MECHANICAL BEHAVIOUR OF HIGH PERFORMANCE CONCRETE BY STEEL SLAG

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Abstract

The use of more environment-friendly materials in any industry in general andconstruction industry in particular, is of paramount importance. Environment of this ‘only living’planet is wary of pollution due to emissions of a host of greenhouse gases from industrialprocesses. Present day construction industry consumes huge amount of concrete and cement isthe binding material used for making concrete. During production of cement huge amount ofenergy is needed and about 8 % of CO2 is released to atmosphere during cement production. Thismakes concrete a non-eco-friendly material. In consideration of these points, the lime is also used as binding material in this project. A constructionindustry has devised a substitute for concrete, popularly known as ‘Steel Slag’.Thestriking feature of this form of concrete is that most of its important ingredients are 100 percentby-products of industries, yet having similar performance record as any other conventionalconcrete material. Compressive strengths of these cubes were determined after 7days 28 days ofcuring period. The compositions of above materials are taken that is 1:1.6:2.56for M20 and 1:1.45:2.25 For M25 and the compressive strength and tensile strength weredetermined adopting conventional testing procedure. To find out the effect of curing period onthe compressive strength, split tensile strength the samples werecured for 7 days and 28 days and tested.

1. Introduction

In this present study a series of experiments have been done to evaluate the characteristic strength of steel slag. The objective of this study is to prevent the exhaustion of natural resources and enhancing the usage of waste materials, concern about global environmental issues, and a change over from the mass-production, mass-consumption, and mass-waste society to a zero-emission society. The physical and chemical properties of the raw materials have been studied to characterize the raw materials. The compressive strength and split tensile strength of these samples were determined after 7 and 28 days.

The Physical properties, chemical properties of materials have been study such as,

1.Gradation of fine aggregate and coarse aggregate

2.Water absorption of Fine aggregate and coarse aggregate.

3.Specific gravity of these above material.

2.MATERIALS USED

Cement:

Portland Slag cement (53 grade) JSW cement conforming to IS: 8112-1989was used. The specific gravity of cement is to found be 2.90.The most important use of cement is to bonding the natural or artificial aggregates to form a strong building material that is durable in the face of normal environmental effects.

Lime:

Lime was procured from the market. It was air dried and mixed thoroughly in dry condition. Then Lime was stored in air tight container for subsequent use. The specific gravity of lime is found to be 2.70 by pycnometer test and it comes under Zone-III (by IS: 12020-19 82).

Classification of Lime by I.S.I:

Indian Standards institute has classified the lime into 3 parts i.e., Class A, B & C. Class A is used for masonry work and can be obtained only in the form of slaked lime. Slaked lime must be the form of powder. Class B is used for mortar whereas class C is used for plaster & white washing. Class C is infecting pure lime. Class B & C can be obtained in the form of slaked or unsliced lime Unsliced lime may contain calcium oxide and little amount of magnesium oxide.

Sand:

The natural river sand confirming zone-III, which was determined by sieve analysis test, was used in this study. The specific gravity of fine aggregate is 2.61 which is found by using pycnometer test.

Blue granite:

Locally available blue granite metals are used. The specific gravity is found to be 2.65which is found by using pycnometer test. The maximum of 20mm size of hard blue granites are used.

Steel slag:

Extraction of 'iron' from ores is a complex process requiring a number of other materials which are added as flux or catalysts. After making steel these ingredients forming a matrix are to be periodically cleaned up. Removed in bulk, it is known as steel –slag. It consists of silicates and oxides. Modern integrated steel plants produce steel through basic oxygen process. Some steel plants use electric arc furnace smelting to their size. In the case of former using oxygen process, lime (CaO) and dolomite (CaO.Mgo) are charged into the converter or furnace as flux. Lowering the launce, injection of higher pressurized oxygen is accomplished. This oxygen combines with the impurities of the charge which are finally separated. The impurities are silicon, manganese, phosphorous, some liquid iron oxides and gases like CO2 and CO. Combined with lime and dolomite, they form steel slag. At the end of the operation liquid steel is poured into a ladle. The remaining slag in the vessel is transferred to a separate slag pot. For industrial use, different grades of steel are required. With varying grades of steel produced, the resulting slags also assume various characteristics and hence strength properties. Grades of steel are classified from high to medium and low depending on their carbon content. Higher grades of steel have higher carbon contents. Low carbon steel is made by use of greater volume of oxygen so that good amount carbon goes into combination with oxygen in producing CO2 which escapes into atmosphere. This also necessitates use of higher amount of lime and dolomite as flux. These varying quantities of slag known as furnace slag or tap slag, raker slag, synthetic or ladle slag and pit or clean out slag.

