ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 7| Issue: 9| September 2021|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2021: 8.047 || ISI Value: 1.188

A STUDY ON THE PERFORMANCE OF SELF-COMPACTING CONCRETE WITH FLY ASH AND ALCCOFINE

Soma Prasanth Reddy[1*], C. Sashidhar[2], B.V. Kavyateja[3]
[1,2,3]*Department of Civil Engineering, Jawaharlal Nehru Technological University, Anantapur, India*

ABSTRACT

The presence of self-compacting concrete (SCC) mix offers many advantages to the structural elements that cast by this type of mix. This paper presents the results on an experimental program carried to explore the possibility of fly ash and alccofine as partial replacement of cement in self-compacting concrete. SCC mixes were designed and cement was replaced with fly ash (i.e. 30%) and alccofine (5, 10 and 15%). Tests were performed to evaluate the compressive strength, split tensile strength and modulus of rupture of SCC. Results indicated that compressive strength, split tensile strength and flexural strength of self-compacting concrete improved with incorporation of 25% of fly ash and 10% of alccofine at all the curing ages.

KEYWORDS: ***Alccofine, Mechanical properties, Self-compacting concrete, Fly ash, Super plasticizers, Alternative materials***

1. INTRODUCTION

The self-compacting concrete (SCC) is classified as a new material in which the concrete gets compacted under its self-weight without main contributions from mechanical vibrator. The self-compacting concrete is very useful to fill the spaces in case of for heavy structural elements such as beams, slabs, columns, shear walls and foundations. Many advantages for self-compact concrete make the structural engineering to adapt such as reduction in time of constructions, no noise, improving the capacity of the structural elements by filling the spacing's and giving excellent structural behaviour. Super plasticizer can be used in concrete mix to avoid segregations and increase the concrete workability [1,2]

Now-a-days cement is being used on large scale in the production of concrete worldwide. Due to this the global demand of cement has reached about 5 billion metric tons. Due to which the large amount of raw material is consumed for the production of cement, which causing huge amount of CO_2 release into the atmosphere [3–7]. About 5% to 7% of manmade CO2 gas emission is released during the production of cement [8,9]. The lot of research is being done to find the supplementary cementitious material in order to safeguard the environment. Efforts are being made for usage of industrial by products as cementitious materials possessing pozzolanic properties [10–12]. The pozzolanic materials such as the Silica Fume (SF), Ground Granulated Blast Furnace Slag (GGBS), Rice Husk Ash (RHA), Fly Ash (FA) etc, which are byproduct from various industries are being used as replacing material for cement [13–16]. The utilization of pozzolanic materials diminishes the cement consumption and furthermore expands the strength and durability of concrete.

The development of SCC has significantly changed the way of concreting without compaction [17]. The development of SCC has led to better quality concrete and an efficient construction process even in the congested reinforced portion of the building. Fluidity and cohesiveness of the SCC mix can be achieved by using Superplasticizer (SP) and large quantity of fine powder materials [18]. Pozzolans are an optimal alternative powder material for cement as it provides adequate strength, enhanced durability, and reduction in cost, energy consumption and less greenhouse gas emission [19]. Kannan and Ganesan [20] studied the chloride and chemical resistance of SCC containing MK and rice husk. They found that higher silica content presents in MK improves pozzolanic reaction of concrete which improves the strength and durability of concrete. Al-Akhras [21] stated the inclusion of MK in concrete improves the resistance to sulphate attack. Kavitha et al. [22] studied the microstructure of MK blended SCC. They stated that incorporation of MK reduces the permeability and ingress of chloride ions into the concrete due to the refined pore structure concrete.

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 7| Issue: 9| September 2021|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2021: 8.047 || ISI Value: 1.188

Kavitha et al [23] investigated the effect of MK on the fresh, mechanical and durability properties of SCC mixes containing 0,5,10 and 15% of MK. They found that the SCC mix containing 10% MK exhibited good fresh and hardened properties. They also reported that the utilization of MK in concrete reduces energy consumption and carbon di-oxide emission.

SCC is a cement based matrix, under tensile stress or impact loading it may subject to brittle failure. But addition of fibers into the cement based SCC will reduce the brittleness of concrete and increases the tensile properties of SCC. Conventional reinforced concrete structures can significantly deteriorate with time, necessitating regular and often costly maintenance. The addition of small closely spaced and uniformly dispersed discontinuous discrete fibers to concrete would significantly improve its static and dynamic properties. Further to extend the possible fields of applications of SCC, fiber may be added to the concrete. The addition of fibers in concrete will resolve these deficiencies of concrete [24]. Aydin [25] investigated the effect of fiber inclusion on the SCC on the mechanical properties such as compressive, split and flexural strength of fiber reinforced SCC.

