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Effect of Admixtures on Engineering Properties of Self Compacting Concrete

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Abstract: An experimental study on self-compacting concrete (SCC) having water cement content of 0.42 with the work involving in three types of mixes namely the first consisting of different percentages of fly ash (FA) mixed with concrete, secondly with different percentages of silica fume (SF) with self-compacting concrete testing for its engineering properties and thirdly using a mixture of Fly Ash with super plasticizer SP-430 for a notable variation in its strength characteristics, after the preparation of each mix cylindrical specimens are casted and cured for 7 & 28 days for testing its properties. Since the study involved is with self-compacting concrete, slump cone and V-funnel tests are carried out on the fresh SCC while concrete compressive & split tensile strength values are determined on hardened blocks as an engineering properties.
It has been found that there is an increase in compressive strength of SCC with 20% addition of silica fumes to the concrete compared with 30% of fly ash for 28 days cured specimens & also the specimens containing super plasticizer with fly ash in the concrete will be strong & gives notable compressive & split tensile strength with good workability characteristics when compared to only fly ash & Silica fumes which has been mixed with self-compacting concrete.
Keywords: Water cement ratio, fly ash & silica fumes, super plasticizer-SP 430, mix design, compressive & Split tensile strength.

I. Introduction

Self-compacting concrete (SCC) can be placed and compacted due to its self-weight with little or no vibration effort & at the same time cohesive enough which can be handled without segregation or bleeding of fresh concrete. SCC contain superplasticizer, high content of fines & viscosity modifying additive, While the use of superplasticizer gives fluidity, the finer content provides stability to the mix resulting in resistance against bleeding and segregation of the mix. Use of silica & fly ash in SCC reduces the dosage of superplasticizer needed to obtain similar slump flow compared to concrete mixes made with only Portland cement. It is found that SCC may result in up to 40% faster construction & gives good workability than using normal concrete with ordinary Portland cement, elastic modulus & shrinkage of SCC will remain as same as of the corresponding properties of normal concrete while the compressive, splitting, and flexural strength of self-compacting concrete shows that the water cured specimens for 28 days will give the highest results of concrete with respect to engineering properties than the specimens cured in air by about 10% to 11%respectively.

When concrete flows between reinforcement, the relative location of coarse aggregate will be changed & results in relative displacement which develops shear & compressive stress in the concrete mix. For concrete to flow through such obstacles smoothly, shear stress should be small enough to allow the relative displacement of the aggregate which can be done by moderate increase in viscosity of the paste is necessary. The shear force required for relative displacement largely depends on the water-to-cementitious materials ratio (W/C) of the paste while increase of the water-to-cementitious materials ratio will increase the flowability of the mix.

self-compacting concrete (SCC) has higher fines content than conventional concrete due to presence of higher binder content & combined aggregate grading curve. The combined mix with specially adapted superplasticizers, produce unique fluidity & compatibility for SCC. The components of SCC are similar to other plasticized concrete which consists of cement, coarse and fine aggregates, mineral and chemical admixtures. Self-compactability of concrete can be affected by the physical characteristics of materials and mixture proportioning. The mixture proportioning is based upon creating a high-degree of flowability while maintaining a low-water/cementitious materials ratio(<0.40). This is achieved using high-range water reducing (HRWR) admixture which is combined with stabilizing agents to ensure homogeneity of the mixture.

A number of methods exist to optimize the concrete mixture proportions for self-compacting concrete which are listed below:

- W/C ratio equal to regular plasticized concrete, assuming the same required strength.

- Higher volume of fine aggregate than most plasticized concrete; for example, cement, fly ash, and mineral fines; Optimized gradation of aggregates; and High - dosage of HRWR (0.5 to 2% by weight of cement, 460 to 1700ml/100kg).
- High-degree of flowability while maintaining a low-water/cementitious materials ratio, W/Cm (<0.40). This is achieved using high - range water reducing (HRWR) admixture combined with stabilizing agents to ensure homogeneity of the mixture.
- Coarse aggregate content is fixed at 50% of the solid volume, Fine aggregate is placed at 40% of the mortar fraction volume & Water-to-cementitious materials ratio in volume is assured as 0.9 to 1.0 depending on properties of the cement. Superplasticizer dosage and the final W/Cm ratio are determined so as to ensure the self-compactability.

