

Experimental Study on Concrete Using Steel Scrap and Foundry Sand as Partial Replacement of Fine Aggregate

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Abstract

Waste Foundry Sand (WFS), is generated from cast metal industry is produced in quantities exceeding 110 million tons annually. Being a high-quality silica sand, it poses a solution for reuse within concrete as a fine aggregate substitute; addressing the increasingly critical issue of foundry waste generation and mitigating the extra extraction of natural aggregates for concrete production in line with Indian government notifications. It is widely known that partial WFS substitution as a fine aggregate within concrete is not only acceptable but beneficial, however the variability in the properties of WFS concrete has yet to be systematically tracked and categorised. Review provides detailed assessment of the typical impact of WFS on concrete performance, highlighting variability in properties, and recent advancements for best effect. Analysis of the lesser examined facets, such as WFS treatment and combination with supplementary cementitious materials is undertaken to provide a robust methodology for WFS concrete optimisation via effective research collation and impact categorisation. Existing studies on long-term durability, and life cycle assessment in terms of both environment and economics, are highlighted as lacking comprehensive insight and thus create a framework for future research.

Concrete being the most extensively used building materials in the entire world because of its versatility and resilience. The concrete industry is evolving, nevertheless, and can now serve a wider variety of customers. The building industry is fully aware of the importance of implementing environmentally friendly policies and practices that increase productivity, product quality, and energy output. One of the major problems with environmental concerns and a lack of space for landfills is the practice of burying trash and food leftovers. The major goal of this study is to establish the maximum allowable replacement percentage of waste foundry sand for sand in concrete without compromising the material's durability or strength properties. The mechanical properties of concrete that included these two waste materials increased by 20 %, but those that included more than 30 % replacement had the opposite effect.

Keywords : Steel Scrap, Waste Foundry Sand, Compressive Strength, Environment

1. Introduction

Waste generated or by-products that are formed during the process are impactful on the environment and have adverse effect. Output that comes in has to go somewhere. And it cannot just be left out as waste. Hazardous waste is dangerous and harmful to the environment and India generates more than 1.50 lakh metric tons of waste per day and the sad scenario is that about 80% of it is dumped and only 20% is processed. And this enhances the mounts on landfill sites. The rate of hazardous waste is increasing by 2-5% every year and about 74.6 lakh tons of hazardous waste is generated annually in India. Industrial waste is the one produced during the manufacturing of different products from factories, manufacturing shops, industries,

etc. This is the waste that is considered waste during the process, and thrown into the dumping grounds or given for treatment. However, we can introduce methods to retreat and reuse this waste in the construction industry. So recycling is the most significant step we can use to reduce

negative impacts. But the chaos in industrial sectors with no proper solutions or thoughts over the reusing and treatment of waste is common throughout the country. Furthermore foundry Industries are booming and majorly practiced in Indian Industrial sector. Also, Foundry Industry has been playing a good and significant role since the industrial revolution.

India is the one of the largest in casting and expected to grow appreciably in the future. As casting production in the year 2018 was about 11mn tones and will be increasing at a compound annual growth rate (CAGR) of ~12.7% from 2018 until 2023 [4]. Also, there are about 5000-7000 foundry units

currently in India out them most of them are small scale industries with foundries. Belgaum, Jalandhar, Coimbatore, Kolhapur, Hyderabad, and Rajkot have the major foundry industry sectors such a foundry industries produce the waste sand, waste slag, chemicals, etc. but the waste sand generated is in enormous amount. Annually about 3 million tons of waste foundry sand (WFS) is generated in India through different foundry units. As such amount of waste sand is generated and if not treated properly will be problematic for nature and humans.