Rao et al. [26] studied the effect of Alkali-resistant (AR) glass fiber (0%, 0.03%, 0.06% and 0.1%) reinforcement on durability of concrete. They reported that maximum improvement in durability of concrete was achieved with different percentages of glass fibers at 0.1% for all the grades of concrete.

Mirza and Soroushian [27] studied the effect of AR glass fiber on crack and temperature resistance of light weight concrete; they found that inclusion GF reduces the crack width and negative effect caused due to temperature. They stated that GF improves the serviceability and durability characteristics of concrete.

Barluenga and Hernandez-Olivares [24] developed SCC with inclusion of AR glass fiber. They conducted compression, flexural strength tests, free shrinkage tests with and without air flow over the sample and double restrained slab cracking tests to assess the cracking control ability of AR glass fiber. They described that the inclusion of low amounts of fiber did not modify the flowability and mechanical properties of concrete. They concluded that less amount of glass fiber showed the maximum cracking control ability, but larger amounts did not increase the fiber efficiency.

Earlier practices were to partially replace the ordinary Portland cement with some suitable industrial and agro waste materials such as fly ash, rice husk ash, ground granulated blast furnace slag which are pozzolanic in nature. As their primary role, slags or Pozzolans are added to cement because they improve properties (durability and mechanical) of concrete as well as concrete structures.

The most significant impacts of pozzolans in the microstructure of concrete or cement paste are changing the interfacial transition zone (ITZ) and reduction of pore structure by pozzolanic reaction [15]. The application of newly developed supplementary cementitious materials or pozzolans has thus become a necessity to improve the strength as well as durability properties of concrete structures, particularly under aggressive environmental conditions.

Alccofine is a new generation, ultra-fine supplementary cementitious material (SCM) having ultrafine particle size with specially controlled granulation which has shown significantly better enhancement in the strength as well as durability properties even better than with other SCM's like cement, fly ash, rice husk ash etc., which are generally adopted by construction industry. Alccofine has surprising effects to improve the overall performance of concrete in fresh and hardened states. Alccofine is an ultrafine slag material and glass based SCM obtained from steel or iron industries. Alccofine is one amongst the mineral admixtures of very finely solid glass spheres of non-crystalline polymorph or amorphous of silicon-dioxide. The higher specific surface area of alccofine particles has greater effect on both fresh and hardened state properties of concrete.

Most of the admixtures are pozzolanic in nature, helps in enhancing strength and durability properties of the concrete with age. Therefore, the combination of different admixtures with cement may leads to many benefits such as reduction in usage of cement, recycling the solid waste produced from industries, improvement in physical characteristics along with the enhancement of rheological, mechanical, and durability of concrete and reduced environmental impact through reduction of greenhouse gases.

The aim of present paper is to examine the strength properties of SCC incorporating alccofine and fly ash. Constant fly ash quantity (i.e. 30% by overall mass) with varying dosage of alccofine (5, 10 and 15%) is added to produce SCC. The SCC is adapted to cast beams, cylinders and cubes specimens and then tested for flexural strength, tensile strength, compressive strength respectively.

2. MATERIALS

In this study Ordinary Portland cement (OPC) 53 grade is used as a binder. The coarse aggregate and fine aggregate are used as filler materials along with superplasticizers. OPC is tested as per Indian Specifications IS 12269: 1987 [28]. The fine and coarse aggregates are tested as per Indian Specifications BIS 383–1970 [29]. The coarse

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 7| Issue: 9| September 2021|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2021: 8.047 || ISI Value: 1.188

aggregates of 20 mm downgrade and fine aggregates 4.75 mm downgraded have been used. Fly ash was obtained from thermal power plant having 540–860 kg/m3 and confirming to ASTM C618. Alccofine (AL-1203) was obtained from Ambuja Cement Ltd, Goa having the specific gravity of 2.9 confirming to ASTM C989-1999 [30] was used in entire study. The physical properties of AL-1203 are given in Tables 1. In the current research, superplasticizer i.e. Conplast SP 430 composed primarily of polycarboxylic ether conforming to ASTM C494-2017 [31] Type F is used. The properties of conplast SP 430 are shown in Table 2.

