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PERFORMANCE ASSESSMENT FOR ALCCOFINE AS PARTIAL REPLACEMENT OF CEMENT IN CONCRETE

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Abstract : Concrete is a material that has been used all over the world for a very long period. Cement is one of the major and irreplaceable ingredients in the production of concrete. Unfortunately, cement making is energy intensive and environment unfriendly in nature. For every one-ton production of cement, an equal amount of Carbon dioxide (CO2) is released into environment. Thus, cement production not only causes natural depletion of resources but also contributes towards disturbing the environment of planet. Alccofine1203 is an eco-friendly SCM used to replace cement which is a relevant approach to minimize its burden on the environment. It is a low calcium silicate based micro fine material that consist of high amount of glass content with high reactivity. Alccofine-1203 is a highly processed material obtained from GGBS, the waste material generated from iron ore industries in India. Replacing OPC clinker with SCMs can reduce CO2 emissions by 30–40% without considerably compromising the main properties such as the strength and durability of cement-based materials. This project is an attempt to study the behaviour of Alccofine-1203 (with varying percentage replacement by weight of cement) on fresh and hard properties of concrete

***IndexTerms* - SCM, replacement, irreplaceable.**

I. INTRODUCTION

INTRODUCTION

Concrete is a vital part in construction sites. A huge amount of energy is utilised for cement production. Day-by-day infrastructure has been growing at high rate, due to that emission of carbon dioxide has increased, which causes global warming. Alccofine 1203 is an eco-friendly SCM used to replace cement for strength enhancement. It is an ultrafine product of GGBS with high glassy content and high pozzolanic reactivity. By using alccofine materials not only improves the concrete's compressive strength but also the fluidity and workability of concrete.

Ambuja Cements industry has introduced the manufacturing of a ultrafine cementitious material named Alccofine which is being manufactured from the industrial by product of Ground granulated blast furnace slag (GGBS) in a controlled manner. Alccofine 1203 is a specifically treated product based on slag of excessive glass content with great reactivity achieved through the method of controlled granulation. The raw materials are mainly low calcium silicates (CS). Treating CS with the selected ingredients results in controlled particle size distribution (PSD). The blain value (it is the fineness of material determined by blain's apparatus) is around 12000 cm^2/gm which is truly ultra-fine. Due to this exceptional chemistry and ultra-fine particle size, it provides reduced water demand and decreases the permeability, and improves durability. Basically, Alccofine is manufactured in two series namely 1200 series and 1100 series. Alccofine 1201 represents fine, 1202 represents microfine and 1203 represents ultrafine particle size.
Alccofine 1101 consists of high calcium silicate which is a micro-fine material used for grouting and improving the soil stabilization and anchoring of rocks. Due to the closed packing of ultrafine particles and chemical composition Alccofine 1203 is used in the construction purpose.

OBJECTIVES

The objectives of this study is to:

- To determine the properties of fresh concrete with varying percentage of alccofine.
- To determine the strength characteristics of concrete with varying percentage of alccofine.
- To do the cost analysis of a $1m^3$ concrete with and without alccofine at optimum percentage

II METHODOLOGY

The literature review review related to the properties of alccofine was done. The mix design was done as per the IS 10262-1982 and Is 456-2000. The mix design considered the characteristics of the components of concrete. The concrete mixes with varying alccofine percentage was made. Cubes, cylinders, prisms were casted to determine the compressive strength, tensile strength and flexural strength of the concrete respectively.

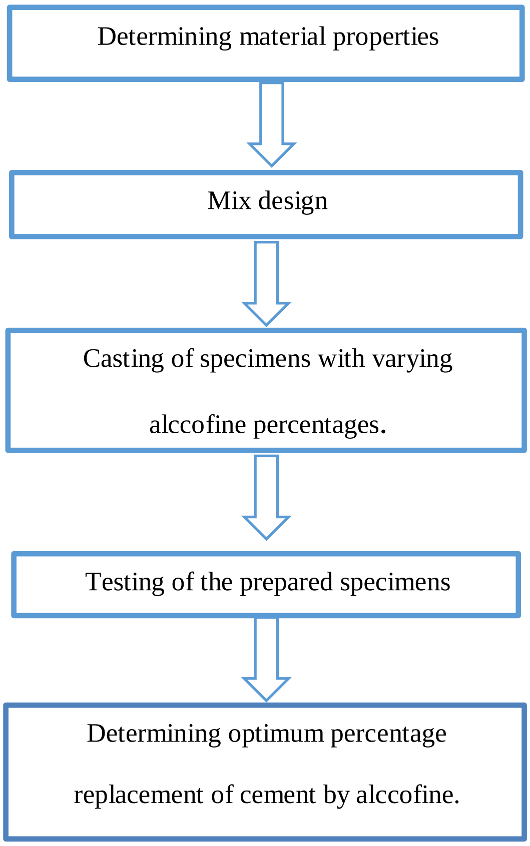

Figure 1: Image of Alccofine purchased

III TESTING OF MATERIAL PROPERTIES

3.1Physical properties

3.1.1 Cement

Cement is a binder, a substance used for construction that sets, hardens and adheres to materials to bind them together. Cement used in construction are inorganic often Lime or Calcium Silicate based and can be characterized as Hydraulic and Non-Hydraulic.

Cement is available in different types and grades. Ordinary Portland Cement (Zuari) of grade 53 is used for this study. Fineness, normal consistency, initial and final setting time of cement have been determined.

