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An experimental investigation of partial replacement steel slag in concrete as a fine aggregates

K.Rajkumar[1] & K.L.Ravisankar[2]
[1]Assisstant Professor , Department of Civil Engineering
Kongunadu College of Engineering & Technology, Trichy, India
[2]Assisstant Professor , Department of Civil Engineering
Nandha Engineering College (Autonomous), Erode, India
krajkumarcivil@gmail.com & ravisankar3391@gmail.com

E – Mail: krajkumarcivil@gmail.com , ravisankar3391@gmail.com

Abstract - **The environment problems are very common in India due to generation of industrial by-products. Due to industrialization enormous by-products are produced and to utilize these by-products is the main challenge faced in India. Iron slag is one of the industrial by-product from the iron and steel making industries. In this paper, the compressive strength of the iron slag concrete was studied. The results confirm that the use of iron slag overcome the pollution problems in the environment. The results shows that the iron slag added to the concrete had greater strength than the plain concrete.**

Keywords - **Compressive strength, , Concrete & Steel Powder.**

I. INTRODUCTION

Concrete is material composed of coarse granular material embedded in a hard matrix that fills the space among the aggregate particles and glues them together. Concrete can be considered as a kind of artificial rocks with the properties similar to that of some kinds of rocks. As it is strong, durable and relatively cheap, concrete is since, almost two centuries, the most used construction materials worldwide, which can easily be recognized as it has changed the physiognomy of rural areas. In the cost point of view, the concrete is costlier, because its constituents are less in availability. Moreover it causes exploitation of natural resources. It is needed to reduce these problems for our future generation. For this purpose several ways are implemented to reduce the problem that arises by the manufacturing of concrete. The history of the use steel powder dates back a long way. In the past, the application of steel powder was not noticeable because enormous volumes of blast furnace slag were available. Through awareness of environmental considerations and more recently the concept of sustainable development, extensive research and development has transformed slag into modern industrial product which is effective and beneficial.

Slag was considered to be essential in the production of steel, but once it served its purpose in refining the metal, it was strictly a nuisance with little or no use. The usefulness of slag was realized with the first are smelting process. The use of slag became a common practice in Europe at the turn of the 19th century, where the incentive to make all possible use of industrial by-products was strong and storage space for by-products was lacking. Shortly after, many markets for slag opened in Europe, the United States, and elsewhere in the world.

Steel powder may be applied safely in aquatic environment, such as rivers, lakes or streams without impacting water quality or aquatic life. The study carried out by an independent nationally renowned chemical laboratory as demonstrated that furnace and steel powder does not pose any threat to human or plant life. The study further revealed that the use of slag has very positive environmental benefits. The use of slag in cement manufacturing significantly decrease CO2 emission and reduce the energy needed to calcium limestone. The use of slag as aggregate reduces the need for virgin material and the energy use and emission produced during the mining, processing and transportation of those materials.

SLAG DEFINED

Slag is a by-product generated during manufacturing of pig iron and steel. It is produced by action of various fluxes upon gangue material within the iron ore during the process of pig iron making in blast furnace and steel manufacturing in steel melting shop. Primarily, the slag consists of calcium, magnesium, manganese and aluminium silicates in various combinations. The cooling process of slag is responsible mainly for generating different types of slag required for various end-use consumers. Although, the chemical composition of slag may remain unchanged, physical properties vary widely with the changing process of cooling.

UTILIZATION OF METALLURGICAL SLAGS

Slag is by-product formed in smelting, and other metallurgical and combustion processes from impurities in the metals or ores being treated. During smelting or refining slag floats on the surface of the molten metal, protecting it from oxidation or reduction by the atmosphere and keeping it clean. In iron and steel production slag phases are generated, formed mainly from the addition of mixture of oxides and fluxes and are also composed of reaction products like those resulting from the oxidation of charge materials and the dissolution of refractories. Primary purpose is to refine the liquid metal by removing impurities.

II. MATERIALS PROPERTIES

Table.1 Properties of OPC 53 Grade Concrete

Sl.No	Characteristics	Values Specified By IS 8112:1989
1.	Specific gravity	-
2.	Initial setting Time, minutes	30min (minimum)
3.	Final setting Time, minutes	600min (maximum)

Table.2 Properties of Coarse Aggregates

Sl.No	Characteristics	Values
1.	Colour	Grey
2.	Shape	Angular
3.	Maximum Size	20 mm
4.	Specific Gravity	2.68

Table.3 Physical Properties of Fine Aggregate

Sl.No	Characteristics	Value
1.	Specific gravity	2.64
2.	Fineness modulus	3.85
3.	Water absorption,%	0.89

Table.4 Specific Gravity of Fine Aggregates

Sl.No	Description	Trail
1.	Weight of pycnometer (W1)	0.607
2.	Weight of pycnometer + Weight of soil(W2)	0.94
3.	Weight of pycnometer + Wt. of soil + Wt. of Water(W3)	1.67
4.	Weight of pycnometer + Wt. of Water(W4)	1.466