TABLE 1: physical properties of Al

Characteristics	Test results
Specific gravity	2.9
Specific surface area [m^2/kg]	1200
Bulk density [kg/m3]	680
Particle Size in Micron	
D10	1.5
D50	5
D90	9

Table 2: Properties of SP 430

Characteristics	Test results
Specific gravity	
Appearance	Brown Liquid
Chloride content	Nil
Air entrainment	<2%

3. EXPERIMENTAL PROGRAM

In the present investigation, M25 grade normal concrete mix design was carried out according to BIS: 10262–2009 [32]. Mix proportions: 1:1.66:2.97:0.52. Self-compact ability can be largely affected by the characteristics of materials and mix proportions. In this experimental study, three types of Self-compacting concrete mixture proportions were adopted. The mortar or the paste in the self compacting concrete requires high viscosity and deformability, thereby the water-powder ratio has been adopted as 0.36 (as per EFNARC guide lines) constantly. A total of five concrete mixes were cast and tested to examine the effect of alccofine and fly ash on the SCC and mix proportion of SCC mixtures as shown in Table 3. After mixing the mixes satisfied the requirements of passing ability, filling ability and segregation resistance were poured into appropriate molds without any external vibration or compaction. The concrete specimens were removed from the mold after 24 h and cured in water until the day of testing. To determine compressive, split tensile strength and flexural strength three cubes of size 150 X 150 X 150 mm, cylinders of 300 X 150 mm and prisms of 100 X 100 X 500 mm were cast and tested for each mix. The mechanical properties namely compressive and flexural strength were performed according to IS: 516–1959 [33] and split tensile strengths was conducted according to IS: 5816–1999 [34]. The cube samples of size 150 mm were placed in between the steel plates the without packing. The load applied was increased constantly at 1.4 N/mm2 / minute till the cube failed. From the dial, the maximum load reading is noted. The cylindrical specimens of size 300 mm X 150 mm diameter were placed horizontally between the loading surface of compression testing machine and the load was applied at a nominal rate of 1.2 N/ mm2 / minute without any shock until the failure of the sample occurs. The beam samples of size 500 mm X 100 mm X 100mmwere placed in the flexural testing machine and two point loading was applied at a nominal rate of 0.7 N/mm2 /minute without any shock or vibration. The load was increased until the specimen failed and the failure load was recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure were noted.

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 7| Issue: 9| September 2021|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2021: 8.047 || ISI Value: 1.188

Table 3: self-compacting concrete mixtures.

Mix	Concrete mixes				
	NC	SCC0	SCC5	SCC10	SCC15
Cement	390	349.30	324.35	299.4	274.45
Fine aggregate	650	863.36	863.36	863.36	863.36
Coarse aggregate	1150	721.6	721.6	721.6	721.6
Water	205	179.64	179.64	179.64	179.64
Fly ash	0	149.70	149.70	149.70	149.70
Alccofine	0	0	24.95	49.90	74.85
Super plasticizer	0	5.99	5.99	5.99	5.99

4. TEST RESULTS AND DISCUSSIONS

4.1. Compressive Strength

The cube compressive test outcomes of SCC and normal concrete mixes of replacing alccofine and fly ash in cement were shown in Figure 1.

Figure 1 depicts the variation of strength in compression at 3, 7, 28 and 90 days with constant quantity of fly ash and alccofine at varying percentages selected for this study. From the strength outcomes of compression experiment, it is noticed that as the substitution of cement with 30% fly ash + 10% alccofine showed maximum strength compared to normal concrete at early (i.e., 3 and 7 days) and later ages (i.e., 28 and 90 days)

From Figure 1, it was observed that after 3 and 7 days of curing, constant quantity of fly as(i.e., SCC0 mix) gave compressive strength of 12.23 MPa and 21.28 MPa for self-compacting concrete, respectively. After 3 and 7 days of curing, the strength in compression of 14.65 MPa and 22.92 MPa was achieved for self-compacting concrete with the percentage of alccofine of 5% (i.e., SCC5 mix), respectively. Similarly, 10% alccofine addition (i.e., SCC10 mix) at 3 and 7 days gave maximum strength in compression of 16.35 MPa and 24.65 MPa for self-compacting concrete, respectively. From Figure 1, it was observed that after 3 and 7 days of curing, 15% alccofine substitution gave strength in compression of 13.25 MPa and 20.65 MPa, respectively [63-66].