▪Fineness

This fineness test is conducted to check the particle size of a type of cement. Samples are passed through the 90µ IS sieve. Before passing the samples, their weights are taken. According to the standard procedure of this test, the lumps of the cement are broken and sieved for at least 15 minutes. Once done, the residue left is weighed. It should not increase by more than 10 percent for the ordinary varieties of cement.

▪ Specific gravity

The Le-Chatelier's flask should be free from moisture content, that mean flask is thoroughly dried. Empty flask is weighed with stopper (**W_1**), then 50 g of cement is taken in Le-Chatlier's flask and weighed the flask along with stopper (**W_2**), Now kerosene was poured to sample up to the neck of the bottle. Mixed thoroughly and saw that no air bubbles left in the flask. Noted the weight as (**W_3**). Emptied the flask and filled with kerosene up to the tip of the bottle and recorded the weight as **W_4**.

$$\text{Specific gravity} = \frac{(w_2 - w_1)}{(w_2 - w_1) - (w_3 - w_4) \times 0.79}$$

Where , Specific gravity of Kerosene = 0.79 g/cc

▪ Initial and final setting time

As Per IS: 4031 (Part 5) – 1988 initial and final setting time of cement is calculated using VICAT apparatus conforming to IS: 5513 – 1976, Initial setting time of concrete is the time period between addition of water to cement till the time at 1 mm square section needle fails to penetrate the cement paste, placed in the Vicat's mould 5mm to 7mm from the bottom of the mould. Final setting time is that time period between the time water is added to cement and the time at which 1 mm needle makes an impression on the paste in the mould but 5 mm attachment does not make any impression.

3.1.2 Aggregate

▪ Specific gravity

Specific gravity is a dimensionless quantity that is defined as the ratio of the weight of oven-dried aggregates to the weight of a volume of pure water displaced by an equal volume of saturated surface dry aggregates. An oven-dry condition of aggregate is obtained by drying the aggregates in the oven for 24 hours at 100°C -110°C.

▪ Bulk density

Bulk density of aggregates where determined in accordance to IS: 2386-3 (1963).By adding aggregates to a unit volume cylindrical container at a particular level of compaction, one can calculate the bulk density of an aggregate sample. As a result, it is dependent on how tightly the aggregates are packed into the container as it is being filled, and it has been classified as either loose or compact bulk density. Additionally, the aggregate's bulk density is influenced by the particle size distribution and form. Similar-sized grains or particles produce more voids and so have lower bulk densities, while aggregates with a range of particle sizes have a lower void content and a greater bulk density.

3.1.3 Alccofine

- Specific gravity

Specific gravity of Alccofine was determined by Le Chatelier's Flask method conforming to IS 2720- Part 3. The Le-Chatelier's flask should be free from moisture content, that mean flask is thoroughly dried. Empty flask is weighed with stopper (**W**$_1$), then 50 g of Alccofine is taken in Le-Chatlier's flask and weighed the flask along with stopper (**W**$_2$), Now kerosene was poured to sample up to the neck of the bottle. Mixed thoroughly and saw that no air bubbles left in the flask. Noted the weight as (**W**$_3$). Emptied the flask and filled with kerosene up to the tip of the bottle and recorded the weight as (**W**$_4$).

$$\text{Specific gravity} = \frac{(w_2 - w_1)}{(w_2 - w_1) - (w_3 - w_4)\ x\ 0.79}$$

Table1: Physical properties of raw materials

NO	Raw materials	Property	Value obtained	Limits
1	Cement	Specific gravity	3.11	3.15
		Setting time	Initial-39 mins Final- 500mins	Initial-30 mins(IS 12269-1987) Final-600 mins
		Fineness	4%	<10% (IS 8112-1989)
2	Fine aggregate	Specific gravity	2.56	2.50 to 2.9(IS 2386 (PART Ⅲ) 1963)
		Bulk density	1.575 g/cc	1.450 to 2.082
3	Coarse aggregate	Specific gravity	2.98	2.50 to 2.9(IS 2386 (PART Ⅲ) 1963)
		Bulk density	1.609 g/cc	1.200 to 1.750
4	Alccofine	Specific gravity	2.71	
5.	Water	pH	7.5	6.5 to 8.5

3.2 Normal consistency

The consistency of cement test is used to assess how much water should be added to cement in order to achieve standard consistency or normal consistency. The Vicat equipment described in IS code 5513 shall be used to conduct the standard consistency of cement test in accordance with the requirements of IS code 4031 part 4. The Vicat apparatus plunger can be used to determine how much water is needed to make cement paste by piercing it 5 to 7 mm from the bottom of the Vicat mold.

Figure 2 : Vicat apparatus

Table 2: Normal consistency of cement

SL No.	Quantity of water added (ml) w	Percentage of weight (w/c) x 100	Time of gauging (mins)	Penetration from bottom of the mold
1	100	25	5	37
2	108	27	5	24
3	116	29	5	11
4	124	31	5	6

Quantity of cement = 400g

Standard consistency= P = (w/c) x100 , W = 124ml, c = 400g

P = (124/400) x100 = 31%

3.3 Bulking of M sand

Bulking of sand refers to the increase in sand volume brought on by an increase in moisture content. The sand particles are surrounded by a thin layer of water, which causes the particles to move apart and increase the volume. Sand fills the pores between cement and coarse particles in concrete, reducing segregation. For example, we need 1 m^3 of sand in concrete, we need to know the approximate sand bulkage value. If the given sample has a bulkage of 25% then we need to take 25% more sand or 1.25 times of the sand while volume batching to get 1 m3 of sand for concrete.

