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Investigation on Ternary Blended Self Compacting Concrete using fly ash and Alccofine

Bode Venkata Kavyateja, J. Guru Jawahar, C. Sashidhar

ABSTRACT--- Self compacting concrete is one of the new concepts, without using any external vibrations and labors can easily fill the formwork even in difficulty places without segregation. For such cases, SCC possesses good flowability and cohesiveness. In this study, two mineral admixtures were used to improve the required quality of concrete. The main aim of this study is to evaluate the workability and compressive strength property of SCC containing mineral admixtures such as fly ash and alccofine. In this study the replacement of cement with fly ash was kept at 30% for all concrete mixes with varying dosages of alccofine (0%, 5%, 10% & 15%). Different tests such as slump flow, V-funnel & L-box tests were conducted to check the workability of SCC. Compressive strength values of SCC mixes were determined at different curing periods. From the test results, it is observed that the optimum replacement of alccofine can be taken as 10%. The test results indicate that the combination of fly ash and alccofine in cement replacement produce M25 grade concrete.

Index Terms— Self Compacting Concrete, Fly Ash, Alccofine 1203, Super Plasticizer and Compressive Strength.

1. INTRODUCTION

Concrete used as a construction material throughtout the world. In the world, by the fast improvement of construction technology concrete properties have been changed. For the advance technology, concrete requires more durable and good quality throughout the construction [1]. Nowadays various concretes are available for the enhancement of properties of concrete.

Self-compacting concrete is one of the innovative concrete, was firstly developed by Okamura in Japan in late 1980s, to overcome the problems on congested reinforcement structures. It has more advantages compared to conventional concrete like it attains homogeneity without bleeding and segregation and it can easily pass through the congested reinforcing bars under its self-weight without considering any mechanical vibrations [2]. This type of SCC was fulfilled by considering the passing ability, filling ability and high segregation resistance of fresh state SCC. SCC was prepared as same as conventional concrete, used materials are cement, aggregate, and water. With the addition admixtures are used to enhance the properties of SCC, this is the main difference to made of SCC compared to conventional concrete [3]. SCC was prepared with reducing the volume of coarse aggregate so to minimize the risk of flow through the congested bars. Usage of chemical admixtures into the SCC, its cost is increased and also due to high amount of cement most heat of hydration is produced. For the overcome of these problems, mineral admixtures those are byproducts or waste products are used to improve the properties of SCC. Most of the studies shown that mineral admixtures used in concrete were cost effective and reduce the cement content with an improved workability. mineral admixtures used in concrete not only reduce the cost, heat of hydration is controlled due to this thermally induced cracking of concrete is to be reduced [4 & 5]. Previous studies proved that different mineral admixtures including fly ash, GGBS, rice husk ash, silica fume are effect as enhance the properties of both fresh and hardened concrete and reduce water content with good homogeneity.

Bletty Baby and Jerry Anto (2017) investigated on self-compacting concrete containing micro steel fibers and alccofine with partial replacement on cement. They studied on alccofine with 5%, 10% & 15% replacement of cement and they get 10% as the optimum for both fresh and hardened state. Further with 10% alccofine they include micro silica fibers with 0.5%, 1% & 1.5% replacement on cement, they conclude that SCCA-10, M1% gives good results than normal mix SCC [6]. Tushar Bansal, Shilpa pal & Jaya Maitra (2018) studied on the performance of partial varying the alccofine and Metakoaline percentages (3%, 6%, 9%, 12% &15%) on M60 grade of SCC with constant fly-ash. They conduct the tests on fresh property (slump flow, v funnel, l-box tests) of mix SCC with different retention times of 30, 60, 90 mins, mechanical properties like compressive test were conducted at 7 & 28 days. Their experiment results showed that with increasing percentage from 3% to 15% of Metakaoline, slump flow, blocking ratio decreases and flow time increases with different retention times as compared to normal AF1mix. It is not acceptable for SCC. And with increasing percentage (3% to 15%) of alccofine, slump flow, blocking ratio increases and flow time decreases with different retention times as compared to control mix, acceptable for workability improvement of SCC. The compressive strength was increased to 72.43 MPa to 80.2 MPa up to 12% replacement of alccofine and Metakoaline on SCC further it decreased [7]. M.S. Pawar and Saoji (2013) investigated on alccofine as partial replacement and fly ash keep constant into the cement.

