IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Effect Of Replacement Of Fine Aggregates By Mill Scale On Properties Of Concrete And Manufacturing Of Interlocking Tiles

[1]Aadish P P, [2]Varsha C, [3]Abhishek C, [4]Ashwin Gopinath, [5]Aswathi K

[1]Student, [2]Student, [3]Student, [4]Student, [5]Assistant Professor

[1]Department of Civil Engineering

[1]Vimal Jyothi Engineering College, Kannur, India

Abstract: Concrete is one of the most widely used materials in construction, primarily composed of cement, water, and natural aggregates. However, the excessive extraction of natural sand has raised serious environmental concerns, including ecosystem disruption and depletion of riverbeds. As a result, the focus has shifted towards sustainable alternatives that incorporate industrial waste materials into concrete mixes. In this context, the present study investigates the use of mill scale, a steel manufacturing byproduct composed primarily of iron oxides, as a replacement for natural fine aggregates. A controlled mix of M20 grade concrete was designed, where sand was partially and fully replaced with mill scale at varying percentages 0%, 20%, 40%, 60%, 80%, and 100% by weight. The performance of each mix was assessed through tests on workability (slump test), compressive strength, split tensile strength, flexural strength, and density. Among these, the 40% replacement level showed significant improvement in strength properties, particularly in compressive, tensile, and flexural strength, indicating that mill scale can effectively enhance the mechanical performance of concrete. Additionally, the optimal mix was used to manufacture interlocking tiles, and their performance was evaluated in terms of load-bearing capacity, dimensional accuracy, and surface finish. This research demonstrates that mill scale not only improves concrete strength but also offers a sustainable solution for waste management and conservation of natural resources in the construction industry.

Index Terms: Mill Scale, Sand Replacement, Interlocking Tiles, Compressive Strength, Tensile Strength, Flexural Strength.

1. INTRODUCTION

Concrete is the most commonly used construction material worldwide. However, producing it with traditional methods and materials heavily affects the environment, contributing to around 22% of global greenhouse gas emissions. As demand for construction increases, there is a growing need to adopt sustainable practices by reducing the use of natural resources and promoting eco-friendly materials. Mill scale is a thin layer of iron oxides that forms on the surface of steel during the hot rolling process. It is dark bluish in color and contains iron in different forms (FeO, Fe2O3, Fe3O4). Though it initially protects steel from rust, it must be removed before painting or welding. Rich in iron content (about 70%), mill scale has potential applications not just in construction but also in producing iron powder and treating environmental waste. Mill scale, a by-product from steel production, can be reused in concrete as a partial substitute for fine aggregates like river sand. This not only helps reduce environmental problems caused by industrial waste but also limits the overuse of natural sand, which leads to riverbed erosion and depletion of groundwater. When used in the right proportion, mill scale can also enhance the strength and durability of concrete.The following literature reviews provide a summary of the existing research on mill scale in concrete and its feactures and use: E. Mahallati et al. (2006)[1]:The study explored using steel mill scale and granite powder as partial replacements in concrete to improve strength and sustainability. It aimed to reduce waste and environmental impact without compromising concrete quality.Jing Ming et al. (2020)[2]:This research examined how mill scale and steel types affect corrosion resistance in reinforced concrete. It showed that mill scale can influence the protective layer on steel, impacting durability in harsh conditions.Jinjie Shi et al. (2019)[3]:The study looked at how mill scale on steel affects corrosion at the steel-concrete interface. Findings help in understanding corrosion spread and improving reinforced concrete durability.Kattekola Srikar et al. (2021)[4]:The research tested using mill scale as a fine aggregate replacement in concrete. Results showed improved compressive strength and highlighted mill scale as a cost-effective, eco-friendly material.Kotaro Doi et al. (2020)[5]:This study investigated how mill scale on steel bars influences corrosion in mortar. It found that mill scale can delay corrosion in some cases but may also create weak spots.M A Khan et al. (2022)[6]:The study evaluated how adding mill scale to concrete affects strength and durability. It found that mill scale can enhance performance and supports sustainable construction.Murat Ozturk et al. (2020)[7]:The research used mill scale in mortar to provide both strength and electromagnetic shielding. It showed potential for use in areas needing EMI protection like hospitals and data centers.P Manikandan et al. (2023)[8]:This study used mill scale and granite waste in concrete to reduce environmental impact. Results showed good strength and durability, proving these wastes can be sustainable alternatives.Ruplali Baghel et al. (2020)[9]:The research tested mill scale and marble slurry in brick making. The bricks met strength standards and offered a sustainable solution by recycling industrial waste.Yogesh Iyer Murthy et al. (2021)[10]:This study explored how mill scale affects concrete properties. It found that low levels of mill scale can improve strength and workability, promoting sustainability in concrete production.


