EXPERIMENTAL STUDY ON EFFECT OF PARTIAL REPLACEMENT OF COARSE AGGREGATE BY OVER BURNT BRICK IN CONCRETE

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ABSTRACT

Concrete is the most widely used construction material in the world owing to its high compressive strength, durability, adaptability, and economic viability. Rapid urbanization and infrastructure development have resulted in excessive consumption of natural aggregates, particularly coarse aggregates, leading to depletion of natural resources and serious environmental concerns. Simultaneously, brick manufacturing industries generate a large quantity of over burnt bricks due to improper firing conditions in brick kilns. These over burnt bricks are generally discarded as waste, causing land pollution and disposal problems. The present study focuses on the experimental investigation of the effect of partial replacement of natural coarse aggregate with over burnt brick aggregate in concrete. M20 grade concrete was designed as per IS 10262:2019, and coarse aggregate was replaced by over burnt brick aggregate at replacement levels of 0%, 5%, 10%, 15%, and 20%. Fresh concrete properties such as workability were assessed using the slump test, while hardened concrete properties including compressive strength, split tensile strength, and flexural strength were evaluated at 7 and 28 days of curing. The experimental results indicate that workability decreases with an increase in replacement percentage due to the porous nature and higher water absorption of brick aggregates. However, strength characteristics showed satisfactory performance up to 10–15% replacement, with an optimum performance observed at 10%. The study concludes that over burnt brick aggregate can be effectively used as a partial replacement of coarse aggregate in concrete, particularly for non-structural and low-load-bearing applications. The utilization of over burnt bricks in concrete promotes sustainable construction practices, conservation of natural resources, and efficient waste management.

Keywords: Over burnt brick, coarse aggregate replacement, sustainable concrete, compressive strength, waste materials.

1. INTRODUCTION

Concrete is the most widely used construction material due to its strength, durability, and adaptability. Coarse aggregate constitutes nearly 60–70% of the concrete volume, making it a major contributor to natural resource consumption. The excessive extraction of natural aggregates has led to environmental concerns such as land degradation and ecological imbalance. Brick manufacturing industries produce a significant amount of over burnt bricks due to uncontrolled firing conditions. These bricks are unsuitable for masonry works and are usually dumped as waste. However, their hardness and rough surface texture make them a potential alternative aggregate material.

Utilization of over burnt brick aggregate in concrete not only reduces environmental pollution but also promotes sustainable construction practices. This study aims to experimentally evaluate the performance of concrete with partial replacement of coarse aggregate by over burnt brick aggregate. Concrete is the backbone of modern infrastructure and is used extensively in buildings, bridges, roads, dams, and other civil engineering structures. It consists primarily of cement, fine aggregate, coarse aggregate, and water. Among these constituents, coarse aggregate occupies the largest volume and significantly influences the strength and durability of concrete. The increasing demand for concrete has resulted in rapid depletion of natural aggregates, causing serious environmental concerns. Therefore, there is an urgent need to explore alternative materials that can partially or fully replace natural aggregates without compromising performance.

Fig.1.1 Over Burnt Bricks as Construction Waste

Fig.1.2 Crushed Over Burnt Clay Bricks

Table 1.1: Characteristics of Conventional Bricks and Over Burnt Bricks

Property	Conventional Bricks	Over Burnt Bricks
Firing temperature	Optimal	Excessively high
Shape	Uniform	Irregular
Strength	Adequate	Brittle
Water absorption	Moderate	High
Suitability for masonry	High	Poor
Reuse potential	Limited	High (as aggregate)

Over burnt bricks are produced due to excessive firing temperatures in brick kilns. These bricks become vitrified, irregular in shape, and brittle, making them unsuitable for masonry work. Large quantities of such bricks are discarded as waste, occupying valuable land and causing environmental pollution. Despite being rejected for masonry, over burnt bricks possess sufficient hardness and strength, making them potential candidates for use as aggregates in concrete.

- Depletion of natural coarse aggregates
- Environmental issues due to brick waste disposal
- Rising cost of construction materials
- Need for sustainable and eco-friendly construction practices

This study aims to address these challenges by evaluating the performance of concrete containing over burnt brick aggregate.

- To study the feasibility of using over burnt brick as partial replacement of coarse aggregate
- To evaluate workability and strength characteristics of concrete
- To determine the optimum replacement percentage
- To promote sustainable and economical construction

The scope of the study is limited to experimental investigation of fresh and hardened concrete properties for M20 grade concrete using partial replacement of coarse aggregate.

