Effect of Partial and Total Replacement of Fine Aggregate by Mill Scale on the Properties of Concrete

Arpit Chatter[1], Prof. J.N.Vyas[2]

[1]*M.Tech. Student, Department of Civil Engineering, MITM Ujjain, (M.P.), India*
[2]*Professor, Department of Civil Engineering, MITM Ujjain, (M.P.), India*

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Abstract - *Concrete is an artificial stones like material used for various structural purposes. Natural aggregate is a major ingredient of concrete which is mined and processed every year, which leaves a significant mark on the environment. Due to growing environmental concern innovations have been directed towards usage of waste material as replacements of natural material. The present work deals with the development of mill scale(iron chips type industrial waste) concrete with partial and total replacement of conventional sand with Mill scale and the study is made with systematic approach with sequential steps.*

A conventional M20 grade Cement is prepared. In the mix sand replacement by weight of 0%, 20%, 40%, 60%, 80% and 100% with Mill scale was considered. Concrete with these six different mix ratios were prepared and for the sake of exclusive reality, no plasticizer was used. For determination of compressive, tensile strength and flexural strength of concrete cubes are casted keeping water/cement ratio 0.5 for all mix proportions. For determination of compressive strength of concrete cubes Compression testing machine was used. Tensile strength of concrete is determined by indirect method (splitting tensile test) using UTM machine and 2 point loading test is performed for determining flexural strength of concrete. Results are compared for varying mill scale content and optimum mill scale content is found for highest strength value. During the preparation of cube workability and water absorption test of concrete also conducted for different mill scale content.

Investigation concludes that with increase in mill scale in concrete required higher workability value. Compression strength of concrete is maximum corresponding to 40-60 % mill scale content. Tensile strength and flexural strength of concrete is maximum corresponding to total replacement of mill scale content. It conclude that increase in mill scale content increases the compressive strength up to a certain limit and then decreases gives a pick value of strength between 40-60 % replacement level .Tensile and flexural strengths are increases as the replacement level increases.

***Key Words*: Mill scale, Compressive strength , Split tensile strength, Flexural strength , Workability characteristic , Sand replacement.**

1. INTRODUCTION

Concrete is the most popular building material in the world as such by its ecstasy, there is no substitute for concrete with conventional constituents. But sustaining the building activity in the long-term to meet the future demand for buildings by using the currently available energy-intensive materials and building techniques or technologies have become seldom possible. The construction industries contribute green house gas (GHG) emissions (22%) into the atmosphere and as the public concern are sensibly addressed regarding climate change resulting from the increased concentration of global warming and sea level rise; concrete technologists are facing the challenges of leading future development in a way that protects environmental quality while projecting concrete as a construction material of preference. Of course, the current environmental problems to technology choices that object the production of durable and environmentally friendly concrete are well related. The environmental impacts of the concrete industry by conservation of cement, aggregates, water or additives and admixtures can be reduced through resource productivity by conserving energy and material for concrete making and by improving the durability of concrete products. Even though the task is most challenging as it results and experiences in the scarcity of resource materials, it can be accomplished if pursued diligently through a possible way without much affecting the basics and requirements of concrete technology and construction techniques so far applied. In this series, globally, the problem of exploitation of conventional river sand is predominantly referred by all.

Study on properties of concrete is carried out with usage of mill scale in Portland cement concrete as a partial replacement for natural fine aggregates. Billons of tones industrial waste produced every year which is causing so many environmental problems. The problem of waste accumulation exist worldwide specially in densely populated country like India.. Hence to overcome the above said the waste product should be employed as construction material. On the other hand usage of river sand as fine aggregate in the concrete leads to exploitation of natural recourses, lowering of water table and erosion of river bed. If fine aggregate replaced by industrial waste by optimum percentage it will trim down the usage of fine aggregate in construction purposes thereby reducing the above ill effects. Understanding the behavior of concrete in terms of strength when mill scale waste is replaced in different proportion with fine aggregates is the focus of this research.

2.OBJECTIVE

The scope and objectives are study in the development of Mill scale concrete as detailed here.

- Investigation on the workability and strength characteristics of mill scale based concrete for sand replacement levels of 20%, 40%, 60%, 80% and 100% with Mill scale.
- Assessment of the comparison of characteristics of different replacement concrete after analysis of their experimental results.
- Assessment on the possibility of maximum replacement level of sand with mill scale in M20 grade concrete.
- Assessment on the possibility of 100% replacement of fine aggregate with mill scale in M20 grade concrete.
- Analyzing the results for comparison between sand concrete and mill scale concrete.
- Arriving at solid conclusions and recommendations.