Fig.1 Mill Scale.

2. MATERIAL USED

2.1 Cement

Table 1: Properties of Cement.

No.	Material	Properties		Relevant code
1	Cement PPC 43 grade	Fineness	10%	IS: 12269-1987
2		Specific gravity	3.15	
3		Initial setting time	50mnt	

2.2 Fine Aggregates (M Sand & Mill Scale)

Table 2: Properties of Fine Aggregates.

No.	Material	Properties		Relevant code
1	Fine Aggregate (M Sand)	Fineness modulus	3.2	IS:2396 (part-1) - 1963
2		Specific gravity	2.63	
3		Bulking factor	8%	

Table 3: Properties of Mill Scale.

No.	Material	Properties		Relevant code
1	Fine Aggregate (Mill Scale)	Fineness modulus	3.16	IS:2396 (part-1) - 1963
2		Specific gravity	4.36	
3		Bulking factor	2%	

2.3 Coarse Aggregate

Table 4: Properties of Coarse Aggregates.

No.	Material	Properties		Relevant code
1	Coarse Aggregate	Fineness modulus	7.6	IS: 2396 (Part-1)- 1963
2		Specific gravity	2.74	
3		Maximum size	20mm	

3. EXPERIMENTAL STUDY AND RESULTS ANALYSIS

3.1 Chemical Analysis of Mill Scale

Table 5: Chemical Analysis of Mill Scale.

Parameters	Results (%)
Silicon (Si)	2.35
Phosphorus (P)	0.025
Chromium (Cr)	4.92
Nickel (Ni)	1.59

IS 383:2016 does not specify a permissible percentage for above mentioned compounds.Usually, the content of phosphorus should typically be less than 0.1%, while chromium is limited to 2% and nickel to 3% respectively. The presence of nickel and chromium enhances the corrosion resistance of the material.

3.2 Comparison Between Fine Aggregate & Mill Scale

Table 6: Mill Scale vs M Sand.

	Mill Scale	M Sand
Specific Gravity	4.36	2.63
Coefficient of Curvature (Cc)	1.04	1.03
Coefficient of Uniformity (Cu)	2.12	2
Fineness Modulus	3.16	3.2

The grading zone is same for mill scale and sand (zone ii). Sand particles are rounded and globular whereas mill scale particles are angular, flaky and irregular in shape. Hence, there is a slight variation in workability.The fineness modulus, coefficient of uniformity and coefficient of curvature for mill scale and M sand are approximately same.The higher specific gravity of mill scale compared to sand leads to an increase in the density of concrete

3.3 Concrete Test

3.3.1 Slump and Compaction Factor Tests

The experimental part satisfactorily conducted for all the six different mix proportioned concrete grades, the properties namely the workability characteristics were grouped type wise and analysed. The test result, analysis and comparison of test results are presented as detailed here. There were six different mix proportions considered for conventional sand concrete with sand replacements accordingly 0%, 20%, 40%, 60%, 80% and 100% with Mill scale. The workability and strength in different aspects are considered and analysed here.

Table 7: The Workability Characteristics of M20 Concrete.

