

# Sustainable Concrete Production Using Stone Dust and Over-Burnt Brick as Aggregate Replacements

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**Abstract**— This study investigates the mechanical properties of concrete produced by partially replacing fine aggregate with stone dust and coarse aggregate with over-burnt brick aggregates. The experimental program was designed to evaluate the influence of these materials on various concrete characteristics, including water absorption, workability, compressive strength, split tensile strength, flexural strength, and microstructural features assessed through Field Emission Scanning Electron Microscopy (FESEM) analysis. Concrete mixes were prepared with stone dust replacing fine aggregate at proportions of 0%, 25.25%, 35.25%, 45.25%, and 55.25%. Concurrently, over-burnt brick aggregates were incorporated as partial replacements for coarse aggregate at levels of 0%, 15%, 30%, and 40%. The study revealed significant variations in mechanical performance across different mix proportions.

**Index Terms**—Stone Dust, Over Burnt Brick Aggregate, Compressive Strength, Split Tensile Strength, Flexural Strength, FESEM Analysis.

## I. INTRODUCTION

Concrete is a widely utilized composite material made from aggregates like sand, gravel, or crushed stone, bound by a cement-based binder. This binder generally includes Portland cement combined with various admixtures. Known for its versatility, strength, cost-effectiveness, and long-lasting qualities, concrete is the most used building material globally and holds a key role in construction. When cement, aggregates, and water are mixed correctly, a chemical reaction occurs between the cement and water, creating a solid, rock-like material known as concrete. The most frequently used forms of concrete rely on lime-based binders, such as Portland cement, or other hydraulic cements. For paving applications, asphalt concrete uses bitumen as its binder, whereas polymer concretes incorporate polymers for additional reinforcement. When dry Portland cement, aggregates, and water are blended, they form a slurry that can be molded and poured. Through a chemical reaction, the cement solidifies and creates a strong, cohesive matrix, forming a durable, stone-like

material. To modify specific properties of either the mix or the hardened concrete, additives are often introduced. Reinforced concrete, strengthened with steel or other materials, is designed to improve tensile strength.

Bricks made from fired molded soil contain a significant amount of clay. However, due to uneven temperature distribution during kiln firing, around 13% of these bricks end up severely over-burned. These over-burned bricks are typically discarded as waste since they are unsuitable for use in cement concrete production, creating a disposal challenge for brick manufacturers. Despite this, over-burned bricks can be utilized in concrete applications with lower stress requirements, such as basic concrete work and certain types of reinforced construction. To prevent the mixing water necessary for cement hydration from being absorbed by the brick aggregates, they should be soaked in water for 24 hours before use. While crushed stone aggregates offer better fire resistance and sound absorption compared to brick aggregates, over-burned bricks—with their compact structure—are sometimes found to be stronger than standard first-class bricks, making them suitable as aggregate in concrete for foundations, floors, road construction, and similar applications. The over-burned bricks are characterized by their irregular shape and darker color.

## II. LITERATURE SURVEY

Ardalan Baradaran-Nasiri and Mahdi Nematzadeh (2017) This research investigated how varying temperatures influence the mechanical characteristics of concrete utilizing fine aggregates sourced from recycled refractory brick and aluminate cement. A total of 210 concrete samples were prepared across ten distinct mix compositions, incorporating refractory brick aggregate as a partial or full replacement for conventional sand at five levels: 0%, 25%, 50%, 75%, and 100%. The experimental setup included two primary groups, one utilizing ordinary Portland cement and the other calcium aluminate cement. Evaluations were conducted on a range of

physical and mechanical attributes of the concrete, such as compressive strength, elastic modulus, weight loss upon exposure to temperatures of 110°C, 200°C, 400°C, 600°C, 800°C, and 1000°C, as well as density, porosity, and water absorption rates prior to heating. The findings revealed that using refractory brick aggregate in combination with aluminate cement notably enhanced the residual strength of concrete, even sustaining strength at temperatures above 800°C. However, despite the benefits observed in residual strength, the inclusion of refractory brick aggregate with aluminate cement did not yield a significant improvement in the concrete's modulus of elasticity under elevated temperature conditions.

B. Basavaraj et al. (2017) research explores the substitution of sand with stone crusher powder in traditional concrete. The findings reveal that stone crusher powder exhibits comparable properties and performance to that of river sand. This paper aims to examine the effects of replacing sand with stone crusher powder, focusing on the strength characteristics of concrete using varying proportions of this material as a fine aggregate substitute. Additionally, the test results concerning the strength of concrete are presented and compared with those of conventional concrete.

