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Strengthening of R. C. Column by Using Fibre Reinforced Concrete

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Abstract

This thesis explores the effects of adding steel fibres to standard-strength reinforced concrete columns and in particular only to the cover of the columns. Early cover spalling occurs when an internally reinforced concrete column is concentrically loaded with excessive force; the column expands laterally due to Poisson effect. The inner core is restrained with the lateral reinforcement leaving the outer cover restrained only by tensile stresses at the cover core interface, forcing the cover to break away. The load at which this phenomenon occurs is called the cover spalling load. The loss of concrete cover significantly reduces the cross sectional area and consequently, increases the stress on the column. The main aim of this study was to determine whether placing fibrous concrete only in the outer cover, would be sufficient to maintain, or enhance, the desirable properties of standard-strength concrete columns. An experimental program was conducted where seven circular reinforced concrete columns were tested with varying fibre content – one with no fibres, three with fibres throughout the cross-section and remaining three with fibres only in the cover concrete. The other column properties were kept the same for all the seven columns. All seven columns were tested by the application of a concentric, axial compression force. Different fibre fractions/percentage, mainly 0.5%, 1%, 1.5% was also tried in this experimental program. The columns consisting of 1.5% FSSC exhibited minimal

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cover spalling and a much higher ultimate strength. Also, columns consisting 1.5% FSSC in the cover only are able to resist higher amounts of lateral expansion due to axial loading. The higher the amounts of steel fibres present in the concrete, the lower the workability and the higher chance of variations in concrete strength and cavities. The addition of 1% to 1.5% steel fibres by volume into the matrix of the standard strength concrete produced the optimal performance in terms of compressive and tensile strength of the concrete.

Keywords: *RC Columns, Fibre Reinforced Concrete, Steel Fibres, Concrete Columns*

I. INTRODUCTION

General

Standard strength concrete (SSC) has become a very popular construction material. Standard strength concrete members are most commonly used in lower storey: high rise buildings, multi-storey car parks and long span bridges. Due to its superior strength, toughness, stiffness and durability, the size of the SSC structural member can be significantly reduced to obtain the same amount of compressive strength as normal strength concrete (NSC), therefore the amount of space required for the structural members can be reduced.

Early Cover Spalling Load

Early cover spalling occurs when an internally reinforced concrete column is concentrically loaded with excessive force; the column expands laterally due to Poisson effect. The inner core is restrained with the lateral reinforcement leaving the outer cover restrained only by tensile stresses at the cover core interface, forcing the cover to break away.

The load at which this phenomenon occurs is called the cover spalling load. The loss of concrete cover significantly reduces the cross sectional area and consequently, increases the stress on the column. Additional research has shown that the addition of steel fibres into the high strength concrete matrix results in the reduction of early cover spalling and improvement in ductility also.

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Figure

The Behaviour of Concentrically Loaded Ssc Columns

While all columns designed to AS3600 (14) and IS 456 are required to incorporate a minimum eccentricity of 0.05D, where D is the overall depth of the section, much insight is gained by reviewing the behaviour of concentrically loaded columns. The load versus deflection behaviour of a HSC & SSC column under load is shown in Figure 1. As the column is loaded the displacement increases in a near linear manner. The proportional limit, as shown in Figure 1, is dependent on the strength of the concrete and can be as high as 80 percent of the spalling load for very Standard strength concrete. Beyond the proportional limit, micro-cracking within the core gives the increased lateral expansion necessary to activate the confining pressure provided by the tie reinforcement. High strength concrete has a higher proportional limit than normal strength concrete leading to a lower expansion of the core at the peak load and, thus, lower tie strains at the spalling load.

