Utilization of Waste From Steel Industry To Construction Projects

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Abstract- *Natural aggregates are becoming increasingly scarce and their production and shipment is becoming more difficult. Steel slag is currently used as aggregate in hot mix asphalt surface applications, but there is a need for some additional work to determine the feasibility of utilizing this industrial by-product more wisely as a replacement for both fine and coarse aggregates in a conventional concrete mixture. The primary aim of this research was to evaluate the durability of concrete made with steel slag aggregates. This study presents result of experimental investigations carried out to evaluate effects of replacing aggregate (coarse and fine) with that of slag on various concrete properties. In the present study M20 and M25 grade of concrete each having four types of concrete mix C:S:A, C:S:SS, C:SS:A, C:SS:SS (SS is steel slag), and the compressive strength, flexural strength and tensile strength were determined adopting conventional testing procedure. From the results of the present study we can say that as the % of steel slag as replacement is increased the strength of aggregate increases. After 75% replacement of sand as steel slag slight decrease in strength is observe but still it is higher than 0% replacement without any adverse effect on the strength of concrete.*

Keywords- compressive strength, flexural strength split tensile strength, water absorption.

I. INTRODUCTION

Global warming and environmental destruction have become the major issue in recent years. Use of more and more environmental- friendly materials in any Industry in general and construction industry in particular, is of paramount importance. Preventing the depletion of natural resources and enhancing the usage of waste materials has become a challenge to the scientist and engineers. A number of studies have been conducted concerning the protection of natural resources, prevention of environmental pollution and contribution to the economy by using this waste material.
In an integrated steel plant, 2 – 4 tons of wastes (including solid, liquid and gas) are generated for every ton of steel produced. Accordingly, today the emphasis is on the avoidance of waste generation, recycling and reuse of waste, and minimizing the adverse impact of disposal on the environment. Among all the solid/liquid wastes, slag generated at iron making and steel making units are created in the largest quantities. With increasing capacities, disposal of large quantities of slag becomes a big environmental concern and a critical issue for steel makers. Over the last few years, with a better understanding of slag, its functions and improvements in process technologies have led to a significant reduction in the volume of slag generated. At the same time, the re-use of iron and steel making slag has also been expanded, and has led to a significant reduction in the environmental impact of these byproducts. However, slag generation remains inevitable and emphasis on its recycling remains the greatest concern.

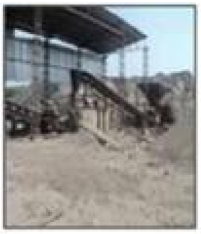
The present work aims at developing a material that can replace the conventional aggregate in concrete work using the waste product of steel industry like steel slag, ground granulated blast furnace slag, and fly ash. Quality assessment of ecofriendly concrete that is made out of cement, steel slag as coarse aggregate, steel slag as fine aggregate and some quantity of fly ash. This will solve the problem of waste disposal side by side preserving our natural resources.

II. MATERIALS AND PROPERTIES

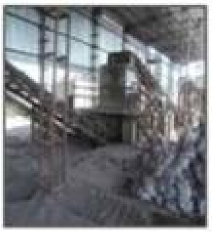
2.1 STEEL SLAG

This is the main ingredient of research program and it is locally available Steel Slag. The Steel slag used in the present investigation was collected from Steel Plant at Wardha. Extraction of ‗iron' from ores is a complex process requiring a number of other materials which are added as flux or catalysts. After making steel these ingredients forming a matrix are to be periodically cleaned up. Removed in bulk, it is known as steel –slag. It consists of silicates and oxides. Modern integrated steel plants produce steel through basic oxygen process. Some steel plants use electric arc furnace smelting to their size. In the case of former using oxygen process, lime (CaO) and dolomite (CaOMgo) are charged into the converter or furnace as flux. Lowering the launce, injection of higher pressurized oxygen is accomplished. This oxygen combines with the impurities of the charge which are finally separated. The impurities are silicon, manganese, phosphorous, some liquid iron oxides and gases like CO2 and CO. Combined with lime and dolomite, they form steel slag. At the end of the operation liquid steel is poured into a ladle. The remaining slag in the vessel is transferred to a separate slag pot. For industrial use, different grades of steel are required. With varying grades of steel produced, the resulting slag also assume various characteristics and hence strength properties. Grades of steel are classified from high to medium and low depending on their carbon content. Higher grades of steel have higher carbon contents. Low carbon steel is made by use of greater volume of oxygen so that good amount carbon goes into combination with oxygen in producing CO2 which escapes into atmosphere. This also necessitates use of higher amount of lime and dolomite as flux. These varying quantities of slag known as furnace slag or tap slag, raker slag, synthetic or ladle slag and pit or clean out slag. Fig. 2.1 presents a flow chart for the operations required in steel and slag making.