Charles K. Kankam et al. (2017) A recent research study explored the potential of quarry dust as a replacement for sand in concrete mixtures, assessing its performance when substituted at rates of 0%, 25%, and 100% by weight of sand. For each replacement level, concrete mixes were designed to achieve strength grades of C25, C30, C35, C40, and C45. The stress-strain behavior was consistent across all levels of sand replacement, with the concrete containing a full replacement (100% quarry dust) exhibiting the highest strain. When analyzing the modulus of elasticity (MoE), the study found that concrete with 25% of the sand replaced by quarry dust showed an MoE increase of 7.9% compared to the concrete with a full sand replacement. In contrast, the MoE of the concrete with 100% quarry dust was 8.6% lower than that of a mix with no quarry dust replacement. The experimental MoE results were also compared against calculated values derived from established formulas in BS, ACI, and IS standards, which estimate MoE based on the concrete's compressive strength. Overall, the study indicates that a blend of sand and quarry dust can improve the concrete's mechanical characteristics.

Er. Lakhan Nagpal et al. (2013) This research explored the potential of crushed stone dust as an alternative fine aggregate in concrete to evaluate its influence on concrete's strength characteristics. The primary goal was to assess whether crushed stone dust could serve as a partial or full substitute for traditional fine aggregates in different concrete compositions. Initial concrete mixtures with natural sand were prepared for M25 and M30 concrete grades. In parallel, similar concrete batches were formulated by replacing natural sand with varying amounts of crushed stone dust, covering both partial and complete replacement scenarios. Experimental results indicated that crushed stone dust could feasibly substitute natural sand, contributing to improved concrete performance. The findings revealed that using crushed stone dust as a fine aggregate boosted the compressive, flexural, and tensile strengths of concrete, thereby supporting its suitability as a sustainable alternative in concrete applications.

Farid Debieb and Said Kenai (2007) The study explored the potential of utilizing both coarse and fine crushed bricks as aggregates in concrete. Specifically, it assessed the viability of incorporating crushed brick to partially replace natural sand, coarse aggregates, or both at varying replacement levels of 25%, 50%, 75%, and 100%. After a curing period of 90 days, the compressive and flexural strengths of concrete mixtures using natural aggregates were compared with those made from crushed brick aggregates. Additionally, the research evaluated key properties of the materials, including porosity, water absorption, water permeability, and shrinkage. The findings indicated that concrete incorporating crushed bricks can achieve properties comparable to those of concrete made with natural aggregates, provided the recycled aggregates are limited to a maximum of 25% for coarse aggregates and 50% for fine aggregates.

Fatih Bektas (2013) In a controlled laboratory investigation, the alkali reactivity of coarse aggregates derived from crushed red clay brick was closely examined. Mortar mixtures were created with incremental proportions of brick aggregate, specifically at 10%, 25%, 50%, and a full replacement of 100%, while concrete mixes were formulated with brick aggregate proportions of 0%, 50%, and 100%. To simulate conditions favorable to alkali-silica reaction (ASR), mortar bars and concrete prisms were exposed to elevated temperatures, high

humidity, and an alkaline environment. This setup allowed researchers to monitor expansion levels under ASR-prone conditions. The study further explored the impact of clay brick aggregate on critical mechanical properties of concrete, including compressive strength, flexural strength, and static elastic modulus. Both cylindrical and prismatic specimens were tested under ASR-inducing conditions. The analysis also included microstructural examination through scanning electron microscopy to provide insights into material behavior at a microscopic level. Results revealed a direct correlation between the proportion of brick aggregate and the extent of linear expansion in the specimens. According to the criterion for expansion, none of the mortar bar mixes reached the harmful expansion threshold of 0.05% after six months in water storage at 38°C. However, when samples with 10%, 25%, and 50% clay brick aggregate were placed in a sodium hydroxide solution at 80°C for a 14-day period, they exhibited notable expansion, surpassing the 0.10% threshold. Microscopy showed signs of alkali-silica gel formation and identified ettringite within the samples. Furthermore, the sodium hydroxide in the mixing water was observed to reduce compressive and flexural strength in concrete containing clay brick aggregate. While concretes with brick aggregates showed more expansion relative to control samples, no visible cracking was noted, and the primary mechanical properties—compressive strength, flexural strength, and static elastic modulus—remained largely unaffected, with no significant reductions documented.

### III. RESEARCH SIGNIFICANCE

The demand for sustainable development has risen, presenting a significant challenge for the construction industry to maximize benefits while minimizing the use of fine and coarse aggregates. This can be achieved by incorporating blended fine and coarse aggregates along with recycled materials in concrete, which not only lowers construction costs but also mitigates environmental pollution.

