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# "A Study on Fly Ash, Recycled Brick Aggregate and steel fibers in self-compacted concrete"

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## Abstract

This study investigates the fresh, mechanical and durability performance of self-compacting concrete (SCC) produced with partial replacement of natural coarse aggregate by recycled brick aggregate (RBA), partial replacement of cement by Class F fly ash (FA), and incorporation of steel fibers. A factorial experimental program included mixes with RBA replacement levels of 0%, 25% and 50%, fly ash replacements of 0% and 10%, and steel fiber contents of 0% and 0.5% by volume. Fresh properties were assessed using slump-flow, tests. Hardened properties evaluated were compressive strength (7, 28, 56 days), split tensile strength (28 days), flexural strength and toughness indices for fiber mixes. Fly ash improved flowability and reduced superplasticizer demand; RBA reduced 28-day compressive strength by 6–14% for 25–50% replacement but remained acceptable for non-critical structural applications; steel fibers significantly improved post-peak behavior and flexural toughness. On balance, SCC with 25% RBA + 10% FA + 0.5% steel fiber achieved the best trade-off between workability, strength and toughness. Recommendations and limitations are discussed.

***Keywords:*** Self-Compacting Concrete (SCC) , Natural Coarse Aggregate, Recycled Brick Aggregate (RBA), OPC 43 grade cement, Class F fly ash (FA), Steel Fibers, Compressive Strength, Tensile Strength and Flexural Strength.

## 1. Introduction

Self-compacting concrete, also known as self-consolidating consolidating concrete, can flow, consolidate, and dehydrate almost completely while in the formwork. It is sufficient to occupy the entire available space without segregation or bleeding. This compels SCC to be used to its maximum potential in places that cannot be effectively compacted. Most concrete failures are caused by improper concrete compaction, which can be avoided by doing so. The best solution is self-compacting concrete, and we can reduce waste during structure demolition by using recycled brick components as a partial replacement for aggregate.

This makes it an excellent alternative for creating buildings and structures with complex geometries and elaborate designs. Furthermore, eliminating the requirement for external vibration minimizes noise pollution, which benefits both workers and surrounding households. SCC's self-compacting nature also makes the construction process safer and more efficient by decreasing the need for manual effort and the risk of damage.

Overall, the usage of SCC has numerous advantages for the construction sector, and its popularity is expected to increase in the future.

Fly ash improved flowability and reduced superplasticizer demand; (2) RBA reduced 28-day compressive strength by 6–14% for 25–50% replacement but remained acceptable for non-critical structural applications; (3) steel fibers significantly improved post-peak behavior and flexural toughness. On balance, SCC with 25% RBA + 10% FA + 0.5% steel fiber achieved the best trade-off between workability, strength and toughness. Recommendations and limitations are discussed.

## 2. LITERATURE REVIEW

### 2.1 Works of Literature

P. Dhamodharan et al. (2023) "Study on Recycled Aggregate and Steel Fibers in Self Compacted Concrete" The self-compacting concrete is a binding composite which involves formworks without need of vibration and high resistance. However, construction waste such as bricks is used as recycled coarse aggregate in order to improve the sustainability demands of structures. While introducing of RBC in SCC Will generate better improvement in construction sectors. In order to increasing of workability we introduce Super plasticizer in concretes. In order to enhanced the durability properties of SCC Crimped steel fiber are added as additive in the concrete mix. Crimped steel fiber develop good bonding properties with the recycled aggregate.

**K. Youvaraj et al. (2023)** "Study on recycled aggregate and steel fibers in self compacted concrete" The self compacting concrete is a binding composite which involves formworks without need of vibration and high resistance. However construction waste such as bricks is used as recycled coarse aggregate in order to improve the sustainability demands of structures. While introducing of RBC in SCC Will generate better improvement in construction sectors. In order to increasing of workability we introduce Super plasticizer in concretes. In order to enhanced the durability properties of SCC Crimped steel fiber are added as additive in the concrete mix. Crimped steel fiber develop good bonding properties with the recycled aggregate.

Kazim Turk et al. (2021) investigated the effect of volume fraction and the combination of macro and microfibers on the workability, mechanical properties and flexural behaviour of SCC. The workability decrease with an increase in the volume of fiber fraction but the flexural toughness is increased with an increase in the volume of fiber fraction. Superior Ductility was also observed. The microfibers gave best results than the macro fibre in all aspects. To achieve better workability macro fiber of low aspect ratio than microfiber is used.

