ISSN: 0974-5823 Vol. 6 No. 3 December, 2021

International Journal of Mechanical Engineering

Microstructure Analysis of M30 Grade Alccofine Concrete

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Abstract

There are extensive researches being done on the use of waste products from industrial, agricultural, and thermoelectric plants in the production of concrete. The toxicity of these materials makes them a problem for landfilling. Alccofine is one of those new-generation Supplementary Cementitious Materials (SCMs) that are ultrafine and much finer than other materials such as cement, fly ash, rice husk ash, etc. Concrete's mechanical and durability properties are improved by alccofine because it accelerates hydration of cement particles. In the present paper, the results of a study exploring these strength characteristics about Alccofine replacing cement at 5%, 10%, 15%, and 20% are performed for M30 grade concrete. Tests of compressive strength were performed on specimens at 28 days. The microstructural analysis was also conducted using a scanning electron microscope (SEM). The added Alccofine displays strength obtaining properties.

1. 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. Concrete is manufactured using cement, coarse and fine aggregates, admixtures, and water. Cement is an extremely important constituent of concrete as it binds together 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. When designed properly, reinforced concrete is significantly more resistant to Cyclones, Earthquakes, Blasts and Fires than Timber and Steel.

Advancement in research and development has made significant changes from the 19th century to the present era. These changes in the design mix methodologies with part replacement of cementitious and other types of aggregates in the aggregate phases in the concrete.

These changes have been very significant for achieving the sustainable development growth initiative to reduce Global warming. This global warming is mainly affecting the CO_2 Gases produced by this industry. In the case of the cement industry for manufacturing 1 ton of cement from clinkering phase, approximately released 1 ton of CO_2. Hence even we consume a fraction percentage of cement, that much of CO_2 is lessened. Man annihilates no material except water in such tremendous additions. Concrete continues to be one of the most ambitious construction materials as we move forward with Human Civilization. The modern concrete industry has been increasingly contributing to numerous environmental issues, including pollution, hazardous waste disposal, smog, and recycling. For concrete to be considered quality, it must possess a wide range of mechanical properties as well as a high resistance to deterioration. It can be said that hardened concrete consists of three distinct phases: the hardened cement paste (HCP) or matrix, the aggregate, and the interfacial zone (TZ) between the HCP and the aggregate. All three phases should be considered explicitly for optimal performance. Concrete volume is composed of about 30% to 40% HCP and 60% to 70% aggregate.

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 characteristics of Alccofine are listed in the table below. 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. By replacing 10% of cement with alccofine, Saurav and Gupta were able to increase the compressive strength by 46.5% compared to the control mix. In their study, Deval Soni et al. found that the most compressive strength and flexural strength were achieved with a mix of 16% fly ash and 8% alccofine. The addition of alccofine to binder materials resulted in higher particle packing, and high strengths formed early in life, according to Suthar et al. The composite concrete developed by Jindal et al. has a high strength from fly ash based geopolymer concrete and has higher compressive strength than specimens with 0% or 5% fly ash replacement. According to Saxena et al. pond fly ash based geopolymer mortar in different curing conditions showed increased compressive strength when treated with alccofine. 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.

Figure 1 Cement and Alccofine

2. Experimental Work

2.1. Materials

2.2. 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.

