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Performance evaluation of self-compacting fibre reinforced concrete infilled tubes under axial compression

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ABSTRACT

The behaviour of self-consolidating fibre reinforced high strength concrete (SCFRHSC) filled hollow structural steel (HSS) columns subjected to an axial load was investigated experimentally. A total of 45 specimens were tested. The main parameters varied in the tests are: (1) % of fibre (2) tube diameter or width to wall thickness ratio (D/t from 15 to 25) (3) L/d ratio from 2.97 to 7.04 The results from prediction were compared with the experimental data. Validation to the experimental results was made.

1. Introduction

Concrete-filled steel tubular (CFST) columns possess excellent earthquake-resistant properties such as high strength, high ductility, and large energy absorption capacity. In the last decades, they have gained increasing popularity in buildings, bridges and other structural applications. The use of concrete-filled steel tubular (CFT) columns for the construction of building structures, bridges and warehouses has become widespread in recent decades. These steel concrete composite columns have manifested several advantages over steel hollow section and reinforced concrete columns, such as high axial load capacity and favourable ductility performance. From a viewpoint of construction, the steel tube of CFT columns can serve as formwork for the concrete infill during construction, which makes CFT columns more economical than reinforced concrete columns. Tubed RC columns offer more advantages compared with conventional RC columns. In an ordinary RC column, the concrete is confined by transverse reinforcement; however, the ordinary reinforcing bars do not confine the concrete cover, which will spall off during an earthquake. The transverse ties cannot effectively prevent the longitudinal bars from buckling after the concrete cover spalls off unless they are very closely spaced. Filling the tube with concrete will increase the ultimate strength of the member without significant increases in cost. The main effect of concrete is that it delays the local buckling of the tube wall and the concrete itself, in the restrained state, is able to sustain higher stresses and strains that when is unrestrained. The use of CFTs provides large saving in cost by increasing the lettable floor area by a reduction in the required cross-section size. This is very important in the design of tall buildings in cities where the cost of letting spaces are extremely high. These are particularly significant in the lower storey of tall buildings where stubby columns usually exist.

More mechanical and economical benefits can be achieved if CFT columns are constructed from high-strength materials. For example, high-strength concrete infill contributes greater damping and stiffness to CFT columns than normal strength concrete. Moreover, high-strength CFT columns require a smaller cross-section to withstand the load, which is appreciated by architects and building engineers. Despite the advantages mentioned above, the use of high-strength CFT columns in the construction industry is still limited owing to the lack of understanding of their structural behaviour and insufficient recommendations in the design codes. In order to fully utilise the advantages of high strength CFT columns, a research need exists to extensively investigate their behaviour and to develop design provisions.

In recent years, the possibility of using thin-walled HSS columns filled with self-consolidating concrete (SCC), or self-compacting concrete, in practical engineering has been of interest to structural engineers. Self-consolidating concrete, as it is sometimes known, arrived as a revolution in the field of concrete technology. The self-compactability of concrete refers to the capability of the concrete to flow under its own weight and fill in the formwork in cast processing. Due to its rheological properties, the disadvantage of vibration can be eliminated while still obtaining good consolidation. Apart from reliability and constructability, advantages such as elimination of noise in processing plants, and the reduction of construction time and labor cost have been cited as arising from the self-consolidation function of SCC. It must be expected that SCC will be used in concrete-filled HSS columns in the future because of its good performance. However, these members are susceptible to the influence of concrete compaction. The literature review points out that the reputed investigation of thin walled structural steel sections with SCC fill are less numerous. fibre reinforced concrete (FRC) is used as an in-fill material, as

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it has greater flexural strength and tensile strength than plain concrete. The purpose of this study was to examine the effects of FRC on the strength and behaviour of composite columns. However it is to be noted that the addition of fibres in the concrete will enhance the load carrying capacity because the infill material has greater flexural strength and tensile strength than plain SCC. Therefore the lack of information on the behaviour of HSS Columns with SCC & Fibres as infill necessities the need for research in this area

The present study is an attempt to study the possibility of using high strength self-compacting concrete and steel fibres in thin walled HSS columns. The objectives of present study are: -

1. To develop High Strength self-compacting concrete by adopting Nan-su method.
2. To study the acceptance characteristics of SCC by measuring filling ability, passing ability and segregation resistance by using different test methods like Slump flow, U-box, L-box, Orimet and V-funnel test.
3. To compare strength parameters (compressive strength, Tensile strength and Flexural Strength) of normal Self-compacting concrete and fibre reinforced self-compacting concrete.
4. A method is to be formulated to study the experimental behaviour of self-compacting fibre reinforced concrete filled tubular columns and the proposed method will be examined with available method used for normally vibrated in filled columns.
5. Based on the analysis in comparison with the test data a parametric study will be carried out to study the influence of physical parameters and mechanical properties on load carrying capacity of column.

