International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.8, pp 507-516, 2017

An Experimental Study on Performance and Durability of Hardened Concrete using Alccofine and Copper Slag

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Abstract : This paper presents the experimental investigation done on strength properties and durability characteristics of concrete using "Alccofine and Copper Slag".In this study, M20 grade of concrete was designed and tests were carried out with different percentage of copper slag as a fine aggregate and constant percentage of Alccofine(10%) for cement in concrete. The concrete is made by replacing Alccofine10% by weight of cement and replacing Fine aggregate by Copper Slag with various percentages like30%, 40%, and 50%. For strength parameters the compressive, tensile and flexural strength are found. For durability parameters Rapid Chloride Penetration test, Water Permeability test, Sea water attack test, Chloride resistance test and density test are found. From experimental work and results it can be accomplished that the 40% is ideal percentage replacement of sand by copper slag.
Key words : Strength Parameters, Durability Parameters, Alccofine, Copper Slag.

1.0 Introduction:

The durability of cement concrete is defined as its ability to resist weathering action, chemical attack, or any other process of deterioration. Durable concrete will retain its original form quality, and serviceability when exposed to environment[1].

Concrete is one of the mainly used materials throughout the globe in the various field, which basically consists of cement, sand and crushed quarry stones that are locally and naturally available. Then sand and crushed stone are used as a filler material in concrete and cement is used for bonding and strength parameter of the concrete[2]. Therefore concrete is used extensively and, it has many disadvantage for the production of one tone of concrete. Nearly one tone of CO_2 is to be released which affect the environment[3]. Also, the concrete can withstand compressive loads, but it fails when tensile loads are applied. To enhance the tensile and flexural strength of concrete, number of experimental studies and investigations are carried out.

1.1 Cement

We have used Ordinary Portland Cement of Grade 43. As per IS requirements, the OPC 43 Grade cement should posses a compressive strength of 43MPa after 28days standard curing.

43 grade OPC produces higher-grade concrete at very economical cement content. In concrete mix design, for concrete M20 and above grades a saving of 8 to 10 % of cement may be achieved with the use of 43 grade OPC.

1.2 Fine Aggregates

Fine aggregate is defined as material that will pass through 4.75mm sieve and will, for the most part, be retained on a 75 sieve. For increasing the workability and economical purpose, the fine aggregate should have a rounded shape.

The purpose of the fine aggregate is to act as a workability agent. For this purpose, we have used aggregates passing through the 1.18mm sieve.

In India, river sand is used as fine aggregate. The sand is washed and screened at site to remove deleterious materials and tested as per the procedure given in IS 2386-1963 and the test results should comply with the requirements of IS383-1970.

1.3 Coarse Aggregates

Coarse aggregate used can be gravel resulting from the crushing of parent rock, natural rock, slags, expanded clay and shale (lightweight aggregates) and other approved inert materials with similar characteristics, having hard, strong, durable particles, conforming to the specifications of IS Codes

1.4Alccofine1203

Alccofine1203 is a specially prepared product having high glass content with more reactivity. Appropriate to its distinctive chemistry and very fine particle size, Alccofine1203 decreases water requirement for a required workability. Alccofine1203 can also be used as high range water decreasing agent to enhance compressive strength or as a super workability assist to improve flow[4,5]. The advantage of Alccofine1203 is to increase the strength for higher and middle range grades of concrete with optimal utilization and increases the durability of concrete. It enhances impermeability and eliminates or minimizes thermal cracks in concrete. It also enhances the strength of concrete. Therefore using alccofine in concrete assured advantages compared to other supplementary cementitious material like fly ash, GGBS, rice husk and metakaolin etc.

1.5Copper Slag (CS):

Copper slag is a byproduct produced during the processing of copper manufacturing. It is a glassy granular material with the high specific gravity. About 2600 tons of copper slag is produced per day and 1.5 million tons per year[6,7,8]. The copper slag utilization is only 15% to 20% and the remaining is dumped as waste material in turn it causes environment pollution. The particle size of the copper slag is same as that of the fine aggregate. The copper slag is used as both cement and sand replacement. Copper slag is used to study the effects and long term properties of mortar and concrete. High performance concrete is designed to have higher workability, strength and durability than normal concrete. The use of copper slag leads to reduction in cost, promoting ecological balance and conservation of natural resources[9,10,11].