Fig1- Steel slag

Utilization of slag

The steel slag is used as coarse aggregates. Natural aggregate resources are becoming more difficult to develop or remove aggregate from the ground when slag can be used as a substitute which reduce waste and conserve resources. It protects and preserves our environment. Benefit from technical advantages offered by many of the steel making slags. High performance products not necessarily low grade applications

3. CONCRETE MIX PROPORTIONS

The procedure for selection of mix proportions used for Portland slag cement concrete is also applicable to concrete incorporating cement, lime or slag with some modifications. The main steps of procedure are as follows,

1. Calculation of cement content i.e. cement + Lime.
2. Calculation of fine aggregate content.
3. Calculation of coarse aggregate content i.e. blue granite + steel slag.

By referring from the code of IS (10262-1982)

For M20 Grade of concrete - 1 : 1.60 : 2.56

Table: 1

S.NO	BLUE GRANITE	STEEL SLAG
1	50%	50%

Table: 2

For M25 Grade of concrete - 1 : 1.40 : 2.25

4. TESTING PROGRAM

COMPRESSIVE STRENGTH:

S.NO	BLUE GRANITE	STEEL SLAG
1	50%	50%
2	25%	75%
3	0%	100%

The compression test is the most important test that can be used to assured the engineering quality in the application of building materials. Prepare the HPC for M20, the mix proportion of cement+lime, sand and blue granite+steel slag was taken as 1:1.60:2.56. The Six different types of specimen were prepared by using these proportion. And the HPC for M25, the mix proportion of cement (75%) +lime (25%), sand and blue granite+steel slag was taken as 1:1.45:2.25. TheHPC concrete cubes were prepared taking cement+lime as binder, sand as fine aggregate and blue granite+steel slagas coarse aggregate and mix was varied as 50, 75 and 100 percent. The nine different types of specimen were prepared by using these proportion. And the standard sizes of cubes of 150 mm *150 mm *150 mm are used.

A specimen of normal concrete with the mix of 1:1.5:3 (cement: sand: aggregate) was prepared to compare with the new HPC. The w/c ratio was taken to be 0.45. To find the effect of curing period on compressive strength, the samples were cured with curing period 7 day and 28 day.The values of all specimens tested 7th, 28th days were recorded and average value was calculated.

SPLIT TENSILE STRENGTH:

The splitting tests are well known indirect tests for determining the tensile strength of concrete sometimes referred as split tensile strength of concrete. This tests were carried out in accordance with IS 516-1999 standards conducted on concrete cylinders of 150 mm diameter and 300 mm length. Each cylinder specimen was placed on its side and loaded in compression along a diameter of the testedcylinder specimens. The load was continuously applied till the specimens failed. The maximum load applied to specimen during the test were recorded and used to calculate split tensile strength of HPC concrete. The split tensile strength of the steel slag concrete was tested for 7 days 28 days.

5.RESULT AND DISCUSSIONS

The compressive strength of concrete from the three different specimens are shown in following table.

SIZE OF SPECIMEN - 150×150×150 mm (cube)

AREA OF SPECIMEN - 22500 mm^2

CEMENT -75%Cement+25% lime

COARSE AGGREGATE - 50% bluegranite+50% steel slag

Table:3 Compressive strength (N/mm^2) test result for M20

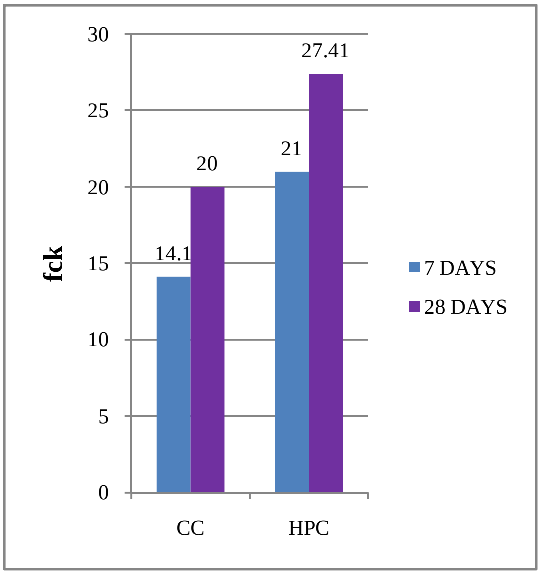


Fig:2

The Split Tensile strength of concrete from the three different specimens are shown in following table.

