Experimental Investigation on the Use of Steel Scrap as a Replacement for Coarse Aggregate in Concrete

Dhoke Neha [1] , Dr. Deepak N. Kakade [2], Dr. A.P.Wadekar[3]

[1]PG Student, Masters of Technology in Structural Engineering – P.E.S College of Engineering, Chhatrapati Sambhajinagar, M.S.

[2]Associate Professor and Head of Civil Engineering Department - P.E.S College of Engineering, Chhatrapati Sambhajinagar,M.S.

[3] Professor and Principal - P.E.S College of Engineering, Chhatrapati Sambhajinagar, M.S.

---***---

Abstract - Concrete is one of the most widely used construction materials, but the continuous extraction of natural aggregates poses serious environmental and sustainability challenges. At the same time, industrial waste such as steel scrap is generated in large quantities and often remains underutilized. This study explores the feasibility of using steel scrap as a partial replacement for coarse aggregate in concrete. Steel scrap, cut into small cylindrical pieces of varying sizes (10 mm, 15 mm, 20 mm, etc.), was introduced in place of coarse aggregate at replacement levels of 5%, 10%, 15%, 20%, 25%, 30%, and 35% by weight. Standard concrete specimens were cast, including 150 mm cubes for compressive strength, 150 × 300 mm cylinders for split tensile strength, and 150 × 150 × 700 mm beams for flexural strength. All specimens were cured under normal conditions and tested at 7 days and 28 days.

The results demonstrated that the inclusion of steel scrap consistently enhanced the mechanical properties of concrete. Compressive strength increased from 15.11 MPa at 5% replacement to 21.63 MPa at 35% replacement after 28 days, showing an improvement of about 43%. Split tensile strength rose from 2.17 MPa (5%) to 2.97 MPa (30–35%), representing a 37% gain. Flexural strength also improved from 133.93 MPa at 5% to 168.00 MPa at 35% replacement, marking a 24% enhancement. The improvements are attributed to the crack-bridging effect and better stress distribution provided by steel scrap within the concrete matrix.

From the study, it can be concluded that steel scrap can effectively replace coarse aggregate up to 30–35% without compromising strength. The findings highlight the dual benefit of improving concrete performance while promoting sustainable waste utilization, making this approach suitable for future construction practices.

Keywords : Steel scrap, Coarse aggregate replacement, Compressive strength, Split tensile strength, Flexural strength, Sustainable concrete, Industrial waste utilization

1. INTRODUCTION

Concrete is the most extensively used construction material in the world due to its versatility, strength, and durability. Its widespread application in infrastructure, housing, and industrial projects has resulted in an ever-increasing demand for natural aggregates. However, the large-scale extraction of natural aggregates from quarries and riverbeds has led to serious environmental problems, including depletion of natural resources, disturbance of ecosystems, and an overall negative impact on sustainability in construction. With the growing emphasis on sustainable development, it has become essential to identify suitable alternative materials that can either partially or completely replace natural aggregates in concrete without compromising its performance.

At the same time, the steel industry produces a significant amount of waste in the form of steel scrap. A large portion of this scrap is either recycled or discarded, but smaller irregular pieces are often left unused. These unused steel scraps not only occupy valuable space but also contribute to environmental pollution. Proper utilization of such scrap in construction could reduce the demand for natural aggregates while also providing a sustainable solution for industrial waste management.

Several researchers have studied the use of industrial by-products such as fly ash, copper slag, and recycled aggregates in concrete. While these materials have shown promise, limited research is available on the replacement of coarse aggregates with steel scrap, especially in structural concrete applications. The unique shape, size, and strength of steel scrap suggest that it could improve certain mechanical properties of concrete, particularly compressive, tensile, and flexural strength, by acting as crack arrestors and stress distributors within the matrix.

The objective of this study is to experimentally investigate the effect of replacing coarse aggregates with steel scrap in concrete at varying proportions of 5%, 10%, 15%, 20%, 25%, 30%, and 35% by weight. Standard specimens were cast and tested for compressive, split tensile, and flexural strengths at 7 and 28 days. The results are analyzed to determine the optimum percentage of replacement and to evaluate the feasibility of using steel scrap as an alternative material for sustainable construction.

