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Enhancing Lightweight Concrete with Overburnt Broken Brickbats: Investigating Optimal Replacement Levels

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Abstract: **The abstract summarizes the research findings on lightweight self-compacting concrete (LWSCC) incorporating unburnt broken brick bats as partial replacements for natural gravel aggregates. Mechanical properties, including compressive, split tensile, and flexural strengths, were evaluated for LWSCC samples with replacement levels of 0%, 10%, 20%, and 30% by volume of natural gravel. The compressive strengths ranged from 28.133 to 33.85 N/mm², split tensile strengths ranged from 8.3 to 10.6 N/mm², and flexural strengths ranged from 3.24 to 5.73 N/mm² across the replacement levels. Additionally, fresh properties of the LWSCC have been assessed using L box, V funnel, and J ring tests to evaluate workability according to EFNARC guidelines. The results have indicated satisfactory workability properties for all replacement levels, confirming the feasibility of using unburnt broken brick bats in LWSCC mixtures. This research contributes to the understanding of incorporating alternative lightweight aggregates in concrete production, potentially reducing environmental impact and resource consumption associated with traditional aggregates. Furthermore, the mechanical properties demonstrate the potential of unburnt broken brick bats as a viable lightweight aggregate option in LWSCC formulations. These findings offer valuable insights for engineers and researchers seeking sustainable solutions in concrete technology and construction practices.**

Index Terms: **Broken Brick Bats, Environmental Impact, Lightweight Concrete, Mechanical Properties, Sustainable Aggregates, Workability Assessment**

I. Introduction

The research focuses on using structural lightweight concrete in multi-storied buildings to reduce the dead load, which is crucial for high-rise structures. The study specifically investigates the use of 'over-burnt brickbats' as a partial replacement for coarse aggregate in the concrete mix.[1]. The aim is to observe the cost and physical properties of concrete. The construction industry increasingly seeks sustainable solutions to address environmental concerns and optimize resource utilization. [2] Concrete, one of the most widely used construction materials globally, plays a significant role in this quest for sustainability. Traditional concrete production relies heavily on natural aggregates, such as gravel and crushed stone, which can deplete finite resources and contribute to environmental degradation through extraction and transportation processes. The use of 'pumice' as a lightweight aggregate also reduces the density of the concrete, resulting in a decrease in the dead weight of the structure. Additionally, pumice has been found to exhibit pozzolanic properties, making it suitable as a cement replacement material [3-5]. To mitigate these challenges, researchers and engineers have been exploring alternative materials and techniques to enhance the sustainability of concrete. One promising approach is the utilization of industrial by-products and waste materials as aggregates in concrete mixtures. These materials offer a sustainable alternative to natural aggregates and opportunities for waste valorization and resource efficiency. Among such materials, Over Burnt Brick Bats (OBB) stand out as a potential coarse aggregate replacement due to their abundance in certain regions and their properties conducive to concrete production [6,7].

The use of OBB in concrete offers several potential benefits, including reduced environmental impact, cost-cutting, and improved material performance. By diverting OBB from landfills and incorporating them into concrete mixtures, the construction industry can contribute to waste reduction efforts and promote circular economy principles. Moreover, OBB possesses intrinsic properties that can enhance concrete's mechanical and durability characteristics, thereby expanding its application in various construction projects. However, the successful integration of OBB into concrete requires a thorough understanding of their effects on concrete properties and performance. Several factors, including the size, shape, and composition of OBB and the replacement ratio, can influence the resulting concrete mixture's workability, strength, and durability. Therefore, comprehensive experimental investigations are necessary to assess the feasibility and efficacy of using OBB to replace traditional coarse aggregates [8-11].

In this context, this study aims to evaluate the potential of OBB as a coarse aggregate replacement in lightweight self-compacting concrete (LWSCC) mixtures. LWSCC offers distinct advantages over conventional concrete, including improved flowability and reduced labor requirements during placement. [12-15] By incorporating OBB into LWSCC mixtures, this study seeks to harness the benefits of lightweight aggregates and waste materials in concrete production. This research focuses on assessing the mechanical properties, including compressive, split tensile, and flexural strengths, of LWSCC samples with varying percentages of OBB replacement. Additionally, the study investigates the fresh properties of concrete mixtures, such as workability, through standardized tests to ensure compliance with industry guidelines and specifications [16-18].

