FLEXURAL CHARACTERISTICS OF SFRSCC AND SFRNC ONE WAY SLABS

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Abstract

Fibre reinforced concrete with steel fibres attracted the attention of engineers and researchers during the last five decades. In recent times self-compacting concrete has been accepted as a quality product and are widely used. A large number of studies are available with respect to several parameters viz., load deflection behavior, toughness, flexural strength, ductility, effects of beam dimensions, concrete filling sequence, flexural toughness parameters, crack control etc. of fibre Reinforced Concrete. The present study aims to study the flexural behavior of SFRSCC and SFRNC slabs with steel fibres.

Keywords: *Self compacting concrete1, Fibre reinforced concrete2, Steel fibre reinforce normal concrete3, Steel fibre reinforce4, Self-compacting concrete5.*

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1. INTRODUCTION

Concrete that is able to flow and consolidate under its own weight, completely fill the formwork of any shape, even in the presence of dense reinforcement, while maintaining homogeneity and without the need for any additional compaction.

Fibre reinforcement can extend the technical benefits of SCC by also providing crack bridging ability, higher toughness and long-term durability.

The use of steel and synthetic fibres however is known to alter the flow properties of fresh concrete. In recent times, few attempts have been made to include steel fibres in plain SCC.
But these studies are limited to small scale specimen such as cubes, prisms and cylinders. The present investigation is to study the flexural behaviour of large scale structural elements, an attempt has been made to develop, cast and test SFRNC and SFRSCC slab elements.

Luciano Ombres et al [8] reported the flexural behavior of FRP reinforced concrete one way slabs. Four one way slabs, three reinforced with GFRP re bars and one reinforced with traditional steel rebar's have been tested up to failure varying the reinforcement ratio, the rebar diameter and rebar spacing.
Monotonic load tests have been conducted on plain and fiber-reinforced concrete slabs on ground to monitor the effect of fiber type and dosage on the strength properties of concrete slabs. The addition of fibres increased the collapse load of slabs, with the key factors affecting the magnitude of the collapse load being fibre type and quantity. Strain and deflection profile measurements

Showed that fibres assisted in crack propagation resistance, crack bridging, and load redistribution.

The development of membrane in plane forces within slabs, depending on the boundary conditions, significantly enhance the slab load-carrying capacity above the commonly adopted design value based solely on flexural behavior. The type, magnitude and final failure mode of membrane action will depend on the horizontal restraint around the slab perimeter.

Since the idea of utilizing fibre reinforced cementations composites in structural elements has been increased exponentially over the past decade. It is necessary to have the concept introduced in the provisions of the concrete codes.

It is necessary to conduct laboratory investigations on various types of structural components under different loading conditions to have a precise understanding of their behavior.
As on date, there are limited investigations on the flexural behavior of slabs cast with steel fibre reinforced self-compacting concrete.

In the present study, a total number of 20 slabs of size (1050x500x65) mm were casted and tested under flexure. Out of 20slabs,10 slabs were cast using Steel Fibre Reinforced Normal Concrete (1.0 %Vf) and 10Steel slabs (1.0%Vf).The grade of concrete used was M40 and M70 . Five different variations of tensile reinforcement were considered for SFRNC and SFRSCC. An attempt has been done to produce M40 andM70 grade of SFRSCC and SFRNC. Casting and testing of SFRNC and SFRSCC reinforced slabs under flexure. Cracking load, ultimate load, mid-span deflections, Width of crack, strain in steel reinforcement using strain gauge were measured during the testing of specimens.

2. MATERIALS

2.1Cement

Selection depends on overall requirement of mix. The Quantity of cement to be used should be in the range of 350 – 450 kg/m3.With the inclusion of the fly ash the quantity of the cement can be restricted to 350 kg/m3

2.2 Fine Aggregate

4.75 mm IS sieve passing, river sand conforming to zone II of IS: 383- 1970 Specific gravity of 2.56. The quantity used should be between 1500 to 1600 kg/m3.

2.3 coarse Aggregate

Locally available crushed granite was used. Passing 12.5 mm and 4.75 mm retained. Specific gravity of CA was 2.66.The quantity used should be in range of 1300 – 1500 kg/m3.