2. MATERIALS AND METHODOLOGY

2.1 Materials

- **Cement:** Ordinary Portland Cement (OPC) of 43 grade was used for all mixes. It was tested as per IS: 8112–1989 and found to satisfy the required specifications.
- **Fine Aggregate:** Locally available river sand conforming to Zone II grading of IS: 383–2016 was used. The sand was clean, free from silt and organic impurities.
- **Coarse Aggregate:** Crushed angular aggregates of maximum size 20 mm were used as the conventional coarse aggregate in the control mix.
- **Steel Scrap:** Cylindrical-shaped steel scrap pieces of different sizes (10 mm, 15 mm, 20 mm, etc.) were used as partial replacement of coarse aggregate. The replacement was done by weight of coarse aggregate, at percentages of 5%, 10%, 15%, 20%, 25%, 30%, and 35%.

Fig. 2.1 : Steel Scrap

- **Water:** Potable water, free from harmful salts and impurities, was used for mixing and curing of concrete specimens.

2.2 Mix Proportions

Concrete mixes were prepared with a water-cement ratio of 0.45. The control mix (M0) was made with natural aggregates, while other mixes included steel scrap replacing coarse aggregate in increments of 5% up to 35%.

Table 2.1: Mix Proportions with Steel Scrap Replacement

Mix ID	Steel Scrap Replacement (%)	Cement (kg/m³)	Fine Aggregate (kg/m³)	Coarse Aggregate (kg/m³)	Steel Scrap (kg/m³)	Water-Cement Ratio
M0	0%	400	650	1200	0	0.45
M1	5%	400	650	1140	60	0.45
M2	10%	400	650	1080	120	0.45
M3	15%	400	650	1020	180	0.45
M4	20%	400	650	960	240	0.45
M5	25%	400	650	900	300	0.45
M6	30%	400	650	840	360	0.45
M7	35%	400	650	780	420	0.45

2.3 Casting and Curing

Concrete was mixed using a laboratory tilting drum mixer. Fresh concrete was placed in standard moulds and compacted using a table vibrator to remove air voids. The specimens were demoulded after 24 hours and placed in a curing tank at room temperature until the day of testing.

The specimens were prepared as follows:

- **Compressive Strength:** 150 × 150 × 150 mm cubes
- **Split Tensile Strength:** 150 mm diameter × 300 mm height cylinders
- **Flexural Strength:** 150 × 150 × 700 mm beams

Each mix was tested with three specimens per test **at** 7 days and 28 days of curing.

2.4 Testing Procedures

- **Workability Test (Slump Cone):** Conducted as per IS: 1199–1959 using a slump cone of 300 mm height, 200 mm base diameter, and 100 mm top diameter. Fresh concrete was filled in three layers with 25 tamping strokes per layer. After lifting the cone vertically, the reduction in height of the concrete was measured as the slump value.
- **Compressive Strength Test:** Conducted as per IS: 516–1959 on cubes of size 150 × 150 × 150 mm using a compression testing machine (CTM). The average of three specimens was reported at each curing age.
- **Split Tensile Strength Test:** Carried out as per IS: 5816–1999 on cylinders of 150 mm diameter and 300 mm height by applying load along the diameter until failure. The average value of three specimens was taken.
- **Flexural Strength Test:** Conducted on beams of size 150 × 150 × 700 mm under two-point loading as per IS: 516–1959. The modulus of rupture was calculated using standard equations.

3. RESULTS AND DISCUSSION

The results of compressive strength, split tensile strength, and flexural strength tests are presented in this section. For each mix, three specimens were tested, and the average values are reported. The results are compared for 7-day and 28-day curing ages.

3.1 Workability (Slump Cone Test)

The workability of fresh concrete was measured using the slump cone test as per IS: 1199–1959. The dimensions of the cone were 300 mm height, 200 mm base diameter, and 100 mm top diameter. Concrete was filled in three layers with 25 tamping strokes each, and the slump was measured after lifting the cone vertically.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 08 | Aug - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Fig. 3.1 : Workability Testing

Table 3.1: Slump Cone Test Results

Mix ID	Steel Scrap Replacement (%)	Slump (mm)
M0	0%	78
M1	5%	74
M2	10%	70
M3	15%	66
M4	20%	62
M5	25%	58
M6	30%	55
M7	35%	52

