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A Comparative Study on Mechanical Properties of Normal Vibrated Concrete and Self Compacting Concrete

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Abstract: **Self- Compacting Concrete (SCC) is a special type of concrete that is able to flow and compact under its own weight and can occupy all the spaces in the form without any vibration effect and at the same time cohesive enough to be handled without bleeding or segregation. SCC is a highly flowable concrete which is able to fill the formwork with admixtures such as Fly Ash (FA), Silica Fume (SF), Ground Granulated Blast Furnace Slag (GGBFS), and Metkaolin (MK) etc. There are no standard mix design procedures available for SCC. In the present work, Normal Vibrated Concrete (NVC) and SCC were developed for M30 grade. NVC is designed by using IS code method and SCC is designed by using Nan Su method. Study of SCC with and without mineral admixtures such as SF and FA was made separately at different percentages as 10%, 20%, and 30% respectively by using appropriate dosage of super plasticizers (SP) and viscosity modifying agent (VMA).The workability properties of SCC such as filling ability, passing ability and segregation resistance are evaluated using workability tests such as slump flow, V-funnel and L-Box tests. Strength properties such as compressive strength, split tensile strength and flexural strength of NVC and SCC were also studied.**

Keywords: **The Self-Compacting Concrete (SCC), Normal Vibrated Concrete (NVC), Fly Ash (FA), Silica Fume (SF), super plasticizers (SP).**

I. INTRODUCTION

SCC is basically a concrete which is capable of flowing into the form work, without segregation, to fill uniformly and completely every corner of it by its own weight without any application of vibration or other energy during placing. SCC was first introduced in the late 1980's by Japanese researchers named Okamura. The main drive for the development of SCC and its research were the endangered durability of reinforced concrete structures, need for easier and high-quality fresh concrete placement and lack of skilled labour force.

Bertil Persson (2001) [1] carried out an experimental and numerical study on mechanical properties, such as strength, elastic modulus, creep and shrinkage of self-compacting concrete and the corresponding properties of Normal Compacting Concrete (NCC) and concluded that the elastic modulus, creep and shrinkage of SCC did not differ significantly from the corresponding properties of NCC.

Nan Su et al (2001) [2] proposed a new mix design method for self-compacting concrete. First, the amount of aggregates required was determined, and the paste of binders was then filled into the voids of aggregates to ensure that the concrete thus obtained has flowability, self-compacting ability and other desired SCC properties. The amount of aggregates, binders and mixing water, as well as type and dosage of super plasticizer to be used are the major factors influencing the properties of SCC. Slump flow, V-funnel, L-flow, U-box and compressive strength tests were carried out to examine the performance of SCC, and the results indicated that the proposed method could be used to produce successfully SCC of high quality. Compared to the method developed by the Japanese Ready-Mixed Concrete Association (JRMCA), this method is simpler, easier for implementation and less time-consuming, requires a smaller amount of binders and saves cost.

Hajime Okam.ura and Masahiro Ouchi (2003) [3] addressed the two major issues faced by the international community in using SCC, namely the absence of a proper mix design method and jovial testing method. They proposed a mix design method for SCC based on paste and mortar studies for super plasticizer compatibility followed by trail mixes. However, it was emphasized that the need to test the final product for passing ability, filling ability, flowability and segregation resistance was more relevant.

Paratibha Aggarwal et al (2008) [4] presented a procedure for the design of self-compacting concrete mixes based on an experimental investigation. At the water/powder ratio of 1.180 to 1.215, slump flow test, V-funnel test and L-box test results were found to be satisfactory, i.e. passing ability, filling ability and segregation resistance developed without using VMA in this study. Further, compressive strength at the ages of 7, 28, and 90 days was also determined. By using the OPC 43 grade, normal strength of 25 MPa to 33 MPa at 28-days was obtained, keeping the cement content around 350 kg/m^3 to 414 kg/m^3.