Here comes the problem with provided solution and scope for sustainable development. As generation and consumption of the waste foundry sand allow sustainable development factors

in places where enormous foundry industries exist as in India

Concrete is employed as a building material across the world, because of its tenacity and availability. In this era, imperishable advancement is a top priority. Granite, sand, and cement are basic building components that are extensively used in the construction industries to produce concrete. Cement production consumes a large amount of energy and relies on naturally produced elements like shale and limestone for manufacturing, which could contribute to a potential shortage of those resources. Moreover, sand shortage is increasing by virtue of its usage in manufacturing sector. Sand shortfalls disrupt the ecosystem also make sand from domestic products more expensive. Hence many scholars and technologists have been quoted to look for and develop novel materials that rely on renewable resources as a consequence of increasing worry over the depletion of resources including environmental pollution. They include the utilization of residues and waste products for new constructions. A large portion of such remnants is being employed as aggregate to produce lightweight concrete. Civil engineers have really been confronted with the task of converting by-products of industrial sectors into useful materials for construction due to the high demand implanted in the construction industry, particularly in the last decade, as a result of the growing population that provokes a persistent scarcity of building materials. To solve the problems mentioned herein, a substitute must be found for use in building construction. As a cement alternative to concrete, WFS comes. When creating structural grade mortar and concrete, Assessment of the utilization of WFS as a partial substitution for cement.

Examination of the potentiality of reusing waste foundry sand for concrete by substituting it for a portion of the fine aggregate. The mixture with 30 % WFS may provide more adhesion than other mixtures with WFS due to its particle size distribution. This study's goal is to examine how concrete that contains waste foundry sand in the range of 0 to 35 % partial substitutes for sand and cement respectively, behaves. The M25 concrete grade's mechanical and durability characteristics have been shown to be an alternative for usage in building construction.

2. Literature Review

Addition of steel scrap in concrete was found to be beneficial to make it more workable, in M20 concrete in which Compressive strength can be increased to 1.5 % by weight and corresponding compressive strength was 28.4 N/mm² in the journal.

Strength Characteristics Analysis of Concrete Reinforced With Lathe Machine Scrap

by Zeeshan Nissar Qureshi¹, Yawar Mushtaq Raina², Syed Mohd Asgar Rufaie³

on July August 2019.

Effect of Lathe Machine Waste on Strength of Concrete journal showed an increase of 28.61% for 0.4% dosage, 34.9% for 0.8% dosage and 43.46% for 1.2% dosage. Published in August 2023.

One more Conducted test and the Results from the test show that the addition of steel scrap waste remarkably increases the strength of concrete. Since, concrete is weak in tension, it is seen that the tensile Strength of Concrete also shows astonishing patterns in strengthening of concrete using lathe scrap waste journal By Mohdamirsheikh in October 2020

Characteristics of Concrete Containing Waste Foundry Sand and Slag Sand by JOJU JOSE showed Compressive strength, split tensile strength, modulus of elasticity and flexural strength of concrete decreased with the increase in waste foundry sand. The replacement of slag sand with waste foundry sand up to 15% is desirable, as it doesn't adversely affect the strength properties of concrete in June 2018.

Application of Foundry Waste Sand In Manufacture of Concrete by Eknath P.Salokhe¹, D.B.Desai² finds as

1. It gives low slump mainly due to the presence of very fine binders, so these mixtures require high superplasticizer dosage in order to maintain a good workability. 2. Compressive strength at 7 days of both ferrous & non ferrous mixtures increases as compared to the ordinary mix. 20% FWS of both types of sand. However 20% ferrous WFS addition gives more value of compressive strength than 20% non ferrous FWS addition. Studied in November 2019

Incorporation Of Waste Foundry Sand by Gurpreet Singh, studies revealed that in concrete WFS can be effectively used as fine aggregate

It is observed by the research that there is 3.7%, 5.6%, 6.29% and 6.02% increase in Modulus of elasticity after 28 days of curing at replacement of 10, 20, 30 and 40% respectively. In July 2018

Sustainable Concrete Development Using Foundry Sand: Strength and Durability Assessment by Pooja Govindsingh Pawar.

