International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-5, June 2019

Influence on Strength and Durability Analysis of Concrete Incorporating Ultra Fine Slag

T. Jaya Krishna, S. Venkatesh, K. Murali

Abstract: ***There have been enormous researches going on the use and utilization of industrial, agricultural and thermoelectric plant residues in the production of concrete. Production of high-performance concrete (HPC) plays an important role with different pozzolanic materials like fly ash, condensed silica fume, blast furnace slag, rise husk ash etc. There has been increase in the consumption of mineral admixture by cement and concrete industries. This rate is expected to increase day by day. The presence of mineral admixture in concrete is known to impart significant improvement in workability and durability in concrete. The present study involves the use of mineral admixture „ultrafine slag" as a cementitous material for cement and to evaluate the threshold limit of replacement of cement. Main aim of this work is to evaluate the flexural strength of High strength concrete by partial replacement of cement (0, 8, 10, 12, and 14%) with ultra-fine slag (Alccofine 1203) for M60 grade of concrete. OPC of 43grade from single source is used in this investigation. The addition of alccofine shows an early strength gaining properties with increase flexural strength of concrete. In the last millennium concrete had demanding requirements both in technical performance wise and economy wise and yet greatly varied in application from architectural masterpieces to the simplest of utilities. This study presents the results of an experimental investigation carried out to evaluate the flexural strength of concrete incorporated with ultrafine slag (alccofine) by studying the effects of different proportions of ultrafine slag in the mix and to find optimum dose of alccofine content in the mix. The concrete specimens were cured on normal moist curing under elevated atmospheric temperature for better heat of hydration. Main aim was confined to find the change of flexural strength of reinforced concrete beams. The flexural strength was determined at 7 ,14 and 28 days and comparisons were made for both plain concrete and reinforced cement concrete (R.C.C). Further experimental investigations were carried out to find the effect of steel fibers embedded in concrete along with ultra fine slag. Different durability analysis of concrete incorporating ultrafine slag was also carried out. The addition of alccofine shows an early strength gaining property. The combination of ordinary Portland cement (OPC) with alccofine was found to increase the compressive strength of concrete on all ages when compared to concrete made with ordinary Portland cement alone and has showed excellent durability characteristic with hydrochloric acid. Alccofine matches the dimensional realms of silica fume as it is finer than GGBS. Silica fume is hard to get hold of as it is imported from outside of India. Based upon the results of this research alccofine - 1203 can be proposed as the substitute for silica fume in partial replacement of concrete. Manufacturing of high-performance concrete (HPC), which is majorly used as building material in the major and huge infrastructure projects, is a daunting task. Though the recent advancements have conquered the hurdles of the preparation of high-performance concrete, the use of green materials such as Fly Ash and Rice Husk Ash is limited. Apart from the green materials, many conventional and mineral admixtures or micro materials are available in the market, which enhances the quality and performance of concrete such as Metakaoline, Alccofine and Silica Fume etc. The quality of concrete mix is assessed through various mechanical properties like compressive strength, flexural strength and split tensile strength and various durability tests like rapid chloride penetration test (RCPT), sorptivity test, chloride resistance test, accelerated corrosion test and sea water attack test are carried out to analyse the performance of HPC. The objective of this study is to evaluate the structural strength of high-performance concrete by utilizing green and pozzolanic material as supplementary cementitious material.***

Index Terms: ***High performance concrete, alccofine, steel fibers, flexural strength***

Manuscript published on 30 June 2019.

