Study on Effect of Various Mineral Admixtures on Self Compacting Concrete

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Abstract— Self- Compacting Concrete (SCC) is a special type of concrete that can flow and compact under its own weight and can occupy all the spaces without any vibration, and at the same time cohesive enough to be handled without bleeding or segregation. The required compaction properties are achieved by adding super-plasticizers and mineral admixtures such as fly ash, rice husk ash, silica fume, etc. The utilization of these treated industrial by-products as cement replacement will not only help to achieve an economical SCC mix, but it is envisaged that it may improve the microstructure and consequently durability of concrete. This provides solution to disposal problems and other environmental pollution issues created by these otherwise waste products. Silica-fume, rice husk ash and fly ash is more effective to produce the high strength performance concrete. Mechanical behavior of SCC has been studied by performing tests on 78 hardened concrete specimens with different variables i.e. partial replacement of cement with FA, RHA and SF (0%, 5%, 10%, 15% and 20%), concrete aged (7 days & 28 days) and water to binder ratio 0.40. Fresh concrete properties have been measured by V-funnel flow time, and slump flow diameter tests. Mechanical properties have been determined in terms of compressive strength. Silica-fume enriches the workability of SCC. This paper presents the results of an experimental study aimed at producing SCC mixes of M30 grade by using the Modified Nan Su method, incorporating three mineral admixtures, viz., Fly Ash, Silica Fumes and Rice Husk Ash as supplementary cementing materials.

Keywords: Self-Compacting Concrete, Fly Ash, Rice Husk Ash, Silica Fume

I. INTRODUCTION

SCC was first developed in Japan in the late 1980s as a concrete that can flow through congested reinforcing bars with elimination of additional compaction and without undergoing any significant segregation and bleeding under its own weight. SCC has gained wide use in many countries for different applications and structural configurations. The use of SCC has many advantages such as: faster construction, eliminating the need for vibration, reducing the noise pollution, improving durability, and the filling capacity of highly congested structural members, better surface finishes and also a safe working environment. SCC consists of the same components as the conventionally vibrated concrete, which is cement, aggregates and water, with the addition of chemical and mineral admixtures in different proportions. While designing SCC the volume of the coarse aggregate should be restricted to avoid the possibility of blockage on passing through spaces between steel bars. This reduction necessitates the use of a higher volume of cement which results in a greater temperature rice and the increase in the cost of construction. Thus incorporating high volumes of mineral admixtures such as fly ash, rice husk ash, silica fume, etc. can make it cost-effective. However, the durability of such SCC needs to be proved. For concrete to be self-compacting it should have the filling ability, pass inability, and resistance against segregation. These properties are obtained by limiting the coarse aggregate content and using lower water-powder ratio together with super-plasticizer. Fly ash is a beneficial mineral admixture for concrete. Research shows that adding fly ash to normal concrete, as a partial replacement of cement (less than 35%), will benefit both the fresh and hardened states From the experimental investigation on SCC containing silica fume it is clear that cement can be replaced with 15% silica fume effectively, thereby reducing the consumption of cement, which in turn reduces the cost. Rice husk ash has been used as a highly reactive pozzolanic material to improve the microstructure of the interfacial transition zone between the cement paste and the aggregate in SCC.

Research shows that the utilization of rice husk ash in SCC mix (less than 20%) produced desired results and also provided an environment friendly disposal of agro-industry waste product. So far a mixed design procedure to fix the ratio of all the ingredients in SCC is not standardized. No method specifies the grade of concrete in SCC except the Nan Su method. But the limitation of this method is that it does not provide required mix proportions for the grade which is less than M50.

II. OBJECTIVE

This project is intended to develop concrete mixtures incorporating the some materials as replacement of cement. The objectives of the study are summarized below.

- To investigate the strength of concrete with fly ash, rice husk ash and silica fume.
- To fulfill the need of cement in the society and use of alternative resources.
- To study the strength properties of concrete by replacement in varying percentage of fly ash, rice husk ash and silica fume powder by weight of cement.
- To comparative study between fly ash, rice husk ash and silica fume. On properties of concrete. To identify the compressive strength properties of M30 grade concrete for 7 and 28 days with fly ash, rice husk ash and silica fume material partially replacement of cement by 0%, 5%, 10%, 15% and 20%%, respectively say as Mix-1, Mix-2 and Mix-3.

