© April 2024 | IJIRT | Volume 10 Issue 11 | ISSN: 2349-6002

A Research on: Appraisal of Mechanical Performance of Concrete with Partial Replacement of Coarse Aggregate with Steel Slag

DR. S.A HUSSAIN[1], KASHISH BAGDE[2], FAZIL KHAN[3], OSAMA SHEIKH[4], RUMMAN SHEIKH[5]

[1] Assistant Professor, Department of Civil Engineering, Anjuman College of Engineering and Technology Sadar, Nagpur, India

[2,3,4,5] U.G. Student, Department of Civil Engineering, Anjuman College of Engineering and Technology Sadar, Nagpur, India

Abstract— Natural aggregates are becoming increasingly scarce, and their extraction and transportation are becoming more complex. There is a great opportunity to use steel slag, an industrial waste product produced as a by-product of steel manufacturing, as an alternative to normally available coarse aggregate. In this study, M25 grade concrete with w/c ratio of 0.4 is used for the partial replacement of 0%, 15%, 20% of the coarse aggregates with steel slag, which is a byproduct of the steel manufacturing industry and has a negative impact on the environment. This study revealed that there is an improvement in compressive strength upto 1 to 2%. The workability of concrete is reduced when % of replacement is increased to 15% and 20% when compare with normal conventional M25 grade of concrete. This suggests that there is an optimal replacement percentage of Steel slag that benefits the use of steel slag as coarse aggregate generally which increased the unit weight of concrete mixtures. Studies shows that a complete i.e., 100% replacement of coarse aggregate by steel slag reduces the strength of the concrete cubes.

Index Terms— Steel slag, Industrial by-product, Coarse aggregate, Fine aggregate, Compressive strength.

I. INTRODUCTION

Concrete is a structural material consisting of a fine and coarse aggregate encapsulated in a liquid matrix that hardens over time. Conventional concrete consists of sand as fine aggregate and gravel, limestone or granite of various sizes and shapes as coarse aggregate. Concrete plays an important role in the planning and construction of the country's infrastructure. As a building material, concrete is the largest produced product among all other materials and aggregates is its most important component. Almost three-quarters of the concrete volume is made up of aggregate. Aggregate give thickness to concrete, reduce shrinkage and ensure cost-effectiveness. Aggregate accounts for almost 70-75 percent of the total volume of concrete and plays an important role in various properties of concrete such as workability, durability, dimensional stability, and strength. The availability of natural aggregates is becoming increasingly scarce, and the price of is also increasing. Therefore, there is a need to focus on the utilization of waste and by-products in all sectors, including the construction industry.

Steel Slag: Steel slag is produced as an industrial by-product of the production of steel in the steel processing industry. It is produced in large quantities during the manufacturing of steel. Steel slag can be used in the construction industry as aggregate in concrete due to its characteristics which are almost similar to conventional aggregates. Significant quantities of steel slag are produced as a major by-product of the conversion of iron to steel in the basic steel making processes (Cement Australia Group). Steel making slag, is formed when molten steel is separated from impurities in steel-making furnaces. Slag is a complex solution of silicates and oxides that exists as a molten liquid and solidifies upon cooling. The consumption of slag in concrete not only helps to reduce greenhouse gases, but also contributes to the production of environmentally friendly materials. Steel slag has unique physical and chemical properties that make it suitable for different applications. Additionally, the crushing and screening process used to prepare steel slag for various applications may further contribute to its grey appearance. Overall, the grey color of steel slag is a result of its chemical composition and processing methods. It is generally harder and more durable than natural aggregates which makes it ideal for road construction and concrete applications. Despite its benefits, steel slag can contain trace elements and heavy metals that may leach into the environment if not properly managed.

Fig: 1 Sample of steel slag

II. MATERIALS AND METHODS

The materials used in experimental investigation include:

1. Cement:

Cement acts as a binding material in concrete. In this project work OPC 53 grade cement was used conforming to IS: 12269 – 1987. It's typically a fine powder made from a mixture of limestone, clay and other materials, which are heated in a kiln at high temperatures. It was collected from local market traders, Gaddigodam, Nagpur. The main reason for using OPC 53 grade is its help in hydration process and it increases the strength of concrete.