3. MATERIAL USED

3.1Cement

Ordinary/Normal Portland cement (opc) of grade 43 is taken for this project as per IS 8992-1989.

Table -1: Properties of Cement

No	Material	Properties		Relevant codes
1	Cement OPC 43 grade	Fineness	5 %	IS: 12269-1987
2		Specific gravity	3.15	
3		Initial setting time	55 min	
4		Final setting time	525 min	

3.2Fine Aggregate/sand

Sand taken for this project was tested for following properties as per IS 2381 (Part1)-1963

Table -2: Properties of sand

No	Material	Properties		Relevant codes
1	Fine Aggregate (Sand)	Fineness modulus	2.71	IS: 2386 (Part-I) - 1963
2		Specific gravity	2.56	
3		Bulking factor	35%	

3.3 Mill Scale

Locally available Mill scale was the primary material used in this experimental work. Properties of mill scale are as follows

Table -3: Properties of Mill Scale

No	Material	Properties		Relevant codes
1	Fine Aggregate (Sand)	Fineness modulus	3.36	IS: 2386 (Part-I) - 1963
2		Specific gravity	2.03	
3		Bulking factor	47%	

3.4 Coarse Aggregate

Table -4: Properties of Coarse Aggregate

No	Material	Properties		Relevant codes
1	Coarse Aggregate (Sand)	Maximum size	12 mm	IS 383 – 1987
2		Fineness modulus	7.14	
3		Specific gravity	2.61	

4. EXPERIMENTAL STUDY AND RESULTS ANALYSIS

The experimental part satisfactorily conducted for all the six different mix proportioned concrete grades, the properties namely the workability and strength characteristics were grouped type wise and analyzed. 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 analyzed here.

4.1 Partial replacement of sand with mill scale

Table -5: The Workability and Strength Characteristics of M20 Concrete

Factors	Sand replacement by Mill scale for M20 Grade Concrete (1:1.5:3 w/c 0.5)					
	0%	20%	40%	60%	80%	100%
Slump(mm)	100	90	85	83	82	80
Compaction factor	0.92	0.87	0.84	0.82	0.81	0.80
Density (kg/cm3)	2452	2590	2656	2748	2832	2914
fcu7 (MPa)	13.99	14.83	16.13	15.84	15.36	15.10
fcu14 (MPa)	19.48	20.01	22.54	21.78	21.21	20.95
fcu28 (MPa)	21.20	22.20	24.80	23.75	23.47	22.95
ftcy (MPa)	2.21	2.24	2.32	2.38	2.39	2.41
fcr (MPa)	3.44	3.52	3.53	3.53	3.54	3.54

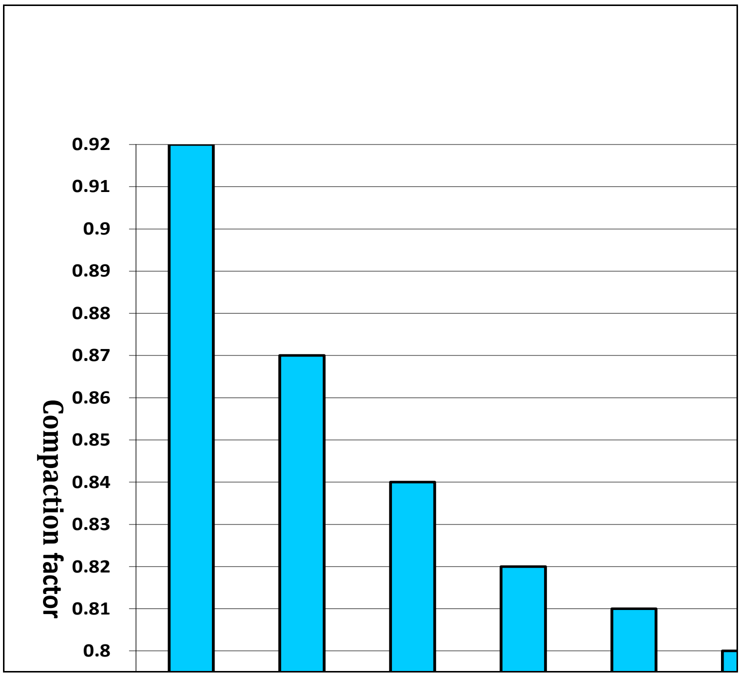
4.2 Total replacement of sand with mill scale