2. LITERATURE REVIEW

Several studies have investigated the feasibility of using brick aggregates as a replacement for natural aggregates in concrete.

Rai et al. (2012) observed that concrete containing brick aggregates showed comparable compressive strength up to 15% replacement. The study attributed this to improved interlocking due to angular brick particles. **Padmini et al. (2009)** reported that over burnt brick aggregates could be effectively used up to 10–20% replacement without significant loss in compressive strength. Beyond this level, strength reduction was attributed to higher porosity and weaker aggregate structure. Tensile and flexural strength behavior of brick aggregate concrete has also been widely studied. Researchers reported that tensile strength trends closely follow compressive strength trends. Islam et al. (2016) observed that split tensile and flexural strength increased slightly at lower replacement levels due to improved bond characteristics. At higher replacement levels, tensile performance decreased due to increased micro-cracking and reduced stiffness of brick aggregates.

Debieb and Kenai (2008): Debieb and Kenai investigated the effect of recycled brick aggregates on the properties of concrete. The study reported that brick aggregates exhibited higher water absorption and lower specific gravity compared to natural aggregates. As a result, concrete made with brick aggregates showed reduced workability.However, the researchers noted that proper mix proportioning, pre-soaking of aggregates, and use of admixtures could significantly improve workability and strength characteristics. The study concluded that partial replacement of coarse aggregate with brick aggregate is feasible. Numerous studies indicate that the compressive strength of concrete containing brick aggregates depends largely on replacement percentage, aggregate quality, and curing conditions.

Khaloo (1994): Khaloo conducted experimental studies on concrete made with crushed brick aggregates. The research reported that brick aggregate concrete exhibited lower density compared to conventional concrete, making it suitable for lightweight applications. Although a slight reduction in compressive strength was observed, the strength values were adequate for non-structural applications. The study highlighted that the rough surface texture of brick aggregates improved bonding with cement paste, partially compensating for their lower strength.

These findings support the observation that moderate replacement levels provide optimum performance.

Research Gaps Identified from Literature

A critical review of existing literature on the use of brick aggregate and over burnt brick waste in concrete reveals that several researchers have explored its feasibility, strength characteristics, durability aspects, and sustainability benefits. However, despite numerous studies, certain gaps and limitations remain unaddressed. Identifying these research gaps is essential to justify the present experimental investigation and to highlight its contribution to the field of sustainable concrete technology. Based on the review of existing literature, the following research gaps were identified:

- Limited experimental data on over burnt brick aggregates specifically
- Lack of standardized guidelines for replacement levels
- Insufficient studies on Indian brick kiln waste
- Limited work on M20 grade concrete using over burnt bricks

3. MATERIALS

The performance of concrete largely depends on the physical and mechanical properties of its constituent materials. In the present experimental study, conventional concrete ingredients such as cement, fine aggregate, coarse aggregate, and water were used along with over burnt brick aggregate as a partial replacement of coarse aggregate. A thorough understanding of the properties of these materials is essential to analyze their influence on the behavior of fresh and hardened concrete.

1. Cement

Cement acts as the binding material in concrete and plays a vital role in strength development. In this study, **Ordinary Portland Cement (OPC) of 43 grade** conforming to **IS 8112** was used. OPC 43 grade is widely used in structural concrete works due to its adequate early strength and consistent quality. The cement used was fresh, uniform in color, and free from lumps. It was stored in dry conditions to prevent moisture absorption. The important properties of cement influencing concrete performance include fineness, standard consistency, setting time, and compressive strength. Proper fineness of cement ensures better hydration and strength development, while standard consistency influences workability. Initial and final setting times are important for handling and finishing operations. The compressive strength of cement directly affects the strength of concrete. OPC 43 grade cement provides sufficient strength for M20 grade concrete and is suitable for experimental studies involving partial replacement of aggregates.

2. Fine Aggregate

Fine aggregate fills the voids between coarse aggregate particles and contributes to the workability and density of concrete. In the present study, **natural river sand** conforming to **IS 383** was used as fine aggregate. The sand was clean, well-graded, and free from deleterious materials such as clay, silt, organic impurities, and salts. The grading of fine aggregate plays a significant role in achieving good workability and reducing segregation. Well-graded sand ensures better packing of particles, reducing void content and improving strength. Excessively fine sand increases water demand, while coarse sand may cause segregation. The physical properties of fine aggregate such as specific gravity, bulk density, and water absorption influence the mix proportioning and water requirement of concrete. The fine aggregate used in this study exhibited acceptable specific gravity and low water absorption, making it suitable for concrete production.