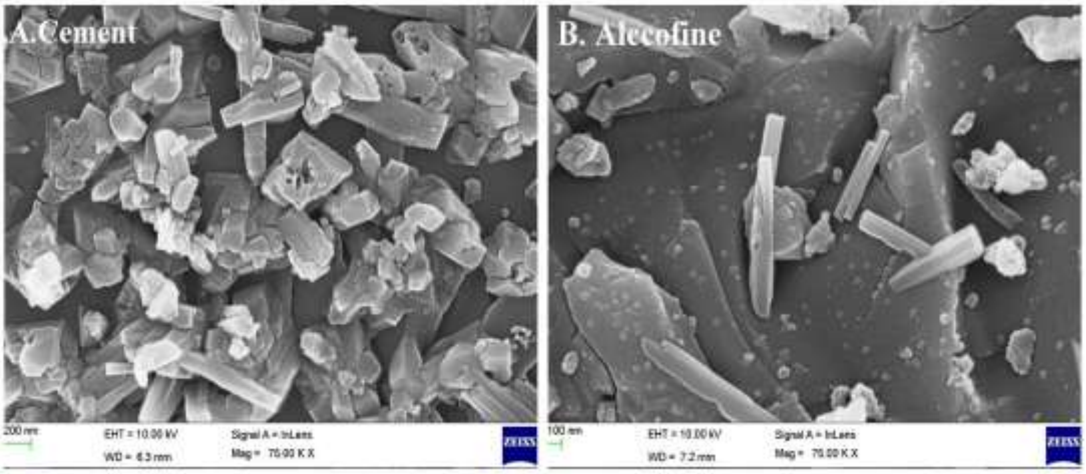


Figure 2 SEM images of cement and Alccofine

2.3. 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. This study used alccofine with a specific gravity of 2.7. The size of the alccofine particles ranges from 1 to 75 µm with a major fraction in the range of 20-50 µm. SEM images of alccofine are shown in figure 2. The elemental compositions of cement and Alccofine by EDAX are shown in Table 2 and figure 3.

Figure 2 shows the SEM images of 53 grade OPC cement and Alccofine revealed that the particles of cement were irregular with sharp edges. EDAX image of cement is shown in Fig. 3, and it has Alite, Calcite, and Larnites as major phase's compounds.

Table 1 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
Colour	Grey	Pale white

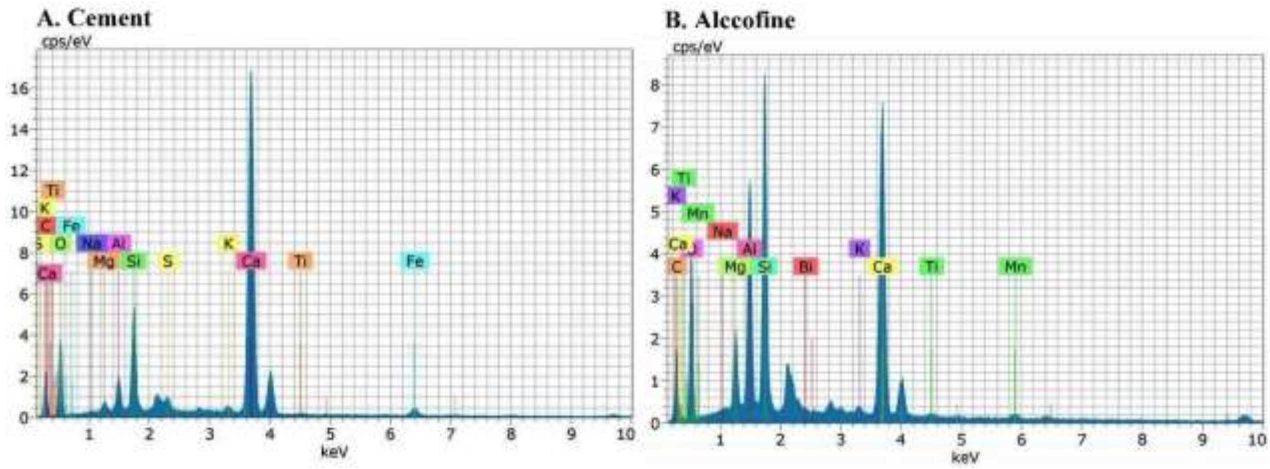


Figure 3 Elemental composition graph of cement and Alccofine sample by EDAX

Table 2 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	-

2.3.1. 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.

2.3.2. 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 3 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

2.3.3. Water

Laboratory water from the university is used for casting and curing, and it is added according to the concrete mix as per mix design.

2.3.4. 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.