There was a significant improvement in compressive strength of SCC mixes because of its high pozzolanic nature and void filling ability which was more pronounced in the presence of alccofine. Compressive strength of 27.35 MPa and 29.01MPa for self-compacting concrete was achieved with 25% substitution of fly ash (i.e., SCC0 mix) at 28 and 90 days, respectively. Similarly, 5% alccofine substitution (i.e., SCC5 mix) gave strength of 30.28 MPa and 32.21 MPa after 28 and 90 days of curing as shown in Fig. 4.4. In case of alccofine at 10% substitution (i.e., SCC10), compressive strength of 32.18 MPa and 34.82 MPa was attained for self-compacting concrete after 28 and 90 days of curing. The substitution of alccofine of 15% (i.e., SCC15) gave compressive strength of 29.87 MPa and 31.49 MPa for self-compacting concrete after the curing period of 28 and 90 days

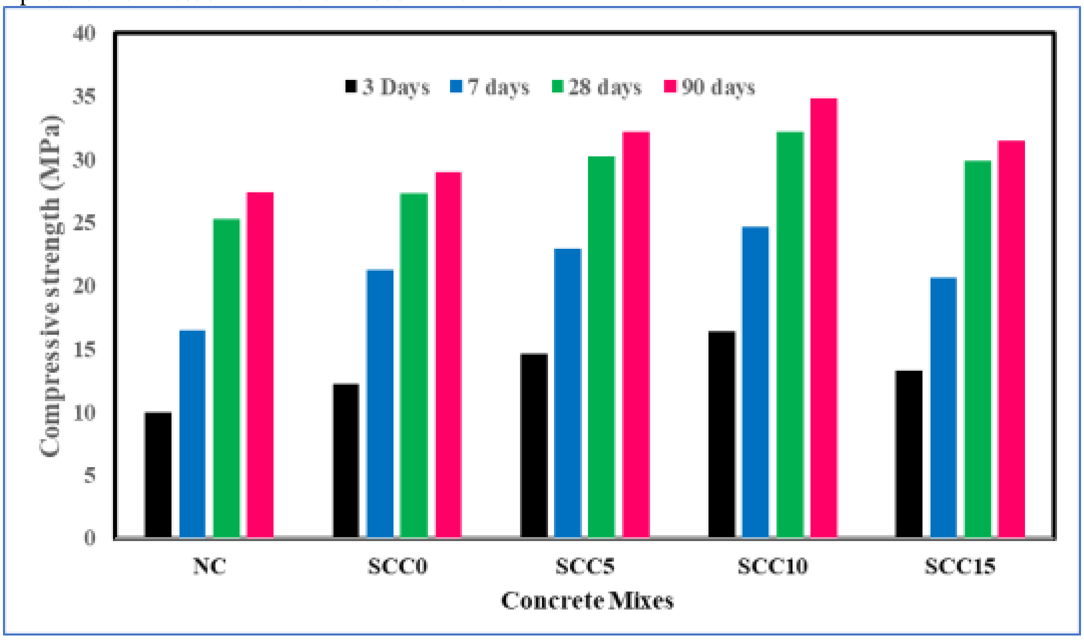

Fig. 4.1: Compressive strength of concrete with combination of AL and FA

The improvement in early age compressive strength of self-compacting concrete mix might be due to the accelerated hydration reaction on addition of Alccofine [15]. Similar types of results were observed at the age of 28 and 90 days. For 28 days curing period the mixes with Fly Ash and Alccofine i.e., SCC0, SCC1, SCC2 and SCC3 showed an improvement in compressive strength by 7.12%, 12.11%, 17.49% and 12.96% respectively with respect to the normal concrete mix. The later age strength (90 days) showed a negligible change with respect to 28 days strength is may be due to the acceleration of heat of hydration by FA and ALC in concrete lead to dense micro structure, from the results it has been observed that maximum percentage of the hydration is completed at 28 days, the rest negligible percentage of hydration will be very very slow and keep going with the time so it had showed the negligible change of strength for 90 days curing period. From the above results, it was observed that the percentage strength gain is higher for 7 days of curing when compared with other ages of curing. Therefore it can be concluded that the rapid development of the compressive strength of self compacting concrete at early age shows that the Alccofine and fly ash not only serves as a filler to increase the density of the micro and nanostructure of concrete but also serves as an activator in the hydration process. The decrease in strength on addition of alccofine beyond 10% is attributed to the reason that alccofine is much finer than cement; it increases the water demand for workable mix that leads to decrease in pore bonding strength [36]. Thus, at this stage the combination of Fly Ash and Alccofine acts as cement replacement materials used for filling the pores but does not involve in the hydration process [15,35]. The inclusion of Fly Ash and Alccofine enhanced the compressive strength for all the employed cases, in comparison with the normal concrete mix. Fig. 6 shows the failing mode of cube samples.

