STUDY OF CONCRETE USING LD SLAG AS PARTIAL REPLACEMENT OF COARSE AGGREGATE

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ABSTRACT: India has an enormous growth in steel industry and Slag is a byproduct of the same which has to be disposed properly. Steel industry generate large quantities of Slags from their iron-making and steel-making processes. Iron making Slags are recycled in cement making and steel-making Slags 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. LD 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 letters **LD** means **L**inz and **D**onawitz, towns in Austria where the process was invented. 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. The objective of the present study is to study the possibility of using LD 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 LD Slag on flexural strength and compressive strength of concrete. Coarse aggregate was replaced with three percentages (1%, 2% and 3%) of LD Slag by volume in M25 grade of concrete with 0.5 water cement ratio (w/c).

Key words: LD Slag, Partial Replacement

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.

Present Uses of LD Slag:

a) 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.

b) 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.

c) The others 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.

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.

Chemical composition of LD Slag:

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

Table 1: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 2: Physical Properties of LD Slag

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

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.

MIX DESIGN OF M25 GRADE CONCRETE

Grade Designation	-	M25
Type of Cement	-	OPC 53 grade
Maximum Nominal Aggregate	-	20mm
Minimum Water Content	-	300 Kg/m^3
Maximum Water Cement ratio	-	0.50
Workability-Slump	-	60 mm
Compacting Factor	-	0.94
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	-	3.08
Specific Gravity of Water	-	1.00
Chemical Admixture	-	Armstrong Chemical
Specific Gravity of Aggregate	-	2.67
Specific Gravity of Sand	-	2.75

MATERIALS REQUIREMENT FOR M25 GRADE

Mix proportions for one cum of Concrete:

Mass of Cement	-	383.16	Kg
Mass of Water	-	191.58	lit
Mass of Fine Aggregate	-	679.905	Kg
Mass of Coarse Aggregate	-	1228.584	Kg
Water Cement Ratio	-	0.50	

Mix Proportion by Weight/by Volume

Mix M25	Cement	Fine Aggregate	Coarse Aggregate	Water
Weight (Kg)	383.16	679.90	1228.58	191.58
Ratio	1	1.77	3.20	0.50

Batching Proportions for M25 grade Concrete

Table 3: Batching Proportions for M25 Grade Concrete per m^3 in Flexure

S.No.	% of LD Slag	Cement	Fine Aggregate	Coarse Aggregate	Water	LD Slag	Super Plasticizer
1.	0 %	18.10	32.06	58.03	9.05	-	108.6
2.	1 %	18.10	32.06	57.44	9.05	0.580	108.6
3.	2 %	18.10	32.06	56.86	9.05	1.160	108.6
4.	3 %	18.10	32.06	56.28	9.05	1.740	108.6

Table 4: Batching Proportions for M25 Grade Concrete per m^3 in Compression

S.No.	% of LD Slag	Cement	Fine Aggregate	Coarse Aggregate	Water	LD Slag	Super Plasticizer
1.	0 %	11.63	20.61	34.54	5.80	-	69.78
2.	1 %	11.63	20.61	34.19	5.80	0.345	69.78
3.	2 %	11.63	20.61	33.84	5.80	0.690	69.78
4.	3 %	11.63	20.61	33.50	5.80	1.036	69.78

Observations of Flexural Strength(N/mm2):

Table 5: Flexural Strength of M25 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	25.00	25.50	25.50	5.28
2.	2	1 %	70	31.00	25.50	25.50	5.28
3.	3	2 %	70	29.30	26.00	26.00	5.39
4.	4	3 %	70	28.90	26.00	26.00	5.39

Table 6: Flexural Strength of M25 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	0 %	70	30.50	26	26	5.39
2.	2	1 %	70	25.50	29	29	6.01
3.	3	2 %	70	33.00	29	29	6.01
4.	4	3 %	70	30.00	32	32	6.63

Table 7: Flexural Strength of M25 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	0 %	70	27.10	28	28	5.80
2.	2	1 %	70	34.50	31	31	6.42
3.	3	2 %	70	33.00	31.5	31.5	6.53
4.	4	3 %	70	29.00	33	33	6.84

Table 8: % 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	5.28	5.39	5.80	-	-	-
2.	1	5.28	6.01	6.42	-	11.5	10.68
3.	2	5.39	6.01	6.53	2.08	11.5	12.58
4.	3	5.39	6.63	6.84	2.08	23	17.93

Observation of Compressive Strength (N/mm2):

