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REHOLOGY BEHAVIOUR AND MECHANICAL PROPERTIES OF FLY ASH CONTENED SELF COMPACTING CONCRETE

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Abstract

Early SCC relied on very high contents of cementitious paste, the mixes required particular and well-controlled placing methods to avoid segregation, but the high contents of cement paste made them susceptible to shrinkage and high heat generation. The overall costs were very high and applications therefore remained very limited. After series of progressions it is no longer a material consisting of cement, aggregates, water and admixtures. Now a day SCC is a hot topic in the industry and that there are possibilities of using it for a wide variety of purposes.

Self-Compacting Concrete is considered to be the most hopeful building material for the expected revolutionary changes on the job site as well as on the desk of designer civil engineers. Self-compacting concrete consists basically of same components as normal vibrated concrete except that excess of the finer material as water reducing agent, is used. SCC has excellent deformability, high resistance to segregation and can filled in heavily reinforced section without applying any vibration. This paper presents a brief review note on the state-of-the-art of self-compacting concrete using waste material, future sustainability and an eco-environment friendly concrete.

Keywords:

Rehology;

Mechanical Property;

SCC;

Fly Ash;

Fresh Concrete;

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In economic point of standard SCC is hardly 10-15% costlier, but it reduces the site man power and time of project completion. This concrete provides thinner section, desired architectural view and freedom in structural design. In environment point of view many industrial wastage like fly ash, silica fume, steel waste fibers, glass fibers, solid waste of stone industries, rice husk ash, slag waste, petroleum waste, and ground granulated blast furnace slag waste which contributes in global warming as well as their Sevier disposal problem. The present research work aim at the viability of the possible utilization of the natural river sand locally available and fly ash for the development of the self compacting concrete and shall include the following points for the properties, durability and repair application study of fibrous self compacting concrete and self compacting concrete:

1. Introduction

A concrete that is capable of consolidating under its own weight & occupying all the spaces in the forms, without segregation & without any external compaction effort, is termed as Self Compacting Concrete (SCC).”SCC is ideally suited for the concreting of structures, which have heavily congested reinforcement or wherein access for concreting is difficult. The problem of the durability of concrete structures due, among other things, to a significant reduction in the number of skilled workers in Japan's construction industry has led to the development of SCC in the beginning of 1990s. SCC originated in Japan and being used about 30% of concrete. Now it is developed all over world and replacing conventional concrete. Self-consolidating concrete is an emerging technology that utilizes flow able concrete that eliminates the need for consolidation. However, the basic principles of this material are substantially based on those of flowing, unsegregable, and super plasticizers. The most important benefit of SCC is the increase in durability.

SCC has proved to be a most revolutionary material in the field of concrete technology especially in the last one decade. Super plasticizer is one of the essential constituents of SCC. It is important that the properties of SCC are maintained for an

Adequate period of time, 90 min. or more after completion of mixing so that concrete can be properly transported & placed. This paper deals with three aspects of future sustainable development of SCC i.e. economic, social, and environmental effect.

It can be regarded as "the most revolutionary development in concrete construction foe several decades". Originally developed to offset a growing shortage of skilled labour. This concept is now taken up as the concrete that meets special performance and uniform requirements that cannot always be obtained by using conventional concrete. Early SCC relied on very high contents of cementitious paste, the mixes required specialized and well-controlled placing methods to avoid segregation, but the high contents of cement paste made them prone to shrinkage and high heat generation. Generally it seems that the overall costs were high and applications therefore remained limited but it is not true. It has proved beneficial economically because of a number of factors as noted below:

- Faster Construction,
- Reduction in manpower,
- Easier Placing,
- Uniform and complete compaction,
- Better surface finish,
- Improved durability,
- Increased bond strength
- Greater freedom in design,
- Reduced noise levels, due to absence of vibrations and
- Safe working environment

The widespread research carried out by the various researchers in the field of the SCC including need, development and study of the properties of fresh and hardened, strength behaviour, mix design procedures of conventional concrete, SCC mix is reviewed. Based on the detailed literature review the following observations can be made on the present state-of-art of self compacting concrete technology.