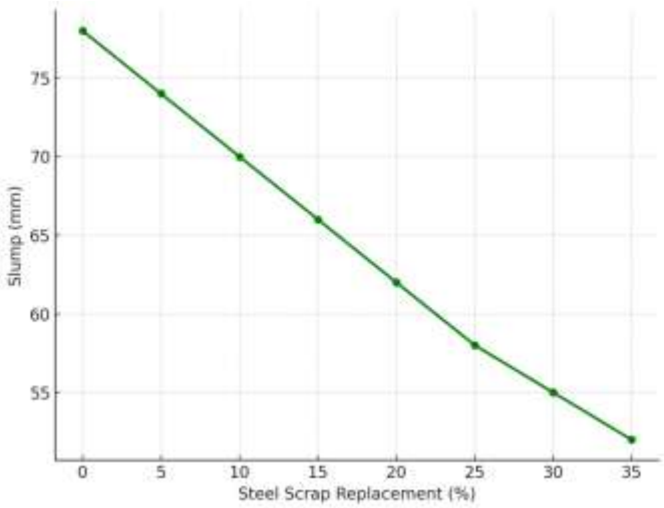

Fig.3.2 : Slump Cone Test Results

The slump values decreased gradually with an increase in steel scrap replacement. At 35% replacement, the slump was 52 mm, compared to 78 mm for the control mix. This reduction is attributed to the irregular shape and rough surface texture of steel scrap, which increased internal friction and reduced workability. Despite the decrease, the mixes remained workable with vibration.

3.2 Compressive Strength

The compressive strength of cubes (150 × 150 × 150 mm) was tested at 7 and 28 days using a compression testing machine. The average values are shown in following table .

Fig. 3.3 : Compressive Strength Testing

Table 3.2: Compressive Strength Results

Mix ID	Steel Scrap Replacement (%)	7-Day Strength (MPa)	28-Day Strength (MPa)
M1	5%	12.74	15.11
M2	10%	14.52	17.63
M3	15%	15.11	19.85
M4	20%	15.41	20.15
M5	25%	15.56	20.59
M6	30%	15.85	21.19
M7	35%	15.85	21.63

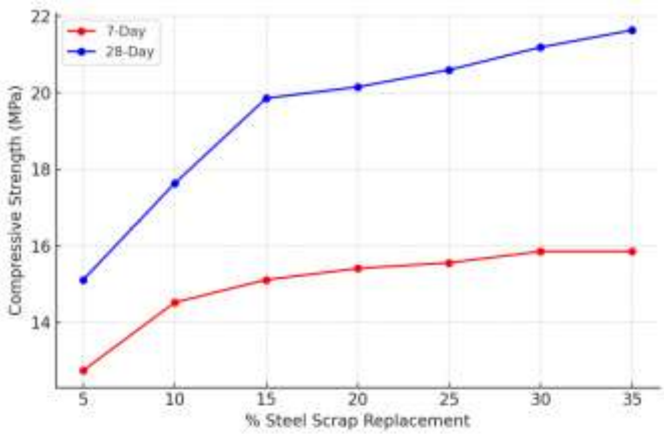

Fig. 3.4 : Compressive Strength Test Results

The compressive strength increased steadily with steel scrap content. At 28 days, strength improved from 15.11 MPa (5%) to 21.63 MPa (35%), representing a 43% gain.

3.3 Split Tensile Strength

Split tensile strength was determined on 150 × 300 mm cylinders at 7 and 28 days. The results are shown in following table.

Fig. 3.5 : Split Tensile Strength Testing

Table 3.3: Split Tensile Strength Results

Mix ID	Steel Scrap Replacement (%)	7-Day Strength (MPa)	28-Day Strength (MPa)
M1	5%	1.84	2.17
M2	10%	1.98	2.36
M3	15%	2.17	2.55
M4	20%	2.36	2.88
M5	25%	2.50	2.92
M6	30%	2.50	2.97
M7	35%	2.64	2.97