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I. INTRODUCTION

Concrete is a hard material that has cementitious medium within which aggregates are embedded [3,4,135,136,137]. With the development of concrete technology, the use of concrete in the construction industries have gained pace. Cement is one of the major constituents of a concrete. Materials other than cement used in the manufacture of concrete are coarse and fine aggregates, admixtures and water. The raw materials used for the manufacture of cement consist mainly of lime, silica, alumina and iron oxide [84,136,137,138]. These oxides interact with one another in the kiln at high temperature to form four major complex compounds [137]. Concrete is strong and tough material. Reinforced concrete resists cyclones, earthquakes, blast and fires much better than timber and steel if designed properly [137]. The developments related to the concrete is used extensively in the production of buildings, bridges, harbours, runways, roads, etc. Concrete is an extraordinary and key structural material in the human history. As written by Brunauer and Copeland (1964), Man consumes no material except water in such tremendous quantities. It is no doubt that with the development of human civilization, concrete will continue to be a dominant construction material in the future. However, the development of modern concrete industries also introduce many environmental problems such as pollution, waste dumping, emission of dangerous gases, depletion of natural resources etc. Compressive strength is an important parameter which determines the characteristic of a concrete [4,136,137]. For the construction of high rise buildings and long span bridges the use of high strength concrete (compressive strength 60-100 MPa) were commercially started in the late 70's.

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This made the concrete technologist to develop high performance concrete (HPC) which not only give high strength but also perform satisfactorily during its service period. The standard code of practice for plain and reinforced concrete IS: 456-2000 [146] has classified concrete on the basis of strength.

II. MATERIALS

1. Cement

Ordinary Portland cement of 43 grade having specific gravity of 3.15 and fineness less than 5 % is used. The Cement used has been tested for various proportions as per IS 8112:1989 grade ordinary Portland cement – specification

2. Coarse Aggregate

Locally available crushed angular aggregate of 20 mm size having specific gravity - 2.88 is used. The aggregate is tested as per IS 383-2016

3. Fine Aggregate

River sand of specific gravity 2.64 from locally available source is used. The aggregate is tested as per IS 383-2016

4. Alccofine

Alccofine is used to replace cement (18% by weight) having specific gravity - 2.9.

5. Silica Fume

Silica Fume having specific gravity of 2.0 is used to replace cement by 10%. Silica fume is tested as per IS 15388-2003.

6. Silica Fume

Silica Fume having specific gravity of 2.0 is used to replace cement by 10%. Silica fume is tested as per IS 15388-2003.

7. Steel Fiber

The addition of fibers is to improve the shear strength and to increase the crack resistance of the ternary blend concrete. Steel fiber of 0.5 mm diameter, aspect ratio of 43.75 and length of 50mm is used.

Figure 1 Steel Fibers

III. LITERATURE

A brief review of literature about the influence of mineral admixtures (fly ash, GGBS and silica fume), chemical admixtures on the fresh concrete, and their effect on strength and durability behaviour of concrete is reported and discussed in this chapter. Literature regarding mix proportioning of HPC is also discussed. This chapter discusses the past research conducted by various researchers to study the applications & different methodology used in understanding of tests and findings due to the above said along with behavior of Alccofine 1203 as an admixture to concrete. This chapter gives a comprehensive review of the findings along with directions for future explorations.

IV. EXPERIMENTAL STUDY

To study the mechanical behavior of Fiber reinforced Concrete teste specimen were tested for

i. Compressive strength,
ii. Split Tensile strength,
iii. Flexure strength.

Cubical specimens with varying percentages of alccofine are designated by C0, C08, C10, C12, C14, C16 and C18. C0 denotes concrete cubes with 0% alccofine and C18 denotes concrete cubes with 18% replacement of cement with alccofine.

Figure 2 Test setup for Compression, Tensile and Flexure Strengths

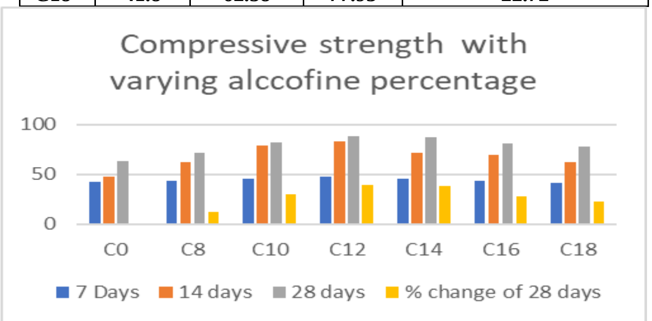
V. RESULTS & DISCUSSION

5.1 Compressive strength:

Compressive strength is increasing when 8% to 12% by weight replacement of alccofine 1203 for cement was done increase in compressive strength was observed. When 14% replacement of cement was done strength started decreasing. Compressive strength of ultrafine slag concrete at 28 days when compared to control mix was found to increase by 11% to 39 % on increasing the alccofine content from 8% to 12%. Decrease in compressive strength was observed when replacement of cement was increased from 12% to 18%.