2.0 Materials Used

2.1 Test on Cement

Table-2.1 Physical Properties of Cement

Sl No	Particulars	Test Results
1.	Fineness of the cement	5%
2.	Specific gravity	3.14
3.	Normal consistency	28%
4.	Initial setting time	35 min
5.	Final setting time	165 min

2.2 Test on Fine Aggregate

Table-2.2 Physical Properties of Fine Aggregate

Sr. No	Properties	Result
1.	Specific Gravity	2.77
2.	Fineness Modulus	3.75
3.	Water Absorption	1%
4.	Free Moisture	1.22%

2.3 Test on Coarse Aggregate

Table-2.3 Physical Properties of Coarse Aggregate

Sl. No	Properties	Result
1.	Specific Gravity	2.66
2.	Fineness Modulus	4.12
3.	Water Absorption	0.45%
4.	Free Moisture	Nil

2.4 Test on Alccofine

Table-2.4 Physical Properties of Alccofine

Type of concrete	Cement Kg	FA Kg	CA Kg	Al Kg	CS Kg
Control Concrete	394	716	1170	0	0
10% Alccofine 30% Copper Slag	354.6	501.2	1170	39.4	214.8
10% Alccofine 40% Copper Slag	354.6	429.6	1170	39.4	286.4
10% Alccofine 50% Copper Slag	354.6	358	1170	39.4	358

Table-2.5 Chemical Properties of Alccofine

Fineness (cm^2/gm)	Specific gravity	Bulk density (kg/m^3)	D10	D50	D90
>12000	2.9	700-900	1.5	5	9

2.5 Test on Copper Slag

Table-2.6 Physical Properties of Copper Slag

Sl No	Properties	Result
1.	Specific Gravity	3.6
2.	Fineness Modulus	5.135

3.0 Experimental Work

3.1 Mix Proportions

The mix proportion used for the preparation of concrete is M20[11,12]. The water to binder ratio was taken as 0.46. Replacing Alccofine by weight of cement as constant percentage of 10% and replacing Copper Slag by weight of Fine aggregate in various percentages like 0%, 30%, 40% and 50%.

Table-3.1Mix proportion for 1m^{3}Concrete

Item	Water	Cement	Fine Aggregate	Coarse Aggregate
Kg	180.69	394	700	1165
Ratio	0.459	1	1.78	2.96

Table-3.2 Mixture proportion of control Concrete with Alccofine and Copper Slag

Test	Result	
Particle Size Distribution(micron)	**D_{10}**	**1.5**
	D_{50}	**5**
	D_{90}	**9**
Chemical Composition	**C_2O**	**61-64%**
	SO_3	**2-2.4%**
	SiO_2	**21-23%**
	$Al2O_3$	**5-5.6%**
	$Fe2O_3$	**3.8-4.4%**
	MgO	**0.8-1.4%**
Specific gravity	**2.9**	
Bulk Density(Kg/m^3)	**700-900**	

4.0 Methodology

1. Samples are prepared by adopting 10% constant replacement of Alccofine by weight of cement and 30%, 40% and 50% variable replacement of Copper Slag by weight of fine aggregates respectively.
2. Cube samples of size 150x150 mm are prepared to find the compressive strength of concrete in the 7th and 28th day.
3. Cylinder samples of size 150x300 mm are prepared to find the split tensile strength of concrete in the 28th day.
4. Prism sample of size 700x150x150 mm are prepared for finding the flexural strength of concrete in 28th day.
5. 5.Cube samples of size 150x150 mm are prepared to find the water permeability of concrete, Sea water attack test of concrete, Chloride resistance test of concrete in 28th and 56 days and density test of concrete in 28th day.
6. Cylinder samples of size 100x50 mm are prepared for Rapid chloride permeability test of concrete in 28th and 56th day.
7. All the materials used to prepare the samples are as per Indian Standard specifications.
8. All the tests performed are as per IS and ASTM C1202.

5.0 Results

5.1 Compressive Strength test

The compressive strength of concrete is given in terms of the Characteristic Compressive Strength of 150mm size cubes tested after 28days of curing. The cubes are tested as per the guidelines given in IS 516 – 1979 [13,14,15,16].

