International Journal of Research in Engineering, Science and Management
Volume 4, Issue 6, June 2021
https://www.ijresm.com | ISSN (Online): 2581-5792

Experimental Investigations On the Partial Replacement of Cement by Alccofine and Flyash

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***Abstract*: Concrete is one of the most commonly used material in the construction sector. It is usually comprised of Portland cement as the main component for making of concrete. Cement manufacturing is highly energy consuming and emissions intensive because of the extreme heat required to produce it. Producing a ton of cement requires 4.7 million BTU of energy, equivalent to about 400 pounds of coal, and generates nearly a ton of CO2. The production of cement release greenhouse gas emissions both directly and indirectly into the environment. The heating of limestone release CO2 directly, while the burning of fossil fuels to heat the kiln indirectly results in CO2 emissions. The major problem due to the production of cement is that the carbon-dioxide is liberated in a large quantity which in-turn increases the temperature of the atmosphere resulting global warming. Hence, we need a permanent replacement of cement in concrete to overcome the issue of global warming due to carbon-dioxide emission.**

In this paper the effects of partial replacement of cement by Alccofine has been studied. Alccofine 1203 is a specially manufactured material based on high glass content with high reactivity achieved through the process of controlled granulation. Concrete attains high strength at a very early age, due to the presence of Alccofine material. In this experimental stretch Alccofine was replaced by 0%, 25%, 50% & 75% by the weight of cement and Various properties like workability of fresh concrete using slump cone & compaction factor test, Compressive strength on concrete cubes, split tensile strength on concrete cylinders at 7, 14 & 28days of curing period were studied. The grade of concrete used was M15. It was observed from the result that the Alccofine material increases the strength to a large extent at an optimum replacement level of 25% after which decrease in the strength of concrete was observed. On the basis of strength increment in the variation of concrete mix, it gives better performance which indicates the consumption of waste material as mineral admixture for concrete could be encouraged in a better way to achieve environmental sustainability.

***Keywords*: Alccofine, Ordinary Portland Cement (OPC). compressive strength, split tensile strength.**

1. Introduction

Concrete is a fusion of materials basically composed of coarse aggregate bonded together with a fluid cement which hardens over time [1]. Producing quality concrete in the present climate does not solely depend on achieving high strength property. [2] Most concretes used are lime-based concretes such as Portland cement concrete or concretes made with other hydraulic cements. However, road surfaces are also a type of concrete, asphalt concrete, where the cement material is bitumen, and polymer concretes are sometimes used where the cementing material is a polymer. In Portland cement concrete (and other hydraulic cement concretes), when the aggregate is combined together with the dry cement and water, they form a fluid mass that is easily molded into shape. The cement reacts chemically with the water and other ingredients to form a hard matrix which binds all the materials together into a durable stone-like material that has many uses. Alccofine is a new generation, micro fine material of particle size much finer than other hydraulic materials like cement, fly ash, silica etc. being manufactured in India. Alccofine has unique characteristics to enhance 'performance of concrete' in both fresh and hardened stages due to its optimized particle size distribution. [1]

Alccofine 1203 and Alccofine 1101 are two types of Alccofine with low calcium silicate and high calcium silicate respectively. Alccofine 1200 series is of 1201, 1202, 1203 which represents fine, micro fine, ultrafine particle size respectively. Alccofine 1203 is a slag-based Material having ultra-fineness with optimized particle size distribution whereas Alccofine 1101 is a micro finer cementitious grouting material for soil stabilization and rock anchoring. The performance of Alccofine is superior to all the other admixtures used in India. Due to high Calcium oxide (Cao) content [2]. The workability of the mix retention is improved due to Alccofine 1203 and increased the flow ability of the mix. It also helps in reduction in segregation and reduction in heat of hydration of the mix [3]. Alccofine 1203 used to improve compressive strength or as a super workability aid to improve flow. Alccofine 1203 is known to produce a high – strength concrete and is used in two different ways as a cement replacement, to reduce the cement content and as an additive to improve concrete properties [4].

2. Objectives of the Study

1. To evaluate the effects of replacing the cement by Alccofine.
2. To determine the compressive strength compressive strength split tensile strength of concrete for 7, 14- and 28-days curing.