Table 9: Compressive Strength of Concrete for 7 days

S.No.	Specimen size (150x150x700)	% of LD Slag	Load (KN)	Avg. Load (KN)	Compressive Strength (N/mm^2)
1.	1	0 %	750	706.6	31.40
	2		820		
	3		550		
2.	1	1 %	650	680.0	30.22
	2		640		
	3		750		
3.	1	2 %	690	700.0	31.11
	2		700		
	3		710		
4.	1	3 %	750	696.6	30.96
	2		650		
	3		690		

Table 10: Compressive Strength of Concrete for 14 days

S.No.	Specimen size (150x150x700)	% of LD Slag	Load (KN)	Avg. Load (KN)	Compressive Strength (N/mm^2)
1.	1	0 %	830	936.66	41.62
	2		980		
	3		1000		
2.	1	1 %	730	793.33	35.25
	2		800		
	3		850		
3.	1	2 %	820	853.33	37.92
	2		850		
	3		890		
4.	1	3 %	800	823.33	36.59
	2		830		
	3		840		

Table 11: Compressive Strength of Concrete for 28 days

S.No.	Specimen size (150x150x700)	% of LD Slag	Load (KN)	Avg. Load (KN)	Compressive Strength (N/mm^2)
1.	1	0 %	940	960.00	42.66
	2		1000		
	3		940		
2.	1	1 %	970	920.00	40.88
	2		950		
	3		840		
3.	1	2 %	940	960.00	42.66
	2		1010		
	3		940		
4.	1	3 %	980	966.66	42.96
	2		1000		
	3		920		

Table 12: % 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			% decrease		
		7 days	14 days	28 days	7 days	14 days	28 days	7 days	14 days	28 days
1.	0	31.40	41.62	42.66	-	-	-	-	-	-
2.	1	30.22	35.25	40.88	-	-	-	3.76	15.31	4.17
3.	2	31.11	37.92	42.66	-	-	-	0.92	8.89	0.00
4.	3	30.96	36.59	42.96	-	-	0.70	1.4	12.09	-

Flexural Strength

In the present investigation 150 x 150 x 700 mm size beams are used. Flexural Strength of Concrete was determined on these specimens, which were cured in clean water until the date of test. One beam was tested in every case at different % of LD Slag for 7 days, 14 days and 28 days respectively.

a) Table 5 gives the results of flexural strength of beams at different % of LD slag i.e., 0%, 1%, 2%, 3% for 7days.
b) Table 6 gives the results of flexural strength of beams at different % of LD slag i.e., 0%, 1%, 2%, 3% for 14days.
c) Table 7 gives the results of flexural strength of beams at different % of LD slag i.e., 0%, 1%, 2%, 3% for 28days.
d) Table 8 gives the percentage increase/decrease of Flexural Strength of Concrete with LD Slag with respect to Conventional Concrete.

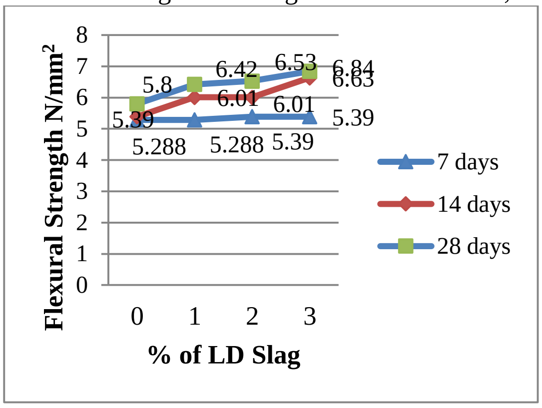
Compressive Strength

a) In the present investigation 150 x 150 x 150 mm size cubes are used. Compressive strength of concrete was determined on these specimens, which were cured in clean water until the date of test. Three cubes were tested in every case and the average value is taken in assessing Compressive Strength at different % of LD Slag for 7 days, 14 days and 28 days respectively.
b) Table 9 gives the results of Compressive Strength of beams at different % of LD Slag i.e., 0%, 1%, 2%, 3% for 7days.
c) Table 10 gives the results of Compressive Strength of beams at different % of LD Slag i.e., 0%, 1%, 2%, 3% for 14days.
d) Table 11 gives the results of Compressive Strength of beams at different % of LD Slag i.e., 0%, 1%, 2%, 3% for 28days.
e) Table 12 gives the percentage increase/decrease of Compressive Strength of Concrete with LD Slag with respect to Conventional Concrete.

