Study on mechanical behavior of Concrete Incorporating Alccofine

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***Abstract*— Making concrete industry sustainable in the present scenario is very important, to reduce its adverse effects on environment. While choosing raw materials for construction it is necessary to go with eco-friendly materials. Alccofine is one such material which is a by-product from steel industry possessing cementitious properties that can be used as replacement of cement in concrete. Concrete mixes of M20 grade with replacement of cement by 0%, 5%, 10%, 15% and 20% of Alccofine were prepared. This concrete's mechanical properties were studied for compressive strength, flexural strength and split tensile strength. It is observed that the strength values are improved by incorporation of alccofine because it accelerates the hydration of cement particles. In the present paper, the results of the study exploring these strength characteristics of Alccofine replacing cement for the curing duration of 28 days. The microstructural analysis was also conducted using a scanning electron microscope (SEM). From the results it was concluded that the addition of Alccofine displays a better strengthening property.**

Keywords*— *Alccofine, SCM, concrete strength

I. INTRODUCTION

Cementitious mediums for concrete that contain aggregates are brittle and allow cementitious materials to adapt. Concrete has been used in the construction industries at an increasing rate, as concrete technology developed. Concrete is primarily composed of cement. Water, cement, coarse and fine aggregates, and admixtures are used in the manufacture of concrete. Concrete is extremely important because cement bonds together with other materials. Alumina, Silica, and Iron Oxide are major raw materials in cement manufacturing. The four major coordinating compounds are formed when these oxides combine at high temperatures in the kiln.

Alccofine is a new generation ultrafine product with low calcium silicate concentration that is readily available in India. It possesses properties that help concrete operate better in both the fresh and hardened states. Alccofine has better qualities than other Indian admixtures. Alccofine is utilized in concrete mixtures with high workability, strength, and modulus of elasticity, as well as high density, dimension stability, low permeability, and chemical resistance. The Alccofine 1203 from Gujarat's Ambuja cement was employed in the experiment.

Researchers Narender and Meena recently concluded that using fly ash and alccofine instead of cement led to concrete that was more eco-friendly than conventional concrete. Compared to the control mix, Saurav and Gupta were able to increase the compressive strength by 46.5% by replacing 10% of cement with alccofine. A mixture of 16% fly ash and 8% alccofine resulted in the greatest compressive strength and flexural strength, according to Deval Soni et al. The addition of alccofine to binder materials resulted in higher particle packing, and high strengths formed early in life, according to Suthar et al. By using fly ash in geopolymer concrete, Jindal et al. developed composite concrete with higher strength than specimens with 0% or 5% fly ash replacement. The compressive strength of pond fly ash based geopolymer mortar in different curing conditions was increased when treated with alccofine, according to Saxena et al. Concrete that contains alccofine showed enhanced microstructural characteristics and improved mechanical properties. As reported by Sagar and Sivakumar, alccofine based HSC behaved under uniaxial stress strains, and a mix with 10% alccofine provided the highest Young's modulus and largest energy absorption capacities than other mixes. To confirm whether it is feasible to develop a more environment-friendly concrete by partially replacing cement with alccofine, this study will conduct an experimental investigation. These results will be applicable for large-scale projects. In this case, alccofine additions will be evaluated on concrete mixes for its effect on mechanical properties. It was found that alccofine was able to significantly influence the studied parameters.

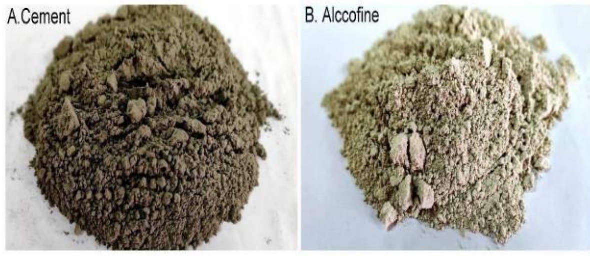

Fig. 1. Cement And Alccofine

II. EXPERIMENTAL WORK

A. Materials

1) Cement

The cement used is standard Portland cement of Grade 53 as shown in figure 1, procured from a single source and meeting IS 12269-2013 standards. As shown in Table 1, cement has the following properties.