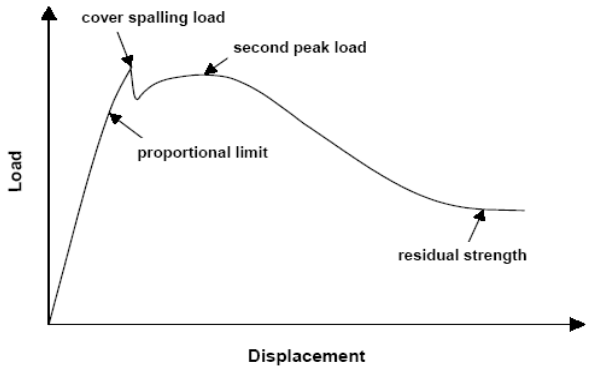


Fig 1 load deflection behaviour of SSC & HSC column

The Mechanics of Cover Spalling

While for SSC columns the strains in the ties at the peak load are small, they are not

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insignificant. In a recent paper by Foster et al, it was shown that the initiation of cover spalling is an inevitable consequence of the triaxial stress state in the cover. Further, the mechanism behind the initiation of the separation exists equally for conventional strength as for high strength concretes and within the constraint $\sigma 3 < fcp$; where $\sigma 3$ is the axial compression stress in the concrete and fcp is the uniaxial strength of the in-place concrete. In providing ties to constrain the core tension stresses are set up at the cover-core interface, as shown in Figure 2. The greater the amount of confinement provided to the core, the greater the tension stress at the cover-core interface due to the higher restraint provided to the core against Poisson's growth.

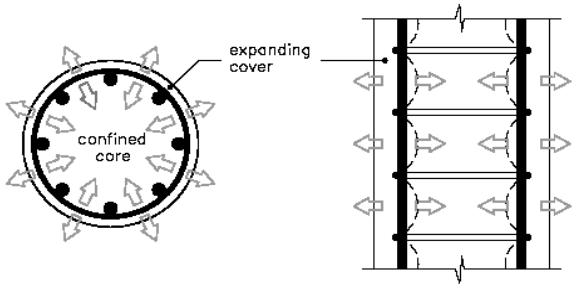


Fig 2: The mechanics of cover spalling

II. LITERATURE REVIEW

Foster and Attard [1](2008) tested 21 HSC columns cast with hooked end fibres at 2% by weight mixed through the concrete matrix. The columns were concentrically and eccentrically loaded until failure and the stress strain relationship was recorded. The results also showed that the concrete that possessed steel fibres did not spall and possessed particularly higher post failure ductility. Further research was recommended into the minimum requirement of fibre needed to overcome spalling and monitor different fibre properties on the post peak behaviour of columns.

Hsu and Hsu [2](2007) found that the addition of steel fibres into the mix of high strength concrete columns increased the behaviour of ductility and toughness. The analysis was based on concrete specimens 76.2 mmØ × 152.4 mm that were subjected to uniaxial compression tests. The columns varied by fibre content ranging 0, 0.5, 0.75 and 1% by volume, and without or with lateral confinement (tie spacing ranging from 25.4 mm to 76.2 mm). It was also concluded that addition of steel fibres causes an increase in strain corresponding to the peak stress. Specimens with a greater percentage of fibre possessed higher ductility and toughness. The concrete possessing fibre appeared to bulge rather than fracture during testing, whereas the

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fibres seem to "act as crack arrestors". No cover spalling was noted.

Hadi [3](2007) incorporated the addition of polypropylene fibres into high strength concrete and strictly locating the fibre reinforced high strength concrete mix in the cover only and placing plain high strength concrete in the remaining core. Hadi [3] concluded that the addition of fibres in the cover increased the strength at which early cover spalling took place. This analysis was based on seven columns cast with varying fibre contents and locations of fibres within the column.

