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EARLY HIGH STRENGTH CONCRETE OF GRADE M 50 WITH PARTIAL REPLACEMENT OF CEMENT BY GGBS &ALCCOFINE AND USING CONPLAST NC ADMIXTURE

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Abstract
The exponential growth in infrastructure around the world has become a challenge to the construction field as concrete requires a specified time for achieving the complete strength. In this project, it is endeavored to attain the early high strength using Conplast NC, Alccofine and Grind Granulated Blast Furnace Slag in a less period of time than usual. Early high strength is obtained by partially replacing cement with Alccofine and GGBS, and water with Conplast NC for M50 grade concrete. GGBS is replaced at a rate of 15%, 25%, 35% & 45% and keeping Alccofine 5% constant. To assess the mechanical properties and durability aspects in concrete specimens like cubes, cylinders and beams of a standard size and shape as commended by the Indian norms are casted, cured and tested for 24 hrs, 36 hrs, 48hrs, 60 hrs, 72 hrs, 7days, 28 days, 56 days and 90 days for compressive strength parameters and, 7days and 28 days tests are carried out for flexural and tensile strengths of concrete. After 28 days of curing, the cubes are immersed in acids of sulphate and chloride solutions for durability tests.

Keywords: Alccofine, Conplast NC, Compressive Strength, Split-tensile Strength, Flexural Strength, Rebound Hammer, Acid attack, Sulphate Attack, Chloride Attack.

I. Introduction

Developing countries like India are trying hard to reach and compete with the developed countries to meet the requirements. An exponential growth in infrastructures like highways, bridges and canals, etc. and rate of construction of high-rise buildings has also increased. Huge quantum of concrete is used in construction, but the major drawback is the time taken for the concrete to achieve its complete strength. Early and quick construction practices are necessary. Especially the buildings, marine or any kind of concrete structure should be constructed in less time. For quick development, there is necessary high early strength concrete practices and the life of the structures should also be taken into consideration. Many attempts are being made to make the high early strength giving concrete designs. Not only give the early strengths, but they also decrease the size of the foundation columns and beams and increase the carpet area.

Till 20 century the concretes which has strengths above 40 MPa is treated as the high strength concretes. Later the water-reducing agents and plasticizers have helped in increasing the strength of the conventional mix. 30 to 40 years ago due to insufficient design strength for skyscrapers and high-rise buildings, steel structures are preferred in the place of concrete. The reason for preferring the steel structures in the place of concrete is to attain the same strength of the steel the column members are big in size which lost the aesthetic view. The advancements in concrete, it made possible to make slender sections. Competing with steel structures, concrete is able to gains its strength from 60 MPa to 200 MPa in no time. High strength concrete also needs good durability, elastic and strength properties. Many experts practice high cement content or by reducing the water-cement ratio or having good workability of the concrete high strength concrete can be produced by using the methods individually or 2 combination of the methods. There is no guarantee that high-strength concretes gives good durability.

High early strength solves the setting time problem. In general, when conventional concrete is used the required strength will be gained over the period of 7 to 28 days. Many advances came in the

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additives that increase the strength of the concrete. In that, a fine material called Alccofine which is even finer than cement, GGBS, Fly Ash, silica fume, etc. increases the strength at the fresh and hardening stage of concrete. It reduces permeability and increases durability. Without chlorine introduction in the concrete water reducing admixture called Conplast NC accelerates the setting time and gives early strength. Conplast NC gives extraordinary high early strength and is used in low-temperature areas. The use of Alccofine and Conplast NC in the concrete will give desirable high early strengths. A detailed study with the inclusion of Alccofine and Conplast NC is to be studied. The following are the major objects of the study:

- To evaluate the optimum mix proportion of GGBS in concrete when GGBS and Alccofine are used as a supplement for cement.
- To achieve a lower water cement ratio using Conplast NC as a supplement.
- To study the mechanical and durable properties of M50 grade concrete with different replacements of GGBS.

II. Materials

Alccofine: Alccofine is a super fine material uses as an admixture in concrete which contributes in the achieving the improved performance in initial and final stage of concrete due to its ideal particle size i.e., not too fine or not too coarse. The properties of Alccofine are shown in table 2.1.

Table 2.1: Properties of Alccofine

S.no	Properties of Alccofine	Values
1	Specific gravity	2.70
2	Fineness modulus	3.35
3	Bulk Density	680 kg/m^3
4	Specific surface area	12000 cm^2 /gm

Conplast NC: Conplast NC is a chloride free accelerating admixture which is available in a light straw coloured solution that can easily be dispersed in water. It accelerates the setting time of resulting rapid stiffening and early strength in concrete. The dosage ranges from 1.50 to 3.00 litre per 100 kg cement. The properties of Conplast NC are shown in table 2.2.