- Concrete strength is affected by many factors, which made the concrete.
- Coarse aggregate contains is limited to 50% of the degree of packing for avoiding collision and contact in the SCC mix.
- Fine aggregate is limited to 60% of the degree of packing.
- W/P ratio and superplasticizer dosages are varied so as to obtain SCC. This is varied to obtain the required range of yield stress and viscosity for self compactability.
- It is found that by controlling some parameters of fresh concrete, the hardened properties of hardened concrete can be significantly improved.

SCC mixes must meet three properties

a) Ability to flow in to and completely fill intricate and complex forms under its own weight.

b) Ability to pass through under its own weight and bond to congested reinforcement.

c) High resistance to aggregate segregation.

Numbers of methods are available for proportioning SCC Mixtures. They can be broadly classified in to four categories.

1. Empirical Method
2. Rheology based methods
3. Particle packing models
4. Statistical methods

Rheology based method require rheometers which are very costly (starts more than 10 lakhs) to make justification for use in SCC design. So it is not possible to adopt these methods. Particle packing models may further be classified as discrete and continuous models. Discrete models are based upon the assumption that each class of the particles will pack to its maximum density in volume available.

Before proceeding towards the objective of the study certain assumptions and limitations were discussed. The assumptions made were as follows:

- Cement, fine Aggregate and coarse aggregate as required in bulk and tested only initially for their physical characteristics and variation during casting schedule have not recorded. Although same lot of material were used.

- It is assumed that whole of the material having same property as initially found.
- The relative humidity and temperature at the casting place remain significant.
- The 3 and 7 days curing was done in normal mode but the 28 days equivalent curing was executed in accelerated curing tank in controlled conditions Concept of maturity was applied for equivalence.
- Calibration of the compression testing machine was carried out before and after testing schedule and found almost equal. It is unlikely to affect the results.
- The properties of superplasticizer Glinium51 was taken as provided by the manufacturer of the products.
- The properties of fly ash were taken as per the testing reports of the "Suratgarh Thermal Power Plant Station".
- The fly ash procured in controlled conditions without strict control over temperature and relative humidity at the storage place.
- The durability process of the various mixes was performed in accelerated mode with higher consternations of chlorides and high temperature ranging 40-60 degree. Equivalence of shorter span cycles was attempted with normal deterioration process.
- Change in the combinations (i.e. the properties and source of ingredients, types and grades of concrete, type of fibers, durability parameters etc.) Studied can affect the overall strength and durability parameters of the various types and grades of the concrete.

On the basis of experimental study of the parameters, the detailed interpretations were made for all the selected parameters for strengths and durability.

2.Pozzolanic Materials

IS: 456 – 2000 allows the use of the fly ash and others in certain percentage as supplementary pozzolanic materials as shown in Table 2.5 to improve the durability and strength performance of concrete. Many researchers have found that the addition of fly ash in concrete improves the performance and durability of the concrete. The utilization of these thermal power plants waste (like flyash) as supplementary cementitious material in concrete reduces the cost of the construction and also improves energy saving with ecological benefits.

Table 1: Mineral Admixtures (IS 456 - 2000)

Material	Permissible Cement Replacement	Blended Products
Fly ash	10% to 25%	Portland Pozzolona Cement (PPC)
GGBS	25% to 65%	Portland Slag Cement (PSC)
Silica fume	5% to 10%	-
Rice husk ash	Depend upon quality	-
Metakaolin	Depend upon quality	-

Table 2: Physical Properties of Fly Ash (form Source)

S. No.	**Physical Properties**	**Test Results**
1.	Colour	Light Grey
2.	Fineness (m^2/Kg)	224.0
3.	Specific Gravity	2.23
4.	Bulk Density (Kg/m^3)	700
5.	Lime Reactivity -average compressive strength after 28 days of mixture	6.4 MPa

Table 3 Chemical Properties of Fly Ash (form Source)

Sr. No.	**Constituents**	**Percent by Weight**
1.	Loss on ignition	2,03
2.	Silica (SiO_2)	64.77
3.	Iron Oxide ($Fe_2O_3 + Fe_2O_3$)	3.98
4.	Alumina (Al_2O_3)	5.98
5.	Calcium Oxide (CaO)	4.88
6.	Total Sulphur (SO_3)	0.14

3.Developments of Various Concrete Mixes

3.1 Normal Conventional Concrete (NC)

In Indian scenario, more than 50 percent of total concrete produced having low to medium strength. Therefore considering wide range applicability, concrete mixes up to M40 grades are selected for this study. In first phase M25, M30, M35 and M40 grades of conventional concrete was designed (Table 4.1) in accordance with IS: 10262-2009 and IS: 456-2000 assuming good degree of quality control and moderate exposure condition using natural sand as fine aggregate. The concrete mix proportions per cubic meter of concrete are tabulated in Table 4.1 for comparative study. The same grades of Self Compacting concrete (SCC) and Fibrous Self Compacting Concrete (FSCC) mixes were also designed.