Conclusion from Literature Review

The past methods of fibre reinforced high strength concrete columns have focused mostly on placing steel fibres throughout the whole cross section of the column. The brittle nature of standard strength concrete results in sudden unpredictable failure. This is a major issue for structural safety. Previous research has demonstrated that ductility and compressive strength can be improved by the addition of lateral confinement. However, due to confinement, confined standard strength concrete columns possess a phenomenon known as early cover spalling. So I want to reduce the early cover spalling effect. So I am decided fiber used only cover of the column

OBJECTIVES OF THE INVESTIGATION

- To study the material properties
- To find the axial load carrying capacity of column
- To find the spalling load
- To find the Ductility of Columns
- To find the Compressive strength
- To find the Split Tensile strength

III. EXPERIMENTAL STUDY

Test Specimens

A total of seven standard strength concrete columns prepared with varying fibre content - one contained no fibres, three contained fibers throughout the cross-section and three contained fibres only in the outer column. Three percentages of fibres were used, 0.5%, 1% and 1.5% by volume. The fibre content and location for each column are shown in Table 1. The overall length of the column was made to 1600mm.The ends of the columns were made bulk head for height of 300mm on either side. The cross-section of column was made 150mm in diameter at mid height and ends 300mm in diameter. These end blocks are provided to prevent

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the end failure of the column during loading. All columns were instrumented to study the behaviour of short column under axial loading condition. The end conditions were made in such a way that the end is partially restrained against rotation. The standard cubes and cylinders were cast as per IS standards mix design procedure. All specimens were moist cured for 28 days. All the specimens were heavily instrumented to measure their overall vertical movements using temech gage. Lateral deflection was measured by using two dial gauges. The temech gage was used to measure the strain in concrete surface of the column in three places like two supports and one central column. During testing of columns sufficient precautions had been taken. Chain pulley and rope was used to hold the column in position before and after testing.

Table 3.1 Parameters Vary

Column	Fibre content (%)	Fibre location
R	-	-
0.5C	0.5	cover only
0.5F	0.5	full cross section
1C	1	cover only
1F	1	full cross section
1.5C	1.5	cover only
1.5F	1.5	full cross section

Where

R- Reference column

0.5C, 1C, 1.5C- fibre used only cover of the column

0.5F, 1F, 1.5F- fibre used full c/s of the column

CASTING PROCEDURE

Casting Procedure for Full C/S of The Column

In order to create the fibrous high strength concrete (FSSC) the SSC was placed directly from the concrete chute into the concrete mixer. The fibres were added evenly to the concrete by hand as it descended the chute as shown in fig1. The mixer machine was switched on for 1.5 to 2 minutes until the fibres were dispersed evenly throughout the mix. The quantities of fibres added to the concrete were 0.320kg for the 0.5%C mix, 0.630kg for the 0.5%F mix, 0.641kg for the 1%C mix, 1.25kg for the 1%F %C mix, 0.96 kg for the 1.5%C mix and 1.88 kg for the 1.5%F. In order to determine the properties of both the SSC and FSSC, sample cylinders and cubes were cast. For each of the four batches (0%, 0.5%, 1% and 1.5%) three small cylinders and cubes were made for split tensile strength test and compressive tests (three for

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7-day strength and three for 28-day strength).

For the columns which had uniform cross-sections, pouring and damping were conducted in three stages. The concrete was scooped into the columns for 1/3 of the height before being damped with a long rod. The middle and top 1/3 were poured in the same manner and finally the surface was finished with a wet trowel.

Casting Procedure for Cover Of The Column

The column was filled in this way until the SSC inside the PVC tube and the FSSC outside the Perspex tube were equal and at roughly 1/3 the column height. The PVC pipe was then lifted until it was roughly 50 mm inside the concrete. This process was then repeated for the middle and upper 1/3 of the column. Casting procedure for cover of the column as shown in fig 4.



