"To increase the compressive strength of concrete by replacing fine aggregate with shredded steel waste"

Chandan Kumar[1], Jagendra Pratap Singh[2], Abhishek Singh[3],Vishal Kumar[4],Dr. Pali Sahu[5]

1,2,3,4, Students Department of Civil Engineering, Oriental College of Technology, Bhopal (M.P), India

5th Associate Professor, Department of Civil Engineering, Oriental College of Technology, Bhopal (M.P), India

Contact us:- Chandansingh15042002@gmail.com

ABSTRACT

Concrete is the backbone of modern infrastructure and one of the most extensively used construction materials worldwide. However, concerns about environmental sustainability and resource depletion necessitate the exploration of alternative materials in concrete production. This study investigates the effect of replacing fine aggregate with shredded steel waste at varying percentages (5%, 10%, and 15%) to enhance the properties of the concrete like compressive strength, workability (slump value and compaction factor) of M20 grade of concrete. The primary objective is to assess whether shredded steel waste can serve as a feasible substitute for natural fine aggregate while addressing sustainability concerns and waste management issues.

This research involved an extensive experimental approach, including concrete mix design, casting, curing, and compressive strength testing. The findings indicate that incorporating steel waste significantly impacts the compressive strength of concrete, with optimal strength achieved at 15% replacement. Beyond this level, a slight decrease in compressive strength was observed, likely due to the lack of proper bonding between steel particles and cement paste. Additionally, the study discusses the environmental and economic benefits of repurposing steel waste and its potential contribution to reducing landfill accumulation. The results suggest that replacing a portion of fine aggregate with shredded steel waste can provide an innovative and sustainable approach to concrete production. Future studies should focus on the long-term durability, flexural strength, and field applications of steel waste concrete.

Concrete is one of the most widely used materials in construction, with its strength and durability playing a crucial role in infrastructure development. However, the rapid depletion of natural aggregates and increasing environmental concerns have led researchers to explore alternative materials that can replace conventional concrete components. This study investigates the use of shredded steel waste as a partial replacement for fine aggregate in M20-grade concrete, with the aim of enhancing its compressive strength while promoting sustainability.

INTRODUCTION

Concrete is one of the most widely used construction materials in the world, valued for its strength, durability, and versatility. However, the increasing demand for concrete has led to excessive exploitation of natural resources, particularly river sand, which is commonly used as fine aggregate. This has raised environmental concerns and called for sustainable alternatives to conventional materials in concrete production.

This project explores the potential of using shredded steel waste as a partial replacement for fine aggregate in concrete. Steel waste, often generated as a by product in industries such as manufacturing and fabrication, poses a significant disposal challenge. By incorporating this waste material into concrete, the project aims to address two major issues simultaneously: reducing environmental pollution from industrial waste and minimizing the depletion of natural sand resources.

The main focus of this study is to investigate the effect of replacing fine aggregate with shredded steel waste on the **compressive strength** of M20 grade concrete. The replacement will be done at varying percentages (e.g., 5%, 10%, and 15%) to determine the optimum level that yields the best strength results. The findings are expected to provide valuable insights into the feasibility of using industrial steel waste as a sustainable and performance-enhancing component in concrete mixes.

Objective of the Study:-

This research aims to assess the feasibility of using shredded steel waste as a fine aggregate replacement in M20 concrete. The key objectives are:

- To determine the effect of shredded steel waste on the compressive strength of concrete.

Significance of the Study:-

The construction industry is constantly seeking sustainable and cost-effective materials that do not compromise quality and durability. By utilizing shredded steel waste, this research contributes to:

- **Sustainability:** Reducing the environmental footprint of construction activities by repurposing industrial waste.
- **Waste Management:** Addressing steel waste disposal issues by incorporating it into concrete.
- **Economic Benefits:** Lowering construction costs by reducing dependence on natural sand.

Performance Enhancement: Investigating the structural advantages of using steel waste in concrete production.

LITERATURE REVIEW

Evolution of Concrete and Sustainable Materials:-

Concrete technology has evolved significantly over the years, with ongoing research focused on improving its strength, durability, and sustainability. Several alternative materials have been explored to enhance concrete properties while reducing environmental impact. The incorporation of industrial waste in concrete production has emerged as a viable approach to sustainable construction.

Steel Waste in Construction Applications:-

The use of steel waste in concrete has gained interest due to its potential to enhance mechanical properties. Steel fibers, steel slag, and shredded steel waste have all been studied for their impact on concrete strength, durability, and resistance to cracking.