Self-compacting concrete is not affected by the skill of workers, and shape and amount of reinforcing bar arrangement of a structure. Due to high-fluidity and resisting power of segregation of self-compacting concrete, it can be pumped longer distances. Self-compacting concrete extends the possibility of use of various mineral by -products in its manufacturing. This non-vibrating concrete allows faster placement and less finishing time leading to improved productivity & there is no universally adopted standardized test method for evaluation of self - compatibility of this concrete. Conplast SP430-SRV obtained from Fosroc chemicals (I) ltd. was used in present experimental research which conforms to Indian standard code, IS: 9103-1999. Conplast SP430-SRV is used where ever there is a high degree of workability required & also as an aid to workability retention where delay in transportation or placing are likely to occur & also when high ambient temperature cause rapid slump loss which facilitate production of high quality concrete with improved durability and water tightness, 2 litres of superplasticizer per 100 kg of cementitious material was used in SCC as per the manufacture recommendations.

II. Review of Literature

The results indicate that SCC gives high early concrete compressive strength when studied with the application of high fly ash content concrete (HFCC) for construction purposes & also their test results showed that with the replacement of fly ash with normal concrete, there will be increase in the compressive strength of up to 50% [1].

The indication to curing conditions have significant effect on the degree of hydration of cement which shows that for specimens (initially cured at 100% relative humidity (RH) for 6 hours to 12 hours) exposed to 90% RH, due to open hydration process all remaining capillary water will be lost due to evaporation. Whilst curing under sealed condition particularly for concretes with W/C ratio of 0.4 or over keeping the surface as saturated will be adequate [2].

The tests carried out to investigate the influence of curing conditions on the mechanical properties of self-compacting concrete, demonstrated that water cured specimens always have the highest values followed by specimens which are sealed cured & air-cured irrespective of type and age of concrete and test methods. For both concrete compressive and tensile strength tests, the SCC with silica fume gives the highest values followed by SCC with fly ash and then PC concrete for all curing periods and conditions [3].

An experimental program carried out which produce & evaluating SCC made with high volumes of kiln Ash while the results of this study suggested that quarry dust (QD), silica fume (SF) and kiln ash (KA) combinations can improve the workability of SCC, more than QD, SF and KA individually. KA can also have a positive influence on the mechanical properties at early ages while SF improved bond between aggregate–matrix resulting from the formation of a less porous transition zone in concrete. SF can better reducing effect on total water absorption while QD and KA will not have the same effect, at 28 days [4].

An optimum combination of W/C with super plasticizer for achievement of self-compatibility can be derived & that can be suggested for a limiting value of coarse aggregate and fine aggregate for self-compactable concrete which can be around 50% of the solid volume for the concrete and 40% for the mortar. a simple approach of increasing the sand content at the cost of coarse aggregate by 4% to 5% to avoid segregation. High flowability requirement of self-compacting concrete allows the use of mineral admixtures in its manufacturing [5].

Use of mineral admixtures such as fly ash, blast furnace slag, limestone powder, etc. could increase the slump of concrete mixture & also reduces the cost of concrete. The incorporation of one or more mineral admixtures or powder materials having different morphology and grain-size distribution can improve particle-packing density and reduce inter-particle friction and viscosity. Hence, it improves deformability, self-compatibility, and stability of the self-compacting concrete [6].

There is a reduction in the dosages of superplasticizer by using fly ash and blast furnace slag in self-compacting concrete & has a similar slump/flow values when compared to concrete mixed with ordinary Portland cement. The advantages of using fly ash in concrete is to improve rheological properties & reduced cracking of concrete due to the reduced heat of hydration of concrete that can also be incorporated in SCC by utilization of this material as a filler. SCC often incorporates several mineral and chemical admixtures, in particular a superplasticizer and a viscosity-modifying admixture (VMA).The superplasticizer is used to insure high fluidity and reduce the water-to-cementitious materials ratio. The VMA is incorporated to enhance the yield value and viscosity of the fluid mixture which will reduce bleeding of the concrete. The homogeneity and uniformity of the self-compacting concrete is not affected by the skill of workers and shape and bar arrangement of structures because of high-fluidity and resisting power of segregation of materials [7].