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Figure 1. Overburnt brickbats

Overburnt brickbats: Overburnt brickbats refer to bricks that have been fired at an excessively high temperature, resulting in a darkened, distorted appearance and reduced strength.

Figure 2. Difference between Normal Brick Bats and Over Burnt Brick Bats

This study aims to provide insights into the feasibility and effectiveness of using OBB as a sustainable alternative in LWSCC production through systematic experimentation and analysis. The findings of this research can be advantageous to concrete producers, engineers, and policymakers about the potential benefits and challenges associated with incorporating OBB into concrete mixtures, contributing to the advancement of sustainable construction practices.

II. Literature Review

Husain M (1995) examined the application of untreated or treated bricks with different viscosity cement syrups as coarse aggregate. They discovered that, at? 28 days, the compressive strengths of crushed brick concrete were 75–80% of those of regular concrete, while the splitting tensile strength and modulus of elasticity were higher and lower, respectively than those of regular concrete.

Khalaf, F .M, and Devenny, A. S. (2005) conducted a study to assess the mechanical and physical characteristics of freshly burned and crushed bricks for aggregate in Portland cement concrete. According to the author, when the parent brick's compressive strength declines, the brick aggregate's impact value rises. The outcomes demonstrated the potential of using over-burned crushed brick aggregates to produce concrete for low-level civil engineering applications.

Farid Debib and Said Kenai (2017) investigated the impact by substituting coarse and fine concrete with crushed bricks from an overburn. Concrete was tested for split tensile, flexure, and compressive strength at 25, 50, 75, and 100% replacement levels.

According to the authors, broken brick concrete has a lower density than regular concrete. The test results gave substitution levels of 25% for coarse aggregate and 50% for fine aggregate.

Vikash Kumar Gautam (2019) This study investigates the use of crushed burn bricks as a coarse aggregate in concrete. Two types of concrete mixtures are prepared, one with a 1:2:4 ratio and the other with varying weights of crushed over-burn bricks. Thirty concrete specimens are tested under compression and split tension according to British standards. Results show that mistreatment of crushed bricks reduces concrete strength and increases the water-to-cement ratio. The study also investigates lightweight foamed concretes made with partial waste substitution over burn brick as coarse aggregate. Four different percentages of concrete mixtures are prepared, with the most optimal proportion being 25th. Foam is injected into the mixture to provide lightweight concrete with the correct proportions. The results show that waste burn bricks are suitable for creating concrete with acceptable strength characteristics. The study concludes that waste burn bricks are lightweight and helpful for creating lightweight concrete structures. However, using crushed bricks as a coarse combination decreases concrete compressive strength by 11-87% at 28 days. The recycled brick combination concrete created with this OBBA is suitable for use in unstable concrete.

Haque (2022) investigates using Khama brick chips as a partial replacement for coarse aggregate in lightweight structural concrete. The study tested the concrete's compressive strength and unit weight at different percentages of jhama brick chip replacements. Results showed up to 25% of the replacements met ASTM C 330 compressive strength requirements. The study also examines the properties of jhama brick chips, including sieve analysis.

III. Experimental Programme

This experimental program aims to determine the behavior of self-compacting concrete produced using overburnt brickbats replacing 10%, 10%, 20%, and 30% of normal coarse aggregate. Mechanical and Fresh properties of lightweight self-compacting concrete at 28 days are investigated for M20 grade.

Objectives

➤ To design the M20 mix by partially replacing the coarse aggregate with overburnt brickbat aggregate.

➤ To find out the fresh properties of LWOBBAC (lightweight overburnt brickbat aggregate concrete).

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➤To study the mechanical properties of LWOBBAC (lightweight overburnt brickbat aggregate concrete).

➤ To reduce the self-weight and density of the LWOBBAC

IV. Materials And Methods

A. Cement

A pozzolanic material is essentially a siliceous or aluminous material that, despite not having cementitious properties, will react with calcium hydroxide, which is released during the hydroxide process at room temperature when it is in a finely divided state and in the presence of water to form a compound with cementitious properties. The physical properties of cement values are shown in Table 1.