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3. To investigate workability of fresh concrete.
4. To determine the optimum level of Alccofine in the concrete.
5. To investigate replacement is economical or not.

3. Materials and Methodology

Cement: Ordinary Portland Cement (OPC) is the basis cement which is best suited for use in general concrete construction. In the present investigation, BIS mark 53 grade cement was used for all concrete mixes. The cement used was fresh and had no lumps. Testing of cement was done as per BIS: 12269-2010. The various tests results conducted on the cement are tabulated below.

Table 1
Test results for Cement

S. No.	Characteristics	Value Obtained	As per BIS:12269- 2010
1.	Normal Consistency (%)	34.%	_
2.	Initial setting time (minutes)	43 min	Not less than 30
3.	Final setting time (minutes)	300 min	Less than 600
4.	Fineness (%)	6.43 %	Max 10
5.	Specific Gravity	3.1	3.15

Alccofine: Alccofine is a new generation, micro fine material of particle size much finer than other hydraulic materials like cement, fly ash, silica etc. being manufactured in India. Alccofine has unique characteristics to enhance 'performance of concrete' in both fresh and hardened stages due to its optimized particle size distribution. Alccofine 1203 and Alccofine 1101 are two types of Alccofine with low calcium silicate and high calcium silicate respectively. Alccofine 1200 series is of 1201, 1202, 1203 which represents fine, micro fine, ultrafine particle size respectively. Alccofine 1203 is a slag-based Material having ultra-fineness with optimized particle size distribution whereas Alccofine 1101 is a micro finer cementitious grouting material for soil stabilization and rock anchoring.

Table 2
Test results for Alccofine

S. No.	Properties	Values
1.	Specific Gravity	2.67
2.	Appearance	Grayish white

Fig. 1. Image of Alccofine bag purchased

Fly Ash: According to the American Concrete Institute (ACI) Committee 116R, fly ash is defined as the finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gasses from the combustion zone to the particle removal system" (ACI Committee 232 2004). The colour of fly ash ranges from almost cream to dark grey essentially depending upon the proportion of unburnt carbon present and the iron content. Fly ash particles are typically spherical, finer than Portland cement and lime, ranging from less than 1 μm to no more than 150 μm. The types and relative amounts of incombustible matter in the coal determine the chemical composition of fly ash. The major influences on the fly ash chemical composition come from the type of coal. In the present experimental work, low calcium, Class F (American Society for Testing and Materials 2001) dry fly ash obtained from the silos of Thermal Power Station, was used as the base material. Fly ash is a high efficiency class F Pozzolanic material confirming to BS 3892, obtained by selection and processing of power station fly ashes resulting from the combustion of pulverized coal.

Fig. 2. Image of Flyash

Fine Aggregates: The sand used for this study was locally procured and conformed to grading zone III as per BIS: 383-2007. The sand was first sieved through a standard 4.75 mm sieve to remove any particles greater than 4.75 mm and then was washed to remove the dust. The results of physical properties of the fine aggregates are represented below.

Fig. 3. Image of manufactured Sand

Table 3
Test results for fine aggregate

S. No.	Characteristics	Value
1.	Type	Manufactured
2.	Specific Gravity	2.4
3.	Packing Factor	1.08
4.	Density	1620 kg/m3
5.	Fineness Modulus	2.41
6.	Grading Zone	Zone III

Coarse Aggregates: The crushed stone are mainly used as aggregates in concrete. Locally available coarse aggregates having the maximum size of 20mm passing and 16mm retained were used in this experimental work. Testing of coarse aggregates was carried out as per the stipulations of BIS: 2386-1963. The results of physical properties of coarse aggregate are described in the table below.

Table 4
Test results for coarse aggregate

S. No.	Tests	Results	As per BIS 2386-1963
1.	Specific gravity	2.63	2.5-2.9
2.	Crushing Value	23.35%	Max 30%
3.	Abrasion Value	21.5%	Max 35%
4.	Impact Value	14%	Max 30%
5.	Elongation Index	8.8%	Max 2%
6.	Flakiness Index	3.2%	Max 30%

Water: Water is the most important ingredient of a concrete as hydration of cement is possible only in the presence of water. It helps in creating a bond between the cementitious materials and the aggregates. portable water confirming to the requirements as per IS 456-2000 which is free from salts and impurities is used for washing aggregates, mixing and curing purposes.