Table no: 1 Compressive strength of concrete mixes, incorporating varying percentages of alccofine:

Mix	Compressive strength Mpa			%Change of 28days strength
	7 Days	14Days	28Days	
C0	42.1	48	63.5	0
C8	43.32	62.6	71.2	12.12
C10	45.32	79.44	82.40	29.76
C12	47.32	83.13	88.60	39.52
C14	45.12	71.33	87.83	38.31
C16	43.27	69.32	81.07	27.66
C18	41.8	62.58	77.93	22.72



Graph no:1 Compressive strength with varying % alccofine

5.2 Flexural Strength:

Flexural strength is one of the important parameter of testing the strength of concrete. For the determination of flexural strength beams of standard

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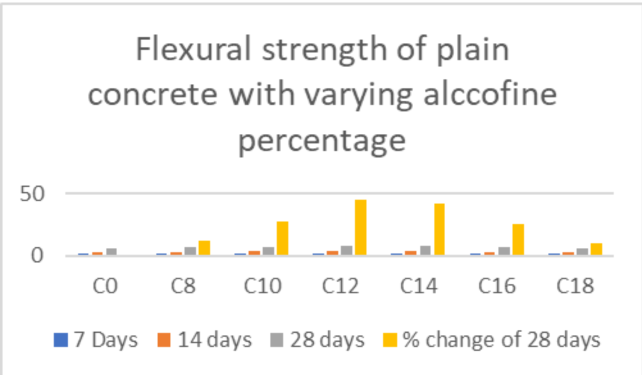
size 500mm×100mm×100mm as per IS 516:1959 [143] was adopted. Whole experiments were dived into two parts i.e. plain cement concrete beams and reinforced cement concrete beams. Total 45 nos of beams were casted for each grade and each type i.e plain cement concrete beams and reinforced cement concrete beam to be tested at different ages of curing. Reinforcement used was 2 bars of 8 mm dia as main reinforcement and vertical stirrups using 6mm dia @150mm c/c was used as shown in the fig 4.3 (a). Different nomenclatures used for plane concrete beams and reinforced concrete beams are tabulated in Table 4.3. Beams were cured for 7, 14 & 28 days time age. The beams were placed normal to the casting and symmetrical two point system was adopted for the flexural tensile strength test as per IS 516:1959 [143]. The deflection of the beams were measured by the dial gauge of least count of 0.01mm, which was placed in the middle third portion of the beam.

Table No: 2 Flexural strength of plain concrete beams with varying % of alccofine at different ages of curing:

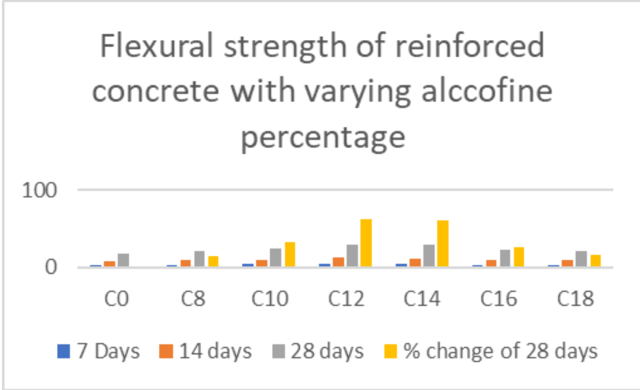
Mix	Flexural strength in Mpa			%Change of 28days strength
	7 Days	14Days	28Days	
C0	1.27	2.69	5.59	0
C8	1.34	2.93	6.26	11.98
C10	1.45	3.25	7.14	27.27
C12	1.58	3.58	8.14	45.62
C14	1.55	3.51	7.92	41.68
C16	1.25	3.11	7.01	25.40
C18	1.11	2.85	6.15	10.11