Table -6: Workability and strength characteristics of SC and MSC

No	Factors	SC	MSC	Remarks
1	Concrete Grade	M20		
2	Mix proportion	1: 1.5: 3 w/c = 0.5	1: 1.5: 3 w/c = 0.5	IS Method of design
3	Density	2452.12	2913.85	SC is more dance than MSC
4	Slump mm	100	80	SC is workable and MSC has segregation
5	Compaction factor	0.92	0.80	
6	fcu7 (MPa)	13.99	15.10	Difference (+7.9)%
7	fcu14 (MPa)	19.48	20.95	Difference (+7.5)%
8	fcu28 (MPa)	21.20	22.95	Difference (+8.25) %
9	ftcy (MPa)	2.21	2.41	Difference (+9.05)%
10	fcr (MPa)	3.44	3.54	Difference (+2.90)%

4.3Analysis for Workability Characteristics

The MC is coarser than sand but the amount of finer particles retained in sieve size between 300 micron to 150 micron is almost double that of sand that increased the water requirement. The MCC required water-cement ratio ranging between 0.42 and 0.45 with 60% to 100% replacement respectively. From the Chart 1, it was observed that the workability goes on reducing according to the percentage of sand replacement level in the slump test as well as compaction factor. For the concrete having totally sand replaced Mill scale concrete MCC, the same trend existed compared to standard concrete SC as detailed in chart 2.