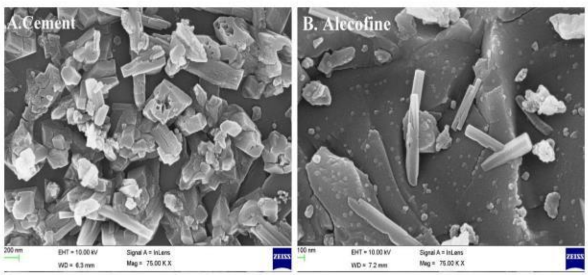

Fig. 2. Sem Images of Cement and Alccofine

2) Alccofine

Alccofine as shown in figure 1, is an ultra-fine slag produced by Ambuja Cement Pvt. Table 1 shows the properties of Alccofine. Figure 2 indicates that the particles are irregularly shaped and have sharp edges. Alccofine was used in this study with a specific gravity of 2.7. The particle sizes ranged from 1 to 75 µm with a major fraction between 20 and 50 µm. In figure 2, you can see images of alccofine scanned using a scanning electron microscope. Table 2 and Figure 3 show the elemental compositions of cement and Alccofine using EDAX.

TABLE I. PROPERTIES OF OPC AND ALCCOFINE

Property	OPC	Alccofine
Bulk density (kg/cum)	1435	660
Surface area (m2/kg)	350	1200
Specific gravity	3.18	2.70
Particle shape	Spherical	Irregular
Color	Grey	Pale white

Based on SEM images of 53 grade OPC cement and Alccofine, it appears that the cement particles are irregular with sharp edges. The figure shows an EDAX image of cement. As a major phase's compound, it has alite, calcite, and larnite.

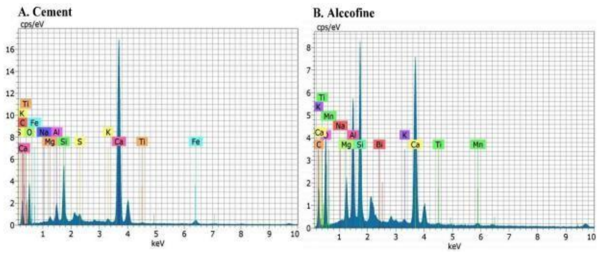

Fig. 3. FIGURE 3 ELEMENTAL COMPOSITION GRAPH OF CEMENT AND ALCCOFINE SAMPLE BY EDAX

TABLE II. ELEMENTAL COMPOSITIONS OF CEMENT AND ALCCOFINE BY EDAX

Elements and compounds	Compound formula	Cement (%)	Alccofine (%)	Composition of cement as per IS 12269-2013 (%)
Calcium	CaO	65.82	39.17	60-67
Silicon	SiO2	14.64	29.22	17-25
Iron	FeO	3.62	-	0.5-6
Aluminium	Al2O3	4.78	20.19	3-8
Sulphur	SO3	2.32	-	1-3
Magnesium	MgO	1.14	6.62	0.1-4
Potassium	K2O	0.4	0.25	0.1-1
Sodium	Na2O	0.22	0.06	0.1-1
Titanium	TiO2	0.07	0.24	-

3) Fine aggregates

In this research, river sand is used, and its physical properties are tested according to IS 383: 2016. Table 3 shows the physical properties of fine aggregates.

4) Coarse aggregate

The gravel of size not larger than 20mm is collected from local supplier which meets the specifications of IS 383: 2016, which describes the physical properties of the material, is used for testing. Given in Table 3, coarse aggregate exhibits the following physical properties.

TABLE III. PROPERTIES OF FINE AGGREGATE AND COARSE AGGREGATE

Property	Fine aggregate	Coarse aggregate
Zone	II	-
Specific gravity	2.65	2.75
Bulk density	1652	Kg/m^3
Fineness modulus	2.77	6.25
Shape	-	Crushed angular
Size	4.75mm	20mm

5) Water

Casting and curing are accomplished with laboratory water from the university, which is added in accordance with the mix design.

6) Superplasticizer

The superplasticizer used in this study is Fosroc Conplast SP430 DIS. Based on the mix, the amount of superplasticizer is adjusted and the final dose is determined by slump testing.

B. CHEMICAL ANALYSIS OF MATERIALS

Using a field emission scanning electron microscope to study material microstructure and surface morphology is very popular in concrete related studies. For examining the chemical composition of concrete and its oxide composition, energy dispersive x-ray analysis (EDAX) is conducted. Using cement and Alccofine as examples, this section discusses the chemical composition of these materials. A FESEM image of cement and alccofine is shown in figure 2.

It can be seen in Figure 2 that the microstructure of the cement sample is spherical. The cement particles also display homogeneous size distributions. The high reactivity of Alccofine is due to its low calcium, silicate content and controlled granulation. Compared to cement, fly ash, and silica, alccofine has a much finer particle size. The amorphous nature of Alccofine is shown in figure 2. Adding Alccofine to concrete increases the cementitious gel, which helps to reduce the permeability of the paste and to improve its durability thanks to its ultra-fineness and calcium oxide content.

