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Study and Behaviour of M40 Grade Concrete using Steel Slag as Partial Replacement of Coarse Aggregate

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***Abstract*— India has an enormous growth in steel industries and slag is a byproduct of the same must be disposed of properly. Steel industries generate large quantities of slag from their iron-making and steel-making processes. Iron making slag are recycled in cement making and steel-making slag are dumped because they are unsuitable for the cement industry owing to the high iron content and other impurities Reuse of waste in integrated steel plants is important with regard to environmental and economic consideration.**

Steel slag is a byproduct of the iron ore and steel making industry. It is produced in large quantities and poses a substantial disposal problem. The generation of Steel slag in Indian steel plants is about 200 kg per ton of hot metal produced. Out of this only 25% is being reutilized in India compared to 70-100% in other countries.

The objective of the present study is to study the possibility of using Steel slag as partial replacement of coarse aggregate and to compare the properties of the proposed concrete with that of existing conventional concrete.

An experimental investigation was carried out to evaluate the effect of replacing coarse aggregate by Steel Slag on flexural strength and compressive strength of concrete. Coarse aggregate was replaced with three percentages (1%, 2%, and 3%) of Steel slag by volume in M40 grade of concrete with water cement ratio (w/c) 0.31.

***Index Terms*— LD Slag, Partial Replacement.**

I. INTRODUCTION

Concrete is widely used structural material consisting essentially of a binder and mineral filler. It has the unique distinction of being the only construction material actually manufactured on the site, whereas other materials are merely shaped to use at the worksite. Steel making slag is a product resulting from the industrial processes carried out to produce first, pig iron and second, steel. LD slag is generated in the steel-making process resulting from the transformation of pig iron in liquid steel. The letters LD come from the fact that the steel is produced in an LD type oxygen converter, **LD** meaning **L**inz and **D**onawitz, towns in Austria where the process was invented. This process is also called as Basic Oxygen Process. The generation of LD slag in Indian steel plants is about 200 kg per ton of hot metal produced. Out of this only 25% is being reutilized in India compared to 70-100% in other countries.

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A. Present Uses of LD Slag

LD Slag as Railway Ballast:

LD Slag bolder is used in road making and floor preparation for its high hardness and cementing property. All the steel plants in India are selling more than 50% LD Slag for road making and ground filling. LD Slag has been proved to be an excellent railway ballast material and, as such, is being used by Indian Railways.

LD Slag in Cement:

LD Slag is used as Cement making for replacement of clinker. LD Slag has higher CaO content in comparison to BF Slag, which acts as an activator and gives better strength.

The other areas where LD Slag is used are:

Road base and sub-base, Yard paving, Asphaltic cover, Soil corrective element for agricultural use, Cleaning of metallic structures, Anti-dust treatment, Rock Plugs, Recycling in steel products, Landfills, River beds, Acidic water treatment.

B. Properties of LD Slag

Resistance to heavy load/compression, Resistance durability, free drainage, interconnected angled particles, Resistance to skidding, Inertia, Basicity/ CaO content, Soluble P_2O_5 content.

C. Chemical composition of LD Slag

The chemical composition of typical LD slag samples generated at steel plant is shown in the following table.

TABLE I: CHEMICAL COMPOSITION OF LD SLAG

Type of Waste (Non-hazardous)	FeO	CaO	MgO	SiO_2	Al_2O_3	MnO
LD Slag	5.89	50.75	10.31	17.99	1.02	1.30

TABLE II: PHYSICAL PROPERTIES OF LD SLAG

S.No.	Properties	Test results
1	Fineness modulus	7.93
2	Specific gravity	2.15

II. CONCEPT OF MIX DESIGN

It will be a worthwhile to recall at this stage the relationship between aggregates and pastes which are the two essential ingredients of concrete. Workability of the mass is provided by the lubricating effect of the paste and it is influenced by the amount and dilution of paste. The strength of the concrete is limited by the strength of the paste, since mineral aggregates with rare exception are for stronger than the quality and continuity of the paste, since little water flows through aggregates either under pressure or capillarity. Further, the predominant contribution to drying shrinkage of concrete is that of paste.

III. MIX DESIGN OF M40 GRADE CONCRETE

Grade Designation	-	M40
Type of Cement	-	PPC 53 grade
Maximum Nominal Aggregate	-	20mm
Minimum Water Content	-	180 Kg/m^3
Maximum Water Cement ratio	-	0.31
Workability-Slump	-	45 mm
Compacting Factor	-	0.9
Exposure Conditions	-	Moderate
Type of Aggregate	-	Crushed Angular
Type of Admixture	-	Super Plasticizer
Test Data for Materials:		
Cement used	-	Jaypee OPC 53 grade

Specific Gravity of Cement - 3.01
Specific Gravity of Water - 1.00
Chemical Admixture - Roofplast
Specific Gravity of Aggregate - 2.61
Specific Gravity of Sand - 2.6

IV. MATERIALS REQUIREMENT FOR M40 GRADE

Mix proportions for one cum of Concrete:

Mass of Cement	-	598.06	Kg
Mass of Water	-	185.4	lit
Mass of Fine Aggregate	-	374.94	Kg
Mass of Coarse Aggregate	-	1182.04	Kg
Water Cement Ratio	-	0.31	

Mix Proportion by Weight/by Volume				
Mix M40	**Cement**	**Fine Aggregate**	**Coarse Aggregate**	**Water**
Weight (Kg)	598.06	374.94	1182.04	185.4
Ratio	1	0.72	1.97	0.31

Batching Proportions for M40 grade Concrete

TABLE III: BATCHING PROPORTIONS FOR M40 GRADE CONCRETE PER M^3 IN FLEXURE

S.No.	% of LD Slag	Cement	Fine Aggregate	Coarse Aggregate	Water	LD Slag	Super Plasticizer
1	0%	28.25	17.52	55.65	8.76	-	114
2	1%	28.25	17.52	55.094	8.76	0.556	114
3	2%	28.25	17.52	54.538	8.76	1.112	114
4	3%	28.25	17.52	53.982	8.76	1.668	114

TABLE IV: BATCHING PROPORTIONS FOR M40 GRADE CONCRETE PER M^3 IN COMPRESSION

S.No.	% of LD Slag	Cement	Fine Aggregate	Coarse Aggregate	Water	LD Slag	Super Plasticizer
1	0%	12.11	7.5	23.85	3.75	-	48.44
2	1%	12.11	7.5	23.6115	3.75	0.2385	48.44
3	2%	12.11	7.5	23.37	3.75	0.477	48.4
4	3%	12.11	7.5	23.13	3.75	0.715	48.44

Observations of Flexural Strength(N/mm^2):

TABLE V: FLEXURAL STRENGTH OF M40 GRADE CONCRETE FOR 7 DAYS

S.No.	Specimen size (150x150x700)	% of LD Slag	Span (Cm)	Distance of fracture	Load (KN)	Avg. Load (KN)	Avg. Strength (N/mm^2)
1	1	0	70	27	22	23	4.77
	2		70	25.5	24		
2	1	1%	70	27	26	26.5	5.49
	2		70	28	27		
3	1	2%	70	29.5	30	30	6.22
	2		70	31	30		
4	1	3%	70	30	27	27	5.6
	2		70	33	27		

TABLE VI: FLEXURAL STRENGTH OF M40 GRADE CONCRETE FOR 14 DAYS

S.No.	Specimen size (150x150x700)	% of LD Slag	Span (Cm)	Distance of fracture	Load (KN)	Avg. Load (KN)	Avg. Strength (N/mm^2)
1	1 2	0	70 70	28 29	25 27	26	5.39
2	1 2	1%	70 70	30 32	29 30	29.5	6.12
3	1 2	2%	70 70	31 33	32 35	33.5	6.94
4	1 2	3%	70 70	29 31	29 30	29.5	6.12

TABLE VII: FLEXURAL STRENGTH OF M40 GRADE CONCRETE FOR 28 DAYS

S.No.	Specimen size (150x150x700)	% of LD Slag	Span (Cm)	Distance of fracture	Load (KN)	Avg. Load (KN)	Avg.* Strength (N/mm^2)
1	1 2	0	70 70	31 30	29 27	28	5.80
2	1 2	1%	70 70	29 27	31 33	32	6.63
3	1 2	2%	70 70	27.5 29	36 37	36.5	7.57
4	1 2	3%	70 70	26 28	32 34	33	6.8

TABLE VIII: % INCREASE OF FLEXURAL STRENGTH IN N/MM^2 OF CONCRETE WITH LD SLAG WITH RESPECT TO CONVENTIONAL CONCRETE

S.No.	% of LD Slag	Flexural Strength (N/mm^2)			% increase		
		7 days	14 days	28 days	7 days	14 days	28 days
1	0	4.77	5.39	5.8	-	-	-
2	1%	5.49	6.12	6.63	15.09	13.5	14.31
3	2%	6.22	6.94	7.57	30.39	28.7	30.5
4	3%	5.6	6.12	6.84	17.4	13.5	17.93

Observation of Compressive Strength (N/mm^2):

TABLE IX: COMPRESSIVE STRENGTH OF CONCRETE FOR 7 DAYS

S.No	Specimen size 150x150x150	% of LD slag	Load KN	Avg. load KN	Compressive strength N/mm2
1	1 2	0%	650 630	640	28.4
2	1 2	1%	700 680	690	30.6
3	1 2	2%	700 720	710	31.56
4	1 2	3%	720 720	720	32

TABLE X: COMPRESSIVE STRENGTH OF CONCRETE FOR 14 DAYS

S.No	Specimen size 150x150x150	% of LD slag	Load KN	Avg. load KN	Compressive strength N/mm2
1	1 2	0%	860 880	870	38.66
2	1 2	1%	920 900	910	40.44
3	1 2	2%	980 970	970	43.11
4	1 2	3%	990 990	990	44