Fig 5 Casting procedure for cover of the column material properties mix design

Table 3.2 Trial Mixes

Trial mix		W/C ratio	Cement	Fine aggregate	Coarse aggregate
Trial mix 1	Quantity of concrete	0.4	515	431	1204.38
	Mix ratio	-	1	0.836	2.3386
Trial mix 2	Quantity of concrete	0.4	420	452	1265
	Mix ratio	-	1	1.076	3.0119

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Trial mix 3	Quantity of concrete	0.4	450	445	1245.72
	Mix ratio	-	1	0.988	2.768

Table 3.3 Design Mix

W/C ratio	cement (Kg/m3)	Fine aggregate (Kg/m^3)	Coarse aggregate(Kg/m^3)
Ratio	1	1.076	3
Quantity of concrete	420	452	1265

Reinforcement Details

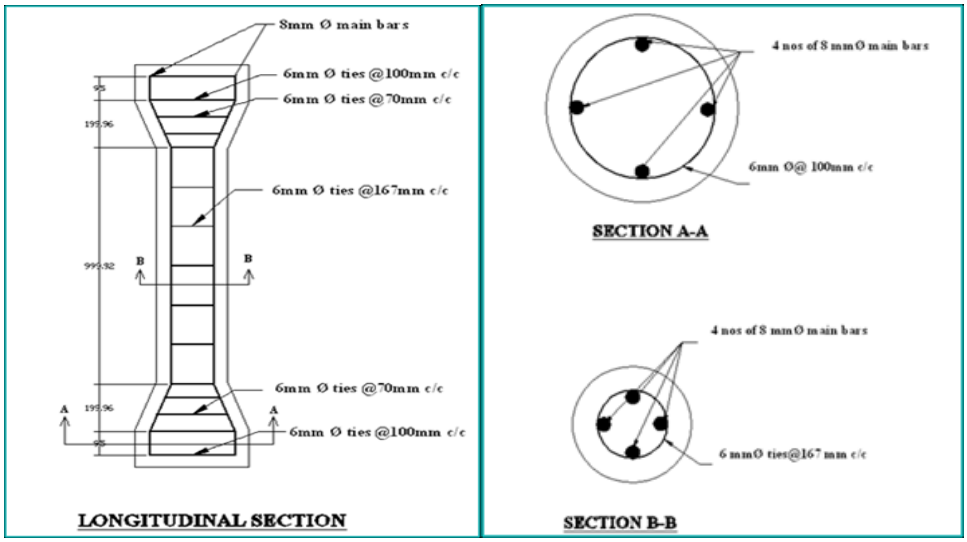




Fig 3.1 Reinforcement details

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Reinforcement Details

- Main bars = 4 No's 8mm dia. bars
- Stirrups = 6 mm dia. at 160mm c/c spacing in tested zone and 100mm c/c spacing for two head portion.

Theoretical Strength of the Column Pu= 0.4 fck Ac + 0.67fy Asc =361.77KN

Properties of Dalmia 43 Grade Cement

Dalmia 43 grade cement has been used throughout this investigation. Its properties obtained from the tests, conducted as per relevant BIS codes are given in table 3.4

Table 3.4 Properties of Dalmia 43 Grade Cement

S.No.	**Description of tests**		**Results**
1.	Specific gravity		3.15
2.	Normal consistency		32%
3.	Setting Time	Initial	40min
		Final	300min
4.	Average compressive strength @	3 days	28.80 N/mm^2
		7 days	33.80 N/mm^2
		28 days	44.50N/mm^2

Fig 3.2 setting time and average compressive strength of cement mortar cube.

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Slump Test

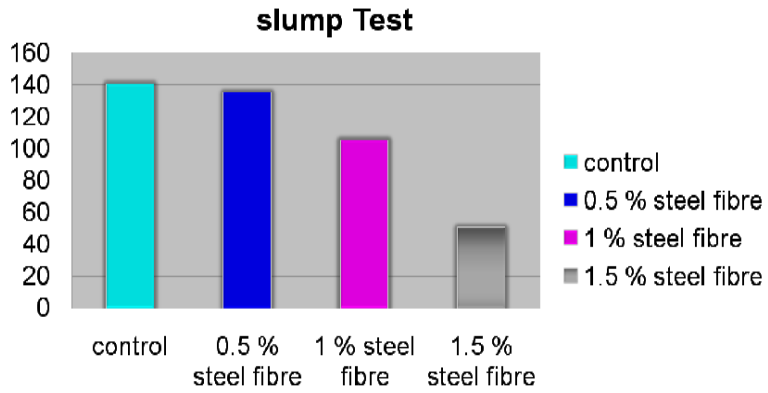


Fig 3.3 slump test

Slump value slightly decreases because adding steel fibre workability will be reduced. So adding some admixture and improve the workability of concrete (conplast 430)