III. MATERIALS USED

A. *Cement:*

Cement is the major ingredient in assembling of concrete. OPC available in the local market of standard brand has been used in the investigation. The Bureau of Indian Standards (BIS) has classified OPC in three different grades. The grades are (i) 43 grade. Ordinary Portland cement has been used conforming IS 12269:1987, available in local market is used in this entire investigation. It is fresh and free from any lumps and the specific gravity of cement was 3.15.

B. Fine Aggregate:

The fine aggregates used in this investigation is Narmada River sand passing through 4.75 mm IS Sieve and retained on 75 micron (0.075 mm) IS Sieve is termed as fine aggregate. With specific gravity of 2.65. The grading zone of fine aggregates was zone I as per Indian standard specification. (IS code 383:1970). Fine aggregate is added to concrete to assist workability and to bring uniformity in mixture.

S.NO.	Particulars	Value of sand
1	Source	Jabalpur
2	Zone	I
3	Specific gravity	2.65

Table 1: Properties of Fine Aggregate

C. Coarse Aggregate:

Machine crushed broken stone angular in shape is used as coarse aggregates. Cubical, or rounded shaped and should have granular or crystalline or smooth (but not glossy) non-powdery surfaces. Aggregate should be properly screened and if necessary washed clean before use. Coarse aggregate containing flat, elongated or flaky pieces or mica should be rejected. The grading of coarse aggregate should be as per specifications of IS 383-1970. Two fraction of coarse aggregates were used, 20mm size having specific gravity of 2.68, and 10mm size having specific gravity of 2.68. The aggregate which passes through 75mm sieve and retain on 4.75 mm are known as coarse aggregate. Angular shape aggregate of size is 20 mm and below. It should be hard, strong, dense, durable, clean, and free from clay or loamy admixtures or quarry refuse or vegetable matter

S.No.	Particulars	Value of sand
1	Source	Jabalpur
2	Specific gravity (10 mm)	2.68
3	Specific gravity (20 mm)	2.68

Table 2: Properties of Coarse Aggregate

D. Water

Ordinary tape water clean, potable free from suspended particles and chemical substances was used for both mixing and curing of concrete. The water should be fit for mixing. The water should not have high concentrations of sodium and Potassium and there is a danger of alkali aggregate reaction. Natural waters that are slightly acidic are harmless, but water containing organic acids may adversely affect the hardening of concrete. The water should conform to IS 456-2000 standards.

E. Rice Husk Ash:

1) Physical Properties:

RHA is fine powdery material of relatively uniform size.

2) Chemical Properties:

RHA has chemical composition similar to that of the conventional Portland cement. The major constituents are compounds of lime, iron, silica, and alumina. the typical chemical composition for fresh RHA Rice husk can be burnt into ash that fulfils the physical characteristics and Chemical composition of mineral admixtures. Pozzolanic activity of rice husk ash (RHA) depends on (i) silica content, (ii) silica crystallization phase, and (iii) size and surface area of ash particles. In addition, ash must contain only a small amount of carbon. RHA that has amorphous silica content and large surface area can be produced by combustion of rice husk at controlled temperature. Suitable incinerator/furnace as well as grinding method is required for burning and grinding rice husk in order to obtain good quality ash. Although the studies on pozzolanic activity of RHA, its use as a supplementary cementitious material, and its environmental and economical benefits are available in many literatures, very few of them deal with rice husk combustion and grinding methods. The optimized RHA, by controlled burn and/or grinding, has been used as a pozzolanic material in cement and concrete. Using it provides several advantages, such as improved strength and durability properties.

3) Chemical Admixture:

Chemical admixture or superplasticiser was used in self compacting concrete. Superplasticiser help us in increase the workability of concrete without addition of water. Use of superplasticiser is economical as the cost of incurred on them is less than the cost of cement saved, this is more so in concrete designed for higher workability.

4) Specification of Chemical Admixture (with the reference of POLYGON CHEMICAL Pvt. Ltd.)

Chloride content <.02%

Colour	Amber brown
Form	Linuid
Specific gravity	1.24 ±1.26
Chloride content	0.2%

F. Silica Fume Generation:-

The raw materials for the production of silica fume are by-products from the production of silicon metal, and these by-products are further processed to produce cementitious materials for use in concrete. Silica fume is a by-product of the manufacture of silicon metal and Ferro-silicon alloys. The process involves the reduction of high purity quartz (SiO2) in electric arc furnaces at temperatures in excess of 2,000°C. Silica fume is a very fine powder consisting mainly of spherical particles or microspheres of mean diameter about 0.15 microns, with a very high specific surface area (15,000–25,000 m2/kg). Each microsphere is on average 100 times smaller than an average cement grain. At a typical dosage of 10% by mass of cement, there will be 50,000–100,000 silica fume particles per cement grain. Fig.