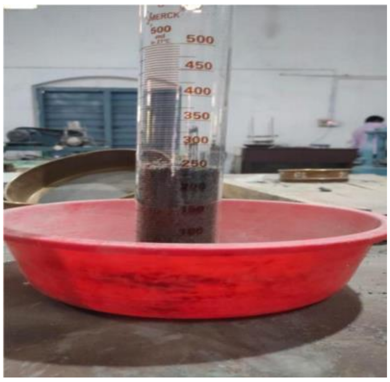

Figure 3: Bulking of M sand

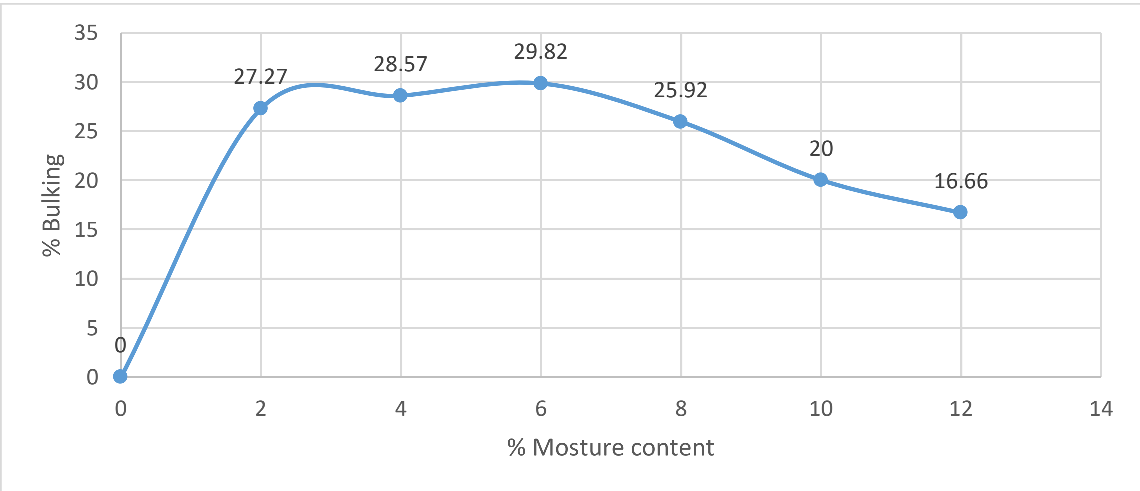

Figure 4: Percentage bulking v/s Percentage moisture content graph

Maximum % of bulking = 29.82 %

3.4 Particle size distribution of aggregates

Table 3: Particle size distribution of coarse aggregate

PARTICLE SIZE IN (MM)	CUMULATIVE % FINER
20	100
16	95.27
12.5	45.87
10	8.4
4.75	0.8
2.36	0
1.18	0

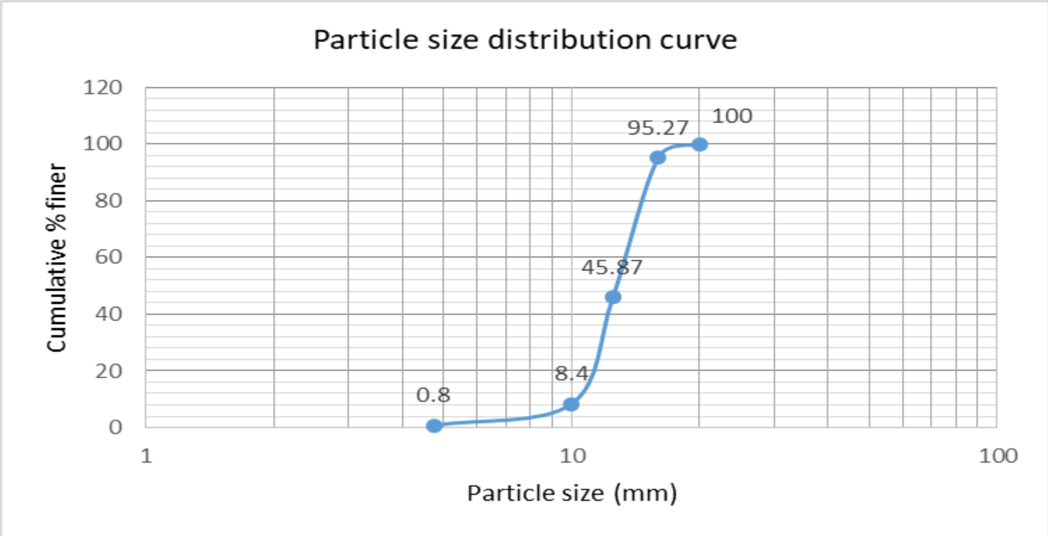

Figure 5 : Particle size distribution curve of coarse aggregate

Table 4: Particle size distribution of fine aggregate

PARTICLE SIZE	CUMULATIVE % FINER
4.75 mm	100
2.36mm	95.53
1.18 mm	87.76
600 µm	58.36
300 µm	24.19
150 µm	5.96
75µm	0.26

Table 5: zones of fine aggregate as per IS code

Sl No. (1)	IS Sieve Designation (2)	Percentage Passing			
		Grading Zone I (3)	Grading Zone II (4)	Grading Zone III (5)	Grading Zone IV (6)
i	10 mm	100	100	100	100
ii	4.75 mm	90-100	90-100	90-100	95-100

iii	2.36 mm	60-95	75-100	85-100	95-100
iv	1.18 mm	30-70	55-90	75-100	90-100
v	600 µm	15-34	35-59	60-79	80-100
vi	300 µm	5-20	8-30	12-40	15-50
vii	150 µm	0-10	0-10	0-10	0-15