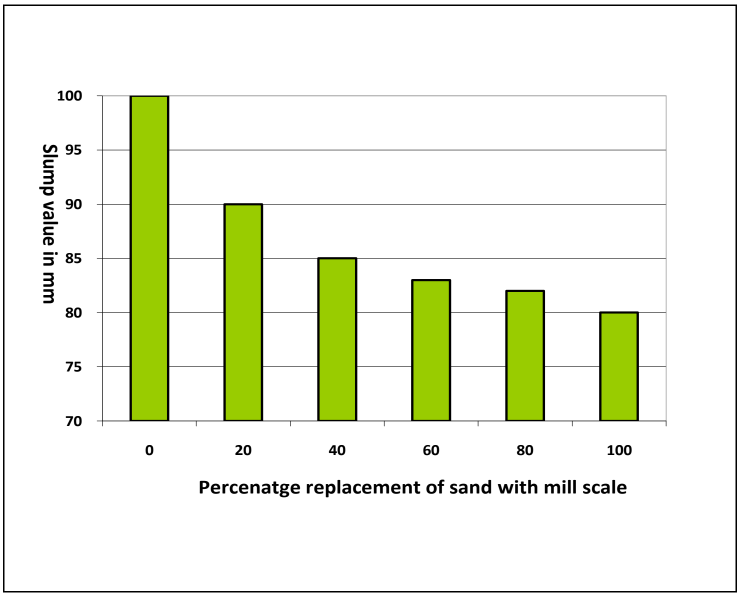


Chart -1: Comparison for workability test

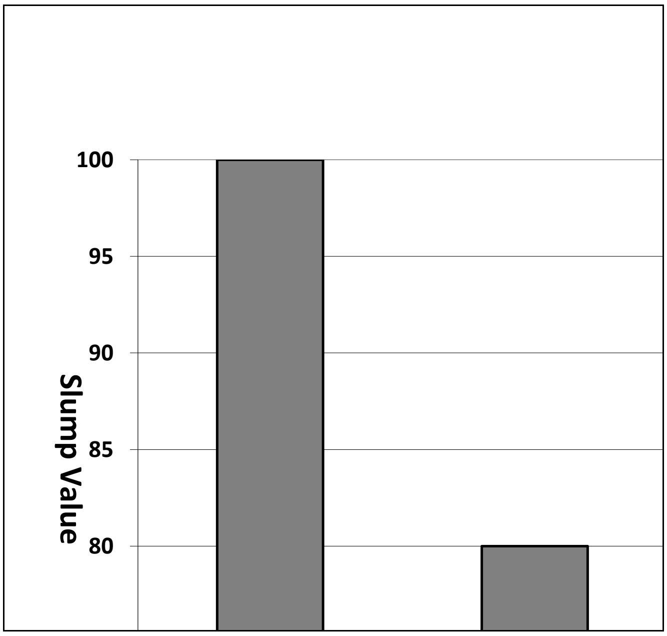


Chart -2: workability characteristic for SC & MSC for M20 concrete

4.4 Analysis for Density Characteristics

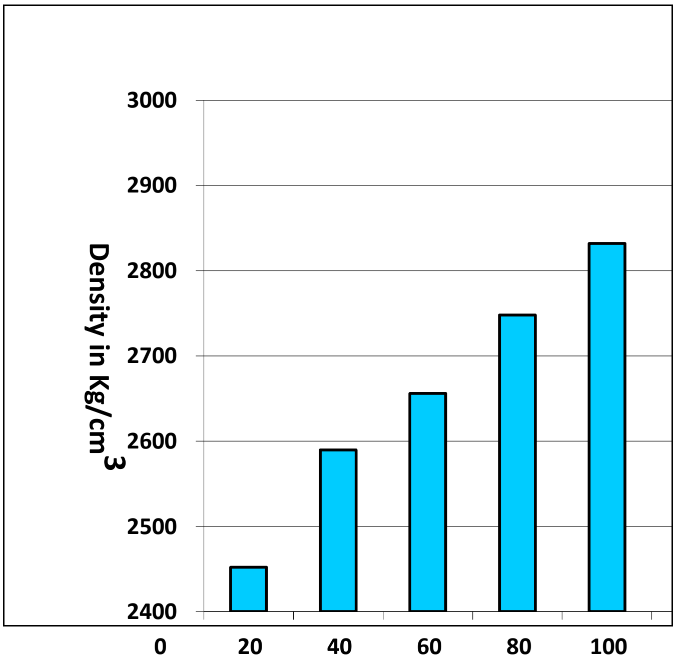


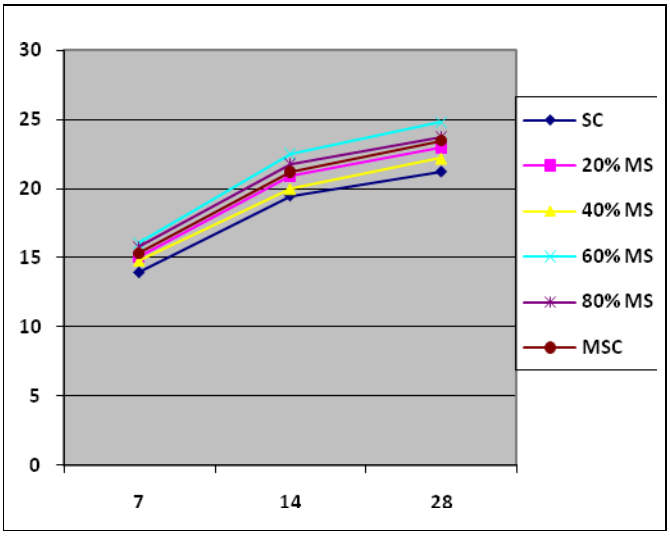
Chart -3: Comparison of Density of M20 Concrete

4.5 Analysis for Strength Characteristics

Even though the 7 day strength was used to assess the quality of the trial mix proportions, the rate of gain of strength in 7, 14 and 28 days of curing was made for comparison to study the variations if any due to percentage variation in the sand replacement levels.

4.5.1 Rate of Gain of Compressive Strength

The rate of gain of cube compressive strength up to 28 days is compared. The cube Compressive strength for concrete mixes with replacement of fine aggregate using mill scale is presented in Chart 4. It is observed that there is a reduction of only 7.09 % for MSC compared to SC and is directly proportional to the increase of sand replacement.



X Axis - Compressive strength in MPA

Y Axis – Age in days

Chart -4: Rate of strength development in M20 Concrete

4.5.2 Compressive Strength in 28 Days

The 28 day compressive strength of concrete grades based on testing cubes are presented in Chart 5. As seen, there is not much variation for the 28 day strength due to the variations in the percentage replacement of sand with mill scale.