TABLE XI: COMPRESSIVE STRENGTH OF CONCRETE FOR 28 DAYS

S.No	Specimen size 150x150x150	% of LD slag	Load KN	Avg. load KN	Compressive strength N/mm2
1	1 2	0%	1140 1200	1170	52
2	1 2	1%	1180 1160	1170	52
3	1 2	2%	1180 1190	1185	52.67
4	1 2	3%	1190 1210	1200	53.33

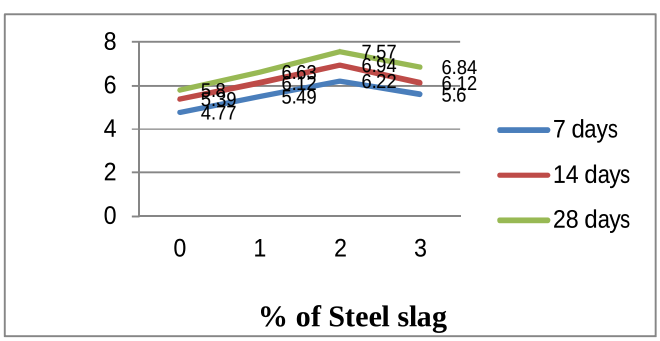
TABLE XII: % INCREASE/ DECREASE OF COMPRESSIVE STRENGTH IN N/MM^2 OF CONCRETE WITH LD SLAG WITH RESPECT TO CONVENTIONAL CONCRETE

S.No.	% of LD Slag	Compressive Strength (N/mm^2)			% increase		
		7 days	**14 days**	**28 days**	**7 days**	**14 days**	**28 days**
1	0	28.4	38.6	52	-	-	-
2	1%	30.6	40.4	52	7.74	4.66	-
3	2%	31.56	43.11	52.67	11.12	11.68	1.29
4	3%	32	44	53.33	12.67	13.98	2.56

V. GRAPHS

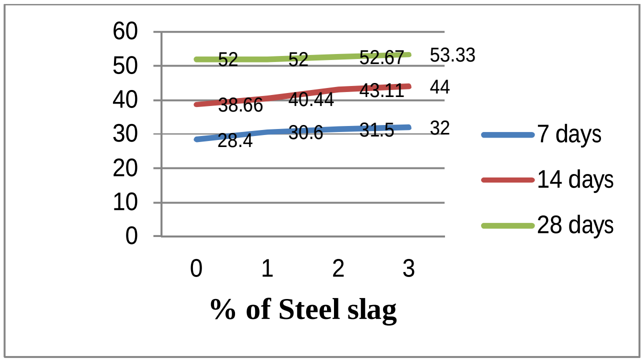
A. Flexural Strength

Graph-1: Flexural Strength of M25 grade Concrete for 7, 14, 28 days



B. Compressive Strength

Graph-2: Compressive Strength of Concrete for 7, 14, 28 days



VI. CONCLUSIONS

Based on the experimental results following conclusions were made:

- The specific gravity of Steel slag is low as compared to the coarse aggregate.
- 1%, 2%, 3% of coarse aggregate was replaced by Steel slag resulted that the compressive strength is increased when compared with the conventional concrete.
- The compressive strength of concrete was found to be increasing with replacement of Steel slag at all percentages.
- The compressive strength at 28 days for 0% & 1% Steel slag replacement was same.
- The flexure strength at 7,14 &28 days for 2% Steel slag replacement was observed to be very high.
- The compressive strength at 28 days for 3% Steel slag replacement indicated increase in strength compared to conventional concrete.

  The percentage increase of strength with respect to conventional concrete was 13.98% at 14 days for 3% replacement.
- The maximum flexural strength was achieved at 3% replacement of Steel slag at 7,14 and 28 days.
- The maximum flexural strength was achieved at 2% at 28 days.
- The maximum compressive strength was achieved at 3% replacement of slag at 28 days.
- The concrete which is prepared by using steel slag can be used for construction of road pavements, footpaths, low traffic village roads etc.,

Environmental Aspect

1. No substantial leaching of the Slag metal content to underground or surface water representing little or no concern regarding potable water quality.
2. Slag has no impact on animals or other forms of life in the areas of use or areas nearby. There is no bioaccumulation of metals present in the slag in the soil.
3. LD slag can be safely used in aquatic environments such as rivers, lakes and water streams with no impact on the quality of the water or aquatic life. Such environments allow enough dilution protect against high pH alteration. It is necessary to be careful when using the slag in smaller water bodies with low water flow such as wet terrains or shallow channels.
4. Slag used in cement manufacturing has partially replaced the use of clinker reducing energy consumption and, therefore CO_2 emissions.
5. Environmental impacts caused by mineral extraction can be eliminated with the use of Slag.

Scope for further study

- The present study can be further carried out on other grades of concrete.
- The effect of fresh properties of concrete due to usage of different proportions may be studied.
- In present investigation the replacement of coarse aggregate was only up to 3%. Further investigation can be carried out at different percentages.

- The investigation can also be done by replacing Steel slag with other materials of concrete i.e., cement, fine aggregate.
- The study can be extended to assess the durability aspects of the concrete with varying replacement proportions.

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