Utilizing Waste Foundry Sand (WFS) in concrete mixes offers a compelling solution for boosting performance and promoting sustainability at 20% in May 2023.

3. Materails and Methods

The research follows a structured approach starting with material collection and testing to ensure quality and suitability.

Concrete mixes are prepared by replacing natural aggregates with lathe machine steel scrap and foundry sand. Then concrete cubes are casted and tested

Finally, all results are analyzed statistically to identify the best and sustainable mix that meets performance standards for cement concrete with lathe machine as scrap and foundry sand.

3.1 Material used

Cement having specific gravity of 3.14

With initial Setting Time of 40 Minutes

Final Setting Time of 7 hours 50 minutes,

Standard Consistency 27%, Coarse Aggregate Size 20mm, having Shape Angular with fineness modulus 3.3

Specific Gravity 2.64

Fine Aggregate

Natural river sand which is easily available in market which confirms IS 383-1970 zone-II whose size is less than 4.75mm and of specific gravity 2.6 with fineness modulus of 2.91 is used in experiment

Water as Portable water used in experiment. PH value of water is greater than 6; recommended by IS code

Steel scrap

Steel scrap is waste material produced by working on the lathe machine when used for shaping metals. We have used mild carbon steel scrap in specimens.

Lathe scrap Fibre properties

Average Length (mm) 1-50 Average

Width (mm) 1.50–2.00

Average thickness (mm) 0.30–0.60

Aspect Ratio 50–100

Young's modulus (GPa) 200

Tensile strength (MPa) 970–1190

Density (kg/m³) 7850

Specific Gravity 7.85

Foundry Sand

Place where metals and alloys are melted and solidified in moulds to obtain shapes of a particular kind, is called foundry and byproduct which is obtained from a casting of ferrous and nonferrous casting is foundry sand or also called WFS(waste foundry sand). Foundry sand contains high-quality silica and is fine in size. This silica sand is used for making the casting moulds. And the sand is used and when reused several times and becomes waste at the end, thus living behind the WFS (waste foundry sand), which if not dumped properly is harmful and hazardous. But it can be used effectively included in the construction industry.

Natural sand's fineness modulus was higher than waste foundry sand's but its bulk density was lower.

Physical properties of waste foundry Sand

Properties Values

Density (kg/m³) 1645

Fineness modulus 1.81

Specific gravity 2.41

Water absorption (%) 3.78

Moisture content (%) 3.28

3.2 Mix proportions

Concrete of M25 grade is prepared with having steel scrap of percentage of 1.5%. 155.98kg/m³ as the best strength found at this value, thereafter foundry sand in proportion of 0%, 25%, 30% and 35% was taken with cement 398 kg, fine aggregate 761 coarse aggregate 1140 water 199, all values in per metre cube.

Accordingly fine aggregate was replaced as per 0%, 25%, 30%, 35%.

3.3 Sample preparation and curing

All ingredients of the concrete to be proposed and formed are mixed and a cube is formed to test at preliminary stage for having an idea of a generalised mechanical stress.

Take a mix as per given proportion which is as follows

Cement : Fine Aggregate : Coarse Aggregate

For finding the compressive strength, cubes of size 15cm×15cm×15cm are casted.

The fine aggregate and cement are mixed & blended then coarse aggregate is added and mixed until it is uniformly distributed. Add water and mix it until concrete appears to be homogeneous and of desired consistency.

Now concrete is casted into moulds and compaction is done. Moulds from concrete specimens are removed after 24 hours and are kept in water until taken out for testing.

Steel scrap and foundry sand are mixed according to varied proportion.

3.4 Testing Procedure

The following tests were conducted as per the Indian code provisions:

Rebound hammer test: Rebound hammer testing is done as per IS13311 (Part2):1992.

Rebound hammer test is done as nondestructive test and it can be used for assessing the compressive strength and quality of concrete from various graphical correlations. The plunger of the rebound hammer is pressed against the surface of the specimens and the impact gives a reading noted as rebound number. A number of readings are taken and through graphs and correlations compressive strength is worked out.

