SUITABILITY OF CONCRETE USING CUPOLA SLAG AS REPLACEMENT OF COARSE AGGREGATE

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Abstract— Main source of getting natural aggregates is through extraction from rocks. The excavation of rocks from valley produce worst environmental impacts of cutting and screening out coarse aggregate make concrete costlier. Even only natural resources of Coarse aggregate can't fulfil the requirements of constructions so there is a need to search a replacing material like cupola waste 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 10 percent for M20 grade concrete with 0.5 constant W/C ratio under accelerated concrete curing condition for 3 days at 85 degree temperature.efforts are made to carry out impact on compressive strength of concrete.

Index Terms— Cupola Slag, Compressive Strength, Aggregate Replacement, Optimum Percentage, Crushing Value, Polypropylene Fibres (PPF), Physical Properties

1 INTRODUCTION

At present, development in India is mainly by implementation of infrastructure projects. Due to that construction projects are executed at very rapid rate. In the developing country like India, availability of natural resources is also an influencing factor apart from funding due to this rapid infrastructural growth it requires large amount of construction material like cement, aggregates, wood etc. R.C.C. structures are preferred over steel structures in India which requires larger quantity of concrete. Since availability of 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 naturally available coarse aggregate with cupola slag aggregates. Cupola slag is by-product of cast iron manufacturing unit it is produced during the separation of the molten steel from impurities in cupola furnaces. The slag occurs as a molten liquid melt solidifies upon cooling. Complex solution of silicates and oxides is generally found in a lump which solidifies upon cooling. About 5-7% of waste is generated in cupola furnaces while production of cast iron. Industry produces 50-3000 Tonnes of C.I. depending upon furnace size and requirements. About 3000 furnaces are running Gujarat at present. Due to that larger amount of waste is generated which is presently going to land filling only, polluting environment. At present Industrialists are paying for disposal of this waste. As per calculations made, this waste can Decrease 1% demand of natural aggregate in Gujarat with crores of economical saving in country benefit. Cupola waste collected from industries is crushed in the jaw crusher and sieved through 20mm sieve to get appropriate size of aggregates. In this work, aggregates passing through 22 mm and retained on 20mm sieve and, passing through 12mm and retained on 8mm is used as 20mm and 10mm aggregates. We get 70% sized aggregates by mechanical crushing due to hardness of material.We have used cupola slag aggregate in M20 grade concrete with constant w/c ratio of 0.5.first efforts were made to find optimum percentage of cupola waste with gap of 10% from 0 to 100 percent.5 cubes were casted for each mix. From that 3 was cured in accelerated concrete curing tank for 3 days at 85 degree temperature and 2 in normal curing for 28 days. Resulting strength was compared for each mix. Physical and chemical properties of waste were carried out to check the suitability to use as aggregate.

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2 Material Used

Physical tests of each material were carried out before used in concrete as per IS 383 and IS 12269 for aggregate and cement respectively.

2.1 CEMENT

ISI marked OPC 53 Grade Riddhi cement was used in this work with specific gravity of 3.15, standard consistency 26%, 42 and 240 minutes of initial and final setting time respectively, soundness of 2mm and compressive strength of 28,39 and 55 MPa at 3, 7 and 28 days respectively.

2.2 SAND

Sand obtained from Banas River, confirming to Zone-II, with fineness modulus of 2.25, specific gravity of 2.78, and water absorption of 3.1% was used in this work.

2.3 COARSE AGGREGATES

Coarse aggregates obtained from basalt rock were used with combination of grits in 60:40 ratios with following physical

properties.

Table 1: Physical Propertites of coarse aggregate and Grit

Properties	Aggregate	Grit
Fineness Modulus	1617	7.87
Bulk Density	3.82	1717
Specific Gravity	2.57	2.31
Water absorption	1.17	1.34
Moisture Content	0.012	0.032
Crushing Value	17%	-
Impact Value	19%	-

2.4 CUPOLA SLAG

Cupola slag procured from, G.I.D.C. Chhatral is used in this work after crushing and sieving operation

Fig.1. Cupola Slag

Fig.2. Cupola Slag crushed to 20mm and 10mm

Physical properties were find out as per IS 383 and compared with natural aggregates as below.

