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# Integrating Recycled Coarse Aggregate and Ground Granulated Blast Furnace Slag in Structural Applications

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**ABSTRACT:** The current study examines how Leemans sustainable concrete could be achieved by combining Recycled Coarse Aggregate (RCA) and Ground Granulated Blast furnace Slag (GGBFS). The two materials (RCA and GGBFS) are by-products, produced during construction and demolition and steel manufacturing respectively, whose use in concrete is environmentally, economically as well as technically related. The concrete blends were created under different proportions of replacing natural aggregates and cement. The findings indicate that, a mixture of 30% GGBFS and 50% RCA gives compressive strength of about 90 percent at day 28 in comparison to normal concrete. The Durability, such as water absorption and chloride permeability, improved significantly when GGBFS was added. The paper determines that concrete using RCA and GGBFS can meet good mechanical and durability results and lessen environmental harm.

**KEYWORDS:** Recycled Aggregate, GGBFS, Sustainable Concrete, Compressive Strength, Environmental Impact, Construction Waste, Durability, Workability, Circular Economy

## I. INTRODUCTION

Concrete is a heterogeneous composit material made using the coarse and fine aggregates and the cementitious matrix. It is a cementious construction material that is used so widely in the world. What has made it popular are its high compressive strength, high durability, low cost, and its moldability which makes it a very indispensable material in numerous infrastructure projects such as residential complexes, commercial structures, bridges, highways, dams, and industrial structures. But this extensive use has a significant ecological price. The cement production industry contributes significantly to emissions of greenhouse gases with cement industry accounting up to 7% of anthropogenic emissions of CO 2 globally [1]. This is attributed mostly to the burning of limestones and combustion of fossil fuels in the making of clinkers.

As well, there is extraction of natural aggregates, including river sand and crushed stone, which have created a tremendous breaking of ecology. After activities like riverbed mining and mountain quarrying, disruption of the aquatic eco system, resignation of biodiversity as well as destruction of the habitats take place [2]. With climate change moving at a fast pace and the scarcity of resources increasing it is now necessary to look at alternative ideas that could minimize the environmental impact of concrete without jeopardizing its performance.

In conjunction with the problem of lack of raw materials is the constantly growing amount of construction and demolition (C&D) wastes added as a result of rapid urbanization and development of infrastructure. In a country like India, around 150 million tonnes of C&D waste is generated each year and only a very little proportion- which is less than 5per cent- of this amount is recycled [3]. A lot of this wastes are disposed of in land and the illegal dumping areas which causes land degradation and pollution. The possible solution to this dilemma is Recycled Coarse Aggregates (RCA) made of crushed concrete, which has the potential to be an acceptable substitute to the use of the natural

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aggregates [4].

A by-product of the iron and steel industry, Ground Granulated Blast Furnace Slag (GGBFS) has been found to be effective Supplementary Cementitious Material (SCM). It gains its languid hydraulic capacity due to which it reacts with calcium hydroxide that was emitted when cement became hydrated and thus results in further formation of calcium silicate hydrate (C-S-H) gel [5]. It enhances the microstructure, minimises porosity and creates durability of the concrete. Furthermore, GGBFS use contributes to the decrease in clinker content in cement and, as a result, the consequent significant reduction in the cement production carbon footprint [6].

The combination of RCA and GGBFS offers an attractive chance to make high- performance sustainable concrete. The research represented herein concentrates on the simultaneously used RCA and GGBFS in M25-grade concrete, based on their impact on the fresh and hardened properties, as well as workability; compressive strength, flexural strength, concrete durability indicators (water absorption and chloride ion permeability).

## II. MATERIALS AND METHODS

### 1.1 Materials

Cement: As the main type of binder, Ordinary Portland Cement (OPC) 43 (grade) as per the IS 8112 was utilised. It had properties like specific gravity, consistency and fineness that were within the standards in place.

Fine aggregates: Fine aggregate used in this project was clean river sand with a fineness modulus of 2.6 and specific gravity 2.65.

Due to their characteristics, crushed granite with 20 mm maximum size was the common coarse aggregate referred to as Natural Coarse Aggregates (NCA).

Recycled Coarse Aggregates (RCA): RCA has been taken out of waste concrete rubble, washed, and screened to no more than 20 mm. Water uptake was more in RCA (4.5 %) relative to NCA (0.5 %).

GGBFS Ground Granulated Blast Furnace Slag, provided by a local steel manufacture in the form of a supplementary cementitious material was used, which substituted OPC by weight.