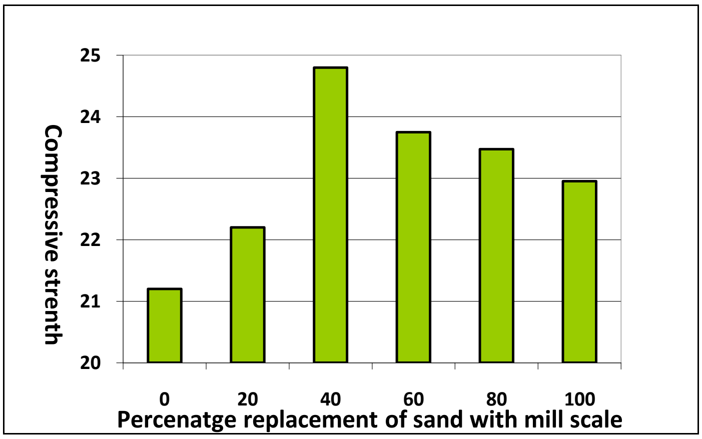


Chart -5: Comparison of compressive strength of M20 Concrete

4.5.3 Splitting Tensile Strength in 28 Days

The splitting (indirect) tensile strength based on testing cylinders on 28 day of curing are presented in Chart 6. As observed, there is not much variation for the 28 day splitting tensile strength due to the variations in the percentage replacement of sand.

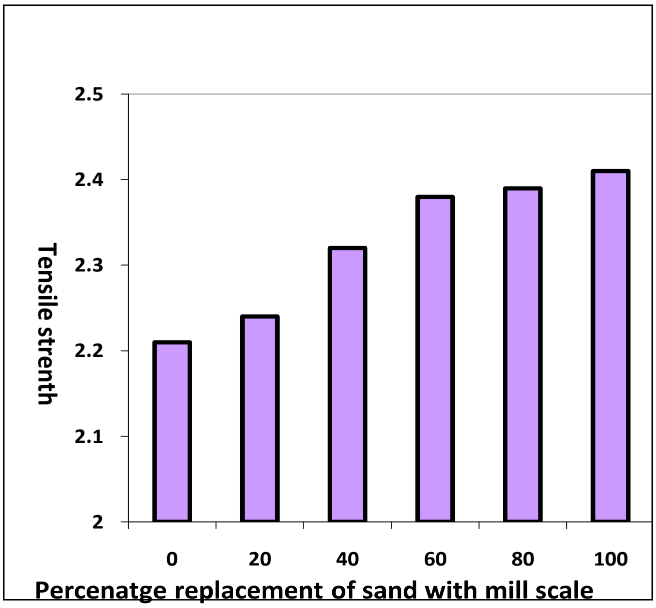


Chart -6: Comparison of Tensile strength of M20 Concrete

4.5.4 Flexural Strength

The flexural strength value by flexure test using prisms are also presented in Chart 7 and it is clear that there is not much variation with respect to variations in the percentage replacement of sand with mill scale

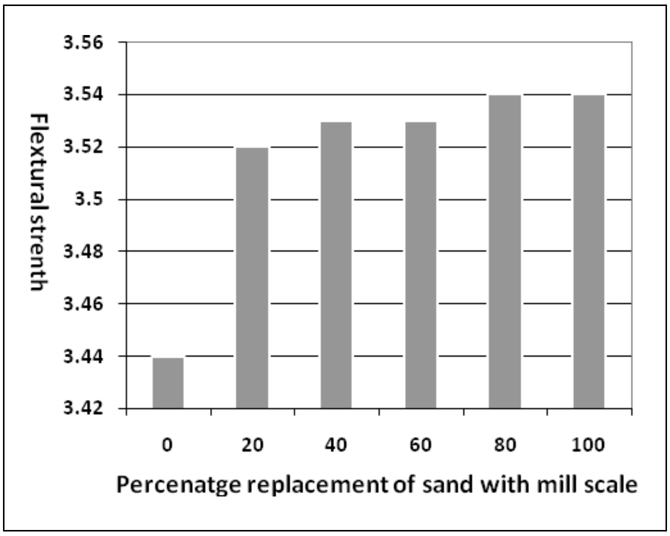
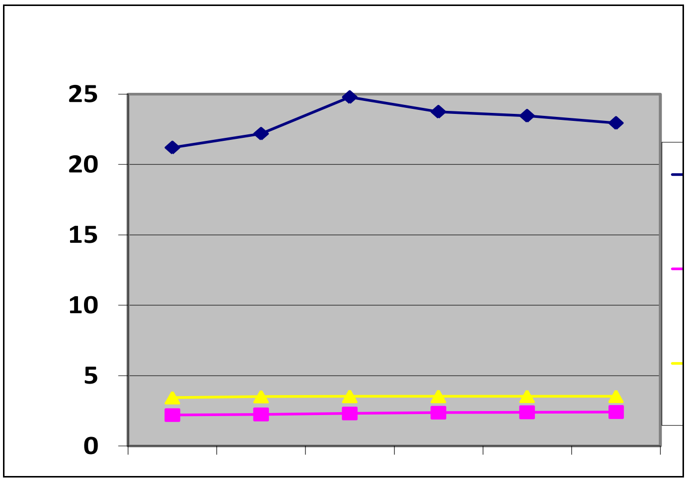


