Replacement of Fine Aggregate in Concrete by Steel Slag Aggregate and Its Cost Implications.

[1]Suhail MU, [2]Thirugnanasambantham N

[1]M Tech Student, [2]Assistant Professor
Department of civil Engineering,
Sree Venkateshwara Hi-Tech Engineering College
Gobi, Erode, Tamil Nadu, India.

***Abstract*- This paper focuses on sustainable construction and the impact of the construction industry on the environment. It highlights the issue of waste management, specifically regarding steel slag, a by-product of steel manufacturing. The study aims to explore the use of steel slag as a replacement for fine aggregate in concrete, aiming to reduce the environmental impact and the cost of construction caused by the extraction of natural aggregates.**

***Key Words*- Steel slag aggregates, Sustainable construction, Steel slag aggregate Cost implications, Aggregate replacement in Concrete.**

I. INTRODUCTION

Sustainable construction primarily focuses on minimizing the adverse environmental impact generated by the construction industry, which is the largest consumer of natural resources. On the other hand, waste management has evolved into one of the world's most intricate and pressing challenges, significantly impacting the environment. The rapid expansion of industrialization has led to the emergence of various environmentally hazardous waste by-products, such as steel slag.
Steel slag which originates from the steel manufacturing industry, is typically relegated to landfill disposal near the industry due to its limited utility. The improper handling of this waste can cause environmental issues, making waste disposal a significant concern. Therefore, effectively harnessing this material can lead to economic benefits and alleviate environmental concerns. This study seeks to explore the use of steel slag as a substitute for fine aggregate.
Concrete primarily comprises aggregates, constituting nearly three-quarters of its volume, traditionally obtained from natural rocks and riverbeds, contributing to their gradual degradation. This study also focuses on the economic benefits of utilizing steel slag, as a viable alternative to fine aggregate in concrete in the construction industry.

II. PROPERTIES OF STEEL SLAG AGGREGATE

Normally, Steel slag aggregates exhibit an angular, generally cubic structure, often displaying flat or elongated forms. They possess a coarse, vesicular texture characterized by numerous non-interconnected cells. This unique composition results in a larger surface area compared to smoother aggregates of the same volume, which helps to make a strong and effective bond with Portland cement.

Table 2.1 Physical Properties of steel slag aggregate.

Physical Properties	**Loose**	**Compacted**
Bulk density (g/cm³)	1.20	0.347
Void ratio	0.784	0.685
Porosity	0.439	0.406
Specific gravity	2.27	2.27

Table 2.1 Bulking of steel slag aggregate.

% Moisture	**Volume Of Water Added (ml)**	**Volume Of Moist Sand (ml)**	**% Bulking**
2	5.32	235	17.5
4	10.64	265	32.5
6	15.96	260	30
8	21.28	255	27.5
10	26.6	250	25

A sieve analysis conforming to IS 383 – 1970 was carried out for steel slag aggregate. The aggregate that passes the IS 4.75 mm sieve is classified as fine aggregate. From sieve analysis, the particle size distribution or gradation in a sample of aggregate is determined.

Table 2.3 Observations of sieve analysis test.

Is Sieve Size	Weight Retained (g)	% Weight Retained	Cumulative % Retained	Cumulative % Passing
4.75 mm	1.79	0.0895	0.0895	99.9
2.36 mm	2.08	0.104	0.1935	99.8
1.18 mm	295.13	10.0125	10.206	89.79
600 micron	904	54.7	64.906	35.09
300 micron	564	26.7	91.606	8.39
150 micron	125	6.25	97.856	2.14
pan	35.68	1.784	99.64	0.36

III. Mix Design

The aim of proportioning concrete mixes is to determine the most cost-effective and feasible blend of various components to create concrete that meets the performance criteria within defined usage conditions. We are considering an M25 grade of concrete using IS Code 10262:2009 and IS Code 456:2000.

Table 3.1 Concrete mix proportioning for M25 design mix per m³.

Cement (Kg)	Water (L)	Fine aggregate (Kg)	Coarse aggregate (Kg)	Coarse aggregate (Kg)	Chemical admixture (Kg)
342	154	739.91	764.24	509.49	2.39

IV. Experiments and Test Results

Various tests were conducted on the different mixes to determine the properties of the fresh and hardened concrete. The tests include slump test, compressive strength test, flexural strength test, split tensile strength, etc.

Table 4.1 Fresh and hardened properties of concrete.

TEST	Replacement Percentage			
	0%	30%	60%	100%
Slump Value (mm)	150	130	120	110
Compressive Strength (N/mm^2)	33.29	35.02	36.25	38.89
Split Tensile Strength (N/mm^2)	2.9	3.01	3.3	3.45
Flexural Strength	4.75	4.91	5.48	5.81

V. COST IMPLICATIONS

The cost of producing concrete is influenced by multiple factors that collectively shape the financial aspects of the production process. Essential components like cement, aggregates, and water make up the fundamental building blocks of concrete, and their costs can fluctuate due to factors like availability, location, quantity, and quality. The type and quality of cement chosen, whether it's ordinary Portland cement or specialized blends, also play a role in determining costs. Similarly, the selection of aggregates, their source, transportation considerations, and processing requirements contribute to the overall expense. The labour involved in mixing, transporting, and placing concrete, along with the operation and maintenance of production equipment, adds to the cost equation.