Table 2.1 Physical Properties of Cement

S. No	Properties	Value
1	Fineness of cement	6.95%
2	Specific gravity of cement	3.15
3	Initial Setting time	35 min
4	Final Setting time	313 min
5	Normal Consistency of cement	31.5%

2. Fine Aggregate:

The river sand was used here as fine aggregate conforming to Zone-II of IS 383-1970. The quality and density of the fine aggregate has a significant impact on the properties of the concrete in its hardened state. Fine aggregate which can passed through an IS 4.75 mm sieve was used for casting for all cube samples.

Table 2.2 Properties of Fine Aggregate

S.No	Properties	Value
1	Specific gravity	2.3
2	Fineness Modulus	2.83
3	Water Absorption	0.95%

3. Coarse Aggregate:

Coarse Aggregate consists of crushed stone with particle size equal to or greater than 4.75mm. It shall comply with the requirements of IS 383-1970. Coarse aggregate, typically made up of gravel or crushed stone, plays a crucial role in construction by providing bulk to concrete mixes. In this project work coarse aggregate of size 20mm is used for casting cubes.

Table 2.3 Properties of Coarse Aggregate

S. No	Properties	Value
1	Specific gravity	2.66
2	Fineness Modulus	5.54
3	Water Absorption	1.88%
4	Impact test Value	15.59%
5	Crushing Test Value	21.45%

4. Water:

Water is important in gradient of concrete as its actively participates in the chemical reactions with cement. Water used in the experimental work is conformed to IS 456-2000 for mixing as well as curing of concrete specimens. Water's PH shouldn't be less than 6. The water content in the concrete mix should be carefully controlled to ensure that the concrete has the desired workability and strength. Overall, water plays a crucial role in concrete mixtures, and its proper management is essential for achieving the desired properties and performance of the concrete.

5. Steel Slag:

Steel slag is produced as an industrial by- product of the production of iron and steel in the steel industry. It is produced in large quantities during steel manufacturing. Steel slag can be used in the construction industry as aggregate in concrete by replacing natural aggregate. Its chemical composition and physical properties make it an attractive substitute for traditional aggregates in concrete production. It has a high density and hardness, making it suitable for various applications. Incorporating steel slag into concrete mixtures enhances its strength, durability, and resistance to environmental factors such as corrosion and abrasion. The steel slag was obtained from CP foundry Works, Nagpur.

Table 2.4 Chemical Properties of steel slag

Elements	Composition
Carbon	1.43%
Oxygen	52%
Sodium	0.54%
Aluminum	4.22%
Silicon	17.29%
Iron	13.26%
Calcium	1.38%
Titanium	0.43%
Chromium	0.35%
Manganese	3.52%
Zinc	0.49%
Potassium	0.36%

Table 2.5 Physical Properties of steel slag

S. No	Properties	Value
1	Specific gravity	2.72
2	Water Absorption	1.7%
3	Flakiness Index	9%
4	Elongation Index	5.5%
5	Impact Strength test	18%

III. MIX PROPORTION

As per IS10262-2009 the concrete mix design prepared for M25 grade concrete. The water cement ratio was taken as 0.4 from IS10262-2009 for maintaining the workability. In this research work we have casted 3 conventional concrete cube and 6 steel slag concrete cube with 15& 20% replacement of coarse aggregate of each size 150mm×150mm×150mm in mould by cement, sand and aggregate ratio 1:1.3:2.5, using tamping rod for levelling the surface of mould, Compaction of concrete in three layers with 25 strokes of 16 mm rod was carried out for each layer and it is allowed to set for 24 hours, after 24 hours it is kept in water for curing for 7 days to determine its compressive strength.

Table 3.1 Material for different proportion in kg.