3.2 Self Compacting Concrete (SCC) and Fibrous Self Compacting Concrete (FSCC):

With the latest development in SCC, the purpose of the research efforts has been to make SCC a standard concrete rather than special one. The EFNARC (2005) specification defines specific requirements for the SCC material, its composition and application. This includes the useful data and guidance to designers, concrete manufactures, contractors, specifying authorities and testing organizations.

An attempt was initially made to obtain the constituents of SCC mixes based on general guide lines given by Okamura (1997), Nan et al (2001) and EFNARC (2005). Using the mix quantities of the different ingredients obtained from EFNARC methods, mixes have been prepared and checked for their self compactability. The ingredients obtained from the mix design method and the self compactability tests results were reported in Table 4.2 for present work. The SCC mixes were tested to check their rheological as well as hardened properties. The rheological properties of SCC mixes are studied by conducting different laboratory tests. An iterative by trial and error procedure is adopted, till a homogeneous, stable and consistent SCC mix is obtained.

3.3 Test Methods for developing SCC Mixes

Equipments required in order verifying the requirements of self compactability used to check the three important rheological properties (filling ability, passing ability and segregation resistance) of self compacting and fibrous self compacting concrete.

The sequential procedure adopted in this study is as follows: Initially mix proportion was obtained for a reference normal conventionally compacted concrete mix using IS method of design (IS: 10262 – 2009). In the absence of any codal recommendation available for design of self compacting concrete (SCC), the proportions were altered based on the EFNARC guidelines. As per the guidelines, usually the coarse aggregate varies from 28% to 35% of the total mass of concrete and fine aggregate balances the volume of the other constituents. The coarse and fine aggregate contents are fixed by trials so that self – compactability can be achieved with adjustment in the water powder ratio and viscosity modifying agent quantity.The following typical range of proportions and quantities as given by EFNARC are used as guide lines.

- Water/powder content by volume 0.8 – 1.1
- Total powder content 400 -600 Kg/m^3 [160 to 240 $liters/m^3$]
- Coarse aggregate content 28% to 35% by volume of the mix
- Water content < 200 Kg/m^3
- Sand content is used to balances the volume of the other constituents
- Adjust the superplasticizer and VMA dosage

Based on the above guidelines, the trail mixes of self compacting concrete and fly ashself compacting concrete were arrived at. Initially the required amount of all dry materials such as coarse aggregate, fine aggregate, fly ash and cement were mixed for 1 minute. Then 50%of water was added slowly and mixing continued for 5 minutes. Finally, the remaining water remixed with superplasticizer is added and mixing continued for 2 minutes. Then the fresh concrete is tested for the rheological properties of self compacting concrete and fibrous self compacting concrete. Once various criteria of self compactability of mix were satisfied, the test specimens (cubes and beams) were cast.

4. Test Results & Interpritattion

4.1 Flexural Strength

Standard beams of 100 mm X 100 mm X 500 mm size beam were casted for 7 days and 28 days flexural strength test. The flexural strength of three beams with its average value and standard deviation were reported in this section.

Table 4.16: Flexural Strength (N/mm^2) of NC at 7 Days

S No.	Mix	Beam 1	Beam 2	Beam 3	Average Strength	Standard Deviation
1	NC 25	3.34	3.73	4.12	3.73	0.39
2	NC 30	4.32	4.91	4.32	4.51	0.34
3	NC 35	5.10	4.32	5.30	4.91	0.52
4	NC 40	5.89	4.71	5.49	5.36	0.60

Table 4.17: Flexural Strength (N/mm^2) of SCC at 7 Days

S No.	Mix	Beam 1	Beam 2	Beam 3	Average Strength	Standard Deviation
1	SCC 25	2.94	3.14	3.92	3.34	0.52
2	SCC 30	3.73	3.92	4.32	3.99	0.30
3	SCC 35	4.32	4.32	5.49	4.71	0.68
4	SCC 40	4.91	4.71	5.10	4.91	0.20