TABLE I.
FRESH PROPERTIES OF CEMENT

S. No.	Property	Test Results
1.	Normal consistency	31%
2	Initial setting time	50 minutes
3	Final setting time	550 minutes
4	Soundness test	3 mm
5.	Specific gravity	3.15

B. Fine Aggregates

River sand that had been sieved up to 4.750 mm and was readily available in the area was used as the "fine aggregate". The IS: 2386-1963 was used to analyze the properties of sand.

C. Coarse Aggregates

Typically, fractured stone serves as the coarse aggregate in concrete mixtures, comprising a significant portion of its volume. Locally sourced coarse aggregates, with a nominal size of 20 mm, were utilized in this study. Before incorporation, the aggregates underwent a thorough washing process to remove any dirt or dust contaminants. The selection of coarse aggregate size depends on the intended application, with maximum sizes dictated by specific project requirements and standards. In accordance with Indian Standard Specifications IS: 383-1970, stringent tests are conducted to assess the quality and suitability of coarse aggregates for concrete production.

C. Over Burnt Brickbats:

Overburnt brickbats are fragments of bricks subjected to excessive firing temperatures, rendering them dark and brittle. They are commonly used as coarse aggregates in concrete production, offering reduced cost and environmental sustainability benefits. However, their high absorption rate and irregular shape can impact concrete properties. OBB Properties values are shown in Table No. 2.

D. Soaking Burnt Brickbats *in water:* Due to the composition of clay and earth materials, overburnt brick bats possess numerous voids, leading to significant absorption capacity. Direct incorporation into concrete without pre-treatment results in water absorption, potentially compromising the mix. Thus, soaking the bats in water followed by drying is imperative to achieve Saturated Surface Dry conditions before utilization.

Figure 3. Soaking Burnt Brickbats in water.

TABLE II.
Physical Properties of Over Burnt Brickbats

S. No.	Properties	Results
1	Size	20mm passing and 16mm retaining
2	Shape	Angular
3	Specific Gravity	2.17
4	Loose Bulk Density	602.3kg/m^3
5	Compacted Bulk Density	698.49kg/m^3
6	Fineness modulus	7.20

D. Water

Water plays a key role in concrete, facilitating the binding of cement and particles and forming a cohesive mixture. Therefore, only clean, and potable water is used to prepare concrete mixes to ensure optimal hydration and strength development.

TABLE III.
Physical Properties of Over Burnt Brickbats

Percentage Replacements	Cement (kg)	Coarse Aggregate	OBB	Fine Aggregate	Water
		(kg)	(kg)	(kg)	(lit)
0%	358.18	1181.77	0	707.335	197
10%	358.18	1063.57	71.40	707.335	197
20%	358.18	945.39	142.0	707.335	197
30%	358.18	827.224	214.4	707.335	197

D. Casting of Specimens: Specimens have been cast using overburnt brickbat concrete to determine compressive, flexural, and split tensile strength. For compressive strength, cube specimens with dimensions of 150mm were molded.

Rectangular prisms of 100mm x 100mm x 500mm were prepared for flexural strength testing. In addition, cylindrical specimens with 150mm diameter and 300mm height were utilized for split tensile strength evaluation. All specimens were vibrated during casting to ensure uniformity and cured under standard conditions before testing.

Figure 4. Casting of Specimens

V. Results And Discussions

Compressive Strength: Place cylindrical specimens in a compression testing machine. Apply load gradually until failure occurs. The compressive strength values at the 7 and 28 days are shown in Table No.7. Calculate compressive strength using the formula:

Figure 5. Compression Test Machine

Split Tensile Strength:
Set cylindrical specimens horizontally between the loading platens of a testing machine. Apply the load perpendicular to the cylinder's axis until it fails. Table 7 shows the split tensile strength values at 7 and 28 days.

Figure 6. Split Tensile test machine.

Flexural Strength:
Position rectangular prisms on a flexural testing machine. Apply load at the midpoint of the specimen until failure. Table 7 shows the flexural strength values at 7 and 28 days.

Figure 7. Flexural Strength Test Machine.