GRAPHS

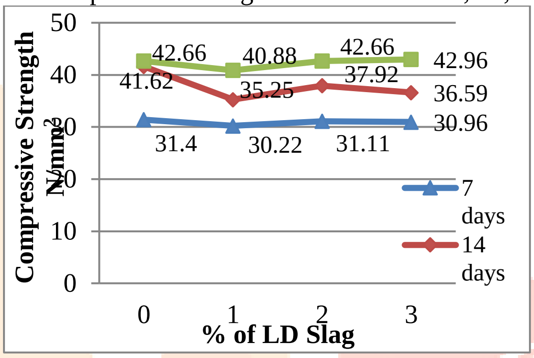
a) FLEXURAL STRENGTH:

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



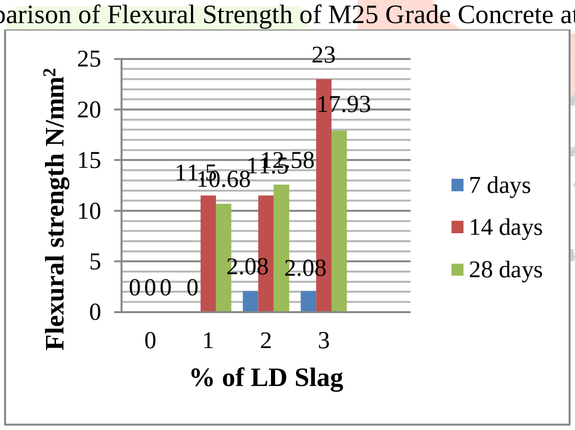
b) COMPRESSIVE STRENGTH

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



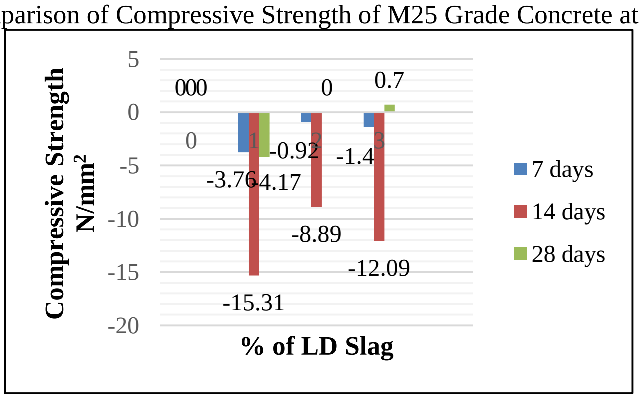
c) RELATION SHOWING % INCREASE OF FLEXURAL STRENGTH

Graph-3: Comparison of Flexural Strength of M25 Grade Concrete at 7, 14, 28 days



d) RELATION SHOWING % INCREASE/DECREASE IN COMPRESSIVE STRENGTH

Graph-4: Comparison of Compressive Strength of M25 Grade Concrete at 7, 14, 28 days



CONCLUSIONS:

Based on the experimental results following conclusions were made:

1. The Specific Gravity of LD Slag is low as compared to the Coarse Aggregate.
2. 1%, 2%, 3% of Coarse Aggregate was replaced by LD Slag resulted that the Compressive Strength is reduced when compared with the Conventional Concrete.
3. The Compressive Strength at 28 days for 2% LD Slag replacement was same as Conventional Concrete Strength.
4. The Compressive Strength at 28 days for 3% LD Slag replacement indicated increase in strength compared to Conventional Concrete.
5. The percentage increase of Strength with respect to Conventional Concrete was 0.7%.
6. The Flexural Strength of Concrete was found to be increasing with replacement of LD Slag at all percentage, the maximum Flexural Strength was achieved at 3% replacement of LD Slag at 7, 14 and 28 days.
7. The maximum Compressive Strength was achieved at 3% replacement of Slag at 28 days.

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.

Advantages of using LD Slag:

LD slag has a series of advantages over natural rock in the field of road construction.

a. Greater Hardness

Slag has a greater resistance to wear. This is the result of its mineral composition. The consequences: less wear and longer road lifetimes. Roads constructed using LD slag demonstrates reduced rutting.

b. Better Adhesion

LD Slag has micro pores and therefore, it retains its adhesiveness with wear. In contrast, natural rock becomes smooth with wear - its surface becomes polished and slippery. As a result, tires can grip better on surfaces constructed using LD Slag and this is particularly important on highways and in curves.

c. Greater Stability and Reduced Wear

LD Slag is harder and internally bound. Natural gravel does not have the same stability and load bearing capacity. As LD slag is harder and more compact than natural rock, roads last longer as there is less wear, particulate pollution is reduced

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