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Bode Venkata Kavyateja, JNTUA college of Engineering, Kalikiri. Andhra Pradesh, India (Email: kavyateja2014@gmail.com)

Dr. J. Guru Jawahar, Annamacharya Institute of Technology and Sciences, Tirupati, Andhra Pradesh, India (Email: gurujawaharj@yahoo.co.in)

Dr. C. Sashidhar, Jawaharlal Nehru Technological University, Anantapur, Andhra Pradesh, India (Email: Sashigunt@gmail.com)

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They concluded that the physical characteristics of SCC, mechanical properties increased up to 10% alccofine replacement of cement compared alccofine 5% & 15% replacement. Manisha and Karjini investigated on alccofine as 5%, 7.5% & 10% by weight of the cement and fiber volume 1.5% fraction by concrete volume added to find the mechanical and fresh properties of concrete. Hybrid fibers enhance the flexural strength as partial replacement of cement in concrete and varying alccofine increases the compressive strength of the fiber reinforced concrete [8]. Sinha Deepa and Sabuwala have reported that pozzolanic materials of alccofine and fly ash act as a highly durable concrete specimen. They showed that alccofine gives the higher slump flow value in concrete but increasing of fly ash gives lesser slump value [9].

In the present study, the main objective is to replace the cement with constant fly ash and varying proportions of alccofine, investigate the properties of SCC both in fresh and hardened state.

2. MATERIALS

A. Materials

Cement was the one of the important material used as a construction material. Ordinary Portland cement of 53 grade was used in this study for the grade of concrete [10]. The physical and chemical properties of OPC 53 grade are shown in below Table 1.

Table 1 Physical Properties of cement

Characteristics	Test Results	Values as per BIS:12269 - 2013
Grade	53	53
Fineness modulus	6.5%	< 10%
Specific gravity	3.12	3.15
Standard consistency	32%	30% - 35%
Initial setting time	50 min	>30 min
Final setting time	450 min	< 600 min
Soundness	1.2 mm	< 10 mm

B. Fly ash

Fly ash is an industrial by-product obtained from the coal industry by electrostatic furnace, which a fuel ash is obtained from the pulverized coal. The size of the fly ash particle is 10-25µm. It helps to enhance the fluidity, workability of concrete and decrease the permeability of concrete; those are forming good quality of fly ash. The quality of class F fly ash is confirmed by IS 3812-2003. In this study used fly ash has specific gravity is 2.3.

Table 2 Fly ash Physical properties

Characteristics	Test Results
Fineness modulus	1.19%
Specific Gravity	2.3

C. Alccofine

Alccofine is a new product from Ambuja cement, based on the slag of high glass content with low calcium silicate. Alccofine 1203 is an ultrafine cementitious material; reduce water demand up to 70% replacement for a given workability of concrete structures. Alccofine 1203 was used as confirmed by ASTM C989-99. The physical properties of alccofine are shown in Table 3.

Table 3 Physical properties of alccofine

Characteristics	Test Results
Specific Gravity	2.9
Specific surface area (m^2/kg)	1200
Bulk density (kg/m^3)	680
Particle	
D_{10}	1.5 Micron
D_{50}	5 Micron
D_{90}	9 Micron

D. Fine aggregate

River sand confirming to zone II was used as fine aggregate. Specific gravity of fine aggregate was 2.682 [9]. The fine aggregate confirmed to IS 383-1970 was used.

Table 4 physical properties of fine aggregate

Characteristics	Test Results	Values as per BIS:12269 – 2013
Specific gravity	2.682	2.1-3.2
Fineness modulus	2.71%	2-4%
Water absorption	1.023%	< 5%

E. Coarse aggregate

Crushed stone used as coarse aggregate in this study, the size of the aggregate used as below 12mm, this range of aggregates reduce the inter blocking effect of SCC in congested areas; it can improve the flow ability without blocking of the particles [9]. The specific gravity of 2.781 was used as coarse aggregate in this study.