Table 4.18: Flexural Strength (N/mm^2) of FSCC at 7 Days

S No.	Mix	Beam 1	Beam 2	Beam 3	Average Strength	Standard Deviation
1	FSCC 25	3.92	4.91	4.32	4.38	0.49
2	FSCC 30	5.10	5.30	5.89	5.43	0.41
3	FSCC 35	5.69	6.08	5.89	5.89	0.20
4	FSCC 40	6.28	5.89	6.08	6.08	0.20

Table 4.19: Flexural Strength (N/mm^2) of NC at 28 Days

S No.	Mix	Beam 1	Beam 2	Beam 3	Average Strength	Standard Deviation
1	NC 25	5.49	4.91	5.49	5.30	0.34
2	NC 30	5.10	5.89	5.69	5.56	0.41
3	NC 35	5.69	6.08	6.47	6.08	0.39
4	NC 40	5.89	6.28	6.67	6.28	0.39

Table 4.20: Flexural Strength (N/mm^2) of SCC at 28 Days

S No.	Mix	Beam 1	Beam 2	Beam 3	Average Strength	Standard Deviation
1	SCC 25	4.71	4.51	5.30	4.77	0.30
2	SCC 30	5.10	4.91	5.49	5.17	0.30
3	SCC 35	5.69	5.69	5.89	5.76	0.11
4	SCC 40	6.47	5.89	5.89	6.08	0.34

Table 4.21: Flexural Strength (N/mm^2) of FSCC at 28 Days

S No.	Mix	Beam 1	Beam 2	Beam 3	Average Strength	Standard Deviation
1	FSCC 25	6.47	5.89	6.08	6.15	0.30
2	FSCC 30	6.08	6.67	6.47	6.41	0.30
3	FSCC 35	6.67	6.08	6.87	6.54	0.41
4	FSCC 40	6.08	6.87	7.65	6.87	0.78