4.2. Splitting Tensile Strength.

The cylindrical tensile strength test outcomes of SCC and normal concrete mixes of replacing alccofine and fly ash in cement were shown in Figure 2. The tensile strength values for normal concrete mix after 7, 28 and 90 days were 1.51 MPa, 1.75 MPa and 1.82 MPa, respectively. SCC0 mix (i.e., 30%FA+0%AL) gave a tensile strength of 1.6 MPa, 1.87 MPa and 1.91 MPa after 7, 28 and 90 days of curing, respectively. After 7, 28 and 90 days of curing, the strength in tension of 1.68 MPa, 1.94 MPa and 1.99 MPa was achieved for self-compacting concrete with the percentage of alccofine of 5% (i.e., SCC5 mix), respectively. Similarly, 10% alccofine addition (i.e., SCC10 mix) at 7, 28 and 90 days gave maximum strength in tension of 1.74 MPa, 1.98 MPa and 2.15 MPa for self-compacting concrete, respectively. The substitution of alccofine of 15% (i.e., SCC15) gave tensile strength of 1.64 MPa, 1.93 MPa and 1.97 MPa for self-compacting concrete after the curing period of 7, 28 and 90 days [73-77].

The tensile strength results were enhanced with addition of alccofine and fly ash. The silicon and aluminium oxide present in fly ash assist for improving tensile strength in concrete at early and later strengths. Calcium and silicate of alccofine in the SCC mixes tries to react and forms CSH gel relating more early and later strength. This rise in tensile strength may be attributed to the better properties of the concrete matrix and the strong inter-phase bond between the binders (i.e., between alccofine, fly ash and cement) and the aggregates used. The Interfacial Transition Zone (ITZ) plays a significant role in the development of split tensile strength. By utilizing micro particles like Alccofine and fly ash, the ITZ becomes denser resulting in improvement of split tensile strength. The optimum tensile strength found to be is 1.74 MPa, 1.98 MPa and 2.15 MPa for SCC10 mix at 7, 28 and 90 days, respectively [78-82].

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 7| Issue: 9| September 2021|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2021: 8.047 || ISI Value: 1.188