III. Materials & Methodology

Materials

a) Ordinary Portland cement of 53 grade.
b) Coarse aggregates pertaining to maximum sieve size of 12.5 mm to 10mm sieves as per IS standards.
c) Fine aggregates will have the particles larger than 0.125 mm and smaller than 4 mm.
d) Particles <0.125mm are used as powder in the concrete which will reduce segregation of concrete materials.
e) Fly ash as a mineral admixture.
f) Silica fumes as an admixture.
g) Super plasticizer (SP-430) as a viscosity modifying agent.
h) Potable water for mixing the constituents.

1. Methodology

Preliminary tests were conducted on the above materials as per IS standards & specifications, cubes & cylinders were casted in the standard metallic moulds & vibrated to obtain the required sample size of specimen. The moulds were cleaned initially and oiled on all the sides before concrete sample is poured in to it, the optimal volume content of sand in the mortar varies between 40 –50% where the amount of binder content is 450kg/m^3 depending up on the concrete properties. Thoroughly mixed concrete is poured into the moulds such that compaction is not allowed since the testing is to be done for self compacting concrete grade of M20 (1:1.5:3) in which for a SCC concrete, replacement of cement is done for 15%, 20% & 30% with fly ash in the first mix & the same ratio with silica fumes for the second mix. Inclusion of fly ash with super plasticizer SP-430 of 5% is done for the third mix of concrete which acts as a viscosity modifier for SCC.

For freshly casted SCC mix slump flow test & V – funnel test has been carried out & the cubes are casted with the excess concrete is removed out of the mould using trowel and the top surface is finished with smooth surface. After 24 hours the samples were demoulded and put in curing tank for the respective periods of 7and 28 days characteristic strength with a set of 5 samples were prepared in each stage for curing. The temperature of curing tank was maintained at 25 degrees during the analysis of compressive strength, split tensile strength is checked for the casted specimens & the results are tabulated.

TABLE-1 Physical properties of cement

Property	Result obtained
Fineness	90µ
Consistency (%)	28%
Initial setting time	150 min
Final setting time	300 min
Specific gravity	3.1

TABLE-2 Chemical composition of Fly ash

constituent	Fly ash (% by mass)
Cao	0.37 – 27.68
Sio_2	27.88 – 59.4
Al_2O_3	5.23 – 33.99
Fe_2O_3	1.21 – 29.63
Mgo	0.42 – 8.79
So_2	0.04 – 4.71
Na_2O	0.2 – 6.90

K_2O	0.64 – 6.68
Tio_2	0.24 – 1.73
Loi	0.21 – 28.37

TABLE-3 Chemical composition of silica fumes

Constituent	Content(%)
Sio_2	97
Fe_2O_3	0.5
Al_2O_3	0.2
Cao	0.2
Mgo	0.5
K_2O	0.5
N_2O	0.2
So_3	0.15
C_1	0.01
H_2O	0.5

TABLE-4 Properties of super plasticizer

Properties	Conplast SP 430
Composition	Sulphonated naphthalene formaldehyde condensate
Active solids (% by wt)	40
Appearance	Brown liquid
Specific gravity	1.2 at 20 degree Celsius
Air entrainment (%)	< 2
Chloride content (%)	Nil
PH value	7.0 – 8.0

Slump flow and T500 test: The slump-flow and T500 time is a test to assess the flow ability and the flow rate of self- compacting concrete in the absence of obstructions. It is based on the slump test to measure two parameters the flow speed and the flow time. The result is an indication of the filling ability of self-compacting concrete. The T500 time is also a measure of the speed of flow and hence the viscosity of the self-compacting concrete. First step is to prepare the cone and base plate then place the cleaned base in a stable leveled position, fill the cone without any agitation or Roding, and strike off surplus from the top of the cone. Allow the filled cone to stand for not more than 30s; during this time remove any spilled concrete from the base plate and ensure the base plate is damp all over but without any surplus water.

Lift the cone vertically in one movement without interfering with the flow of concrete. If the T500 time has been requested, start the stop watch immediately the cone ceases to be in contact with the base plate and record the time taken to the nearest 0.1 s for the concrete to reach the 500 mm circle at any point. Without disturbing the base plate or Concrete, Measure the largest diameter of the flow spread and record it & then measure the diameter of the flow spread at right angles to the nearest 10 mm. Check the concrete spread for segregation if any has occurred and that the test will be therefore unsatisfactory.