The final objective was to evaluate the possibility of using High strength self-compacting concrete with fibres (HSSCFRC) in thin-walled HSS columns in practice.

2. Past research

Experimental research on CFT columns has been ongoing worldwide for many decades, with significant contributions having been made particularly by researchers in Australia, Europe, and Asia. The vast majority of these experiments have been on moderate scale specimens (less than 200 mm in diameter) using normal and high-strength concrete. Neogi et al. investigated numerically the elasto-plastic behaviour of pin ended, CFT columns, loaded either concentrically or eccentrically about one axis.

It was assumed complete interaction between the steel and concrete, triaxial and biaxial effects were not considered. Eighteen eccentric loaded columns were tested, in order to compare the experimental results with the numerical solution. The conclusions were that there was a good agreement between the experimental and theoretical behaviour of columns with L/D ratios greater than 15, inferred that triaxial effects were small for such columns. Where for columns with smaller L/D ratios, it showed some gain in strength due to triaxial effect .

The studies on behaviour of the CFT columns are becoming more sophisticated in recent years. Some valuable analytical studies were carried out by Hajjar and Gourley(1996), Hu et al. (2003), Sakino et al. (2004), Lakshmi and Shanmugam (2002), and O'Shea and Bridge (2000). Hajjar and Gourley (1996) presented a polynomial equation to represent the three-dimensional cross-sectional strength of square or rectangular CFT columns. To verify the accuracy of proposed polynomial equation, analysis results were compared to other experimental results and showed strong agreement with experimental results. Hu et al. (2003) proposed material constitutive models and used the nonlinear finite element program to examine different cross sections of CFT columns. They attempted to show that the effect of the confining pressure is varied by different types of cross sections and the various geometric properties of the CFT columns. Sakino et al.(2004) attempted to derive methods to characterize the load deformation relationship of the CFT columns. In their research, a total of 114 specimens of axially loaded CFT short columns were fabricated and tested by the parameters. of tube shape, tube tensile strength, tube diameter-to-thickness ratio, and concrete strength. Lakshmi and Shanmugam (2002) proposed an analytical method to predict the inelastic and ultimate load behaviour and to compute the ultimate strength of the CFT columns. In their paper, non-linear equilibrium equations resulting from geometric and material nonlinearities were solved by an incremental-iterative numerical scheme based on the generalized displacement control method. O'Shea and Bridge (2000) developed several design methods to estimate circular thin-walled concrete-filled steel tubes under different loading conditions. In O'Shea and Bridge's study, several equations were verified by experimental test results, and thus, adopted for the prediction of the strength of the CFT columns. Experimental work on CFT columns also becomes quite extensive Tomii et al. (1977); Xiao (1989); Xiao et al. (2005); Hayashi (1990); Sato (1995); Huang et al. (2002); Schneider (1998)_. As a set of classical tests, Tomii et al. (1977) executed the experimental and analytical studies of the triaxial compressive behaviour of concrete-filled steel tube stub columns and they tested about two hundred seventy CFT columns with different cross sections. Xiao (1989) conducted a series of CFT stub column tests with loading only the internal concrete infill core. Hayashi (1990) examined the behaviour of reinforced circular concrete columns under axial compression and provided experimental test results of spiral reinforced concrete columns and concrete-filled steel tube with different geometries and material properties. Sato(1995) tested 33 different types of the CFT columns to investigate the interactions between steel tube and concrete in CFT columns. Huang et al. (2002) tested CFT columns under axial load to show the improved behaviour using different stiffening schemes. In the experiments, they used the CFT columns with the width-to-thickness ratios between 40 and 150, and conducted the non-linear finite element analysis to investigate the stress distribution at the ultimate strength. Schneider(1998) presented an experimental and analytical study on the behaviour of short, concentrically loaded CFT columns with different shapes and depth-tube wall thickness ratios and experimental results suggested that circular tubes offer substantial post yield strength and stiffness, not available in most square or rectangular cross sections.

