

# High Volume Fly Ash Self Compacting Concrete with Lime and Silica Fume as Additives

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**Abstract.** SCC is expensive when compared with normal conventional concrete. Hence, it is desired to produce low cost SCC by replacing cement with higher percentages of fly ash, which is a no cost material and available in abundance. At the same time to achieve higher grade HVFASCC, micro silica which is otherwise condensed silica fume can also be used along with fly ash to enhance the strength properties of HVFASCC. By replacing fly ash in high volumes in the mix, high amount of pozzolanic material becomes available, majorly reactive silica, for which more calcium hydroxide is necessary for further pozzolanic reaction. As we are reducing cement quantity, the amount of calcium hydroxide available is reduced thus demanding external addition of hydrated lime which can be supplied as additive to cater to the need of calcium hydroxide required for reactive silica in fly ash. The present investigation aims to achieve strength for high volume fly ash self-compacting concrete. The replacement of cement with fly ash is made in 45%, 50%, 55%, 60%, 65% and 70% with 20% hydrated lime and 10% silica fume in one trial. In another trial, 30% hydrated lime and 10% silica fume is added with replacement of fly ash to cement varying in same percentages. The design mix is tested for workability and flowability and cubes are casted for compression strength test and tested at 28 day,, 56 day, and 90 day,.

## 1 Introduction

The best mineral admixture that can be added easily at low cost is fly ash[1]. Vibration and compaction is not required for self-compacting concrete, but use of ultra-fine fly ash demands addition of super plasticizer while mixing in the pan mixer so that flowability of mix increments and workability builds up. But increasing the usage percentage of super plasticizer brings up segregation and eventually adds detrimental effects like bleeding in fresh mixed concrete and to avoid this, an admixture that modifies viscosity is adopted to augment the viscosity of concrete in pan mixer in mixing stage [5-8]. Also, it is important to understand that replacing the cement with ultra-fine admixtures at high weight percentage sways the features of SCC due to variation in weight of cement and proportionate water (content) to be added. In industries like ferrosilicon manufactures and metallic silicon making firms, the temperatures are at highest values owing to the production of highly fine minute sized particles which is otherwise called as fumous silica (Micro silica). This is liberally considered mineral admixture with glassy spherical particles of silicon dioxide. When pozzolanas that are of no cost like fly ash and silica fume are blended with amalgamation in the mixing process of concrete, the silicon dioxide is

readily available to participate in making a reaction with free radicals of calcium hydroxide that evolve in cement hydration process. This accelerates formation of hydrates of calcium silicate in higher quantity influencing the chemistry of cement hydration and technology of concrete.

Addition of hydrated lime into HVFASCC increases the stabilization and gains long term pozzolanic strength [1-4]; also calcium carbonate formed from hydrated lime makes the silica in fly ash to react with hydroxide and concludes in the formation of solid hydrates of silicates and aluminates. Hence, hydrated lime is to be added as a performance enhancer for high volume fly ash self-compacting concrete mixes.

## 2 Materials Used and Mix design

### 2.1 Cement

Cement is influencing material in giving good bonding when mixes are made with fly ash replacement. In such cases, cement containing finely graded is of utmost important in giving the furthest values in compliance with expected strength such that trial mixes are successful. 53 grade (Bharathi cement) OPC is procured.

## 2.2 Fly ash

SUPER POZZ p500 which is ultra-fine fly ash was used in the experimental procedure and obtained from ACC Limited, Miyapur. **Table 1** represents the physical features of the Superpozz p500. This material is in accordance with IS 3812 Part 1, EN 450-1 (category S) with ASTM C618 Class F Compliance. ASJTECH's product research team has developed this ultra-fine FA. When particles are more fine, the reaction between the fine particles provides extra bonding. SUPER POZZ p500 is rich in alumina-silicates and hence reactive thereby strengthening cementitious systems and providing enhanced durability. This is highly compatible with any type of cement and is effective when used with other finely ground solid materials like GGBS along with fumous silica (silica fume).

## 2.3 Coarse Aggregate

Course aggregate which is obtained from a local source in Nizampet, Hyderabad is tested for modulus of fineness along with specific gravity test. The specific gravity of coarse 2.561 with absorption percentage of water being only one third percent (0.3). The greatest size in the coarsely grained aggregate being 12.5mm.

