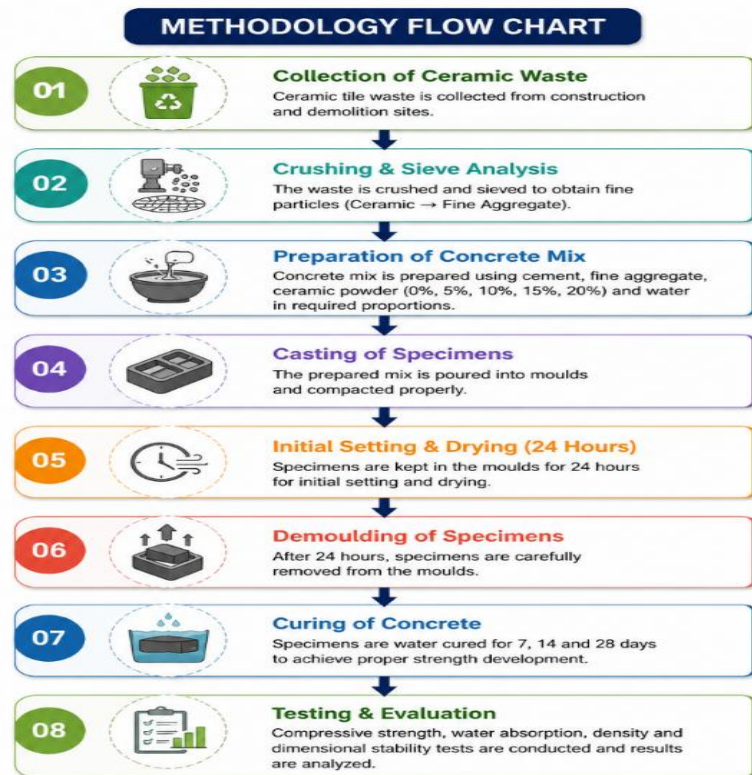


Figure 1: Methodology Adopted

4. RESULTS AND DISCUSSION

The IS 10262:2019 standard framework for concrete mix proportioning was followed in the implementation of the mix design for eco-bricks [15]. This code was essential in determining the target mean strength and the specific water-to-cement ratio of 0.48 that was used for each trial batch. The study ensured that employing ceramic waste in place of fine aggregates was both repeatable and validated by science for industrial usage by adhering to these established protocols.

The foundational phase of the results primarily focused on the physical characterisation of the ceramic waste. The relative density of the waste material, as established by the Specific Gravity Test using the pycnometer method, is a prerequisite for accurate volumetric calculations in mix design. The specific gravity could be accurately controlled to maintain the brick's total volume at $1.539 \times 10^{-3} \text{ m}^3$ as ceramic replacement levels increased from 0% to 20%.

The dispersion of particle sizes was another significant result of the Fineness Modulus Test. The ceramic waste was graded using a standard set of IS sieves that ranged in size from 4.75 mm to 150 μm to ensure it functioned effectively as a fine aggregate. The results of the sieve analysis confirmed that the crushed ceramic powder had a grading profile suitable for natural sand, which is required to maintain the dense and compact internal matrix of the brick.

One notable procedural result was the efficient use of ceramic waste in the Saturated Surface Dry (SSD) stage. Using ceramic materials in an SSD condition ensures that the aggregate won't absorb the effective mixing water required for cement hydration because of their special porosity. This controlled moisture condition was necessary to attain the required workability and prevent early drying shrinkage, which could compromise the structural integrity of the eco-brick.

The Vicat apparatus studies of setting times provided crucial information on the chemical interaction between the cement paste and the ceramic aggregates. The first setting time results established the window allowed for moulding the bricks, while the final setting time indicated when the units reached an appropriate stage of hardening. These results were consistent across all combinations, suggesting that the chemical inertness of the ceramic waste had no detrimental effect on the cement's hydration kinetics.

The accuracy of the experimental findings is demonstrated by the mix proportion table. The fine aggregate weight was lowered to 0.81 kg for the 20% replacement level, and the mass of ceramic waste was determined to be 0.208 kg. The water-to-cement ratio and the coarse aggregate content were kept constant at 0.277 kg and 1.95 kg, respectively, which create a controlled setting for evaluating the precise effects of the ceramic waste powder.