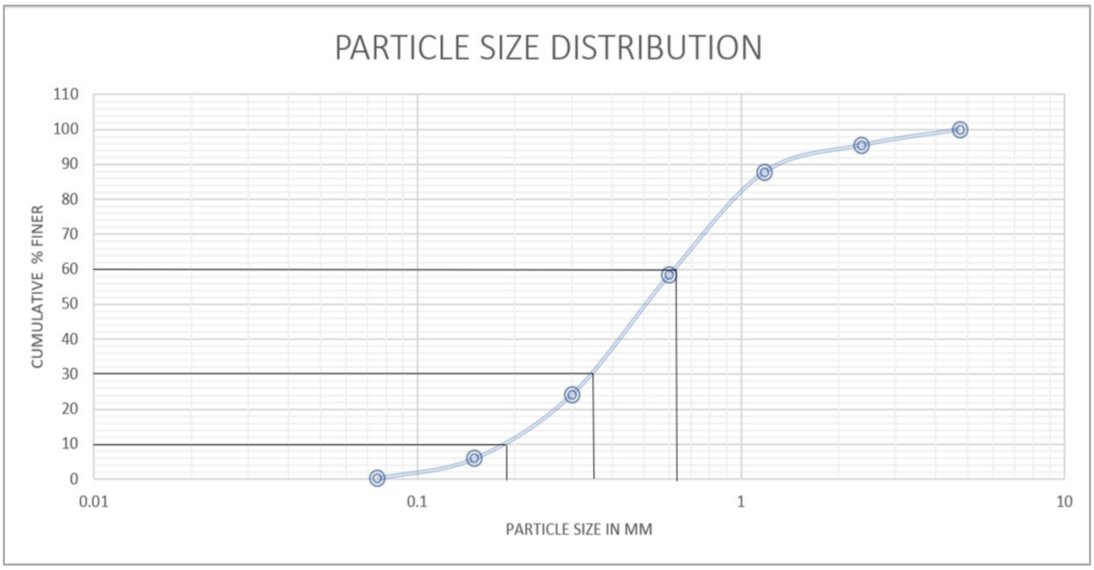

Figure 6: Particle size distribution curve of fine aggregate

3.5 Compressive strength of mortar cube

The compressive strength of mortar cube was determined by compressive strength tests on mortar cubes conforming to IS 4031 (Part 6). A total of 3 specimens of size 70 x 70 x 70 mm were casted for the study. Cement and sand were taken in ratio of 1:3 and Water (P/4+ 3.0) percent of combined mass of cement and sand, where **P** is the normal consistency of cement. Average compressive strength was calculated by equation (P/A), where P is load in N and A is the area of specimen in mm.

Table 6: Compressive strength of cement

Weight of cement(w1) g	200g	200g	200g
Weight of standard sand(w2) g	600g	600g	600g
Weight of water((P/4)+3)(W1+W2)/100 g	86 g	86 g	86 g
Area of specimen	7 x 7 cm	7 x 7 cm	7 x 7 cm
Load of fracture (P) Tonne 3 days	16.3	15.6	16.5
Compressive strength P/A (N/mm²) 3 days	33.26	31.83	33.67

Average Compressive strength = 32.92 N/mm^2 (In reference to IS 12269. 1987)

3.6 Mix design ratio

Table 7: M25 Mix

Cement	Fine aggregate	Coarse aggregate	Water
383.16	643.14	1164.5	191.58
1	1.67	3.03	0.5

Table 8: M30 Mix

Cement	Fine aggregate	Coarse aggregate	Water
394	648.97	1226.2887	157.6
1	1.7	2.71	0.4

3.7 Workability-Slump test

- M25 MIX

Table 9: Slump values for M25 mix with varying percentage of Alccofine

Mix (%)	Cement (Kg/m ^{3})	Fine aggregate (Kg/m^3)	Alccofine (Kg/m^3)	Coarse aggregate (Kg/m^3)	w/c ratio	Workability (mm)
0	383.16	643.14	0	1164.5	0.5	57
5	364.002	643.14	19.158	1164.5	0.5	61
10	345	643.14	38.16	1164.5	0.5	65
15	325.686	643.14	57.474	1164.5	0.5	70
20	306.528	643.14	76.632	1164.5	0.5	67

- M30 MIX

Table 10: Slump value for M30 mix with varying percentage of Alccofine

Mix (%)	Cement (Kg/m ^{3})	Fine aggregate (Kg/m^3)	Alccofine (Kg/m^3)	Coarse aggregate (Kg/m^3)	w/c ratio	Workability (mm)
0	394	648.97	0	1226.2887	0.45	83
5	374.3	648.97	19.7	1226.2887	0.45	87
10	354.6	648.97	39.4	1226.2887	0.45	91
15	334.9	648.97	59.1	1226.2887	0.45	94
20	315.2	648.97	78.8	1226.2887	0.45	88