## 2.4 Fine Aggregate

It is obtained from the local source in Nizampet, Hyderabad. It is sieved through the set of sieves in a mechanical sever for accuracy. After the test the fineness modulus is calculated and noted down as 2.8. Further, specific gravity test is conducted on fine aggregate and it is observed to be 2.782. The water absorbed by fine aggregate is important to be known before being used in the mix as the volume changes are notable with the amount of water being absorbed by the particles of aggregate. Hence, test for absorption is conducted and it is 0.6%

## 2.5 Hydrated lime

Hydrated lime contains calcium hydroxide and also calcium silicates similar to the main cementitious components of Portland cement that enhances pozzolanic action of the high volume present in the mix [15-19]. Hydrated lime with 96% purity calcium oxide was used. Now-a-days, it is a real-time challenge to procure appropriate hydrated lime in the market. The raw lime, the major ingredient of cement making plants is tried initially by grinding them into finer particles in laboratory with the helping of pounding tools. Another trial is done by using lime from a familiar fly ash brick making plant. Those of two trials had not given much of satisfactory results. There were moulding and workability issues. As a next level trial, the material was procured from Universal Chemicals, Nacharam, Hyderabad. With this the trial has been successful where it has become feasible to make cubes for experimenting. The properties of hydrated lime are as shown in **Table 2**. Also while mixing hydrated lime with cement and fly ash utmost care must be taken to see that there are no balls and lumps formed before applying water and superplasticizer. The hydrated lime must be sieved and made uniformly spread while mixing all ingredients in dry state itself. Also lime releases ample amount of heat due to which it is necessary to apply quite little extra fraction of excess water based on the water absorption percentages of other concrete constituents in order to nullify the evaporating water due to the release of heat from lime mixing. Also getting in contact with lime directly harms the skin. It is identified that lime must be added only after adding and mixing all the other ingredients in dry state.

## 2.6 Super plasticizer & Viscosity modifying agent

Viscocrete6030 which is a new generation copolymer based super plasticizer which also acts as viscosity modifying agent was used.

**Table 1.**Characteristic feature –ultra fine Fly ash

Feature type	Characteristics
Appearance	Pale grey ultra-fine powder
Relative Density	2.12 -2.30
P <sup>H</sup> in water	11-12
Surface area (Sq.-cm/Kg)	13000
Loss on Ignition in %	<1.0
Carbon Content in %	<0.4
Moisture Content in %	<0.5
Mean Particle Size in microns	3.9-5.0
Sum of Oxides( Si+Al+Fe)	95%

**Table 2.**Characteristics of hydrated lime

Composition	Percentage of Composition
CaO	72.8
CaCO <sub>3</sub>	0.1
MgO	0.3

Acid insoluble	0.1
Alumina	Trace
Iron	Trace
Chloride	Trace
Moisture	0.5

### 3 Mix design method

There is no exact or stringent procedure to be followed in designing the SCC mix; it is majorly carried out in trial and error method. The properties that are to be given a note and observed while confining the proportions of ingredients in mix design are:

- Aggregate selection with best passing ability.
- Appropriate selection of water/powder ratio.

Mortar-paste fraction with required slump flow and stability. Nan-su mix method [9,12] is brought in making the trial mixes. This is one of many trial methods being picked up for reliable results. The idea is predetermined volume of ingredients in right proportions greases in achieving higher strengths in concrete making and enhances the timely hydration process with steady stature.

### 4 Discussion of variation Results

#### 4.1 Characteristics of HVFASCC in fresh state

The result of flow test gives the spread diameter of concrete. In this test also the time taken for HVFASCC to flow to a diameter of 50 cm circle is recorded and the time is noted as T50. According to EFNARC [13] the mix with slump flow diameters from 55cm to 75cm to be considered as self-compacting mix. Concrete flow that exceeds 75 centimeter diameter attributes segregation, and when the flow dia is less than 55 cm, indicates that this concrete has insufficient passing ability in congested reinforcement.

The concrete characteristics when it is in fresh state are recorded by flowability tests namely slump T50, V-funnel T5, L-box. These tests are carried out before the concrete loses its fresh properties i.e., before 20 minutes of time of applying water.

The flow test, important test to understand flow properties is carried out accordingly the EFNARC

guidelines. In execution of this test, the cone through which concrete moves easily with self movement is used for self – compacting concrete, then lift the cone, measure extreme diameter , meanwhile also note the time elapsed to cross the 50 cm diameter circle , this elapsed time is time taken and noted in seconds as time column T 50. The V-funnel test is also performed accordingly EFNARC guidelines. To quantify the fluidity, segregation, passability of concrete v-funnel is made use of. The time traveled in seconds is recorded from the time the outlet is opened at the bottom until the light is seen from above. For a good concrete, the test time is between 6 and 12 seconds.