Venkateswara Rao et al (2010) [5] developed standard and high strength self-compacting concrete with different sizes of aggregate based on Nan su's mix design procedure. The results indicated that Self Compacting Concrete can be developed with all sizes of graded aggregate satisfying the SCC characteristics. The mechanical properties such as compressive strength, flexural strength and split tensile strengths were found at the end of 3, 7 and 28 days for standard and high strength SCC with different sizes of aggregate. The optimum size of aggregate was found to be 10mm for standard self-compacting concrete (M30), while it was 16mm for high strength self-compacting concrete (M70) though all other sizes also could develop properties satisfying the criteria for SCC. A comparison of M30 and M70 grade concrete confirmed that the filling ability, passing ability and segregation resistance were better for higher grade concrete for the same size of aggregate. This is due to the higher fines content in M70 concrete. It was noted that 10mm size aggregate and 52% fly ash resulted in highest mechanical properties in standard SCC, whereas 16 mm size aggregate with 31% fly ash content resulted in highest strength in case of high strength SCC.

Chockalingam. M (2014) [6] carried out an experimental investigation to evaluate about Self-Compacting concrete which gets compacted under its self-weight. In this experimental work different percentages of marble powder (MP) and silica fume (SF) are added. Experiments are carried out for the effective replacement of cement with silica fume (0%, 15%, 20%, 25%, 30%) and Marble powder (15%). The results show that 15% to 20% replacement of cement with silica fume and 15% marble powder improves the properties of SCC.

II. MATERIAL USED

A. Cement:

All through the experimental study, Ordinary Portland Cement of 53grade (ultratech cement) conforming to IS 12269-1987 was used and properties are shown below in Table 1.

TABLE I: PROPERTIES OF CEMENT

S.no	Properties of Cement	Result
1.	Normal consistency	31%
2.	Initial setting time	120 min
3.	Final setting time	250 min
4.	Specific gravity	3.11
5.	Compressive strength of cement at 28 days	55.6 N/mm^2

B. Fine Aggregate:

Fine aggregate used in the present study is from the river bed of Tungabhadra, Kurnool. The sieve analysis of F.A has been carried out as per IS 383-1970 and from that it is confirmed to grading zone-II and other properties of F.A are shown in Table 2.

TABLE 2 PROPERTIES OF FINE AGGREGATE

S.no	Properties of Fine Aggregate	Results
1.	Bulk density Kg/m^3	1650
2.	Specific gravity	2.68
3.	Fineness modulus	2.81

C. *Coarse aggregate:*

Normal coarse aggregate of size below 20mm available in local market is used and tested as per IS: 2386-1963(I, II, III) specifications and the properties are shown in Table 3.

TABLE 3 PROPERTIES OF COARSE AGGREGATE

S.no	Properties of Coarse Aggregate	Results
1.	Maximum nominal size, mm	20
2.	Bulk density Kg/m^3	1800
3.	Specific gravity	2.75
4.	Fineness modulus	4.6

D. Fly ash:

Fly ash is a by-product obtained during the process of combustion of pulverized coal in electric power generating plants. Fly ash produced from Raichur thermal power plant Karnataka, was used as partial addition for cement and its physical properties are shown in Table 4.

TABLE 4 PHYSICAL PROPERTIES OF FLY ASH

S.no	Properties of Fly Ash	Results
1.	Fineness Modulus of ash (passing through 75µ)	7.5
2.	Specific Surface area of particle	372
3.	Specific Gravity of fly ash	2.5

E. Silica fume:

The silica fume was used in this experiment conforms to ASTM C 1240 and IS 15388:2003 [8]. The silica fume is in white colour powder form. Silica fume has been procured from Astra chemicals Ltd-Chennai and properties are shown in Table 5.

TABLE 5 PROPERTIES OF SILICA FUME

S.no	Properties of Silica Fume	Results
1.	Particle size	0.5µm-1µm
2.	Pack density	0.76 gm /cm^3
3.	moisture content	0.058%
4.	Specific gravity	2.63

F. Water:

Fresh, colourless, odourless and tasteless potable water is used.

G. Super Plasticizer:

Conplast SP 430 super plasticising admixture procured from Fosroc Chemicals India Pvt. Ltd. Secunderabad and properties are as shown in Table 6.

TABLE 6 PROPERTIES OF SUPER PLASTICIZER

S.no	Properties of Super Plasticizer	Result
1.	colour	brownish
2.	density	1.2 kg/l
3.	Specific gravity	2.10
4.	air entrainment	1% (approximately)

H. Viscosity Modifying Agent:

Glenium stream 2 colourless free flowing liquid was used obtained from BASF India Ltd construction chemicals-Secunderabad.