a) +100 mm size of Slag poured in Ist hop. & 2nd hop. crushes the Slag unto 60mm size

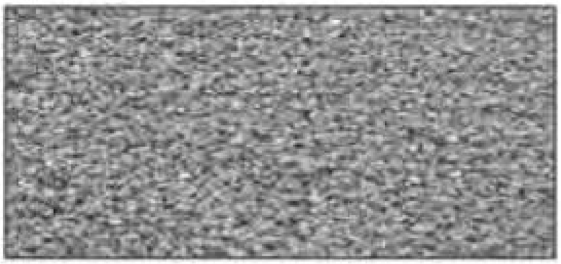


b) 3rd Hopper Crushes 60 mm size of Slag to 20mm size



c) Magnetic Separator which separates Metallic slag

d) Screeners Separat



e) Slag Hip

Fig.2.1 Flow chart of Steel Slag production through BOF and EAF(NSA2006)

The steel slag produced during the primary stage of steel making is known as furnace slag or tap slag which is the major share of the total slag produced in the operation. After the first operation, when molten steel is poured into ladle, additional; flux is charged for further refining. This produces some more slag which is combined with any carryover slag from first operation. It helps in absorbing of deoxidation products, simultaneously providing heat insulation and protection of ladle refractories. Slag produced on this operation is known as raker and ladle slag.

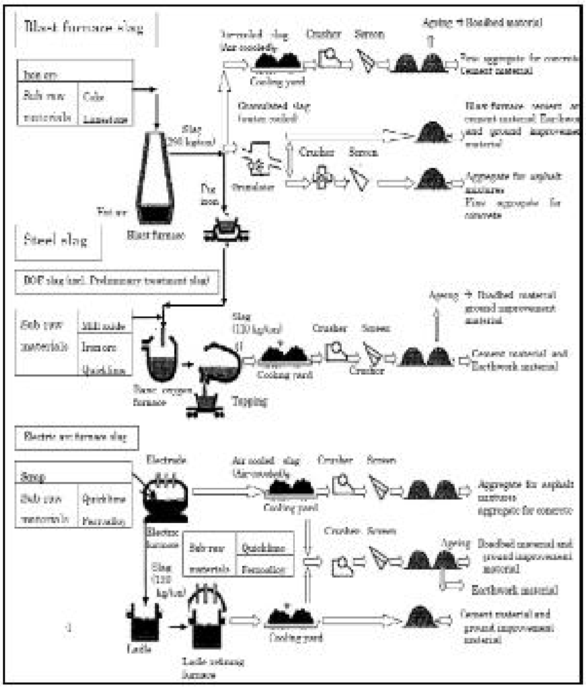


Fig.2.2 Flow chart of crushing of steel slag

The Steel Slag is crushed to get the desired size of aggregates. The slag had grayish white color. Fig. 2.2 shows the flow chart of crushing of steel slag in local steel industry. Steel slag must be allowed to undergo the weathering process before using as an aggregate in construction because of its expansive nature. This is done in order to reduce the quantity of free lime to acceptable limits. The steel slag is allowed to stand in stockpiles for a period of at least 4 months and exposed to weather as shown in Fig. 3.3. During this weathering process, the steel slag is required to be in contact with water so that the hydration process between lime and water takes place. Hydration of free lime (CaO) or free magnesia (MgO) is responsible for expansive nature of steel slag.