Table-4.1 of the 7th day Compressive strength of concrete

S.No	Specimen	Load (KN)	Strength (N/mm^2)	Average strength (N/mm^2)
1	Control concrete	565	25.1	24.88
		520	23.1	
		595	26.44	
2	Alccofine 10% Copper slag 30%	680	30.22	32
		760	33.78	
		720	32	
3	Alccofine 10% Copper slag 40%	800	35.56	36.3
		830	36.89	
		820	36.44	
4	Alccofine 10% Copper slag 50%	695	30.89	32.22
		750	33.33	
		730	32.44	

Table-4.2of the 28th day Compressive strength of concrete

S.No	Specimen	Load (KN)	Strength (N/mm^2)	Average strength (N/mm^2)
1	Control concrete	270	12	12.44
		290	12.88	
		280	12.44	
2	Alccofine 10% Copper slag 30%	490	21.78	22
		500	22.22	
		495	22.67	
3	Alccofine 10% Copper slag 40%	520	23.1	22.66
		500	22.22	
		510	22.67	
4	Alccofine 10% Copper slag 50%	510	22.67	22.23
		490	21.78	
		500	22.22	

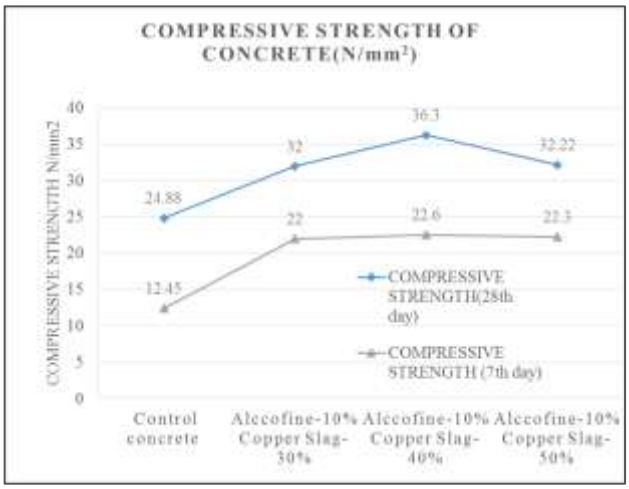

Fig -4.1 Compressive strength of concrete in 7th and 28th day.

Table-4.3 Split tensile strength of concrete in 28th day.

S.no	Specimen	Load (KN)	Strength (N/mm^2)	Average strength (N/mm^2)
1	Control concrete	125	1.77	1.86
		135	1.91	
		135	1.91	
2	Alccofine 10% Copper slag 30%	150	2.12	2.24
		160	2.26	
		165	2.33	
3	Alccofine 10% Copper slag 40%	160	2.26	2.38
		175	2.48	
		170	2.41	
4	Alccofine 10% Copper slag 50%	130	1.84	1.98
		140	1.98	
		150	2.12	

4.2 Split Tensile Strength Test

A method of determining the tensile strength of concrete is by using a cylinder which splits across the vertical diameter. The specimen is prepared with designed concrete mix of size 150mm diameters and 300mm height. Theconcrete is filled in three layers and compacted well and vibrated using table vibrator. The specimen is subjected to curing for 28 days

Fig -4.2Split tensile strength of concrete in the 28 day.

4.3Flexural Strength of Concrete

Table-4.4 Flexural strength of concrete in the28 day

Specimen	Control Concrete	Alccofine 10% Copper slag 30%	Alccofine 10% Copper slag 40%	Alccofine 10% Copper slag 50%
28th day strength (N/mm^2)	2.82	3.65	4.0	3.47

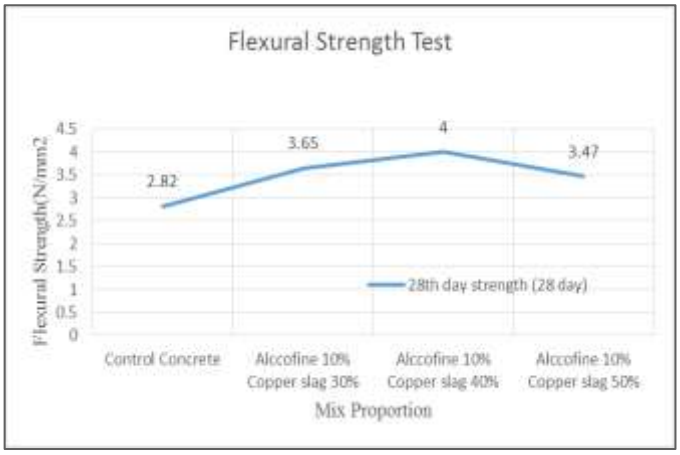

Fig -4.3 Flexural strength of concrete in the 28th day.

4.4Rapid Chloride Penetration test

Table-4.5Rapid penetration test in the 28th day.