Compression test: The compression testing is done afterwards which gives more accurate values. The samples are placed in the universal testing machine

The load is applied gradually at the rate of 140 kg/cm²/minute until the specimens fail.

The maximum load at which it fails is recorded and compressive strength is determined

Split tensile test: It is an indirect method of testing tensile strength of concrete using a cylinder which splits across the vertical diameter. The length of the specimens shall not be less than the diameter and not more than twice the diameter. We prepared specimen of specifications: Diameter of specimen d=15cm Length of specimen l=30cm

4. Result and Discussion

Different data for different tests are found out as workability, compressive strength, splitting tensile strength test.

4.1 Workability

Workability value reduced as when different workability test was done. Slump reduced from 65mm at 0% steel scrap to 12mm at 1.5% steel scrap.

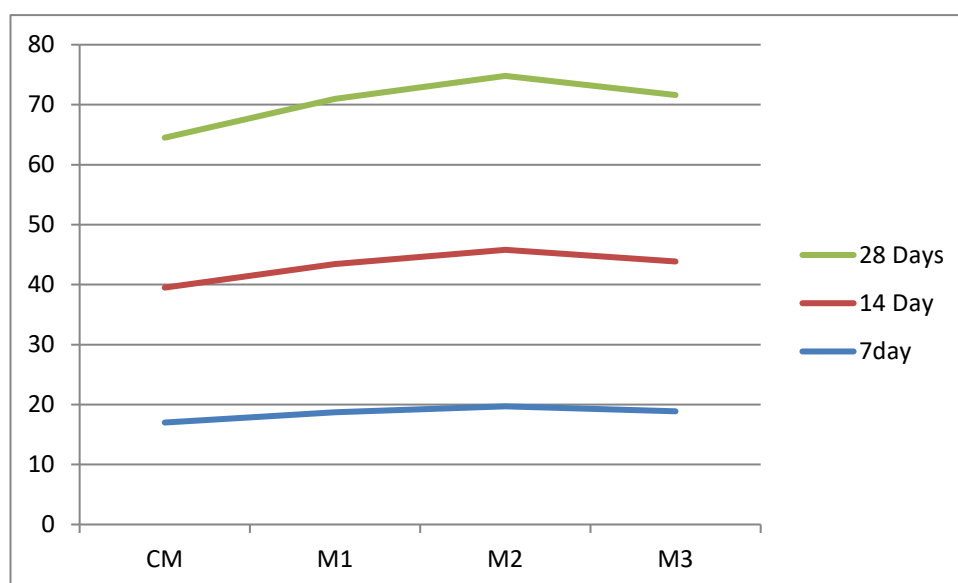
Steel scrap makes interlocking stronger than other so strength increase with reduced workability.

4.2 . Compressive Strength Test

Compressive strength test was conducted on various specimens and results are obtained as follows

Table 4.1: Compressive Strength for Various Mixes

Mix ID	Steel Scrap	Foundry Sand	7day	14 Day	28 Days
CM	0	0	17	22.5	25
M1	1.5	25	18.7	24.75	27.5
M2	1.5	30	19.7	26.1	29
M3	1.5	35	18.87	24.975	27.75