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Fig.2.3 Stockpiling of steel slag aggregates at Steel Industry Wardha

The chemical and physical data for the above steel slag is presented as follows. The tests on Steel Slag were carried out as per Indian Standard Codes. This material replaces the fine aggregate and coarse aggregate in normal concrete. The different physical and chemical properties of steel slag are given below.

Table 2.1 Physical properties of steel slag

Aggregates	Absorption (%)	Specific Gravity	LA Abrasion(%
Steel slag	2.5	2.91	27

Steel Slag is found in the form of big pebbles. It is crystalline in microstructure and non-hydraulic in nature. The microstructure and distribution of steel slag was studied. Microphotographs of the sample are shown in fig. It is found that quartz, iron oxide, aluminum oxide and various silicates are predominantly present. It is clearly observed that most of the particles are spherical structure with few irregular particles. The surfaces of spherical particles are found to be irregular and round as it is a high calcium steel slag with particle size varying from 0.075mm to 80mmm. However the present case steel slag passing through IS sieve 20mm is used for making Steel slag concrete blocks. The chemical composition was given in Table 3.2 below.

Table 2.2 Chemical Composition of Steel Slag

Steel Slag Present study (%)	Steel Slag Present study (%)	Composition provided by NSA (%)
Iron Oxide	1 – 2.5	24
FeO	45 – 50	42
Calcium Oxide Cao	20 – 22	15
Silicon Oxide SiO2	10 – 15	8
Mag.Oxide MgO	4 – 8	1 -5
Allu.Oxide Al2O3		

The values in the 2nd column were provided by Steel Industry and determined by Alternative Testing Laboratories. The values in the 3rd column are typical steel slag chemical compositions provide by National Slag Association (accessed Nov 2003)

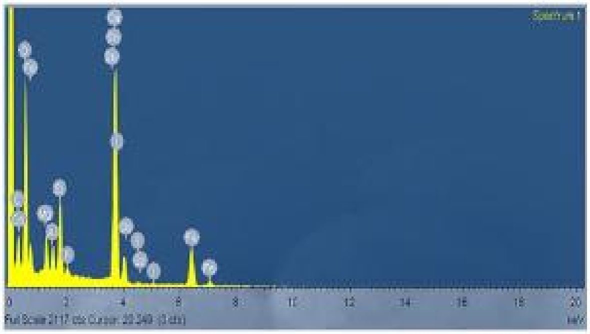

Fig. 2.4 Microscopic pattern of steel slag (Meena, NIT Rourkela 2009)

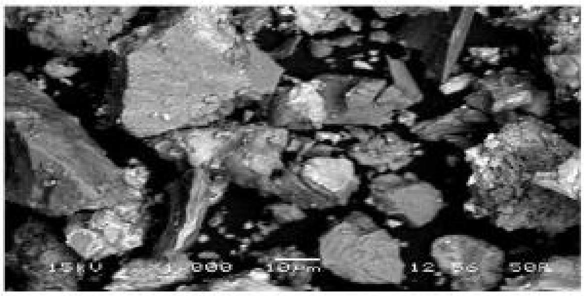

Fig2.5. Microstructure of steel slag (Meena , NIT Rourkela 2009)

2.2. CEMENT

Cement Brand : Ultratech Cement
Cement Type : Ordinary Portland Cement (OPC) Grade of Cement :53 grade
Specific Gravity of Cement : G = 3.14 Standard Consistency of cement : Quantity of Cement: W1=400gms
Quantity of Water: W2= 33%= 132ml
Penetration of Plunger from Top = 34 mm
(Desirable is 33 to 35 mm)
Initial Setting Time: Quantity of Cement: W1=400gms
Weight of Water as per Standard Consistency:
P = 33 % = 132 ml
Weight of Water to be added: 0.85 x P = 112.20 ml Initial Setting Time of the Cement : 160mins
Fineness of Cement:
W = weight of the cement = 100 gms
Residue left on 90 µ sieve = W1 = 6 gms
% weight retained = 6 % (< 10 %)

2.3 SAND (FINE AGGREGATE):

The aggregate fraction ranging from 4.75 mm to 150 microns are termed as fine aggregate. Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The most common constituent of sand, in inland continental settings and non-tropical coastal settings, is silica (silicon dioxide, or SiO2), usually in the form of quartz which, because of its chemical inertness and considerable hardness, is the most common mineral resistant to weathering. It is used as fine aggregate in concrete.