3. Natural Coarse Aggregate

Coarse aggregate forms the skeleton of concrete and contributes significantly to its compressive strength. In this study, **crushed stone aggregate of 20 mm maximum size** was used as natural coarse aggregate. The aggregate was angular in shape, hard, dense, and durable. The important properties of coarse aggregate include size, shape, surface texture, strength, and water absorption. Angular aggregates provide better interlocking and higher strength compared to rounded aggregates. The rough surface texture of crushed stone aggregates improves bond strength between cement paste and aggregate. The natural coarse aggregate used in the study complied with IS 383 requirements. It exhibited low water absorption and high crushing strength, making it suitable for use as a control material against which the performance of over burnt brick aggregate concrete was compared.

4. Over Burnt Brick Aggregate

Over burnt bricks are bricks that are subjected to excessive temperature during firing in brick kilns, resulting in vitrification, deformation, and brittleness. These bricks are unsuitable for masonry work and are generally discarded as waste. However, when crushed into aggregate form, over burnt bricks can be used as an alternative construction material. One of the key characteristics of over burnt brick aggregate is its **higher water absorption**, which is mainly due to its porous internal structure. This property significantly affects the workability of concrete, as more water is absorbed during mixing. To address this issue, the brick aggregates were pre-soaked before mixing to minimize rapid water absorption.The surface texture of over burnt brick aggregate is rough and angular, which enhances mechanical interlocking and improves bond strength with cement paste. However, the internal structure of brick aggregate is relatively weaker compared to natural stone aggregate, which may lead to reduced strength at higher replacement levels. Despite these limitations, over burnt brick aggregate offers several advantages such as reduced unit weight of concrete, effective utilization of waste material, and conservation of natural aggregates.

Fig.3.1 Crushed Over Burnt Clay Bricks used in the work

5. Water

Water is an essential component of concrete, required for hydration of cement and to provide workability to the mix. In the present study, **clean potable water** free from impurities such as oils, acids, alkalis, and organic matter was used for both mixing and curing of concrete.

The quality of water used in concrete significantly influences setting time, strength development, and durability. Impure water can adversely affect the hydration process and reduce concrete strength. The water used in this study satisfied the requirements of IS 456:2000.

The water–cement ratio was carefully controlled to maintain consistency across all mixes, ensuring that variations in concrete properties were primarily due to the replacement of coarse aggregate by over burnt brick aggregate.

6. Influence of Material Properties on Concrete Performance

The combined effect of material properties plays a crucial role in determining the behavior of concrete. The use of over burnt brick aggregate affects workability due to higher water absorption, but improves bonding due to rough surface texture. At lower replacement levels, these effects balance each other, resulting in satisfactory strength performance. However, at higher replacement levels, increased porosity and weaker aggregate structure lead to a reduction in strength. Understanding the properties of each constituent material helps in optimizing the mix design and determining suitable replacement levels for achieving sustainable and economical concrete.

4. EXPERIMENTAL METHODOLOGY

The experimental investigation on the effect of partial replacement of coarse aggregate by over burnt brick in concrete requires careful selection of materials to ensure reliability and consistency of results. All materials used in the present study were selected in accordance with relevant Indian Standard (IS) specifications. The properties of each material play a crucial role in influencing the fresh and hardened characteristics of concrete.

1. Mix Design

Concrete mix of **M20 grade** was designed as per **IS 10262:2019** with a water–cement ratio of **0.50**. Design stipulations form the basis for proportioning the concrete mix to achieve the desired strength, workability, and durability. In the present study, the mix design was carried out in accordance with the provisions of **IS 10262:2019 – Concrete Mix Proportioning** and **IS 456:2000 – Plain and Reinforced Concrete – Code of Practice**. The following design stipulations were adopted for preparing the control mix and mixes incorporating partial replacement of coarse aggregate with over burnt brick aggregate.