Prior Studies on Fine Aggregate Replacement:-

Numerous studies have evaluated the replacement of fine aggregate with materials such as steel slag, crushed glass, and fly ash. However, limited research has focused specifically on shredded steel waste. This study seeks to fill this research gap by providing comprehensive experimental data.

Sustainability and Waste Management in Construction:-

The integration of industrial by products into construction materials contributes to circular economy initiatives, minimizing waste accumulation and reducing environmental degradation. Several case studies have demonstrated the benefits of sustainable construction materials in real-world projects.

Research Gaps and Future Scope:-

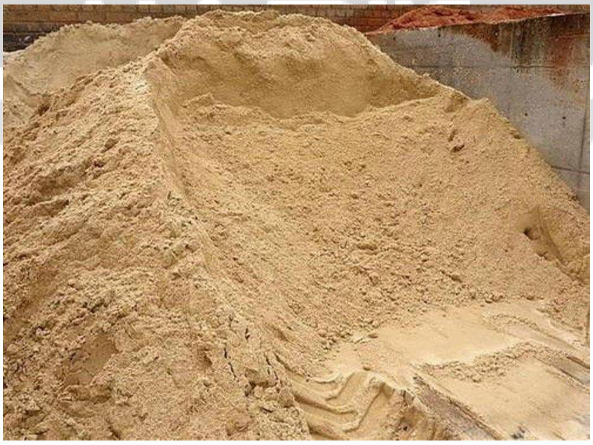
While existing research highlights the advantages of using steel waste in concrete, there is a need for more in-depth studies on long-term performance, corrosion resistance, and field applications. This study aims to bridge these gaps by presenting an extensive analysis of shredded steel waste in concrete.

Materials and Methodology

Materials Used:-

- **Cement :-** Ordinary Portland Cement (OPC 43 Grade)

• **Fine Aggregate :-** Natural river sand



- **Coarse Aggregate :-** Crushed granite

- **Shredded Steel Waste :-** Industrial scrap steel processed to pass through a 2.38 mm sieve.

- **Water :-** Potable water free from impurities

Mix Design:-

The study follows a standard M20 mix design (1:1.5:3). Shredded steel waste is introduced at replacement levels of 5%, 10%, and 15% by weight of fine aggregate, along with a control mix. The water-cement ratio is maintained at a constant level for all mixes.

Casting and Curing Process:-

Concrete cubes (150mm x 150mm x 150mm) are cast for each mix and cured for 28 days. The curing process ensures proper hydration and strength development.

Testing Procedures

Compressive Strength Test:-

- Prepare concrete mix as per M20 grade with replacement of fine or coarse aggregate by **shredded steel fiber or shredded steel waste** at 5%, 10%, and 15% levels.
- Fill the concrete mix into molds in **three layers**, compacting each layer with a tamping rod (25 blows per layer).
- Level the surface using a trowel and allow it to set.
- Cure the specimens in water **28 days**, depending on the required testing age.

Slump Test:-

Step 1: Preparing the Concrete Mix

- Prepare **M20 concrete** with the required **water-cement ratio.**
- **Ensure shredded steel waste** is mixed at **5%, 10%, or 15% replacement levels.**
- The mix should be **homogeneous** and **freshly prepared** before testing.

Step 2: Setting Up the Slump Cone

1. **Place the slump cone** on a **flat, level, and non-absorbent base plate.**
2. **Hold the cone firmly** (either by footrests or an assistant) to prevent movement.

Step 3: Filling the Slump Cone with Concrete

The cone is filled in **three equal layers**, ensuring proper compaction:

1. **First Layer:**
    - Fill the cone up to **1/3rd (about 100mm height).**
    - Compact the layer using **25 tamping strokes** with the **tamping rod.**
2. **Second Layer:**
    - Add more concrete until the cone is **2/3rd full (about 200mm height).**
    - Compact again with **25 tamping strokes**, ensuring uniform density.
3. **Third Layer:**
    - Fill the cone completely to the top.
    - Compact with **25 tamping strokes** and level the top surface with a **trowel.**

Step 4: Lifting the Slump Cone

1. **Carefully lift the cone vertically in 5 to 10 seconds** without disturbing the concrete.
2. The concrete will **slump (settle down)** due to gravity.