Table: 2 Physical Properties of Cupola Slag

Property	Results	IS Requirements
Fineness Modulus	4.60	-
Crushing Value	27%	Concrete < 45 Road < 30
Impact Value	26%	Concrete < 45 Road < 30
Flakiness Index	11%	< 15%
Elongation Index	14%	< 15%
Specific Gravity	2.50	-
Bulk density	1640	-
Moisture Content	0.004	-
Water Absorption	0.4	< 2

Chemical properties of slag tested by WDXRF method at divine metallurgical services was found as under.

Table 3: Chemical Properties of Cupola Slag

Element	Percentage
Al_2O_3	9.5
MnO	2.9
SiO_2	45.0
MgO	2.35
TiO_2	1.00
CaO	14.250
Fe_2O_3	23.500
Cr_2O_3	0.300
Na_2O	0.500
K_2O	0.200

2.5 POLYPROPYLENE FIBRES

Polypropylene fibres with following physical and chemical properties are used in this work.

Table 4: Physical and Chemical Properties of PPF

Sr. No.	Properties	Value
1	Specific Gravity	0.91
2	Apperance	Whitish
3	Melting Point	165 C

4	Diameter	30 Micron
5	Cut Length	20mm
6	Water absorption	<0.1%
7	Resistance to Alkalies	Excellent
8	Resistance to Acids	Excellent
9	Resistance to oxidizing Agents	Good
10	Resistance to organic Solvent	Good
10	Biological Solvent	Non biodegradable.
11	Elongation Percentage	58%

3. EXPRIEMENTAL METHODOLOGY

M20 Concrete grade was selected to find optimum percentage with 1:1.5:3 mix composition with constant w/c ratio of 0.5. Total 55 Cubes of size 150mm x 150mm x 150mm was casted for assessment of compressive strength. Curing comparison was made between ACC tank and normal curing for 3 day and with degree and 28 days with 27 degree temperatures respectively. Detailed mix proportion for each mix is tabulated in table 3.

COMPRESSIVE STRENGTH

All cubes were tested under 2000 KN capacity compression testing machine after 28 days according to IS: 516. Specimen was placed at centre of CTM as shown in figure 3. load was applied gradually still the failure of specimen. Compressive strength was carried out using following relation.

$$C = P/A$$

Here, C is compressive strength in MPa, P is the load applied in KN, A is the surface area of cube in mm^2

Table 5: Material Requirement for different replacement levels

Name	Cement (Kg)	F.A.	Coarse Aggregate(Kg)		Cupola Slag Aggregate(Kg)	
			20mm	10mm	20mm	10mm
CMO	10	15	18	12	-	-
10C	10	15	16.2	10.8	1.8	1.2
20C	10	15	14.4	9.6	3.6	2.4
30C	10	15	12.6	8.4	5.4	3.6
40C	10	15	10.8	7.2	7.2	4.8
50C	10	15	9	6.0	9.0	6
60C	10	15	7.2	4.8	10.8	7.2
70C	10	15	5.4	3.6	12.6	8.4
80C	10	15	3.6	2.4	14.4	9.6
90C	10	15	1.8	1.2	16.2	10.8
100C	10	15	-	-	18	12

4 RESULTS AND DISCUSSION

Results for compressive strength for both ACC and natural curing are tabulated in table 6.

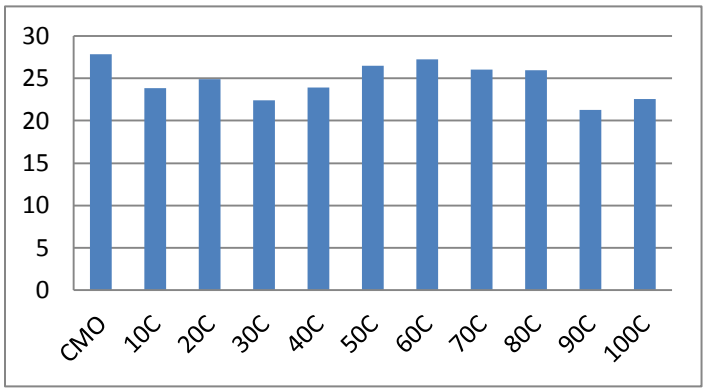
For ACC curing, we are getting strength drop for Initial and final replacement, but in between replacement percentages strength is increased in between 50 to 80 percent replacement. For ACC curing 60% replacement gives higher strength.
For normal curing required characteristic mean strength for M20 grade concrete is also obtained at 80% replacement. So it can be considered as optimum percentage of replacement.
Due to hardness of material there may flexural strength can be decreased which can be improved by addition of polypropylene fibers.
Addition of 0.2% PPF by weight of cement increases compressive strength by 23%