Pei Ge et al (2021) The compressive strength of RBAC is at its highest when the volume fraction of RBA is between 44% and 47% and the overall volume fraction of RBA and sand is about 70%. In this test, the volume fraction of RBA, sand/cement and water/cement ratio were taken into consideration. It was established that the RBAC mix percentage design method was based on the aggregate skeleton theory. In comparison to ACI 211.2 and ACI 211.6, the mix proportion design approach suggested in this work involves mixing more RA and less sand and cement in the concrete mix proportion while maintaining concrete strength and slump, which is advantageous for environmental protection.

Bo Wang et al. (2021) provided a comprehensive review of the RA and RCA about their history, manufacturing process and their material properties etc. A summary is also provided of the techniques for enhancing the mechanical characteristics and durability of RACs. Addition to the challenges in the application of RAC is also reviewed in this study. Artificial Intelligence methods are employed to predict the RAC compressive properties.

Chang Sun et al. (2020) evaluate the feasibility of preparing SCC by incorporating waste concrete recycling materials. The investigation carried on both fresh and hardened properties of self-compacting concrete with recycled concrete. There is a decrease in the workability and mechanical properties of SCC and the replacement percentage is also limited. The high water absorption rate decreases the workability with an increase in the waste concrete recycling materials. The mechanical properties also decrease with an increase in rates of waste concrete recycling materials.

Guoliang Bai et al. (2020) The performance of RA at the material level and the amount of old attached mortar were shown to have a quantitative relationship. The presence of the old mortar in RA accounts for the differences in characteristics between recycled aggregate and natural aggregate. The performance of RA is enhanced not only by removing the old mortar, but also by regulating the water-cement ratio and modifying the aggregate moisture content. This straightforward and cost-effective technique can also be used to obtain higher RA quality. The key factor contributing to the RA's worse quality compared to the NA is the presence of adhering mortars.

Fernando Lopez Gayarre et al (2019) This research examines the use of recycled brick aggregates (RBA) in concrete to replace both the fine and coarse fractions of natural aggregates used to make prestressed joists. For structural purposes, concrete with a 35% RBA displays acceptable shrinkage values, but the decline in elasticity modulus may call for more research.

Hui Guo et al (2018) Inadequate durability is caused by the decline in recycled aggregate. Utilising pozzolanic materials, either as a surface coating or combined with the concrete, increases the durability. Concrete's durability and the characteristics of recycled aggregate are improved by the $CO_2$ treatment. The durability is inversely related to the amount of adhering mortar.

Kho Pin Verian et al. (2018) The original aggregate's characteristics and the state of the demolished concrete affect the RCA's quality. The presence of mortar on the surface of recycled aggregate is what causes its different qualities when compared to natural aggregate. This literature mentions a number of strategies to raise the calibre of concrete incorporating RCA.

### 2.2 Gap of study

- While several studies have independently examined the effects of recycled brick aggregates (RBA), fly ash, or steel fibers in concrete, there is limited experimental research that investigates their combined influence on self-compacting concrete (SCC).
- The synergistic effects of using RBA (as a partial coarse aggregate replacement), fly ash (as a cementitious replacement), and steel fibers (as reinforcement for ductility) on the rheological behavior, mechanical strength, and durability of SCC remain insufficiently understood.
- There is no standard guideline or consensus on the optimum proportions of RBA, fly ash, and steel fibers that achieve both workability (self-compaction) and mechanical performance simultaneously.
- Most available studies focus on compressive strength, with little data on durability parameters (e.g., permeability, shrinkage, microstructure, and long-term performance) for SCC made with these combined materials.
- Few studies have quantified the environmental benefits (e.g., embodied carbon, waste reduction) of using RBA, fly ash, and steel fibers together, despite their potential to enhance sustainable construction.

## 3. Objective of the study

The main objective of the present research is to evaluate the feasibility and performance of Self-Compacting Concrete (SCC) incorporating recycled brick aggregates (RBA), fly ash, and steel fibers as sustainable and performance-enhancing materials. The specific objectives of the study are as follows:

1. To develop M30 grade Self-Compacting Concrete (SCC) mixes using OPC 43 grade cement, natural aggregates, fly ash, and steel fibers in accordance with EFNARC guidelines.
2. To investigate the effect of recycled brick aggregates (RBA) as a partial replacement of natural coarse aggregates at replacement levels of 10%, 20%, 30%, and 40% on the fresh and hardened properties of SCC.
3. To study the influence of fly ash as a supplementary cementitious material at replacement levels of 5% to 20% on workability, flowability, and strength characteristics of SCC.
4. To evaluate the role of steel fibers at 1% and 2% by volume of concrete in improving the mechanical properties, ductility, and crack resistance of SCC.