V-funnel test: The V-funnel test is used to assess the viscosity and filling ability of self-compacting concrete with a maximum size aggregate of 20 mm. A V shaped funnel is filled with fresh concrete and the time taken for the concrete to flow out of the funnel is measured and recorded as the V-funnel flow time. V-funnel, made to the dimensions & fitted with a quick release, watertight gate at its base. The V-funnel shall be made from metal; the surfaces shall be smooth, and not be readily attacked by cement paste or be liable to rusting. However container is needed to hold the test sample and having a volume larger than the volume of the funnel and not less than 12 times the Length.

2. Tests conducted for coarse aggregates

1. Sieve analysis
2. Specific gravity and Water absorption test
3. Aggregate shape test

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The aggregate gradation was continuous with the maximum aggregate size of 12.5mm passing & retaining on 10 mm sieve. The gradation & other tests were performed as per ASTM standards with 5 trials on each test & the below table represents the physical properties of materials.

TABLE-5 Test on coarse aggregates

Si no	Test	Method of test	Average Result	Permissible value
1	Sieve analysis	IS:2720-Pt-4	Fineness modulus = 2.90	2.3 to 3.1
2	Specific gravity	IS:2386-Pt-3	Bulk specific gravity = 2.60	2.5 to 3.2
			Apparent specific gravity = 2.5	
3	Water absorption	IS:2386-Pt-3	0.5	<2%
4	Aggregate shape test Flakiness index	IS:2386-Pt-1	12%	Max 30%
	Elongation index		14%	

TABLE-6 Obtained values for fresh SCC

Method	Obtained value			Typical range values	
	SCC+ Fly Ash	SCC + Silica	SCC+ Fly Ash +SP 430	Minimum	maximum
Slump Flow (Abram cone) in mm	600	640	710	650	800
T_{50}Cm slump flow in sec	6	5	4	2	5
V funnel in sec	11	7	9	6	12

IV. Results & Discussion

1. Replacement of cement with Fly ash for Compressive & split tensile Strength for 7 & 28 days

The values are obtained for casted concrete specimens in calculating compressive & split tensile strength with varying percentage of 15 to 30% are tabulated below which indicate that, in type I (with Fly Ash) with increase in percentage of Fly Ash gives the higher values of compressive & split tensile strength upto 30%. After that the increase in the percentage of FA leads to the decrease in values of concrete compressive & split strength which has been checked for both 7 days & 28 days of compressive & split tensile strength values.

TABLE-7 Replacement of cement with Fly ash for Compressive & split tensile Strength for 7 & 28 days

Si no	% Fly ash	Compressive strength in N/mm^2		Split tensile strength in N/mm^2	
		7 days	28 days	7 days	28 days
1	15	38	55	3.7	4.5
2	20	41	50	3.1	4.0
3	30	43	66	4.0	5.0

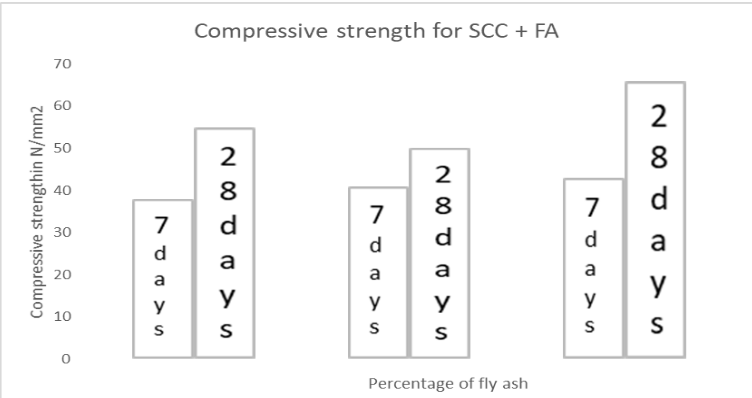

Fig – 1 Comparison of cement with Fly ash for Compressive strength for 7 & 28 days