Type of concrete mix	Cement (kg)	Coarse aggregate (kg)	Fine Aggregate (kg)	Steel slag (kg)	w/c ratio
M0	4.707	11.874	6.318	0	0.4
M1 (15%)	4.707	10.08	6.318	1.779	0.4
M2 (20%)	4.707	9.48	6.318	2.376	0.4

Where, Mix M0 denotes the mix, with 0% steel slag,
M1 denotes the mix, with 15% steel slag,
M2 denotes the mix, with 20% steel slag.

IV. EXPERIMENTATION

1. Test on Fresh Concrete

The concrete slump test measures the consistency of fresh concrete before it sets. Slump cone test is to use to determine the workability of concrete mix prepared at the laboratory. A concrete mix M25 by weight with suitable water/ cement ratio of 0.4 we have prepared in the laboratory for testing the workability of concrete mix. It involves filling a cone shaped container with freshly mixed concrete in three layers each approximately one third full, using a trowel, compacting each layer evenly and uniformly with 25 strokes using a round- rounding bar, and then carefully lifting the cone to see how much the concrete slumps. This measurement helps assess the concrete’s consistency, which is crucial for ensuring its suitability for construction purposes. The slump is carried out as per procedures mentioned in IS 1199-1959.

Fig: 2 Slump cone test

2. Test on Hardened Concrete

Compressive strength is crucial for evaluating the ability of hardened concrete to withstand loads. The Compressive strength of the specimen is an indicator of the quality of the concrete mix. The compressive strength test depends on many factor such as moisture, content, curing conditions, shape can influence test results. Test for compressive strength is carried out either on a cube Compressive strength of each specimen was conducted accordance with IS: 516 -1959 Compressive strength has been measured for 7 days. Specimens were cube with a 150 mm side for compressive strength.

Fig 3: Compressive strength test

V. RESULTS

The result indicated that compressive strength is increased about 1 to 2% in replacement of coarse aggregate with steel slag in 15 & 20%. In full replacement of steel slag reduces the strength.

Sr.No.	M25 Normal Concrete Cube Testing (7 days)		
	Load Failure (KN)	Compressive Strength (N/mm^2)	Average
Cube 1	478	21.24	21.61
Cube 2	489	21.73	
Cube 3	492	21.86	

Table 5.1 Compression Strength test on Normal Concrete cubes.

Graph. 5.1 Graphical representation of Compression strength test of Normal concrete cube (7 day)

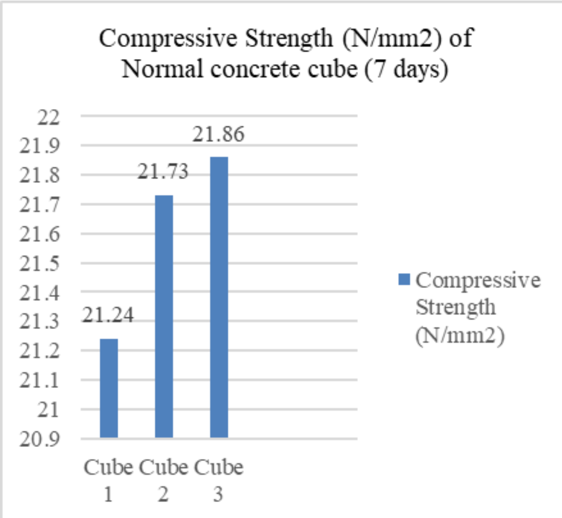


Table 5.2 Compression Strength test on 15% replacement steel slag concrete cubes (7 days).