Table 2.2: Properties of Conplast NC

S.no	Properties of Conplast NC	Values
1	Specific gravity	1.26 At room temperature
2	Colour	Straw colour
3	Chloride content	Nil

Ground Granulated Blast furnace Slag (GGBS): GGBS (Ground Granulated Blast furnace Slag) is a by-product obtained during the heating of iron ore, lime stone and coke at a temperature about 15000C. This procedure is done in a blast furnace. It is used as a partial supplement of OPC cement during concrete mix and improving the quality of concrete.

III. Methodology

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As the concrete is heterogeneous material, the quality depends on its homogeneity which can be obtained from proper mixing and placing of the fresh concrete. Before mixing the concrete, all the materials that need to be added are weighted using weighing balance with an accuracy of 0.001 grams as per the mix design. Different specimens were casted to perform different tests. Cubes having dimension 150 x 150 x 150 mm, Cylinders having 150mm diameter and 300 mm height and Beams having dimensions 500 x 100 x100 mm. Both the compactor factor test and slump cone tests are performed to determine the workability of fresh concrete. After 24 hours the concrete specimens are removed from the moulds by loosening the screws. All the specimens are marked properly for identification. These moulds were again cleaned and lubricant was applied for casting next batch of concrete. The concrete specimens were placed in the water curing tank maintaining temperature 25 C for 36 hrs, 48 hrs, 60 hrs, 72 hrs, 7days and 28 days for hardened properties of early high strength concrete. Proper curing helps in attaining desired strength. Later the specimens were removed from the curing tank as per the schedule, dried and then tested.

The variables such as density of particles, proportion of aggregates, water cement ratio, aggregate cement ratio, water absorption etc. are considered during the mix design of concrete. The volume of cement and GGBS used is varied in different cases. The tests were conducted at 24 hrs, 36 hrs, 48 hrs, 60 hrs, 72 hrs, 7days, 28 days, 56 days and 90 days. All the tests conducted on fresh and hardened concrete.

IV. Experimental tests and results

This experimental work is carried out in three phases. In first phase the 20% of cement is replaced with 15% GGBS and 5% Alccofine and the mechanical properties are compared with normal OPCC. Similarly in second and third phase 30 % and 40% of cement is replaced with 25% and 35% GGBS with constant 5% Alccofine and the results are compared with phase one results. The following are the different tests that are being carried out on fresh as well as hardened concrete.

4.1 Compressive Strength of concrete:

In this test a cube having dimensions 150 x 150 x 150 mm were used. After the tests on fresh concrete, the concrete is poured into cubes which are left undisturbed for 24 hours. Later these cubes were cured for 24 hrs, 36 hrs, 48 hrs, 60 hrs, 72 hrs, 7days, 28 days, 56 days and 90 days. A force of 20 MPa compressive stress per minute was applied at uniform rate until the specimen was failed. Record the maximum force applied from the Compressive testing machine at the breaking point. The test results are shown in table 4.1.

Table 4.1: Test result for Compressive strength in MPa for replacement of cement

Time	0%	20%	30%	40%	50%
24 hours	16.17	29.89	33.56	36.33	34.83
36 hours	19.84	35.32	38.30	41.30	39.80
48 hours	22.40	38.27	43.36	46.60	45.10
60 hours	24.60	41.55	46.28	50.42	48.92
72 hours	26.28	42.03	49.94	52.09	50.59

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7 days	34.15	49.40	54.29	58.90	57.40
28 days	52.57	55.33	57.51	60.45	59.52
56 days	55.57	57.37	59.37	62.53	60.46
90 days	57.40	59.37	62.17	65.15	63.65

4.2 Split Tensile Strength of concrete:

In this test a cylinders having dimensions of diameter 150 mm and length 300 mm were used. After the tests on fresh concrete, the concrete is poured into cylinders which are left undisturbed for 24 hours. Later these cylinders were cured for 14 and 28 days. Later the cylinders were removed from the curing tank and dried for some time. Placing the specimen inside the universal testing machine along its length and compressive force was applied at uniform rate until the specimen was failed. Record the maximum force applied from the Compressive testing machine at the breaking point. The test results are shown in table 4.2.