Georgios Giakoumelis, Dennis Lam proposed an equation with a co-efficient for the ACI/AS equation to take into account the effect of concrete confinement on the axial load capacity of concrete filled steel tube, a revised equation was proposed as follows:

$N_U = 1.3\ Ac\ fc + As\ fy$

Where Nu= Predicted Failure load

Ravi kumar et al (7) proposed two equations based on previous experimental data of researchers(1-6)

1)First equation $P_{the} = C\ A_c f_c + A_s f_y$ where C=1.18 Constant.

2)Formula Predicted-2 $P_{the} = 1.71C\ (D/t)^a\ (fy/fck)^b \quad A_c f_c + A_s f_y$ where a & b are constants, Which were found using **multiple regression analysis** a=-0.35 ,b=0.45 and value of C is 0.60.

.The average of Predicted Theoretical Load /Experimental load for 213 Data is 0.92..

The average of Predicted equation 1 Theoretical Load /Experimental load for 213 Data is 1.01 and co-efficient of Variation is 0.30. Hence the formula may be used for predicting the load carrying capacity.

The average of equation 2 Predicted Theoretical Load /Experimental load for 213 Data is 0.92 and coefficient of Variation is 0.21

3) Experimental program

3.1) Concrete Properties

Concrete of design strength of 70 MPa was produced using commercially available materials with mixing using simple curing techniques. Mix design of grades was carried out in accordance to the Nan-Su method .The mix designs are shown in Table 1. These grades of concrete are designated as controlled concrete. The concrete mix was obtained based on Nan Su method dosages: 500 kg/m^3 of Portland cement, 728.25 kg/m^3 of sand, 720.82/m^3 of stone aggregate with maximum size 10 mm and. the fibres employed, with volume percentage equal to 0.5% to 2.0% by volume of concrete corresponding to 76 kg/m3 were steel corrugated type of The steel fibres used metal composites, and the type of fiber used was crimped which was made from low carbon drawn flat wires. These are commercially marketed as SW 30 crimped steel fibres.length L f = 30 mm and diameter Df = 0.5 mm (aspect ratio L f /D f = 60). These fibres were distributed randomly in the concrete during the mixing stage. The slump flow values of 11 trials of varying combinations were recorded in the Table 2. The compressive strength of concrete mixes satisfying the workability criteria were determined. The final optimum process involved 5 fresh property tests like slump flow, U-box test, L-box test and Orimet test were conducted to check the fresh properties of the fresh concrete (Table 3) and mix design for M-70 without and with fibres are tabulated are summarised in table no The scope of the present study is limited to following: -

1. To study the behavior of CFT by using SCFRC with respect to D/t and L/D ratio.
2. The materials used in this study are aggregates of 10mm downsize, sand confirming to zone II as fine aggregate, Class F-type fly ash from Raichur power plant, 53 grade Ordinary Portland Cement (Birla Super), super plasticizer (Glenium 6100).
3. The measurement of fresh properties of SCC for experimentations is limited to filling ability (slump flow, T50 slump flow, Orimet and V funnel) and passing ability (L-box and U-box) and segregation resistance (V funnel at T5 minutes).

In order to characterize the mechanical behaviour of concrete, three cubes, three prismatic and three cylindrical specimens were prepared from each type and tested.

Standard cube tests, flexure test and indirect tensile strength were used to determine the compressive strength, flexural strength and split tensile strength of concrete. In these concretes a vibrator was not employed for compaction A total of 45 cubes, 45 prisms, 45 cylinders (as presented in Table 2) were prepared by adding different percentage of steel fibre tlyash and discussed admixtures and tested after 28 days of curing on a compression testing machine of 2000 kN capacity.

3.2. CFT details

The curing of the CFT specimens was done by sealing the top surface with a polyethylene sheet, after wetting the top surface in order to avoid shrinkage of the concrete.

In order to study the behaviour of the composite CFT column, the following methodology is followed

1) Casting and testing of 45 CFT Specimens of circular shape for M70 grades of concrete will be tested.

2) The main variables was 0%, 1% .1.5% 2.0% fibre content for D/t ratios.

3) Available properties such as outer nominal dia., Actual dimensions, Actual wall thickness, D/t, L/D ratio are measured. (Table 1)

4) Dial gauges were used to measure the lateral deflections and strain gauges wee used to measure the horizontal and longitudinal strain in strain respectively. All specimens were loaded upto failure.