Mix proportion (by weight):
1 : 1.88 : 3.08 (Cement : Fine Aggregate : Coarse Aggregate)

2. Replacement Levels

Table 4.1: Mix Identification and Percentage Replacement of Coarse Aggregate

Mix ID	Percentage Replacement of Coarse Aggregate	Type of Aggregate Used
M0	0%	Natural Coarse Aggregate
M1	5%	Over Burnt Brick Aggregate
M2	10%	Over Burnt Brick Aggregate
M3	15%	Over Burnt Brick Aggregate
M4	20%	Over Burnt Brick Aggregate

Table 4.2: Final Mix Proportion (Control Mix – M0)

Material	Quantity
Cement	372 kg/m³
Fine aggregate	699 kg/m³
Coarse aggregate	1166 kg/m³
Water	186 litres

Mix Ratio (by weight): 1 : 1.88 : 3.13 with w/c ratio = 0.50

Table 4.3: Mix Proportions with Over Burnt Brick Aggregate

Mix ID	% Replacement	Natural CA (kg/m³)	OBB Aggregate (kg/m³)
M0	0%	1166	0
M1	5%	1108	58
M2	10%	1050	116
M3	15%	991	175
M4	20%	933	233

3. Casting and Curing

Concrete was mixed manually and specimens were cast:

- Cubes (150 × 150 × 150 mm)
- Cylinders (150 × 300 mm)
- Beams (100 × 100 × 500 mm)

Specimens were demoulded after 24 hours and cured in water for 7 and 28 days.

4. TESTING OF SPECIMENS

1. Workability Test
Slump test was conducted to assess workability.

2. Compressive Strength Test
Compressive strength of cubes was tested using a compression testing machine.

3. Split Tensile Strength Test
Cylinders were tested under diametral compression.

4. Flexural Strength Test
Beam specimens were tested under two-point loading.

5. RESULTS AND DISCUSSION

5.1 Slump Test Results:

The slump test is a standard method used to assess the workability and consistency of fresh concrete. Workability is an important property that influences mixing, placing, compaction, and finishing of concrete. In the present study, the slump test was conducted to evaluate the effect of partial replacement of natural coarse aggregate with over burnt brick aggregate on the workability of concrete mixes. The slump test was conducted to evaluate the workability of fresh concrete mixes containing different percentages of over burnt brick aggregate as a partial replacement of coarse aggregate

Table 5.1: Slump Test Results

Mix ID	**% Replacement of Coarse Aggregate**	**Slump Value (mm)**
M0	0%	75
M1	5%	70
M2	10%	65
M3	15%	58
M4	20%	50

Observation:

Slump value decreases with increase in replacement percentage due to higher water absorption and porosity of over burnt brick aggregate.

5.2 Compressive Strength Test Results

Compressive strength is the most important mechanical property of concrete and is widely used as an indicator of its overall quality and performance. In this study, compressive strength tests were conducted to evaluate the effect of partial replacement of natural coarse aggregate with over burnt brick aggregate on the strength characteristics of concrete.

Table 5.2: Compressive Strength at 7 Days

Mix ID	% Replacement	Average Compressive Strength (MPa)
M0	0%	18.6
M1	5%	19.2
M2	10%	20.1
M3	15%	18.9
M4	20%	17.4

Table 5.3: Compressive Strength at 28 Days

Mix ID	% Replacement	Average Compressive Strength (MPa)
M0	0%	26.8
M1	5%	27.5
M2	10%	28.6
M3	15%	26.9
M4	20%	24.8