TABLE IV.
MECHANICAL PROPERTIES OF LWOBBA CONCRETE

Designation	Cube Compressive Strength Mpa		Prism flexural strength Mpa		Cylinder split tensile. strength Mpa	
	7Days	28 Days	7 Days	28 Days	7 Days	28 Days
NC	19.5	29.92	1.1	5.5	2.4	9.4
10%	19.6	31.1	1.2	5.6	2.4	9.6
20%	19.7	33.85	1.4	5.73	2.6	10.6
30%	16.2	28.133	1.8	3.24	2.2	8.3

Mechanical properties like compressive strengths got 29.92, 31.106, 33.85 and 28.133 N/mm2, split tensile strengths got 9.4, 9.6, 10.6 and 8.3 N/mm2, and flexural strengths got 5.5,5.6, 5.73 and 3.24 for the lightweight self-compacting concrete partially replaced with over burnt brickbats with 0%, 10%, 20% and 30% respectively by volume of natural gravel and its fresh properties using L box, V funnel, and J ring test performed to verify its workability properties and got satisfied as per EFNARC guidelines,

Density: The density of Overburnt brickbat concrete for 0%, 10%, 20%, and 30% replacements was determined by weighing each specimen. Using the formula below, densities were calculated for comparison. Density of concrete values shown in table 5.

$$\text{density} = \frac{\text{Average Weight Of Samples (kg)}}{\text{volume of sample } (m^3)}$$

TABLE V.
DENSITIES OF LWOBBA CONCRETE

Percentage of replacement	Density in (in Kg/m^2)
LWOBBAC-0%	2359
LWOBBAC -10%	2364
LWOBBAC -20%	2370
LWOBBAC -30%	2079

Slump Test: The workability of Over Burnt Brickbat concrete at 0%, 10%, 20%, and 30% replacements was assessed using the slump test. A slump cone was filled in three layers, each compacted with 25 blows. After removal, the decrease in height from the cone's top to the displaced concrete surface was measured. The reduction in slump with increasing replacement percentage is due to the presence of coarse aggregates like brickbats, which can result in decreased workability as they may hinder the flow of the concrete mix. The workability of concrete by slump test values is shown in Table 7.

Figure 8. Workability by Slump Test

TABLE VI.
WORKABILITY OF LWOBBA CONCRETE

Percentage of replacement	Workability in mm
LWOBBAC-0%	75
LWOBBAC -10%	72
LWOBBAC -20%	65
LWOBBAC -30%	50

Firstly, regarding compressive strength, it is observed that as the percentage of OBB replacement increases from 0% to 20%, there is a progressive enhancement in compressive strength, with values ranging from 29.92 to 33.85 N/mm². This indicates that the potential for OBB to influence the structural integrity of LWSCC mixes positively. However, beyond 20% replacement, a slight decrease in compressive strength is noted, suggesting a threshold beyond which excessive OBB content may compromise overall strength. Similarly, the split tensile strength exhibits a similar trend, with incremental improvements observed up to 20% OBB replacement, ranging from 9.4 to 10.6 N/mm². Beyond this point, a reduction in tensile strength is observed, indicating a diminishing returns scenario.

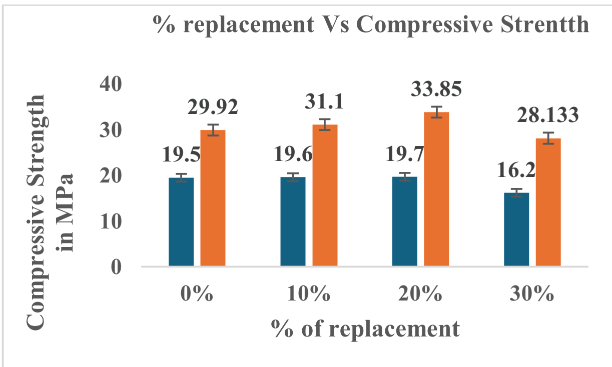

Figure 9. Compressive Strength of 7 and 28 days cured M20 grade concrete.