4. Test results and discussions

The typical structural behaviour of the tested columns is represented in Fig. 6 by the relationship between the load *P* and the lateral deflection at mid-height. This figure shows quite clearly that deflection was small during the initial part of the loading and increased rapidly near the ultimate load Furthermore, the figure also shows that columns filled with plain concrete exhibit greater mid-height displacement than columns filled with FRC at any given level of load. It is seen, therefore, that the FRC filled specimens exhibit lower flexibility compared with plain concrete filled specimens throughout the entire load–deflection range. The reason may be attributed to the fact that FRC has higher flexural strength than plain concrete. The curve also implies that FRC filled specimens have relatively less strain gradient, as seen from the higher slope of the ascending branch, than plain concrete filled specimens until failure occurred. This was most likely influenced by the higher elastic modulus of FRC.

5 Conclusions

This paper presents an experimental study on circular concentrically loaded concrete filled steel tube columns. Parameters for the study included the diameter, D/t ratio of steel tube, L/D ratio of steel tube and addition of % of steel fibre. The influence of these parameters on the confinement of the concrete core, the compression shared by the steel tube and ultimately load carrying capacity of the CFTs was investigated.

The results obtained from the tests on composite columns presented in this paper allow the following conclusions to be drawn.

1. FRC filled steel tubular columns has relatively high stiffness compared with plain concrete filled columns.
2. The ductility is found to be almost equal for both plain and FRC filled steel tubular columns.
3. The use of FRC in the steel tube results in an enhanced energy absorption capacity of the composite columns.
4. The use of FRC as a filling material increases the load bearing capacity to a much greater extent compared with that of unfilled columns and reduces the lateral displacements. From the bare tube results it was observed that the load carrying capacity of the steel tube per unit volume decreases as the D/t ratio increases. Hence it is suggested to fix the correct D/t ratio in order to make optimum usage of the material.
5. Ultimate loads were found to be increasing till 1.5% of steel fibres added to Self compacting concrete

6.Comparison of experimental failure loads with the predicted failure loads showed good agreement .

Table 1: Selection Criteria For CFT

D (mm)	t(mm)	$A_{s\,(mm2)}$	$f_{y\,(N/mm^2)}$	$A_{c\,(mm^2)}$	$f_{c(N/mm^2)}$	D/t	L	L/D
48.3	3.2	453.00	310.00	1379.03	70.00	15.09	340.00	7.04
76.1	4.5	1010.00	310.00	3536.44	70.00	16.91	340.00	4.47
114.3	4.5	1550.00	310.00	8709.69	70.00	25.40	340.00	2.97

Table 2: Mix Design Parameters

The fresh property tests along with their limitations are tabulated.

TRIAL NO	CA Kg/m^3	FA Kg/m^3	C Kg/m^3	FLA Kg/m^3	W Kg/m^3	SP Kg/m^3
1	720.82	728.25	500.00	137.508	214.732	4.93
2	720.82	728.25	500.00	137.508	214.732	5.55
3	720.82	728.25	500.00	137.508	214.732	6.16
4	720.82	728.25	500.00	137.508	214.732	6.78
5	720.82	728.25	500.00	137.508	214.732	7.40
6	720.82	728.25	500.00	137.508	214.732	8.01
7	720.82	728.25	500.00	137.508	214.732	8.63
8	720.82	728.25	500.00	137.508	214.732	9.24
9	720.82	728.25	500.00	137.508	214.732	9.86
10	720.82	728.25	500.00	137.508	214.732	10.47
11	720.82	728.25	500.00	137.508	214.732	11.09
12	720.82	728.25	500.00	137.508	214.732	11.71
13	720.82	728.25	500.00	137.508	214.732	12.32
14	720.82	728.25	500.00	137.508	214.732	12.90

Table 3: Fresh Property Tests For Confirmation

Trial No			Slump flow		
	SP Kg/m^3	SP (ml)	Horizontal(mm)	T50 cm(sec)	SP For 100 kg of cement 'ml'
1	4.93	34.4	300	15.78	800
2	5.55	38.7	450	15.60	900
3	6.16	43	480	14.00	1000
4	6.78	47.3	500	13.00	1100
5	7.40	51.6	550	12.20	1200
6	8.01	55.9	600	10.02	1300
7	8.63	60.2	680	7.16	1400
8	9.24	64.5	705	6.00	1500
9	9.86	68.8	720	5.90	1600
10	10.47	73.1	740	5.06	1700
11	11.09	77.4	750	5.00	1800
12	11.71	81.7	760	4.91	1900
13	12.32	86.0	780	4.09	2000
14	12.90	90.3	790	4.00	2100
Values			650-800	2-5 secs	