2.4 Fly Ash

Class F Fly ash is used. Fly ash decreases bleeding and enhances flow ability. 15 to 25% of cement can be replaced by fly ash. Specific gravity is 2.4

2.5 Water

Normal potable water is used. The water must be free from suspended particles and organic materials.

2.6 Super Plasticizer

Glenium B-233 (BASF construction chemicals).Normal dosage for SP is 0.5 to 1.5 liters per 100 kg of cementitious material.

2.7 Viscosity Modifying Agent (VMA)

Glenium Stream-2 is batched on the total of fines below 0.1mm and is recommended between 0.5-1.0 litres per cubic meter. Other dosages may be recommended in special cases according to specific job site condition is used for M70.

2.8 Steel Fibres

30 mm length, 2-3 mm width, and 0.5 mm thick Low-carbon drawn flat wires.1 % by volume of concrete was used.

2.9 Steel Reinforcement

Diameter 8 mm TMT bars. Yield strength of 590 N/mm2
Steel Crimped Fibre's:The steel fibres used were supplied by Kasthuri metal composites, Mumbai and the type of fiber used was crimped which was made from low carbon drawn flat wires.

Length of Fiber (I)	30 mm
Aspect ratio	60
Diameter (d)	0.5 (+/- 0.05 mm)
Width (w)	2 mm - 2.5 mm
Tensile Strength	400 Mpa to 600 Mpa
Appearance and Form	Clear, bright and undulated along the length
ASTM Specs	ASTM AB20 M04 Type 1
Material Type	Low Carbon Drawn Flat Wire

Figure1: steel crimped fiber

3. TEST SPECIMENS

The twenty number one-way simply supported rectangular slabs tested, ten slabs were Steel Fiber Reinforced Normal Concrete slabs (1.0 %Vf) and the rest ten were Steel Fibre Reinforced Self Compacting Concrete slabs(1.0%Vf). The thickness of the slab was 65 mm. The slabs had an overall length of 1100mm x 500mm with an overhang of 25mm beyond the support to give necessary anchorage to the reinforcement. The main reinforcement is of 8mm diameter bars and the distribution steel was of 6mm dia. In all the five slabs of SFRSCC and fiveslabs of SFRNC the main reinforcement was varied and the distribution steel was kept constant.

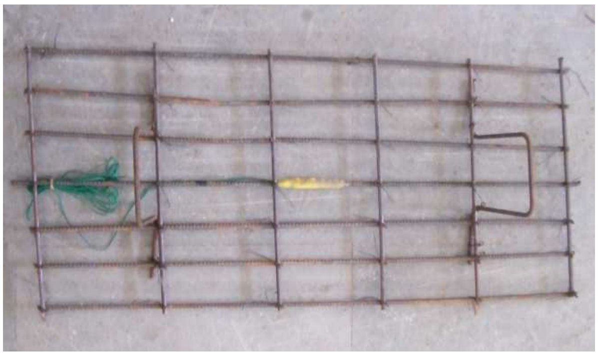


Figure2: Reinforcement Layout of Slab Specimen

3.1 Strain Gauge and Strain Indicator

Strain in steel is measured using digital strain indicator.Strain gauges have Gauge factor of 2.05 ±0.5 and Resistance of 120 ±0.5Ω.

01	Display	4 ½ digit display of red, 7 segment LED of 12.7mm character height
02	Measuring Range	19, 999 micro strains with 1 micro strain resolution
03	Accuracy	Within ±0.25% FSR ± 1 count.
04	Input	From strain gauge bridges
05	Acceptable Bridge Configuration	Full bridge Half bridge Quarter bridge with external dummy gauge