Chemical properties		
S.No.	compositions	Silica fume
1.	Calcium oxide (Cao)	0.28
2.	Silicon dioxide (Sio2)	95.0
3.	Aluminium oxide (Al203)	0.1
4.	Iron oxide (Fe203)	0.48
5.	Magnesium oxide (Mgo)	0.2
6.	Potassium oxide (K20)	0.1
7.	Sodium oxide (Na2O)	0.4
8	Titanium dioxide (TiO2)	Nill
9.	Loss of ignition	1.65

Physical properties		
S.No.	Property	Silica fume
1.	Specific Gravity	2.2
2.	Bulk Density(kg/m3)	1710 - 1810
3.	Absorption (%)	1.0 - 1.5
4.	Moisture (%) Content	Nil
5.	Fine particles less than 0.075mm (%)	12 – 15
6.	Sieve Analysis	ZONE II

G. Fly Ash

Fly ash is a by-product obtained during the process of combustion of pulverized coal in electric power generating plants. Fly Ash has particles of diameter about 10 – 25 µm. The particles are smooth and spherical. This improves fluidity of the SCC mixture. Also, Fly Ash has pozzolanic properties where it reacts with calcium hydroxide, to produce calcium silicate hydrate, which is the product formed during hydration of cement. This helps in strength gain at later ages of curing and reduces heat of hydration which in turn reduces free shrinkage of concrete, resulting in a reduction of thermal shrinkage cracking. Fly ash also refines the pore structure of concrete and decreases its permeability, which has good implications on durability and long-term strength. The quality of slag is governed by IS: 3812-1 2003.

The objective of this study is to produce nine SCC mixtures that combine FA at 25 %–70 %. The workability criterion for the SCC production was satisfied by keeping the water-cementitious materials ratio (w/b) and superplasticizer quantities constant. Tests of the fresh concrete and hardened concrete, in order to find the correlations between the compressive strength and other properties, were also conducted. These tests are especially important for SCC, which includes high volumes of supplementary cementitious materials, to ensure that it is a suitable material for the construction industry economically and sustainably.

IV. METHODOLOGY

Modified Nan Su Method The important parameter in SCC is the mix proportioning methodology. So far a proper mix design procedure to get the proportion of the ingredients in SCC is not standardized. No method specifies the grade of concrete in SCC except the Nan Su method. Unlike other proportioning methods like the Okamura and EFNARC methods, it gives an indication of the target strength that will be obtained after 28 days of curing. But the limitation of this method is, it does not give required mix proportions for normal grades (grades less than M50). Research shows that the cement content was not sufficient to attain the required strength for normal grades. So a number of trials are required to attain the target strength. To avoid the number of trials and to satisfy the requirement of strength of the mix some modifications are made in the Nan Su method. Here, the mix designs were carried out for M30 grade concrete and are based on the modified Nan Su method.

A. Physical properties of coarse aggregates (20mm and 10mm size)

- Sieve analysis and fineness modulus
- Specific gravity
- Water absorption

B. Physical properties of fine aggregates

- Sieve analysis
- Specific gravity
- Water absorption

C. Superplasticizer

D. Dosage

E. Mix design.

F. Mixing of concrete

G. Preparation of specimen

H. Testing of specimen for compressive strength.

I. EFNARC-GUIDELINE

EFNARC has prepared specification and guidelines for self-compacting concrete for European Nation for the both at site and in precast concrete works. The test methods have been standardized. The some countries like Germany, Norway, Turkey and Sweden have their own national companion codes. There is no Indian national code explicitly covering self-compacting concrete, IT is possible to specify SCC within the BS 8500 systems using the proprietary concrete category. Based on the current state of knowledge, the following performance specifications for SCC have been achieved through proper mix design and testing.

- Work ability in terms of slump flow > 700 mm
- Remain flow able ≥ 90 minutes
- Pump able ≥ 90 minutes through pipes >100 meter long
- Mechanical properties
- 28 days compressive strength similar to HPC
- Creep and shrinkage similar to HPC
  Durability parameter ≥ HPC

In design the mix it is most useful to consider the relative proportions of the key component by volume rather than by mass.