Table 3.5 Properties of Hooked End Steel Fibre

S. No	***Properties of hooked end steel fibre***	
1	Type	Hooked end fibre
2	Fibre Length	60mm
3	Fibre Diameter	1mm
4	Aspect ratio	60
5	Yield Strength	1100-1380 MPa
6	Tensile strength	500–1100N/mm^2
7	Elastic modulus	(>200 Gpa)

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Advantages Of Hooked End Steel Fibre

- Hooked end steel fibres are hooked at each end to give improved mechanical anchorage of the fibres within concrete.

- It provides to improve the ductility, impact resistance, flexural strength, and shear strength & abrasion resistance relative to straight fibres.

Application of Hooked End Steel Fibre

- Hooked end steel fibre fibres are used in concrete slabs or overlays for roads, airfields, bridge decks, canal linings and industrial floors.

- When these clips enter the mix the adhesive is dissolved and individual fibres are distributed evenly throughout the mix.

Fine Aggregate

Fine aggregate used in this investigation was clean river sand passing through 4.75mm sieve with fineness modules of 2.57 and the specific gravity 2.47.

Determination of Bulk Density, Specific Gravity And Void Ratio

Bulk density = (W2 – W1)/ (W4 – W1) = 0.7986 gm./cc

Specific gravity = (W2 –W1)/ ((W4 –W3) + (W2 –W1)) = 2.76

Void ratio = (W3 – W2)/ ((W4 – W3) + (W2-W1)) = 2.46

Sieve Analysis Test Results For Fine Aggregate

Fineness modulus = $\frac{\sum F}{100}$ = 328.79/100= 3.28

Coarse Aggregate

For standard strength concrete, the maximum size of aggregate should be less. So the size of crushed granite angular aggregate used in the experiment was between 12.5 mm and 4.75 mm with the specific gravity of 2.7 and fineness modules of 6.89.

Determination of Bulk Density, Specific Gravity and Void Ratio

Bulk density = (W2 – W1)/ (W4 – W1) = 0.948 Kg/cc

Specific gravity = (W2 –W1)/ ((W4 –W3) + (W2 –W1)) = 2.71

Void ratio = (W3 – W2)/((W4 – W3)+(W2-W1)) = 1.86

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Chemical Admixture The properties of SP430 are given below.

Table 5.9 Specification Of Super Plasticizer

Specific gravity	1.220 to 1.225
Chloride content	Nil as per IS : 456 and BS : 5075
Air content	Approx. 1% additional air is entrained

Advantage

- Improved workability- easier, quicker placing and compaction
- Increased strength – provide high early strength for precast concrete if water reduction taken advantage.
- Improved quality – denser, close textured concrete with reduced porosity and hence more durable.

Uses

- To produce high workability of concrete requiring no vibration during placing
- To produce high strength, high grade concrete by substantial reduction in water resulting in low permeability and high early strength.

Instrumentation and Testing Procedure

Longitudinal strain were measured by using temech gauge and lateral displacement were measured by using two dial gauge in opposite of the column. The demec gauge pins are pasted to the three locations like top and bottom and center of the column as shown in Fig 1.

The axial displacement of specimen of specimen was recorded using six temech gauge value (front side three values and back side three value). The gauge length of temech gauge is 200mm. (original length). The entire specimen where tested vertically in a loading frame of capacity 1000KN shown in fig.

The loading was applied at the bottom of the column by using 100KN capacity hydraulic jack as shown in Fig 2.