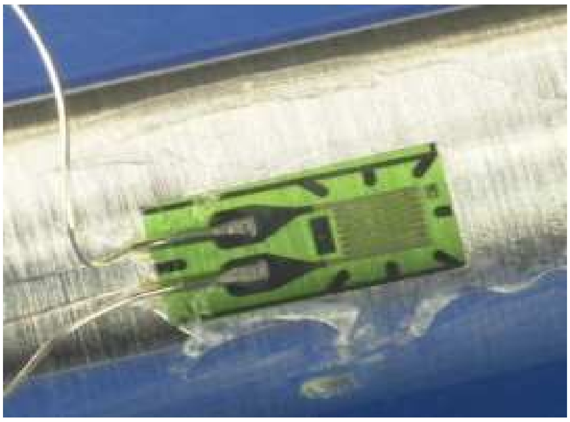


Figure 3: Photo graph showing the strain gauge

3.2 Casting of Slabs

First was to prepare a proper form work to cast the slabs. Second to prepare the steel cages and strain gauge is fixed to main steel reinforcement and bonding is done is using wax, so that the concrete doesn't penetrate in to strain gauge. A wooden frame of 65mmheight, 500mm width and 1100mm in length was used as the formwork to cast the slabs Cover blocks of 15mm thickness were made using a high strength mortar, so that they wouldn't appear as weakness points after hardening of the concrete, to act as concrete clear cover. SFRSCC was poured into the formwork continuously so that the effect of self-compacting comes to the picture properly. Apparently, there is no compaction used to place the SFRSCC into the mould [3-4].SFRNC was poured into the mould and was compacted thoroughly by means of a needle vibrator of 20mm diameter. After compaction, finishing was done by means of a trowel to achieve a smooth and level final surface.

Figure4: Finished Surface of the Slab Specimen

3.3 Curing of Slabs

The moulds of the specimen of conventional concrete (i.e., SFRNC) were removed after 24 hours of casting for SFRSCC the moulds were removed after 48 hours of casting. The specimens were numbered for identification and the auxiliary specimens were cured in curing tank and the slabs were cured continuously for 28 days using wet gunny bags.

4. TESTING

After a curing period of 28 days, all the slabs and their auxiliary specimens were taken out. The slabs were then allowed to dry and white washed, to have a smoother surface, to easily locate crack propagation pattern, measuring crack widths during testing [10 - 12].The location of dial gauges and points of measurements of crack widths were marked on the tension face of the slab. All the slabs were tested under four point loads.

The following observations were made during the testing of the specimen:

Downward central deflections of the slab at different stages of loading Crack pattern and crack widths at different stages of loading Strain in steel is measured while testing specimen from strain indicator.

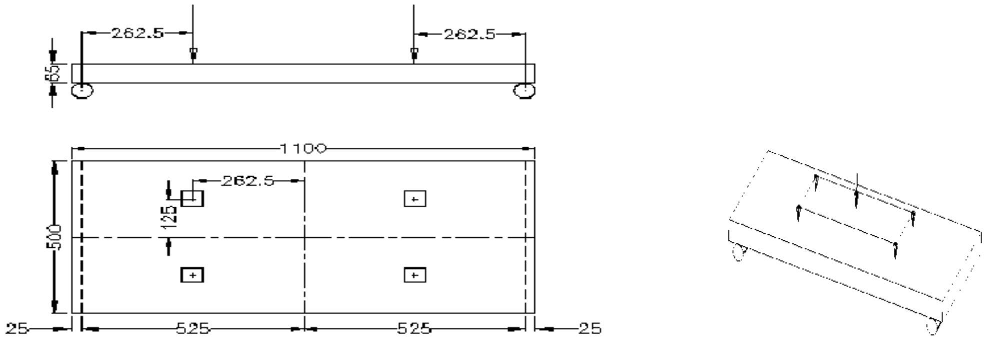
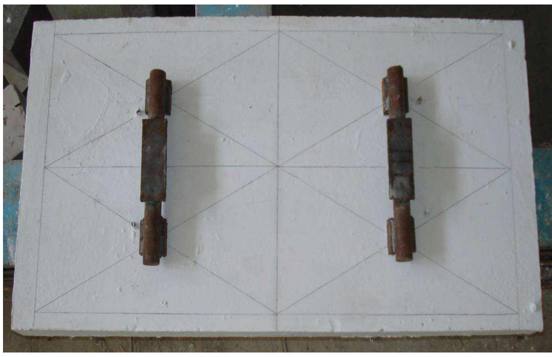