Sr.No.	M25 (15%) Replacement Concrete Cube Testing (7 days)		
	Load Failure (KN)	Compressive Strength (N/mm^2)	Average
Cube 1	507	22.53	22.36
Cube 2	493	21.91	
Cube 3	509	22.62	

Graph 5.2 Graphical representation of Compression strength test of 15% replacement concrete cube (7 day)

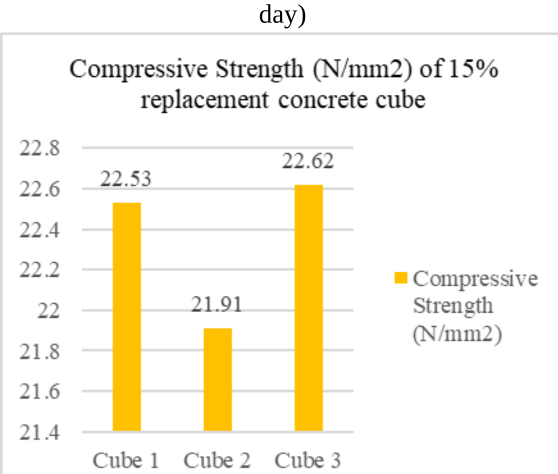


Table 5.3 Compression Strength test on 20% replacement steel slag cube (7 days) Concrete cubes.

Sr.No.	M25 (20%) Replacement Concrete Cube Testing (7 days)		
	Load Failure (KN)	Compressive Strength (N/mm^2)	Average
Cube 1	468	20.8	21.34
Cube 2	483	21.46	
Cube 3	490	22.78	

Graph 5.3 Graphical representation of Compression strength test of 20% replacement concrete cube (7 day)

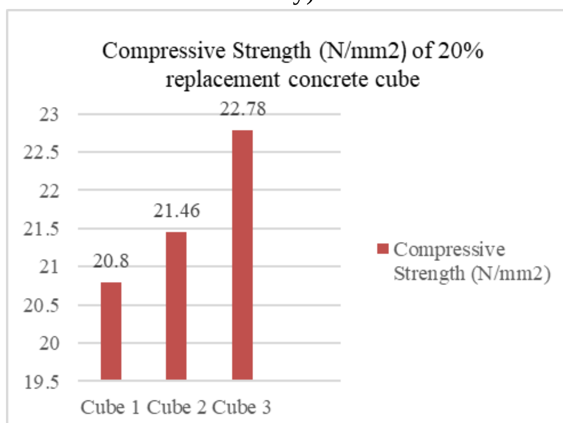


Table 5.4 Comparison on compression strength test on Average of Normal OPC concrete, 15% replacement steel slag cube and 20% replacement steel slag cube (7 days).

Sr.No.	Comparison on compression strength test on average of M25 normal and replacement concrete cubes		
	Average of Compressive Strength test (N/mm^2) normal	Average of Compressive Strength test (N/mm^2) 15% replacement	Average of Compressive Strength (N/mm^2) 20% replacement
Cube 1	21.61	22.36	21.34

Graph 5.4 Graphical representation of Comparison on compression strength test on average of Normal OPC

concrete and replacement (15% and 20%) steel slag concrete.

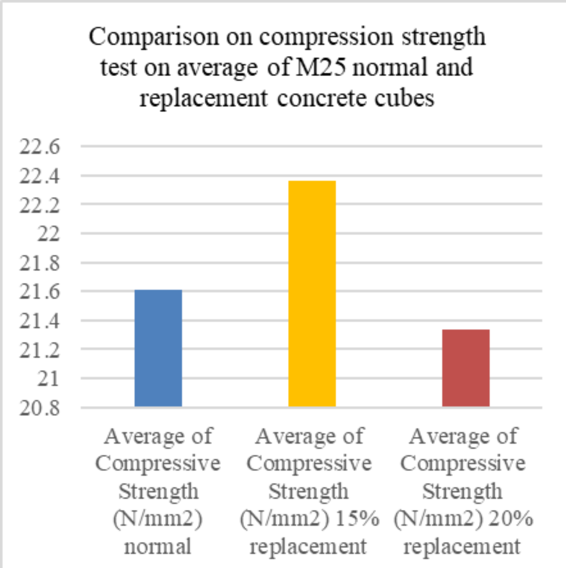
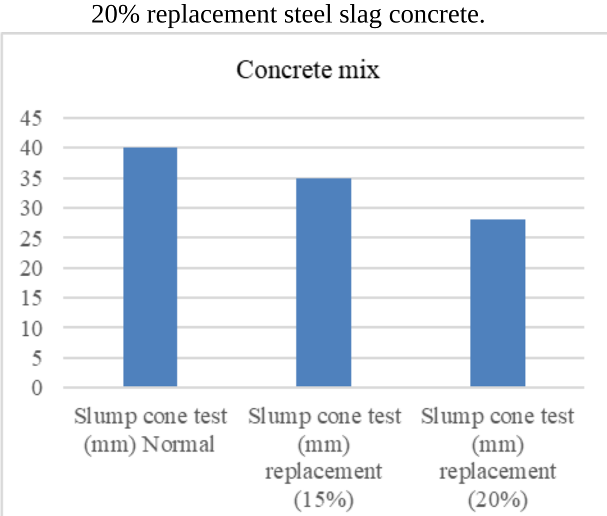