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Fig 3.4 Failure Modes of Column



Fig3.5 Arrangement of Demec gauge pins and dial gauges

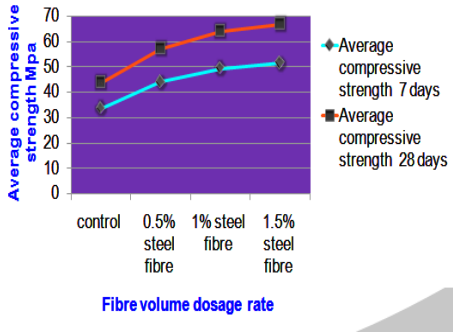


Fig 4.1 Average Compressive Strength Vs. Fibre Volume Dosage Rate

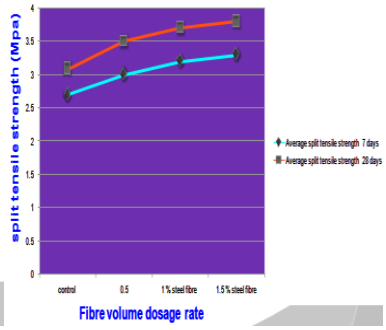


Fig 4.2 Average Split Tensile Strength Vs. Fibre Volume Dosage Rate

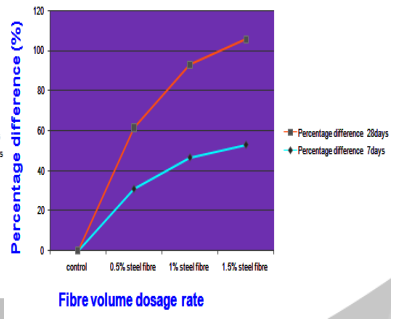


Fig 4.3 Percentage difference Ultimate Load, Yield Load, Spalling Load and First Crack Load of Column

IV RESULTS AND DISCUSSION

Behaviour of FRSSC under Axial Loading

Compressive Strength

Testing the concrete for its compressive strength revealed that it had a value of 43.615 MPa. This value increased to 57 MPa, 63.84 MPa and 66.586 MPa for the fibre mixes of 0.5, 1 and 1.5, respectively. Average compressive strength and percentage difference is as shown in Fig 4.1.

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Split Tensile Strength

Testing the concrete for its split tensile strength revealed that it had a value of 3 MPa. This value increased to 3.5 MPa, 3.7 MPa and 3.8 MPa for the fibre mixes of 0.5, 1 and 1.5, respectively. Average split tensile strength and percentage difference is as shown in fig4.2

Table4.3 shows yield load, ultimate load, first crack load and the spalling load columns.

Column	Yield load	Ultimate load	First crake load	Spalling load
R	360	375	280	360
0.5C	380	400	290	380
0.5F	385	405	325	385
1C	400	425	310	400
1F	360	380	330	360
1.5C	405	430	325	405
1.5F	420	450	340	420

Table 4.4 Shows Yield Load and Ultimate Load Corresponding Displacement

Column	Yield load(KN)	Displ. At yield load(mm)	Ultimate load (KN)	Displ. At Ulti. Load(mm)	Max displ. (mm)
R	360	0.8	375	3	10
0.5C	380	0.2	400	3.4	10
0.5F	385	0.2	405	2.2	9.6
1C	400	0.4	425	3	9.4
1F	360	0.2	380	2.2	9.4
1.5C	405	0.2	430	2.8	8.5
1.5F	420	0.4	450	2.4	8

Axial load versus lateral deflection relationship

Reference versus 0.5% fssc configurations

Table 4.5 axial load vs deflection

Axial load(KN)	Lateral deflection(mm)						
	Control	0.5C	0.5F	1C	1F	1.5C	1.5F
0	0	0	0	0	0	0	0
50	0.1	0.1	0.1	0.1	0.1	0.1	0.1
100	0.2	0.2	0.2	0.12	0.1	0.12	0.2
150	0.45	0.25	0.21	0.14	0.12	0.14	0.22
200	0.5	0.3	0.22	0.2	0.2	0.2	0.3
250	0.52	0.35	0.3	0.34	0.34	0.3	0.36