Figure5: Plan and Cross Section of the Location of Loading Points



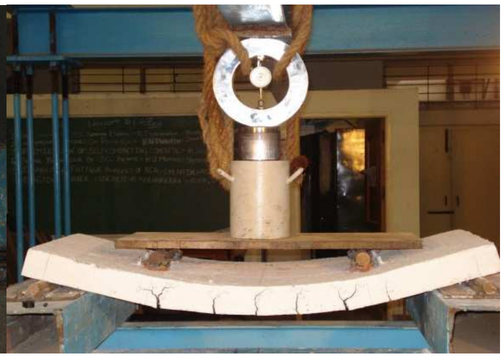


Figure6: Location of Loading Points

Figure7: Slab Behavior near to Ultimate Stage

5. EXPERIMENTAL RESULTS

Table1: Test Results of Auxiliary Cubes, Prisms and Slabs

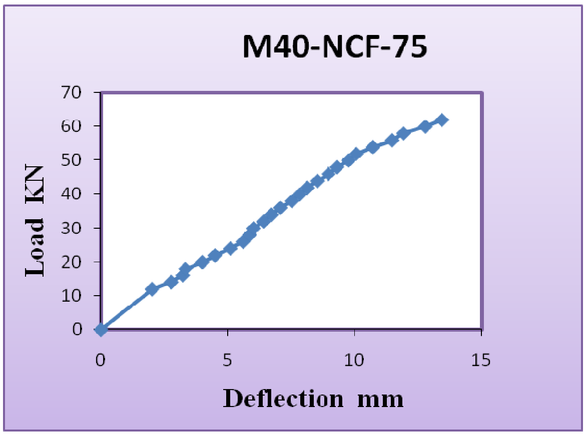
Slab No	D mm	L (mm)	B (mm)	f_{ck} (N/mm^2)	f_r (N/mm^2)	% of Main Steel	Spacing (mm)	P_{cr} kN	P_u kN
40-NCF-75	65	1050	500	50.3	4.96	1.202	75	18	74
40-NCF-100	65	1050	500	51.5	5.02	0.859	100	22	62
40-NCF-150	65	1050	500	54.0	5.14	0.687	150	20	40
40-NCF-200	65	1050	500	48.3	4.86	0.601	200	20	36
40-NCF-215	65	1050	500	46.1	4.75	0.57	215	18	36
40-SCF-75	65	1050	500	40.8	4.74	1.202	75	22	60
40-SCF-100	65	1050	500	41.9	4.83	0.859	100	20	52
40-SCF-150	65	1050	500	40.1	4.69	0.687	150	18	44
40-SCF-200	65	1050	500	43.1	4.92	0.601	200	14	34
40-SCF-215	65	1050	500	42.3	4.86	0.57	215	18	38
70-NCF-75	65	1050	500	91.92	6.71	1.202	75	28	74
70-NCF-100	65	1050	500	103.14	7.11	0.859	100	24	56
70-NCF-125	65	1050	500	95.91	6.86	0.687	125	22	44
70-NCF-200	65	1050	500	86.4	6.51	0.601	200	18	38
70-NCF-215	65	1050	500	93.1	6.75	0.57	215	20	40

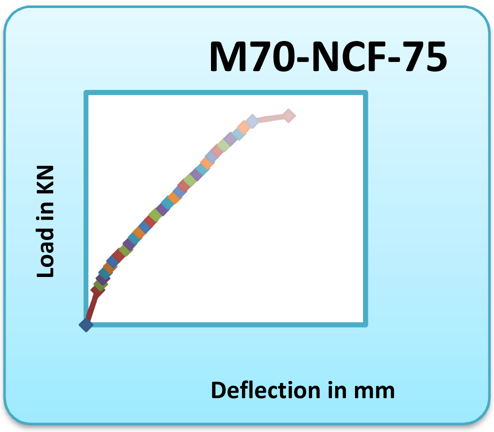
70-SCF-75	65	1050	500	68.1	6.67	1.202	75	26	84
70-SCF-100	65	1050	500	67.3	6.62	0.859	100	24	60
70-SCF-125	65	1050	500	69.8	6.78	0.687	125	20	52
70-SCF-200	65	1050	500	71.3	6.88	0.601	200	20	38
70-SCF-215	65	1050	500	70.8	6.85	0.57	215	20	40