Table 4 physical properties of Coarse aggregate

Characteristics	Test Results	Values as per BIS:12269 – 2013
Specific gravity	2.781	2.1-3.2
Fineness modulus	7.22%	6.5-8%
Water absorption	0.83%	< 5%

F. Superplasticizer

Superplasticizer is a high range water reducing admixture used to reduce water content for required workability of SCC. In this study, conplast SP430 was used as a superplasticizer.

Table 5 Physical properties of Superplasticizer

Characteristics	Test Results
Appearance	Brown liquid
Specific gravity	1.20
Chloride content	Nil
Water absorption	24%

G. Water

Potable water was used for concrete mixing

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3. FABRICATION OF SELF COMPACTING CONCRETE MIXES

In the present study, Self Compacting Concrete was prepared with constant fly ash and partial replacement of alccofine. Firstly, the finer materials including cement, sand, fly ash and alccofine were added into the pan mixer stirred well without any lumps. Coarser materials are added to the fine particles mixer and blended well mechanically. Afterwards premixed liquid including water with super plasticizer was added to the dry mixture of the pan. Finally, freshly mixed SCC was prepared. For obtaining good workability of SCC it must satisfy the fresh properties of filling ability, passing ability and high segregation resistance at acceptable limits. Filling ability is the ability to flow under its self-weight into all spaces within the formwork. Passing ability of SCC is the ability to pass through congested openings such as gap between steel and reinforcing bars under its self-weight. Segregation resistance is the ability to maintain uniform paste throughout the process of transporting and placing, without separation and migration. The fabrication of concrete mixes is shown in Table 6.

Table 6 Fabrication of SCC mixes

Mixes	Cement	Fly ash	Alccofine
SCCF-A0	70%	30%	0%
SCCF-A5	65%	30%	5%
SCCF-A10	60%	30%	10%
SCCF-A15	55%	30%	15%

4. FRESH PROPERTIES

For finding fresh properties of SCC, different tests are conducted on fresh SCC including T_{50} slump test. V funnel, L box tests. These tests are helpful to evaluate the workability and consistency of SCC.

A. Slump flow & T_{50} test

This test is used to determine the filling ability characteristic of SCC. Present days slump flow test is one of the most commonly used SCC tests. Firstly, fresh concrete is poured into the frustum cone. When cone lifted upwards it spread evenly and reaches up to 50cm diameter within limiting time. The main difference of the slump flow test to the conventional slump as per ASTM C 143 is the slump flow measures the spread and flow property of concrete.

B. L-Box Test

This test is used to determine the passing ability of SCC. In this test, the concrete is poured into the L-box of vertical part. When the control gates are lifted, the fresh concrete flows through the horizontal part of L-box and then determine the blocking ratio of h_2/h_1. If concrete flows freely into the horizontal part within limiting value it gives good workability of SCC.

C. V-Funnel

This test is used to assess the filling ability and viscosity of SCC. The fresh concrete poured into the V funnel apparatus with maximum aggregate size of 20mm. the funnel is filled with approximately 12 liters of concrete and the time it takes through the apparatus is measured, record as the V funnel flow time. The above fresh of acceptance range are detailing in the Table 7.

Table 7 SCC-Workability requirements as per EFNARC

Test method	Properties	Limiting Value
Slump Flow	Filling ability	650-800 mm
T50	Filling ability	2-5 Sec
L-Box	Passing ability	0.8-1.0
V-Funnel	Viscosity	6-12 Sec

5. MECHANICAL PROPERTIES

Mechanical properties of SCC are determined by conducting compressive strength test, split tensile test and flexural tests on hardened concrete of SCC. In this study, the concrete was prepared with constant fly ash and partially replacement of alccofine with the cement.

A. Compressive strength

Compressive strength was measured on the standard cube specimens of 150x150x150mm after 7, 14 & 28 days of curing using compression testing machine capacity of 2000 kN as confirming to IS 516-1959. For 7, 14 and 28 Days average number of specimens were cast and tested to calculate the compressive strength [10].