Specific Gravity (G) = 2.64

Table.5 Sieve Analysis of Fine Aggregate

Weight of sample taken =1000 gm.					
Sl. No	**IS-Sieve (mm)**	**Wt. Retained (gm.)**	**%age retained**	**%age passing**	**Cumulative %retained**
1	4.75	13.6	1.36	98.64	1.36
2	2.36	37	3.7	94.94	5.06
3	1.18	423	42.3	52.64	47.36
4	0.60	202	20.2	32.44	67.56
5	0.30	228	22.8	9.64	90.36
6	0.150	96.4	9.64	0.01	99.99
				FM	**3.1**

Table.6 Sieve Analysis of Steel powder

Weight of sample taken = 1000 gm.					
Sl. No	**IS-Sieve (mm)**	**Wt. Retained (gm.)**	**%age retained**	**%age passing**	**Cumulative %retained**
1	4.75	23.6	2.36	97.64	2.36
2	2.36	37.6	3.76	93.88	6.12
3	1.18	104.16	10.41	83.47	16.53
4	0.60	199.17	19.9	63.57	36.43
5	0.30	339.15	33.91	29.66	70.34
6	0.150	296.31	29.6	0.06	99.94
				FM	**2.31**

III. FRESH CONCRETE TEST

Table.7 Slump Value

Sl.No	Degee of Workability	Slump in mm
1.	Very low	-
2.	Low	25-75
3.	Medium	50-100
4.	High	100-150
5.	Very high	-

The slump value of the concrete = 72 mm

Table.8 Compaction Factor Test

Sl.No	Description	Trial 1
1.	Weight of cylinder (W1)kg	7.21
2.	Weight of cylinder + partially compacted concrete (W2)kg	18.36
3.	Weight of partially compacted concrete (W2-W1)kg	11.15
4.	Cylinder + weight of fully compacted concrete (W3)kg	19.52
5.	Weight of fully compacted concrete (W3-W1)kg	12.31
Average		0.91

Compaction of concrete is = 0.91

IV. MIX PROPORTION

Water : Cement : Fine Aggregate : Coarse Aggregate
0.45 : 1 : 1.56 : 2.29

Table.9 Proportion of Concrete Mixtures

Type	Cement	Fine Aggregate	Steel powder (SP)	Coarse Aggregate	W/C Ratio
Conventional	1	1.56	-	2.29	0.45
15% of SP	1	1.40	0.16	2.29	0.45
25% of SP	1	1.33	0.23	2.29	0.45

V. HARDEN CONCRETE TEST

Compressive Strength

Test specimens of size 150 x 150 x 150 mm were prepared for testing the compression strength concrete. The concrete mixes with varying percentages (15 % and 25 %) of steel powder as partial replacement of fine aggregate were cast into cubes and cylinders of subsequent testing. In this study, to make concrete, cement and fine aggregates were first mixed dry to uniform colour and then coarse aggregates was added and mixed with the mixture of cement and fine aggregates. Water was then added and the whole mass mixed. The interior surface of moulds and base plate were oiled before concrete was placed.

Table.10 Compressive strength of concrete with steel powder

Mix	Compressive Strength (N/mm^2)			Avg. Compressive Strength (N/mm^2)		
	7 days	14 days	28 days	7 days	14 days	28 days
CC	16.64	26.48	28.60	17.25	27.13	29.3
	17.86	27.78	30.00			
15 % of SP	19.30	28.77	31.07	19.99	28.895	31.73
	20.60	30	32.4			
25 % of SP	26.20	31.70	34.20	25.44	30.995	33.42
	24.88	30.22	32.64			

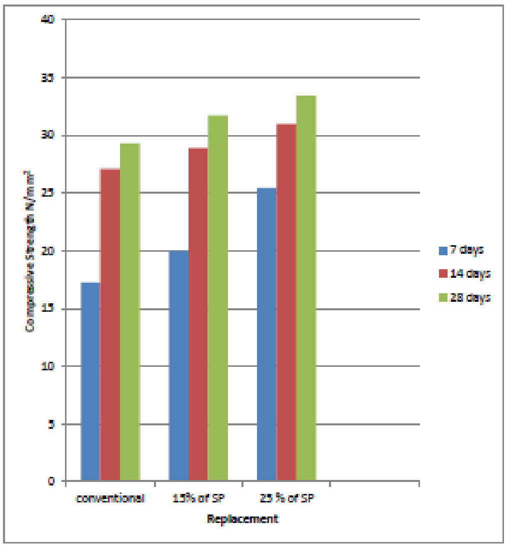

Figure.1 Compressive Strength of Steel Powder Concrete

FLEXURAL STRENGTH TEST

Test specimens of size 300 x 100 x 100 mm were prepared for testing the compression strength concrete. The concrete mixes with varying percentages (15 % and 25 %) of steel powder as partial replacement of fine aggregate were cast into cubes and cylinders of subsequent testing. In this study, to make concrete, cement and fine aggregates were first mixed dry to uniform colour and then coarse aggregates was added and mixed with the mixture of cement and fine aggregates.