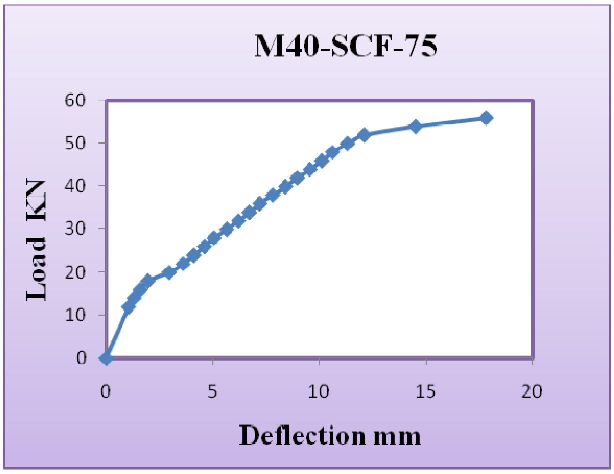
Table2: Ultimate Load and Deflection of all the Slabs

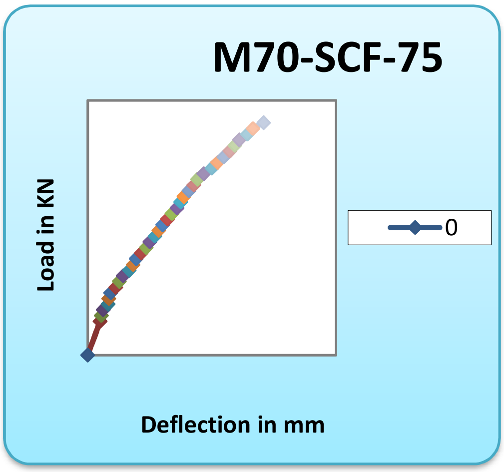
Slab No.	P_{cr}(kN)	δ_{cr}(mm)	P_w (kN)	δ_w(mm)	P_u(kN)	δ_u(mm)
M40-SCF-75	22	3.6	40.00	11.54	60	17.8
M40-SCF-100	20	3.25	34.66	10.12	52	17.85
M40-SCF-150	18	3.95	29.33	9.00	44	15.75
M40-SCF-200	14	4.40	22.66	7.37	34	13.70
M40-SCF-215	18	3.45	25.33	7.35	38	14.75
M40-NCF-75	18	3.30	49.33	11.82	74	13.40
M40-NCF-100	22	2.80	41.33	10.55	62	12.65
M40-NCF-150	20	5.85	26.66	9.51	40	15.20
M40-NCF-200	20	4.25	24.00	8.31	36	9.60
M40-NCF-215	18	4.15	24.00	8.41	36	9.50
M70-SCF-75	28	3.15	56	9.81	84	14.15
M70-SCF-100	24	3.85	40	8.16	60	16.1
M70-SCF-150	22	3.45	34.66	7.77	52	13.4
M70-SCF-200	18	3.7	25.33	5.78	38	10.65
M70-SCF-215	20	2.3	26.67	6.36	40	8.55
M70-NCF-75	26	2.55	49.33	7.69	74	14.5
M70-NCF-100	24	3.25	37.33	6.34	56	12.25
M70-NCF-150	20	2.5	29.33	5.17	44	10.3
M70-NCF-200	20	3.8	25.33	5.18	38	10.2
M70-NCF-215	20	2.15	26.67	5.48	40	10.25

