EVALUATION OF STEEL SLAG AS PARTIAL REPLACEMENT OF CEMENT IN CONCRETE

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ABSTRACT

A well-maintained infrastructure is crucial for modern societies, but meeting all requirements poses challenges. Concrete has been a reliable construction material for decades, and engineers seek to enhance its performance using modern admixtures and waste materials. Incorporating waste materials in concrete consumption and improving its properties are benefits. This research explores the use of Steel Slag as a partial replacement for cement in varying proportions (0%, 5%, 10%, and 15%). The study focuses on compressive strength and other parameters such as workability, water-to-cement ratio, setting time, and surface hardness, which impact concrete performance. Results indicate that Industrial steel slag is a promising cement substitute, outperforming reference concrete. Implementing a circular economy in construction necessitates studying waste utilization as material replacements. Substituting cement with slag reduces cement consumption, lowers CO2 emissions, and addresses waste management concerns. Embracing such sustainable practices will lead to a more resilient and eco-friendly infrastructure.

Keyword : - *Steel Industry, Cement, Steel Slag, partial replacement of cement, Admixtures.*

1. INTRODUCTION

Concrete is a widely used construction material due to its durability, versatility, and cost-effectiveness. However, the production of ordinary Portland cement (OPC), a key component of concrete, is associated with significant carbon dioxide (CO2) emissions, contributing to environmental concerns. As a result, there is a growing interest in exploring alternative materials that can partially replace OPC in concrete mixtures, reducing its environmental impact.

One such alternative material is steel slag, a byproduct of the steel manufacturing process. Steel slag possesses cementitious properties and has the potential to enhance the performance of concrete while offering a sustainable solution for waste management. By incorporating steel slag in concrete, not only can the demand for OPC be reduced, but the overall carbon footprint of the construction industry can also be minimized.

This research project aims to investigate the feasibility and efficiency of using steel slag as a partial replacement for ordinary Portland cement in concrete. The study will focus on evaluating the mechanical properties of concrete with varying proportions of steel slag, including compressive strength and split tensile strength. Additionally, the durability parameters of the concrete will be examined to ensure the long-term performance of the material.

The outcomes of this research hold significant implications for sustainable construction practices. Finding an optimal combination of cement and steel slag can lead to reduced CO2 emissions and a more cost-effective concrete mix. Moreover, the study contributes to the circular economy concept by promoting the reuse of industrial byproducts, thereby moving towards a greener and more environmentally friendly construction industry.

By addressing these research objectives, this study seeks to pave the way for a more sustainable and resilient approach to concrete production, aligning with the global efforts to mitigate climate change and foster environmentally conscious construction practices.

1.1 Research Significance

This research holds significant importance for several reasons:
1. The potential discovery of a new concrete with improved strength and durability.
2. Gaining valuable insights into the behavior of concrete through various tests.
3. Contributing to substantial research on the resistance and viability of replacement materials.

1.2 Objectives

The main objectives of this study are as follows:
1. To utilize industrial waste Steel Slag in concrete, providing an environmentally-friendly alternative for its disposal.
2. To enhance the overall strength of concrete by incorporating Steel Slag as a partial replacement for cement.
3. To investigate the feasibility of using Steel Slag as a replacement material for cement in concrete through the following tests:
   a. Compressive strength test
   b. Split Tensile strength test

2. REVIEW OF LITERATURE

Kounrounis et al. (2007); conducted a study to explore composite cement with varying proportions of steel slag, ranging up to 45% by weight. The steel slag used in the research was in the size range of 0–5 mm. Several tests were performed on cement pastes and mortars, including assessments of initial and final setting times, standard consistency, flow of normal mortar, autoclave expansion, and compressive strength.

The authors' findings indicate that "slag can be effectively incorporated into the production of composite cement with strength classes 42.5 and 32.5 as per EN 197-1 standards." Moreover, they observed that slag cement demonstrates satisfactory physical properties. The presence of steel slag in the blended cement leads to a reduction in the hydration rate, attributed to the morphology of the contained C2S (dicalcium silicate) and its low content of calcium silicates.This research highlights the potential of using steel slag as a supplementary material in cement production, providing valuable insights into its effects on cement properties and performance.

V. Subathra Devi et al. (2014); conducted an experimental study to investigate the impact of partially replacing coarse and fine aggregates with steel slag (SS) on the strength and durability properties of concrete. The research employed a mix design of M20 grade concrete. The study aimed to determine the optimal percentage of replacement for both fine and coarse aggregates with steel slag.The workability of the concrete was assessed using the slump test, revealing a gradual decrease in workability as the percentage of replacement increased. Various strength parameters, including compressive strength, tensile strength, and flexural strength, were examined alongside durability tests involving acid resistance (using HCl and H2SO4) and Rapid chloride penetration.
The results indicated that replacing a portion of fine and coarse aggregates with steel slag in conventional concrete led to improvements in compressive, tensile, and flexural strength. Additionally, the mass loss observed in concrete cubes immersed in acids was found to be minimal, suggesting enhanced durability.