The obstruction possibility that hinders the self moving capability and flow capacity of SCC which are incorporated with fibrous admixtures are tested and evaluated with the help of box named L-Box. This test is made use to observe filling of self compacting concrete in structural elements which are confined and congested.

The procedure lies in finding the height of withheld concrete at exit outlet, which must be more than 0.8.

Table 4. Indicates the test results discussed so far.

#### 4.2 Compression test results:

The cube compressive strength tests are conducted on Cubes measuring 100mmx100mmx100mm were casted and tested is done after number of day, 28 day, 56 day and 90 day, to evaluate compressive strength. For each batch of trial mix designed, three specimens are casted and tests conducted to take the average compressive strength value for each age (3 ages). Table 5 notifies the variations in cube compressive strengths for three different ages for the trial mixes. The notations for each composition and proportion of mix are given. For understanding graphical variation, Fig.s 1 to 4 are evolved.

**Table 4.** Notations and flowability reports of mix

Mix	Notation	Slump flow(cm)	T50 (Sec)
UFFA45+SF10+HL20	M1	60	2.4
UFFA50+SF10+HL20	M2	61	2.5
UFFA55+SF10+HL20	M3	59	2.5
UFFA60+SF10+HL20	M4	57	2.6
UFFA65+SF10+HL20	M5	55	2.6
UFFA70+SF10+HL20	M6	53	2.7
UFFA45+SF10+HL30	M7	62	2.5
UFFA50+SF10+HL30	M8	62	2.6

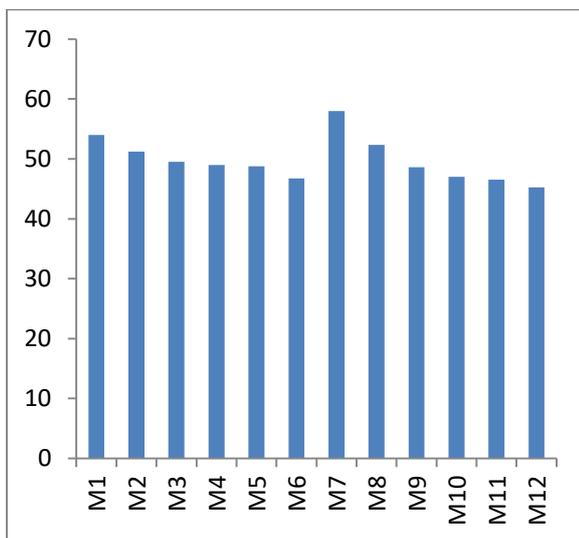
UFFA55+SF10+HL30	M9	59	2.6
UFFA60+SF10+HL30	M10	56	2.7
UFFA65+SF10+HL30	M11	55	2.7
UFFA70+SF10+HL30	M12	49	2.8

Ultra-fine fly ash is used for the present study to represent the high volume fly ash. Silica fume is used to attain high strengths due to its fine powder size it acts more like a filler giving dense structure to the concrete.

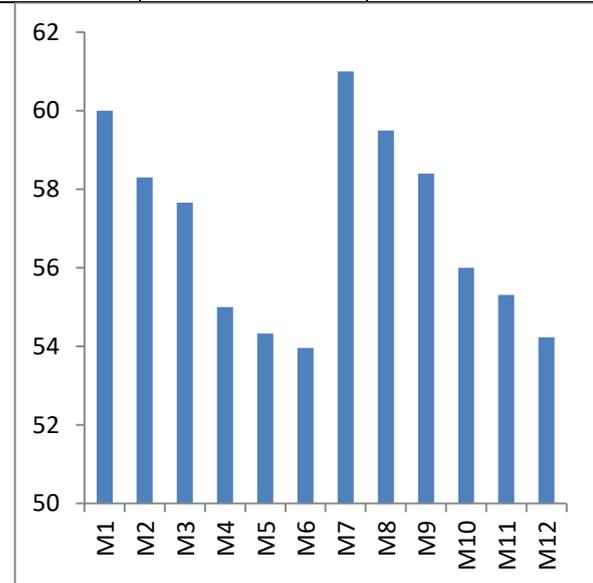
Hydrated lime is used as additive to react with calcium hydroxide from fly ash. This give you more hydration products to enhance the compressive strength of the concrete.