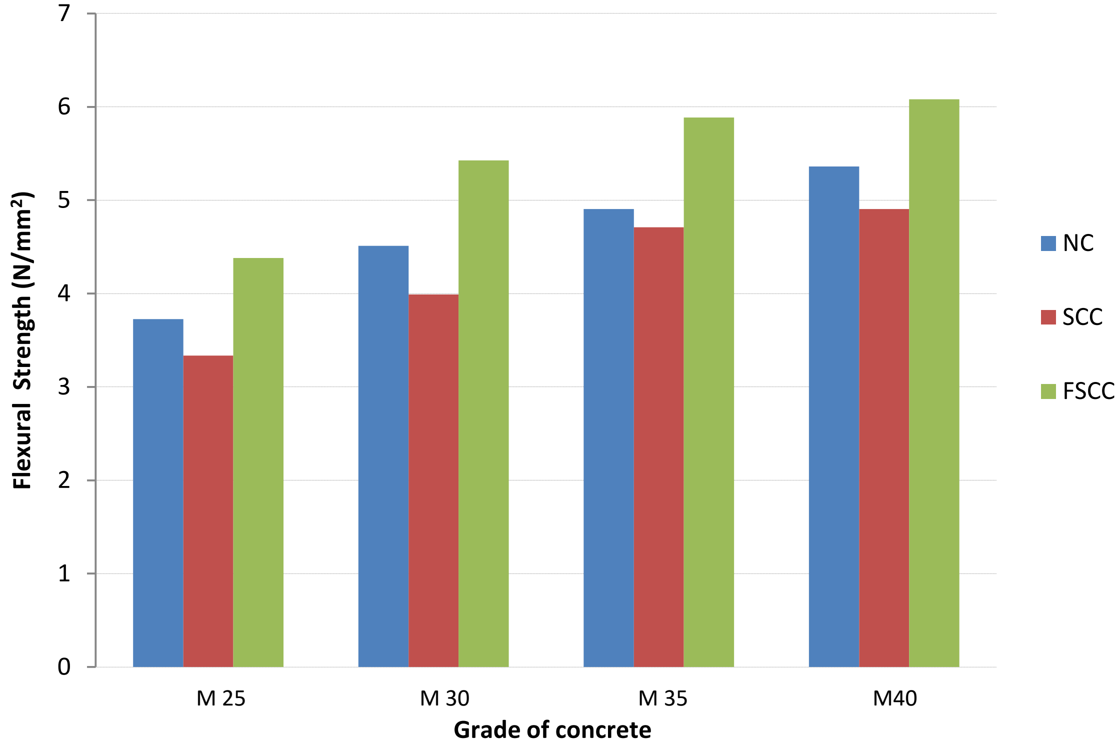

Figure 4.4: Flexural Strength of NC, SCC and FSCC at 7 Days

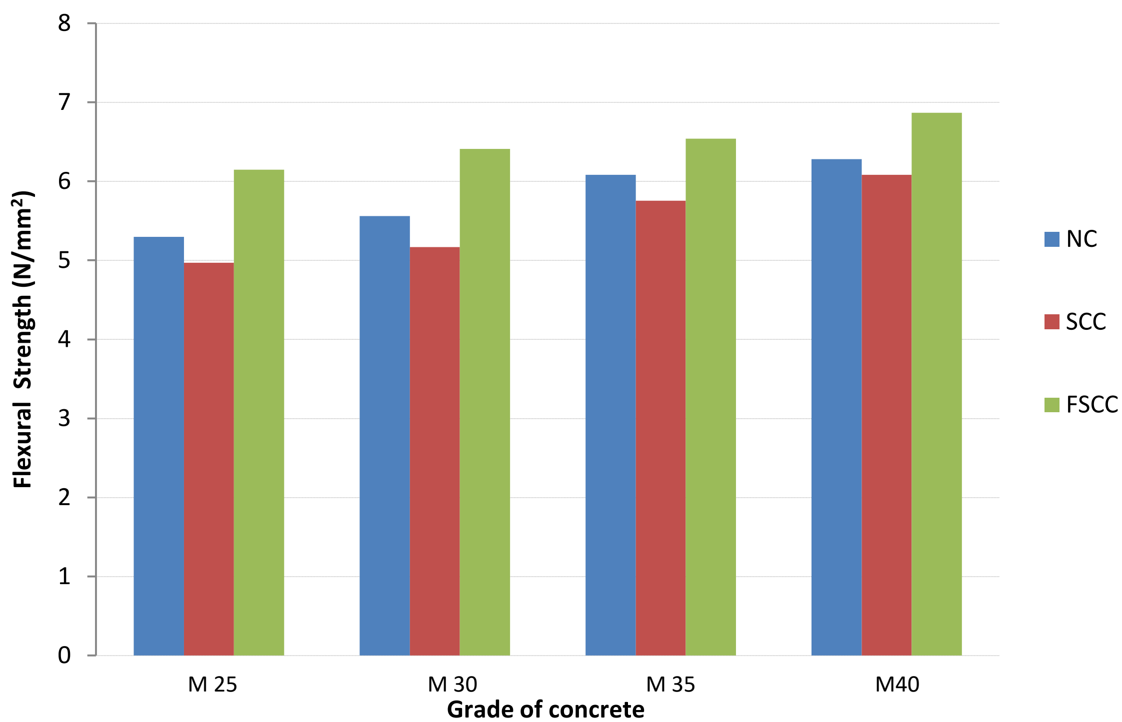

Figure 4.5: Flexural Strength of NC, SCC and FSCC at 28 Days

4.2 Modulus of Elasticity

The modulus of elasticity of NC, SCC and FSCC for M 25 grade of concrete is calculated with the IS code method and from the stress strain curve drawn for cube specimen subjected to gradually increasing compressive load. The results are shown in respective tables.

Table 4.22: Load Deformation for Normal Conventional Concrete of Grade 25

S. No	Load (Kg)	Deformation (mm)
1	0	0
2	10000	0.05
3	20000	0.13
4	30000	0.22
5	40000	0.3
6	50000	0.45
7	60000	0.55
8	70000	0.8
9	80000	1.07
Crushing load	80333	

Table 4.23: Load Deformation for Self Compacting Concrete of Grade 25

S. No	Load (Kg)	Deformation (mm)
1	0	0
2	10000	7
3	20000	17
4	30000	29
5	40000	37
6	50000	55
7	60000	67
8	70000	80
9	80000	117
Crushing load	84000	