Factors	Sand replacement by Mill scale for M20 grade concrete (1:1.92:3.12 w/c 0.55)					
	0%	20%	40%	60%	80%	100%
Slump (mm)	96	84	79	70	68	55
Compaction factor	0.96	0.92	0.89	0.85	0.76	0.68
Density (kg/m^3)	2574.17	2602.96	2820.23	3130.54	3385.17	3679.23

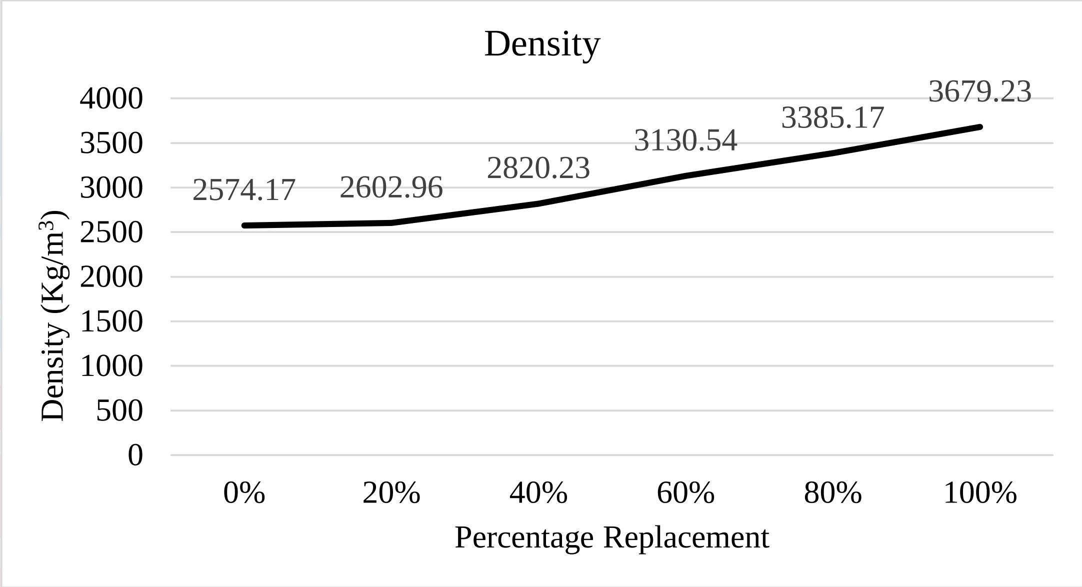

Fig.2 Density vs Percentage Replacement.

The slump value and compaction factor decrease with an increasing percentage of fine aggregate replacement by mill scale. However, the workability remains within the acceptable range of 50 to 100 mm. Additionally, the density increases with higher mill scale replacement, which in turn enhances the compressive strength of the concrete**.**

3.3.2 Compressive Strength Test

Table 8: Compressive Strength Test.

% of replacement	Date of casting	Load (KN)		Compressive strength (N/mm^2)	
		7th day	28th day	7th day	28th day
0	08/10/24	360	580	16	25.78
20	15/10/24	390	610	17.33	27.11
40	06/12/24	440	660	19.55	29.33
60	07/12/24	420	620	18.67	27.55
80	10/12/24	350	510	15.55	22.66
100	10/12/24	290	360	12.88	16