Specimen Type	Total Charge Passed After 28 days (Coulomb)	Chloride Ion Permeability
Control Concrete	1020	Low
Alccofine10% Copper slag 30%	2037	Medium
Alccofine10% Copper slag 40%	2843	Medium
Alccofine10% Copper slag 50%	3269	Medium

Table-4.6Rapid penetration test in the 56th day.

Specimen Type	Total Charge Passed After 56 days (Coulomb)	Chloride Ion Permeability
Control Concrete	967	Very Low
Alccofine10% Copper slag 30%	1993	Low
Alccofine10% Copper slag 40%	2672	Medium
Alccofine10% Copper slag 50%	2935	Medium

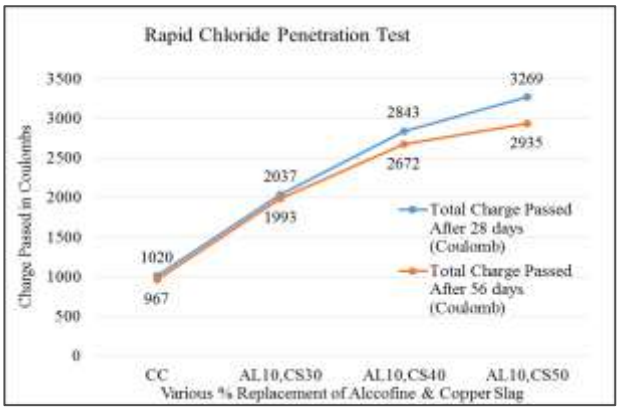

Fig-4.4Rapid penetration test in the 28th and 56th day.

4.5Water Permeability Test

The equipment was installed on a levelled ground. The compressor used for testing was 5 bars capacity. The air dried concrete cubes (150x150x150mm) were mounted on the table with suitable rubber gaskets below the cubes. The M.S.Plate was kept on the cube and the bolt was tightened on the cube. The pressure of 5 bars was maintained for 72 hours. The compressor was switched off and the pressure was released. The maximum water penetration level was observed from the burette tank and the concrete cube. The average value was found.

Table-4.7 Water permeability test in the 28th day

Specimen Type	Max. depth of penetration (cm)	Coefficient of permeability (10^4) (mm/s) K = Q / A T (H/L)
Control Concrete	2.2	1.85
Alccofine10% Copper slag 30%	3	1.85
Alccofine10% Copper slag 40%	2.4	1.85
Alccofine10% Copper slag 50%	1.9	1.85

4.6 Sea Water Attack Test

The Sea water attack test as presented in the table 6.11. The average loss of weight and Loss of compressive strength of concrete is considerably low. This indicates that incorporation of Alccofine and Copper Slag in Concrete is responsible for more Sea water attack.

Table-4.7 Sea water attack test for 30 days

Specimen Type	Control Concrete	Alccofine-10% Copper Slag-30%	Alccofine-10% Copper Slag-40%	Alccofine-10% Copper Slag-50%
Loss of weight (kg)&%	7.60 1.05%	8.32 2.09%	8.30 3.19%	8.47 4.23%
Loss of strength (N/mm2)&%	24.57 1.25%	31.24% 2.36%	35.05 3.45%	30.73 4.62%

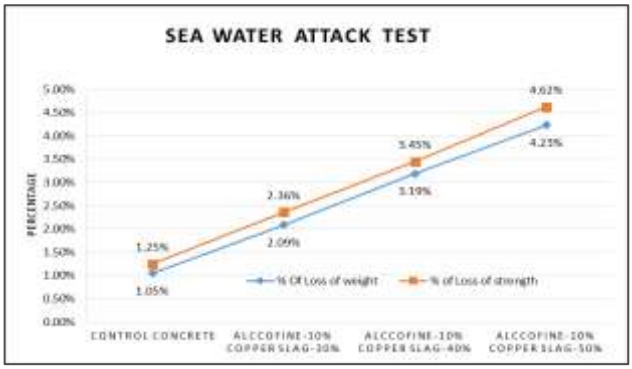

Fig-4.6Sea water attack test 30 days

4.7 Chloride Resistance Test

The Chloride Resistance test is given in table 6.10. The average loss of weight and Loss of compressive strength of concrete is considerably low. This indicates that incorporation of Alccofine and Copper Slag in Concrete could be responsible for more Chloride resistance.