Recent studies have delved into the potential of improving concrete properties through the incorporation of alternative materials such as stone dust and over-burnt brick. However, the majority of current research predominantly examines the effects of these materials individually. To address this gap, the present study seeks to explore the combined impact of both stone dust and over-burnt brick aggregate on the mechanical properties of concrete.

Specifically, it will focus on evaluating the compressive, flexural, and tensile strength characteristics of concrete mixtures that contain varying proportions of these two materials. By investigating their synergistic effects, this research aims to provide valuable insights into enhancing the performance and sustainability of concrete.

### IV. METHODOLOGY FOR EXPERIMENTS

To assess the hardness characteristics of concrete, several essential tests are conducted. These include:

1. **Compressive Strength Test:** This test measures the concrete's ability to withstand axial loads. A cylindrical or cubic specimen is subjected to increasing pressure until failure occurs, allowing for the calculation of compressive strength, which is crucial for determining how well the concrete can support loads in structural applications. The compressive strength for each tested specimen is calculated by dividing the maximum load at failure by the cross-sectional area of the cube. This method yields the strength values necessary for evaluating the performance of the different concrete mixes assessed during the testing process.

2. **Split Tensile Strength Test:** This evaluation focuses on the tensile strength of concrete by measuring its resistance to splitting when subjected to axial loading. The split tensile strength was computed using the relevant formula tailored for this type of test.

$$\sigma_t = 2 P / \pi L d$$

A cylindrical specimen is placed horizontally in a testing machine, and force is applied until it fractures. The results provide insight into the material's performance under tensile stresses.

3. **Flexural Strength Test:** This test assesses the concrete's capacity to resist bending. A beam-shaped specimen is supported at both ends, and a load is applied at the center until failure occurs. The maximum load carried divided by the beam's dimensions gives the flexural strength, which is vital for understanding the material's behavior in structural elements like beams and slabs.

4. This test is performed to assess the microstructural behavior of the concrete samples having stone dust as replacement of fine aggregates and burnt clay bricks as the replacement of coarse aggregates. A sample of 1X1 cm was cut from the hardened concrete cubes and cylinders which was thereafter made completely

even on the side to be tested using ambrane papers. External gold coating was done too understand the microstructure more precisely.

V. RESULTS AND DISCUSSIONS

In accordance with IS 516:1959, compressive strength tests were conducted for each concrete mix design using cube specimens measuring 150 mm. The testing was performed after a curing period of 7 days. The results detailing the compressive strength of the concrete, influenced by different proportions of stone dust and over-burnt brick aggregates, are summarized in Table 6.1.

The split tensile strength test was conducted using a cylindrical specimen with a diameter of 150 mm and a length of 300 mm, following the guidelines outlined in IS 5816-1999, after a curing period of seven days. The results, which detail the split tensile strength at various proportions of stone dust and over-burnt brick aggregates, are presented in Table 6.2.

The SEM image for the over burnt brick aggregates have been shown in the figure below at various magnification levels. Scanning electron microscopy images (SEM) of overburnt bricks at different resolutions in Figure 1 and Figure 2 show that particles of burnt bricks are very fine, irregular in shape, rough in texture, and have a porous surface.

For crack propagation, the control mix exhibited more extensive crack development due to the weaker ITZ and lack of micro-filler particles. In the modified samples, however, SEM showed fewer microcracks and voids, attributed to the improved ITZ and filler effect of stone dust. Although the use of over-burnt brick introduced minor microcracks, the reduction in CH and the enhanced formation of C-S-H compensated for these, resulting in fewer visible cracks in the modified samples. Overall, SEM analysis confirmed that the modifications led to a more refined microstructure, potentially enhancing both the strength and durability of the concrete.

Table 6.1: Compressive Strength

Mix	CA (%)	OBBA (%)	FA (%)	Stone Dust (%)	Cement (%)	Compressive strength after 7 days (N/mm <sup>2</sup> )
MU00	100	0	100	0	100	19.24
MU01	100	0	74.75	25.25	100	20.80

MU02	100	0	64.75	35.25	100	21.09
MU03	100	0	54.75	45.25	100	21.87
MU04	100	0	44.75	55.25	100	22.24
MU05	85	15	74.75	25.25	100	22.81
MU06	85	15	64.75	35.25	100	22.98
MU07	85	15	54.75	45.25	100	23.28
MU08	85	15	44.75	55.25	100	23.79
MU09	70	30	74.75	25.25	100	24.44
MU10	70	30	64.75	35.25	100	25.16
MU11	70	30	54.75	45.25	100	25.66
MU12	70	30	44.75	55.25	100	25.87
MU13	55	45	74.75	25.25	100	25.21
MU14	55	45	64.75	35.25	100	24.91
MU15	55	45	54.75	45.25	100	24.61
MU16	55	45	44.75	55.25	100	23.84