III. METHODOLOGY

Figure 4 depicts the overall research methodology used in this study. Concrete mix designs for M20 grade concrete are based on the Indian standard IS: 10262-2019. M20 specimens without Alccofine are used as control mixes1. In this case, water-cement ratio was set at 0.40 and superplasticizer dosage was set at 1% by weight of binding material (Alccofine and cement).

Table 4 outlines the proportions of concrete mix at each level of replacement of 1m3 of concrete. Alccofine is substituted for cement in the following ways (5, 10, 15%, and 20%) in the casting of test specimens. As per Indian standards concrete specimens were prepared in three shapes: cube, cylinder, and beam. Compressive strength is determined by cubes of 100mmx100mmx100 mm size as shown in figure 4.

Fig. 4. COMPRESSION TESTING MACHINE (CTM)

The split tensile strength of cylinder specimens with a diameter of 150mm and a height of 300 mm is also measured as shown in figure 5. For testing the flexural strength of beams, 100mmx100mmx500mm size specimens are used. Lab tests were conducted on all cast specimens after 28 days of curing as shown in figure 6.

Fig. 5. SPLIT TENSILE TESTING

Fig. 6. FLEXURAL STRENGTH TESTING

IV. PARAMETERS STUDIED

Using the Indian standard IS 10262-2019 as a guide, Table 4 under-represents the mix calculations in detail. All the test specimens were evaluated for their flexural, compressive, and split tensile strength after 28 days of curing in this study. In this study, the samples were also analyzed microscopically after they were cured for 28 days.

TABLE 4 MIX PROPORTIONS Kg/m^3 OF ALCCOFINE CONCRETE

Alccofine replacement	**0%**	**5%**	**10%**	**15%**	**20%**
Cement	345	344	326	308	290
Alccofine	0	18	36	54	72
Water	148	152	152	152	152
F.A.	750	652	652	652	652
C.A.	1170	1322	1322	1322	1322
SP	3.45	3.63	3.63	3.63	3.63

V. ANALYSIS AND DISCUSSION

Alccofine was attempted to be used in concrete of grade M20 in this experiment. Concrete was formulated using various proportions of Alccofine (0%, 5%, 10%, 15% and 20%) in order to reduce cement consumption. For experiments to be reported using various tests, it is necessary to detail various properties and visualize them graphically. Therefore, the next section includes details about numerous properties illustrated with graphs of different shades, in order to symbolize comparative standings.

Table 5 represents the results of testing the compressive strength of concrete as per Indian standards IS 516-1959 at 28 days of curing. Concrete specimens were tested for mechanical properties at 28 days after curing, as shown in Table 5. Comparing the specimens with Alccofine up to 15% to the control specimens, the specimens with Alccofine up to 15% achieve the maximum compressive strength. For M20 grade concrete mix 4 with 15% Alccofine replacement exhibited a maximum compressive strength of 30.10mpa 28 days. The compressive strength gain of Mix 4 compared to conventional Mix 1 is 7%.