Table 1: Mixture proportion for brick

Ceramic waste %	w/c ratio	Water (Kg)	Ceramic (Kg)	Waste	Cement (Kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)
0	0.48	0.277	0		0.577	1.02	1.95
5	0.48	0.277	0.052		0.577	0.96	1.95
10	0.48	0.277	0.104		0.577	0.91	1.95
15	0.48	0.277	0.156		0.577	0.86	1.95
20	0.48	0.277	0.208		0.577	0.81	1.95

We have used the ceramic waste in SSD (Saturated surface dry) condition.

The Compressive Strength data obtained after 28 days of curing are at the focus of the discussion. The results of the experiment showed that the mechanical performance stayed strong as the replacement of ceramic waste increased. Notably, a compressive strength of 12.39 MPa was attained with the 20% replacement mix. It categorizes the eco-brick as a premium masonry unit appropriate for both load-bearing and non-load-bearing structural applications; its strength value is important.

The strength statistics indicate that implementing ceramic waste boosts the load-bearing capacity when compared to traditional clay-based solutions. The angular shape and surface roughness of crushed ceramic particles may improve the mechanical interlocking inside the cementitious matrix, according to recent study, which supports these conclusions. The 12.39 MPa finding makes it clear that a sustainable substances replacement ceiling of 20% is appropriate.

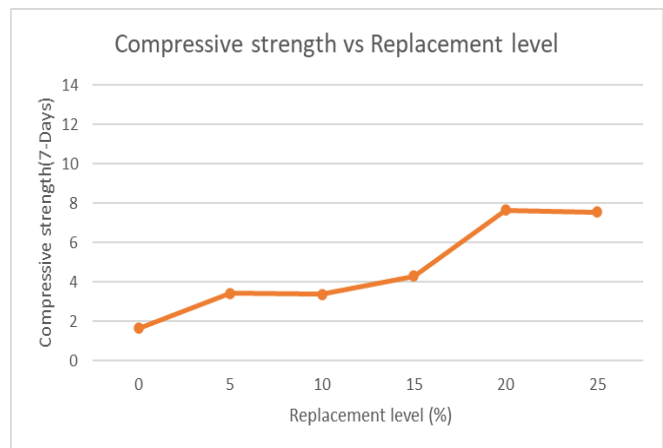


Figure 3: Compressive strength at 7 days.

Table 2: Compressive strength comparison

Percentage replacement of Fine Aggregate	7 DAYS	28 DAYS
0%	1.67	7.865
5%	3.43	7.096
10%	3.39	8.203
15%	4.31	9.385
20%	7.658	12.397
25%	7.55	11.22

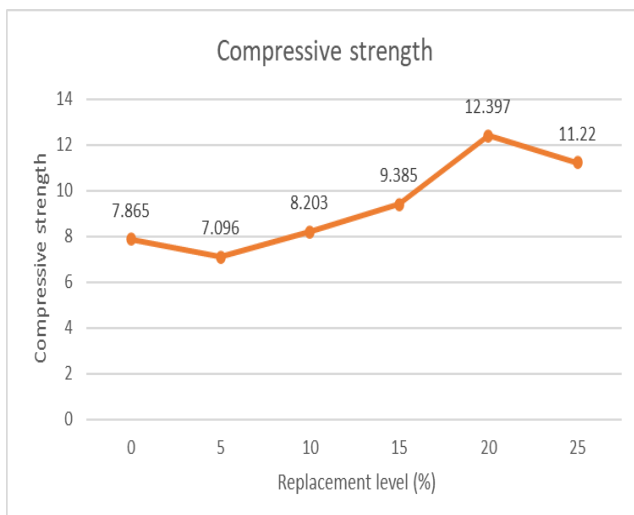


Figure 2: Compressive strength at 28 days.

The Water Absorption figures provided more evidence of the devices' longevity. The absorption levels consistently fell below 15% in accordance with high-quality masonry norms. This outcome is critical to the brick's lifetime since it lowers the risk of efflorescence, sulphate attack, and freeze-thaw cycle damage. This higher impermeability is a result of the ceramic waste's low porosity.