- Water / powder ratio by volume of 0.80 to 1.10
- Total powder content – 160 to 240 liters (400-600 kg) per cubic meter
- Coarse aggregate content normally 0%-20% percent by volume of the mix.
- Water cement ratio is selected based on requirements in EN 206. Typically water content does not exceed 200 liter/m3.
- The sand content balanced the volume of the other constituents

1.7.1 Workability standards:
Slump flow = 650-800 mm
T-50 cm slump flow 2-5 seconds V-
funnel 8-12 seconds
L-box H2/H1 = 0.8-1.0

1) For getting the design of self-compacting concrete without replacement (S0) for checking the strength of design, some testing cubes were casted and tested for 7 days and 28 days. Test results are show in table 3.

No. of days	Cube1 strength (N/mm^2)	Cube2 strength (N/mm^2)	Cube3 strength (N/mm^2)	Average compressive strength (N/mm^2)
7 days	33.89	32.56	33.00	33.15
28 days	43.67	43.72	44.11	43.67

Table 3.13 Strength of cubes

Immediately after concrete mixing, slump flow test followed by slump flow diameter (spread) L-box, V-funnel were conducted. Mould size150×150×150mm were cast without any compaction for strength testing. Total 78 samples have been casted. For each mix 6 samples were prepared, which consist of 6 cubes for 7 and 28 days compressive strength. The square specimens were released from mould after 24 hour and then specimen cured with water for 7 and 28 days.

Cement Kg	Fine aggregate Kg	Coarse aggregate Kg	W/C ratio
442.00	975.00	737.00	190
1	2.20	1.67	0.40

Table 5: Mix Proportions by WEIGHT

V. RESULTS AND DISCUSSIONS:

The present study reports the results of experimental study conducted to evaluate compressive strength of concrete, by partial replacement of cement by various percentages of fly ash rice, husk ash and silica fume. The compressive strength tests are done. 26 sets sample of concrete such as 0% of plane concrete and fly ash content is from 5%, 10%, 15%, 20% whereas rice husk ash content is from 5%, 10%, 15%, 20%. The binary blends content such as silica fume partial replacement of cement by various percentages are 5%, 10%, 15%, 20%. Each set consist three no. of specimens. Therefore total 78 cubes specimen were tested for 7 and 28 days compressive strength.

In the present analysis the cement is replaced by ash rice, husk ash and silica fume up to 20% by weight of cement and quantities of the fine aggregate and coarse aggregate are kept constant i.e. 975 kg/m3 and 737 kg/m3 respectively.

The water powder ratio is kept 0.40 by weight. For this the total powder content is taken as 442 kg/m3. The mixes thus prepared to follow the EFNARC guidelines. As the quantity of fly ash, rice ash silica fume increases from 0 to 20%, the quantity of super plasticizer reduces significantly from 9.0 kg/m3 to 5.40 kg/m3, 2% by weight of cement. The results of slump flow (spread), slump flow time and V-funnel flow time are summarized in Table 1. The following table presents the findings based on the various fresh properties tests conducted.

A. Slump flow:

Slump flow is the common test to assess the horizontal free flow of fresh concrete. Slump flow results from all the mixes are within the EFNARC range of 650 - 800 mm. By adding mineral admixtures in the cement, slump flow increased at satisfactory level when compared with conventional SCC

S.NO.	MIX DISCRIPTION	Slump Flow (mm)	V-funnel (sec)
1	normal (0%)	670	12.0
2	FA(5%)	678	9.0
3	FA(10%)	680	8.7
4	FA(15%)	685	8.6
5	FA(20%)	688	8.3
6	RHA(5%)	662	8.8
7	RHA(10%)	665	8.7
8	RHA(15%)	670	8.7
9	RHA(20%)	677	8.3
10	SF (5%)	680	8.5
11	SF(10%)	689	8.3
12	SF(15%)	690	8.4
13	SF(20%)	695	8.0

Table 1: fresh property test result

B. Experimental Test Result

Mechanical properties like 7 and 28 days compressive strength tests were investigated. Table 2 presents the mechanical properties of SCC mixes made with 5% to 20 % of fly ash and Table 3 presents the mechanical properties of SCC mixes made with 5% to 20 % rice hush ash. Table 4 presents the mechanical properties of SCC mixes made with 5% to 20 % of silica fume. Table 7. Checking the Strength of cube for 7days and 28 days. (For Nominal Mix)(M30)