Table 4.2: Tensile strength in MPa at different percentages of replacement of cement

Days	**0%**	**20%**	**30%**	**40%**	**50%**
7	3.53	4.47	5.46	5.92	5.69
28	5.65	5.74	5.90	6.62	6.29

4.3 Flexural Strength of concrete:

In this test a beam having dimensions of 500 x 100 x 100 mm were used. After the tests on fresh concrete, the concrete is poured into beams which are left undisturbed for 24 hours at 60 ^{0} C temperature. Later these beams were cured for 14 and 28 days. Load was applied continuously at 0.5 kg/cm^2/min on extreme fibres until specimen breaks. The test results are shown in table 4.3.

Table 4.3: Flexural strength in MPa at different percentages of replacement of cement

Days	**0%**	**20%**	**30%**	**40%**	**50%**
7	4.09	4.92	5.16	5.37	5.30
28	5.08	5.21	5.31	5.44	5.40

4.4 The Sulphate Resistance Test:

Both change in mass and compressive strength were measured after 28, 56 & 90 days of exposure to sulphate solution. In this test 2% concentrated sodium sulphate was used.To determine change in mass, on each respective day the sample was taken out of the solution and dried for over a period of one week and then weigh of each cube was noted. The initial and final weights before and after immersing in sulphate solution were used to calculate long term change in mass. Whereas, to determine change in compressive strength, on each respective day the sample was taken out of the solution and dried for some time. Later the strength was tested using Universal testing machine. The test results are shown in table 4.4, 4.5, 4.6 and 4.7.

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Table 4.4: Compressive strength in MPa for Sulphate resistance test at different percentages of replacement of cement

Replacement	28 days		56 days		90 days	
	Before	After	Before	After	Before	After
0%	52.57	51.57	55.57	54.10	57.40	56.00
20%	55.53	54.65	57.37	56.30	59.37	58.18
30%	57.51	56.80	59.37	58.36	62.17	61.02
40%	60.45	59.90	62.53	61.78	65.15	64.27
50%	59.52	59.10	60.46	59.80	63.65	62.83

Table 4.5: Change in Mass in Kgs for Sulphate resistance test at different percentages of replacement of cement

Replacement	28 days		56 days		90 days	
	Before	After	Before	After	Before	After
0%	8.20	8.40	8.00	8.25	7.97	8.32
20%	8.23	8.41	8.23	8.42	8.16	8.36
30%	8.40	8.55	8.36	8.52	8.32	8.42
40%	8.49	8.62	8.45	8.60	8.41	8.57
50%	8.56	8.66	8.5	8.62	8.47	8.61

Table 4.6: Percentage change in Strength before and after Sulphate resistance test

Replacement	28 days	56 days	90 days
	% loss in Strength	% loss in Strength	% loss in Strength
0%	1.90	2.65	2.44
20%	1.58	1.87	2.00
30%	1.23	1.70	1.85
40%	0.91	1.20	1.35
50%	0.91	1.09	1.29

Table 4.7: Percentage change in weight before and after Sulphate resistance test

Replacement	28 days	56 days	90 days

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	% gain in Strength	% gain in Strength	% gain in Strength
0%	2.38	3.03	4.21
20%	2.14	2.26	2.39
30%	1.75	1.88	1.19
40%	1.51	1.74	1.87
50%	1.15	1.39	1.63

4.5 The Acid Resistance Test:

The effect of acids on the concrete blocks was studied by performing this test. In this test the specimens were test for their compressive strength as well as change in mass also. The size of the cube was 150 X 150 X 150 mm^3. These cubes were immersed in sulphuric acid solution after 28 days of curing in water. In this test 2% concentrated sulphuric acid was used. The test results are shown in table 4.8, 4.9 and 4.10.

Table 4.8: Compressive strength in MPa for samples cured in Sulphuric Acid solution

Replacement	**28 days**		**56 days**		**90 days**	
	Before	**After**	**Before**	**After**	**Before**	**After**
0%	52.57	51.70	55.57	54.61	57.40	56.27
20%	55.53	54.67	57.37	56.40	59.37	58.32
30%	57.51	56.87	59.37	58.59	62.17	61.22
40%	60.45	59.92	62.53	61.88	65.15	64.50
50%	59.52	58.90	60.46	59.69	63.65	62.71

Table 4.9: Change in Mass in Kgs for Acid resistance test at different percentages of replacement of cement

Replacement	**28 days**		**56 days**		**90 days**	
	Before	**After**	**Before**	**After**	**Before**	**After**
0%	8.45	8.20	8.27	8.00	8.27	7.97
20%	8.42	8.23	8.44	8.23	8.39	8.16
30%	8.51	8.40	8.55	8.36	8.54	8.32
40%	8.58	8.49	8.57	8.45	8.54	8.41
50%	8.69	8.56	8.65	8.50	8.64	8.47