Table 6.2: Split Tensile Strength

Mix	CA (%)	OBBA (%)	FA (%)	Stone Dust (%)	Cement (%)	Split tensile strength after 7 days (N/mm <sup>2</sup> )
MU00	100	0	100	0	100	2.14
MU01	100	0	74.75	25.25	100	2.18
MU02	100	0	64.75	35.25	100	2.25
MU03	100	0	54.75	45.25	100	2.33
MU04	100	0	44.75	55.25	100	2.64
MU05	85	15	74.75	25.25	100	2.79
MU06	85	15	64.75	35.25	100	2.84
MU07	85	15	54.75	45.25	100	2.97
MU08	85	15	44.75	55.25	100	3.12
MU09	70	30	74.75	25.25	100	3.21
MU10	70	30	64.75	35.25	100	3.25
MU11	70	30	54.75	45.25	100	3.31
MU12	70	30	44.75	55.25	100	3.22
MU13	55	45	74.75	25.25	100	3.19

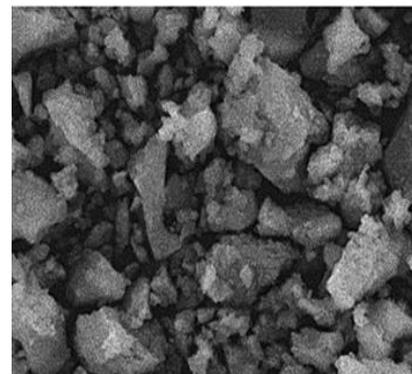


Figure 1 SEM image for burnt brick aggregate at 5µm

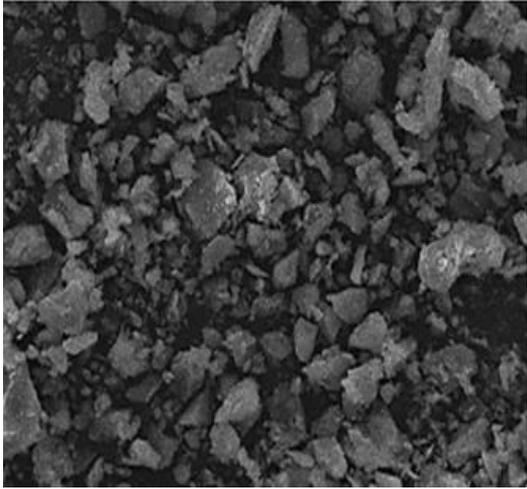


Figure 2 SEM image for burnt brick aggregate at 10µm

environment”, *Construction and Building Materials*, Vol. 164, pp 837–849, 2018.

## VII. CONCLUSIONS

1. The MU12 concrete mix demonstrated a compressive strength of 25.87 N/mm<sup>2</sup> after a curing period of 7 days.
2. For the MU11 mix, which contained 30% overburnt brick aggregate as the coarse component and 45.25% stone dust in the fine aggregate, the split tensile strength reached 3.31 N/mm<sup>2</sup> after 7 days of curing.

## REFERENCES

- [1] Ardalan Baradaran-Nasiri and Mahdi Nematzadeh , “The effect of elevated temperatures on the mechanical properties of concrete with fine recycled refractory brick aggregate and aluminated cement”, *Construction and Building Materials*, Vol. 147, pp 865–87, 2017.
- [2] Eva Navrátilová and Pavla Rovnaníková, “Pozzolanic properties of brick powders and their effect on the properties of modified lime mortars”, *Construction and Building Materials*, Vol. 120, pp 530–539, 2016.
- [3] Farid Debieb and Said Kenai, “The use of coarse and fine crushed bricks as aggregate in concrete”, *Construction and Building Materials*, Vol. 22, pp 886–893, 2008.
- [4] Fatih Bektas, “Alkali reactivity of crushed clay brick aggregate”, *Construction and Building Materials*, Vol. 52, pp 79–85, 2014.
- [6] Mahdi Nematzadeh, Javad Dashti and Behnoud Ganjavi, “Optimizing compressive behavior of concrete containing fine recycled refractory brick aggregate together with calcium aluminated cement and polyvinyl alcohol fibers exposed to acidic