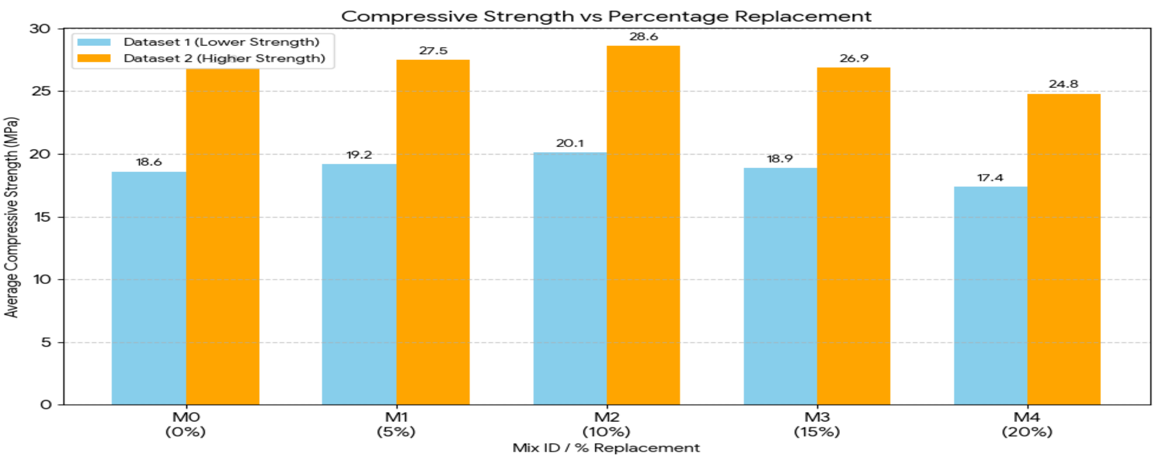

Fig.5.1 Compressive Strength vs Percentage Replacement of Coarse Aggregate

Compressive strength tests were conducted on **150 × 150 × 150 mm concrete cubes** at **7 days and 28 days** curing periods as per IS 516:1959.

Observation:
Maximum compressive strength is observed at **10% replacement**. Beyond this level, strength decreases due to weaker and porous brick aggregates.

5.3 Split Tensile Strength Test Results

Split tensile strength is an important mechanical property of concrete that indicates its resistance to tensile stresses. Since concrete is weak in tension, the split tensile strength test provides valuable insight into cracking behavior and structural performance. The split tensile strength increased gradually up to 10% replacement, reaching a maximum value of 2.86 MPa at 28 days. This improvement can be attributed to better mechanical interlocking and improved aggregate–paste bond due to the rough surface texture of brick aggregates.

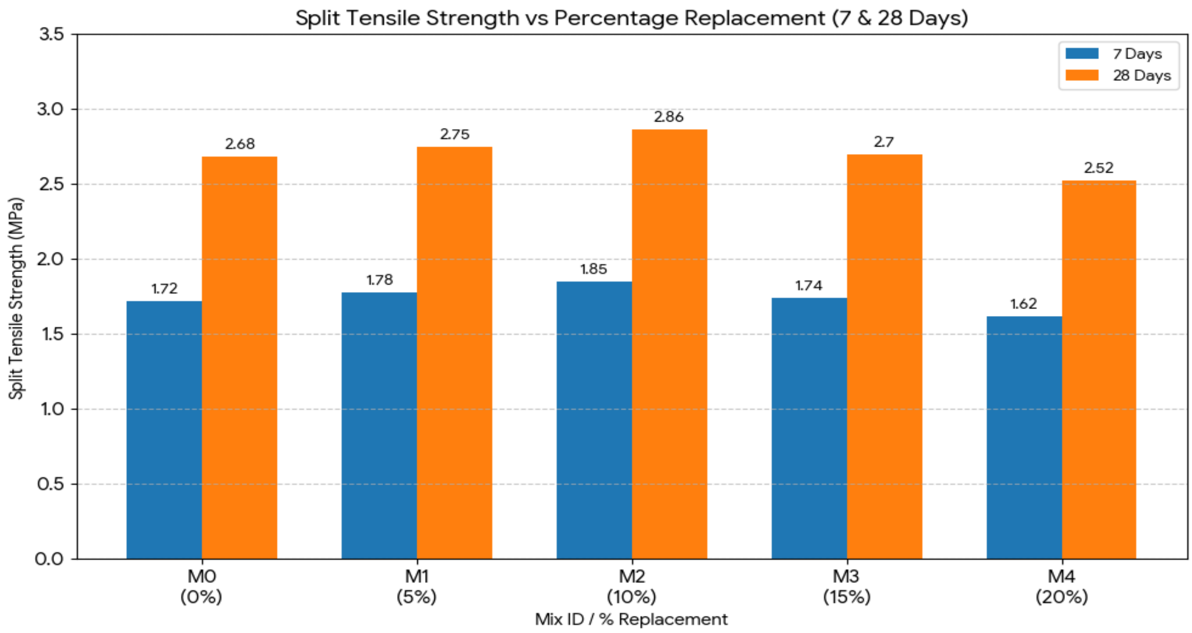

Fig.5.2 Split Tensile Strength vs Percentage Replacement of Coarse Aggregate

Observation:
Split tensile strength follows a similar trend as compressive strength, with optimum performance at **10% replacement**.

