International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 12
April 2018

Experimental Study on Mechanical Properties of Hardened Concrete using Cupola Slag as Partial Replacement of Cement and Coarse Aggregate

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ABSTRACT:

The simplest way of getting aggregate is from naturally available sources. Excavation of rocks from valley which is generally produces worst environmental impacts. Cutting and screening out of coarse aggregate makes the conventional concrete more costly and scarce due to small sized limited quantity of natural materials which is used. Cupola slag can be use in construction industry as replacement of coarse aggregate and cement. Cupola slag is replaced with coarse aggregate and cement with optimum percentage of replacement to check the suitability of concrete to Mechanical properties, Durability, Workability and Environmental feasibility.

Even only Coarse aggregate can not fulfill the requirements of constructions so there is a need to search a replacing material cupola slag in this study efforts are made to replace the natural aggregate with cupola slag aggregates in varying percentage of replacement from 0 to 100 percent for intervals of 20 percent for M25 grade concrete with 0.4 constant W/C ratio under accelerated concrete curing condition for 7 & 28 days are made to carry out impact on compressive strength, split tensile tests and flexural strength of concrete.

Key words:-Cupola Slag, Compressive Strength test, Spilt tensile test, Flexural test, Rapid chloride permeability test.

1. INTRODUCTION

Concrete is the preferred construction material for a wide range of building, bridges and any other civil engineering structures. It is the second most widely consumed substance on earth after water.

Natural resources of concrete is limited as we get it from natural deposits at present, there is a need to develop a new material that can effectively replace with conventional without compromising with strength and durability properties of concrete. In this study efforts are made for replacing It is also available in limited quantity. So there is a need to replace these natural materials by alternative options which are obtained to industrial byproduct like Cupola slag. Now a day,sustainable infrastructural growth demands the alternative material that should satisfy technical requirements of natural aggregate as well as it should be available great quantity. The cheapest and the easiest way of getting substitute for natural aggregates is by crushing Cupola Slag to get artificial aggregates of desired size and grade.

Industry produced a large amount of by-product material during casting process. It also has environmental issues in disposal of these by product since it cannot be used anywhere expect the land filling at present. So by there is a need to replace natural aggregates by Cupola Slag to solve concrete as well as environmental and industry problem.

1.1. Objective of the Study

a) To study the compressive strength, flexural strength and split tensile strength of concrete on using Cupola Slag aggregate as partial replacement of coarse aggregate.

b) To study the compressive strength, flexural strength and split tensile strength of concrete on using Cupola Slag powder as partial replacement of cement.

c) To study the durability of all the specimens using Rapid Chloride Penetration Test (RCPT).

1.2. Scope of the Study

a) The same work can be extended to higher grades of concrete with varying water/cement ratio.
b) Analysis of the properties of concrete with Mix proportion use admixtures and fly ash.
c) The same work can be extended to replacement of fine Aggregate.

2. EXPERIMENTAL DETAILS

2.1. *Cement*

ISI marked OPC 53 cement used in this study of Ordinary Portland cement that satisfies the requirements of Indian standards IS 12269:1987.

2.2. *Coarse Aggregate*

The coarse aggregates obtained from the locally available quarries with maximum size of 20 mm and satisfying the grading requirements of BIS (IS: 383-1970) is used during this work.

2.3. *Fine Aggregate*

The Size of aggregate 4.75 mm and smaller is called fine aggregate.IS:383-1970 has divided the fine aggregate in to four grading zones. The grading zones become progressively finer from grading zone I to grading zone IV. Zone III used during this work.

2.4. *Water*

Portable drinking water having pH value of 7 and conforming to IS 456-2000 IS used for concreting as well as curing of specimens.

2.5. *Cupola Slag*

Cupola Slag procured from, G.I.D.C. Makarpura is used in this work after crushing and sieving operation, Physical properties were find out as per IS 383.The slag was dumped in large lump forms. It was first dusted and isolated to remove the visible earth impurities. It was then crushed to sizes less than 20 mm with the use of jaw crusher.

Figure 1. Cupola Slag

A number of research works had been conducted on the successful use of cupola furnace slag to partially or wholly replace native coarse aggregate in concrete. Cupola slag has also been reported suitable for use as aggregate in asphalt mixtures and as roadbed, base course, or sub-base material for highways.