3. Chemical analysis of materials

Using a field emission scanning electron microscope (FESEM) 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.

4. Methodology

Figure 4 depicts the overall research methodology used in this study. Concrete mix designs for M30 grade concrete are based on the Indian standard IS: 10262-2019. M30 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).

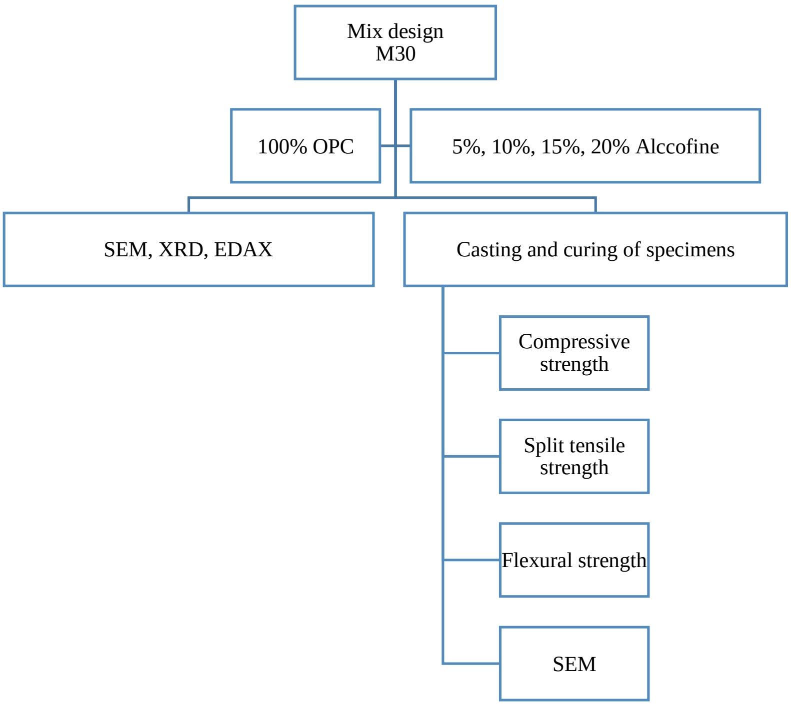


Figure 4 Methodology followed

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 5.

Figure 5 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 6.

Figure 6 Split tensile strength testing

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 7.

Figure 5 Split tensile strength testing

4.1. 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 per m^3 of concrete

Grade of Concrete	Alccofine percentage	Mix designation	Cement (kg)	Alccofine (kg)	Water (liters)	Fine aggregate (Kg)	Coarse Aggregate (Kg)
M30	0%	M 1	356	-	1.50	646	1301
	5%	Mix 2	353	19			
	10%	Mix 3	334	37			
	15%	Mix 4	316	55			
	20%	Mix 5	290	72			

5. Analysis and discussion

Alccofine was attempted to be used in concrete of grade M30 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 Test results of mechanical properties of concrete specimens

Grade of Concrete	Alccofine Percentage	Mix Designation	Compressive strength (N/mm2)	Split Tensile strength (N/mm2)	Flexural strength (N/mm2)
			28 Days	28 days	28 days
M30	0%	Mix 1	39.25	5.10	3.80
	5%	Mix 2	40.90	5.50	3.90
	10%	Mix 3	44.35	5.90	4.10
	15%	Mix 4	45.40	6.20	4.20
	20%	Mix 5	44.60	5.80	3.90

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 M30 grade concrete mix 4 with 15% Alccofine replacement exhibited a maximum compressive strength of 45.40mpa 28 days. The compressive strength gain of mix4 compared to conventional mix1 is 15.67%.