Table 4.24: Load Deformation for Fibrous Self Compacting Concrete of Grade 25

S. No	Load (Kg)	Deformation (mm)
1	0	0
2	10000	4
3	20000	8
4	30000	14
5	40000	23
6	50000	35
7	60000	47
8	70000	62
9	80000	110
Crushing load	91000	

Table 4.25: Modulus of Elasticity of NC, SCC and FSCC

S No	Mix	Modulus of Elasticity (N/mm^2) by IS 456 - 2000	Modulus of Elasticity (N/mm^2) by Stress Strain Curve
1.	NC 25	29593.07	26141.56
2.	NC 30	31839.44	27089.45
3.	NC 35	33342.92	28567.47
4.	NC 40	35457.72	30465.12
5.	SCC 25	30257.23	25346.45
6.	SCC 30	32066.34	27983.47
7.	SCC 35	33830.46	31132.45
8.	SCC 40	34992.86	32345.34
9.	FSCC 25	31496.03	26930.08
10.	FSCC 30	32848.14	27985.48
11.	FSCC 35	33290.39	30123.48
12.	FSCC 40	36417.72	32897.50

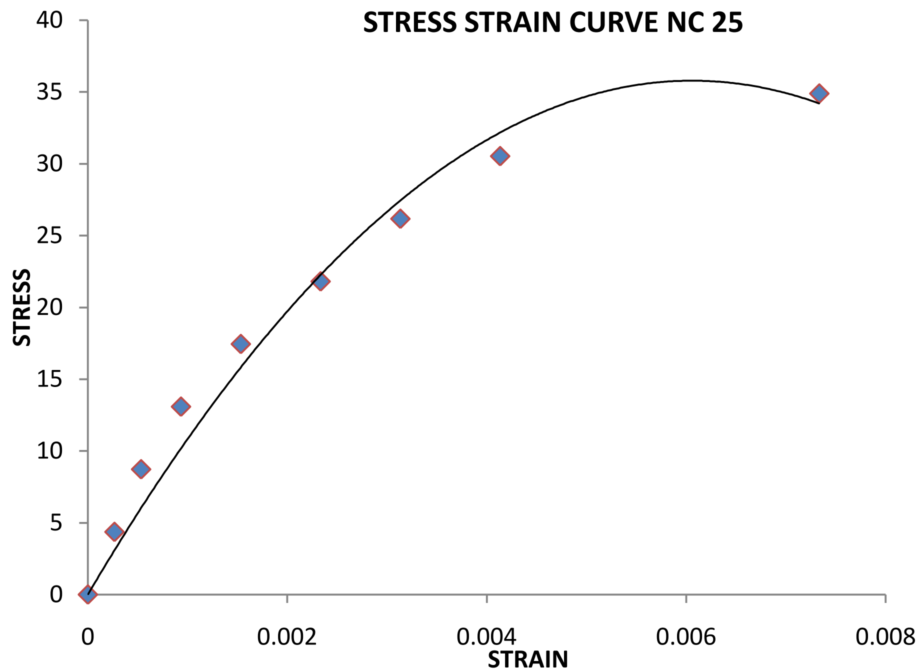

Figure 4.6: Stress Strain Curve for NC 25

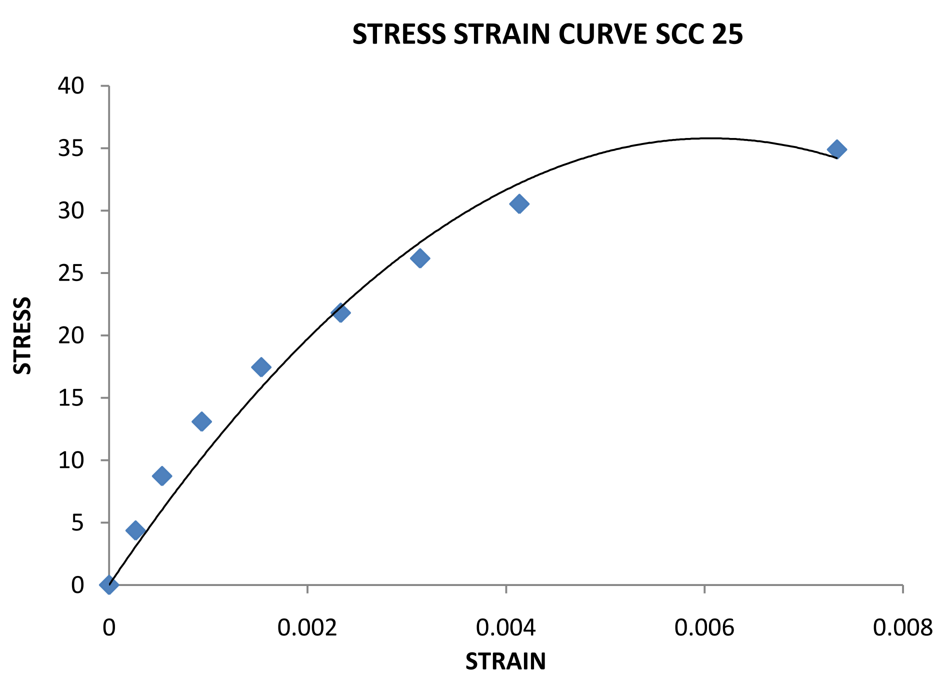

Figure 4.7: Stress Strain Curve for SCC 25