Compressive strength is to be calculated by using the formulae is

$$F_{ck} = P/A$$

Where P= Ultimate load in Compression in KN
A= Area of cross section in mm^2

6. RESULTS AND DISCUSSION

A. Fresh properties

The European Federation of specialist's chemicals and concrete systems guidelines specify the basic properties of self-compacting concrete. Self-compacting concrete must have the key characteristics such as passing ability, filling ability and segregation resistance at required level. Different Tests are conducted on self-compacting concrete to determine workability.

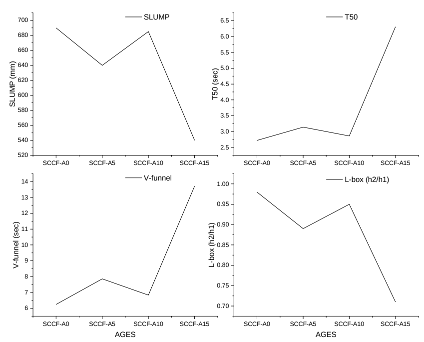

Figure 1 Fresh properties of SCC

The obtained test results are shown above Figure 1. From results it clearly seen that up to SCCF-A10 concrete mix slump flow value, flow time in V-funnel, T50 value and blocking ratio values all are in acceptable range are shown in Figure1. Further increasing the percentage of alccofine V-funnel flow time & T50 value increased and blocking ratio, slump flow diameter value decreased. This demonstrates that alccofine effectively improving fresh properties due to its ultra-fine nature [11&12] up to 10% level further adding its properties are not in acceptable range.

B. Compressive strength

In this research, ternary blended materials (cement is replaced by constant high volume of 30% fly ash and partial replacement 5%,10% &15% of alccofine) were taken to evaluate the cube compressive strength at 7, 14 & 28 curing days are shown in Table 8. The compressive strength of concrete at 7 days of SCCF-A0 concrete mix was 28.36Mpa. For SCCF-A5 & SCCF-A10 mixes compressive strength were 27.32Mpa & 20.95 Mpa respectively, compared to SCCF-A0 mix at 5% & 10% of alccofine achieved the strength were 96.33% & 73.87% respectively. At 14 days curing, the compressive strength of the concrete mix (i.e SCCF-A0) was 32.29Mpa. The concrete mixes SCCF-A5, SCCF-A10 were achieved by 98.79% & 87.64% compared to SCCF-A0 mix. At later (28 age) curing days the compressive strength of SCCF-A0 concrete mix was 35.14 MPa. The SCCF-A5& SCCF-A10 concrete mixes were achieved by 94.90% & 92.48% respectively compared to SCCF-A0 mix. Further addition of percentage of alccofine shows the decreased the compressive strength at all ages as shown in Figure 2. Therefore, the addition of alccofine up to 10% gave the satisfactory results in this study.

Table 8 Compressive strength results of SCC mixes

Mixes	7 days	14 days	28 days
SCCF-A0	28.36	32.29	35.14
SCCF-A5	27.32	31.9	33.35
SCCF-A10	20.95	28.3	32.5
SCCF-A15	15.7	20.82	23.9

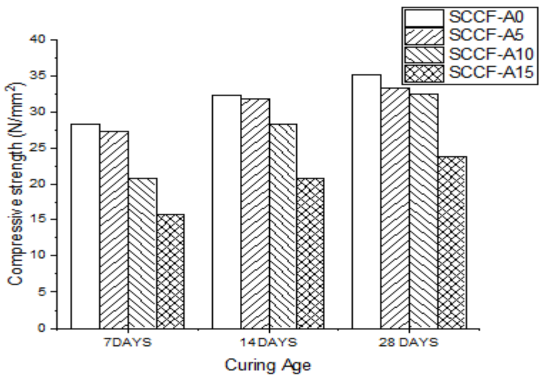

Figure 2 Compressive strength of SCC mixes

Further addition of alccofine the compressive strength was decreased, the reason was that the quantity of alccofine particles is higher than that of liberated lime quantity in the hydration process resulting that decrease in pore bonding strength. Thus, at this stage Alccofine acts as cement replacement materials used for filling the pores but does not involve in the hydration process [13].