**Table 5.** Compression test results

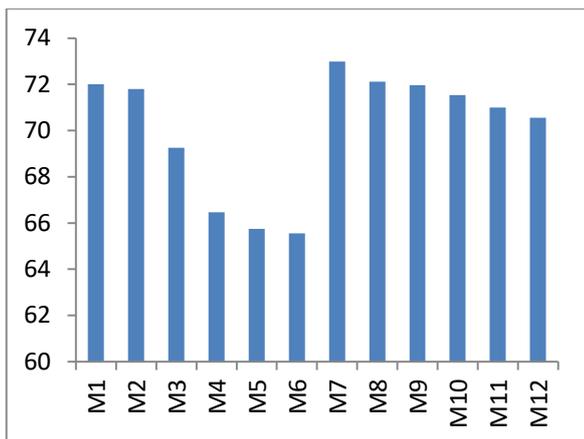
Mix	Notation	28 day, (MPa)	56day, (MPa)	90 day, (MPa)
UFFA45+SF10+HL20	M1	54	60	72
UFFA50+SF10+HL20	M2	51.2	58.3	71.79
UFFA55+SF10+HL20	M3	49.5	57.66	69.26
UFFA60+SF10+HL20	M4	49	55	66.47
UFFA65+SF10+HL20	M5	48.77	54.33	65.74
UFFA70+SF10+HL20	M6	46.77	53.96	65.55
UFFA45+SF10+HL30	M7	58	61	72.99
UFFA50+SF10+HL30	M8	52.33	59.5	72.12
UFFA55+SF10+HL30	M9	48.6	58.4	71.96
UFFA60+SF10+HL30	M10	47	56	71.54
UFFA65+SF10+HL30	M11	46.55	55.31	70.99
UFFA70+SF10+HL30	M12	45.23	54.23	70.55



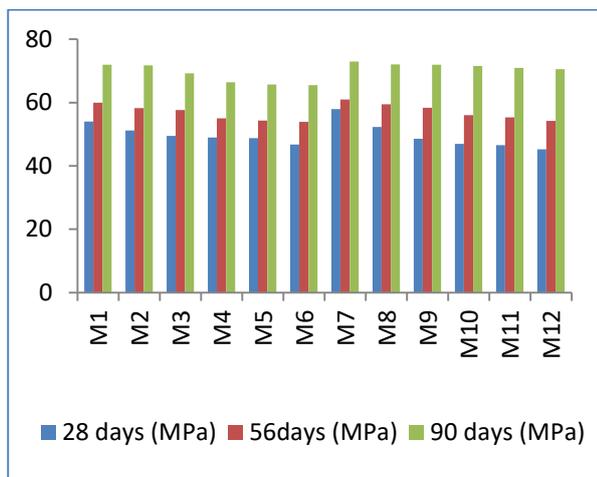
**Fig.1.** Variance in 28 day, cube comp. strength



**Fig.2.** Variance in 56 day, cube comp. strength



**Fig.3.** Variance in 90 day, cube comp. strength



**Fig.4.** Variation in cube comp. strength - 28 day, 56 day, and 90 day, of all the mixes

### 5. Conclusion:

1. The flowability and compression strength properties are tested for the trial mixes.
2. The flowability properties in concrete are varying when there is increase in percent of replacement of cement with ultra-fine fly ash. With the increase in powder content, flowability of concrete is being reduced.
3. For the mix M1 and M2 the slump value is observed as 60 and 61 cm which gradually reduced from M3 to M6 when higher percentage of cement is restituted with ultra fine pozzolanic Superpozz 500.
4. When mixes are designed with silica fume and hydrated lime in percentages of 10 and 30 respectively i.e., for mixes from M7 to M12, variation in restitution of Superpozz 500 instead of cement has credited the same trend as observed for mixes with addition of silica fume in percentage of 10 and 20% hydrated lime.
5. The compression strength test results for high volume ultrafine Superpozz 500 fly ash self compacting concrete at 28, 56 and 90 day, are obtained.

6. When fly ash is in higher volume in mix of concrete, strength results shows down trend, but with lesser decrements. The reason being the additives silica fume and hydrated lime that are added at different percentages.
7. For Mixes M6 and M12 (70% fly ash), the 28, 56 day, compressive strength is high for M6 but 90 day, strength is high for mix M12.
8. When mixes M6 and M12 are compared, it can be concluded that addition of 20% of hydrated lime along with 10% silica fume is optimum and suitable to achieve high strength for high volume fly ash self compacting concrete.

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