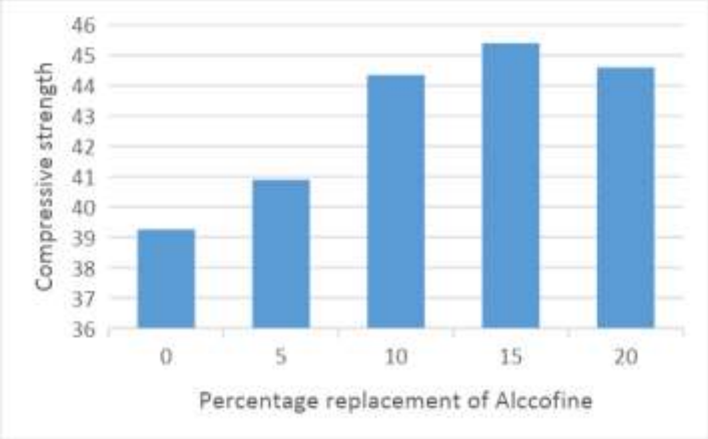


Figure 8 Compressive strength test results of concrete at 28 days curing period

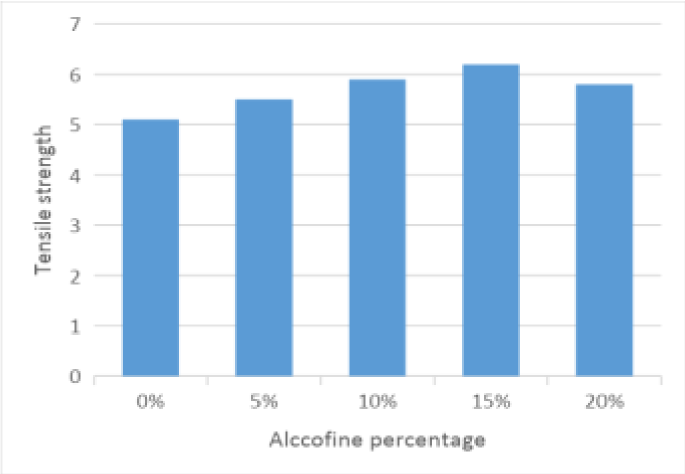


Figure 9 Split tensile strength test results of concrete at 28 days curing period

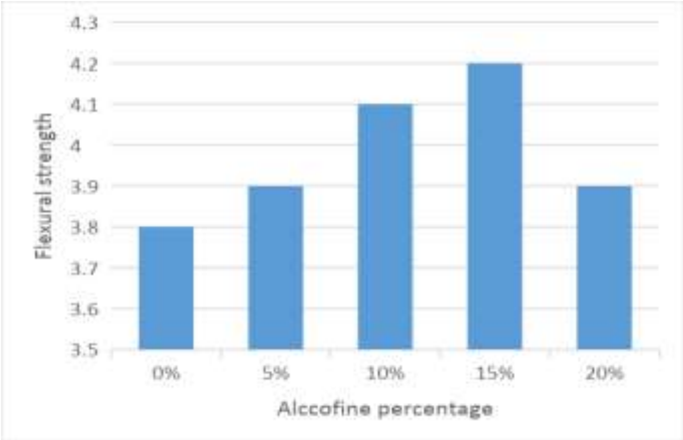
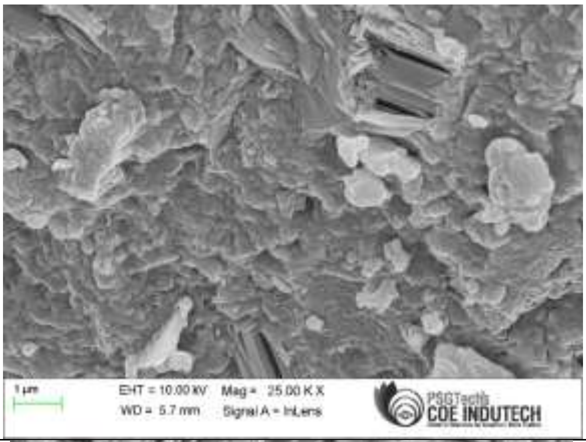
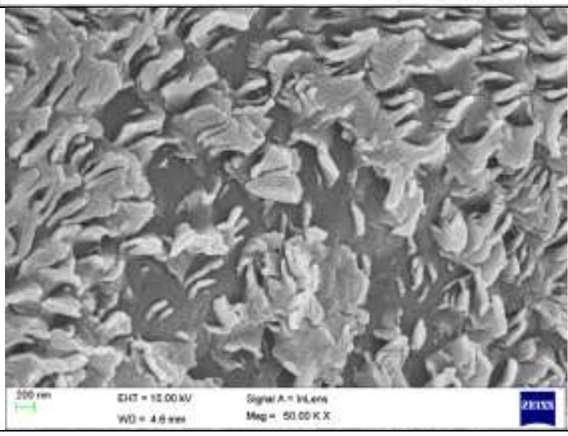
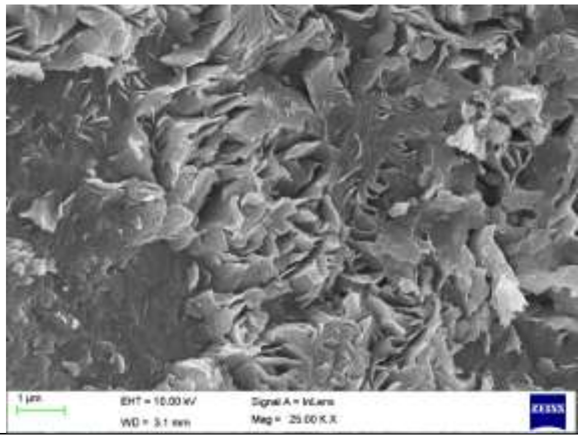