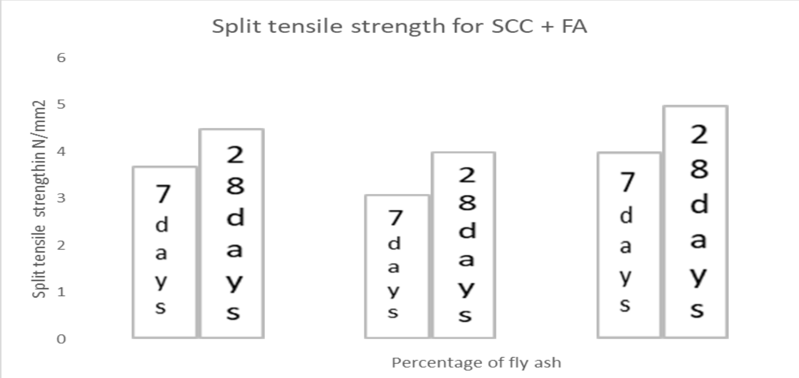

Fig – 2 Comparison of cement with Fly ash for Split tensile strength for 7 & 28 days

2. Replacement of cement with Silica fumes for Compressive & split tensile Strength for 7 & 28 days

In this Silica Fumes were added with varying percentages of 15% to 30% with which the highest value of concrete compressive strength is obtained for 20% of Silica Fumes in the concrete mix. It can be noticed that with varying content of silica fumes with cement content gives higher values of concrete compressive strength than the specimens of type I which has up to 30% replacement of Fly Ash content in the concrete mix. Also It has been noticed that the highest value of compressive & split tensile strength for all test cases is obtained from specimens cured in water for 28 days followed by those cured in water for 7 days when compared to air cured specimens.

TABLE-8 Replacement of cement and with Silica fumes for Compressive & split tensile Strength for 7 & 28 days

Si no	% Silica Fumes	Compressive strength in N/mm^2		Split tensile strength in N/mm^2	
		7 days	28 days	7 days	28 days
1	15	40	65	3.9	5.2
2	20	45	68	5.0	6.2
3	30	37	58	4.1	5.5

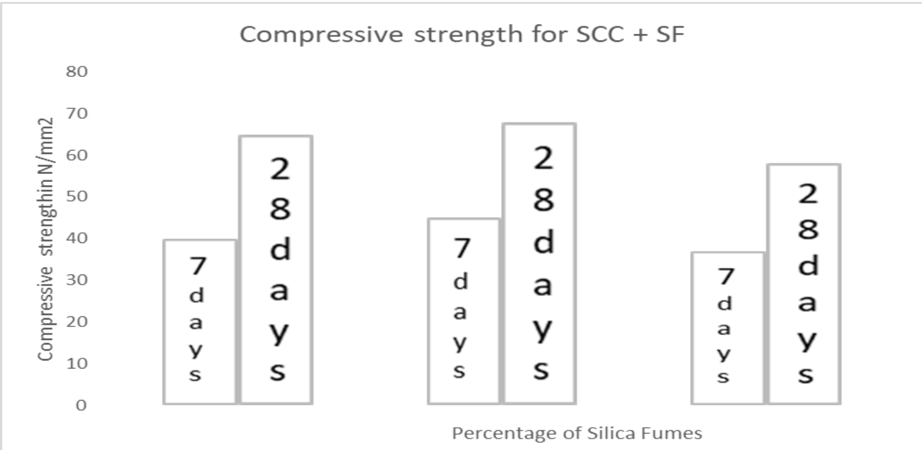

Fig – 3 Comparison of cement with Silica Fumes for Compressive strength for 7 & 28 days

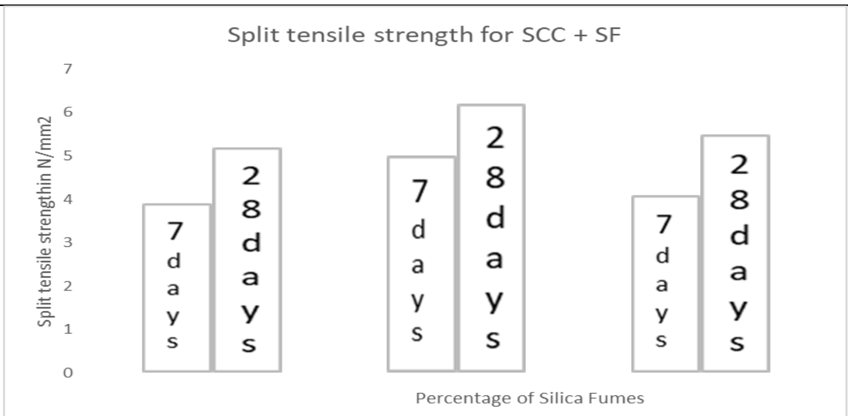

Fig – 4 Comparison of cement with Silica Fumes for Split tensile strength for 7 & 28 days