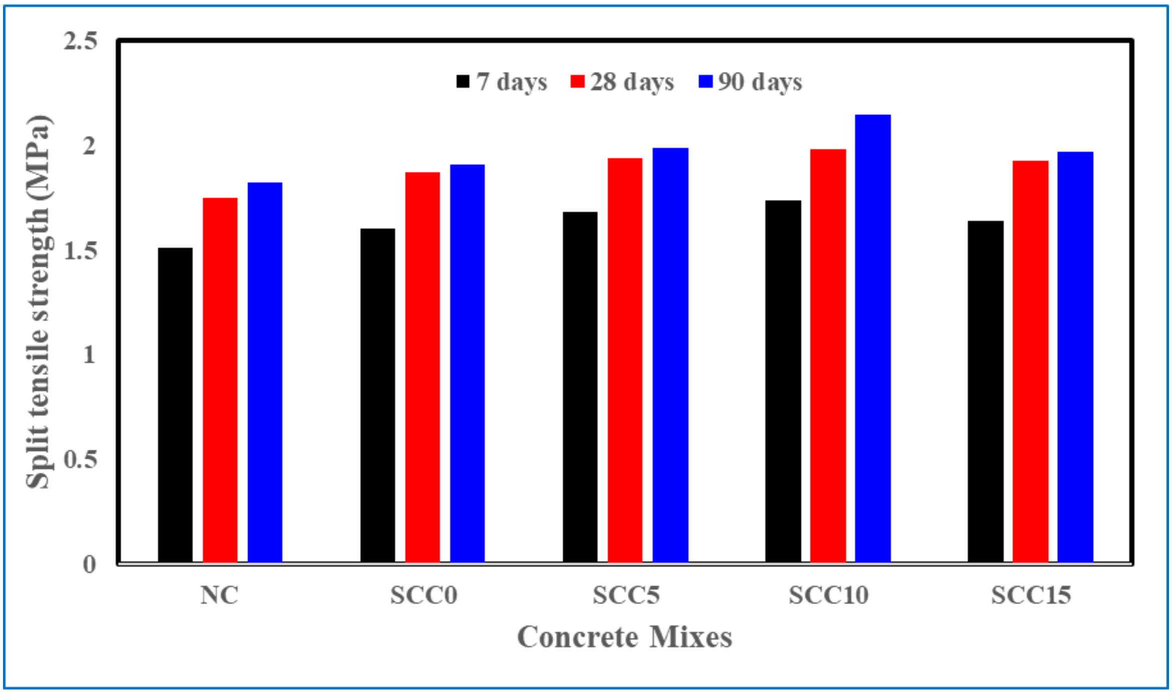

Fig. 4.2: Split tensile strength of concrete with combination of AL and FA

From the results it has been observed that maximum percentage of the hydration is completed at 28 days, the rest negligible percentage of hydration will be very slow and keep going with the time so it had showed the negligible change of strength for 90 days curing period. This increase in tensile strength may be attributed to the improved properties of the concrete matrix and the strong inter-phase bond between the binders (i.e., between cement, Fly ash and Alccofine) and the aggregates used [35]. The Interfacial Transition Zone (ITZ) plays a key role in the development of split tensile strength. By utilizing micro particles like Alccofine and fly ash, the ITZ becomes denser resulting in improvement of split tensile strength [37,38]. It was also noticed that the Split tensile strength of self compacting concrete samples was enhanced when cement content was replaced up to 10% AL and declined slightly on increasing the alccofine content. The decrease in tensile strength with greater than 10% AL replacement is attributed to the reason that the quantity of alccofine particles is higher than the of liberated lime quantity in the hydration process resulting in alccofine is much finer than cement, it increases the water demand for workable mix that leads to decrease in strength [15,35].

4.3. Modulus of rupture

The modulus of rupture was conducted for all concrete mixes; the test was done after 7, 28 and 90 days of curing. Figure 3 shows the strength values attained for all SCC mixes at all curing ages. The tests were conducted as per IS 516-1959.

The modulus of rupture for normal concrete mix at 7, 28 and 90 days of curing were 2.15 MPa, 3.52 MPa and 3.65 MPa, respectively. From Figure 3, it was observed that after 7, 28 and 90 days of curing, SCC0 (i.e., 30%FA+0%AL) gave a modulus of rupture values of 2.6 MPa, 3.94 MPa and 4.5 MPa, respectively. After 7, 28 and 90 days of curing, the modulus of rupture of 3.2 MPa, 4.8 MPa and 4.93 MPa was achieved in self-compacting concrete with SCC5 mix (i.e.,25%FA+5% AL), respectively. Similarly, 10% alccofine substitution (i.e., SCC10 mix) gave maximum modulus of rupture of 3.3 MPa, 5.12 MPa and 5.25 MPa in self-compacting concrete. On the other hand, 15% alccofine substitution (i.e., SCC15 mix) gave a modulus of rupture of 3.05 MPa, 4.42 MPa and 4.68 MPa in self-compacting concrete after 7, 28 and 90 days, respectively [36-38].

The presence of alccofine and fly ash has improved the modulus of rupture results. The reason for strength enhancement is due to the pozzolonic reactivity which is relatable to higher silicon amount in fly ash as it improves CSH gel in concrete and also helps in enhancing the modulus of rupture. Silicates and calcium contents of alccofine in the concrete samples reacts and form CSH gel which gives rise to increment in modulus of rupture. The optimum flexural strength found to be are 3.3 MPa, 5.12 MPa and 5.25 MPa for SCC10 mix at 7, 28 and 90 days, respectively

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 7| Issue: 9| September 2021|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2021: 8.047 || ISI Value: 1.188