Table 5.5 Comparison on Workability of Normal OPC concrete and replacement (15% and 20%) steel slag concrete.

Sr. No	Comparison on normal and replacement slump cone test mix.		
	Slump cone test (mm) Normal	Slump cone test (mm) replacement (15%)	Slump cone test (mm) replacement (20%)
Concrete mix	40	35	25

Graph 5.5 Graphical representation of Compression strength test of Normal OPC concrete and 15%and 20% replacement steel slag concrete.



CONCLUSION

1. From the result it is observed that the compressive strength is highest at 15% replacement of Coarse aggregate by steel slag whereas at 20% replacement of coarse aggregate by steel slag there is reduction in strength.
2. For normal conventional concrete the average result of compressive strength came out to be 21.61 N/mm^2 while compare to 15% steel slag concrete and 20% steel slag concrete the average result of compressive strength came out to be 22.36 N/mm^2 and 21.34% respectively.
3. For 15% steel slag replacement in place of coarse aggregate**,** there is a slight increase in compressive strength compared to normal OPC concrete, ranging from 1% to 2%. The slight improvement in strength may be due to shape, size and surface texture of steel slag aggregates, which provide better adhesion between the particles and cement matrix**.**
4.The workability of concrete is reduced when % of replacement is increased to 15% and 20% when compare with normal conventional M25 grade of concrete. This suggests that there is an optimal replacement percentage of Steel slag that benefits the use of steel slag as coarse aggregate generally increased the unit weight of concrete mixtures.
5. This result suggests that while steel slag continues to contribute to the strength development of the concrete, the effect is not as pronounced as with 20% replacement. With higher level of replacement of coarse aggregate by steel slag there was slightly bleeding and segregation tendency. The strength may be affected with time and so long-term effects on hardened properties of concrete which require further investigation.

REFERENCES

[1] Collions RJ. “Waste products as a potential replacement for aggregate.” *In: Proceedings of the fourth international ash utilization symposium March 24-25, St. Louis, MO; 1976 .*

[2] Montgomery DG, Wang G. instant – “Chilled steel slag aggregate in concrete – strength related properties.” *Cement concrete Res 1991; 21(6):1083-91.*

[3] MansoJ, Polanco J, Losanez M, Gonzalez JJ. "Durability of concrete made with EAF slag as an aggregate." *Cement concrete compos 2006; 28(6):528-34.*

[4] Li YF,Yao Y, Wang L."Recycling of industrial waste and performance of steel slag green concrete." *JCent South Univ Tech 2009.p.419-26.*

[5] E.Taskiridis, G.D. Papadimitrious, STsivilis, et al., "Utilization of steel slag for Portland cement clinker production." *J. Hazard Mater.152(2)(2008) 805-811.*

[6] C.Shi, "Steel slag its production processing , characteristics, and Cementitious properties." *ASCE J. Mater. Civil Eng. 16(3) (2004) 230-236.*