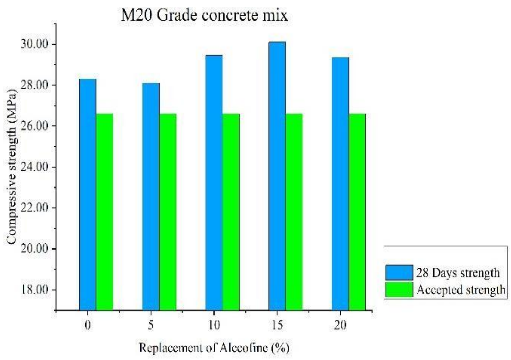

Fig. 7. COMPRESSIVE STRENGTH

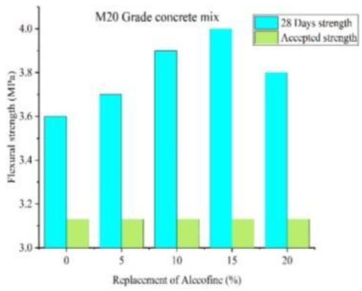

Fig. 8. FLEXURAL TENSILE STRENGTH

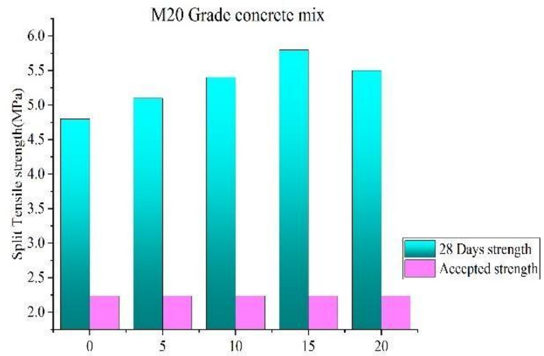

Fig. 9. SPLIT TENSILE STRENGTH

- Increasing split tensile strength occurs at each replacement level. At 28 days after curing, the maximum strength of 15% Alccofine is observed. Alccofine was substituted for up to 15% of the cement in the control mix to achieve the maximum split tensile strength.

- As Alccofine percentage increases, the split tensile strength is shown to decrease suddenly beyond 15 % replacement. Based on this test, a concrete containing 15 % Alccofine showed extremely promising results as compared to concrete with a lower dosage. For 15% replacement of Alccofine in the concrete, the splitting tensile strength of M20 grade concrete is increased from 4.80 N/mm^2 to 5.8 N/mm^2 for 28 days of curing time. Depending on the Alccofine replacement level, the flexural tensile strength of the M20 grade ranged from 3.60 N/mm^2 to 4.0 N/mm^2.

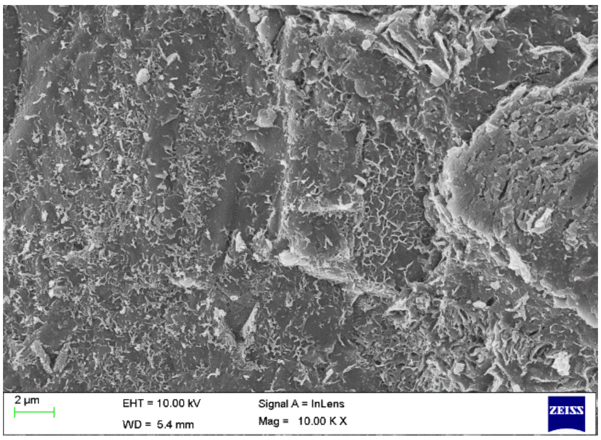

Fig. 10. FIGURE 10 MICROSCOPIC IMAGES OF M20 GRADE CONCRETE AT 15% OPTIMUM DOSAGE OF ALCCOFINE

SCANNING ELECTRON MICROSCOPY

The morphology of M20 grade of concrete shows homogeneous and denser microstructure. As the concrete mix contains ordinary Portland cement (OPC) and Alccofine (ultra-fine slag) as binder which are rich in calcium and silica, there was formation of calcium hydroxide ($Ca(OH)_2$) and calcium silicate hydrate (C-S-H) gels in the microstructure. M20 grade of concrete exhibited slightly denser microstructure which may be due to formation of higher amount of calcium silicate hydrate gels. The calcium hydroxide which represented as hexagonal plate like structure was identified in all concrete mixes, however, it formed in higher amount in the M20 grade of concrete. Further, the formation C-S-H gel was identified as reticular network in the morphology of concrete as shown in the above figure.

VI. CONCLUSIONS

- In terms of hydration process and strength gain, 15% Alccofine Replacement is optimum. Conversely, partial replacements of 10% Alccofine and 20% Alccofine might have behaved as fillers in the concrete's bonding phase.

- With respect to SEM images, it can be understood that in M20 grade concrete, the active reaction of alccofine can be observed. This means that alccofine shows good reaction in concrete when replaced for 15%.

- A marginal improvement can be seen in both flexural and split tensile strength results also, this specifies that there are no negative advantages of using alccofine in concrete.

- Also, from the chemical composition table it is observed that there is silica and alumina difference compared to cement. Silica and alumina are contributing for strength improvement in M20 grade of concrete.

- The formation of CSH gel and CASH gel is improved due to the presence of excessive alumina from alccofine. This means silica and alumina are acting as secondary reactive components which are gaining extra strength to concrete. Also there is a possibility that only alccofine is standing responsible for addition of strength. Calcium has instantaneous reaction for strength, but more calcium is already available in cement, so it only forms a gel, but expecting strength improvement in long term is being possible in the form of secondary reactions.

- Thus, the secondary reaction is not happening just due to cement, but also with the help of a third-party materials that are coming from alccofine i.e., silica and alumina which are excessive in quantity which is deficient in cement. This is the most obvious reason the extra strength gain when alccofine is added to the concrete.

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