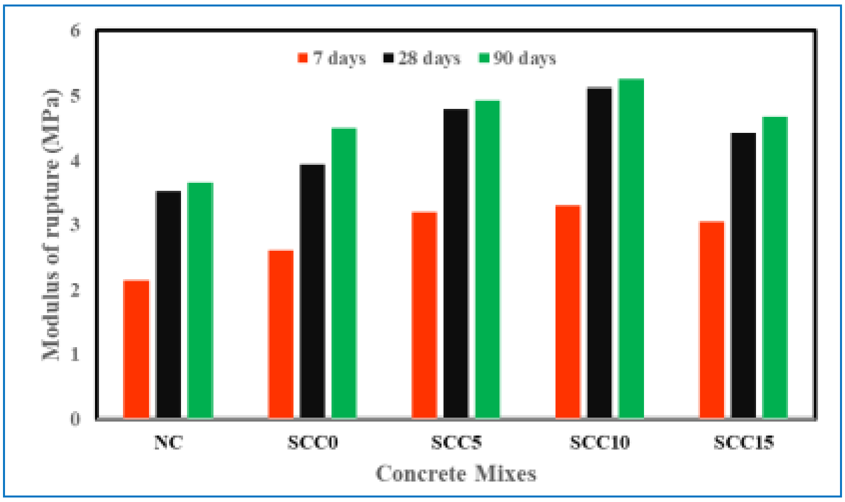

Fig. 4.3: Modulus of rupture of concrete with combination of AL and FA

5. CONCLUSIONS

Based on the experimental investigation carried out on self-compacting concrete mixes, it can be concluded that the compressive strength, split tensile strength and modulus of rupture of SCC increased due to higher specific surface area and high pozzolanic activity nature of AL and fly ash resulting in high production of C-S-H gel which helps in formation of compact structure in the concrete and also helps in improving the early strength gaining capacity and pore filling effect making the concrete denser and compacted. From the above studies it is concluded that 30% FA and 10% ALC in concrete was found to be more beneficial and better performance in compressive strength, split tensile strength and modulus of rupture when compared with all other mixes. Beyond 10% AL content the strength properties tends to decrease due to the higher quantity of alccofine particles than that of liberated lime quantity in the hydration process resulting in increases the water demand for workable mix and strength which may leads to effect pore structure of concrete. Using the combination of alccofine and fly ash as a replacement for cement leads to eco-friendly and sustainable concrete.

REFERENCE

1. *Panga Narasimha Reddy, Javed Ahmed Naqash, Properties of Concrete Modified with Ultra-Fine Slag.'' Karbala International Journal of Modern, Karbala Int. J. Modern Sci. 5 (3) (2019) 4.*
2. *Mohan, K.M. Mini, Strength and durability studies of SCC incorporating silica fume and ultra fine GGBS, Constr. Build. Mater. 171 (2018) 919–928.*
3. *R.M. Andrew, Global CO2 emissions from cement production, Earthq. Syst. Sci. Data. 10 (2018) 195–217.*
4. *M. Aly, M.S.J. Hashmi, A.G. Olabi, M. Messeiry, E.F. Abadir, A.I. Hussain, Effect of colloidal nano-silica on the mechanical and physical behavior of waste-glass cement mortar, Mater. Des. 33 (2012) 127–135.*
5. *M.H. Zhang, H. Li, Pore structure and chloride permeability of concrete containing nano-particles for pavement, Constr. Build. Mater. 25 (2011) 608– 616.*
6. *K. Gopalakrishnan, B. Birgisson, P. Taylor, O.A.O. Nii, Nanotechnology in Civil Infrastructure, Springer, Berlin, Heidelberg, Germany, 2011.*
7. *P. Narasimha Reddy, J. Ahmed Naqash, Effect of Alccofine on Mechanical and Durability Index Properties of Green Concrete, Int. J. Eng. 32 (6) (2019) 813–819.*
8. *C. Vaidevi, T.F. Kala, A.R.R. Kalaiyarrasi, Mechanical and durability properties of self-compacting concrete with marble fine aggregate, Mater. Today Proceed. 22 (2020) 829–835.*
9. *V. Malhotra, Introduction: Sustainable development and concrete technology, Concrete Int. 24 (7) (2002) 235–242.*
10. *Martin, J.Y. Pastor, A. Palomo, A.F. Jiménez, Mechanical behaviour at high temperature of alkali-activated aluminosilicates (geopolymers), Constr. Build. Mater. 93 (2015) 1188–1196.*
11. *K. Naveen Kumar, D. S. Vijayan, R. Divahar et al., An experimental investigation on light-weight concrete blocks using vermiculite, Mater. Today Proceed. 22 (2020) 987–991.*
12. *P. Narasimha Reddy, J. Ahmed Naqash, Development of high early strength in concrete incorporating alccofine and non-chloride accelerator, SN Appl. Sci. 1 (7) (2019) 755.*
13. *S. Saha, C. Rajasekaran, Mechanical properties of recycled aggregate concrete produced with Portland pozzolana cement, Adv. Concrete Constr. 4 (1) (2016) 27–35.*
14. *X. Shi, N. Xie, K. Fortune, J. Gong, Durability of steel reinforced concrete in chloride environments (An overview), Constr. Build. Mater. 30 (2012) 125– 138.*
15. *H. Li, M.H. Zhang, J.P. Ou, Flexural fatigue performance of concrete containing nano-particles for pavement, Int. J. Fatig. 29 (2007) 1292–1301.*
16. *M.S. Morsy, Y.A. Al Salloum, H. Abbas, S.H. Alsayed, Behavior of blended cement mortars containing nano-metakaolin at elevated temperatures, Constr. Build. Mater. 35 (2012) 900–905.*