Table 5.1 Cost comparison for materials used in 1 m³ of concrete.

Replacement percentage	**0 %**	**30 %**	**60 %**	**100 %**
Cost of cement	2599	2599	2599	2599
Cost of Coarse aggregate	853	853	853	853
Cost of fine aggregate (M sand)	717	502	287	0
Cost of fine aggregate (Steel slag)	0	149	297	495
Total Cost	4169	4103	4036	3947
Cost savings	0	66	133	222
Percentage cost savings	**0%**	**1.58 %**	**3.19 %**	**5.32 %**

From table 5.1, it's inferred that by adopting steel slag instead of sand as fine aggregate the total material cost to produce 1 m3 of concrete can be reduced by 5.32 %.

However, steel slag aggregate has not yet been widely adopted by the construction industry, even though it is a good substitute material for aggregate. To find out the root cause of this problem, we have surveyed construction contractors and engineers. The following observations were made based on the results of the survey.

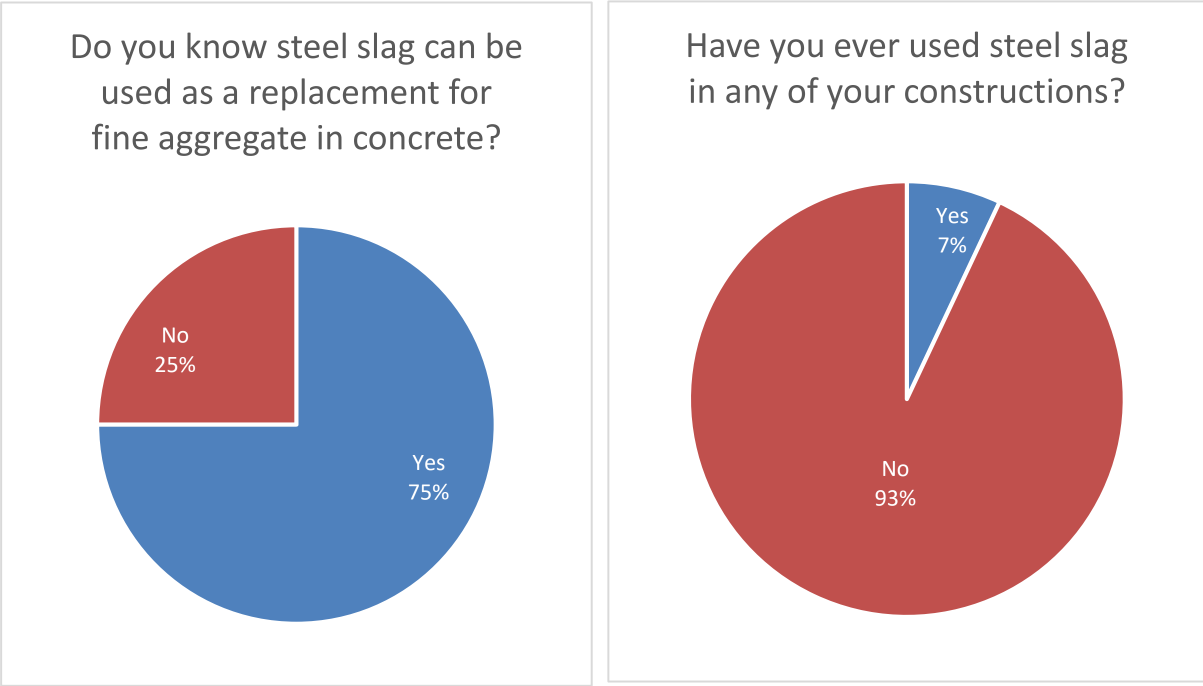

Figure 5.1 Graphical representation of survey results.

75 percent of engineers who participated in this survey know steel slag can be used as a replacement for fine aggregate in concrete. But, only 7 percent of engineers used steel slag in their construction projects.

This study was conducted in Kerala, a southern state of India, where the mining industry is highly regulated and mining of natural sand from river beds is completely banned in some districts. Even though it is harder to get fine aggregates in the market at a low cost, engineers and contractors are not preferring any alternative materials. I have compiled a list of key reasons provided by the engineers who took part in the survey, explaining why they do not use steel slag aggregates in concrete.

- **Traditional Practices**: The construction industry often relies on established and well-understood materials and practices. These practices are trusted for their reliability and performance over time. Any change from these established standards could be viewed with doubts.
- **Supply Chain issues**: Steel slag aggregate is not readily available and its supply is inconsistent, contractors are hesitant to rely on it.
- **Risk Aversion**: New materials, even if they are technically sound, are risky due to the lack of historical data and experience.
- **Public Perception**: The construction industry considers public perception and acceptance when making material choices. Using new and unfamiliar materials can raise questions among clients and the public.
- **Performance Testing**: Adopting a new material involves extensive testing and evaluation to ensure it meets performance requirements. This is time-consuming and costly, and some stakeholders are hesitant to invest in such testing.