Table 1 Chemical composition of cupola slag

Sr. No.	Test Details	Test Resultof Cupola Slag (%)
1	Silicon dioxide (SiO_2)	56.30
2	Magnesium oxide (MgO)	2.26
3	Calcium oxide (CaO)	9.38
4	Aluminiumoxide (Al_2O_3)	10.20
5	Iron oxide ($Fe_2 O_3$)	15.95
6	Sodium Oxide (Na_2O)	0.45

Table 2 Physical Properties of Cupola Slag

Sr. No.	Property	Results
1	Crushing value,%	27
2	Impact value,%	26.71
3	Specific gravity	2.50
4	Water absorption %	0.4
5	Bulk density	1640

Figure 2. Rapid Chloride Permeability Test

3. MIX DESIGN OF M-25 CONCRETE

Table 3 Mix Design of M-25 Concrete

Proportion	Water	Cement	Fine aggregate	Coarse aggregate
By weight (kg/m^3)	197	492.5	683.23	1067.55
Weight	0.4	1	1.387	2.1676

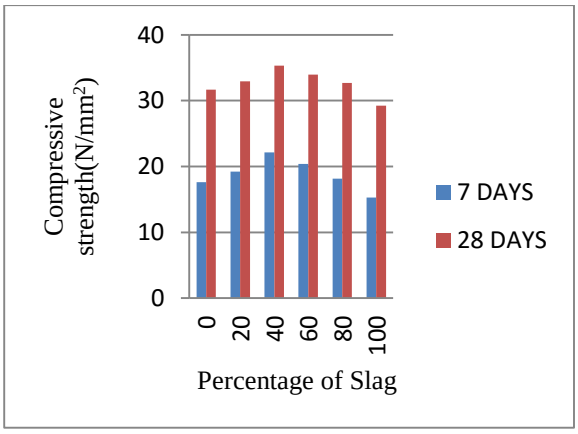
4. RESULTS AND DISCUSSION

4.1. Compressive Strength Test Results

4.1.1. Replacement of coarse aggregate with cupola slag

Table 4 Result of Compressive Strength for Replacement of coarse aggregate with cupola slag

Type of Concrete	7 Days		28 Days	
	Compressive Strength N/mm^2	Average Compressive Strength N/mm^2	Compressive Strength N/mm^2	Average Compressive Strength N/mm^2
Conventional Concrete(M_{25})	17.60	17.6	31.23	31.68
	17.68		32.07	
	17.52		31.75	
Concrete(M_{25}) + 20% Cupola Slag	18.36	19.2	32.91	32.91
	19.51		33.58	
	19.73		32.25	
Concrete(M_{25}) + 40% Cupola Slag	22.18	22.15	36.05	35.33
	21.73		35.07	
	22.55		34.88	
Concrete(M_{25}) + 60% Cupola Slag	20.78	20.38	34.75	33.97
	20.93		32.77	
	19.45		34.39	
Concrete(M_{25}) + 80% Cupola Slag	19.30	18.14	30.91	32.69
	18.11		33.48	
	17.03		33.69	
Concrete(M_{25}) + 100% Cupola Slag	15.15	15.27	28.32	29.23
	14.88		30.47	
	15.78		28.91	



Graph 1 Compressive Strength for Replacement of coarse aggregate with cupola slag for 7 & 28 days

Discussion on Compressive Strength

1. In conventional as well as Replacement aggregate concrete the compressive strength at 7 days and 28 days are found out and results are tabulated.
2. The maximum value of compressive strength obtained is 35.33 N/mm^2 for M25 grades of concrete respectively when the coarse aggregate is replaced by 40% cupola slag.
3. The compressive strength of the concrete decreases beyond 40% replacement of coarse aggregate with cupola slag.
4. The required strength of M25 concrete is achieved for 20%, 40%, 60%, 80% replacement in the case of M25 grade concrete.