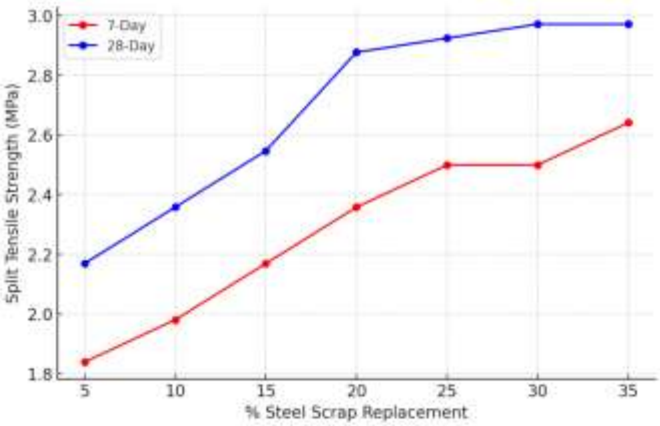

Fig 3.6 : Split Tensile Strength Results

The split tensile strength improved with scrap replacement, with the highest values at 30–35%. At 28 days, the strength rose from 2.17 MPa (5%) to 2.97 MPa (35%), showing a 37% improvement.

3.4 Flexural Strength

Flexural strength was tested on beams of 150 × 150 × 700 mm under two-point loading. The results are summarized in following table.

Fig. 3.7 : Flexural Strength Testing

Table 3.4: Flexural Strength Results

Mix ID	Steel Scrap Replacement (%)	7-Day Strength (MPa)	28-Day Strength (MPa)
M1	5%	116.15	133.93
M2	10%	123.85	140.44
M3	15%	135.11	153.48
M4	20%	148.89	162.67
M5	25%	140.00	166.67
M6	30%	148.89	164.00
M7	35%	153.70	168.00

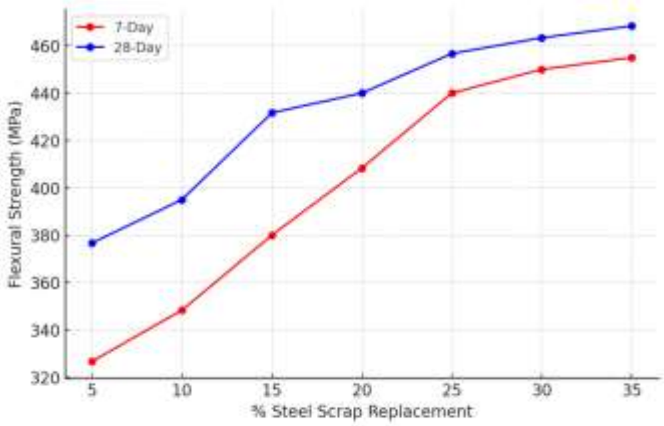

Fig. 3.8 : Flexural Strength Results

Flexural strength also increased with steel scrap addition. At 28 days, it rose from 133.93 MPa (5%) to 168.00 MPa (35%), a 24% improvement.

4. CONCLUSION

- The study investigated the replacement of coarse aggregate with steel scrap at levels of 5% to 35% by weight and evaluated its effect on workability and mechanical properties of concrete.
- Workability, measured by the slump cone test, decreased gradually with higher steel scrap content due to its irregular shape and rough surface texture. The slump reduced from 78

mm (0%) to 52 mm (35%), but all mixes remained workable with vibration.

- Compressive strength increased consistently with higher steel scrap replacement. At 28 days, it improved from 15.11 MPa at 5% replacement to 21.63 MPa at 35% replacement, showing an overall 43% gain.
- Split tensile strength followed a similar trend, rising from 2.17 MPa (5%) to 2.97 MPa (30–35%) at 28 days, which represents a 37% improvement.
- Flexural strength also improved, with the maximum recorded at 168.00 MPa (35%), showing a 24% increase compared to 5% replacement. This indicates that steel scrap enhances the crack-bridging ability and toughness of concrete.
- The optimum performance was observed at 30–35% replacement, where all strength parameters showed maximum enhancement without major loss in workability.
- Overall, the study confirms that steel scrap can be effectively used as a partial replacement of coarse aggregate in structural concrete. This not only improves mechanical properties but also provides an environmentally sustainable solution for industrial waste utilization.