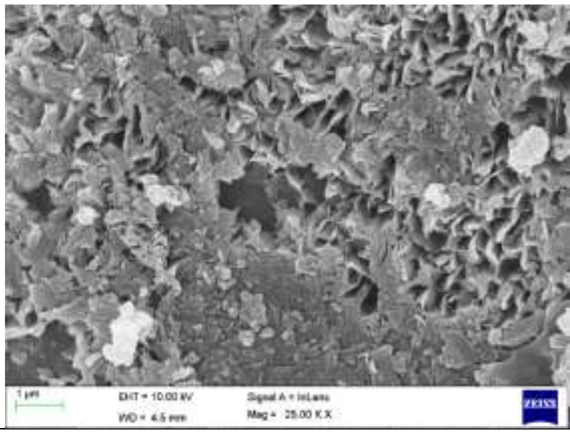
Figure 10 Flexural strength test results of concrete at 28 days curing period

- At each replacement level, the split tensile strength increases. Maximum strength is observed for 15% Alccofine at 28 days of curing. In comparison to the control mix, Alccofine up to 15% as partial replacement of cement achieved 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. The split tensile strength of M30 grade is increased from 5.10 N/mm2 to 6.20 N/mm2 for 15% Alccofine replacement. The 28 days flexural tensile strength of M30 grade varied from 3.80 N/mm2, to 4.20 N/mm2 up to 15% Alccofine replacement.

Table 5 Microstructural SEM images of concrete

Binder composition	**SEM Images**
100 % Cement – Nominal Mix	
90 % cement + 10% Alccofine	
85% cement + 15% Alccofine	

80 % cement + 20% Alccofine	

6. FESEM

The morphology of M30 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. M30 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 M30 grade of concrete. Further, the formation C-S-H gel was identified as reticular network in the morphology of concrete as shown in table no 6.