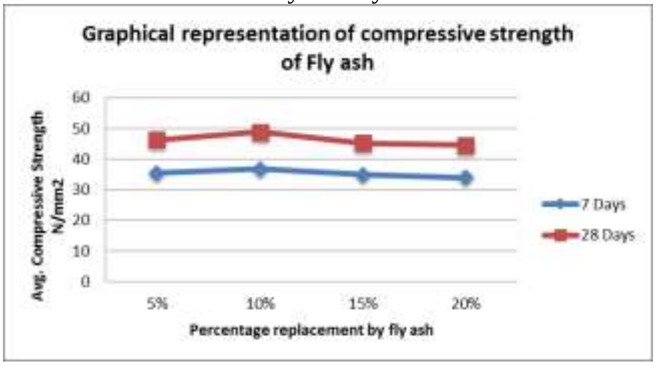
C. Compressive Strength Test:

For Compressive strength test standard cube size of 150mm x 150mm x150mm are used. An average of three specimens is taken for all mixes. A compressive testing machine of 2000 KN capacity with a least count of 10 KN was used for testing the Compressive strength is obtained by applying crushing load on the cube surface. So it is also called as Crushing strength. Compressive strength is regarded as the paramount property of any concrete mix. Cubes are cast with cement replaced with varying percentages of fly ash rice husk ash and silica fume test the compressive strength. The test results are presented here for the compressive strength of 7 days, 28 days. Compressive strength of the specimens the specimens are water cured for 28 days. The specimen was placed on the platform of the compression testing machine. The load was applied gradually until the failure stage. The specimens were tested after a curing period of 28 days. The ultimate load was noted and calculated the compressive strength of corresponding specimen.

S.No.	Designation	Compressive strength 7 days N/mm^2		Average compressive strength 28 days N/mm^2	
		7 days	28 days	7 days	28 days
1	FA 5%	35.66	46.33	35.37	46.33
		35.66	45.89		
		34.78	46.78		
2	FA 10%	36.11	47.67	36.70	48.81
		37.00	48.56		
		37.00	47.22		
3	FA 15%	35.22	44.56	34.93	45.15
		34.33	45.89		

		35.22	45.00		
4	FA20%	34.33	44.11	33.89	44.56
		33.00	45.00		
		34.33	44.56		

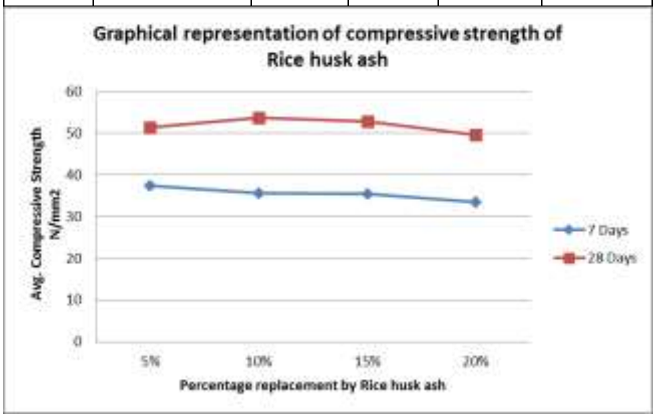
Table 4.2: Result of Compressive strength testing for 7 and 28 days for fly ash



Graph 1: Compressive strength for 7 days and 28 days for partial replacement of cement by fly ash.

1) Result of Compressive strength testing for 7 and 28 days for rice husk ash

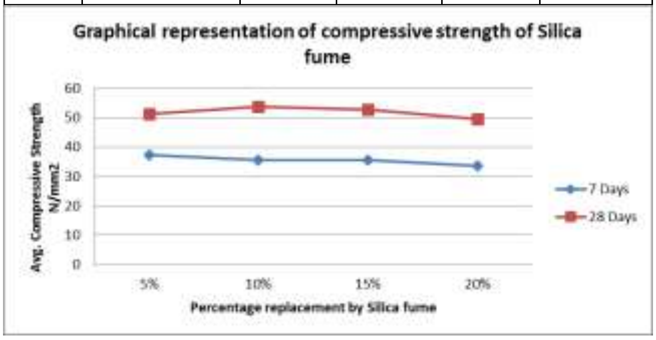
S.No.	Designation	Compressive strength N/mm^2		Average compressive strength N/mm^2	
		7 Days	28 Days	7 days	28 days
		25.78	39.89		
1	RHA 5%	25.56	40.88	25.85	40.37
		26.23	40.34		
		24.44	38.56		
2	RHA 10%	24.00	39.78	24.23	40.86
		24.23	39.23		
		23.12	37.45		
3	RHA 15%	22.23	36.89	22.67	36.48
		22.67	35.11		
4	RHA 20%	22.89	36.23	22.01	36.13
		21.78	36.00		