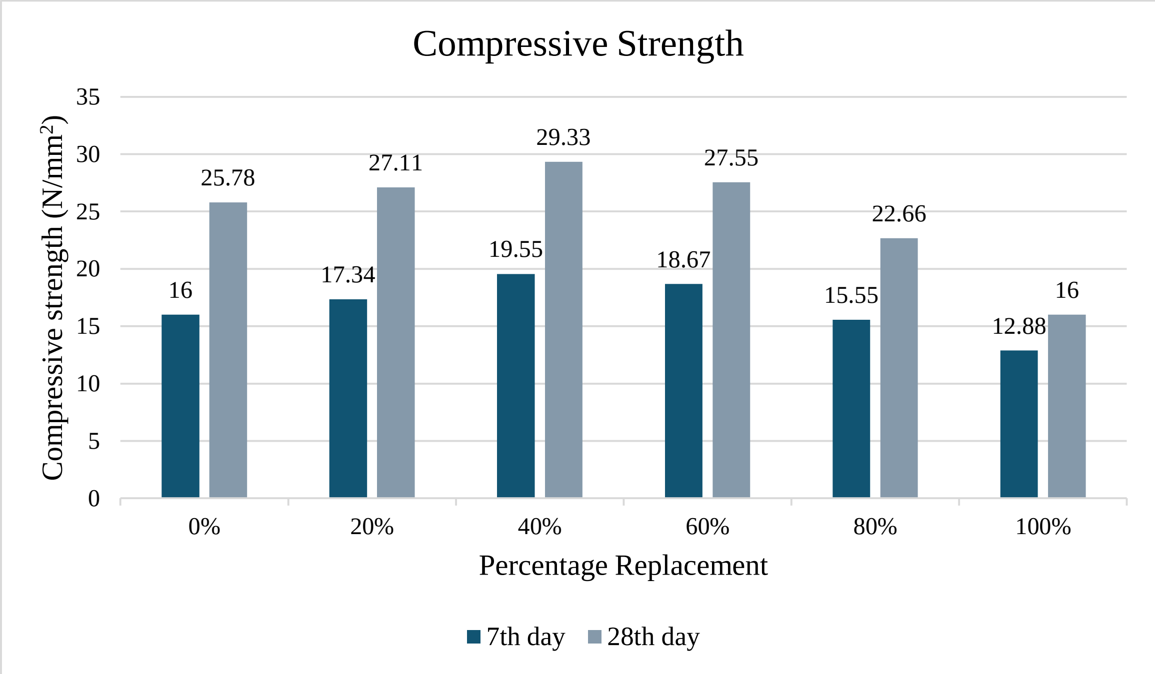

Fig.3 Comparison of Compressive Strength.

3.3.3 Split Tensile Strength Test

Table 9: Split Tensile Strength Test.

% of replacement	Date of casting	Load (KN)		Split Tensile Strength (N/mm^2)	
		7th day	28th day	7th day	28th day
0	08/10/24	230	310	3.25	4.38
20	15/10/24	250	320	3.53	4.53
40	06/12/24	270	350	3.81	4.95
60	07/12/24	330	380	4.66	5.38
80	10/12/24	260	300	3.68	4.24
100	10/12/24	220	290	3.11	4.1

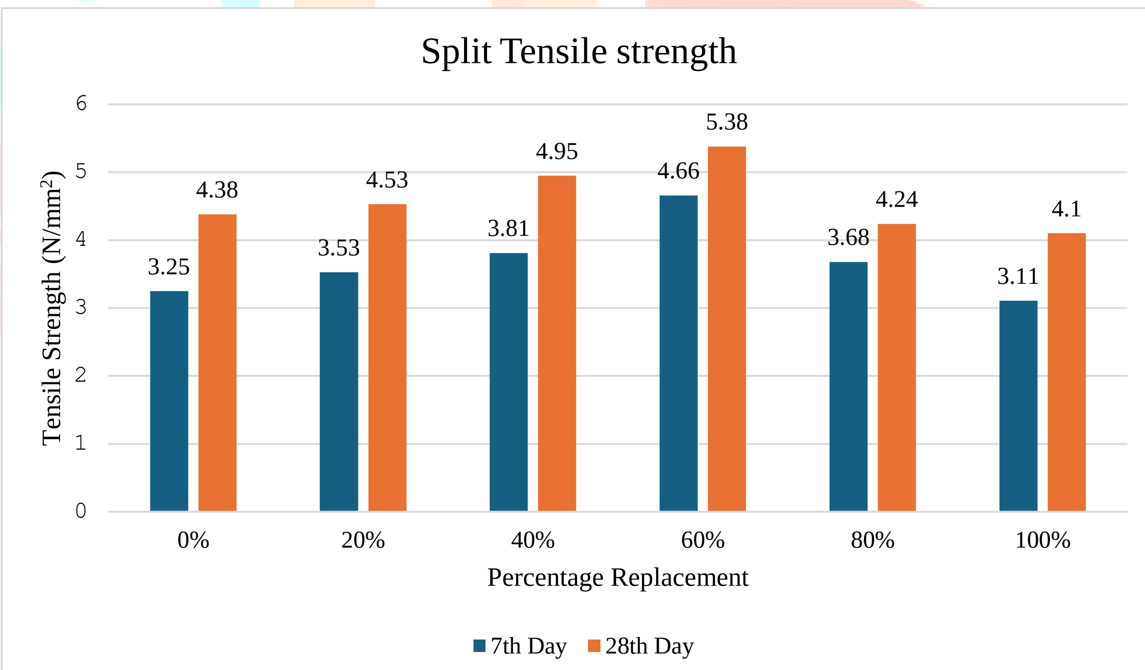

Fig.4 Comparison of Split Tensile Strength.