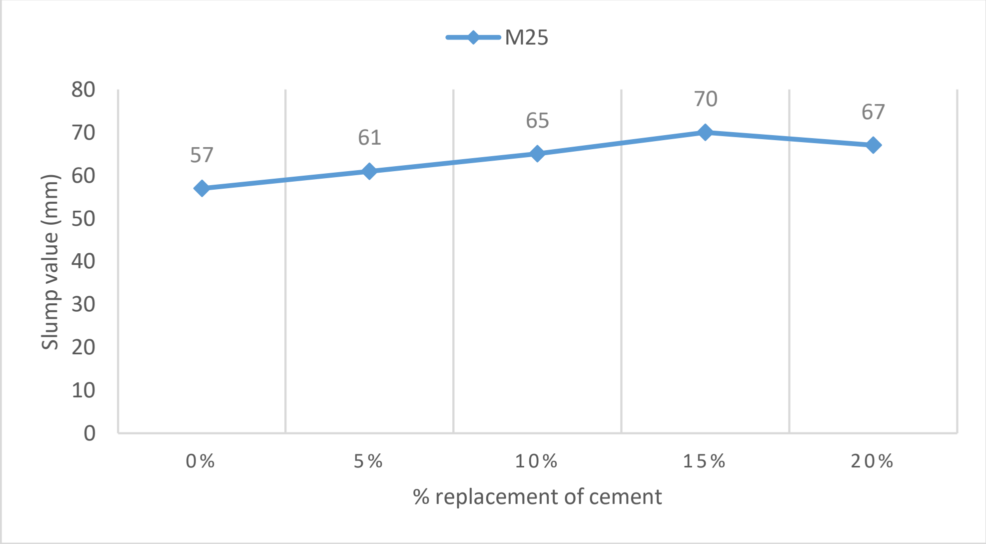

Figure 7: Slump value v/s % replacement of cement graph for M25 mix

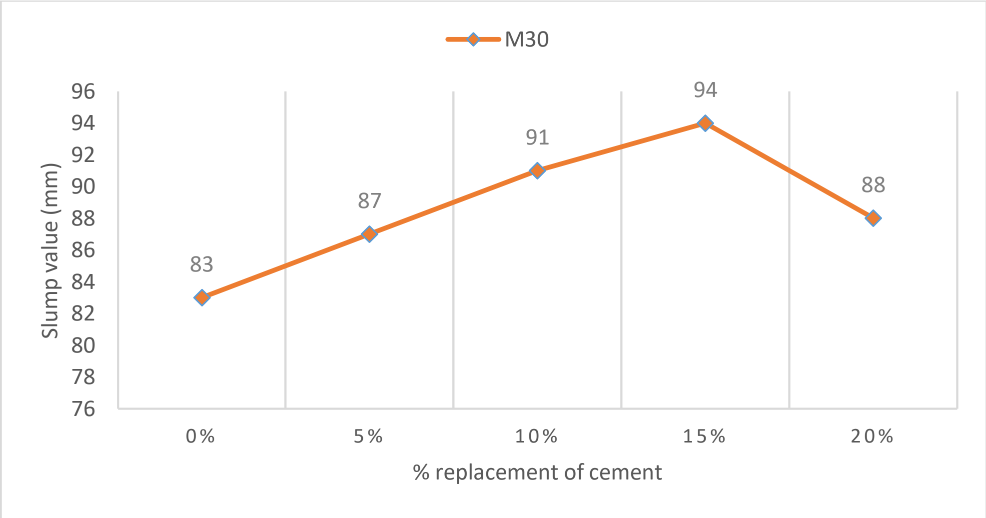

Figure 8: Slump value v/s % replacement of cement graph for M30mix

IV TESTING OF MECHANICAL PROPERTIES

4.1Compressive strength

The cube specimens of conventional concrete and concrete cubes with 5%, 10%, 15% and 20% replacement of cement with Alccofine were casted in mix M25 and M30. The specimens were constructed using OPC 53 grade cement (Zuari), M sand, Alccofine, 20mm coarse aggregate. Water cement ratio used for M25 and M30 mix were 0.5 and 0.4 respectively. The compressive strength was assessed using a standard cube sample measuring 150 mm x 150 mm x 150 mm. The specimens underwent testing with each percentage of alccofine substitution after being demoulded after 24 hours of casting and being cured in water for 7 and 28 days. The test was conducted in compression testing machine. Each layer that was added to the concrete was compacted before the next layer was added.

Figure 9 : Casted concrete cubes and cylinders

Figure 10: Test for compressive strength on cube

4.2 Split tensile strength

Concrete's tensile test can be evaluated indirectly using the split tensile test. The cylinder specimens of conventional concrete and concrete cubes with 5%, 10%, 15% and 20% replacement of OPC 53 grade cement with alccofine were casted in mix M25 and M30. The specimens were constructed using OPC 53 grade cement (Zuari), M sand, Alccofine, 20mm coarse aggregate. In this test, a conventional cylindrical specimen is set out horizontally, and force is applied radially over its surface until a vertical crack forms along the specimen's diameter. Specimens degrade in the direction of the applied force, and tensile stress rises as radial compressive force increases. The split tensile strength of cylinder is calculated by $f_{cs} = 2P/\pi dl$. Where: P is the fracture compression force acting along the cylinder generatrix, d is the cylinder diameter; l is the cylinder length = 300mm

Figure 11: Test for tensile strength on cylinder

4.3 Flexural strength

Flexural strength or modulus of rupture of concrete is an important parameter that decides the flexibility of the material under bending. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending.

Specimens of size 700 mm x 150 mm x150 mm were casted with varying percentages of alccofine (0%,5%,10%,15%,20%) in mix M25 and M30. The specimens are demoulded after 24 hours of casting and tested for strength after curing for 7 days and 28 days.