[7] Akihiko Y, Takashi Y. "Study of utilization of steel slag as coarse aggregate for concrete." *Akshikaya Kogyo Daigaku Kenkyu Shuroku 1996:23:79 / 85.*

[8] Alnuaimi S (2005) "Use of steel slag as a replacement for coarse aggregate in reinforced concrete slender columns". *the WIT e Lib, Paper ID = 20138.*

[9] Hwang CL, Laiw JC. (1989) "Properties of concrete using steel slag as a substitute for coarse aggregate", *the 3rd international conference, SP11482, pp 1677 – 95.*

[10] Mohammed, T. U., Hasnat, A., Awal, M. A., Bosunia, S. Z. (2015), "Recycling of Brick Aggregate Concrete as Coarse Aggregate", *Journal of Materials in Civil Engineering, ASCE.27*

[11] Sandhu R. S., Singh, J., Dhanoa, G. S. (2015), "Use of Air Cooled Blast Furnace Slag (ACBFS) as Coarse Aggregates – A Case Study". *International Journal of Innovations in Engineering Research and Technology (IJIERT). 2(4), 1-10.*

[12] Padmapriya, R.; Bupesh Raja, V.K.; Kumar, V.G. and Baalamurugan J.: "Study on Replacement of Coarse Aggregate by Steel Slag and Fine Aggregate by Manufacturing Sand in Concrete", *International Journal of ChemTech Research, 8(4), 1721-1729, (2015).*

[13] Anifowose, M.A.; Adebara, S.A.; Odeyemi, S.O.; Olahan, A.B. and Aliyu, T.: "Density, Workability and Compressive Strength Assessment of Steel Slag In Concrete": *ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering, Tome X [2017], Fascicule 4 [October -December], 63-67, (2017).*

[14] Dubravka Bjegovic´, Goran Vrhovac, Ivanka Netinger, (2011), 'Utilization of steel slag as an aggregate in concrete', Materials and Structures. *International Journal of ChemTech Research, 2011.*

[15] Padmapriya, R.; Bupesh Raja, V.K.; Kumar, V.G. and Baalamurugan J.: "Study on Replacement of Coarse Aggregate by Steel Slag and Fine Aggregate by Manufacturing Sand in Concrete", *International Journal of ChemTech Research, 8(4), 1721-1729, (2015).*

[16] Dubravka Bjegovic´, Goran Vrhovac, Ivanka Netinger, (2011), 'Utilization of steel slag as an aggregate in concrete', Materials and Structures. *International Journal of ChemTech Research, 2011.*

[17] Juan M Manso, Juan A Polanco, and Javier J Gonzalez (2004), "Electric Arc Furnace Slag in Concrete", *Journal of Materials in Civil Engineering, Vol. 16.pp 639-645.*

[18] Abdul Kadar, J. and Dhanalakshmi, G.: "Experimental Investigation on Concrete by Partial Replacement on Cement by Bentonite and Coarse Aggregate by Steel Slag", *International Journal of Innovative Research in Science, Engineering and Technology, 5(6): 10302-10309, (2016).*

[19] Chinnaraju, (2013) "Study on concrete using steel slag as coarse aggregate replacement and eco sand as fine aggregate replacement ", *Geotechnical Engineering Limited for steel making slag Technical committee*, April 1993.

[20] Anastasiou, (2015) " Utilization on fine recycled aggregates in concrete with fly ash and steel slags", *Magazine of concrete Research, Vol 19, pp59.*

[21] Adegoloye, (2013) "Concrete made of eaf slag and and slag aggregates from stainless steel process: mechanical properties and durability", *International journal of Engineering, Vol 324 pp45.*

[22] IS: 516-1959 method of test for strength of concrete.
[23] IS 4031-2 (1999) for fineness test procedure.
[24] IS 4031-11 (1998) for specific gravity of cement
[25] IS 383:1970 for sieve Analysis of Fine and Coarse Aggregate
[26] IS 12269: 1987 for physical properties of Cement
[27] IS 383: 2016 for physical properties of steel slag