5.4 Flexural Strength Test Results

Flexural strength, also known as modulus of rupture, represents the ability of concrete to resist bending stresses. This property is particularly important for structural elements such as beams, slabs, pavements, and lintels where tensile stresses develop due to flexure. In the present study, flexural strength tests were conducted to assess the effect of partial replacement of natural coarse aggregate with over burnt brick aggregate on the bending strength of concrete.The flexural strength increased from 4.12 MPa for the control mix to a maximum of 4.38 MPa at 10% replacement for 28 days curing. The increase in flexural strength at lower replacement levels is due to enhanced bonding and improved stress transfer across the aggregate–paste interface.

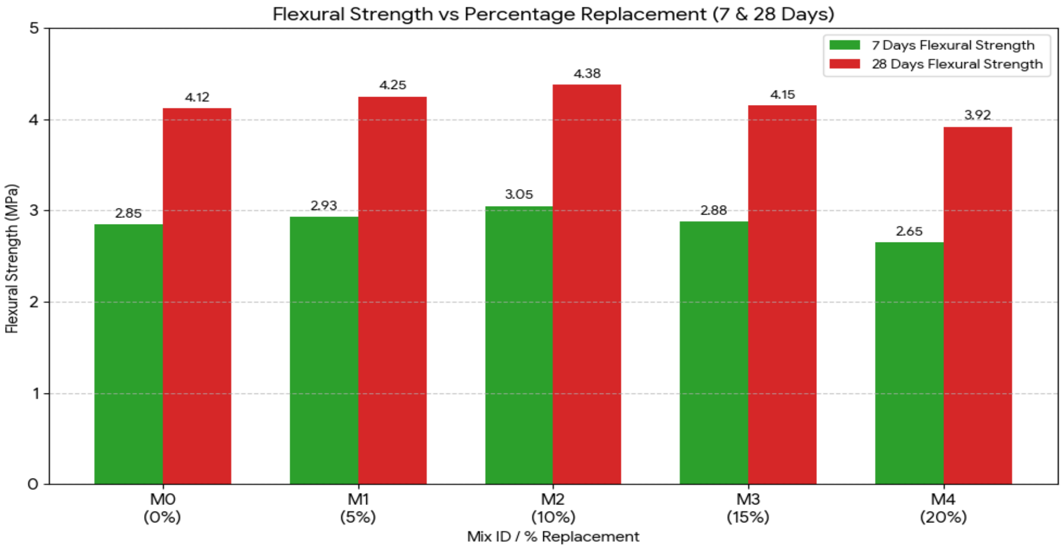

Fig.5.3 Flexural Strength vs Percentage Replacement of Coarse Aggregate

Observation:
Flexural strength improves up to **10% replacement** due to improved aggregate–paste bond and rough surface texture of brick aggregates.

6. CONCLUSIONS

From the experimental investigation, the following conclusions are drawn:

1. The experimental study confirmed that over burnt brick aggregate can be effectively used as a partial replacement for natural coarse aggregate in concrete, contributing to sustainable and eco-friendly construction practices.
2. The workability of concrete decreased with an increase in the percentage replacement of coarse aggregate by over burnt brick aggregate. This reduction in slump value is attributed to the higher porosity and water absorption capacity of over burnt brick aggregate.
3. Concrete mixes containing up to **20% replacement** of coarse aggregate exhibited acceptable workability suitable for normal construction practices. Beyond this level, workability reduction became more significant.
4. Compressive strength results indicated that concrete with **5% to 20% replacement** achieved strength values comparable to the control mix. The reduction in compressive strength at these levels was marginal and within permissible limits.
5. At replacement levels above 20%, a noticeable decrease in compressive strength was observed, mainly due to the lower crushing strength and weaker interfacial bonding characteristics of over burnt brick aggregates.
6. Split tensile strength and flexural strength followed trends similar to compressive strength. Concrete mixes with lower replacement levels showed satisfactory tensile and flexural performance, making them suitable for low to medium strength applications.

7. Water absorption increased with increasing over burnt brick content due to its porous nature. However, concrete mixes with replacement levels up to 20% remained within acceptable durability limits.
8. The density of concrete decreased slightly with the inclusion of over burnt brick aggregate, indicating the potential for producing relatively lightweight concrete, which may be beneficial for non-load-bearing elements and seismic-resistant structures.

FUTURE SCOPE

- Durability studies such as permeability and chemical resistance.
- Use in pavement concrete and precast elements.
- Combination with supplementary cementitious materials like fly ash and GGBS.
- Long-term performance and cost analysis.
- Development of lightweight concrete using full replacement.

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