Table-4.8 Chloride resistance test for 30 days

Specimen Type	Control Concrete	Alccofine-10% Copper Slag-30%	Alccofine-10% Copper Slag-40%	Alccofine-10% Copper Slag-50%
Loss of weight (kg)&%	7.62 0.92%	8.33 1.97%	8.31 3.01%	8.48 4.08%
Loss of strength (N/mm2)&%	24.6 1.13%	31.26% 2.3%	35.03 3.5%	30.71 4.7%

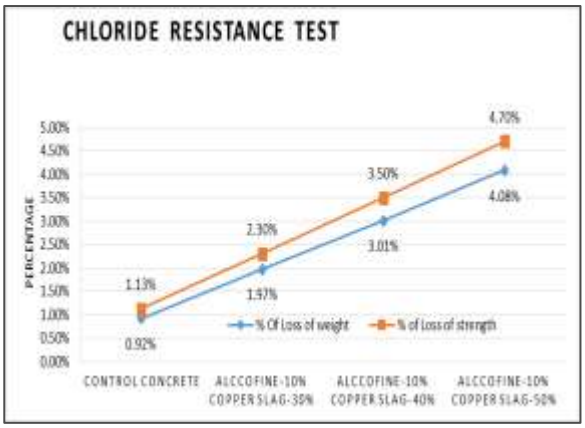

Fig-4.7Chloride resistance test for 30 days

4.8 Density Test

Density of specimen or material is one of the important factors in building industry. The weight & volume of specimen is measured to calculate density and it is increased while increasing the % of laterite in concrete.

Table-4.8 Density test in the 28 days

Mix proportion	Weight (kg)	Percentage (%)
Control Concrete	7.68	0
Alccofine-10 %Copper Slag-30%	8.50	10.677
Alccofine-10% Copper Slag-40%	8.57	11.590
Alccofine-10 %Copper Slag-50%	8.84	15.100

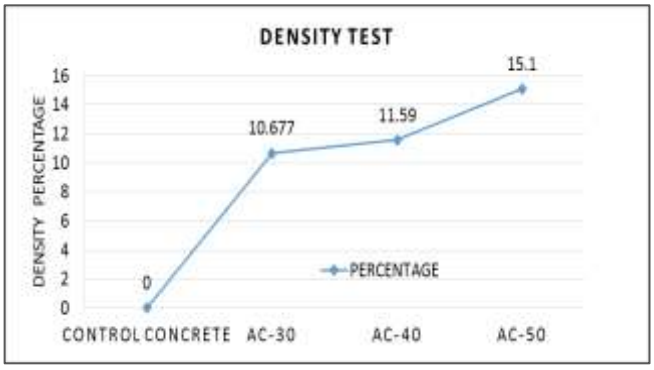

Fig-4.7Density test in the 28th day

5.0 Conclusion

The conclusion from the experimental investigations are as follows:

1. The compressive strength of concrete while replacing Alccofine 10% by the weight of cement and Copper Slag 40% by the weight of fine aggregate shows an increase in the strength of 46% than Control Concrete. The strength decreases while increasing the Copper Slag beyond 40%.
2. The Split tensile strength of concrete with Alccofine 10% by weight of cement and Copper Slag 40% by weight of fine aggregate show an increase of 28% of strength compared to Nominal Concrete.
3. Flexural strength is increased by 42% while replacing Alccofine 10% by weight of cement and Copper Slag 40% by weight of fine aggregate.
4. For all mix proportions the Chloride Ion Permeability values increases with compared to normal concrete. The maximum RCPT value occurred for Alccofine 10% and Copper slag 50% in the $28^{th}$and 56^{th} day test. The test results indicate that the concrete allows 2000 to 4000 Coulombs giving medium rating as per ASTM 1202.
5. The depth of penetration of water decreases with increase in copper slag when compared to Control Concrete in water permeability test. Since Alccofine 10% by weight of cement and Copper Slag 50% by weight of fine aggregate show an decrease in depth of penetration 58% than Control Concrete
6. In Sea water attack test, the resistivity decreases with increase in Copper Slag. While the 50% copper slag shows 3.18% decrease in weight and 3.37% decrease in strength compared to control concrete.
7. In chloride resistance test the resistivity decreases with increase in Copper Slag. While the 50% copper slag shows 3.16% decrease in weight and 3.57% decrease in strength compared to control concrete.
8. The density of the concrete increases with the increase in Copper Slag, since the Specific gravity of Copper Slag is high.
9. Thus, by adding Alccofine 10% and Copper Slag 40% in concrete the strength properties like Compressive strength, Split tensile strength and Flexural strength gives maximum result.

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