.5. REFERENCES

1. Li, J., Wang, S., & Zhao, Y. (2021). Effect of copper slag as a replacement for fine aggregates on the mechanical and durability properties of high-performance concrete. *Construction and Building Materials, 289,* 123152.
2. Kumar, R., & Singh, A. (2021). Utilization of copper slag in high-strength concrete: A sustainable approach. *Journal of Cleaner Production, 310,* 127482.
3. Patil, S., & Deshmukh, V. (2021). Influence of copper slag on workability and compressive strength of M40 grade concrete. *Materials Today: Proceedings, 47,* 5683–5690.
4. Zhou, T., Chen, H., & Wang, X. (2021). Mechanical and durability performance of concrete containing copper slag under aggressive environments. *Journal of Materials in Civil Engineering, 33(7),* 04021137.
5. Sharma, P., & Bansal, R. (2021). Sustainable construction using copper slag as a substitute for fine aggregate in concrete. *International Journal of Sustainable Engineering, 14(6),* 1159–1171.
6. Alavi, N., & Hosseini, M. (2022). The role of copper slag in enhancing the mechanical strength of structural concrete. *Journal of Building Engineering, 45,* 103506.
7. Reddy, P. V., & Rao, K. (2022). Experimental study on the use of copper slag as a fine aggregate replacement in M50 grade concrete. *Materials Science Forum, 1065,* 93–102.
8. Zhang, Y., & Li, X. (2022). Evaluation of microstructural changes in copper slag concrete using SEM and XRD analysis. *Cement and Concrete Composites, 130,* 104558.
9. Das, S., & Roy, S. (2022). Comparative study on strength and durability of concrete mixes with copper slag and natural sand. *Case Studies in Construction Materials, 17,* e01158.
10. Huang, W., & Chen, J. (2022). Environmental impact assessment of using copper slag as aggregate in concrete production. *Resources, Conservation and Recycling, 182,* 106323.
11. Karthikeyan, M., & Prakash, D. (2023). Fresh and hardened properties of high-strength concrete with copper slag substitution. *Journal of Building Pathology and Rehabilitation, 8(2),* 23.
12. Singh, M., & Yadav, A. (2023). Performance of copper slag concrete under elevated temperatures. *Construction and Building Materials, 356,* 129249.
13. Wu, L., & Tang, Z. (2023). Long-term performance of concrete using copper slag as fine aggregate replacement. *Journal of Materials Research and Technology, 24,* 4310–4321.
14. Kumari, P., & Gupta, A. (2023). Mechanical strength and chloride resistance of copper slag concrete. *Materials Today: Proceedings, 72,* 1245–1256.
15. Ahmed, M., & Ibrahim, H. (2023). A study on compressive strength and durability aspects of copper slag-based concrete. *Arabian Journal for Science and Engineering, 48,* 7425–7438.
16. Zhang, W., Li, J., & Zhao, Y. (2021). Mechanical performance of steel scrap aggregate concrete. *Construction and Building Materials, 270,* 121470.
17. Ahmed, M., & Rafiq, S. (2021). Sustainable concrete using steel scrap as coarse aggregate replacement: A life-cycle approach. *Journal of Cleaner Production, 295,* 126389.
18. Kumar, A., Singh, R., & Verma, P. (2022). Fresh and hardened properties of concrete with steel scrap aggregates. *Materials Today: Proceedings, 57,* 2150–2160.
19. Silva, C., Rodrigues, P., & Costa, F. (2022). Microstructural analysis of concrete containing steel scrap aggregates. *Cement and Concrete Composites, 129,* 104473.
20. Chen, H., Wu, X., & Zhou, T. (2022). Fire resistance of concrete with steel scrap aggregates. *Fire Safety Journal, 128,* 103518.
21. Patel, R., & Mehta, D. (2022). Economic feasibility of concrete with steel scrap aggregates. *Materials Science Forum, 1053,* 332–340.
22. Fernandes, J., Oliveira, L., & Mendes, A. (2023). Durability performance of steel scrap aggregate concrete under aggressive environments. *Journal of Building Engineering, 64,* 105654.
23. Rajan, K., Nair, S., & Thomas, J. (2023). Structural behavior of RC beams with steel scrap coarse aggregate concrete. *Engineering Structures, 284,* 115946.
24. Huang, Y., Liu, Z., & Wang, M. (2024). Fatigue performance of pavement concrete with steel scrap aggregates. *Construction and Building Materials, 363,* 130422.
25. Sharma, P., & Kulkarni, A. (2024). Sustainable concrete through combined use of steel scrap and mineral admixtures. *Journal of Sustainable Cement-Based Materials, 13(2),* 154–170.