Study on Replacement of Coarse Aggregate with Iron Slag

[1]Prof. Sathe Pooja R.[2]Domkawle Dhanashri A,[3]Mane Vaibhav H,[4] Palwe Tushar B., [5] Thombare Nikhil A.
Assistant Professor, Department of Civil Engineering
Students, Department of Civil Engineering

Abstract: The replacement of coarse aggregate with iron slag in concrete production has gained attention as a sustainable construction practice. This study investigates the potential of using iron slag, a by-product of the iron and steel industry, as a partial or complete substitute for conventional coarse aggregates in concrete. The experimental work involved analyzing the mechanical properties, durability, and workability of concrete mixes with varying proportions of iron slag (0%, 15%, 30%, 45%,) replacing coarse aggregates.

The results demonstrate that concrete incorporating iron slag exhibits improved compressive strength and durability due to the slag's dense structure and high toughness. However, slight variations in workability were observed, which could be mitigated through the use of admixtures. The study concludes that iron slag can be effectively utilized as an alternative aggregate, promoting waste management, reducing the demand for natural aggregates, and enhancing the sustainability of construction practices. Further research is recommended to evaluate long-term performance and environmental implications.

This approach aligns with green construction principles, reducing industrial waste and minimizing environmental degradation caused by aggregate extraction.

Keywords—Industrial by-product, Steel Slag, coarse aggregate, Compressive strength, Water Absorption.

I. INTRODUCTION

Concrete is the most widely used construction material globally, owing to its versatility, durability, and strength. However, the production of concrete, particularly its aggregate components, has significant environmental implications. Natural aggregates are typically sourced from riverbeds and quarries, leading to habitat destruction, resource depletion, and environmental degradation.

In parallel, the steel industry generates large quantities of by-products, including iron slag, which is often treated as waste. Iron slag, a by-product of steel manufacturing, is rich in mineral content and has properties that can potentially make it an effective replacement for conventional coarse aggregates in concrete.

The replacement of natural aggregates with iron slag offers a dual benefit:

1. It reduces the dependency on non-renewable natural resources.

2. It provides an environmentally friendly solution to manage industrial waste.

This study investigates the feasibility of using iron slag as a replacement for coarse aggregates in concrete. By doing so, it aims to improve the sustainability of concrete production while ensuring that the mechanical and durability properties meet the required standards for structural applications.

This report details the materials used, the experimental methodology, the tests conducted, and the results obtained from replacing natural aggregates with varying proportions of iron slag. It also explores the economic and environmental benefits of this substitution, along with its potential limitations.

1.2 OBJECTIVES

- To use the waste material Iron slag in concrete
- To improve the strength of concrete
- To make eco-friendly concrete
- To preserve the natural aggregate using the iron slag

Introduction to concrete:
Concrete is widely used construction material. Without concrete we cannot even imagine the construction. Concrete is a mixture of cement, fine

aggregate, coarse aggregate and water. Concrete consists of 75% of aggregate.

1.1.1 Grades of concrete:

There are various grades of concrete with various uses. Some of them are as follows by IS 456-2000: M10, M15, M20, M25, M30, M35, M40. Where M denotes to the mix design and the number specifies the strength in 28 days in N/mm2. Normal grade used for the construction of residential and commercial building are M20, M25. For important structures like dams, bridges, runways of airport high strength concrete of M40 and above are used.

1.1.2 Types of concrete:

There are various types of cement or admixtures are available in market, by using which we can prepare variety of the concrete as per our requirement. The various types of concrete provide different purposes. For eg. There is no need of compaction to the self-compacting concrete.

Types of concrete are as follow:
➢ Normal concrete
➢ High strength concrete
➢ High performance concrete
➢ Air entraining concrete
➢ Light weight concrete
➢ Self-compacting concrete
➢ Pervious concrete

1.1.3 Uses of concrete:
Concrete is important construction material which is used for many purposes. Concrete used with the reinforcement is known R.C.C (Reinforced Cement Concrete) and plane concrete is termed as P.C.C (plane cement concrete).

Concrete is widely used for following purpose:
➢ Commercial and industrial Buildings
➢ R.C.C. structures
➢ Roads
➢ Bridges
➢ Water tanks
➢ Dams
➢ Parking lots
➢Residential built

II.RESEARCH METHODOLOGY

4.1 Material and its property

4.1.1 Cement:

Ordinary Portland cement, 53Grade conforming to IS: 269 – 1976. Birla super cement is used for casting all the cubes. Different types of cement have different water requirements to produce pastes of standard consistency. Different types of cement also will produce concrete have a different rates of strength development. It is also important to ensure compatibility of the chemical and mineral admixtures with cement.