SIZE OF SPECIMEN -150×300mm (CYLINDER)

Mix	Days	Sample	Split tensile strength (N/mm^2)	Avg. tensile Strength (N/mm^2)
M20	7	1	1.78	1.96
		2	2.00	
		3	2.11	
	28	1	2.55	2.57
		2	2.55	
		3	2.61	

Mix	Days	Sample	Compressive strength (N/mm^2)	Avg. Compressive strength (N/mm^2)
M20	7 days	1	23.11	21.85
		2	21.11	
		3	21.33	
	28 days	1	26.67	27.41
		2	27.78	
		3	27.78	

AREA OF SPECIMEN - 45000mm^2

Table-4 Split Tensile Strength(N/mm^2)

Test result for M20

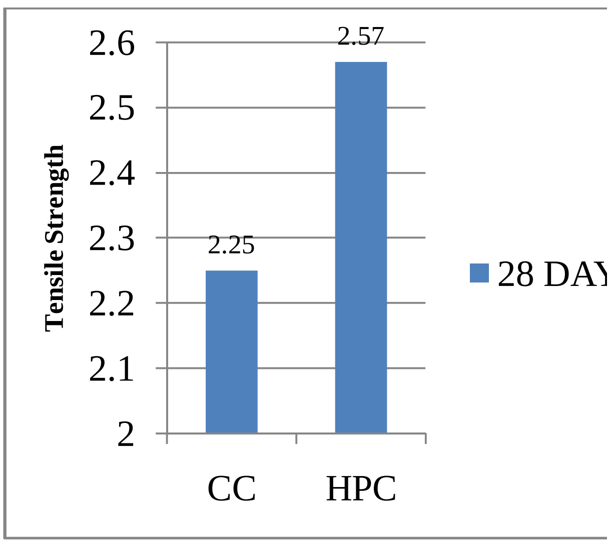


Fig:3

The compressive strength of concrete from the three different specimens are shown in following table.

SIZE OF SPECIMEN -150×150×150mm (CUBE)

AREA OF SPECIMEN - 22500 mm^2

CEMENT -75% Cement+25% lime

COARSE AGGREGATE -50% blue granite+50% steel slag

Mix	Days	Sample	Compressive strength (N/mm^2)	Avg. Compressive strength (N/mm^2)
M25	7 days	1	24.89	24.15
		2	23.33	
		3	24.22	
	28 days	1	32.44	32.37
		2	33.56	
		3	31.11	

Table-5 Compressive strength (N/mm^2) test result for M25

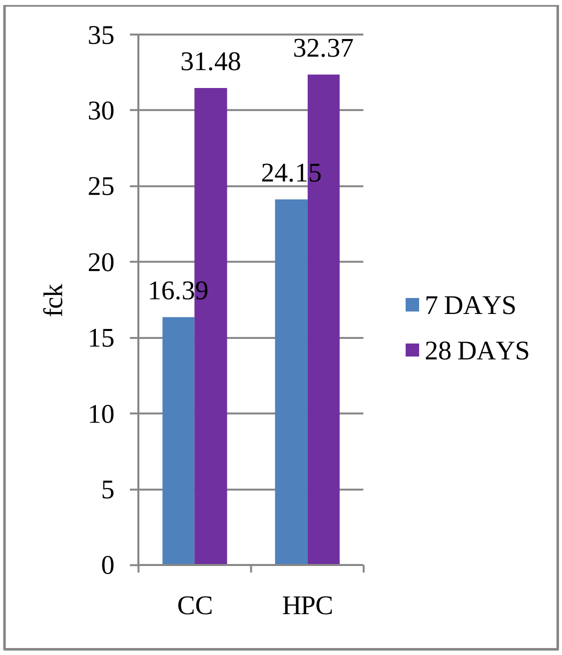


Fig:4

The Split Tensile strength of concrete from the three different specimens are shown in following table.