5.1 Load Deflection Behavior of Slabs

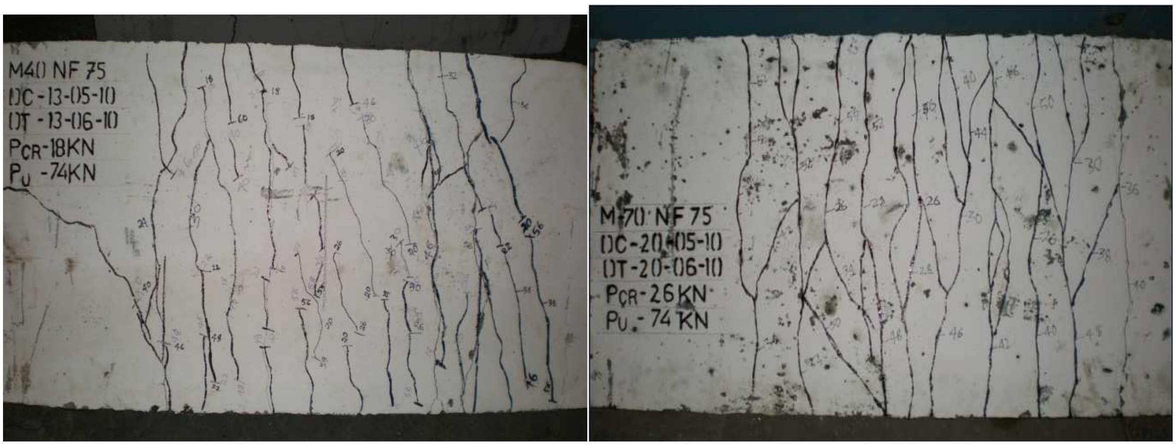








CRACKING BEHAVIOUR



6. RESULTS AND COMPARISONS

Table3: Showing Ultimate Load of SFRSCC and SFRNC Slabs

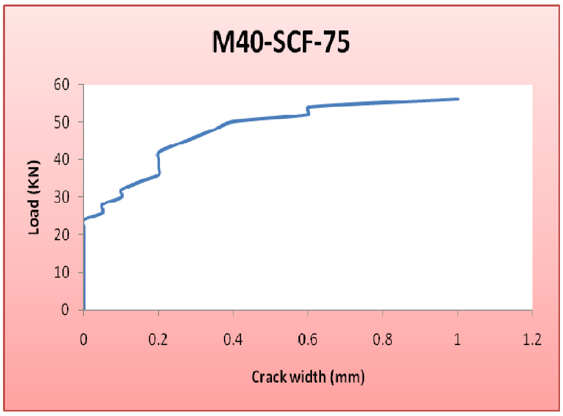
SLAB NO.	PuExp(KN)	Pu Cal / PuExp(KN)		
		IS	ACI	EURO
40-NCF-75	74	0.68	0.83	0.85
40-NCF-100	62	0.62	0.74	0.75
40-NCF-150	44	0.73	0.86	0.87
40-NCF-200	36	0.67	0.79	0.80
40-NCF-215	36	0.67	0.79	0.80
40-SCF-75	68	0.70	0.87	0.90
40-SCF-100	52	0.72	0.86	0.88
40-SCF-150	44	0.70	0.83	0.85
40-SCF-200	34	0.71	0.83	0.84
40-SCF-215	38	0.63	0.74	0.75

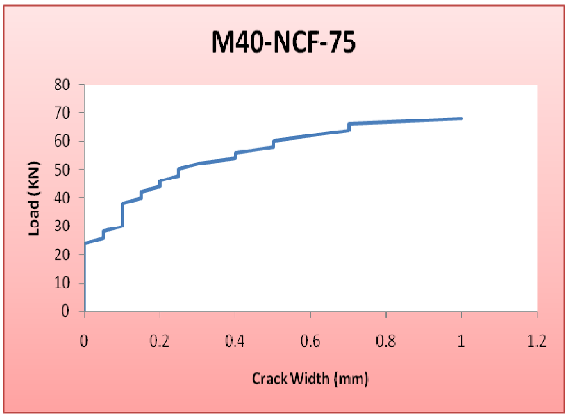
70-NCF-75	74	0.75	0.89	0.89
70-NCF-100	56	0.74	0.86	0.86
70-NCF-125	44	0.76	0.89	0.89
70-NCF-200	38	0.66	0.77	0.77
70-NCF-215	40	0.63	0.73	0.74
70-SCF-75	84	0.64	0.76	0.77
70-SCF-100	60	0.66	0.79	0.79
70-SCF-150	52	0.63	0.74	0.74
70-SCF-200	38	0.66	0.77	0.77
70-SCF-215	40	0.62	0.73	0.73
MEAN		0.68	0.80	0.81
SD		0.04	0.06	0.06
CV		0.06	0.07	0.07