7. Conclusions

- 15% replacement of Alccofine has shown the higher strengths values
- This 15% replacement was found to be optimum dosage of Alccofine Replacement for the hydration process and Strength gain satisfying the codal provisions. However, the partial replacements 10% and 20 % acts as filler material in the bonding phase in the concrete.
- With respect to SEM images, it can be observed that in M30 grade concrete active reaction of alccofine is observed this means that alccofine shows good reaction in concrete when replaced for 15%. From this it is clearly understood that the percentage contribution of alccofine is improving with the increase in grade of concrete.
- A marginal improvement can be seen in both flexural and split tensile strength results also, this indicates 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 higher 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, it is clear that 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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References

[1] D. Singhal, B.B. Jindal, S.K. Sharma, Parveen, D.K. Ashish, (2017) Improving compressive strength of low calcium fly ash geopolymer concrete with alccofine, Advances in Concrete Construction: 17-29

[2] Kala TF, Vaidevi C, Kalaiyarrasi (2020) Mechanical and durability properties of self-compacting concrete with marble fine aggregate. Materials Today Proceedings.

[3] Naqash JA, Reddy PN (2019) Properties of concrete modified with ultra-fine slag. Karbala International Journal of Modern Science. Vol 5.

[4] Naqash JA, Reddy N (2019) Effect of alccofine on mechanical and durability index properties of green concrete. IJE Transactions 813–819

[5] Ahmed JN, PN Reddy (2019) Development of high early strength in concrete incorporating alccofine and non-chloride accelerator. SN Applied Sciences: 755

[6] Naqash JA, Reddy NP (2019) Durability and mechanical properties of concrete modified with ultra-fine slag. International Journal of Innovative Technology and Exploring Engineering: 230–234

[7] Naqash JA, Reddy PN (2019) Strength prediction of high early strength concrete by artificial intelligence. International Journal of Engineering and Advanced Technology: 330–334

[8] Sashidhar C, Jawahar JG, Kavyateja BV (2019) Investigation on ternary blended self-compacting concrete using fly ash and alccofine. International Journal of Recent Technology and Engineering: 447–451

[9] Kaur D, Siddique R (2012) Properties of concrete containing ground granulated blast furnace slag (GGBFS) at elevated temperatures. Journal of Advanced Research: 45–51.

[10] Shah BK, Suthar Sunil B (2013) Study on strength

development of high strength concrete containing alccofine and Flyash. Indian Journal of Research: 102–104

[11] Patel PJ, Shah BK, Suthar S (2013) Study on the effect of alccofine and fly ash addition on the mechanical properties of high-performance concrete. International Journal for Scientific Research & Development: 464–467

[12] Ramesh Kumar, R. Venkatasubramani, P. Muthupriya (2013) the experimental investigation on durability characteristics of high-performance concrete, International journal of scientific and technical research. 239-250

[13] Kulkarni S, Soni D, Parekh V (2013) Experimental study on high-performance concrete, with the mixing of alccofine and Flyash. Indian Journal of Research: 84–86

[14] Saurav AK (2014) Experimental study of strength relationship of concrete cube and concrete cylinder using ultrafine slag alccofine. International Journal of Scientific & Engineering Research, 102-107

[15] Patil PN, Patil YO, Dwivedi (2013) GGBS as partial replacement of OPC in cement concrete—an experimental study. International Journal of Scientific Research: 189–191

[16] Saoji AC, Pawar MS (2013) Effect of alccofine on self-compacting concrete. The International Journal of Engineering and Science: 05–09

[17] Venkateswararao K, Swaroop AHL, Kodandaramarao P (2013) Durability studies on concrete with fly ash and Ggbs. Int J Eng Res Appl 3(4):285–289.

[18] K. Gayathri, K. Ravichandran, and J. Saravanan, “Durability and Cementing Efficiency of Alccofine in Concretes”, International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 5 Issue 05, May-2016, Page 460-467.