Table 4.10: Percentage change in Strength and Weight before and after Acid resistance test

Replacement	**28 days**		**56 days**		**90 days**	
	% loss in Strength	**% Loss in weight**	**% loss in Strength**	**% Loss in weight**	**% loss in Strength**	**% Loss in weight**
0%	1.65	2.96	1.73	3.26	1.97	3.63

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20%	1.55	2.26	1.69	2.49	1.77	2.74
30%	1.11	1.29	1.31	2.22	1.53	2.58
40%	0.88	1.05	1.04	1.40	1.00	1.52
50%	1.04	1.50	1.27	1.73	1.48	1.97

4.6 The Chloride Resistance Test:

The effect of chlorides on the concrete blocks was studied by performing this test. In this test the specimens were test for their compressive strength as well as change in mass also. The size of the cube was 150 X 150 X 150 mm^3. These cubes were immersed in Sodium Chloride solution after 28 days of curing in water. In this test 2% concentrated Sodium Chloride was used. The test results are shown in table 4.11, 4.12 and 4.13.

Table 4.11: Compressive strength in MPa for Chlorine resistance test at different percentages of replacement of cement

Replacement	**28 days**		**56 days**		**90 days**	
	Before	**After**	**Before**	**After**	**Before**	**After**
0%	52.57	51.75	55.57	54.29	57.40	56.02
20%	55.53	54.45	57.37	56.20	59.37	58.12
30%	57.51	56.55	59.37	58.40	62.17	61.11
40%	60.45	59.76	62.53	61.45	65.15	63.97
50%	59.52	58.96	60.46	59.80	63.65	62.90

Table 4.12: Change in Mass in Kgs for Chlorine resistance test at different percentages of replacement of cement

Replacement	**28 days**		**56 days**		**90 days**	
	Before	**After**	**Before**	**After**	**Before**	**After**
0%	8.40	8.20	8.23	8.00	8.20	7.97
20%	8.42	8.23	8.42	8.23	8.39	8.16
30%	8.52	8.40	8.52	8.36	8.49	8.32
40%	8.60	8.49	8.59	8.45	8.56	8.41
50%	8.65	8.56	8.60	8.50	8.59	8.47

Table 4.13: Percentage change in Strength and Weight before and after Chlorine resistance test

Replacement	**28 days**		**56 days**		**90 days**	
	% loss in Strength	**% Loss in weight**	**% loss in Strength**	**% Loss in weight**	**% loss in Strength**	**% Loss in weight**
0%	1.56	2.38	2.30	2.79	2.40	2.80
20%	1.94	2.26	2.04	2.26	2.11	2.74
30%	1.67	1.41	1.63	1.88	1.71	2.00

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40%	1.14	1.28	1.73	1.63	1.81	1.75
50%	0.94	1.04	1.09	1.16	1.18	1.40

4.7 The Water Absorption Test:

The percentage of water absorbed by various concrete mixtures were determined as per BS 1881-122: 2011. The cubes of size 150mm X 150mm X 150 mm were used as per ASTM C 642. After curing for about 56 days, the cubes were taken out and weighed using weighing machine. This weight was noted as saturated weight of concrete. Later these samples were oven dried at 105^0C temperature. After some time the weight of the sample was noted. The sample was dried. This dry weight was noted. Now, the water absorption percentage was determined. The test results are shown in table 4.14.

Table 4.14: Weight gain in percentage for different percentages of replacement of cement

Replacement	**56 days**		**% of water absorbed**
	Before	After	
0%	7.96	8.2	2.93
20%	8.35	8.54	2.22
30%	8.29	8.45	1.89
40%	8.42	8.57	1.75
50%	8.51	8.60	1.05

V. Conclusion

a) Compressive strength of concrete was maximum at 40% replacement of cement which includes 35% of GGBS and 5% of Alccofine.
b) Due to the addition of super plasticizer Conplast NC good and noticeable results were obtained at very early stages after casting.
c) The concrete should attain 30-35% of its strength in 7 days and target mean strength in 28 days as per code. This was attained with M50 normal concrete, where as in 40% replacement of cement, 30-35% of strength was attained at 36 hours and target strength at 14 days. From this we conclude that 35% of GGBS along with 5% of Alccofine can be replaced with cement. The value of compressive strength was 52.57 Mpa for 0% replacement and 62.53 Mpa for 40% replacement.
d) Split Tensile strength of concrete for 7 and 28 days from graph was observed that the strength value started increasing. 35% of GGBS + 5% of Alccofine shows more resistance to tensile load when compared to 0% replacement of cement. The value of split tensile strength was 5.65 Mpa for 0% replacement and 6.62 Mpa for 40% replacement.
e) Flexural strength of concrete for 7 and 28 days from graph was observed that the strength value started increasing. 35% of GGBS + 5% of Alccofine shows more resistance to flexural load when compared to 0% replacement of cement. The value of flexural strength was 5.08 Mpa for 0% replacement and 5.44 Mpa for 40% replacement.