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300	0.58	0.4	0.32	0.38	0.38	0.34	0.4
350	0.59	0.44	0.4	0.39	0.4	0.38	0.41
400	1	0.42	0.41	0.4	0.4	0.4	0.43
420	1.1	1.2	0.8	0.8	1.2	0.8	0.45
400	1.5	1.2	1.2	1.2	2	1.2	1.2
370	2	1.6	1.21	1.6	2.8	2.8	1.21
380	2.2	2	1.2	2.8	4.4	4	1.6
400	4	4	1.6	4.2	5.6	5.2	2
380	4.1	4.8	2	4.3	6.8	6	3.6
350	6.5	6.8	4.2	4.8	10	8	4
300	8.1	8	6.2	7.2		9.4	6
270	10	10	8.2	8			6.4
250			10.2	10			8

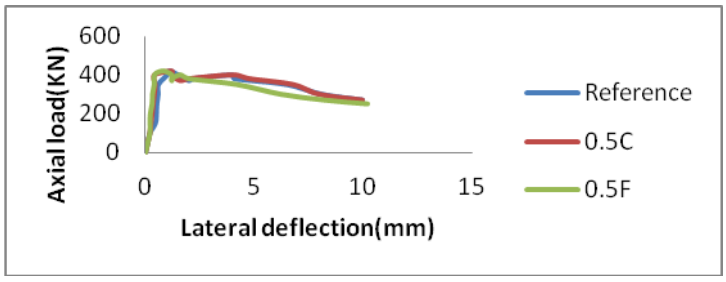


Figure 4.5 References versus 0.5% FSSC Configurations

Reference Versus 1% FSSC Configurations

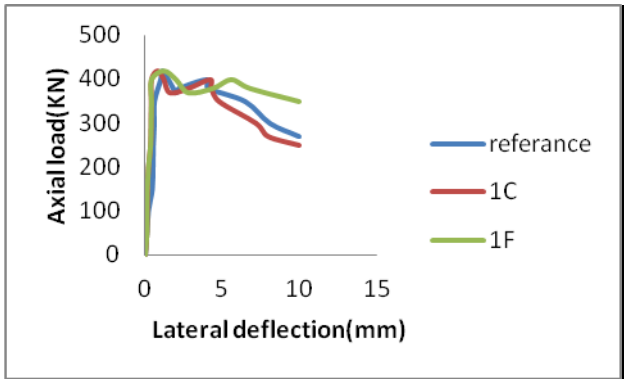


Figure 4.6 References Versus 1% FSSC Configurations

Reference Versus 1.5% FSSC Configurations

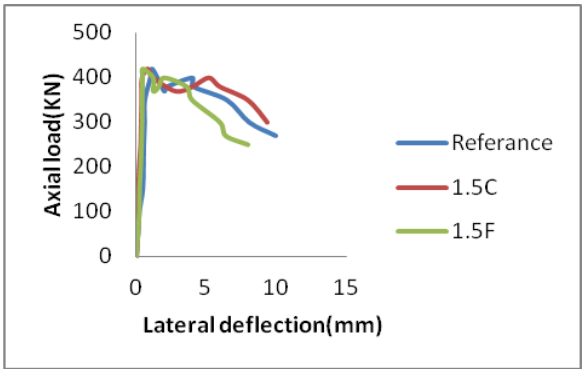


Figure 4.7 References versus 1.5% FSSC Configurations

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FRSSC in Cover, Plain in SSC in Core (0.5c, 1c, 1.5c) &Frssc In Full Cross Section(0.5f, 1f, 2f)