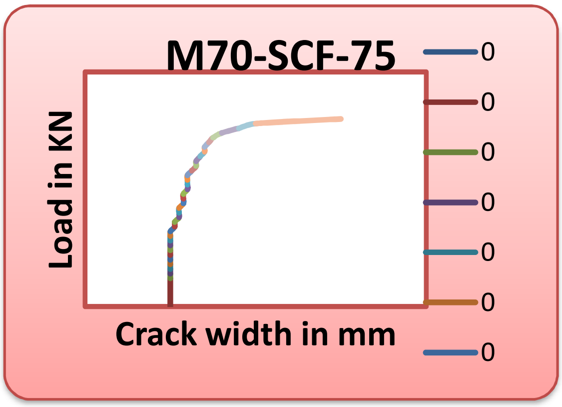
Table4: Experimental and Calculated Ultimate Moments of SFR (SCC & NC) Slabs

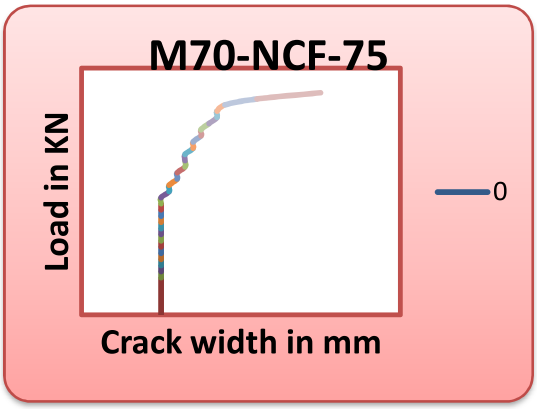
Slab Designation	MuIS (N-mm/mm)	MuACI (N-mm/mm)	Mu (N-mm/mm)	Mu /MuIS	Mu /MuACI
40-NCF-75	13277.33	16161.65	16721.30	1.26	1.03
40-NCF-100	10113.53	12071.88	12759.14	1.26	1.06
40-NCF-150	8379.28	9904.81	10668.37	1.27	1.08
40-NCF-200	6365.24	7486.63	8289.81	1.30	1.11
40-NCF-215	6338.31	7463.80	8255.61	1.30	1.11
40-SCF-75	12582.52	15572.66	16040.12	1.27	1.03
40-SCF-100	9774.00	11784.06	12397.88	1.27	1.05
40-SCF-150	8065.12	9638.50	10311.09	1.28	1.07
40-SCF-200	6297.15	7428.92	8203.54	1.30	1.10
40-SCF-215	6285.19	7418.78	8188.45	1.30	1.10
70-NCF-75	14628.45	17306.99	18072.98	1.24	1.04
70-NCF-100	10855.49	12700.84	13565.27	1.25	1.07
70-NCF-125	8775.31	10240.53	11128.47	1.27	1.09
70-NCF-200	6614.08	7697.58	8610.53	1.30	1.12
70-NCF-215	6636.79	7716.82	8640.22	1.30	1.12
70-SCF-75	14057.29	16822.82	17497.17	1.24	1.04

70-SCF-100	10461.44	12366.80	13134.25	1.26	1.06
70-SCF-125	8584.43	10078.72	10905.34	1.27	1.08
70-SCF-200	6547.27	7640.94	8523.58	1.30	1.12
70-SCF-215	6544.58	7638.66	8520.08	1.30	1.12









Plot showing variation of $W_{cr\ CAL}$ and $W_{cr\ EXP}$.