3.3.4 Flexural Strength Test

Table 10: Flexural Strength Test.

% of replacement	Date of casting	Load (KN)		Flexural Strength (N/mm^2)	
		7th day	28th day	7th day	28th day
0	08/10/24	7	11	3.5	5.5
20	15/10/24	8	13	4	6.5
40	06/12/24	8	14	4	7
60	07/12/24	4	9	2	4.5
80	10/12/24	3	6	1.5	3
100	10/12/24	1	4	0.5	2

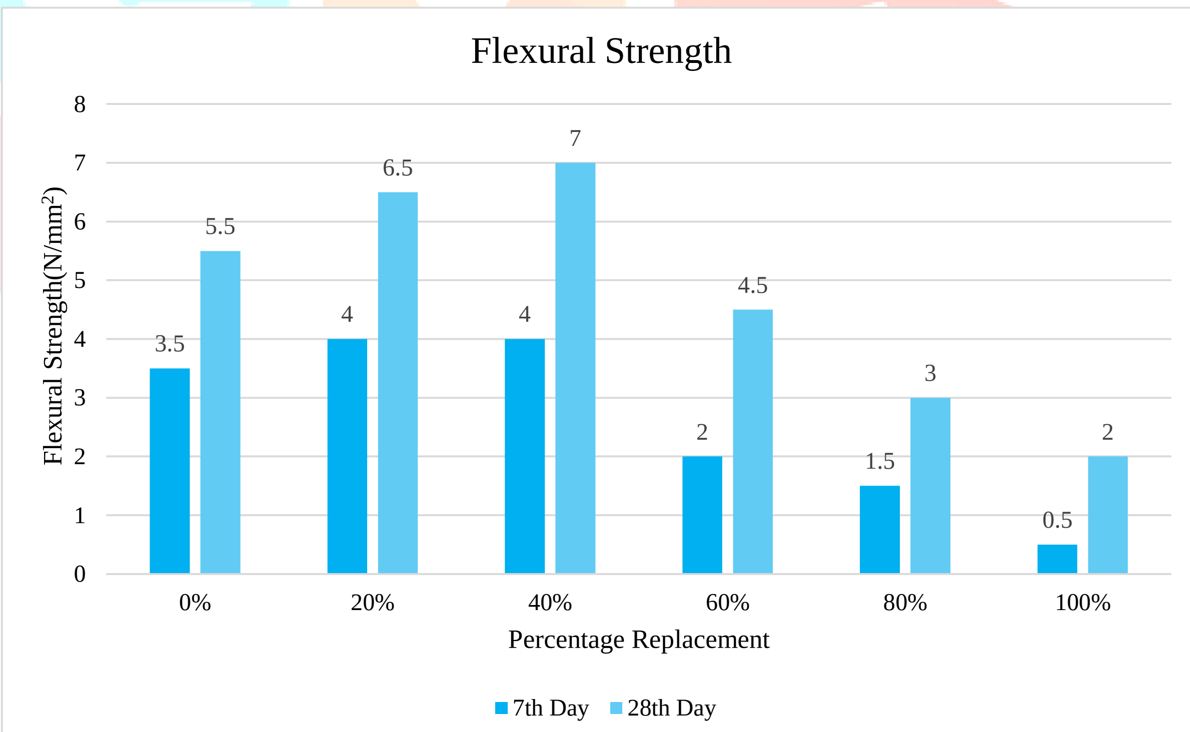

Fig.5 Comparison of Flexural Strength.

Based on the conducted tests, it was observed that at 40% replacement of fine aggregate with mill scale, the concrete exhibited a 13.78% increase in compressive strength, a 13.00% increase in split tensile strength, and a 27.27% increase in flexural strength compared to conventional M20 grade concrete.

Hence interlocking tiles are manufactured with 40% replacement of fine aggregate with mill scale.

3.3 Manufacturing of Interlocking Tiles

Interlocking tiles are modular flooring tiles designed to fit together like puzzle pieces, without the need for adhesives, grout, or nails. They lock into place using special edges, making installation quick and easy. Here manufacturing of interlocking tiles using M20 grade concrete, with 40% of fine aggregates replaced by mill scale.