Graph 2: Compressive strength for 7 days and 28 days for partial replacement of cement by Rice husk ash

2) Result of Compressive strength testing for 7 and 28 days for Silica fume

S ON.	Designation	Compressive strength 7 days N/mm^2	Average compressive strength 28 days N/mm^2		
		7 days	28 days	7 days	28days
		37.55	51.33		
1	SF 5%	37.55	50.89	37.37	51.33
		36.98	51.78		
		35.11	52.67		
2	SF10%	36.00	53.56	35.70	53.81
		33.33	52..22		
		34.22	50.87		
3	SF15%	35.28	52.46	35.53	52.81
		33.56	49.22		
		32.20	48.50		
4	SF20%	33.30	50.40	33.34	49.67
		31.50	50.30		



Graph 3: Compressive strength for 7 days and 28 days for partial replacement of cement by Silica fume

VI. DISCUSSION ON RESULTS

Based on the experiments conducted on M-30 grade of concrete and partially replacement of cement with varying percentage of fly ash, rice husk and silica fume the following points are observed.

1) The workability of concrete increases with increasing percentage of fly ash and silica fume replacement level.
2) The workability of concrete decreases with increasing percentage of rice husk ash replacement level.
3) On replacement of 5%, 10%, 15% and 20% fly ash as partial replacement of OPC, the 28 days strength increases by 6.78%, 12.78%, 4.60%, 2.88% of concrete respectively.

Whereas replacement of 5%, 10%, 15% and 20% silica fume as partial replacement of OPC, the 28 days strength increase by 17.81%,and 23.58%, 21.25%, 11.05% of concrete respectively.

Whereas replacement of 5%, 10%, 15% and 20% rice husk ash as partial replacement of OPC, the 28 days strength decreases 5%, 15% and20% by 3.07%, and 5.02%, 21.25%, 10.05% increase by10% by0.44% of concrete respectively.

The partial replacement of OPC with 15% fly ash, rice husk ash and silica fume was found to be maximum, as compare to plane concrete. The increase in 28 days compressive strength at 10% replacement was found to be 25.58%. respectively. Concrete attain maximum compressive strength when exposed to 0.44%.. When the replacement exceeds 20%, the compressive strength is found to be decreasing.

VII. CONCLUSIONS

In this study to develop self-consolidating concrete (SCC) by incorporating two different type of supplementary cementing materials and their different proportions. 26 set of concrete mixtures were developed based on a control SCC mix. Fly ash, rice husk and silica fume were the materials used as supplementary cementing material (SCM). Mixtures were produced with different percent of Fly ash, rice husk and silica fume from 5% to 20% properties of all 26 mixtures including the control SCC were evaluated. The fresh properties of the concrete mixtures were evaluated using empirical methods such as slump flow (spread) and V-funnel flow time tests. In addition the hardened properties such as compressive strength tests were conducted and evaluated. The ability of SCC mixtures to flow was evaluated using the slump flow test tests. The slump flow for the various SCC mixtures varied between 662 and 695 mm. the self-consolidating properties for all mixtures were considered satisfactory.

The fresh state properties were assessed as per EFNARC guideline such as slump flow. Based on the above investigation the following conclusion has been drawn:-

1) With increase in Fly ash, rice husk and silica fume blends content the flow ability of concrete improves (The slump flow increases from 662 mm to 695 mm for W/B= 0.40).
2) The reduction in V-funnel time from 12 sec to 8 sec (for W/B= 0.40) also indicate that content of Fly ash, rice husk and silica fume resulted a greater flow ability.
3) The addition of fly ash resulted in a decreases of super plasticizer content for same or better workability.
4) Among different replacement level, the use of Fly ash, rice husk and silica fume at the replacement level of 10% performed the best, which resulted in the highest strength increase over the control concrete at all the test ages.

All of the SCC mixtures made by incorporating various proportions of Fly ash, rice husk and silica fume satisfies the criteria for SCC and hence are recommended for use in construction of different applications.

1) The compressive strength at the age of 7 days and 28 days was increased at mix M3 of about 23.58% than the Nominal mix of concrete M30.
2) As the Percentage of fly ash silica fume powder in concrete increases.
3) Compressive strength increase as percentage of rice husk ash powder in concrete increases.
4) The strength achieved with the replacement of 5% fly ash and silica fume powder shows highest compressive strength. When increases varying percentage of rice husk ash compressive strength is reduced.

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