Table 4 : Summarized mix proportioning of M70 without fibers:

Particulars	Values	Units
Coarse Aggregate	720.83	kg/m^3
Fine Aggregate	728.25	kg/m^3
Cement	500.00	kg/m^3
Fly-ash	137.508	kg/m^3
Water	214.732	kg/m^3
Super Plasticizer Dosage (SP)	12.908	kg/m^3

Table 5: Fresh Property Test

Trial No.	Slump flow		L- Box	V- funnel		U- Box			Orimet
	Horizontal (mm)	T_{50} cm (sec)	Blocking ratio (H_2/H_1)	(Tr) Flow (sec)	Flow at T_5 min (sec)	Left Limb (cm)	Right Limb (cm)	Diff in height (mm)	Flow (sec)
1	760	4.91	0.8	17	21	30.5	30.2	3	5
2	760	4.09	0.85	16	19	30.0	30.3	3	5
3	790	5.00	0.85	15	18	30.5	30.3	2	4
Values	600-800	2-5	0.8-1	6-12	$\leq$ Tr+3			Max 30	0-5

TABLE 6The summarized mix proportioning of M70 with fibres Vf: 0.5 %

Particulars	Values	Units
Coarse Aggregate	720.83	kg/m^3
Fine Aggregate	728.25	kg/m^3
Cement	500.00	kg/m^3
Fly-ash	137.508	kg/m^3
Water	214.732	kg/m^3
Super Plasticizer Dosage (SP)	14.79	kg/m^3

Table 7: Results Of The Fresh Properties Tests Of Sfrscc (0.5% Vf)

SL. No	Slump Flow		V-Funnel	
	$T_{50(sec)}$	Dia(mm)	$T_{1(sec)}$	$T_{5(sec)}$
1	5.85	740	25.6	26
2	4.73	750	24.9	25.4
3	4.08	760	24.3	25

Table 8:The summarized mix proportioning of M70 with fibres Vf: 1.0 %

Particulars	Values	Units
Coarse Aggregate	720.83	kg/m^3
Fine Aggregate	728.25	kg/m^3
Cement	500.00	kg/m^3
Fly-ash	137.508	kg/m^3
Water	214.732	kg/m^3
Super Plasticizer Dosage (SP)	18.49	kg/m^3

Table 9: Results Of The Fresh Properties Tests Of Sfrscc (1.0% Vf)

SL.No	Slump Flow		V-Funnel	
	$T_{50(sec)}$	Dia(mm)	$T_{1(sec)}$	$T_{5(sec)}$
1	6.37	730	30.1	32.2
2	5.84	740	28.2	30.7
3	4.26	755	27.8	29.4

Table 10 :The summarized mix proportioning of M70 with fibres Vf: 1.5 %

Particulars	Values	Units
Coarse Aggregate	720.83	kg/m^3
Fine Aggregate	728.25	kg/m^3
Cement	500.00	kg/m^3
Fly-ash	137.508	kg/m^3
Water	214.732	kg/m^3
Super Plasticizer Dosage (SP)	23.43	kg/m^3

Table 11: Results Of The Fresh Properties Tests Of Sfrscc (1.5% Vf)

SL.No	Slump Flow		V-Funnel	
	$T_{50(sec)}$	Dia(mm)	$T_{1(sec)}$	$T_{5(sec)}$
1	5.28	720	32.4	33.7
2	4.82	745	30.1	32.2
3	4.47	750	29.8	31.2

Table 12: The summarized mix proportioning of M70 with fibres Vf: 2.0 %

Particulars	Values	Units
Coarse Aggregate	720.83	kg/m^3
Fine Aggregate	728.25	kg/m^3
Cement	500.00	kg/m^3
Fly-ash	137.508	kg/m^3
Water	214.732	kg/m^3
Super Plasticizer Dosage (SP)	29.58	kg/m^3

Table 13: Results Of The Fresh Properties Tests Of Sfrscc (2.0% Vf)

SNo	Slump Flow		V-Funnel	
	$T_{50(sec)}$	Dia(mm)	$T_{1(sec)}$	$T_{5(sec)}$
1	5.18	690	34.2	35.7
2	4.11	700	35	36.1
3	4.02	720	36.4	37.3

