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Experimental Investigation on Partial Replacement of Coarse Aggregate with Steel Slag in Concrete

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Abstract: *The proposed study aims to explore the feasibility of partially replacing coarse aggregate with steel slag in the production of concrete. The investigation is motivated by the need for sustainable construction materials that minimize environmental impact while maintaining or possibly enhancing the mechanical properties and durability of concrete. Steel slag is a byproduct of steel making process, formed when impurities from molten iron are removed known for its strength and durability, replaces conventional coarse aggregate at 20%,30%,40% by weight. These substitutions are hypothesized to not only reduce the consumption of virgin materials and environmental footprint associated with concrete production but also potentially enhance the properties of the resulting concrete. The project will focus on assessing the compressive strength, flexural strength, split tensile strength, workability and durability of the modified concrete. By conducting this experiment, it is anticipated that the findings will contribute to the development of more sustainable concrete practices, promoting the use of waste materials in construction and potentially leading to innovations in building materials that are both environmentally and economically beneficial.*

Keywords: Steel slag, Sustainable Construction Materials, Replacement, Waste materials, resource utilization.

1.INTRODUCTION

Concrete is a widely used construction material composed primarily of cement, aggregates (fine and coarse), and water. The properties of concrete can be tailored by using additives and reinforcements, which enhance its strength, durability, and workability. As one of the most common materials used in construction worldwide, concrete is in high demand due to the rapid growth in global infrastructure development. However, this widespread use has led to an increasing strain on natural resources such as sand and coarse aggregates, which are essential raw materials for concrete production. The growing scarcity of these materials, coupled with rising construction costs, necessitates the exploration of alternative, sustainable solutions to reduce the environmental impact and cost of concrete production.

In recent years, the utilization of industrial by-products and alternative materials in concrete mixes has gained considerable attention to alleviate the pressure on natural resources. This project investigates the feasibility of replacing coarse aggregates with steel slag. An industrial by-product that hold promise for reducing waste and enhancing the sustainability of concrete. Steel slag is a waste material from steel production, can be utilized to replace conventional coarse aggregates. Additionally, the use of steel slag as a partial replacement for coarse aggregate may improve the mechanical properties of concrete, such as its strength and durability, due to the enhanced bonding between the cement matrix and the rougher surface texture of the slag particles. However, the use of these alternative materials also introduces challenges related to mix design, workability, and the long-term durability of the concrete. It may also affect the weight, workability, and overall performance of the concrete mix. The density of steel slag, for example, is typically higher than that of natural aggregates, potentially influencing the weight of the concrete structure. This project aims to explore the potential of steel slag as sustainable alternatives in concrete production, offering a solution to the growing demand for natural resources and the need to reduce construction waste. By investigating the impact of these materials on the concrete mix, this study seeks to contribute valuable insights into the development of more sustainable and cost-effective concrete formulations that can help meet the challenges posed by the construction industry's increasing reliance on natural aggregates.

2.MATERIALS USED

2.1 Cement

Cement Portland Pozzolana cement of 53 grade conforming to IS 1489 (PART 1) was used throughout the experiment. The specific gravity of cement is 2.912, The fineness modulus of cement is 3%, The initial and Final setting time of cement are 1hr 45 min and 5hr 25 min, The Standard consistency of cement is 32%.

2.2 River Sand

Locally available River Sand passing through 4.75mm IS Sieve having Specific gravity of 2.6 and fineness modulus of 2.814 was used. The Sand was dried in sun light before it is used for standard design mix concrete.

2.3 Coarse Aggregate

20mm downsize natural crushed stone having specific gravity of 2.89 and water absorption of 0.39% was used.

2.4 Water

Locally available potable water is used having pH value of 6.5. Water is important ingredient for strength and durability characteristics of concrete.

2.5 Steel Slag

Steel slag is the byproduct of the steel manufacturing process. Formed when impurities are added to iron ore in blast furnaces or basic oxygen furnaces, resulting in a molten slag that is separated from the liquid metal.

Fig: 2.5 Steel slag

3.PROCEDURE

3.1 Mix Design proportion

The mix proportion chosen is as follows: We adopted M25 grade of mix proportion i.e., 1:1.12:2.41 by partial replacement of Coarse aggregate with percentage of Steel slag (20%,30%,40%).