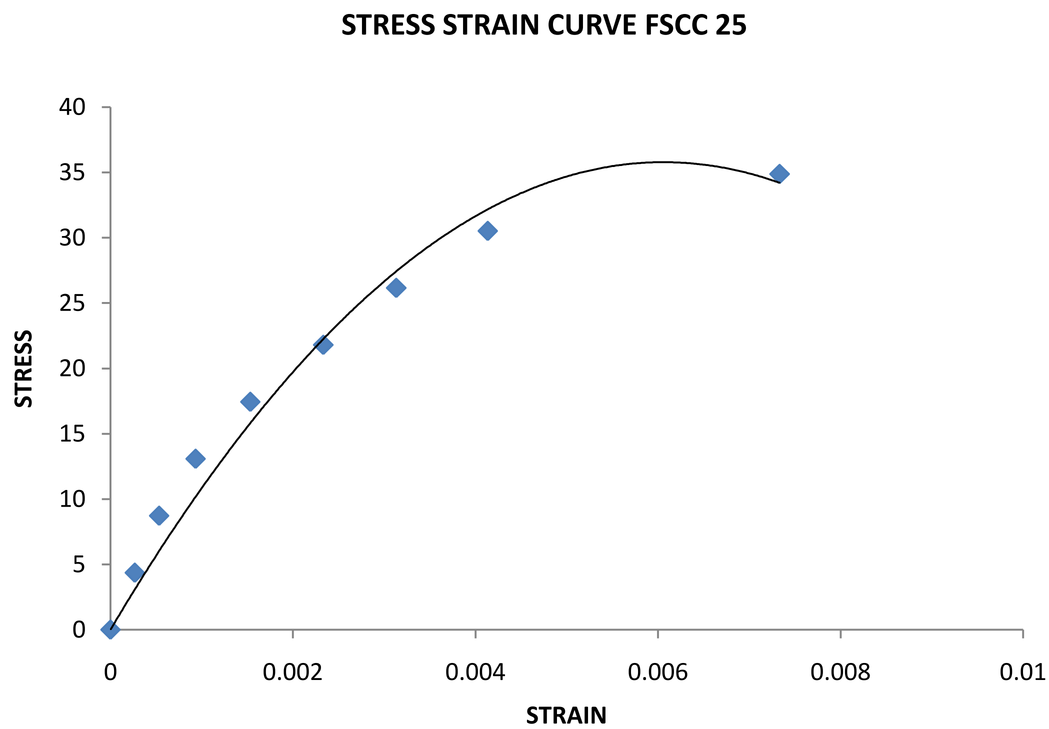

Figure 4.8: Stress Strain Curve for FSCC 25

5.Conclusions

- It is observed from the test results obtained, the later age strengths of SC and FSCC mixes with local materials are very close to the strengths of the same NC mixes, than their strengths at earlier ages. This may be attributed to the contribution of pozzolanic reaction of fly ash at later ages.
- The number of tests conducted for rheological characteristics of SCC and FSCC is more in the present investigation, but it may be limited to 2-3 tests to check the rheology of the SCC and FSCC in the field.
- The difference in modulus of elasticity evaluated with stress strain curve is lesser for the M 35 and M 40 grades of SCC and FSCCs in comparison to IS code equation.
- SCC has high potential for greater acceptance and wider applications in construction field.