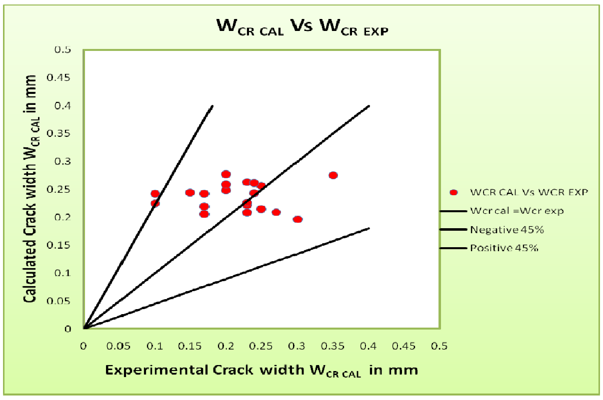


Table5: Ratio of calculated and experimental strain in steel reinforcement

SLAB NO	ϵ_{CAL}	ϵ_{EXP}	$\epsilon_{CAL}/\epsilon_{EXP}$
40-NCF-75	0.003861	0.00174	2.22
40-NCF-100	0.004346	0.00175	2.48
40-NCF-150	0.003753	0.00165	2.27
40-NCF-200	0.004024	0.00162	2.48
40-NCF-215	0.004032	0.0016	2.52
40-SCF-75	0.003760	0.0021	1.79
40-SCF-100	0.003826	0.00192	1.99
40-SCF-150	0.003939	0.00124	3.18
40-SCF-200	0.003929	0.00165	2.38
40-SCF-215	0.004395	0.00205	2.14
70-NCF-75	0.003719	0.0016	2.32
70-NCF-100	0.003787	0.0015	2.52
70-NCF-125	0.003654	0.0013	2.81
70-NCF-200	0.004147	0.00104	3.99
70-NCF-215	0.004353	0.00124	3.51
70-SCF-75	0.004466	0.00138	3.24
70-SCF-100	0.004282	0.00142	3.02
70-SCF-125	0.004509	0.00162	2.78
70-SCF-200	0.004283	0.00152	2.82
70-SCF-215	0.004510	0.00115	3.92
		MEAN	2.72
		SD	0.60
		CV	0.22

6. RESULTS AND COMPARISON

6.1 Ultimate Load:

The ultimate load capacity of SFRSCC and SFRNC slabs were calculated using IS-456, ACI-318, EN-1992. It is noted that there is an under estimation of ultimate load with a range of 18-32% compared to the experimental ultimate load.

The ACI-318 and EN-1992 codes predict the nearest ultimate loads and thus can be used to calculate load carrying capacity

6.2 Deflection

Deflection of SFRSCC and SFRNC slabs were calculated IS-456, ACI-318, EN-1992 and Bilinear method. Except for ACI method, all the other codes over- estimates the deflection in the range of 4 to 26%.

The ACI-318 and the Bilinear method predict deflections very nearer to the experimental values with a co variance of around 0.2.

6.3 Crack Width

Crack width of the SFRSCC and SFRNC slabs were calculated using IS-456. The IS 456 over-estimates the crack width by around 28% with a co variance of 0.38.
It is necessary to study further the crack width predicted by various other codes before coming to a clear conclusion regarding the crack width.

6.4 Strains in Steel

The strain in steel is calculated by using IS 456 and the experimental values are obtained by using a strain gauge.
IS 456 over estimates the strain in steel by three times as compared to the experimental strain indicated, with a covariance of 0.22.In most of the slabs the failure occurred due to the failure in steel reinforcement.

SUMMARY AND CONCLUSIONS

An experimental program has been designed to cast and test, tenM40 grade SFRSCC and ten M40 grade SFRNC one way rectangular slabs under flexure.

The available codal equations and by researchers were used to analyze the structural characteristics of the tested slabs which include the load-deflection behavior, ultimate load, short term deflection, crack width and strain in reinforcement steel at working load.

The codes predict a 20% variation in the deflection studies. The ratio of calculated deflection to experimental deflection being 1.15 for IS 456:2000, 0.94 for ACI 318, 1.26 for EN 1992:2002 codes and 1.04 for Bilinear method.Except for the ACI 318 codes all the other codes predict a higher deflection than the experimental deflection.

The Ultimate loads predicted by all the codes are lesser than the experimental ultimate load. The predictions are very consistent which is shown by the CV being 6.5%.

The Ultimate moment carrying capacity is calculated using Sameer’s approach which takes into account the effect of steel fibers.

The IS 456:2000 predicts a 28% higher crack width compared to the experimental crack width.

It is observed that calculated strain in steel by IS 456:2000 method is almost higher by three times than the experimental strain obtained by installing strain gauge in the main steel reinforcement.

But as the studies and the test results available on SFRSCC and SFRNC slabs are very limited, a general conclusion like the above has to be examined for further validation.

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