Fig.2.6 Sieve Analysis of sand

The Sieve Analysis of sand is carried out to know the zone of the sand.

Total weight of sand = 1 Kg

Table 2.3 Sieve Analysis of Sand as Fine Aggregate

Sr. No.	IS Sieve	Weight of Slag Retained (gms)	% Weight Retained (%)	Cum. Wt. Retained (%)	Cum. Wt. Passing (%)
1	4.75mm	68	6.8	6.8	93.2
2	2.36mm	383	38.3	45.	54.9
3	1.18mm	282	28.2	73.3	26.7
4	600micron	75	7.5	80.8	19.2
5	300micron	82	8.2	89.0	10.8
6	150micron	78	7.8	96.8	3.2
7	Pan	32	3.2	100	0
			∑=100		

From the sieve analysis result shown in Table 3.3, Sand falls under Zone I.

Fineness Modulus of sand, FM = 2.94
Specific Gravity of Sand : G = 2.56
Dry Loose Bulk Density : 1.54Kg/lt
Water Absorption : 1.0 %

2.4 STEEL SLAG (FINE AGGREGATE)

The aggregate fraction ranging from 4.75 mm to 150 microns are termed as fine aggregate. It is used as fine aggregate in concrete. In this study steel slag passing through 4.75mm is taken as partial and full replacement of sand.

Sieve Analysis of steel slag as fine aggregate:

The Sieve Analysis of sand is carried out to know the zone of the sand.
Total weight of sand = 1 Kg

Table 2.4 Sieve Analysis of Steel Slag as Fine Aggregate

Sr. No.	IS Sieve	Weight of Sand Retained (gms)	% Weight Retained (%)	Cum.Wt. Retained (%)	Cum. Wt. Passing (%)
1	4.75 mm	24	2.4	2.4	97.6
2	2.36 mm	60	6.0	8.4	91.6
3	1.18 mm	178	17.8	26.2	73.8
4	600micron	426	42.6	68.8	31.2
5	300micron	204	20.4	89.2	10.8
6	150micron	93	9.3	98.5	1.5
7	Pan	15	1.5	100	0
			∑=100		

From the sieve analysis result shown in Table 3.4, Steel Slag falls under Zone I.
Fineness Modulus of sand, FM = 3.91
Specific Gravity of Sand : G = 2.8 Dry Loose Bulk Density : 1.62Kg/lt Water Absorption : 1.2 %

2.5 AGGREGATE (COARSE AGGREGATE)

The aggregate fraction ranging from 80 mm to 4.75 mm are termed as coarse aggregate. Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. The concrete making properties of aggregate are influenced to some extent on the basis of geological formation of the parent rocks together with the subsequent processes of weathering and alteration.

Within the main rock group, say granite group, the quality of aggregate may vary to a very great extent owing to changes in the structure and texture of the main parent rock from place to place. The aggregate used is natural aggregate which is locally available.

Fig.2.7 Set of Sieves for Coarse Aggregate

Total weight of sand = 2 Kg

Table 2.5 Sieve Analysis of Crushed Stone as Coarse Aggregate

Sr. No.	IS Sieve	Wt. of Slag Retained (gm)	% Weight Retained (%)	Cum.Wt. Retained (%)	Cum.Wt. Passing (%)
1	80 mm	0	0	0	100
2	40 mm	0	0	0	100
3	20 mm	886	44.30	44.30	55.7
4	10 mm	1099	54.95	99.25	0.75
5	4.75mm	10	0.50	99.75	0.25
6	Pan	5	0.25	100	0
			∑=100		

Elongation Index: 12% (should not be more than 15 %)
Flakiness Index : 13 % (should not be more than 15 %
Specific Gravity of Aggregate : G = 3.23 Aggregate impact value : 4.30 % (should not be more than 30 %)
Crushing value : 18.114 % (should not be more than 45 %)
Dry Loose Bulk Density : 1.48 Kg/lt
Water Absorption : 0.9 % (should not be more than 2 %)
Abrasion Value : 12 % (should not be more than 30 %)

2.6 STEEL SLAG (COARSE AGGREGATE)

The aggregate fraction ranging from 80 mm to 4.75 mm are termed as coarse aggregate.