- Surface finish and durability aspects of SCC have been studied globally and are found to be superior to those of conventional concrete. In fact SCC is superior to in respect of all properties.
- SCC's unique properties give it significant economic, constructability, aesthetic and engineering advantages and eco friendly because of using waste material.
- SCC provides benefits beyond those of conventional concrete in all three aspects of sustainable development: economic, social, and environmental as discussed earlier in paper.
- With the use of fly ash, as partial replacement of cement, up to 60% by volume of binder, we can reduce cost incurred in production of SCC.

References

[1] EFNARC (European Federation of national trade associations representing producers and applicators of specialist building products), Specification and Guidelines for self-compacting concrete, may 2005, Hampshire, U.K.

[2] Specification and Guidelines for SCC EFNARC Feb 2002.

[3] Khayat K.H., Manai K., Lesbetons autonivlants: proprietes, charcterisation et applications , colloque sur les betons autonivlants, Universite de Sherbroke, Canada, November 1996, p. 8.

[4] P.J.M. Bartos, (Paisley, 1993) 183-190.

[5] Ozawa, K., Sakata, N., Okamura, H., 'Evaluation of Self-Compactibility of Fresh Concrete Using

[6] Rooney, M., Bartos, P.M.J., 'Development of the settlement column segregation test for fresh selfcompactingworking environment through using self-compacting concrete'.

[7] Glavind, M., D. Mathiesen, and C.V. Nielsen, "Sustainable Concrete Structures: A Win-Win Situation for Industry and Society," Achieving Sustainability in Construction, Thomas Telford, London, 2005, pages 1-14. Text book "Concrete Technology " by M.S.Shety.

[8] Prveen Kumar, Haq, M.A. and SC, S.K. Early age strength of SCC with large volumes of fly ash, The Indian Concrete Journal, June 2004, Vol 78, No 6, pp.30-34.

[9] Mahesh, Y.V.S.S.U. & Manu Santhanam Simple test methods to characterize the rheology of SCC, The Indian Concrete Journal, June 2004, Vol 78,No 6, pp.39-43.

[10] Internet websites: www.worldofconcrete.com, www.concrete.org, www.efnarc.org, www.selfcompactingconcrete.com

[11] Bouzoubaa, N. and Fournier, B. (2001). "Concrete incorporating rice husk ash on compressive strength and chloride ion penetrability", Materials Technology Laboratory, CANMET, Department of Natural Resources, Canada, pp 1-16.

[12] Dr. Martin F. Bäuml und Dr. Giovanni Martinola, “Self Compacting Concrete (SCC): Quality and Quality Control”, abstract retrieved from report of Concretum Construction Science AG, Zürich 2006.

[13] IS : 1489-(P-1)-1991, "Specification for Portland Pozzolana Cement (Part I), Fly ash based", Bureau of Indian Standards, New Delhi.

[14] Khatib, J.M., “Performance of Self-Compacting Concrete Containing Fly Ash”, Construction and Building Materials, 01-September-08.

[15] N. Bouzoubaâa and M. Lachemi, “Self Compacting Concrete Incorporating High-Volumes of Class F Fly Ash: Preliminary Results”, Cement and Concrete Research, Vol. 31, No. 3, Mar. 2001, pp. 413-420.

[16] Praveen Kumar and Kaushik S.K. (2005b), "SCC with crusher dust, fly ash and micro-silica", Indian Concrete Journal vol. 4, No. 7, August, pp 33-37.

[17] Pravin Kumar, and Kaushik S.K., "SCC with Crusher Dust, Fly Ash and Micro Silica", The Indian Concrete Journal, vol. 79, No. 8, August 2005, pp 32-37.

[18] Saravanarajamohan K., A. Rajaraman and P. Jeyabalan, "Role of Fly Ash based FRC Composites in Resisting Seismic Damage", International Conference on Earthquake Engineering, Feb 2006, SoCE, SASTRA, Deemed University, Thanjavur.

[19] Selc¸Uk Tu¨ Rkel and Yig˘ It Altuntas, “The Effect of Limestone Powder, Fly Ash and Silica Fume on the Properties of Self-Compacting Repair Mortars”, Sadhana, vol. 34, Part 2, April 2009, pp. 331-343