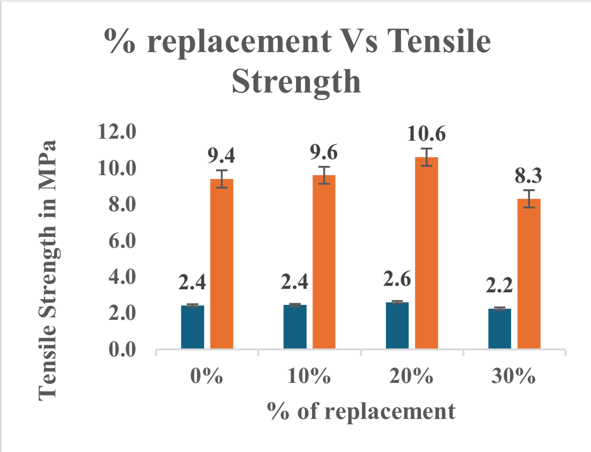

Figure 10. Split tensile strength of 7 and 28 days cured M20 grade concrete.

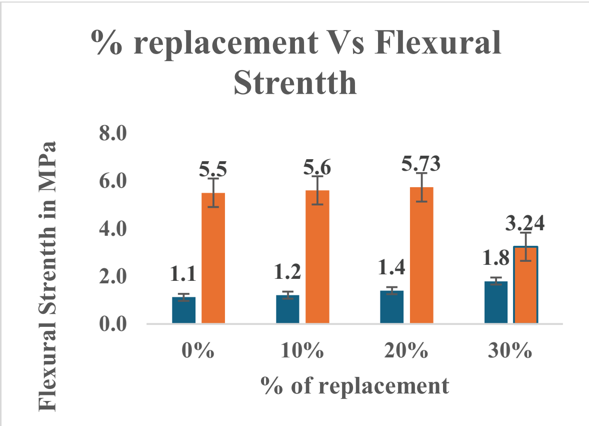

Figure 11. Flexural strength of 7 and 28 days cured M20 grade concrete.

On the contrary, the flexural strength findings exhibit a nuanced trend in response to OBB replacement. Initially, there is a rise in flexural strength with up to 20% replacement, reflected in values ranging from 5.5 to 5.73 N/mm². However, a notable decrease is evident at 30% replacement, indicating a potential structural constraint at higher replacement rates. Additionally, the satisfactory workability performance of NWC, validated through Abram's cone test, evaluates the workability of concrete by measuring the time it takes to flow through a standard cone. Codal provisions ensure concrete consistency for construction quality. This suggests that incorporating OBB maintains the concrete's ability to flow and fill molds effectively. These findings imply that OBB can be successfully employed as a partial substitute for natural gravel in NWC mixes, enhancing mechanical properties up to a certain replacement threshold. Nonetheless, carefully considering the optimal replacement level is imperative to ensure balanced performance and structural soundness.

VI. Conclusion

The following significant conclusions are derived from the experimental investigations that have been conducted.

The investigation focused on determining optimal replacement levels for enhancing lightweight concrete with overburnt broken brick bats.

1. Slump values decreased with increasing over burnt brickbat aggregate replacement: 75 mm (0%), 72 mm (10%), 65 mm (20%), and 50 mm (30%).
2. Compressive strengths varied: 29.92 MPa (0%), 31.1 MPa (10%), 33.85 MPa (20%), and 28.133 MPa (30%), Flexural strengths exhibited fluctuations: 5.5 MPa (0%), 5.6 MPa (10%), 5.73 MPa (20%), and 3.24 MPa (30%) and Split tensile strengths displayed changes: 9.4 MPa (0%), 9.6 MPa (10%), 10.6 MPa (20%), and 8.3 MPa (30%).
3. The density of lightweight aggregate concrete was altered to 2359 kg/m³ (0%), 2364 kg/m³ (10%), 2370 kg/m³ (20%), and 2079 kg/m³ (30%).
4. The study identified 20% of over burnt brickbat aggregate replacement as optimal, balancing workability, mechanical properties, and density.
5. These findings offer practical insights for engineers and practitioners to enhance lightweight concrete while utilizing overburnt broken brick bats.
6. Utilizing recycled materials in concrete production contributes to sustainability and resource conservation in the construction industry.
7. Future research could investigate lightweight concrete's long-term performance and durability with overburnt brickbat aggregates.
8. Further exploration of the economic feasibility and environmental impacts of integrating overburnt brickbats into concrete production processes is warranted.
9. This study contributes valuable data and insights into optimizing lightweight concrete with overburnt brickbat aggregate, advancing sustainable construction practices and resource utilization in the industry.

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