7. RESPONSE SURFACE METHOD

Response surface method is a statistical method for improving, developing and initializing products. It is usually used in cases where multiple factors influence the more than one response [14]. RSM is used to optimize the desired set of requirements or responses. In this study, RSM was implemented to develop a regression equation to predict concrete strength. This is used to obtain optimum values of the considered variables [15]. In RSM, the percentage of alccofine added to the mix, age of the specimen and compressive strength of the concrete are regarded as variables. By using Minitab program design of experiments was performed with 95% confidence level [18]. In this study, RSM is used to draw the relation between age of the specimen (Y) and percentage variation of alccofine (X) and compressive strength (Z) with regression equation [16].

$$Z = A+BX+CY+DX^2+EXY+FY^2 \quad (1)$$

Where Regression Coefficients A=20.71,B=-1.6, C=1.227, D=-604, E=0.869 and F= -0.02583

Error obtained from RSM is shown in Table 8 from the table clearly observed that the error rate is less than 5 percent, it has concluded that the curve obtained is within a range of 95% confidence level [17].

Fig 3 shows the regression model using RSM. It expresses the relation of compressive strength Vs age of the specimen Vs percentage variation of alccofine. From Table 8 and Figure 3 the regression model obtained in Equation 1 is fitting well. Figure 4 shows the Actual compressive strength values in MPa and Predicted Values in MPa

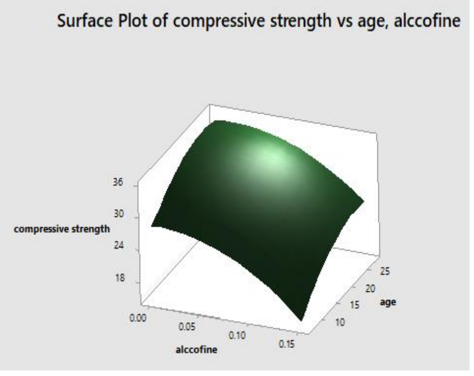

Figure 3 Surface plot for CS Vs Age & Alccofine

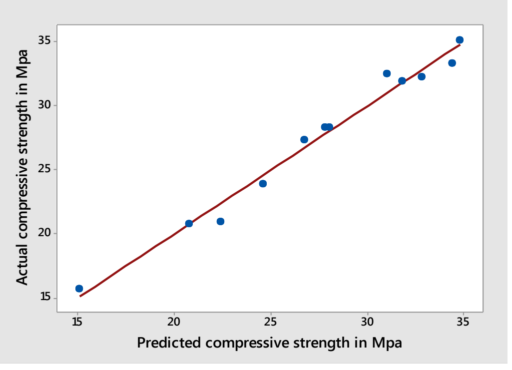

Figure 4 Actual values of CS Vs Predicted values of CS.

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Table 9 Experimental and Predicted values by regression equation

Alccofine (X)	Age (Y)	Actual Z (MPa)	Predicted Z (MPa)	Residual (MPa)
0.00	7	28.36	28.0278	0.33217
0.05	7	27.32	26.7432	0.57683
0.10	7	20.95	22.4402	-1.49017
0.15	7	15.70	15.1188	0.58117
0.00	14	32.29	32.8168	-0.52683
0.05	14	31.90	31.8362	0.06383
0.10	14	28.30	27.8372	0.46283
0.15	14	20.82	20.8198	0.00017
0.00	28	35.14	34.7998	0.34017
0.05	28	33.35	34.4272	-1.07717
0.10	28	32.50	31.0362	1.46383
0.15	28	23.90	24.6268	0.72683

8. CONCLUSION

- The combination of fly ash and alccofine has improved the workability properties of SCC up to 40% replaceme nt of cement (30% fly ash + 10% alccofine).
- The dosage of 10% alccofine can be considered as opti m- um dosage.
- SCC mixes with 15% alccofine performed poorly both in fresh and compressive strength properties.
- The response surface method was used to validate the e xp-erimental data and the observed error was within ac ceptab-le range.

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