Table no.2

Sr no	Property of Cement	Value
1	Fineness Of Concrete	7.5%
2	Grade Of Concrete	53 grade OPC
3	Specific Gravity of Cement	3.15
4	Initial Setting Time	30min
5	Final Setting Time	60min

4.1.2 Fine Aggregate:
Locally available river sand conforming to Grading zone III of IS: 383 1970.Clean and dry river sand available locally will be used. Sand passing through IS 4.75mm Sieve will be used for casting all the specimens. Sand is clean from soil and other clay material.
Table no. 3

Sr no	Properties	Value
1	Specific gravity	2.72
2	Fineness Modulus	2.78

Sr no	Properties	Value
1	Specific gravity	2.72
3	Water absorption	2.12%
4	Bulk density	1803 kg/cubic meter
5	Free surface moisture	1.87%

4.1.3 Coarse Aggregate:

Locally available crushed blue granite stones conforming to graded aggregate of nominal size 20 mm as per IS: 383 – 1970. Crushed granite aggregates with specific gravity of 2.77 and passing through 4.75 mm sieve and will be used for casting all specimens. Several investigations concluded that maximum size of coarse aggregate should be restricted in strength of the composite. In addition to cement paste – aggregate ratio, aggregate type has a great influence on concrete dimensional stability.

Table no.4

Sr no	Properties	Value
1	Specific gravity	2.80
2	Water absorption	2.30%
3	Free surface moisture	NIL
4	Fineness modulus	2.97
5	Impact crushing value	12.83
6	Size of Aggregate	20mm

Slag is a partially vitreous by product of the process of smelting ore. Slag is usually a mixture of metal oxides and silicon dioxides. Slag is named based on the furnaces from which they are generated. Slag, the by-product of steel and iron producing processes, has been used in civil engineering for more than 100 years. Even there are some research works about the properties of concrete, in which air-cooled and ground granulated FS is used as aggregate. Steel slag has higher strength characteristics than normal aggregate, which result in more strength differences between slag aggregate concrete and natural aggregate concrete, in high strength concrete series. Slag is a waste metallic material which might have long term delayed reactions, further experiments would be necessary to evaluate the durability of concrete made by steel slag aggregates. The following size of slag available 4-12mm,12-20mm,20-40mm and above 40mm. In addition to cement paste – aggregate ratio, aggregate type has a great influence on concrete dimensional stability Slag is one of the artificial lime stone and silica, commonly used as coarse aggregate in HPC. Slag is a partially vitreous by product of the process of smelting ore. Slag is usually a mixture of metal oxides and silicon dioxides. One of the most beneficial uses for furnace slag is in concrete.

Table no.5

Sr no	Properties	Value
1	Specific gravity	3.70
2	Water absorption	3.12%
3	Free surface moisture	NIL
4	Fineness modulus	2.80
5	Impact crushing value	17%
6	Size of aggregate	20mm

4.1.4 Iron slag:

The particle size, color, oversize, specific gravity, etc. are explained briefly: -

1. Particle Size: - Slag particles are granular shape; spherical size is 1/100 the diameter of Portland cement particle and average particle diameter lies between 0.1-to-0.2-micron range.
2. Color: - The color of Slag depends on silica content, in contrast to the stony grey of concrete made with Portland cement, the near white color of furnace slag cement permits architects to achieve the lighter color finish.
3. Specific Gravity: - The specific gravity of slag produced from high quality silica and high-grade ferrosilicon alloys typically ranges between 3.0 and 3.6.

Chemical properties of slag:

Table no.6

Chemical Properties	% in Slag
SiO_2	10-19%
Al_2O_3	1-3%
Fe_2O_3	10-40%
CaO	40-52%
MgO	5-10%
MnO	5-8%
Metallic Fe	0.5-10%

4.2 Mix design for concrete:

Definition: Mix design is the process of selecting suitable ingredient if concrete and determines their relative proportions with the object of certain minimum strength and durability as economically as possible CONCRETE MIX DESIGN – M20 GRADE CONCRETE

Grade Designation = M-20

Type of cement = O.P.C-53

grade Brand of cement = Birla super

Admixture = no admixture is used

Fine Aggregate = Zone-III

Specific Gravity

Cement = 3.15

Fine Aggregate = 2.65

Coarse Aggregate (20mm) = 2.80

Coarse Aggregate (10mm) = 2.87

Minimum Cement (As per IS456:2000) =250kg

Maximum water cement ratio (As per IS456:2000) = 0.50

Concrete Mix Design Calculation: –

1. Target Mean Strength = 26.56

2. Selection of water cement ratio: Assume w/c ratio as 0.45

3. Calculation of water content: Approximate water content for 20mm max.

Size of aggregate = 180 kg /m3 as per Table No. 5, IS: 10262. Now water content = weight of cement/0.45 =185kg per cubic meter

4. Calculation of cement content:

Water cement ratio = 0.45

Water content per m3 of concrete = 185

Cement content = 250kg

Say cement content = 411.1 kg

Hence OK.