Graph no:2 flexural strength of plain concrete with varying % alccofine

Table No: 3 Flexural strength of reinforced concrete beams with varying % of alccofine at different ages of curing:

Mix	Flexural strength in Mpa			%Change of 28days strength
	7 Days	14Days	28Days	
C0	3.02	8.34	18.05	0
C8	3.21	8.99	20.49	13.51
C10	3.55	10.10	23.95	32.68
C12	4.06	11.84	29.34	62.54
C14	3.99	11.68	28.98	60.55
C16	3.43	9.67	22.67	25.59
C18	3.17	8.96	20.87	15.62



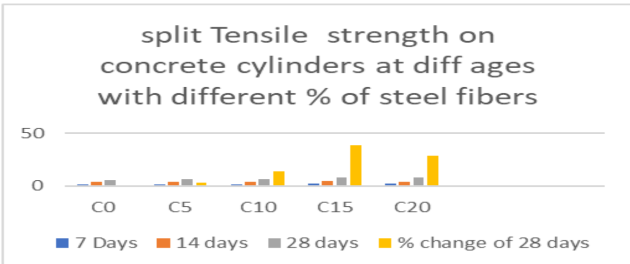
Graph no:3 flexural strength of reinforced concrete with varying % alccofine

5.3 Split Tensile test for SFRC:

When compared with controlled concrete, split tensile strength is maximum at 1.5% steel fibers with 12% alccofine common to all mixes. Different values of tensile tests performed on different cylindrical concrete with varying percentages of steel fibers are tabulated in Table For each combination of steel fibers, three cylinders were casted and tested at 7, 14 and 28 days of curing and average strength was determined. One such arrangement of split tensile test is shown in Fig. It is seen that the split tensile strength with 12% alccofine and varying % of steel fibers initially there is very less gain of strength but after 28 days there is significant gain of tensile strength. From Fig 4.7 it can be observed that tensile strength of concrete cylinders in SC15 has shown 38% of increase in tensile strength when compared with controlled concrete SC0.

Table No:4 Split tensile test on concrete cylinders at different ages with different % of steel fibers:

Mix	Tensile strength in Mpa			%Change of 28days strength
	7 Days	14Days	28Days	
C0	1.2	3.5	5.9	0
C5	1.2	3.6	6.1	3.4
C10	1.3	3.9	6.7	13.6
C15	2.4	4.4	8.2	38.9
C20	2.2	3.8	7.6	28.8



Graph no:4 split tensile strength on concrete diff ages with diff % of steel fibers

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VI. CONCLUSION

1. Compressive strength of concrete increases after adding alccofine. Optimum dose of alccofine that can be replaced is 12%. As compared with controlled concrete there is 39.5% increase in compressive strength.
2. Flexural strength of plain concrete beams at 12% replacement of cement with alccofine shows 45% increase in flexural strength when compared with controlled concrete.Flexural strength of reinforced concrete beams at 12% replacement of cement with alccofine shows 62% increase in flexural strength when compared with controlled concrete. From Table 2.11 it can be concluded that to achieve same amount of deflection higher amount of load is required in case of concrete incorporated with alccofine.
3. From durability analysis test it can be concluded that the concrete incorporating ultra fine slag (alccofine) shows much improved resistant to acid attack. From Table 2.16 it can be observed that % reduction in compressive strength of concrete cubes incorporating alccofine cured in 5% HCl is much less than ordinary concrete cured under same conditions.
4. There is significant increase in split tensile strength of steel fiber reinforced concrete when compared with controlled concrete. There is increase in 38% of split tensile strength of concrete cylinders with 12% alccofine and 1.5% by volume of steel fibers. There is also significant increase in flexural strength of steel fiber reinforced concrete beams with same amount of alccofine and steel fibers.

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