SIZE OF SPECIMEN - 150×300 mm (cylinder)

AREA OF SPECIMEN- 45000mm

Table-6 Split Tensile Strength(N/mm^2) test

Mix	Days	Sample	Split tensile strength (N/mm^2)	Avg. tensile Strength (N/mm^2)
M25	7	1	1.78	1.96
		2	2.00	
		3	2.11	
	28	1	2.69	2.62
		2	2.61	
		3	2.55	

result for M25

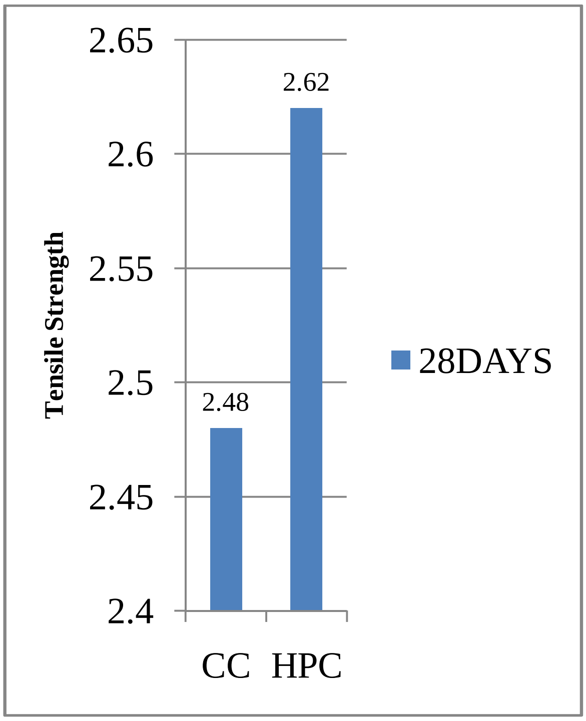


Fig.5

The compressive strength of concrete from the three different specimens are shown in following table.

SIZE OF SPECIMEN - 150×150×150 mm (CUBE)

AREA OF SPECIMEN - 22500 mm2

CEMENT - 75% Cement+25% lime

COARSE AGGREGATE - 25% blue granite+75% steel slag

Mix	Days	Sample	Compressive strength (N/mm^2)	Avg. Compressive strength (N/mm^2)
M25	7 days	1	28.89	28.67
		2	27.78	
		3	29.33	
	28 days	1	39.00	37.30
		2	35.56	
		3	37.33	

Table-7 Compressive strength (N/mm^2) test result for M25

Mix	Days	Sample	Split tensile strength (N/mm^2)	Avg. tensile Strength (N/mm^2)
M25	7	1	1.27	1.39
		2	1.49	
		3	1.41	
	28	1	1.56	1.58
		2	1.41	
		3	1.77	

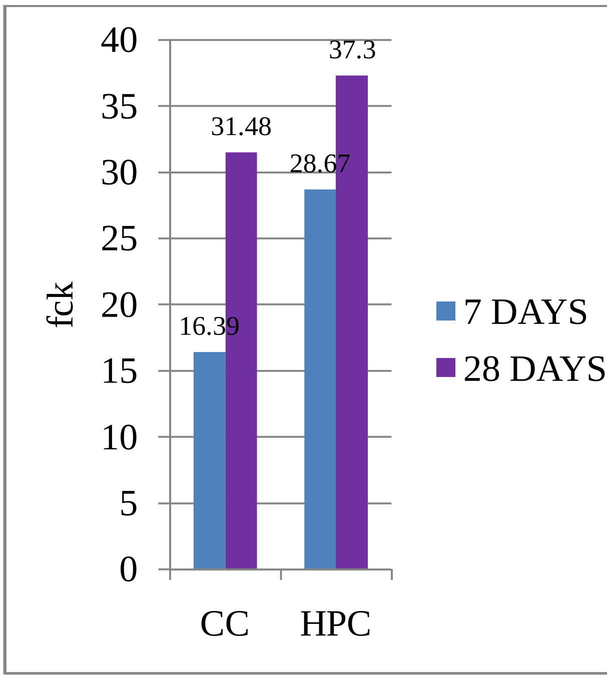


Fig.6

The Split Tensile strength of concrete from the three different specimens are shown in following table.

SIZE OF SPECIMEN - 150×300 mm (CYLINDER)