Figure 12: casted concrete prism

Figure 13: Test for flexural strength on prism

Results of mechanical properties

M25 MIX

4.1.1) Compressive strength of cube

Table 11: Compressive strength of M25 mix concrete cubes with varying percentages of Alccofine

% Replacement	Compressive Strength (N/mm^2)			
	Failure load in tonnes	7 days	Failure load in tonnes	28 days
0%	52.3	22.8	72.54	31.63
5%	54.26	23.66	79.9	34.84
10%	55.43	24.17	82.82	36.11
15%	56.33	24.56	84.22	36.72
20%	55.52	24.21	82.77	36.09

- Sample calculation (0% Replacement)

Compressive strength (7days) = 52.2 T

$= (52.3 \times 10^3 \times 9.81) / 22500 = 22.8 \text{ N/mm}^2$

Compressive strength (7days) = 72.54 T

$= (72.54 \times 10^3 \times 9.81) / 22500 = 31.63 \text{ N/mm}^2$

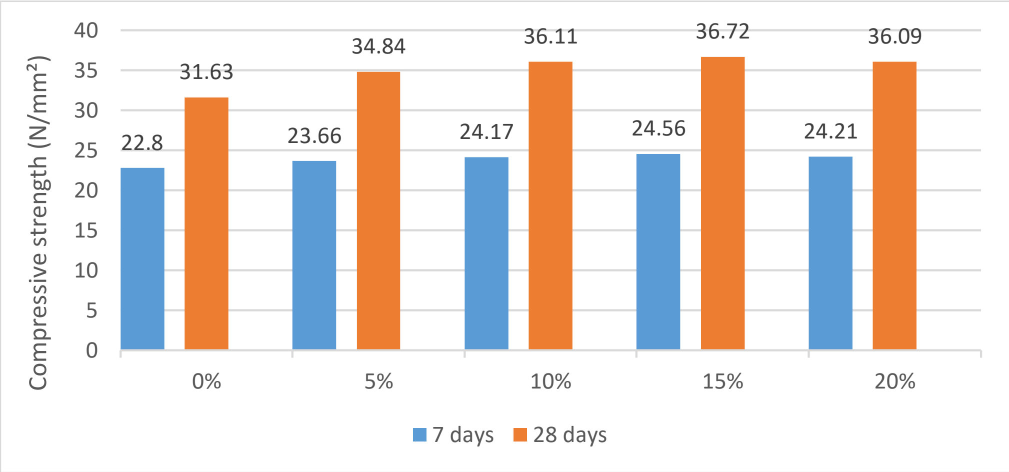

Figure 14: Compressive strength of M25 grade concrete with varying percentage of Alccofine

4.2.1) Split tensile strength of cylinder

Table 12: Split tensile strength of M25 mix concrete cylinders with varying percentages of Alccofine

% Replacement	Split Tensile Strength (N/mm²)			
	Failure load in tonnes	7 days	Failure load in tonnes	28 days
0%	13.39	1.86	23.39	2.73
5%	13.75	1.91	21.77	2.94
10%	14.11	1.96	21.67	3.01
15%	14.54	2.02	22.82	3.17
20%	13.97	1.94	21.38	2.97

- Sample calculation (0% Replacement)

Split tensile strength (7 days) = 13.39 T

$= (2 \times 131409) / (3.14 \times 150 \times 300) = 1.86 \text{ N/mm}^2$

Split tensile strength (28 days) = 19.66 T

$= (2 \times 192874.5) / (3.14 \times 150 \times 300) = 2.73 \text{ N/mm}^2$

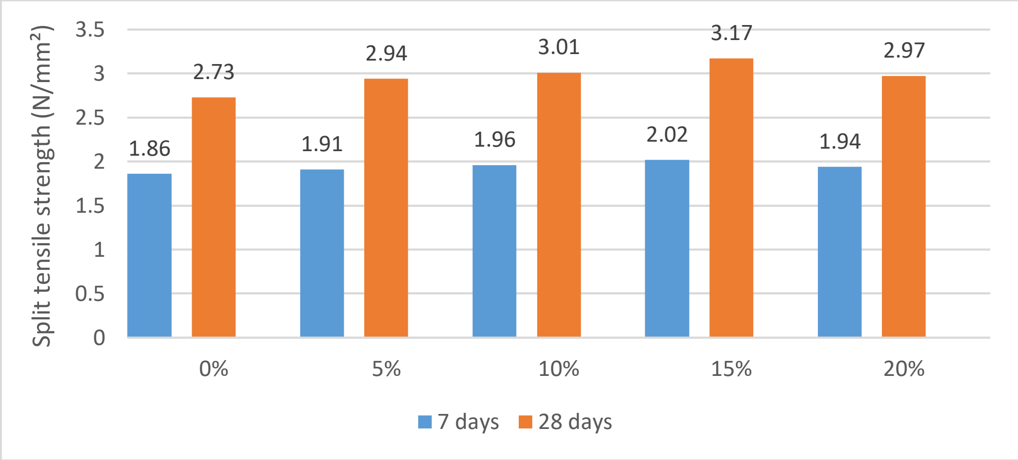

Figure 15: Split tensile strength of M25 grade concrete with varying percentage of Alccofine

4.3.1) Flexural strength of prism

Table 13: Flexural strength of M25 mix concrete prism with varying percentages of Alccofine

% Replacement	Flexural Strength (N/mm^2)	
	Failure load in KN	28 days
0%	21.21	4.4
5%	22.03	4.57
10%	22.95	4.76
15%	23.57	4.89
20%	22.61	4.69

- Sample calculation (0% Replacement)