A. Experimental Programme

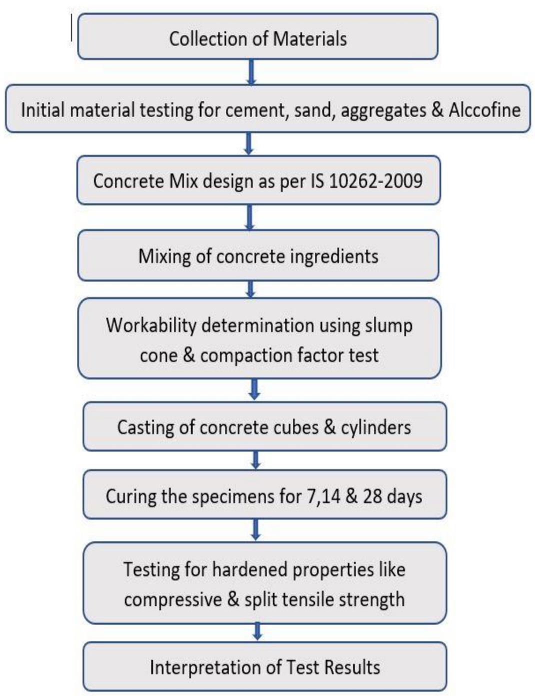

Fig. 4. Flowchart

*NOTE: F*or the partial replacement of 25%, two parts of 25% i.e., (12.5% of flyash & 12.5% of Alccofine) was used so to get a cementitious mix of 25% & this 25% of cementitious mix was used as 25% of replacement. For 50% of replacement (25% of flyash & 25% of Alccofine).

4. Result and discussion

A. Workability Test

The concrete immediately after mixing was tested for workability by Slump cone & compaction factor method & the following observations were recorded.

Table 5
Variation in Workability by Slump cone method

S. No.	% of Replacement	Slump in mm
1	0%	80
2	25%	50
3	50%	25
4	75%	17

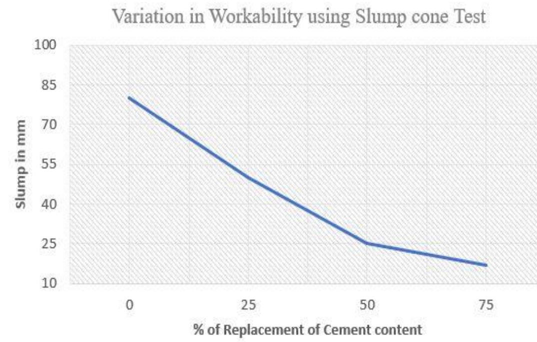

Fig. 5. Graphical representation of variation in workability by slump cone method

Table 6
Variation in Workability by compaction factor method

S. No.	% of Replacement	Compaction Factor
1	0%	0.85
2	25%	0.87
3	50%	0.93
4	75%	0.82

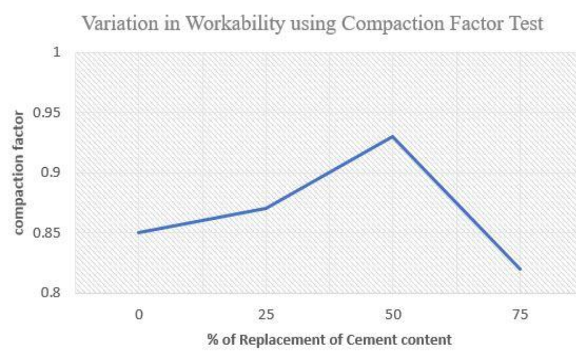

Fig. 6. Graphical representation of variation in workability by compaction factor method

B. Compressive Strength Test

Compressive strength test was carried on the specimens after a curing period of 7, 14 & 28 days and the following observations were made.

The variation of compressive strength at a period of 7 days are as represented in the tabulated form below.