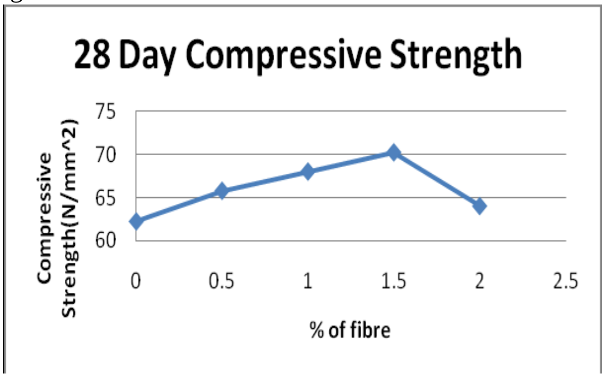
Fig 1 : Cutting of Specimens of required size

Fig.2. Specimens of concrete filled tubes

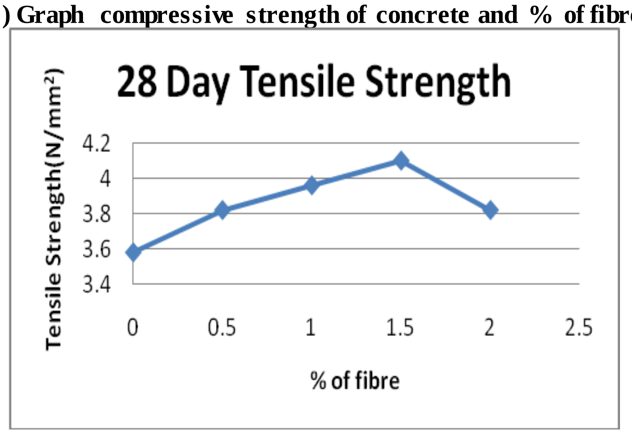
The formula for calculating the theoretical value of compressive strength:-

$P_{the} = C A_c f_c + A_s f_{y,}$ (Reference no.7)

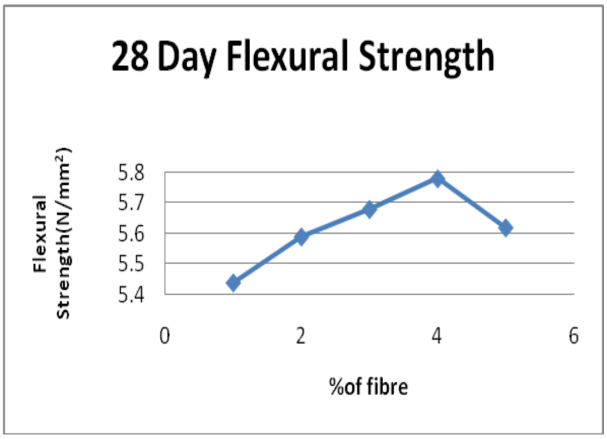
Here, C= constant=1.18 ,A_c =area of concrete, f_C = characteristic strength of concrete , A_s = area of steel ,f_y =characteristic strength of steel



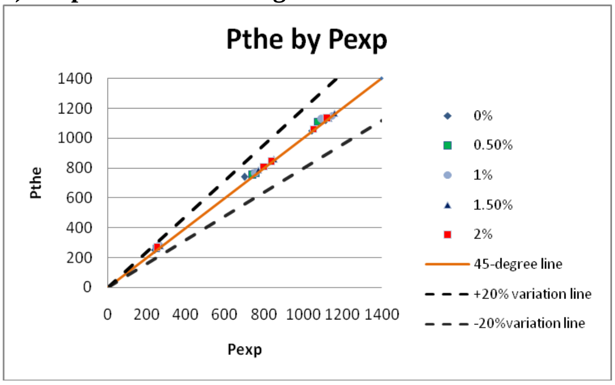
1) Graph compressive strength of concrete and % of fibre