3. Replacement of cement with 20% by weight of Fly Ash & 5% by weight Super Plasticizer SP-430 for Compressive & split tensile Strength for 7 & 28 days

With addition of the plasticizer in varying proportion, there will be a significant different in strength performances of SCC which acts as a water reducer & a good curing agent material. 20% Fly Ash with 5% SP 430 by weight of cement is added to SCC mix for analysis of engineering properties which will give increase in the strength properties of up to 20% in compressive & tensile strength.

TABLE-9 Replacement of cement with 20% by weight of Fly Ash & 30% by weight Super Plasticizer SP-430 for Compressive & split tensile Strength for 7 & 28 days

Si no	Fly ash in %	Super plasticizer – SP-430 in %	Compressive strength in N/mm^2		Split tensile strength in N/mm^2	
			7 days	28 days	7 days	28 days
1	20	30	43	69	5.6	6.4

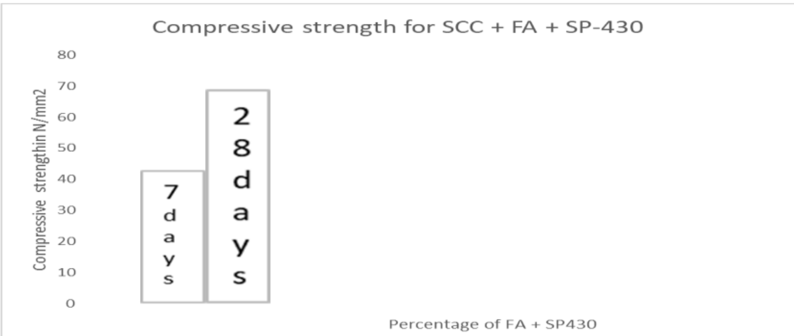

Fig – 5 Comparison of cement with 20% by weight of Fly Ash & 30% by weight Super Plasticizer SP-430 for Compressive strength for 7 & 28 days

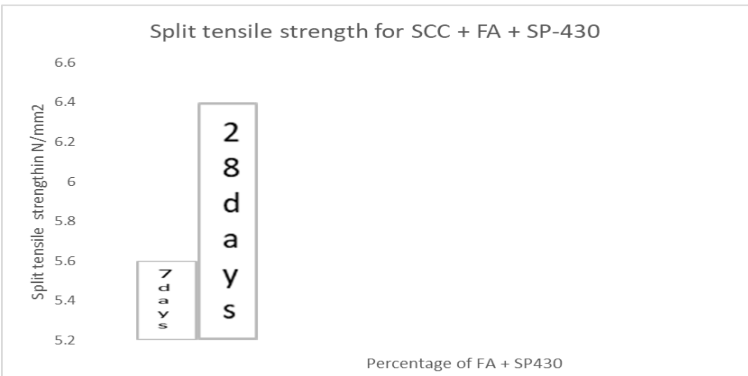

Fig – 6 Comparison of cement with 20% by weight of Fly Ash & 30% by weight Super Plasticizer SP-430 for Split tensile strength for 7 & 28 days

Conclusion

Based on the various laboratory tests as per IS standards for the porous concrete by varying the composition the following conclusions are drawn:

- The effect of curing conditions on the SCC with different percentage of Fly Ash and Silica Fumes for finding out the optimal dosage with respect to concrete compressive & split tensile Strength is evaluated where in water cured specimens will give better results than air cured specimens.
- With varying percentage of Fly Ash initially in the mix will give optimal increase in strength characteristics of the concrete specimens however for 30 % replacement of FA with cement there will be ideal increase in strength characteristics with further increase in proportion, strength will be decreased in concrete specimens.
- For a mix of SCC with 20% replacement of Silica Fumes by weight of cement, the value of compressive & split tensile strength was more when compared to other replacements of Silica fumes in 450 kg/m^3 cement content.
- With 20% FA and 5% variation of SP 430 plasticizer in concrete mix gave the highest value of concrete compressive & split tensile strength when compared to other two mixes which consisted of combination of Fly Ash and Silica Fumes alone in SCC.

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Bibilography

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