Step 5: Measuring the Slump Value

1. **Place a measuring scale** vertically be side the slumped concrete.
2. **Measure the vertical difference** between the **top of the cone (300mm height)** and the **highest point of the slumped concrete.**
3. **Record the slump value in millimeters (mm).**

Compaction factor test:-

1. Prepare the concrete mix with the required proportions.
2. Place the empty apparatus on a level surface.
3. Fill the upper hopper completely with concrete without compacting.
4. Open the first trapdoor, allowing the concrete to fall into the lower hopper.
5. Open the second trapdoor, letting the concrete fall into the cylindrical container without applying force.
6. Weigh the container with the partially compacted concrete (W1).
7. Remove and refill the container, this time fully compacting the concrete using the tamping rod.
8. Weigh the container with fully compacted concrete (W2).
9. Calculate the compaction factor using:

Compaction Factor=W2/W1

Implementation and Analysis

Workability Observations:-

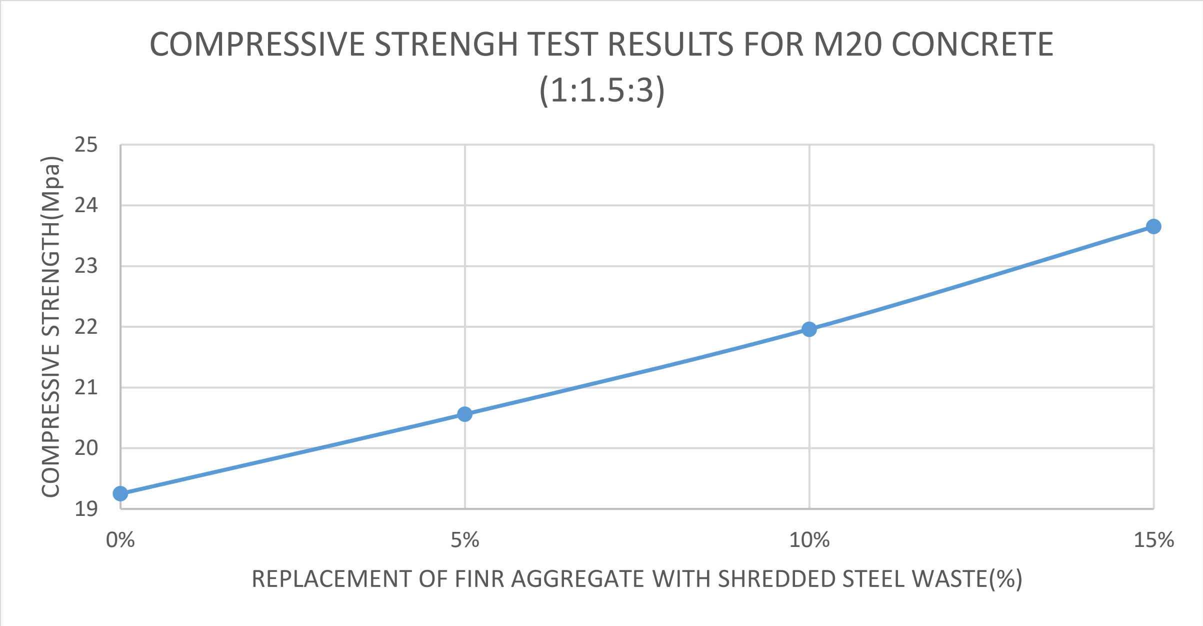
The workability of concrete decreases slightly with increasing steel waste content. Admixtures may be required to improve consistency.

Compressive Strength Results:-

The highest compressive strength is observed at a 15% replacement level. Strength increases due to the enhanced bonding effect of steel particles, but declines slightly at 5% due to poor cohesion.