III. WORKABILITY TEST FOR FRESH CONCRETE

The basic properties of SCC are specified by The European Federation of Specialist Construction Chemicals and Concrete Systems – EFNARC [7] guidelines. Fresh SCC must possess the key properties including filling ability, passing ability and resistance to segregation at required levels. The filling ability is the ability of the SCC to flow into all spaces within the formwork under its own weight. Passing ability is the ability of the SCC to flow through tight openings such as spaces between steel reinforcing bars, under its own weight. The resistance to segregation is the resistance of the components of SCC to migration or separation and remains uniform throughout the process of transport and placing.

The equipment's used for T50 slump flow and V-funnel test for filling ability of SCC are as shown in fig 1 and fig 2 and L-box test for passing ability of SCC is as shown in fig 3.

Fig: 1. Slump flow

Fig: 2. V-funnel

Fig: 3. L-box

Basic properties of SCC is specified by EFNARC are shown in table 7.

TABLE-7 BASIC PROPERTIES OF SELF-COMPACTING CONCRETE

S. No	**Method**	**Unit**	**EFNARC limit**
1.	slump flow by Abrams cone	mm	650-800
2.	T50cmslump flow	sec	2-5
3.	V-funnel	sec	Up to 12
4.	L-box	mm	0.8-1.0

IV. EXPERIMENTAL PROGRAM

In the present study NVC of M30 grade was designed by using IS code - 10262:2009 method and SCC of M30 grade was designed by using Nan Su method without mineral admixture. SCC with mineral admixtures such as SF and FA was made separately at different percentages as 10%, 20%, and 30% respectively by using appropriate dosage of super plasticizers (SP) and viscosity modifying agent (VMA).The slump, V-funnel and L-box tests are carried out on the fresh SCC. The strength properties such as compressive, split tensile and flexural strengths of normal vibrated concrete and self-compacting concrete were studied.

TABLE-8

S. no	**Mix type**	**Cement in Kg**	**FA in Kg**	**CA in Kg**	**Fly ash in Kg**	**Silica Fume in Kg**	**TP in Kg**	**Water in lit**	**W/P**	**S.P in lit**	**VMA in lit**
1.	**M30 NVC mix**	**371**	**702.856**	**1258.848**	**-**	**-**	**371**	**148.8**	**0.40**	**3.72**	**-**
2.	M30 SCC mix without mineral admixture	332.608	957.685	731.86	-	-	332.08	129.451	0.389	5.9869	0.5
3.	M30 SCC 10%F.A	332.608	957.685	731.86	33.260	-	365.868	142.395	0.389	6.585	0.5
4.	M30 SCC 20%F.A	332.608	957.685	731.86	66.521	-	399.129	155.340	0.389	7.184	0.5
5.	**M30 SCC 30%F.A**	**332.608**	**957.685**	**731.86**	**99.782**	**-**	**432.390**	**168.286**	**0.389**	**7.783**	**0.5**
6.	**M30 SCC 10%S.F**	**332.608**	**957.685**	**731.86**	**-**	**33.2608**	**365.868**	**142.395**	**0.389**	**6.585**	**0.5**
7.	M30 SCC 20%S.F	332.608	957.685	731.86	-	66.5216	399.129	155.340	0.389	7.184	0.5
8.	M30 SCC 30%S.F	332.608	957.685	731.86	-	99.7824	432.390	168.286	0.389	7.783	0.5

From each mix, the specimens of standard cubes (150mmx150mmx150mm), cylinders (150mm dia x300mm height) and beams (100mmx100mmx500mm) were cast with various percentages of FA and SF. Compression testing machine (2000 KN capacity) was used to find compressive strength and split tensile strength of specimens at 28 days. Universal Testing Machine (60T capacity) was used to test 28 days flexural strength of specimens.

The mix proportions of NVC and SCC for one cubic meter are summarized in Table 8.

The workability properties were obtained for the fresh SCC mixes of M30 grade of concrete is shown in Table 9.

TABLE-9 TEST PROPERTIES OF SCC FOR M30 GRADE

MIX TYPE	SLUMP FLOW	$T50_{CM}$SLUMP FLOW	V-FUNNEL	L-BOX
M30 SCC MIX	650	3.26	11	0.80
M30 10% F.A	660	3.89	9	0.83
M30 20% F.A	710	3.96	6	0.83
M30 30%F.A	720	4.12	6	0.96
M30 10%S.F	650	3.54	6	0.902
M30 20%S.F	690	3.36	6	0.846
M30 30%S.F	710	3.82	7	0.869

Compressive strength, Split tensile strength, and Flexural strength, of NVC and SCC mixes are as shown in table 10.