### 1.2 Mix Proportions

The concrete mixes were designed for M25 grade with a water-cement ratio of 0.45. Replacement levels included:
- G30R25: 30% GGBFS, 25% RCA
- G30R50: 30% GGBFS, 50% RCA
- G50R50: 50% GGBFS, 50% RCA
- G30R75: 30% GGBFS, 75% RCA

A control mix (CM) with 100% OPC and natural aggregates was prepared for comparison.

### 1.3 Testing Procedure

Slump cone test was used to determine the workability as prescribed by IS 1199. The compressive strength was determined on 150 mm cube when it had a 28 days curing time in line with IS 516. The beams with the dimensions of 100x100x500 mm were tested by the third-point loading method to determine the flexural strength. The water absorption tests and Rapid Chloride Permeability Test (RCPT) according to ASTM C1202 were used to test the durability.

## III. EXPERIMENTAL RESULTS

The findings of the experiment bring about useful information on the impacts of the addition of RCA and GGBFS in concrete mixes. The results are recorded in aspects of workability, compressive- and flexural- strength and durability properties including gauges of water absorption and high chloride penetration.

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### 3.1 Workability

The results of the experiment will offer important feedback on the effects of the addition of RCA and GGBFS in concrete mix. Its results are given on the basis of workability, compressive strength, flexural strength, and durability parameters like water absorption and rapid chloride permeability.The slump test as per the IS:1199 is carried out to indicate workability. With the addition of GGBFS it was noted that slump value also rose. This could be explained by the fact that GGBFS particles were spherical in shape and had a smooth surface texture, which enhanced the flow of the concrete. On the other hand, RCA minimized the slump because it has increased the capacity of water absorption and angular type that needed more water to remain workable.

| Mix ID | Slump (mm) |
|---|---|
| CM | 65 |
| G30R25 | 80 |
| G30R50 | 85 |
| G50R50 | 88 |

### 3.2 Compressive Strength

The results of the compressive strength test that was conducted over a 28 days duration indicated that the use of RCA is likely to lead to a decrease in strength because of decreasing adhered mortar, but GGBFS compensated the reduction. Improving secondary hydration of the cementitious binder material and densifying the microstructure is an asset to GGBFS, and it balances the disadvantages of RCA. It was found that the mix (G30R50 30 percent GGBFS and 50 percent RCA) was almost capable of producing 90 percent of the compressive strength of the control mix.

| Mix ID | Strength (MPa) | % of Control |
|---|---|---|
| CM | 32.6 | 100 |
| G30R25 | 31.2 | 95.7 |
| G30R50 | 29.3 | 89.8 |
| G50R50 | 27.4 | 84.0 |
| G30R75 | 26.1 | 80.0 |

### 3.3 Strength

Flexural strength was assessed on 100×100×500 mm beams. As with compressive strength, RCA reduced the flexural capacity, though the values remained within acceptable limits for structural use. GGBFS enhanced the paste-aggregate bonding and delayed microcracking, which helped in maintaining strength.

| Mix ID | Flexural Strength (MPa) |
|---|---|
| CM | 3.7 |
| G30R50 | 3.3 |
| G50R50 | 3.1 |

### 3.4 Durability Indicators

The testing of durability was done by analyzing the water absorption and rapid chloride permeability test (RCPT). The outcome showed that as the content of GGBFS increased, the water absorption reduced because of the high packing density and the decreased capillary pores. In the same way, RCPT decreased more in GGBFS blends, which means increased chloride ion pore barrier.

| Mix ID | Water Absorption (%) | RCPT (Coulombs) |
|---|---|---|
| CM | 4.2 | 2280 |
| G30R50 | 3.6 | 1820 |
| G50R50 | 3.1 | 1400 |

## IV. CONCLUSION

The experimental study made it clear that recycled Coarse Aggregate (RCA) and Ground Granulated Blast Furnace slag (GGBFS) as concrete workable media, is not only a viable option but also economically and environmental friendly. Among the main conclusions of this study, the following can be pointed out:

1. Concrete with 30 percent GGBFS and 50 percent RCA performed as well as the control mix in terms of compressive strength, or about 90 percent, which satisfied the M25-grade concrete pre-requisites.
2. Addition of GGBFS enabled better performance of mixes via enhancement of flow properties in the mix which overturned the high rate of water absorption of the RCA.
3. Water absorption and chloride ions permeability resistance, which is also a key indicator of durability, were greatly improved by adding GGBFS, which is an indication that the cement contributes to compacting the concrete at the microscopic level.
4. There was a minimal reduction of flexural strength with the usage of RCA but was within acceptable limits of structural application when GGBFS was incorporated.
5. In terms of sustainability, RCA + GGBFS allowed the interesting decrease in the carbon footprint and the cost of construction materials, contributing to the promotion of green construction.

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