5. Calculation of Sand & Coarse Aggregate Quantities:

Volume of concrete = 1 m3

Volume of cement = 411.1 / (3.15 X 1000) = 0.130 m3

Volume of water = 185/ (1 X 1000) = 0.185 m3

Total weight of other materials except coarse aggregate = 0.315 m3

Volume of course and fine aggregate = 1 – 0.315= 0.685 m3

Volume of F.A. = 0.685 X 0.33 = 0.226 m3 (Assuming 33% by volume of total aggregate)

Volume of C.A. = 0.685- 0.226 = 0.459 m3

Therefore, weight of F.A. = 0.315x2.72x1000=614.72kg/ m3

Say weight of F.A. = 620 kg/ m3

Therefore, weight of C.A. = 0.459x2.80x1000= 1140.2 kg/ m3

Say weight of C.A. = 1140 kg/ m3

Considering 20 mm: 10mm = 0.6:0.4 20mm = 774 kg 10mm = 516 kg

Hence Mix details per m3

Cement content = 411kg Water content: 185 kg

Fine aggregate = 620 kg

Coarse aggregate 20 mm = 774 kg

Coarse aggregate 10 mm = 516kg

Water: cement: F.A.: C.A. = 1: 1.508: 2.80 6.

Calculation for per mould material required = Cement: 411 x (0.00375) = 1.4kg

Fine aggregate: 620 x (0.00375) = 2.2kg

Coarse aggregate: 1140 x (0.00375) =4.070kg.

Water: 185 x (0.00375) = 0.70kg

1. For nominal mix:

Table no.7

	Cement	F. Aggregate	C. Aggregate	Water	w/c ratio
Kg/m3	411	620	1140	185	0.45
Ratio	1	1.508	2.77	0.45	0.45
Kg Per 3 cubes	4.2	6.6	12.20	2	0.45

2. For 15% replacement:

Table no.8

	Cement	F. Aggregate	C. Aggregate	Iron Slag	Water	w/c ratio
Kg/m3	411	620	969	171	185	0.45
Ratio	1	1.5	2.357	0.41	0.45	0.45
Kg Per 3 cubes	4.2	6.2	9.88	1.85	2.1	0.45

3. For 30% replacement:

Table no.9

	Cement	F. Aggregate	C. Aggregate	Iron Slag	Water	w/c ratio
Kg/m3	411	620	797	343	185	0.45
Ratio	1	1.5	1.9	0.8	0.45	0.45
Kg Per 3 cubes	4.2	6.2	8.04	3.50	2.1	0.45

4. For 45% replacement:

Table no.10

	Cement	F. Aggregate	C. Aggregate	Iron Slag	Water	w/c ratio
Kg/m3	411	620	627	513	185	0.45
Ratio	1	1.5	1.52	1.248	0.45	0.45
Kg Per 3 cubes	4.2	6.2	6.40	5.20	2.1	0.45

4.4 Batching, mixing, placing and compaction of concrete:

4.4.1 Batching:

It is the process of measuring concrete mix ingredients either by volume or by mass and introducing them into the mixture. Traditionally batching is done by volume but most specifications require that batching be done by mass rather than volume.

4.4.2 Cleaning & Fixing of mould:

Clean the cube-mould properly and apply oil on inner surface of mould. But no oil should be visible on surface. Fix the cube mould with base plate tightly. No gap should be left in joints so that cement-slurry doesn't penetrate. Place the mould on leveled surface.

4.4.3 Mixing:

Mixing of concrete is defined as Complete blending of the materials which are required for the production of a homogeneous concrete.

4.4.4 Placing:

Before placing concrete, the formwork and reinforcement should be checked to make sure that they are clean and free of any debris, such as ends of tying wire. The fresh concrete should be deposited as close as possible to its final position. Care should be taken when discharging concrete from skips to avoid dislodging the reinforcement or over filling the formwork. When filling columns and walls, care should be taken that the concrete does not strike the face of the formwork, which might affect the surface finish of the hardened concrete. For deep sections the concrete should be placed in uniform layers, typically not more than about 500 mm thick, each layer being fully compacted. Excess handling can cause segregation of the course and fine aggregates.

4.4.5 Compaction:

Compaction is the process that expels entrapped air from freshly placed concrete and packs the aggregate particles together so as to increase the density of the concrete

4.4.6 Curing of specimen:

Curing plays an important role on strength development and durability of concrete. Curing takes place immediately after concrete placing and finishing, and involves maintenance of desired moisture and temperature conditions, both at depth and near the surface, for extended periods of time. Properly cured concrete has an adequate amount moisture for continued hydration and development of strength, volume stability, resistance to freezing and abrasion and scaling resistance.