Table 10 - 28 DAYS STRENGTH RESULTS FOR NVC AND SCC OF M30 GRADE

MIX TYPE	COMPRESSIVE STRENGTH in N/mm^2	SPLIT TENSILE STRENGTH in N/mm^2	FLEXURAL STRENGTH in N/mm^2
M30 NVC MIX	**39.52**	**3.71**	**3.9**
M30 SCC MIX	31.39	3.09	3.15
M30 10% F.A	33.29	3.35	3.43
M30 20% F.A	35.48	3.62	3.72
M30 30% F.A	**38.89**	**3.67**	**3.79**
M30 10% S.F	**38.62**	**3.70**	**3.82**
M30 20% S.F	36.54	3.50	3.65
M30 30% S.F	32.36	3.34	3.45

V. RESULTS AND DISCUSSIONS

- NVC of M30 grade is designed as per IS code - 10262:2009 and attained compressive strength 39.52 N/mm^2 at 28 days.
- SCC was designed for M30 grade without mineral admixture and it gives less strength in comparison with NVC of M30 grade.
- SCC was produced by using mineral admixtures as additives separately such as FA and SF with different percentages like 10%, 20% and 30%.
- SCC with 30% FA addition gives nearly same strength of NVC of same grade.
- SCC with 10% SF addition gives nearly same strength of NVC of same grade.
- SCC containing 30% FA obtained maximum compressive strength and is as shown in Fig 4.

- SCC containing 10% SF obtained maximum compressive strength and is as shown in Fig 5.
- SCC containing 30% FA obtained maximum split tensile strength and is as shown in Fig 6.
- SCC containing 10% SF obtained maximum split tensile strength and is as shown in Fig 7.
- SCC containing 30% FA obtained maximum flexural strength and is as shown in Fig 8.
- SCC containing 10% SF obtained maximum flexural strength and is as shown in Fig 9.