17. *M.H. Beigi, J. Berenjian, O.L. Omran, A.S. Nik, I.M. Nikbin, An experimental survey on combined effects of fibers and nanosilica on the mechanical, rheological, and durability properties of self-compacting concrete, Mater. Des. 50 (2013) 1019–1029.*
18. *R. Madandoust, S.Y. Mousavi, Fresh and hardened properties of self-compacting concrete containing metakaolin, Constr. Build. Mater. 35 (2012) 752–760.*
19. *C. Franck, M. Michel, E. Gilles, B. Philippe, B. Alexandre, Metakaolin, a solution for the precast industry to limit the clinker content in concrete: mechanical aspects, Constr. Build. Mater. 24 (2010) 1109–1118.*
20. *V. Kannan, K. Ganesan, Chloride and chemical resistance of self-compacting concrete containing rice husk ash and metakaolin, Constr. Build. Mater. 51 (2014) 225–234.*
21. *N.M. Al-Akhras, Durability of metakaolin to sulfate attack, Cem. Concr. Res. 36 (2006) 1727–1734.*
22. *O.R. Kavitha, V.M. Shanthi, G. Prince Arulraj, V.R. Sivakumar, Microstructural studies on eco-friendly and durable self-compacting concrete blended with Metakaolin, Appl. Clay Sci. 124 (2016) 143–149.*
23. *O.R. Kavitha, V.M. Shanthi, G. Prince Arulraj, P. Sivakumar, Fresh micro-and macrolevel studies of metakaolin blended self-compacting concrete, Appl. Clay Sci. 114 (2015) 370–374.*
24. *G. Barluenga, F. Hernandez-Olivares, Cracking control of concretes modified with short AR-glass fibers at early age. Experimental results on standard concrete and SCC, Cem. Concr. Res. 37 (2007) 1624–1638.*
25. *A.C. Aydin, Self compactability of high volume hybrid fiber reinforced concrete, Constr. Build. Mater. 21 (2007) 1149–1154.*
26. *P.S. Rao, K.C. Mouli, T.S. Sekhar, Durability studies on glass fibre reinforced concrete, J. Civ. Eng. Sci. 1 (2012) 37–42.*
27. *F.A. Mirza, P. Soroushian, Effects of alkali-resistant glass fiber reinforcement on crack and temperature resistance of lightweight concrete, Cem. Concr. Compos. 24 (2002) 223–227.*
28. *BIS 12269 (2013), Ordinary Portland Cement 53 Grade-Specification, New Delhi, India*
29. *BIS 383 (2016), Specification for Coarse and Fine Aggregates from Natural Sources for Concrete, New Delhi, India.*
30. *ASTM C989 (1999), Standard Specification for Ground Granulated Blastfurnace Slag for Use in Concrete and Mortars,West Conshohocken, USA.*
31. *ASTM, C494. ''Standard specification for chemical admixtures for concrete.'', Philadelphia: American Society for Testing and Materials (2004).*
32. *BIS, Indian Standard. ''10262 Concrete Mix Proportioning—Guideline.'' Bureau of Indian Standards, New Delhi, India (2009).*
33. *BIS 516, Methods of Tests for Strength of Concrete, New Delhi, India, 1959*
34. *BIS 5816, Split Tensile Strength of Concrete – Method of Test, New Delhi, India.*
35. *S. Chithra, S.R.R. Senthil Kumar, K. Chinnaraju, The effect of Colloidal Nanosilica on workability, mechanical and durability properties of High-Performance Concrete with Copper slag as partial fine aggregate, Constr. Build. Mater. 113 (2016) 794–804.*
36. *D. S. Vijayan, Dineshkumar, S. Arvindan et al., Evaluation of ferrock: A greener substitute to cement, Mater. Today Proceed. 22 (2020) 781–787.*
37. *F. Sanchez, K. Sobolev, Nanotechnology in concrete - a review, Constr. Build. Mater. 24 (2010) 2060–2071.*
38. *Aly M. Said, Mohamed S. Zeidan, M.T. Bassuoni, Ying Tian, Properties of concrete incorporating nano-silica, Constr. Build. Mater. 36 (2012) 838–844.*