AREA OF SPECIMEN - $45000mm^2$

Table-8 Split Tensile Strength (N/mm^2) test result for M25

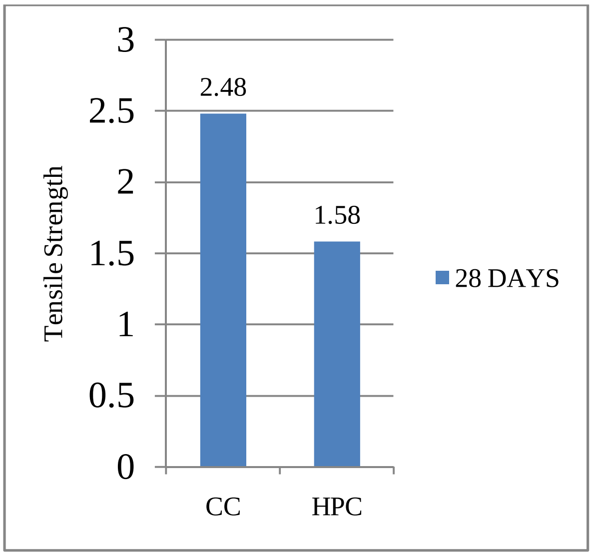


Fig 7

Comparison of test results of each specimen:

Compression strength Test Results: (For M25 grade of concrete at 28 Days)

Table-9 Comparison of Compression test results of each specimen

Specimen	% of replacement		Load (KN)	Compressive Strength (N/mm^2)
	lime	Steel slag		
Control concrete	0	0	708	31.48
1	25%	50%	730	32.37
2			755	
3			700	
1	25%	75%	800	37.30
2			840	
3			875	
1	25%	100%	590	25.33
2			575	
3			545	

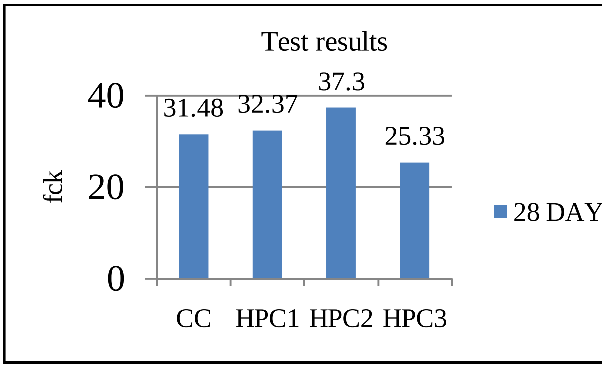
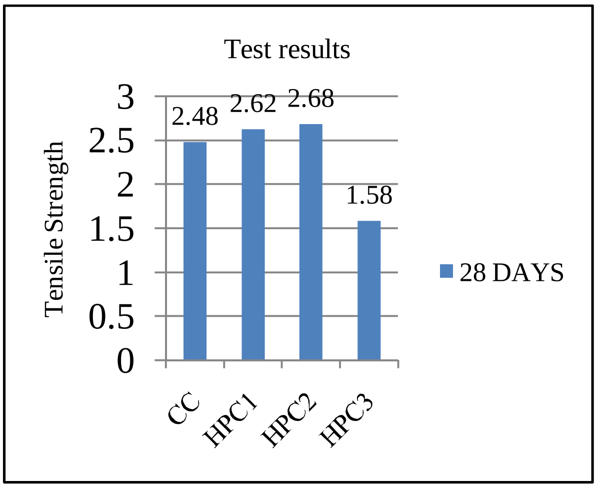


Fig 8

Split tensile strength Test Results: (For M25 grade of concrete at 28 Days)

Specimen	% of replacement		Load (KN)	Tensile strength (N/mm²)
	lime	Steel slag		
Control concrete	0	0	175	2.48
1	25%	50%	190	2.62
2			185	
3			180	
1	25%	75%	195	2.68
2			190	
3			185	
1	25%	100%	100	1.58
2			110	
3			125	

Table-10 Comparison of tensile strength results of each specimen



CONCLUSION

From the present studies following conclusions were drawn, The 7 and 28 days compressive strength of concrete of HPC is found to be higher than the normal cement concrete.

For M20 grade of concrete the compressive strength of HPC after 28 days of curing was found to be higher than control concrete. And the Split Tensile strength after 28 days of HPC is also higher than the normal concrete. For M25 grade of concrete the compressive strength of HPC after 28 days of curing was found to be higher than control concrete.Split Tensile strength after 28 days of HPC is also higher than the normal concrete in 50% and 75% the percentage replacement of coarse aggregate.

The more high compressive strength and Split Tensile strength of HPC achieved at 75 percentage replacement of blue granite by steel slag after 28 days of curing. But the fully replacement of the blue granite by steel slag that result in the reduction in the compressive strength and split tensile strength of high performance concrete compare to the control concrete. In this project work, some attempts have been made to get an alternative material for the preparation of concrete using waste products from steel industry. So we concluded that after sufficient aging, the steel slag can be used as concrete aggregate along mineral admixtures, to produce a higher quality concrete.

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