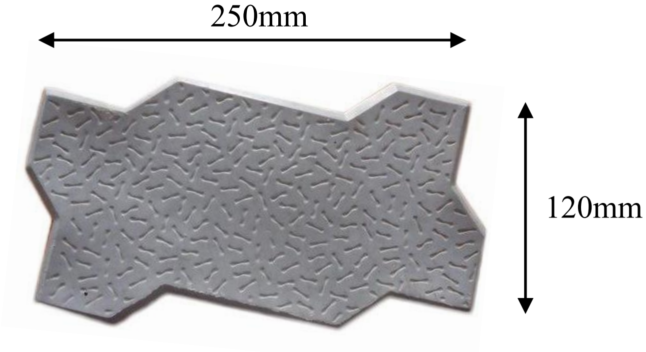

Fig.6 Interlocking Tile.

Fig.7 Manufacturing of Interlocking Tiles.

Here interlocking tiles are manufactured using concrete in which fine aggregate is partially replaced with mill scale. The objective is to achieve higher compressive strength while using a lower-grade concrete mix. To determine the optimal replacement percentage, a trial-and-error method was conducted with varying levels of fine aggregate replacement (0%, 20%, 40%, 60%, 80%, and 100%). Laboratory testing revealed that the highest compressive strength was obtained when 40% of the fine aggregate was replaced with mill scale. Therefore, this proportion was selected as the most suitable mix for producing durable and high-strength interlocking tiles.

3.4 Tests Conducted On Interlocking Tiles

3.4.1 Compressive Strength (IS 15658:2006)

Area of Block =306 cm^2

Thickness = 80 mm

Age of Block = 28 days

Correction Factor = 1.18

Table 11: Compressive strength of Interlocking Tiles.

SI No.	Specimen No.	Weight of the Specimen (Kg)	Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	C.P-1	5.98	1160	44.73	42.93
2	C.P-2	5.62	1080	40.87	
3	C.P-3	5.86	1120	43.18	

Fig.8 Compressive Strength Test on Interlocking Tiles.

3.4.2 Split Tensile Strength (IS 15658:2006)

Table 12 Split Tensile Strength on Interlocking Tiles.

SI No.	Specimen No.	Failure load per unit length (N/mm)	Split Tensile_Strength (N/mm^2)	Average Split Tensile Strength (N/mm^2)
1	ML25/W-00630/S1-01	260	2.1	2.2
2	ML25/W-00630/S1-02	270	2.2	
3	ML25/W-00630/S1-03	290	2.4	

Fig.9 Split Tensile Strength on Interlocking Tiles.

3.4.3 Flexural Strength (IS 15658:2006)

Table 13: Flexural Strength Test on Interlocking Tiles.

SI No.	Specimen No.	Flexural Strength (N/mm^2)	Average Flexural Strength (N/mm^2)
1	ML25/W-0630/S1-01	2.4	2.6
2	ML25/W-0630/S1-02	2.7	
3	ML25/W-0630/S1-03	2.6	

Fig.10 Flexural Strength Test on Interlocking Tiles.

3.4.4 Water Absorption Test (IS 15658:2006)

Table 14: Water Absorption Test on Interlocking Tiles.

SI No.	Specimen No.	Weight of Saturated Specimen (Kg)	Dry Weight of Specimen (Kg)	Water Absorption (%)	Average Water Absorption (%)
1	W.P-1	5.56	5.35	4	4
2	W.P-2	5.83	5.63	3.6	
3	W.P-3	5.62	5.38	4.4	

The obtained a compressive strength of 42.93 MPa, flexural strength of 2.6 MPa and split tensile strength 2.2 MPa for M20 grade interlocking tiles when 40% of fine aggregates were replaced with mill scale. As per IS 15658:2006, the permissible water absorption for interlocking tiles is 5%. The water absorption observed in our tests was 4%, which is within the acceptable limit.According to IS 15658:2006**,** M40 grade interlocking tiles are recommended for medium traffic. Since the M20 grade interlocking tiles with 40% mill scale replacement meet the required strength criteria for medium traffic, they can be used for this application. However, since the split tensile strength and flexural strength of the M20 mill scale tiles are lower than the required values for medium traffic, they are more suitable for light traffic applications.