VI. CONCLUSION

The results showed that steel slag aggregates have properties similar to natural aggregates and it would not cause any harm if incorporated into concrete. A comparison was made between concrete having natural fine aggregates and concrete with various percentages of steel slag aggregates replaced by weight. The results of this research were encouraging, since they show that using steel slag as fine aggregates in concrete has no negative effects on the short-term properties of hardened concrete.

The results can be summarized as follows:

- Physical properties like grain size distribution, specific gravity, bulk density, etc. of steel slag aggregate are very similar to natural fine aggregates.
- The workability of concrete decreased and all other properties like compressive strength, flexural strength, and split tensile strength increased with an increase in replacements of fine aggregate with steel slag aggregate. The drop in workability could be attributed to the porous and rough surface of slag aggregate.
- Substituting steel slag as fine aggregate can reduce the cost of concrete up to 5.32 % which is significant in projects with huge volumes of concrete. This can be increased by establishing a proper supply chain for steel slag aggregates which further reduce the cost of steel slag.
- The adoption of new materials and practices in the construction industry can be a slow and cautious process for several reasons, even if a material like steel slag aggregate is proven to be a good replacement for natural fine aggregate. Overcoming the challenges associated with the adoption of new construction materials requires a concerted effort from all stakeholders, including researchers, industry professionals, government agencies, and the public.

○ Offering training programs and workshops to educate construction contractors, engineers, architects, and regulators about the benefits and proper use of steel slag aggregate.

- Funding and executing demonstration projects that showcase the successful use of steel slag aggregate in real-world construction applications.
- Working with steel manufacturers and recycling facilities to ensure a consistent and reliable supply of steel slag aggregate and developing partnerships with suppliers and contractors to establish a dependable supply chain.
- Engaging public outreach campaigns to inform the public about the benefits of using sustainable construction materials and providing performance guarantees or warranties for projects using steel slag aggregate to assure project owners and developers.

Hence, it could be recommended that steel slag aggregate could be effectively utilized as fine aggregate in M25 grade concrete either as partial or full replacements of natural fine aggregates.

REFERENCES:

1. IS code 10262:2009 Guidelines for Concrete Mix Design.
2. IS code 456:2000 Plain and Reinforced Concrete.
3. IS 2386 (Part I to VIII) - Test For Aggregates for Concrete.
4. IS 516:1959 - Method Of Test For Strength OF Concrete.
5. IS 383:1070- Specification For Coarse And Fine Aggregates From Natural Sources For Concrete.
6. Indian Minerals Yearbook (Part- II: Metals & Alloys) – 2022.
7. Y. Mahendra, Mr. B. Siva Prasad " An experimental Investigation on the effect of Induction furnace slag as Full replacement of fine Aggregate and partial Replacement of coarse Aggregate in m25 grade Concrete" International Journal of Engineering Applied Sciences and Technology, Vol. 4, Issue 3, pp. 368-373, July 2019.
8. Sunidhi Rajhans, Ajay Kumar Singh, " Study on Partial Replacement of Coarse Aggregate with Steel Slag" International Journal for Research in Applied Science & Engineering Technology (IJRASET) Volume 10, Issue II Feb 2022.
9. Sonali Gadpalliwar, Shraddha Kathalkar, Nikhil Agrawal, "Experimental Analysis of Concrete by Replacing Aggregate with Steel Slag" International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE), Vol 3, Issue 3, March 2018.
10. A. Vijayakumar, J, Raja Murugadoss, S. Praveen, " Development of Sustainable Concrete Using Alternative Building Materials By Replacing Industrial Waste Steel Slag for Aggregates" International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249-8958 (Online), Volume-8 Issue-6, August, 2019.
11. R . Mahalingam G, Sri Durga N, Varshini M, Sharmila R, Vishnu Priya, "An Experimental Study on Partial Replacement of Fine Aggregate using Steel Slag" GRD Journals - National Conference on Emerging Trends in Electrical, Electronics and Computer Engineering (ETEEC-2018) April 2018.
12. Mujedu K A., Lamidi I O, Familusi A O, Olatunji A A, "Utilization of Blast Furnace Slag as Coarse Aggregate in Concrete Production" The International Journal of Engineering and Science (IJES), Volume 7, Issue11 Ver.II, pp. 50-57, 2018.
13. Nandini Suri, Y.Anandh Babu, " Experimental investigations on partial Replacement of steel slag as coarse Aggregates and eco sand as fine aggregate" International Journal of Civil Engineering and Technology (IJCIET), Volume 7, Issue 5, September-October 2016, pp. 322–328.
14. 1Gaurav Desai, Prem Lohakare, Akshay Bhavsar, Akash Ugale, Nayan Bhavsar , "Partial Replacement Of Fine Aggregate Using Steel Slag" IJEDR 2018, Volume 6, Issue 2, pp 730-732.