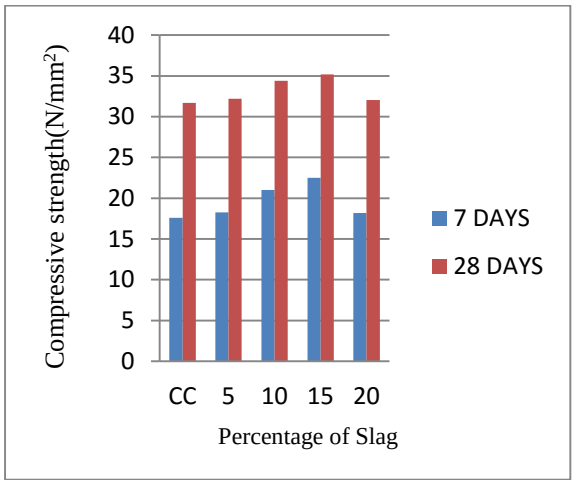
Figure 3. Spilt Tensile Test

Figure 4. Compressive Strength Test

4.1.2. Replacement of cement with cupola slag

Table 5 Result of Compressive Strength for Replacement of cement with cupola slag

Type of Concrete	7 Days		28 Days	
	Compressive Strength N/mm^2	Average Compressive Strength N/mm^2	Compressive Strength N/mm^2	Average Compressive Strength N/mm^2
Conventional Concrete(M_{25})	17.60	17.6	31.23	31.68
	17.68		32.07	
	17.52		31.75	
Concrete(M_{25}) + 5% Cupola Slag	17.80	18.25	32.45	32.18
	19.66		31.14	
	17.31		32.97	
Concrete(M_{25}) + 10% Cupola Slag	22.03	21.01	34.62	34.38
	19.86		34.78	
	21.16		33.75	
Concrete(M_{25}) + 15% Cupola Slag	22.71	22.5	35.87	35.19
	21.57		35.08	
	23.22		34.62	
Concrete(M_{25}) + 20% Cupola Slag	19.21	18.17	31.26	32.02
	17.97		31.64	
	17.33		33.17	



Graph 2 Compressive Strength for Replacement of cement with cupola slag for 7 & 28 days

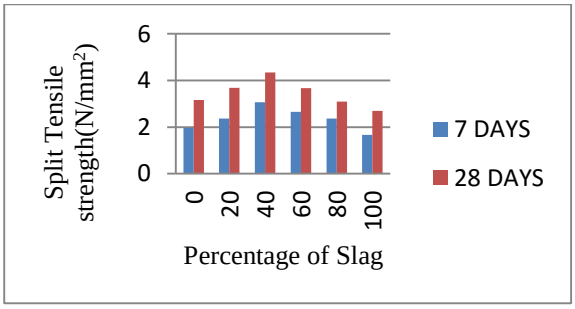
Discussion on Compressive Strength

1. The maximum value of compressive strength obtained is 35.19 N/mm^2 for M25 grades of concrete respectively when the Cement aggregate is replaced by 15% cupola slag.
2. The compressive strength of the concrete decreases beyond 15% replacement of cement aggregate with cupola slag.
3. The required strength of M25 concrete is achieved for 5%,10%,15% replacement in the case of M25 grade concrete.

4.2. Spilt Tensile Strength Test Results

Table 6 Result of Split Tensile for Replacement of coarse aggregate with cupola slag

Type of Concrete	7 Days		28 Days	
	Split Tensile Strength N/mm^2	Average Split Tensile Strength N/mm^2	Split Tensile Strength N/mm^2	Average SplitTensile Strength N/mm^2
Conventional Concrete(M_{25})	1.90	1.96	3.18	3.16
	2.04		3.04	
	1.94		3.27	
Concrete(M_{25})+ 20% Cupola Slag	2.61	2.36	4.03	3.69
	2.37		3.19	
	2.12		3.86	
Concrete(M_{25}) + 40% Cupola Slag	3.08	3.06	4.38	4.35
	2.88		4.18	
	3.23		4.51	
Concrete(M_{25}) + 60% Cupola Slag	2.46	2.65	3.73	3.67
	2.93		3.46	
	2.56		3.81	
Concrete(M_{25}) + 80% Cupola Slag	2.32	2.37	3.03	3.09
	1.97		2.79	
	2.82		3.45	
Concrete(M_{25}) + 100% Cupola Slag	1.76	1.67	2.76	2.70
	1.34		3.07	
	1.93		2.27	



Graph 3 Split Tensile Test for Replacement of coarse aggregate with cupola slag for 7 & 28 days