Table 7
Variation in 7 days' compressive strength for 0% GGBS content

Trial No.	% mix	Failure load in KN	Compressive stress in N/mm^2	Average compressive stress in N/mm^2
1	0%	214.65	9.54	9.57
2		219.37	9.75	
3		212.18	9.43	

Table 8
Variation in 7 days' compressive strength for 25% GGBS content

Trial No.	% mix	Failure load in KN	Compressive stress in N/mm^2	Average compressive stress in N/mm^2
1	25%	229.27	10.19	10.65
2		241.42	10.73	
3		248.40	11.04	

Table 9
Variation in 7 days' compressive strength for 50% GGBS content

Trial No.	% mix	Failure load in KN	Compressive stress in N/mm^2	Average compressive stress in N/mm^2
1	50%	157.95	7.02	7.04
2		138.15	6.14	
3		179.10	7.96	

Table 10
Variation in 7 days' compressive strength for 75% GGBS content

Trial No.	% mix	Failure load in KN	Compressive stress in N/mm^2	Average compressive stress in N/mm^2
1	75%	157.50	7.00	6.45
2		140.17	6.23	
3		137.92	6.13	

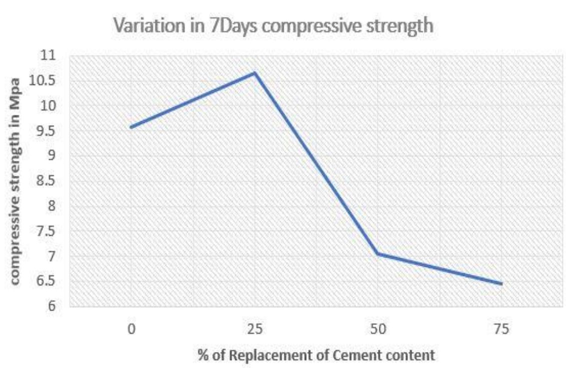

Fig. 7. Graphical representation of variation in 7days Compressive strength

The variation of compressive strength at a period of 14 days are as represented in the tabulated form below.

Table 11
Variation in 14 days' compressive strength for 0% GGBS content

Trial No.	% mix	Failure load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
1	0%	299.25	13.3	13.00
2		303.75	13.5	
3		274.5	12.2	

Table 12
Variation in 14 days' compressive strength for 25% GGBS content

Trial No.	% mix	Failure load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
1	25%	314.32	13.97	13.76
2		320.17	14.23	
3		294.30	13.08	

Table 13
Variation in 14 days' compressive strength for 50% GGBS content

Trial No.	% mix	Failure load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
1	50%	248.17	11.03	10.75
2		227.02	10.09	
3		250.87	11.15	

Table 14
Variation in 14 days' compressive strength for 75% GGBS content

Trial No.	% mix	Failure load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
1	75%	249.75	11.10	10.64
2		236.92	10.53	
3		231.07	10.27	

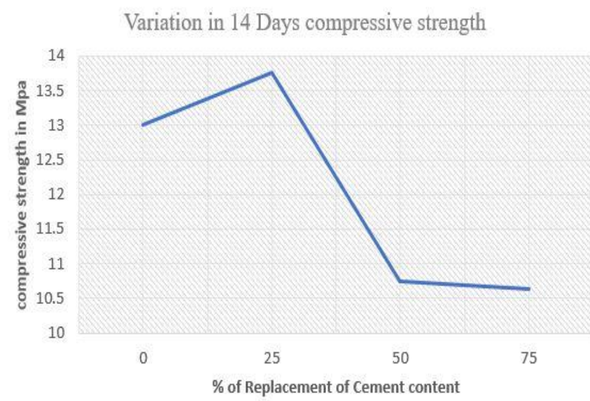

Fig. 8. Graphical representation of variation in 14days Compressive strength

The variation of compressive strength at a period of 28 days are as represented in the tabulated form below.