3.2 Mix Proportioning:

Table 1.Mix proportioning56

Cement (Kg)	Fine aggregate (Kg)	Coarse aggregate (Kg)	Water (liter)
493.45	550.732	1188.3102	197.38
1	1.12	2.41	0.4

Table 2. Details of mix designation using steel slag

Sl No.	Mix code%	Cement %	Fine aggregate%	Coarse aggregate or steel slag %
1	MIX 0	100	100	100
2	MS 20	100	100	20% SS,80% Coarse agg
3	MS 30	100	100	30% SS,70% coarse agg
4	MS 40	100	100	40% SS,60% coarse agg

4.METHODOLOGY

This study investigated the feasibility of using steel slag as sustainable alternatives in concrete production. The research involved selecting M25 grade concrete and PPC cement, collecting materials, and testing their properties. The study prepared conventional concrete and modified concrete with steel slag (20%, 30%, 40%) replacing coarse aggregate. Specimens were cured for 14 and 28 days and tested for strength. The optimal replacement values were determined, and concrete with steel slag was prepared and tested. The results were compared with conventional concrete.

4. Experimental investigation and Results

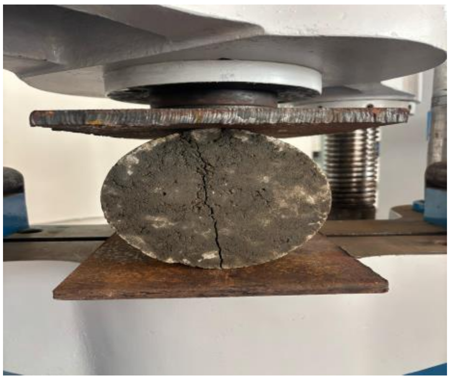
4.1Compressive strength test:

IS Code 516:1959 was used for method of tests for compressive strength of concrete. The size of specimens 150mm x 150mm x 150mm. At the time of testing, the maximum load at which the concrete block break was noted. From the noted values, the compressive strength was calculated by using below formula.

Compressive Strength = Load / Area

4.2 Split tensile strength test:

IS Code 5816:1999 was used for method of test split tensile strength of concrete. The size of cylinder was 300 mm (length) x 150mm(diameter). The specimens were tested after 28 days curing. The split tensile strength calculated by using below formula. Splitting Tensile Strength = $2P/\pi ld$ (Unit = N/mm2 or MPa) Where: P= Load, l= Length of Cylinder, d = Diameter of Cylinder.



4.3 Flexural strength test:

flexural strength test, often used to assess a material's resistance to bending, flexural strength was calculated by using below formula.

$F = (PL)/(bd^2)$

4.4 Compressive strength test result

Table 3. Compressive strength test results:

Mix ID	Maximum load (KN)	Compressive strength (N/mm²)	Average compressive strength(N/mm²)
MS 20	650 615 630	28.89 27.33 28	28.07
MS 30	725 710 755	32.22 31.55 33.56	32.43
MS 40	645 690 665	28.67 30.67 29.56	29.63

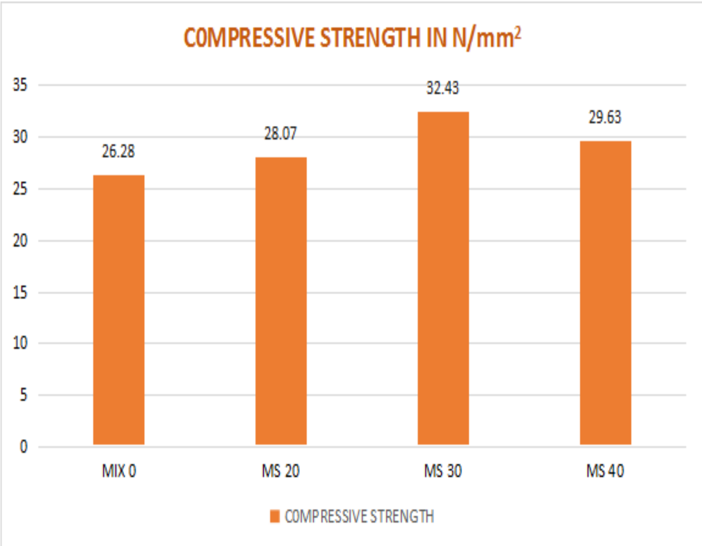


Fig 4.4: compressive strength

4.5 Split tensile strength test results:

Table 4. Split tensile strength test results:

Mix ID	Maximum load (KN)	Split tensile strength(N/mm²)	Average Split tensile strength(N/mm²)
MS 20	170.5 182.5 160.5	2.412 2.58 2.27	2.42
MS 30	212.5 243.5 225.5	3.01 3.44 3.19	3.21
MS 40	200 185.5 232.5	2.83 2.62 3.29	2.91