Fig. 3: Compressive Strength Test on Cube

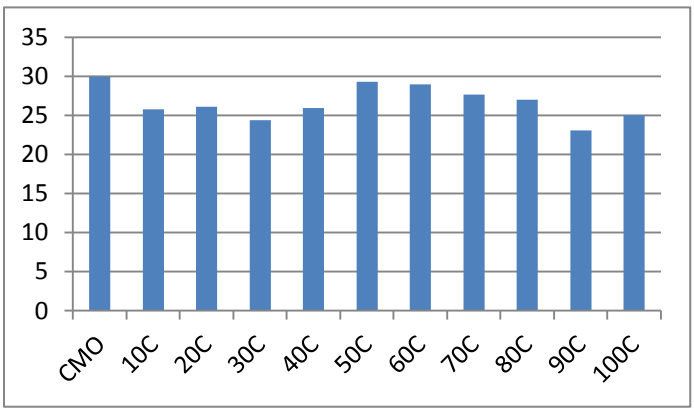
Table 6: Compressive strength results for ACC and Natural Curing

Name	Compressive Load Taken	Compressive Strength	Mean Compressive Strength (ACC Curing)	Mean Compressive Strength (Natural Curing)
CMO	630.9	28.04	27.85	29.95
	659.20	29.29		
	590.53	26.24		

10C	538	23.91	23.85	25.75
	535.20	23.78		
	584.80	25.99		
20C	594.80	26.43	24.89	26.10
	497.50	22.11		
	525.30	23.34		
30C	514.3	22.85	22.36	24.36
	508.9	22.61		
	486.20	21.60		
40C	560.9	24.93	23.89	25.97
	537.9	23.90		
	514.1	22.84		
50C	602.7	26.78	26.46	29.28
	552.3	24.54		
	631.7	28.07		
60C	659.90	29.32	27.24	29.0
	567.0	25.20		
	612.30	27.21		
70C	572.90	25.46	25.99	27.65
	579	25.73		
	602.8	26.79		
80C	**548.7**	**24.38**	**25.95**	**27.02**
	646.5	**28.79**		
	555.4	**24.68**		
90C	461.80	20.52	21.25	23.08
	502.60	22.33		
	470.90	20.92		
100C	482.4	21.44	22.58	25.0
	529.1	23.51		
	513.3	22.81		



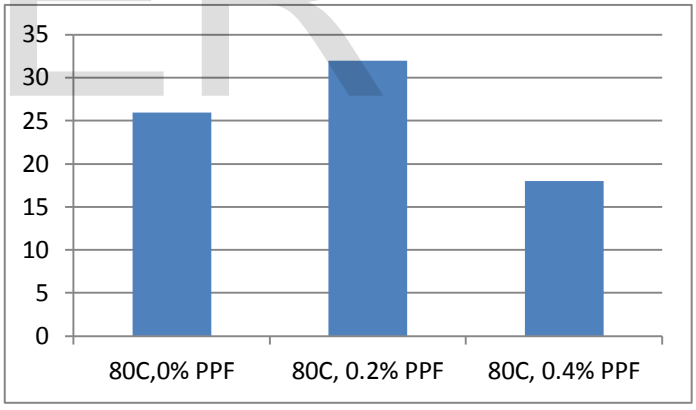
Graph 1: 28 Days Compressive Strength for ACC Curing



Graph 2: 28 Days Compressive Strength for Natural Curing

Table 7: Compressive strength Results for Optimum Percentage with Different Percentage of PPF

Replacement	Addition of PPF (By percentage of cement)	Average Compressive strength achived (Mpa)
80C	0%	25.95
80C	0.2%	32
80C	0.4%	18



Graph 3: 28 Days Compressive Strength with PPF

5 FUTURE WORKS

Flexural and split tensile strength will be carried out for M20 grade of concrete with optimum percentage. Environmental feasibility will be carried out as per Le-chat analysis. Further, workability and durability aspects of the same grade will be checked and compared to control mix.

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