Table 15
Variation in 28 days' compressive strength for 0% GGBS content

Trial No.	% mix	Failure load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
1	0%	331.21	14.72	14.57
2		318.12	14.13	
3		334.13	14.85	

Table 16
Variation in 28 days' compressive strength for 25% GGBS content

Trial No.	% mix	Failure load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
1	25%	337.05	14.98	15.27
2		337.72	15.01	
3		355.95	15.82	

Table 17
Variation in 28 days' compressive strength for 50% GGBS content

Trial No.	% mix	Failure load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
1	50%	278.77	12.39	12.87
2		296.32	13.17	
3		293.62	13.05	

Table 18
Variation in 28 days' compressive strength for 75% GGBS content

Trial No.	% mix	Failure load in KN	Compressive strength in N/mm^2	Average Compressive strength in N/mm^2
1	75%	280.80	12.48	12.08
2		255.82	11.37	
3		279.22	12.41	

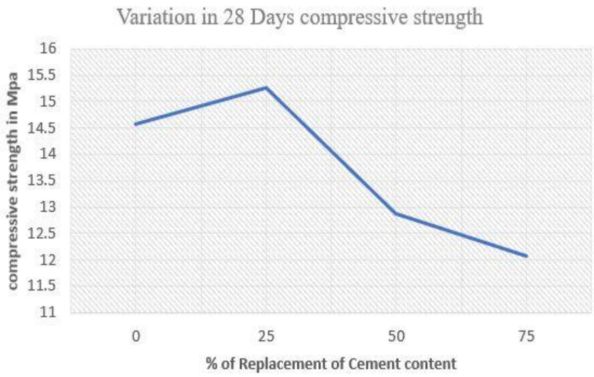

Fig. 9. Graphical representation of variation in 28 days' Compressive strength

C. *Split Tensile Strength Test*

This test was carried on the cylinder specimens of 150mm dia & 300mm height after a curing period of 07, 14 & 28 days and the following observations were made.

The variation of tensile strength at a period of 7 days are as represented in the tabulated form below.

Table 19
Variation in 7 days' tensile strength for 0% replacement

Trial No.	% mix	Failure load in KN	Tensile strength in N/mm^2	Average Tensile strength in N/mm^2
1	0%	209.1	2.95	2.30
2		132.6	1.875	
3		149.0	2.10	

Table 20
Variation in 7 days' tensile strength for 25% replacement

Trial No.	% mix	Failure load in KN	Tensile strength in N/mm^2	Average Tensile strength in N/mm^2
1	25%	165.2	2.33	2.36
2		162.7	2.30	
3		174.1	2.46	

Table 21
Variation in 7 days' tensile strength for 50% replacement

Trial No.	% mix	Failure load in KN	Tensile strength in N/mm^2	Average Tensile strength in N/mm^2
1	50%	85.20	1.20	1.18
2		80.72	1.14	
3		85.71	1.21	

Table 22
Variation in 7 days' tensile strength for 75% replacement

Trial No.	% mix	Failure load in KN	Tensile strength in N/mm^2	Average Tensile strength in N/mm^2
1	75%	35.6	0.50	0.479
2		40.6	0.57	
3		25.9	0.367	

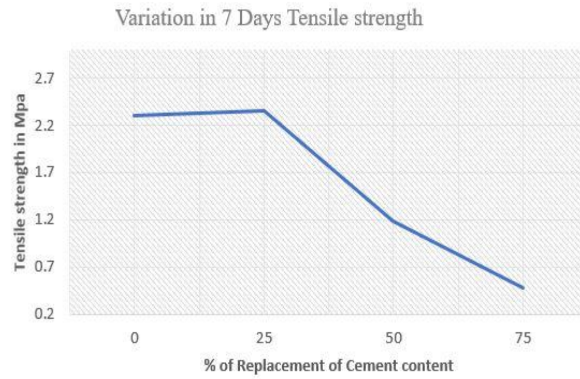

Fig. 10. Graphical representation of variation in 7 days' tensile strength

The variation of tensile strength at a period of 14 days are as represented in the tabulated form below.

Table 23
Variation in 14 days' tensile strength for 0% replacement

Trial No.	% mix	Failure load in KN	Tensile strength in N/mm^2	Average Tensile strength in N/mm^2
1	0%	177.4	2.5	2.14
2		119.8	1.69	
3		158.0	2.23	

Table 24
Variation in 14 days' tensile strength for 25% replacement

Trial No.	% mix	Failure load in KN	Tensile strength in N/mm^2	Average Tensile strength in N/mm^2
1	25%	181.2	2.56	2.90
2		218.5	3.09	
3		219.8	3.10	