Flexural strength (28 days) = 21.21 KN

$= (21.21 \times 1000 \times 700) / (150 \times 150^2)$

$= 4.4 \ N/mm^2$

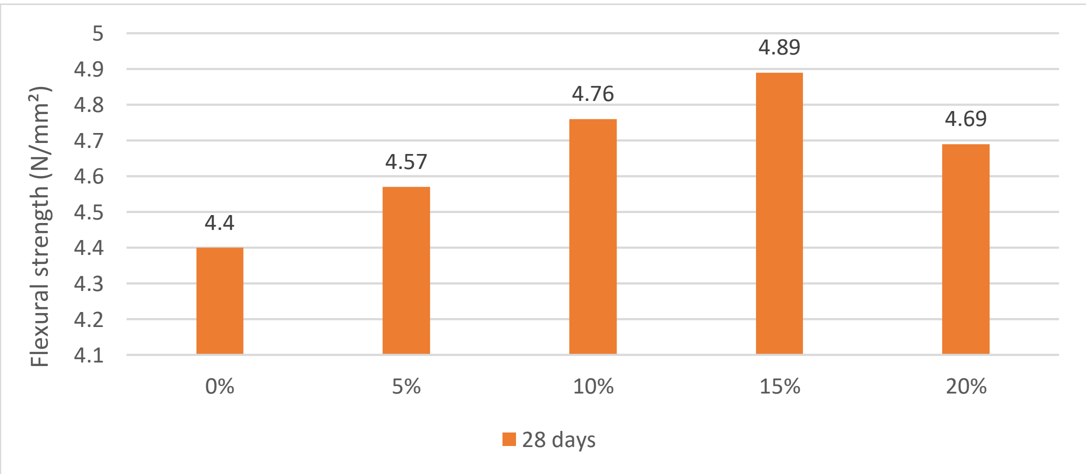

Figure 16: Flexural strength of M25 grade concrete with varying percentage of Alccofine

M30 MIX

4.1.2 Compressive strength of cube

Table 14: Compressive strength of M30 mix concrete cubes with varying percentages of Alccofine

% Replacement	Compressive Strength (N/mm²)			
	Failure load in tonnes	7 days	Failure load in tonnes	28 days
0%	61.39	26.77	85.43	37.25
5%	63.61	28.61	91.51	39.9
10%	69.31	30.22	100.2	43.69
15%	70.58	30.78	101.83	44.40
20%	68.96	30.07	99.81	43.52

▪Sample calculation (0% Replacement)

Compressive strength (7days) = 61.39 T

$$= (61.39 \times 10^3 \times 9.81)/22500 = 26.77 \text{ N/mm}^2$$

Compressive strength (28days) =85.43 T

$$= (85.43 \times 10^3 \times 9.81)/ 22500 = 37.25 \text{ N/mm}^2$$

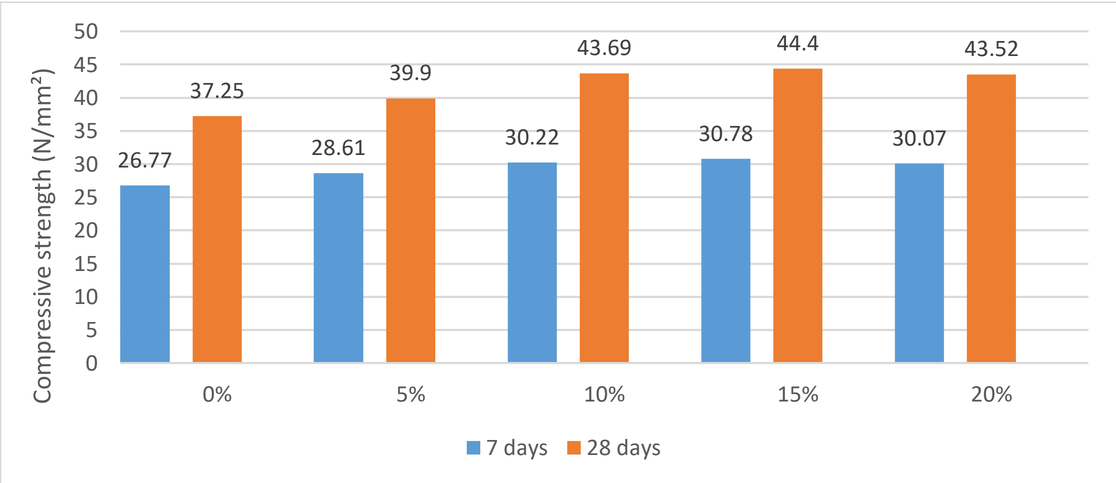

Figure 17: Compressive strength of M30grade concrete with varying percentage of Alccofine

4.2.2 Split tensile strength of cylinder

Table 15: Split tensile strength of M30 mix concrete cylinder with varying percentages of Alccofine

% Replacement	Split Tensile Strength (N/mm²)			
	Failure load in tonnes	7 days	Failure load in tonnes	28 days
0%	13.86	1.93	21.46	2.98
5%	15.41	2.14	22.97	3.19
10%	17.28	2.40	24.91	3.46
15%	17.71	2.46	25.35	3.52
20%	15.71	2.18	22.61	3.14

- Sample calculation (0% Replacement)

