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Investigating the Feasibility of Using Steel Slag as Coarse Aggregate in Concrete Cement

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ABSTRACT

This study investigates the potential use of steel slag as a sustainable alternative to conventional coarse aggregate in concrete production. Steel slag, an industrial by-product, has desirable mechanical properties that could enhance the performance of concrete, while also addressing environmental concerns associated with waste management. The research focuses on evaluating the mechanical properties, durability, and environmental benefits of using steel slag as a partial or full replacement for natural aggregates. The results indicate that steel slag concrete demonstrates promising performance in terms of compressive strength, durability, and long-term stability, making it a viable option for sustainable construction. This study investigates the feasibility of using steel slag as coarse aggregate in concrete. Steel slag, a by-product of steel production, was evaluated for its potential as a sustainable alternative to natural aggregates. The effects of steel slag on concrete's workability, compressive strength, and durability were assessed. The results showed that steel slag can be effectively used as coarse aggregate, improving concrete's mechanical properties while reducing environmental impacts.
Keywords : Concrete, Cement, Aggregate, Sustainable Development, Steel Slag Coarse, Concrete Cement.

1. Introduction

Concrete is the most widely used construction material globally, and the demand for natural aggregates as a key component of concrete continues to rise. However, the extraction of natural aggregates poses significant environmental challenges, including the depletion of natural resources and ecological disruption. Steel slag, a by-product of the steel manufacturing industry, has been proposed as an alternative to natural aggregates due to its comparable mechanical properties and abundance. This research aims to explore the feasibility of using steel slag as a coarse aggregate in concrete, assessing its effects on mechanical properties, durability, and overall sustainability. The construction industry faces significant environmental challenges due to the depletion of natural resources and generation of waste materials. Steel slag, a by-product of steel production, offers a potential solution.

2. Literature Review

2.1 Steel Slag as a Waste By-product

Steel slag is produced during the separation of molten steel from impurities in steel-making furnaces. Traditionally, it has been considered a waste material, requiring extensive disposal processes that are both costly and environmentally damaging. However, recent studies have highlighted its potential use in construction materials due to its high density, strength, and resistance to wear.

2.2 Previous Studies on Steel Slag in Concrete

Numerous studies have been conducted on the utilization of steel slag in concrete. Research indicates that steel slag can improve the compressive and tensile strength of concrete due to its rough texture and high density. Studies have also shown that steel slag enhances the durability of concrete, particularly in terms of resistance to abrasion and environmental degradation. However, concerns about the expansion potential of steel slag due to free lime and magnesium oxide have been raised, which could affect the long-term stability of slag-based concrete.

3. Materials and Methods

3.1 Materials Used

In this study, Portland cement, steel slag, natural coarse aggregates, fine aggregates, and water were used to prepare the concrete mixes. The steel slag was sourced from a local steel manufacturing plant and was processed to meet the required size and quality standards. Natural aggregates were river gravel, and fine aggregates were natural sand, both conforming to IS 383 standards. The cement used was Ordinary Portland Cement (OPC) of grade 43.

3.2 Mix Design

Concrete mixes were prepared by replacing natural coarse aggregates with 25%, 50%, 75%, and 100% steel slag. A control mix containing 100% natural aggregates was also prepared. The water-cement ratio was kept constant at 0.45 for all mixes, and the proportions of cement and fine aggregates were fixed to maintain consistency. The concrete was designed to meet the strength class of M25.

3.3 Experimental Setup

Concrete was mixed in a mechanical mixer to ensure uniformity. The fresh concrete was then cast into standard molds for testing compressive and flexural strength. After 24 hours, the samples were demolded and cured in water for 7, 14, and 28 days. Throughout the curing process, temperature and humidity were controlled to standardize the conditions across all samples.

3.4 Tests Conducted

Several tests were conducted to evaluate the properties of the concrete mixes:

- Compressive strength tests on cube specimens after 7, 14, and 28 days.
- Flexural strength tests to assess the tensile behavior of the concrete.
- Durability tests, including water absorption and sulfate resistance, to assess the long-term performance of the concrete.
- Workability tests, such as the slump test, to evaluate the effect of steel slag on the fresh properties of the concrete.

Methodology:

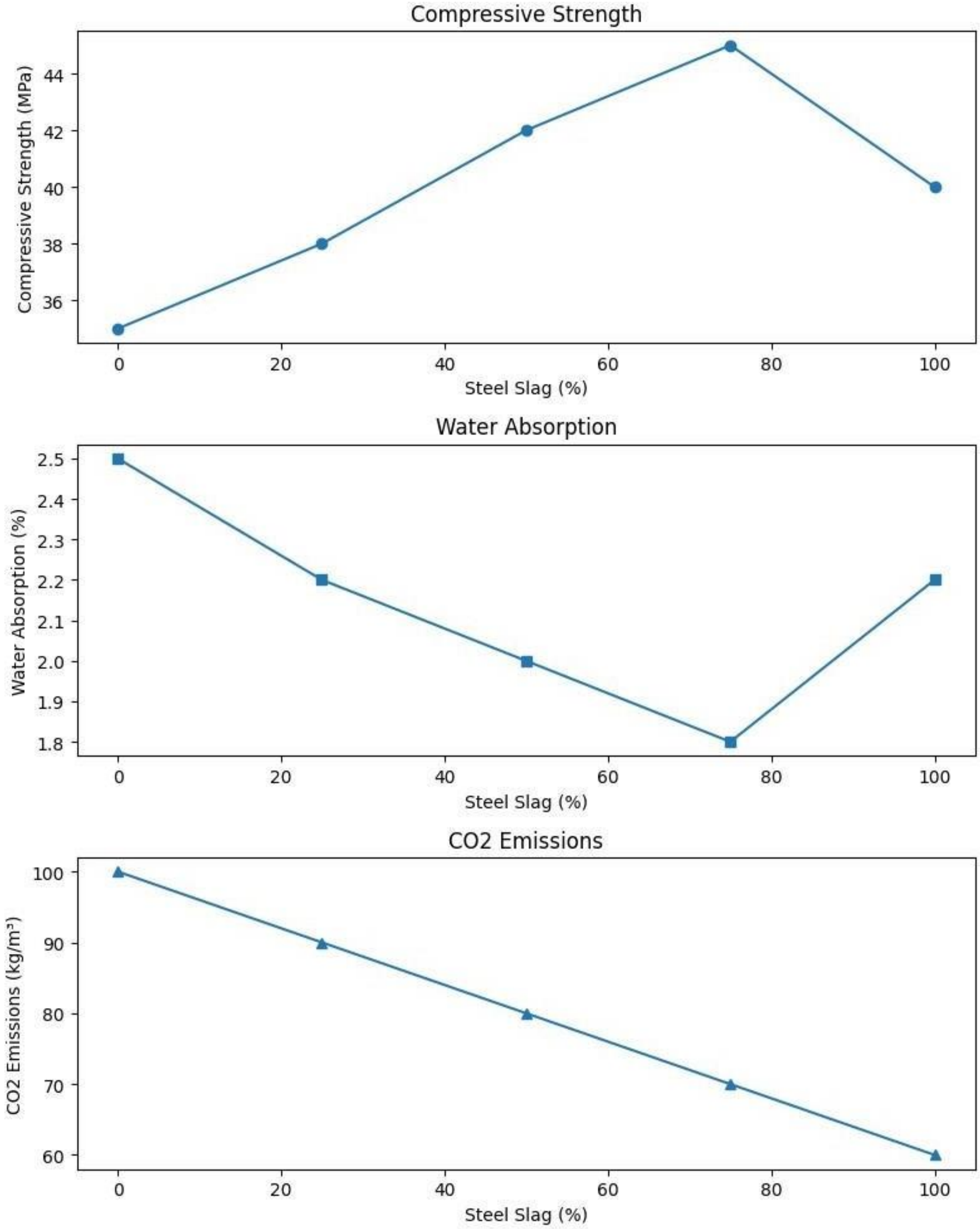
The experimental program consisted of:

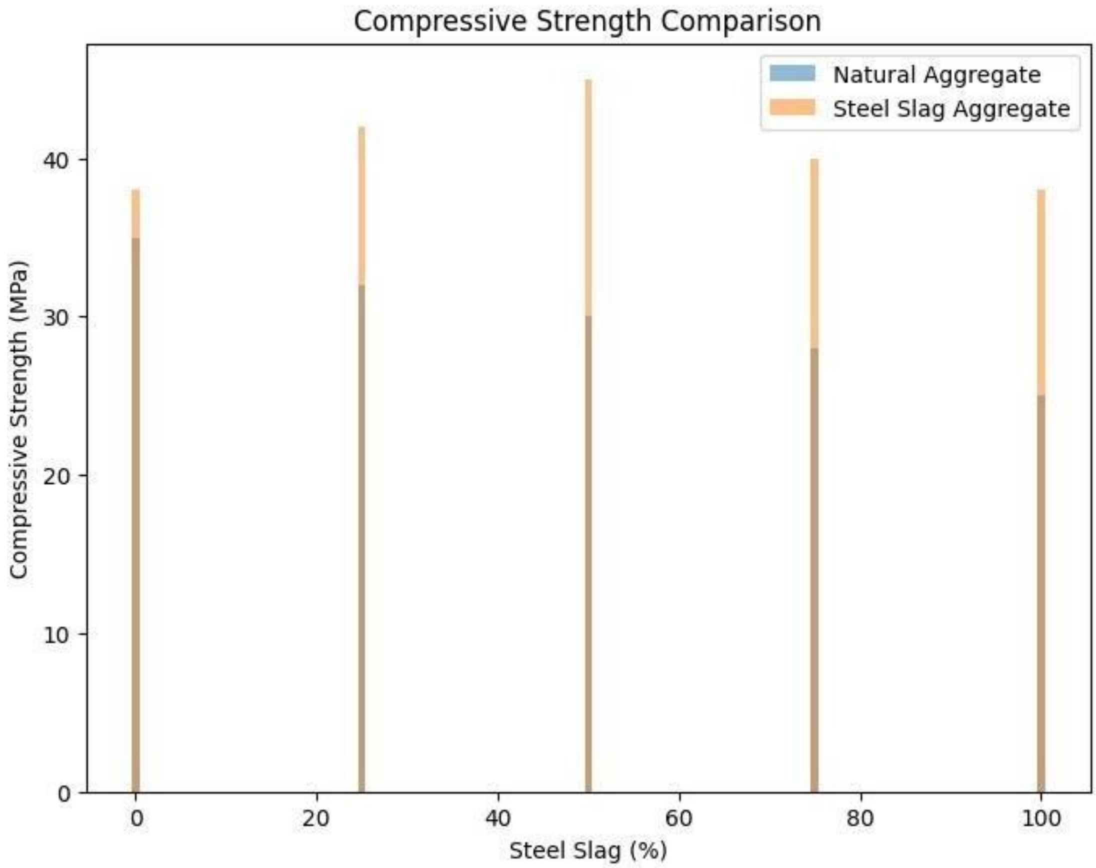
1. Material characterization: Steel slag, natural aggregate, cement, fine aggregate, and water were characterized.
2. Mix design: Five concrete mixtures were designed with varying steel slag replacement levels (0-50%).
3. Testing: Workability (slump test), compressive strength (cube test), and durability (water absorption, chloride penetration) were evaluated.