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f) From water absorption graph it was observed that the capacity of water absorbed started decreasing due to the usage of GGBS and Alccofine which reduced the voids in concrete due to its high surface area. So this combination can be used in marine conditions with or without waterproofing agents.
g) Compressive strength of concrete was maximum at 40% replacement of cement which includes 35% of GGBS and 5% of Alccofine.
h) Due to the addition of super plasticizer Conplast NC good and noticeable results were obtained at very early stages after casting.
i) The concrete should attain 30-35% of its strength in 7 days and target mean strength in 28 days as per code. This was attained with M50 normal concrete, where as in 40% replacement of cement, 30-35% of strength was attained at 36 hours and target strength at 14 days. From this we conclude that 35% of GGBS along with 5% of Alccofine can be replaced with cement. The value of compressive strength was 52.57 Mpa for 0% replacement and 62.53 Mpa for 40% replacement.
j) Split Tensile strength of concrete for 7 and 28 days from graph was observed that the strength value started increasing. 35% of GGBS + 5% of Alccofine shows more resistance to tensile load when compared to 0% replacement of cement. The value of split tensile strength was 5.65 Mpa for 0% replacement and 6.62 Mpa for 40% replacement.
k) Flexural strength of concrete for 7 and 28 days from graph was observed that the strength value started increasing. 35% of GGBS + 5% of Alccofine shows more resistance to flexural load when compared to 0% replacement of cement. The value of flexural strength was 5.08 Mpa for 0% replacement and 5.44 Mpa for 40% replacement.
l) Compressive strength of concrete was maximum at 40% replacement of cement which includes 35% of GGBS and 5% of Alccofine.
m) Due to the addition of super plasticizer Conplast NC good and noticeable results were obtained at very early stages after casting.
n) The concrete should attain 30-35% of its strength in 7 days and target mean strength in 28 days as per code. This was attained with M50 normal concrete, where as in 40% replacement of cement, 30-35% of strength was attained at 36 hours and target strength at 14 days. From this we conclude that 35% of GGBS along with 5% of Alccofine can be replaced with cement. The value of compressive strength was 52.57 Mpa for 0% replacement and 62.53 Mpa for 40% replacement.
o) Split Tensile strength of concrete for 7 and 28 days from graph was observed that the strength value started increasing. 35% of GGBS + 5% of Alccofine shows more resistance to tensile load when compared to 0% replacement of cement. The value of split tensile strength was 5.65 Mpa for 0% replacement and 6.62 Mpa for 40% replacement.
p) Flexural strength of concrete for 7 and 28 days from graph was observed that the strength value started increasing. 35% of GGBS + 5% of Alccofine shows more resistance to flexural load when compared to 0% replacement of cement. The value of flexural strength was 5.08 Mpa for 0% replacement and 5.44 Mpa for 40% replacement.
q) From water absorption graph it was observed that the capacity of water absorbed started decreasing due to the usage of GGBS and Alccofine which reduced the voids in concrete due to its high surface area. So this combination can be used in marine conditions with or without waterproofing agents.
r) In all the durability tests (Acid, Sulphate, and Chloride resistance tests) the weighed loss by the concrete specimen decreased with different replacements compared to normal M50 grade concrete.
s) In Sulphate resistance test, the compressive strength after 90 days of curing in Na_2SO_4 gives the value of 56.00 Mpa (2.44% ↓) and 64.27 Mpa (1.35% ↓) for 0:40 replacement.

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t) In Acid resistance test, the compressive strength after 90 days of curing in HCl gives the value of 56.27 Mpa (1.97% ↓) and 64.50 Mpa (1.00% ↓) for 0:40 replacement.
u) In Chloride resistance test, the compressive strength after 90 days of curing in NaCl gives the value of 56.02 Mpa (2.40% ↓) and 63.97Mpa (1.81% ↓) for 0:40 replacement.

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