Split tensile strength (7 days) = 13.86 T

= (2 x 136354.5) / (3.14 x 150 x 300) = 1.93 N/mm^2

Split tensile strength (28 days) = 21.46 T

= (2 x 210537) / (3.14 x 150 x 300) = 2.98 N/mm^2

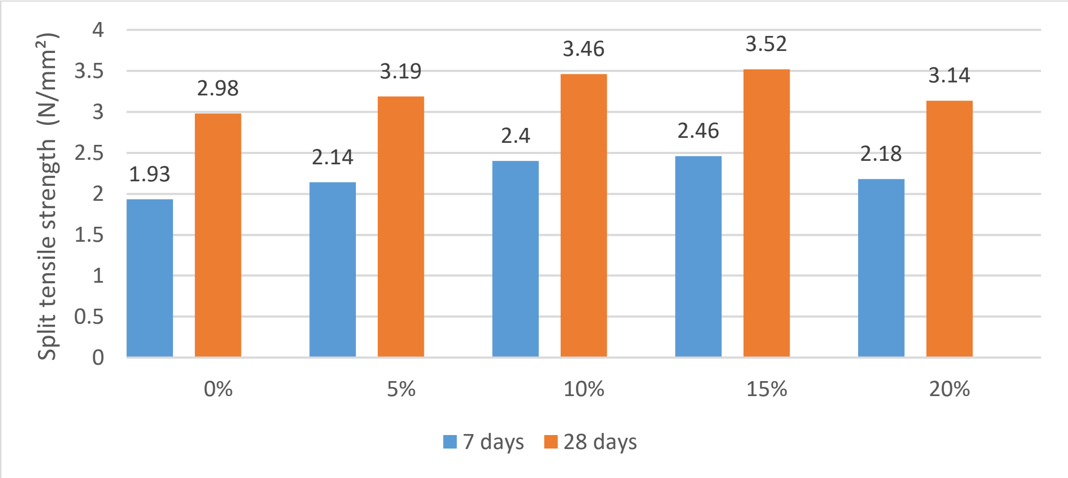

Figure 18: Split tensile strength of M30grade concrete with varying percentage of alccofine

4.3.2 Flexural strength of prism

Table 16: Flexural strength of M30 mix concrete prism with varying percentages of Alccofine

% Replacement	Flexural Strength (N/mm^2)	
	Failure load in KN	28 days
0%	27.09	5.62
5%	27.62	5.73
10%	28.3	5.87
15%	28.73	5.96
20%	27.91	5.79

- Sample calculation (0% Replacement)

Flexural strength (28 days) = 27.09 KN

= (27.09 x1000 x 700)/ (150 x 150^2) = 5.62 N/mm^2

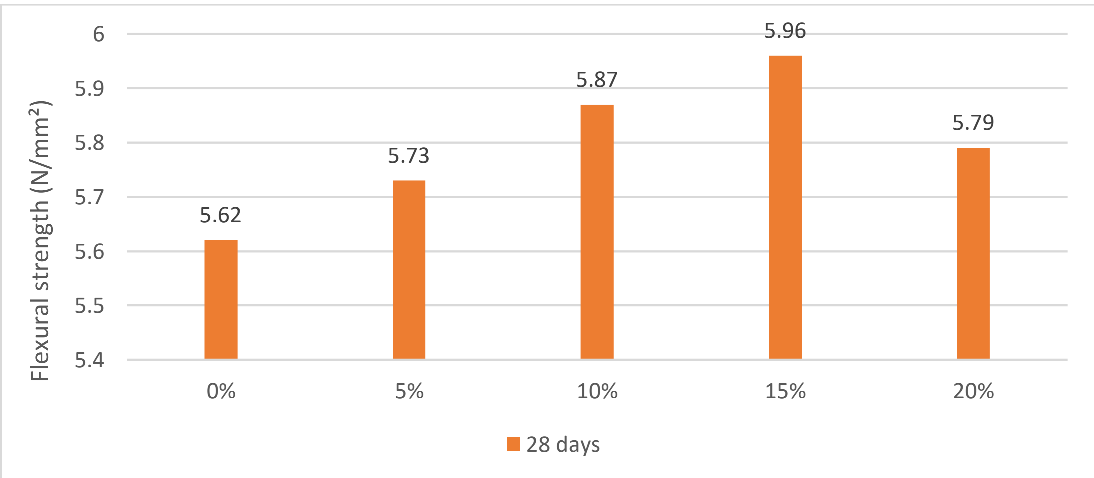

Figure 19: Flexural strength of M30 grade concrete with varying percentage of Alccofine

Note: Analysing the results of above tests conducted substitution of 15% Alccofine by replacing cement in both M25 and M30 grade concrete gave higher strength and workability, hence it can be inferred that 15% is the optimum percentage for replacement.

CONCLUSION

Alccofine 1203 is an enhanced supplementary cementatious material. The presence of calcium (CaO) and silica (SiO2) in alccofine-1203 improved the mechanical and durability properties of concrete better than the other SCMs. The unique chemical composition and glassy surface characteristics of alccofine-1203 particles improve the workability of concrete and reduce segregation and bleeding by lowering the water demand. From the study concrete with 15% of alccofine replacement has shown an increase in strength characteristics and fresh properties. The slump values are increasing as the percentage of alccofine increases in the concrete. The compressive strength and split tensile strength of concrete has shown 15% -20 % increase in strength with 15% of alccofine replacement. The flexural strength has enhanced by 6% -12% with 15% alccofine replacement. The reduction in consumption of large quantity of cement in the manufacturing of concrete can be achieved by use of supplementary cementitious materials (SCMs) as a partial or full replacement to cement. The alccofine can reduce the emission of greenhouse gasses which is released as a byproduct of cement production; thus, it is eco-friendly in nature. Alccofine materials are costlier than cement, though it is preferred when compared to the environmental effects and strength characteristics of normal concrete.

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