The aggregate used is steel slag which is locally available waste product of Steel Industry.

Total weight of sand = 2 Kg

Table 2.6 Sieve Analysis of Steel Slag as Coarse Agg.

% Replacement	28 day Compressive Strength (f=P/bd) For sample Width (b) =150 mm, Depth (d) = 150 mm,		
	Avg. Strength (C:SS:A) Mpa	Avg. Strength (C:S:SS) MPa	Avg. Strength (C:SS:SS) MPa
0 %	30.22	30.22	30.22
25 %	32.50	36.63	37.50
50 %	36.26	40.67	42.29
75 %	42.70	43.90	44.48
100 %	34.78	37.03	38.99

Elongation Index: 1.01 % (should not be more than 15 %)
Flakiness Index : 4.48 % (should not be more than 15 %)
Specific Gravity of Agg. : G = 2.91
Aggregate impact value: 23.21 % (should not be more than 30 %)
Crushing value: 36.55 % (should not be more than 45 %)
Dry Loose Bulk Density: 1.12 Kg/lt
Water Absorption: 2.5 % (should not be more than 2 %)
Abrasion Value: 27 % (should not be more than 30 %)

III. RESULTS AND DISCUSSIONS

3.1 COMPRESSIVE STRENGTH OF M20 GRADE OF CONCRETE

28-day compressive strength of various concrete mix i.e. C:SS:A, C:S:SS and C:SS:SS are tabulated in Table 3.1 and bar chart is shown in Fig. 3.1

Table 3.1 28-day Compressive Strength test result of M20 grade concrete

Sr. No.	IS Sieve	Wt. of agg. Retained (gms)	Percentage Retained	Cum. % Retained	Cum. % Passing
1	80 mm	0	0	0	100
2	40 mm	0	0	0	100
3	20 mm	190	9.50	9.50	90.5
4	10 mm	1552	77.60	87.10	12.9
5	4.75 mm	250	12.50	99.60	0.40
6	Pan	8	0.40	100	0
			∑=100		

Graphical Representation

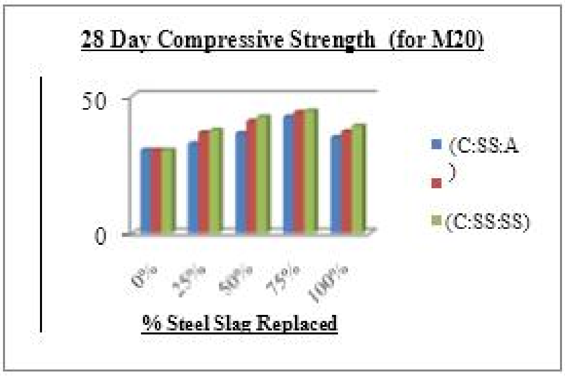

Fig 3.1 Compressive Strength (MPa) of M20 grade Concrete (Bar Chart)

Fig 3.2 M20 Grade Concrete Compression Test

It is observed that the strength of concrete increases with the increase in the quantity of steel slag as replacement to **natural aggregates. Upto 75% of replacement by Steel** Slag the compressive strength of concrete of all concrete mix increases but beyond 75% decrease in the strength is observed.

The maximum increase in the characteristic strength is observed in 75% replacement criterion for all the concrete mix.
The compressive strength of concrete increases up to 41% if 75% of sand is replaced by steel slag.
The compressive strength of concrete increases up to 45% if 75% of coarse aggregates is replaced by steel slag.
The compressive strength of concrete increases up to 47% if 75% of fine aggregate and coarse aggregates both are replaced by steel slag.