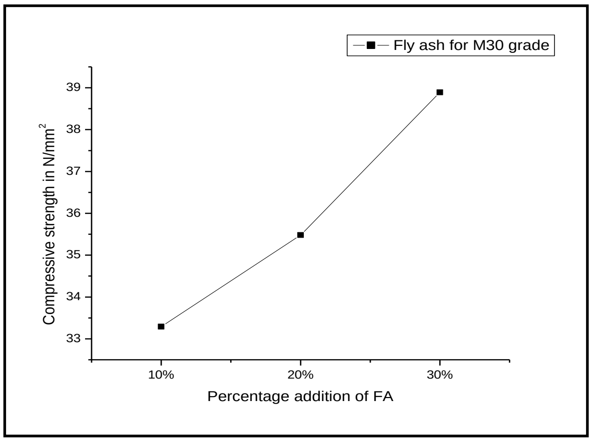

Fig 4 Compressive strength for FA

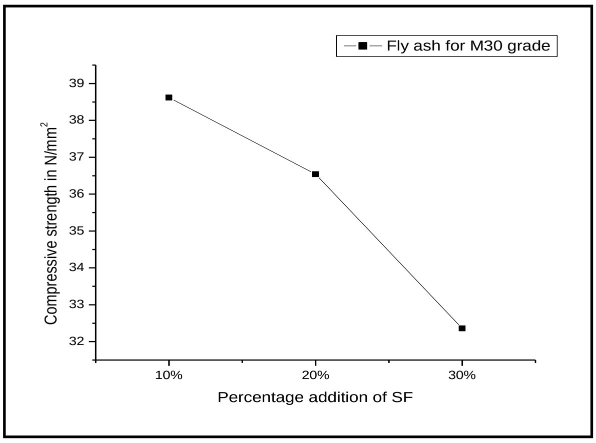

Fig: 5 Compressive strength for SF

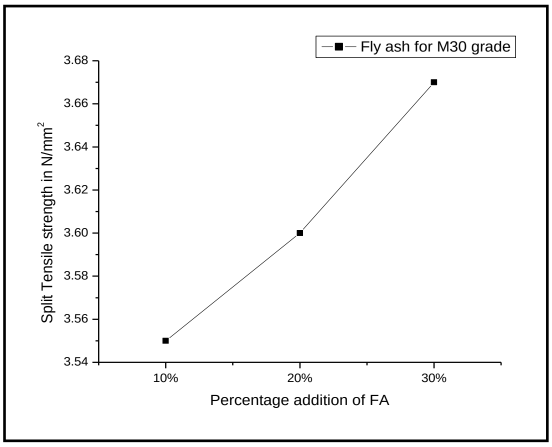

Fig 6 Split Tensile strength for FA

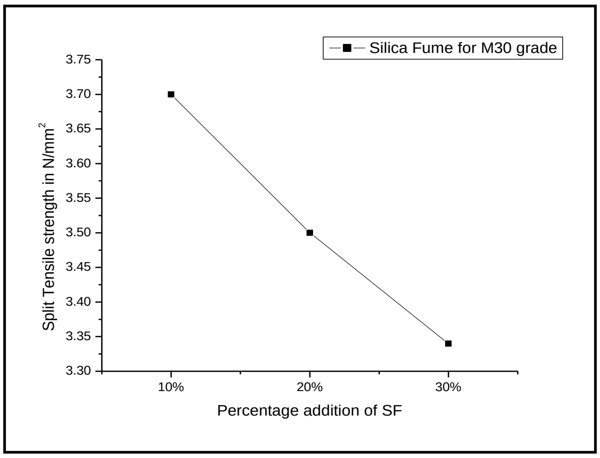

Fig 7 Split Tensile strength for SF

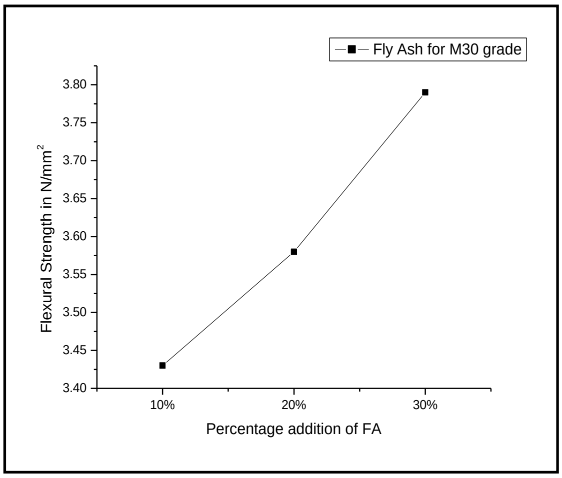

Fig 8 Flexural strength for FA

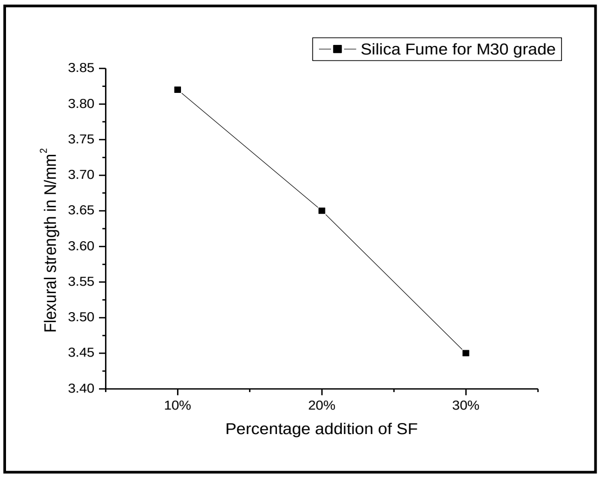

Fig 9 Flexural strength for SF

VI. CONCLUSIONS

The following conclusions were made based on experimental study on NVC and SCC of M30 grade using mineral admixtures FA and SF.

- SCC with 30% FA shows the maximum compressive strength, split tensile strength and flexural strength among all additive percentages of FA.
- SCC with 10% SF shows the maximum compressive strength, split tensile strength and flexural strength among all additive percentages of SF.
- SCC produce with 30% addition of FA achieved nearly same strength of NVC of same grade.
- SCC produce with 10% addition of SF is also obtained nearly equal strength of NVC of M30 grade.
- The percentage increase in compressive strength, split tensile strength and flexural strength at 30% FA for SCC M30 grade is 23.89%, 18.77%, 20.31% more than that of SCC without mineral admixture.
- The percentage increase in compressive strength, split tensile strength and flexural strength at 10% SF for SCC M30 grade is 23.03%, 19.74%, 21.58% more than that of SCC without mineral admixture.

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