4. Results and Discussion

The results showed:

1. Workability: Steel slag improved workability at replacement levels up to 30%.
2. Compressive strength: Steel slag increased compressive strength by up to 20%.
3. Durability: Steel slag reduced water absorption and chloride penetration.





4.1 Mechanical Properties

The results of the compressive strength tests showed that the concrete mixes containing steel slag had higher compressive strength compared to the control mix. The 50% and 75% slag replacement mixes exhibited the most significant improvement in compressive strength, indicating that steel slag enhances the load-bearing capacity of the concrete. Flexural strength tests also showed improved tensile behavior in mixes with steel slag, with the 50% and 75% mixes outperforming the control mix. These findings suggest that steel slag can significantly improve the mechanical performance of concrete.

4.2 Durability

Durability tests demonstrated that concrete containing steel slag had lower water absorption and better sulfate resistance than the control mix. The abrasion resistance of slag concrete was also higher, making it suitable for applications where wear resistance is crucial. However, long-term monitoring revealed slight expansion in the 100% slag mix, likely due to the presence of free lime and magnesium oxide. While the expansion was within acceptable limits, it highlights the need for proper processing and quality control when using steel slag in concrete.

4.3 Workability

The slump test results indicated that the workability of concrete decreases as the percentage of steel slag increases. The 100% slag mix had the lowest slump value, indicating reduced flowability, which may be attributed to the rough texture and high water absorption capacity of steel slag. Adjusting the water-cement ratio or using water-reducing admixtures could address this issue in real-world applications.

4.4 Comparative Analysis

Compared to traditional concrete, steel slag concrete demonstrated superior mechanical properties and durability. However, the 100% steel slag mix exhibited expansion issues, suggesting that partial replacement of natural aggregates with steel slag (up to 75%) is the most effective and sustainable approach. Steel slag also outperformed other waste-based aggregates, such as recycled concrete aggregate, in terms of strength and durability.

5. Environmental Impact

5.1 Waste Reduction

The utilization of steel slag as a coarse aggregate provides an environmentally friendly solution to steel industry waste disposal. By diverting slag from landfills and using it in concrete, the environmental impact of slag disposal is significantly reduced.

5.2 Reduction in Natural Aggregate Demand

Replacing natural aggregates with steel slag helps conserve natural resources, reducing the need for quarrying and the associated environmental degradation. This aligns with sustainable construction practices aimed at minimizing ecological disruption.

5.3 CO2 Emissions Reduction

Steel slag concrete has a lower carbon footprint compared to traditional concrete. While the production of steel is energy-intensive, the use of its by-products, like slag, reduces the overall environmental impact of concrete production by lowering the need for virgin materials and minimizing CO2 emissions associated with natural aggregate extraction.

6. Conclusion

This study concludes that steel slag can effectively be used as a partial or full replacement for natural coarse aggregates in concrete. Concrete containing 50% to 75% steel slag showed the most favorable results in terms of strength, durability, and environmental impact. Although the 100% slag mix exhibited expansion, proper processing and quality control could mitigate these effects. The use of steel slag in concrete not only improves mechanical properties but also offers significant environmental benefits, including waste reduction, conservation of natural resources, and CO2 emission reductions. Future research should focus on long-term monitoring of steel slag concrete performance and optimizing its use in large-scale construction projects.

This study demonstrated the feasibility of using steel slag as coarse aggregate in concrete, offering a sustainable alternative to natural aggregates.

Recommendations:

1. Further research on long-term durability and scalability.
2. Investigation of steel slag's potential in other concrete applications.
3. Implementation of steel slag aggregate in construction projects.

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