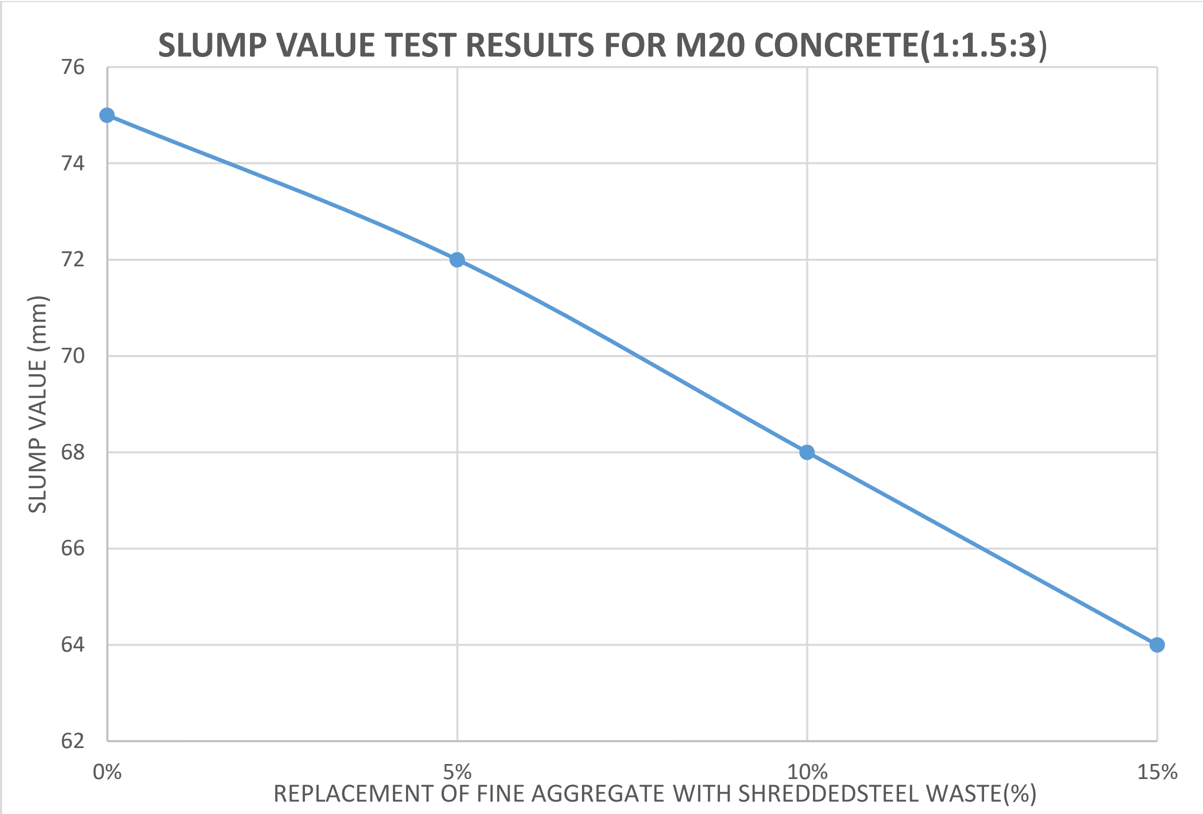
Compressive strength graph:-

S.NO.	% REPLACEMENT OF SHREDDED STEEL	COMPRESSIVE STRENGTH IN N/MM^2 FOR M20
1.	0%	19.25
2.	5%	20.56
3.	10%	21.96
4.	15%	23.65