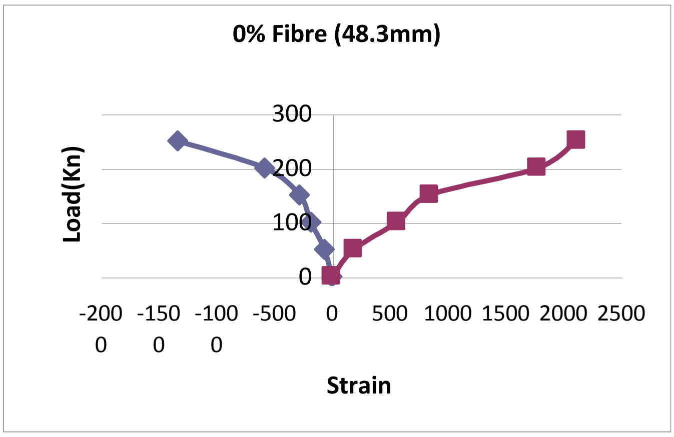
2) Graph Tensile strength of concrete and % of fibre



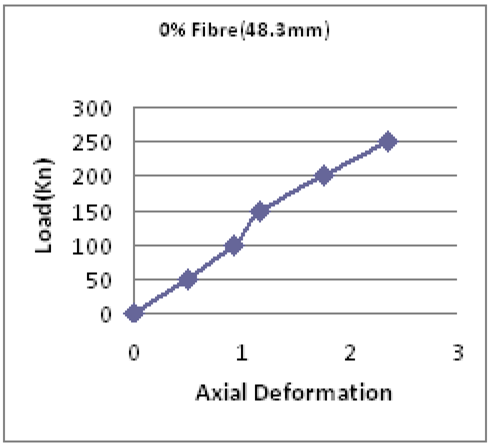
3) Graph Flexural strength of concrete and % of fibre



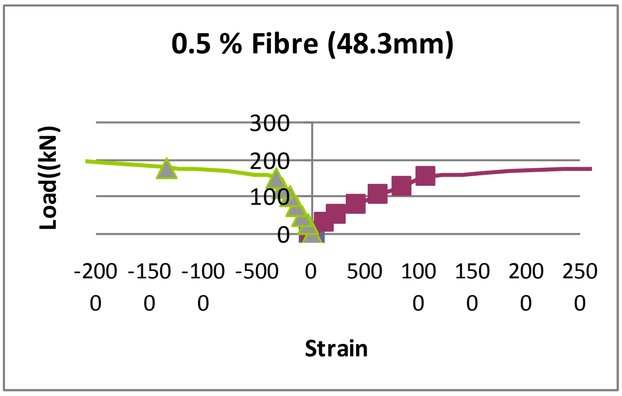
4) Graph P theoretical versus experimental value (CFT)



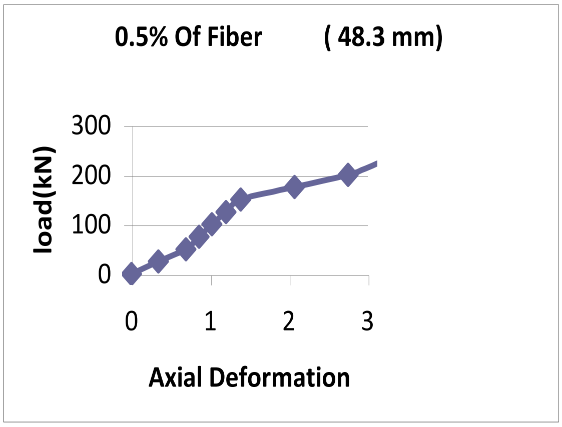
5) Graph Load (Y axis) vs. linear(-)and lateral strain(+)