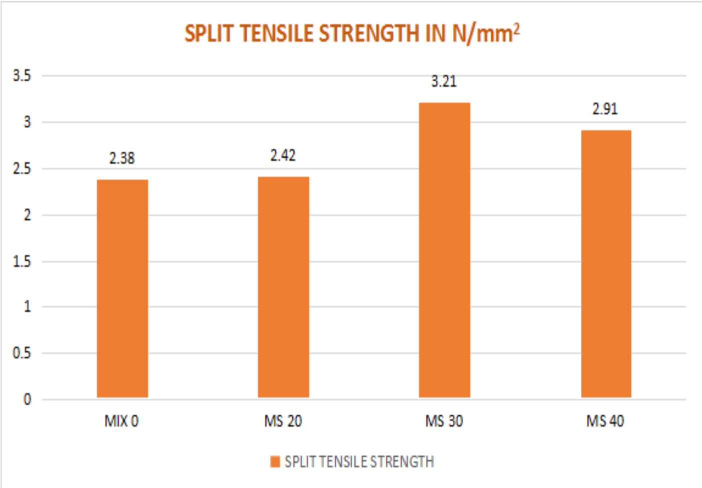


Fig 4.5: Split tensile strength

4.6 Flexural strength test results:

Table 4. Flexural strength test results:

Mix ID	Maximum load (KN)	Flexural strength (N/mm²)	Average Flexural strength(N/mm²)
MS 20	10.3 12.4 15.3	5.56 5.4 6.2	5.72
MS 30	13.6 12.5 13.1	6.73 6.75 7.07	6.85
MS 40	11.8 14.3 14.2	5.31 6.43 6.17	5.97

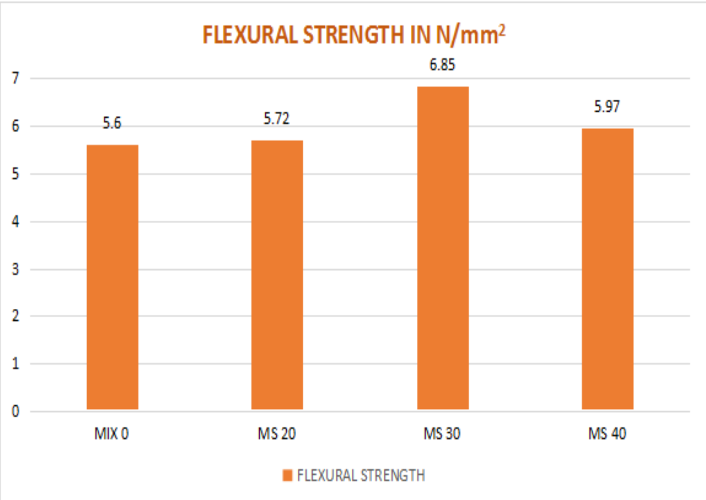


Fig 4.6: Flexural strength

5. CONCLUSIONS

Replacement of coarse aggregate with steel slag:

- The optimum percentage of compressive strength using steel slag 30%, which was a 23.4% increase over conventional concrete.
- The optimum percentage of split tensile strength using steel slag 30%, which was a 34.47% increase over conventional concrete.
- The optimum percentage of flexural strength using steel slag 30%, which was a 23.32% increase over conventional concrete.
- An increase in the split tensile strength of concrete offers several advantages, particularly in structural performance and durability.
- Higher tensile strength helps prevent the formation and propagation of cracks, reducing the risk of structural failure.
- Concrete structures subjected to bending, such as beams, slabs, and pavements, benefit from increased split tensile strength, which enhances their load-bearing capacity. With better tensile properties, concrete can resist environmental stresses like temperature fluctuations, shrinkage, and freeze-thaw cycles, leading to longer service life.
- Structures such as bridges, high-rise buildings, and industrial floors can sustain heavier loads without cracking or failure.
- In earthquake-prone areas, higher tensile strength improves a structure's ability to withstand dynamic forces and reduces the risk of catastrophic failure.
- Fewer cracks and structural issues mean lower repair and maintenance costs over the lifespan of the structure.
- Concrete with higher split tensile strength is more resistant to cyclic loading, making it ideal for roads, runways, and bridges subjected to repeated stress.
- Higher tensile strength reduces microcracking, which minimizes water penetration and protects against corrosion of embedded steel reinforcement.

6. REFERENCES

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