Chart -7: Comparison of Flexural strength of M20 Concrete



X Axis:- Percentage Replacement of sand by mill scale
Y Axis :- Strength in Mpa

Chart -8: Comparison of 28 day Strength of M20 grade concrete

4.6 Total Replacement of Sand with Mill Scale

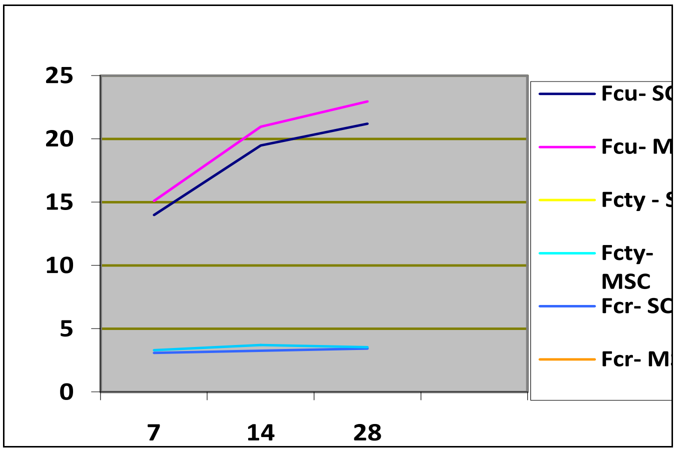
For the concrete grade of M20, exclusively sand concrete and mill scale concrete were made to determine and compare various strength parameters

4.6.1 Compressive Strength

It is observed from Chart 9 that the cube compressive strength of MSC is uniformly more (7.5 to 8.25 %) than SC in 7, 14 and 28 days of testing. This increase in the strength of MSC is due to interlocking nature of particles in the MS.

4.6.2 Splitting tensile strength and Flexural strength

The split tensile strength and Flexural strength are more for MSC in than SC, the difference is (9.05%) for split tensile strength and (2.9-7.11%) for Flexural strength.



X Axis:- Percentage Replacement of sand by mill scale Y Axis :- Strength in Mpa

Chart -9: Comparison of Strength properties of SC & MSC of M20 grade concrete

5. QUANTITATIVE AND QUALITATIVE CONCLUSIONS

The experimental investigations were conducted with Mill Scale as fine aggregate. Partial replacement and total replacement of sand with mill scale was studied. Based on this, concrete prepared and the characteristics in Workability and Strength were studied and compared with natural sand concrete. Based on the test results following conclusions and recommendations are made.

1. The grading zone is same for mill scale and sand but, Mill scale is coarser than sand. Sand particles are rounded and globular where as mill scale particles are angular, flaky and irregular in shape.

2. The Mill scale is coarser than sand but the amount of finer particles between 300 - 150 micron is almost double that of sand that increased the water requirement.

3. In the preliminary study for the conventional M20 concrete having sand replaced from 0-100 percent with mill scale. The workability goes on reducing according to sand replacement level (0, 20, 40, 60, 80 and100%) by slump and compaction factor. For the concrete having totally sand replaced MSC, the same trend existed as standard concrete SC.

4. The rate of gain of cube compressive strength of M20 grade concrete up to 28 days is typical for 0-100% replacement of sand with mill scale. There is a reduction of only 7.09 % for MSC compared to SC and is directly proportional to the increase of sand replacement. There is not much variation for the 28 day strength due to the variations in the percentage replacement of sand with Mill scale.

5. There is not much variation for the 28 day splitting tensile strength and Flexural due to the variations in the percentage replacement of sand for M20 grade concrete.

6. For the M20 grade of MSC, the cube compressive strength is uniformly more (7.5 to 8.25 %) than sand concrete in 7, 14 and 28 days. This increase in the strength due to interlocking nature of particles in the mill scale.

7. The split tensile strength and Flexural strength are more for MSC in than SC, the difference is (9.05%) for split tensile strength and (2.9-7.11%) for Flexural strength.

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