[19] LJ Sanjeev Kumar, P Bhuvaneshwari, Moka Eswar and K Aditya Subramanian “Strength Characteristics Of Alccofine Based Light Weight Concrete” International Journal of Advanced Research in Engineering and Technology (IJARET) Volume 10, Issue 1, January- February 2019, pp. 268-275

[20] Author Narender Reddy and T. Meena "An Experimental Study to Find the Optimum Dosage of Admixtures in Blended Concrete" International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-7, Issue-6, March 2019

[21] Keyur S Jasani, S. Manivel, and G. Senthil Kumar “An Experimental Investigation on Strength Properties Of Alccofine 1203 Along With Recycled Aggregate In Concrete” International Journal of Civil Engineering and Technology (IJCIET) Volume 9, Issue 4, April 2018, pp. 138–148

[22] Mohammed Asad Agha, Peta Purnachandra Sai, R Vinay, A Anil Goud “Development Of Early Compressive Strength In High-Performance Concrete Using Perlite And Alccofine” International Journal of Civil Engineering and Technology (IJCIET) Volume 9, Issue 4, April 2018, pp. 382–388.

[23] B.Kaviya, K.Rohith, Soniya Kindo, Manoj Kumar J, Divya P “Experimental Study On Partial Replacement Of Cement Using Alccofine” International Journal of Pure and Applied Mathematics Volume 116 No. 13 2017, 399-405

[24] Nista lama Ghising and Vijay Kumar “Experimental Investigation On Properties Of Concrete With Alccofine1203 As Partial Replacement Of Cement Subjected To Different Curing Regimes” International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) Vol. 10, Issue 3, Jun 2020, 4249–4256.

[25] Rajesh Kumar, AK Samanta and DK Singha Roy, “An experimental study on the mechanical properties of Alccofine based high-grade concrete”, International Journal of Multidisciplinary Research and Development, Vol. 2 Issue 10 2015, Page 218-224.

[26] P. Narasimha Reddy and J. Ahmed Naqash “Effect of Alccofine on Mechanical and Durability Index Properties of Green Concrete”, IJE TRANSACTIONS C: Aspects Vol. 32, No. 6, (June 2019) 813-819

[27] Mahim Mathur, Ashish Mathur “Performance of Concrete by Partial Replacement of Alccofine -1203” International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 RTCEC - 2018 Conference Proceedings.

[28] Ankit Nainwal, Akshay C, Jaibeer Bhandari, “Comparison between Simple Concrete Cubes and Alccofine Mixed Concrete Cubes (M20 Grade)”, IJSRE Volume 05 Issue 2017, Page 6857-6871.

[29] Saurav and Ashok Kumar Gupta. 2014 “Experimental study of strength relationship of concrete cube and concrete cylinder using ultrafine slag Alccofine” Int. J. Sci. Eng. Res. 5(5) 102-7.

[30] R Suganya and Latha Maheshwari, “Experimental Investigation on Alccofine Concrete” Vol. 8 Issue 04, April-2019, International Journal of Engineering Research & Technology (IJERT), 2019.

[31] IS 383. Specification for Coarse and Fine aggregates from Natural Sources of Concrete. Bureau of Indian Standards. New Delhi, India; 1970.

[32] IS 456. Code of practice for Plain and Reinforced Concrete (Fourth Revision). Bureau of Indian Standards. New Delhi, India; 2000. 34. IS 2386. Methods of Tests for Aggregates for concrete. Bureau of Indian Standards. New Delhi, India; 1963.

[33] IS 10262. Concrete Mix Proportioning – Guidelines. Bureau of Indian Standards. New Delhi, India; 2019.

[34] Bhanavath Sagar, Sivakumar M.V.N 2020 “Mechanical and Microstructure Characterization of Alccofine Based High Strength Concrete”, Silicon: springer nature 2021

[35] Balamuralikrishnan R, Saravanan J, “Effect of Alccofine and GGBS Addition on the Durability of Concrete”, Civil Engineering Journal Vol. 5, No. 6, 1273-1288.

[36] Sachin Tiwari, Preeti Gangwar, “Evaluate the effect of acid attack on rubberized concrete using crumb tyre rubber and replacement of cement by alccofine”, 2020, Materials Today: Proceedings.

[37] Sanjeev Kumar, Bhuvaneshvari, Moka Eswar, KS Aditya, "Strength Characteristics of Alccofine Based Light Weight Concrete” 2019, International Journal of Advanced Research in Engineering and Technology, 268-27