3.2 FLEXURAL STRENGTH OF M20 GRADE OF CONCRETE

28-day flexural strength of various concrete mix i.e. C:SS:A, C:S:SS and C:SS:SS are tabulated in Table
3.2 and bar chart is shown in Fig. 3.3

Table 3.2: 28-day Flexural Strength M20 concrete

Percentage Replacement	28 day Flexural Strength (MPa		
	C:SS:A	C:S:SS	C:SS:S
0 %	3.82	3.82	3.82
25 %	3.91	4.36	4.50
50 %	4.27	4.44	4.62
75 %	4.71	4.80	4.89
100 %	4.18	4.30	4.53

Fig.3.4 M20 Grade Concrete Flexure Test

It is observed that flexural strength of concrete increases with the increase in the quantity of steel slag as replacement to natural aggregates. Upton 75% of replacement by Steel Slag the flexural strength of concrete of all concrete mix increases but beyond 75% decrease in the strength is observed.

The maximum increase in the flexural strength is observed in 75% replacement criterion for all the concrete mix.
The flexural strength of concrete increases up to 23% if 75% of sand is replaced by steel slag.

The flexural strength of concrete increases up to 26% if 75% of coarse aggregates is replaced by steel slag. The flexural strength of concrete increases up to 28% if 75% of fine aggregate and coarse aggregates both are replaced by steel slag.

3.3 SPLIT TENSILE TEST OF M20 GRADE OF CONCRETE

28-day Tensile Strength with various incremental replacement of natural sand , aggregate and both by steel slag are tabulated in Table 3.3 and line graph is shown in Fig. 3.5

Table 3.3 28-day Split Tensile strength of M20 grade

Percentage Replacement (C:SS:SS)	28 day Compressive Strength		
	(C:SS:A)	(C:S:SS)	(C:SS:SS)
0%	34.79	34.79	34.79
25%	35.50	37.90	38.33
50%	39.46	40.67	43.80
75%	42.77	45.81	48.61
100%	35.96	37.97	41.33

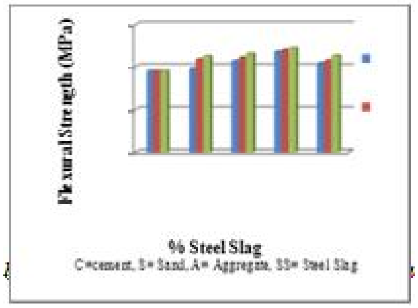

Fig. 3.3 Flexural Strength (MPa) of M20 grade concrete (Bar Chart)

Graphical Representation

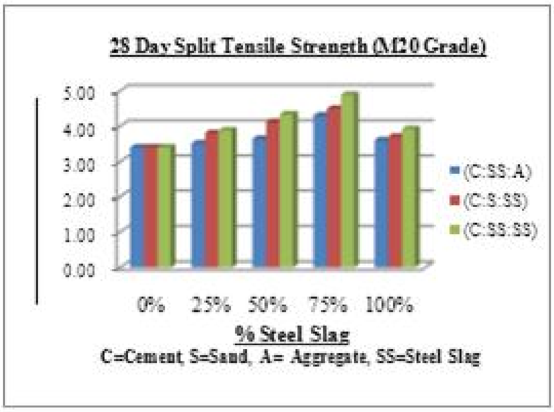

Fig 3.5 28 day Split Tensile Test of M20 grade of concrete (Bar Chart)

Fig 3.6 M20 Grade Split Tensile Strength (MPa)

It is observed that there is Split Tensile Strength of concrete increases with the increase in the quantity of steel slag as replacement to natural aggregates. up to 75% of replacement by Steel Slag the Split Tensile strength of concrete of all concrete mix increases but beyond 75% decrease in the strength is observed.

The maximum increase in the Split Tensile Strength is observed in 75% replacement criterion for all the concrete mix.

Split Tensile strength of concrete increases unto 26% if 75% of sand is replaced by steel slag.
Split Tensile strength of concrete increases up to 32
% if 75% of coarse aggregates is replaced by steel slag.
Split Tensile strength of concrete increases up to 44 % if 75% of fine aggregate and coarse aggregates both are replaced by steel slag.