Table.11 Flexural strength of concrete with steel powder

Mix	Flexural Strength (N/mm^2)			Avg. Flexural Strength (N/mm^2)		
	7 days	14 days	28 days	7 days	14 days	28 days
CC	9.34	14.10	15.23	10.57	14.37	15.52
	11.80	14.64	15.81			
15 % of SP	7.5	10.52	11.36	7.25	10.78	11.64
	7.0	11.03	11.91			
25 % of SP	11.02	15.5	16.74	10.77	17.52	18.92
	10.54	19.54	21.10			

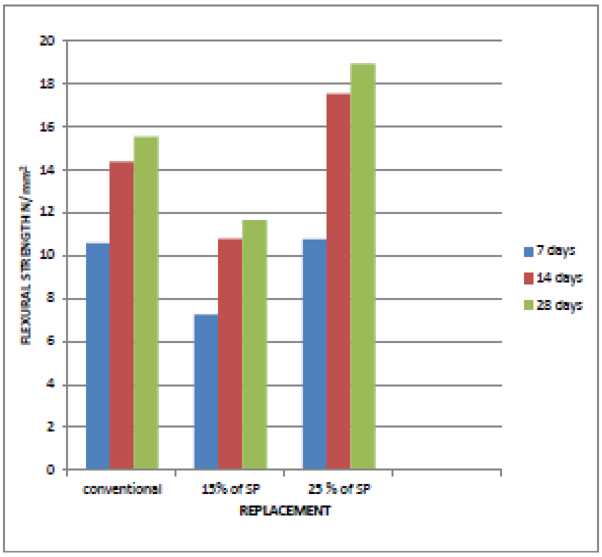

Figure.2 Flexural Strength of Steel Powder Concrete

SPLIT TENSILE STRENGTH TEST

Test specimens of size300 x 150 x 150 mm were prepared for testing the compression strength concrete. The concrete mixes with varying percentages (15 % and 25 %) of steel powder as partial replacement of fine aggregate were cast into cubes and cylinders of subsequent testing. In this study, to make concrete, cement and fine aggregates were first mixed dry to uniform colour and then coarse aggregates was added and mixed with the mixture of cement and fine aggregates. Water was then added and the whole mass mixed. The interior surface of moulds and base plate were oiled before concrete was placed. After 24 hours the specimens were removed from the mould and placed in clean water at a temperature of 270oC. The specimens so casted were tested after 7, 14 and 28 days of curing measured from the time, water is added to dry mix. The load was applied axially without shock till the specimen was crushed.

Table.12 Tensile strength of concrete with steel powder

Mix	Tensile Strength (N/mm^2)			Avg. Tensile Strength (N/mm^2)		
	7 days	14 days	28 days	7 days	14 days	28 days
CC	1.62	1.78	1.922	1.53	1.69	1.83
	1.44	1.60	1.73			
15 % of SP	1.82	1.98	2.13	1.84	1.91	2.06
	1.86	1.84	1.99			
25 % of SP	2.06	2.60	2.81	2.02	2.54	2.75
	1.98	2.48	**2.68**			

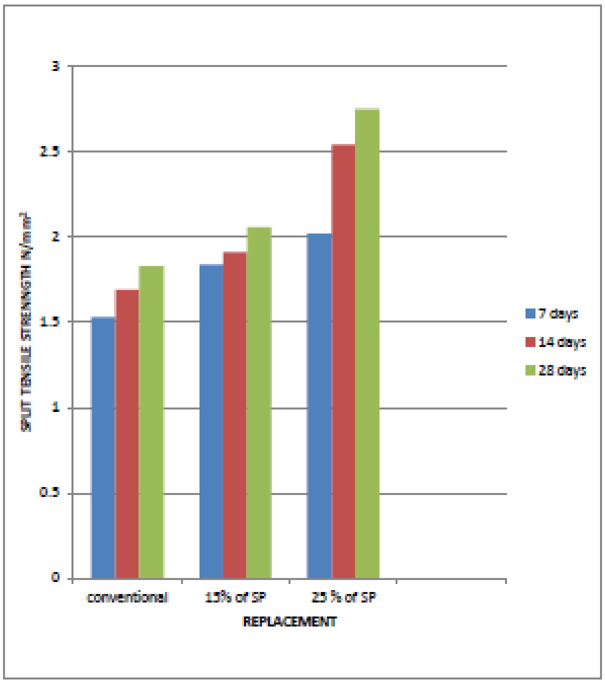

Figure.3 Split Tensile Strength of Steel Powder Concrete

VI. CONCLUSION

- The strength and durability characteristics of concrete mixtures have been computed in the present work by replacing 15% and 25% of steel powder with the sand. On the basis of present study, following conclusions are drawn.
- Generally steel powder has the acceptable property in the entire respective manner when compared to normal fine aggregates. Recycling steel powder as aggregates in concrete not only improves mechanical property of concrete, but also helps surrounding environment to be protected against its severe deposit problems.
- As there is a considerable increase in the strength characteristics of concrete with the partial replacement of fine aggregate by using steel powder in the range of about 25% can be used in structural element.
- This type of replacement work helps in the construction industry with a development of cost efficiency building.
- When the Steel Powder replaces the Fine Aggregate, there is minor chances in Strength of the blocks.

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