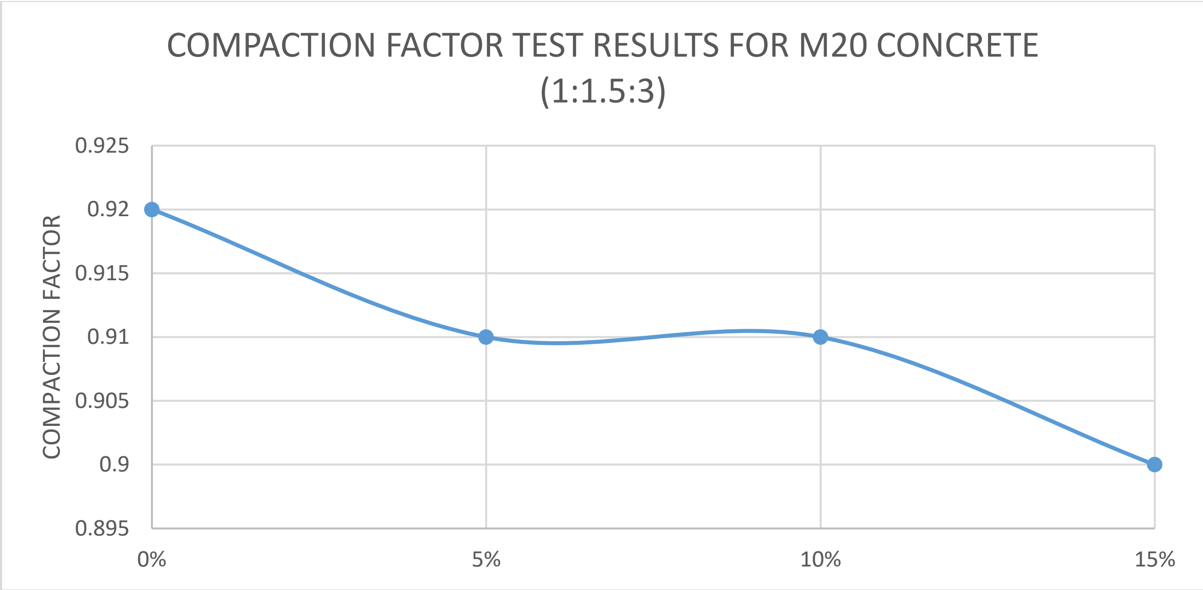
Slump test:-

S.NO.	% REPLACEMENT OF SHREDDED STEEL	SLUMP VALUE IN MM FOR M20
1.	0%	75
2.	5%	72
3.	10%	68
4.	15%	64



Compaction factor test:-

S.NO.	% REPLACEMENT OF SHREDDED STEEL	COMPACTION FACTOR
1.	0%	0.92
2.	5%	0.91
3.	10%	0.91
4.	15%	0.90



Environmental and Economic Analysis:-

Incorporating steel waste reduces sand extraction, lowering environmental degradation. Additionally, steel waste utilization in concrete reduces construction costs, making it an economically viable solution.

Discussion

Compressive Strength Results:-

The highest compressive strength is observed at a 15% replacement level. Strength increases due to the enhanced bonding effect of steel particles, but declines slightly at 5% due to poor cohesion.

Workability and Durability Analysis:-

The workability of concrete decreases slightly with increasing steel waste content. Admixtures may be required to improve consistency. Durability tests indicate improved resistance to environmental degradation.

Conclusion

This study concludes that shredded steel waste can be effectively used as a fine aggregate replacement in M20 concrete. The optimal replacement level for maximum strength enhancement is 15%. The use of steel waste not only improves compressive strength but also promotes sustainability and cost efficiency in construction. However, further research is needed to assess long-term durability and large-scale applications.

The study on replacing fine aggregate with shredded steel waste in concrete reveals significant improvements in compressive strength. The experimental results indicate that incorporating shredded steel waste enhances the overall mechanical properties of M20 concrete, particularly at optimal replacement levels of 1**5%**.

Key findings include:

- **Increased compressive strength** compared to conventional concrete, with the highest improvement observed at 1**5% replacement**.
- **Improved durability** due to the enhanced bond between the cement matrix and steel particles.

- **Environmental benefits**, as utilizing shredded steel waste reduces landfill disposal and promotes sustainable construction practices.

However, excessive replacement levels beyond **5%** may lead to **workability issues and reduced strength**, emphasizing the need for optimal mix design. Further research is recommended to explore **long-term durability, corrosion resistance, and economic feasibility** before large-scale applications.

References

- ACI Committee 318. "Building Code Requirements for Structural Concrete." American Concrete Institute, 2019.
- IS 10262:2009. "Concrete Mix Proportioning – Guidelines." Bureau of Indian Standards.
- Mehta, P.K., and Monteiro, P.J.M. "Concrete: Microstructure, Properties, and Materials." McGraw-Hill, 2014.
- Recent studies from scientific journals on alternative aggregates in concrete.
- Kumar, R., & Dhaka, S. (2018). Experimental study on properties of concrete by partial replacement of fine aggregates with waste steel chips.
- Gul, W., &Naseer, A. (2021). Combined effect of waste glass powder and recycled steel fibers on the performance of concrete.
- Solahuddin, B. A., &Yahaya, F. M. (2022). Inclusion of Waste Paper on Concrete Properties: A Review.
- Zhang, H., & Zhao, Y. (2020). Experimental Study of Utilizing Recycled Fine Aggregate for the Preparation of High Ductility Cementitious Composite.

 Kumar, R., & Dhaka, S. (2018). Experimental study on properties of concrete by partial replacement of fine aggregates with waste steel chips.

 Patil, M. S., &Patil, Y. D. Effect of Steel Slag as Partial Replacement of Fine Aggregate on the Strength Properties of Concrete. IJERT, 2013.

 Sharma, A. K., &Sangwan, R. Utilization of Waste Steel Scrap for Increased Strength in Concrete. IJESRT, 2014.

 Mahesh, K. S., &Sreeja, M. S. Experimental Investigation on Concrete with Partial Replacement of Fine Aggregate by Steel Slag. IJSR, 2015.

 Patil, S. M., &Kumbhar, P. D. Performance of Concrete with Partial Replacement of Fine Aggregate by Steel Slag and its Flexural Strength. IJIRSET, 2013.

 Singh, M., & Singh, S. P. Sustainable Use of Steel Industry Slag (SIS) for Concrete Production. Procedia Environmental Sciences, 2016.