This research sheds light on the potential benefits of incorporating steel slag as a partial replacement for aggregates in concrete, offering insights into how it can positively affect concrete's strength and durability properties.

Venkata Kiranmayi K. et al. (2014); conducted a study focusing on waste management, a prevalent and challenging global issue. The research specifically addressed the solid waste generated by the steel-making industry, known as steel slag. Steel slag is a residue produced during steel-making operations. The study explored the potential of utilizing steel slag as a viable alternative to sand in various applications.

Despite being considered a solid waste pollutant, steel slag can be effectively employed in road construction, as clinker raw materials, filling materials, and other suitable applications. The research highlights the beneficial uses of steel slag, contributing to waste reduction and sustainable practices in the steel industry.

3. METHODOLOGY

The following figure shows the methodology involved in the entire project work

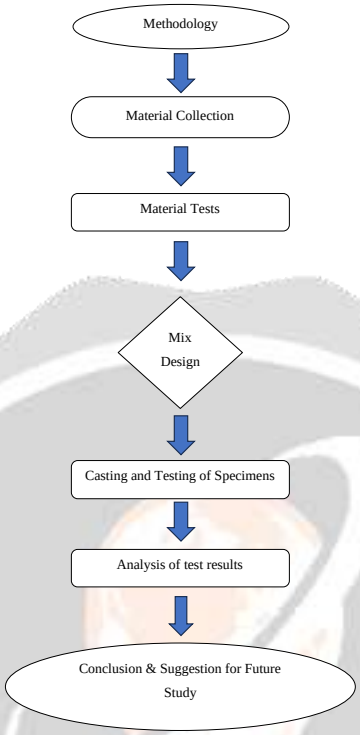

Fig -1: Methodology involved in the entire project work

3.1 Mix Proportions

- Cement = 420 kg/m3
- Water = 164 l/m3
- Fine aggregate = 786 kg/m3
- Coarse aggregate 20mm = 549.25 kg/m3
  10mm = 549.25 kg/m3
- Chemical admixture = 2.1 kg/m3 (0.6% by the weight of cement)
- Density of concrete = 2450 kg/m3
- Water-cement ratio = 0.39
- Mix Proportion By weight = 1: 1.871: 2.615

Table -1: Mix proportions for M40 by weight

Ingredients	**Water (Kg)**	**Cement (Kg)**	**Aggregate 20 mm (Kg)**	**Aggregate 10 mm (Kg)**	**Sand (Kg)**	**Chemical Admixture (Kg)**
By Weight	164	420	549.25	549.25	786	2.1
By Volume	0.39	1	2.615		1.871	0.005

Table -2: Mix Proportions for Replacement of Cement by Steel Slag

Sr No.	1	2	3	4	5
Mix Design (Kg/m^3)	CC	M-1	M-2	M-3	M-4
Replacement Percentage	0	5%	10%	15%	20%
Cement	420	399	378	357	336
Steel Slag	0	21	42	63	84
Water	164	164	164	164	164
Coarse Aggregate (20mm)	549.25	549.25	549.25	549.25	549.25
Coarse Aggregate (10mm)	549.25	549.25	549.25	549.25	549.25
Fine Aggregate	786	786	786	786	786
Super Plasticizer	0.005%	0.005%	0.005%	0.005%	0.005%
W/C Ratio	0.39	0.39	0.39	0.39	0.39