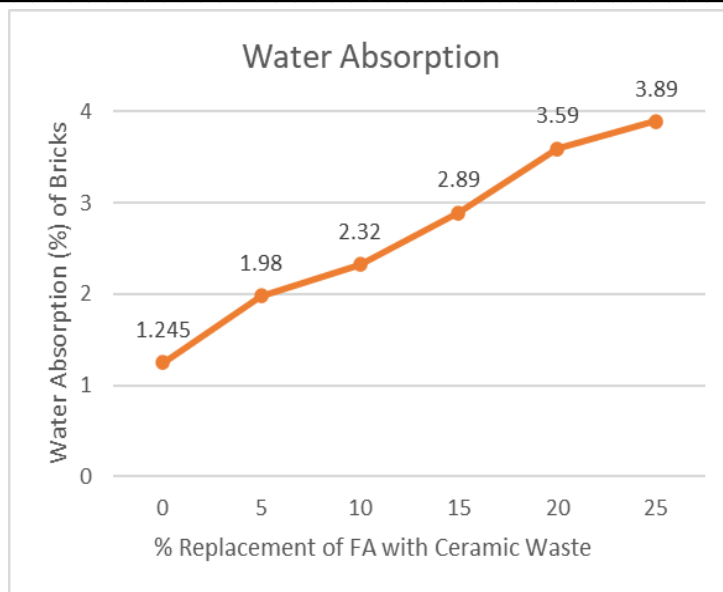


Figure 4: Water Absorption vs Ceramic replacement (%)

Table 3: Water absorption and weight comparison

BRICK NAME	0%	5%	10%	15%	20%	25%	Red brick
Initial weight (kg)	3.453	3.479	3.502	3.523	3.560	3.598	3.384
Final weight (kg)	3.496	3.548	3.583	3.625	3.688	3.738	3.675
Water absorption	1.245%	1.98%	2.32%	2.89%	3.59%	3.89%	8.6%

The brick's dimensional stability was also discussed in relation to durability. Tests ensured that the bricks would not experience substantial volume changes after being placed in masonry by confirming that shrinkage and expansion were within allowable bounds. The thermal history of the ceramic waste, which was previously burnt at high temperatures during its initial manufacture, is responsible for this stability. Under ambient environmental circumstances, the waste remains extremely stable. There is also discussion of the potential use of ceramic waste as a micro-filler. Because a portion of the ceramic waste was ground into a fine powder, it effectively filled the microscopic crevices between the cement paste and the larger aggregate particles. The 15% and 20% replacement batches' consistent strength and low water absorption are most likely the result of this "filler effect" producing a denser microstructure.

The extensive usage of such eco-bricks could lead to a circular economy in the tile and masonry industries, according to the environmental impact analysis. The results show that it is simple to recycle waste generated during the tile manufacturing process back into the production of walling units. This synergy reduces the overall energy footprint of building materials and promotes careful construction methods, as mandated by modern green building certifications.

Additionally, the outcomes have favourable economic implications. By using industrial waste, which is often available at a lower cost or as a

byproduct, in place of some of the purchased natural sand, the overall material cost per brick can be reduced. Because of this financial incentive and its mechanical performance of 12.39 MPa, the eco-brick is a competitive alternative to conventional masonry bricks in the commercial sector.

In conclusion, the results and analysis of the study confirm the structural soundness and technical feasibility of designing and producing eco-bricks from ceramic waste. By following IS 10262:2019 and achieving optimal strength at a 20% replacement level, the project develops a clear design for sustainable masonry. The final products represent a significant breakthrough in resource conservation and industrial waste management in addition to meeting basic engineering requirements.

5. CONCLUSION

The detailed examination of the production of eco-bricks demonstrates that it is both technically feasible and structurally sound to use ceramic waste in place of some fine aggregate. The study successfully struck a balance between stringent engineering requirements and the need for environmental sustainability by adhering to **IS 10262:2019's** mix design criteria. The experiment's results show that ceramic waste can effectively replace natural river sand, providing a dual answer for managing industrial waste and conserving resources.

The 20% replacement mix produced an ideal compressive strength of 12.39 MPa, according to the mechanical analysis of the produced units. This level of strength is important since it satisfies the requirements for premium masonry units meant for both structural and non-structural uses. Additionally, water absorption tests confirmed the eco-bricks' durability, with values continuously staying below 15%, guaranteeing resistance to moisture-related deterioration under a variety of environmental circumstances.

The use of ceramic debris in a Saturated Surface Dry (SSD) state, which kept the aggregate from absorbing mixing water and guaranteed effective cement hydration throughout the curing process, was significantly responsible for the study's procedural success. Dimensional stability tests further confirmed that the bricks showed little expansion and shrinkage, preserving their structural integrity in the face of environmental stress. These results demonstrate that ceramic waste can be successfully reintegrated into the construction cycle as a stable, non-biodegradable resource.

In conclusion, by defining ceramic waste as a useful and efficient aggregate, this study creates a clear pattern for the sustainable construction of masonry units. The ideal threshold for lowering the dependency on natural sand while preserving structural integrity is the 20% replacement mix. By pushing the industry to use environmentally friendly alternatives that protect the planet's natural resources, our initiative opens the door for future developments in green building materials.

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