Discussion on split tensile strength

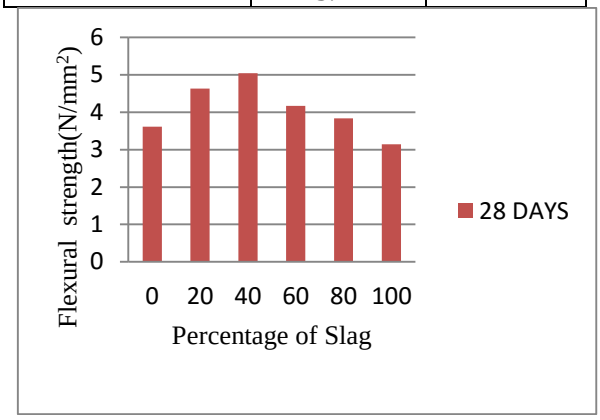
1. The maximum value of Split Tensile strength obtained is 4.35 N/mm^2 for M25 grades of concrete respectively when the

coarse aggregate is replaced by 40% cupola slag.
2. The Split Tensile strength of the concrete decreases beyond 40% replacement of coarse aggregate with cupola slag.
3. The required strength of M25 concrete is achieved for 20%, 40%, 60%, 80% replacement in the case of M25 grade concrete.

4.3. Flexural Strength Test Results

Table 7 Result of Flexural Strength for Replacement of coarse aggregate with cupola slag

Type of Concrete	28 Days	
	Flexural Strength N/mm^2	Average Flexural Strength N/mm^2
Conventional Concrete(M_{25})	3.44	3.61
	3.68	
	3.71	
Concrete(M_{25}) + 20% Cupola Slag	4.61	4.63
	4.31	
	4.97	
Concrete(M_{25}) + 40% Cupola Slag	5.31	5.04
	5.01	
	4.81	
Concrete(M_{25}) + 60% Cupola Slag	4.67	4.17
	3.49	
	4.35	
Concrete(M_{25}) + 80% Cupola Slag	3.11	3.84
	4.76	
	3.67	
Concrete(M_{25}) + 100% Cupola Slag	2.86	3.14
	3.12	
	3.44	



Graph 4 Flexural Strength Test for Replacement of coarse aggregate with cupola slag for 28 days

Discussion on Flexural Strength

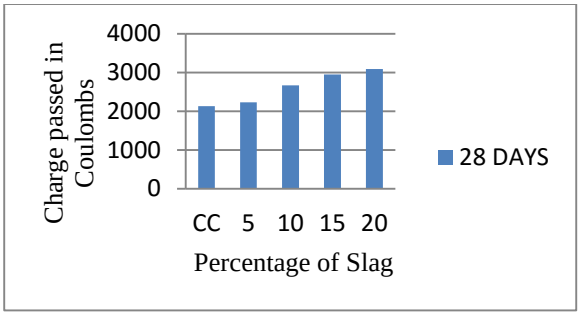
1. The maximum value of Flexural Tensile strength obtained is 5.04 N/mm^2 for M25 grades of concrete respectively when the coarse aggregate is replaced by 40% cupola slag.
2. The Flexural strength of the concrete decreases beyond 40% replacement of coarse aggregate with cupola slag.
3. The required strength of M25 concrete is achieved for 20%, 40%, 60%, 80% replacement in the case of M25 grade concrete.

4.4. Rapid Chloride Permeability Test Results

Table 8 Result of Rapid Chloride Permeability Test for Replacement of cement with cupola slag

Type of Concrete	28 Days		
	Charge passed in Coulombs	Average Charge passed in Coulombs	As per ASTM C1202: Chloride penetrating rate
Conventional Concrete(M_{25})	2152	2129	Moderate
	2105		
	2132		
Concrete(M_{25}) + 5% Cupola Slag	2221	2233	Moderate
	2226		
	2253		
Concrete(M_{25}) + 10% Cupola Slag	2642	2666	Moderate
	2695		
	2661		
Concrete(M_{25}) + 15% Cupola Slag	2973	2947	Moderate
	2915		
	2953		

Concrete(M_{25}) + 20% Cupola Slag	3115	3091	Moderate
	3065		
	3093		



Graph 5 Rapid Chloride Permeability Test for Replacement of cement with cupola slag for 28 days

Discussion on Rapid Chloride Permeability Test

1. As per ASTM C1202, the value obtained for cupola slag admixed concrete is graded under the category "Moderate". As such, it is indicating lesser permeability of slag admixture concrete .The important observation is that addition of slag definitely reduces the pores of concrete and makes the concrete impermeable.

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