3.4 COMPRESSIVE STRENGTH OF M25 GRADE OF CONCRETE

28-day compressive strength of various concrete mix
i.e. C:SS:A, C:S:SS and C:SS:SS are tabulated in Table 3.4 and bar chart is shown in Fig. 3.7

Table 3.4: 28-day Compressive Strength test result of M25 grade concrete

Percentage Replacement (C:SS:SS)	28 day Compressive Strength		
	(C:SS:A)	(C:S:SS)	(C:SS:SS)
0%	34.79	34.79	34.79
25%	35.50	37.90	38.33
50%	39.46	40.67	43.80
75%	42.77	45.81	48.61
100%	35.96	37.97	41.33

Graphical Representation

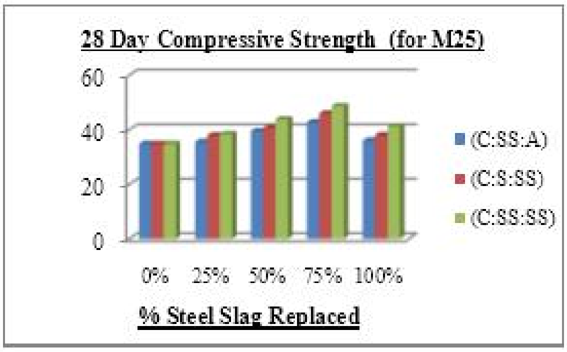

Fig 3.7 Compressive strength (MPa) of M25 grade concrete

Fig.3.8 M25Grade Concrete Compression Test

It is observed that the strength of concrete increases with the increase in the quantity of steel slag as replacement to natural aggregates. up to 75% of replacement by Steel Slag the compressive strength of concrete of all concrete mix increases but beyond 75% decrease in the strength is observed.

The maximum increase in the characteristic strength is observed in 75% replacement criterion for all the concrete mix.
The compressive strength of concrete increases up to 23% if 75% of sand is replaced by steel slag.
The compressive strength of concrete increases up to 32% if 75% of coarse aggregates is replaced by steel slag.
The compressive strength of concrete increases up to 40% if 75% of fine aggregate and coarse aggregates both are replaced by steel slag.

3.5 FLEXURAL STRENGTH OF M25 GRADE OF CONCRETE

28-day flexural strength of various concrete mix i.e. C:SS:A, C:S:SS and C:SS:SS are tabulated in Table

3.5 and Bar Chart is shown in Fig. 3.9

Table 3.5 28-day Flexural Strength M25 concrete

Percentage Replacement	28 day Flexural Strength (MPa)		
	(C:SS:A)	(C:S:SS)	(C:SS:SS)
0%	4.18	4.18	4.18
25%	4.27	4.28	4.36
50%	4.44	4.53	4.62
75%	4.62	4.8	4.89
100%	4.54	4.64	4.72

Graphical Representation

concrete

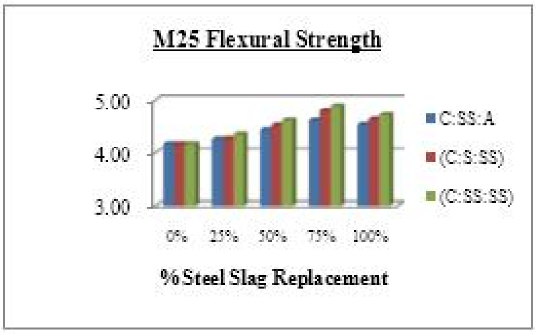

Fig.3.9Flexural Strength (MPa) of M25 grade concrete (Bar Chart)

Fig.3.10 M25 Grade Concrete Flexure Test

It is observed that flexural strength of concrete increases with the increase in the quantity of steel slag as replacement to natural aggregates. up to 75% of replacement by Steel Slag the flexural strength of concrete of all concrete mix increases but beyond 75% decrease in the strength is observed.

The maximum increase in the flexural strength is observed in 75% replacement criterion for all the concrete mix.
The flexural strength of concrete increases up to 11% if 75% of sand is replaced by steel slag.
The flexural strength of concrete increases up to 15
% if 75% of coarse aggregates is replaced by steel slag.
The flexural strength of concrete increases up to 17 % if 75% of fine aggregate and coarse aggregates both are replaced by steel slag.