4. CONCLUSION

This study investigated the feasibility of using steel mill scale as a partial replacement for fine aggregates in concrete, particularly for the manufacturing of interlocking tiles. Mill scale and manufactured sand (M-sand) fall under the same grading zone (Zone II) and exhibit comparable grain size indices, indicating similar engineering behavior. However, due to the angular, flaky, and irregular nature of mill scale particles, a slight variation in workability was noted. Despite this, slump values remained within the acceptable range of 50 mm to 100 mm.

The use of mill scale resulted in a higher specific gravity, which in turn increased the density of concrete and significantly enhanced its strength properties. Replacing 40% of the fine aggregates with mill scale led to a 13.78% increase in compressive strength, 13.00% increase in split tensile strength, and a 27.27% increase in flexural strength compared to conventional M20 grade concrete.

The interlocking tiles produced with this optimized mix design achieved a compressive strength of 42.93 MPa, thereby satisfying the strength criteria for M40 grade interlocking tiles intended for medium traffic applications. Although there was a slight reduction in split tensile and flexural strengths compared to M40 standards, the values still exceeded the requirements for M30 grade tiles, making them a reliable and sustainable alternative for light traffic applications.

Thus, mill scale proves to be a promising substitute for fine aggregates, contributing to environmental sustainability by utilizing industrial waste and reducing dependence on natural resources, while also improving the mechanical performance of concrete products.

REFERENCE

[1] E. Mahallati, M. Saremi (2006), "An assessment on the mill scale effects on the electrochemical characteristics of steel bars in concrete under DC-polarization", Elsevier, *Cement and Concrete Research.*

[2] Jing Ming, Ph.D, Jinjie Shi, Wei Sun (2020), "Effects of Mill Scale and Steel Type on Passivation and Accelerated Corrosion Behavior of Reinforcing Steels in Concrete", *American Society of Civil Engineers.*

[3] Jing Ming, Jinjie Shi (2019), "Distribution of corrosion products at the steel-concrete interface: Influence of mill scale properties, reinforcing steel type and corrosion inducing method", *Cement and Concrete Research.*

[4] Kattekola Srikar, Dr. Marthi Kameswara Rao (2021), "The Benefits Of Using Refurbished Steel Mill Scale For Fine Aggregate On Concrete Performance", *Webology.*

[5] Kotaro Doi, Sachiko Hiromoto, Tadashi Shinohara, Koichi Tsuchiya, Hiteki Katayama, Eiji Akayama (2020), "Role of mill scale in corrosion behaviour of steel bars in mortar", *Corrosion Science.*

[6] M A Khan, M S Khan, A Jawad (2022), "A study of concrete incorporating steel mill scale waste", *Journal off mechanics of continua and mathematical sciences.*

[7] Murat Ozturk, Tolga Depci, Ersin Bahceci, Muharrem Karaaslan, Oguzhan Akgol, Umur Korkut Sevim (2020), "Production of new electromagnetic wave shielder mortar using waste mill scales", *Construction and Building Materials.*

[8] P Velumani, P Manikandan (2023), "Steel mill scale waste and granite production waste in concrete production-An experimental study", *Materials TodayProceedings.*

[9] Ruplali Baghel, Upender Pandel, Apoorva Vashishta (2020), "Manufacturing of sustainable bricks: Utilization of mill scale and marble slurry", *Materials Today-Proceedings.*

[10] Yogesh Iyer Murthy (2021), "On the Mechanical Aspects Concrete Containing Mill scale", *International Journal of Civil Enginering.*

[11] IS 383:1970, "Specification for Coarse and Fine Aggregates for Concrete", *Bureau of Indian Standards, 1970.*

[12] IS 456:2000, "Code of Practice for Plain and Reinforced Concrete", *Bureau of Indian Standards,2000.*

[13] IS 2396 (Part 1): 1963, "Methods of Testing Aggregates for Concrete", *Bureau of Indian Standards,1963.*

[14] IS 10262:2019, "Code for Concrete Mix Proportioning (Mix Design)", *Bureau of Indian Standards,2019.*

[15] IS 15658:2006, "Precast Concrete Blocks for Paving – Specification", *Bureau of Indian Standards,2006.*