Table 25
Variation in 14 days' tensile strength for 50% replacement

Trial No.	% mix	Failure load in KN	Tensile strength in N/mm^2	Average Tensile strength in N/mm^2
1	50%	112.3	1.58	1.41
2		91.9	1.30	
3		95.9	1.35	

Table 26
Variation in 14 days' tensile strength for 75% replacement

Trial No.	% mix	Failure load in KN	Tensile strength in N/mm^2	Average Tensile strength in N/mm^2
1	75%	52.0	0.73	0.76
2		55.9	0.79	
3		54.2	0.76	

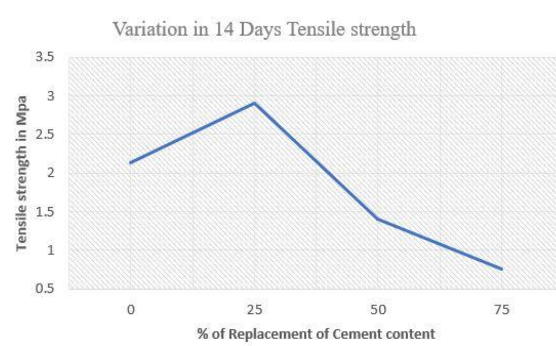

Fig. 11. Graphical representation of variation in 14 days' tensile strength

The variation of tensile strength at a period of 28 days are as represented in the tabulated form below.

Table 27
Variation in 28 days' tensile strength for 0% replacement

Trial No.	% mix	Failure load in KN	Tensile strength in N/mm^2	Average Tensile strength in N/mm^2
1	0%	176.8	2.50	2.61
2		179.4	2.53	
3		199.0	2.81	

Table 28
Variation in 28 days' tensile strength for 25% replacement

Trial No.	% mix	Failure load in KN	Tensile strength in N/mm^2	Average Tensile strength in N/mm^2
1	25%	190.0	2.68	2.94
2		214.4	3.03	
3		220.5	3.11	

Table 29
Variation in 28 days' tensile strength for 50% replacement

Trial No.	% mix	Failure load in KN	Tensile strength in N/mm^2	Average Tensile strength in N/mm^2
1	50%	120	1.69	1.60
2		96.6	1.36	
3		125.2	1.77	

Table 30
Variation in 28 days' tensile strength for 75% replacement

Trial No.	% mix	Failure load in KN	Tensile strength in N/mm^2	Average Tensile strength in N/mm^2
1	75%	79.5	1.12	1.08
2		64.4	0.91	
3		86.3	1.22	

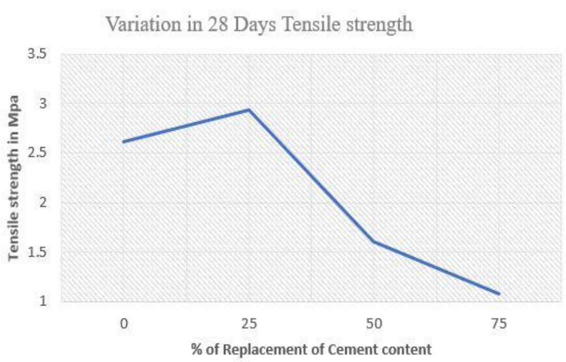

Fig. 12. Graphical representation of variation in 28 days' tensile strength

5. Conclusion

From the experimental investigation, partial replacement of about 25% (12.5% of both Alccofine and Fly Ash) was concluded as an optimum dosage. High levels of cement content which tends to increase the heat of hydration. Alccofine helps to high flowable concrete without bleeding and segregation. Alccofine also enables the dual action Hydraulic as well as pozzolanic. Alccofine facilitates the High strength high performance concrete for durable structures. It was found that the addition of Alccofine show early strength gaining prop term strength. It is recommended to utilize the Alccofine material with cement after checking its durability studies. In this study the effects of Alccofine as a supplementary cementing material and filling material on the strength of concrete was investigated. The addition of Alccofine increases the self-compatibility characteristics like filling ability, passing ability and resistance to segregation. It increases the durability and resistance to chemical attack and also reduces the heat of hydration. The relative cost of Alccofine is cheaper then cement hence it is economic with higher strength. By use of super plasticizer reduces the water demand and increase the workability of concrete.

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