4. RESULTS

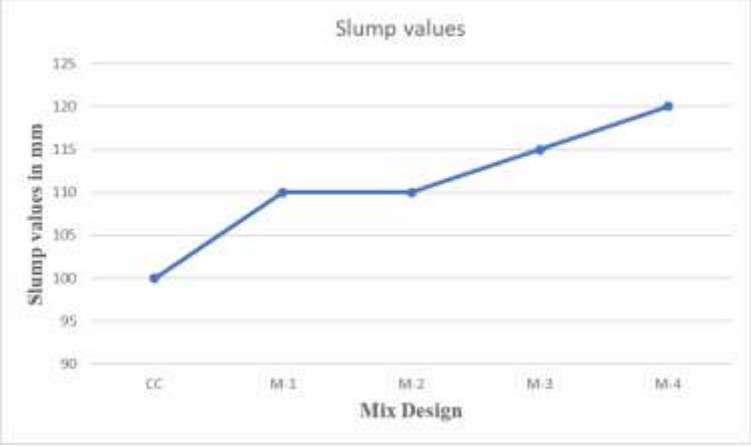

Chart -1: Slump values for the replacement of Cement by Steel Slag

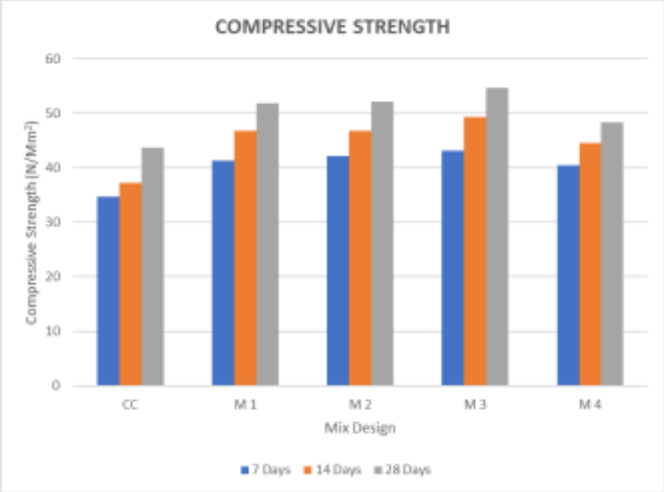

Chart -2: Comparing Compressive strength test results for 7,14 and 28 Days

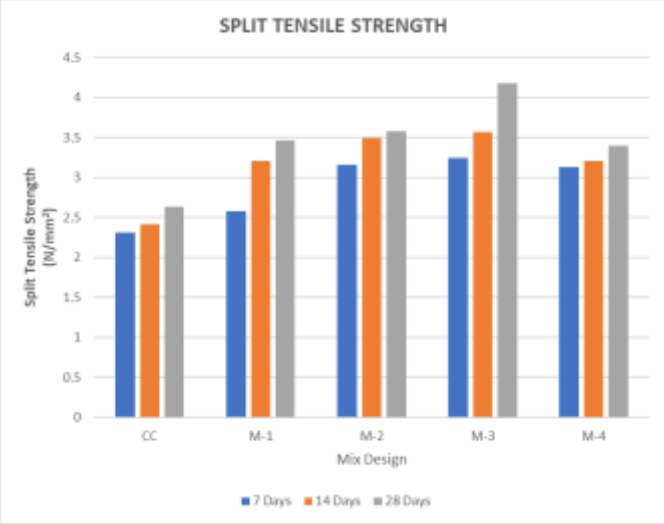

Chart -3: Comparing Split tensile strength for 7,14 and 28 days

5. CONCLUSIONS

In this study, the impact of Steel Slag as a partial replacement for cement in concrete was investigated, and the following conclusions were drawn:

[1] Workability: As the percentage of Steel Slag replacement decreased, the workability of the concrete increased. Slump values showed an increase from 110mm to 120mm for replacement percentages of 5% and 20% of Steel Slag, respectively.

[2] Compressive Strength: Replacing cement with Steel Slag at 15% and 20% led to an increase in compressive strength. However, when the Steel Slag replacement exceeded 15%, compressive strength decreased. Thus, it is concluded that replacing 15% of cement with Steel Slag is optimal for concrete performance.

[3] Split Tensile Strength: Similar to compressive strength, the split tensile strength increased with a 5% replacement of cement with Steel Slag and decreased with higher replacement percentages. Hence, the ideal replacement percentage for cement by Steel Slag is 15% for enhanced split tensile strength.

Based on the test results, it can be inferred that a 15% partial replacement of cement with Steel Slag improves workability, compressive strength, and split tensile strength more effectively than conventional concrete. Therefore, incorporating Steel Slag in concrete mixtures is recommended for the construction of various structures.

6. REFERENCES

[1] V. Subathra Devi, B. K. Gnanavel, "Properties of Concrete Manufactured Using Steel Slag", Procedia Engineering Volume 97, 2014, Pages 95-104.

[2] Dilip Kumar Singha Roy, Amitava Sil, (2012) "Effect of Partial Replacement of Cement by SilicaFume on Hardened Concrete", International Journal of Emerging Technology and Advanced Engineering, IJETAE, Volume 2, Issue 8.

[3] Veena G. Pathan, Vishal S. Ghutke, Gulfam Pathan, (2012), "Evaluation of Concrete Properties Using Ground Granulated Blast Furnace Slag" International Journal of Innovative Research in Science, Engineering and Technology Volume 1, Issue 1.

[4] P.S.Kothai and R.Malathy, (2012), "Utilization Of Steel Slag In Concrete As A Partial Replacement Material for Fine Aggregates" International Journal of innovative research in science engineering and technology. Volume 3, Issue 4.

[5] Ansu John and Elson John (2013), "Study on the Partial Replacement of Fine Aggregate using Induction Furnace Slag", American Journal of Engineering Research, Volume 4, Issue 5.

[6] Ajay Wanode, Ranjana Samrit, Kanchan Suryawanshi, (2015), "Effect of Industrial Steel Slag on Compressive Strength of Concrete", International journal of emerging trends engineering basic sciences, Volume 2, Issue 4.

[7] Banothu Ravinder, (2017), "Experimental study for investigating properties of concrete by using steel slag", IJRET Volume 4, Issue 11.

[8] M.S.Shetty, (2004), "Concrete Technology and Theory of Practice", S. Chand & Co. Ltd 2004

[9] Domoaa R. Hussein, Mohammed M. Salman and Khalid M. Owaid, (2016), "Impact of Iraqi steel slag used as a partial replacement on ordinary Portland cement properties" Applied research journal. Volume 3, Issue 6.

[10] Samdish Abrol, Puneet Sharma, Nitin Verma, Ismitpal Singh (2018), "Effect of steel slag in concrete" International journal research of Engineering and Technology. Volume 5, Issue 7.