3.6 SPLIT TENSILE TEST OF M25 GRADE OF CONCRETE

28-day Tensile Strength with various incremental replacement of natural sand , aggregate and both by steel slag are tabulated in Table 3.6 and line graph is shown in Fig. 3.11

Table 3.6 28-day Split Tensile strength of M25 grade

Percentage Replacement by Steel Slag	28 day Split Tensile Strength		
	Avg. Tensile Strength (C:SS:A) MPa	Avg. Tensile Strength (C:S:SS) MPa	Avg. Tensile Strength (C:SS:SS) MPa
0%	3.8	3.8	3.8
25%	3.91	4.02	4.15
50%	4.12	4.33	4.5
75%	4.50	4.62	4.87
100%	3.88	3.95	4.48

Graphical Representation

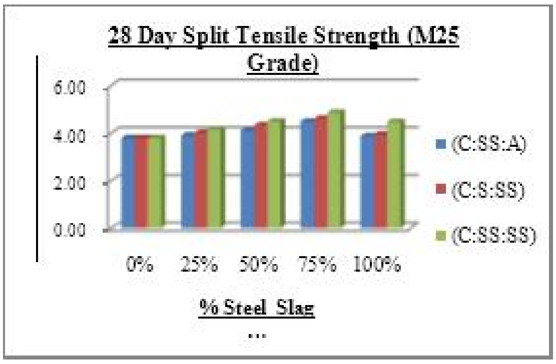

Fig.3.11 M25 Grade Concrete 28 day Split Tensile Test (Bar Chart)

Fig.3.12 M25 Grade Split Tensile Test

It is observed that there is Split Tensile Strength of concrete increases with the increase in the quantity of steel slag as replacement to natural aggregates. up to 75% of replacement by Steel Slag the Split Tensile strength of concrete of all concrete mix increases but beyond 75% decrease in the strength is observed.

The maximum increase in the Split Tensile Strength is observed in 75% replacement criterion for all the concrete mix.

Split Tensile strength of concrete increases up to 16% if 75% of sand is replaced by steel slag.

Split Tensile strength of concrete increases up to 22
% if 75% of coarse aggregates is replaced by steel slag.

Split Tensile strength of concrete increases up to 23 % if 75% of fine aggregate and coarse aggregates both are replaced by steel slag.

IV. CONCLUSIONS

The results of the research program can be summarized as follows:

1. Compressive strength, Flexural strength and Split Tensile strength for steel slag aggregates concrete were higher than conventional concrete. The maximum increase in the characteristic strength is observed in 75% replacement criterion for all the concrete mix.
2. It is concluded that the strength of M20 and M25 concrete increases with the increase in the quantity of steel slag as replacement to natural aggregates. The results of various mix proportions are presented in tabular form in Table 5.19 for M20 and M25 grades respectively. The 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 paste.

Table Test Results for various concrete mix ingredient after 75% replacement of natural aggregates by Steel Slag

Concrete Mix	Increase in Strength of Concrete	
	M25 Grade	M20 Grade
Compressive Strength		
C:SS:A	23 %	41 %
C:S:SS	32 %	45 %
C:SS:SS	40 %	47 %
Flexural Strength		
C:SS:A	11 %	23 %
C:S:SS	15 %	26 %
C:SS:SS	17 %	28 %
Split Tensile Strength		
C:SS:A	16 %	26 %
C:S:SS	22 %	33 %
C:SS:SS	23 %	44 %

3. It could be said that 75% replacements of aggregate with crystallized slag enhanced concrete density by 4 to 6% in all the concrete mixes. The improvement in density was due to the higher unit weight of Crystallized slag aggregate than natural aggregate. The strength may be affected with time and so long-term effects on hardened properties of concrete require further investigation. Proper care should be taken during the aging of steel slag and during the stockpiling of steel slag.
4. The cost of slag is nearly 50% of that of natural aggregates hence it is economical to use the waste product of Steel Industry.

Hence, it could be recommended that slag aggregate could be effectively utilized as coarse and fine.
aggregate in all plain concrete applications such as P.C.C. works, divider blocks, concrete plugs, mile stones, gravity retaining walls, paver blocks, road subgrade, rural road development schemes, etc. either as partial or full replacements of normal crushed coarse and natural fine aggregates.

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