## 4. Materials Details

### [1] Ordinary Portland Cement (OPC 43 Grade)

Ordinary Portland Cement of 43 grade, conforming to IS 8112:2013, was used as the primary binding material in the present investigation. OPC 43 grade cement is widely used in structural concrete due to its adequate early strength, consistency, and compatibility with mineral admixtures such as fly ash.

### [2] Fly Ash

Fly ash is a finely divided residue obtained from the combustion of pulverized coal in thermal power plants. In this study, Class F fly ash, conforming to IS 3812 (Part 1):2013, was used as a supplementary cementitious material to improve workability, durability, and sustainability of SCC.

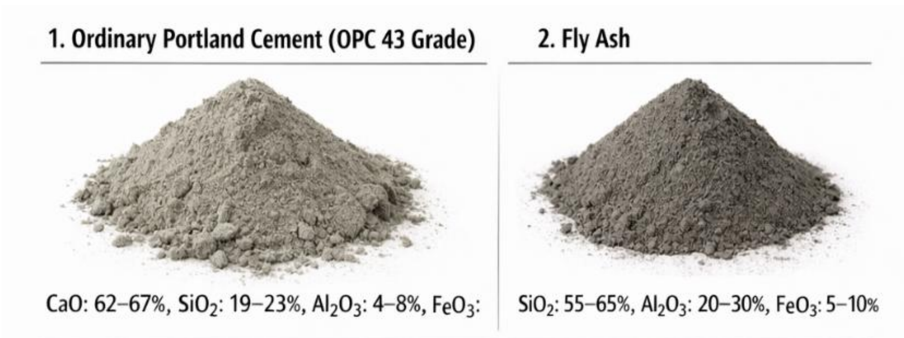


Figure 1. Ordinary Portland Cement (OPC 43 Grade) & Fly Ash

### [3] Fine Aggregate (FA – Natural River Sand)

Natural river sand obtained from the Narmada River was used as fine aggregate. The sand was clean, well-graded, and conformed to Zone II grading as per IS 383:2016.

### [4] Coarse Aggregate (CA – Natural Aggregate)

Crushed angular stone aggregate of **20 mm nominal maximum size**, conforming to **IS 383:2016**, was used as natural coarse aggregate.


Figure 2. Fine Aggregate & Coarse Aggregate

### [5] Recycled Brick Aggregates (RBA)

Recycled brick aggregates were obtained by crushing **discarded clay bricks** collected from demolition waste. The aggregates were sieved to achieve a nominal size of **20 mm** and used as a partial replacement of natural coarse aggregate.

### [6] Steel Fibers

Hooked-end steel fibers were used to improve the **tensile strength, flexural strength, and crack resistance** of SCC.

### [7] Chemical Admixture (Superplasticizer)

A **polycarboxylate ether (PCE)–based superplasticizer** conforming to **IS 9103:1999** was used to achieve the required flowability of SCC.


Figure 3. Recycled Brick Aggregates (RBA) , Steel Fibers & Superplasticizer

## [8] Mixing Water

Potable water free from impurities

Conforming to **IS 456:2000**

### 5. Conclusion

- All materials used in the present investigation satisfy the relevant Indian Standard specifications.
- The chemical compositions and physical characteristics of OPC, fly ash, aggregates, and steel fibers ensure compatibility, durability, and performance, making them suitable for producing M30 grade Self-Compacting Steel Fiber Reinforced Concrete incorporating recycled brick aggregates. To compare the performance of Steel Fiber Reinforced SCC (SFRC-SCC) with conventional SCC without fibers.
- The sustainability benefits of using recycled and industrial by-product materials in SCC by reducing natural aggregate consumption and cement content.
- The suitability of RBA-based SCC for structural applications, promoting eco-friendly and cost-effective construction practices.

### Declaration of Conflicting Interests

The authors declare no potential conflicts of interest with respect to the research, authorship and publication of this article.

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