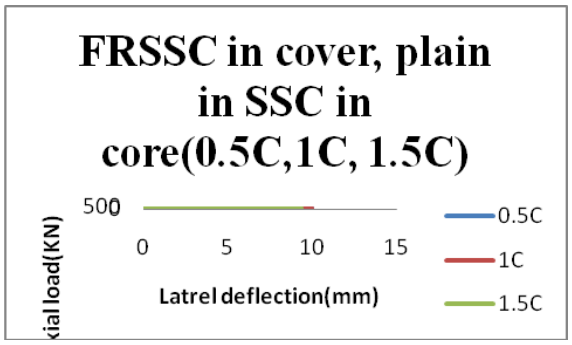


Fig 4.8 FRSSC in Cover, Plain in SSC in Core (0.5c, 1c, 1.5c)

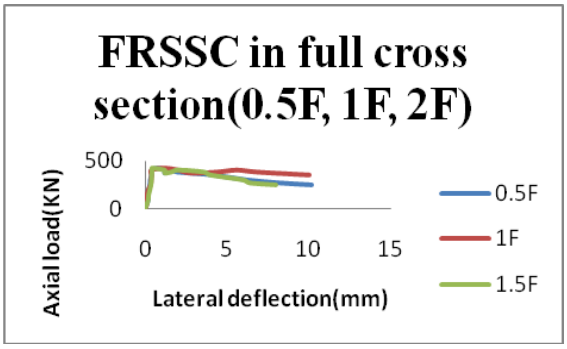


Fig 4.9 Frssc In Full Cross Section (0.5f, 1f, 2f)

Frssc In Full Cross Section (0.5f, 1f, 2f)

The columns with a full cross section of FHSC experience a higher first yielding failure and ultimate load proportional to the content of steel fibre, the greater the amount of steel fibre, the higher the load at failure. It can also be seen that the columns with a full cross section of FHSC possess a unique failure pattern where the load incrementally drops down in steps. The failure pattern of Column 1F is slightly different due to the helix failing prematurely, resulting in a strange pattern.

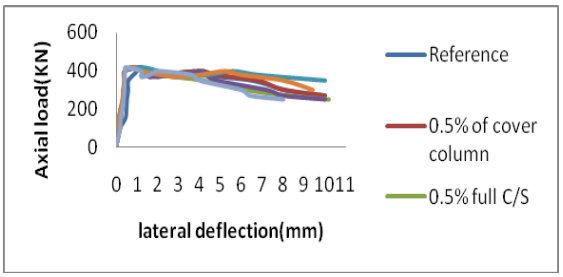


Fig 4.10 Reference Vs. 0.5%, 1%, 1.5% steel fibres used in cover and full c/s configurations

Cost of Adding Steel Fibres into Concrete

Table 4.8 - Cost Of Adding Steel Fibres Into Concrete

Percentage by Volume	Weight of Fibre Needed for /Specimen (Kg/Specimen)	Steel Fibre, Cost Per kg (Rs/kg)	Cost of Steel Fibre Needed for /Specimen (Rs)
0.5%C	0.320	250	80
0.5%F	0.630	250	157.5
1%C	0.641	250	160.25
1%F	1.25	250	312.5
1.5%C	0.96	250	240
1.5%F	1.88	250	470
TOTAL AMOUNT			1420.25

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V. CONCLUSIONS

This study of fibre reinforced concrete columns involved the testing of seven high strength concrete columns with varying fibre contents and fibre locations. The main aim of this study was to determine whether placing fibrous concrete only in the outer cover, would be sufficient to maintain, or enhance, the desirable properties of standard strength concrete columns. The following is a list of the conclusions drawn from this study.

- The addition of 1% to 1.5% steel fibres by volume into the matrix of the standard strength concrete produced the optimal performance in terms of compressive and tensile strength of the concrete.

- The higher the amounts of steel fibres present in the concrete, the lower the workability and the higher chance of variations in concrete strength and cavities.

- The addition of steel fibres into the concrete of the column increases the load and strain at which cover spalling takes place regardless of the content and location.

- The addition of enlarged end steel fibres into the cover of the column considerably increases its ductility.

- The columns consisting of 1.5% FSSC exhibited minimal cover spalling and a much higher ultimate strength. Also, columns consisting 1.5% FSSC in the cover only are able to resist higher amounts of lateral expansion due to axial loading.

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