Graph 4.1 : Compressive Strength for different mixes

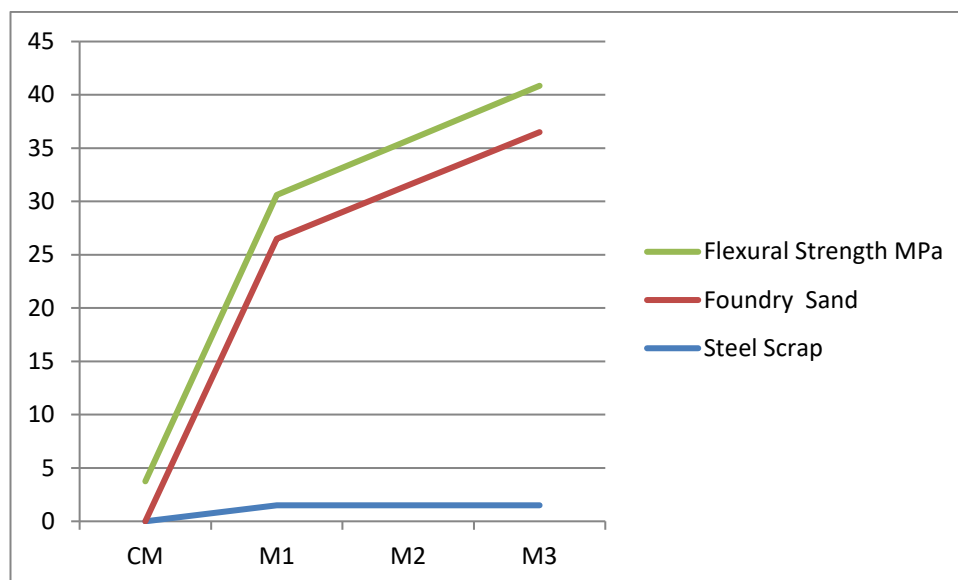
Flexural Strength:

It shows similar trend in somewhat extent as compressive strength test.

Flexural strength comes out to be as follows.

Table 4.2 : Flexural Strength of Beam Specimen (28 days)

Mix ID	Steel Scrap	Foundry Sand	Flexural Strength MPa
CM	0	0	3.75
M1	1.5	25	4.125
M2	1.5	30	4.218
M3	1.5	35	4.35


Graph 4.2 : Flexural Strength of beam specimen (28 days)

4.3 Water Absorption

Water Absorption values are higher for concrete containing waste foundry sand reaches upto 15 % of the water to sand ratio. Water absorption Characteristics are given below by test

Table 4.3 Water Absorption Test Result

Mix ID	Steel scrap	Waste foundry sand	Water absorption
CM	0	0	3%
M1	1.5	25	8%
M2	1.5	30	11%
M3	1.5	35	15%

4.4 Acid Resistance

Acid resistance values found to improve

Table 4.4 Weight Loss % after 28 days in 6% Acid

MIX ID	Steel Scrap	Waste foundry Sand	Weight Loss
CM	0	0	2.6
M1	1.5	25	2.4
M2	1.5	30	3.1
M3	1.5	35	4%

5. Conclusion

By performing the research on various aspects of WFS with steel scrap and its potential applications in , concrete were done. The following conclusions are the result of this work:

Compressive Strength is maximum at 30 % replacement of fine aggregate with Waste Foundry sand, which is best at 28 days keeping values of steel scrap as 1.5%

Flexural Strength followed almost the same path with 30 % having highest strength with value of 4.35 MPa for M25 Concrete.

Water Absorption values are maximum for 35 % to be 15% as waste foundry sand absorb more amount of water.

In concrete, WFS showed impact on density, between 1.45% and 3%. Workability tends to decrease with increasing WFS, although a replacement of up to 10% does not present high variations. A higher replacement can result in losses from 20% to 80% of workability and incorporation of up to 20% of WFS in concrete decreases workability within a range of 3–17% due to inter particle sizes and impurities. The compressive strength can increased by up to 14% with 15% of WFS.

However, the loss of compressive strength becomes more evident starting from a 35% replacement.

- The Changes in the results found in workability, mechanical strength, and durability may be due to differences in composition, fineness modulus, cementitious material, and replacement rate used.
- The incorporation of WFS with steel scrap results in material cost savings ranging from 7.5% to 10%. This will depend on the degree of substitution and the prices of materials in each country.

In summary, while incorporating WFS with steel scrap in concrete offers environmental sustainability issues remain in workability and strength, particularly at higher replacement levels. By Pretreatment methods like water washing and acid treatment it can be made better performing but a careful mix design should be done due to variability in WFS properties.

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