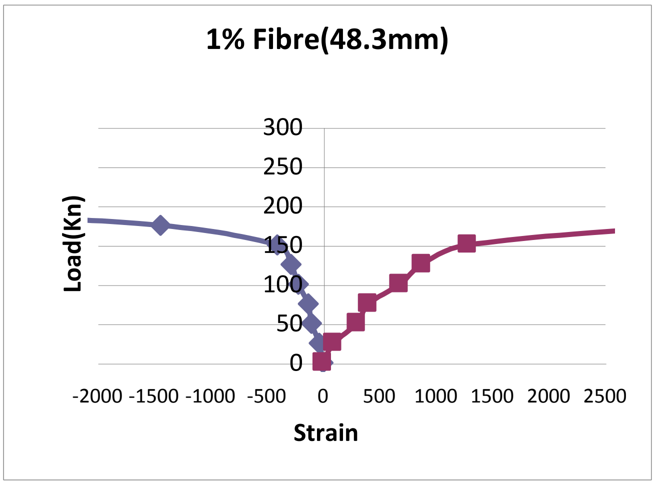
6) Load Versus Axial Deformation

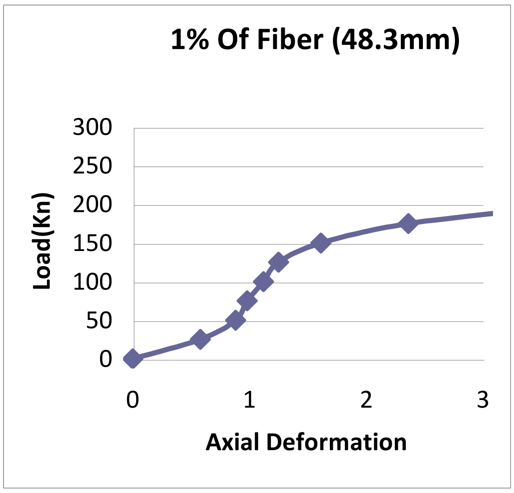


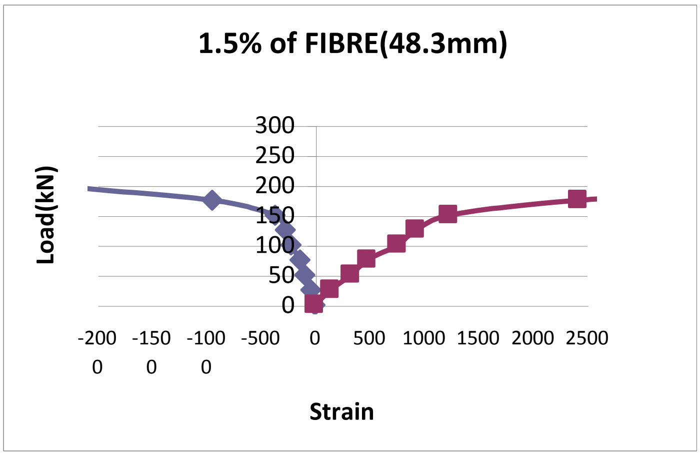
5) Graph Load (Y axis) vs. linear(-)and lateral strain(+)

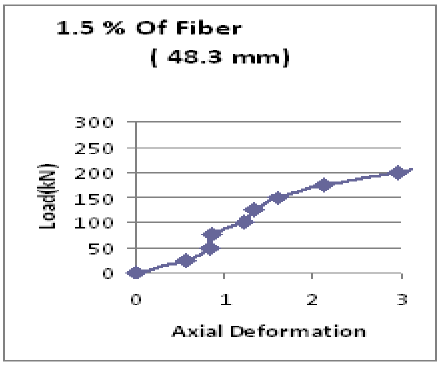


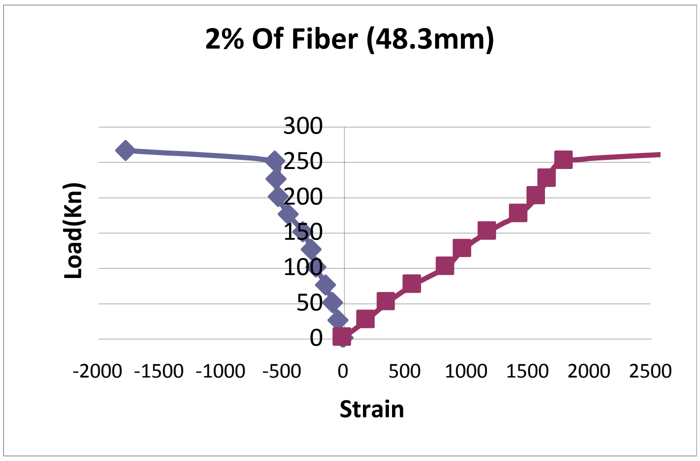
6) Load Versus Axial Deformation











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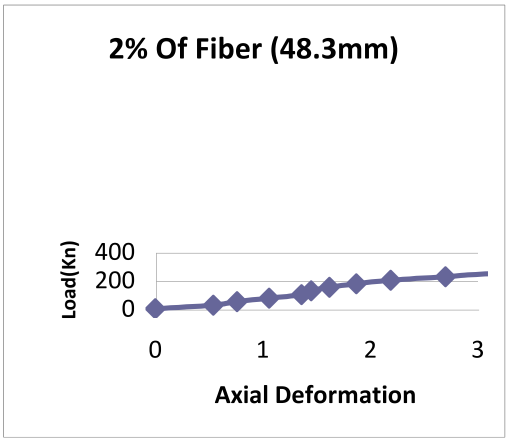
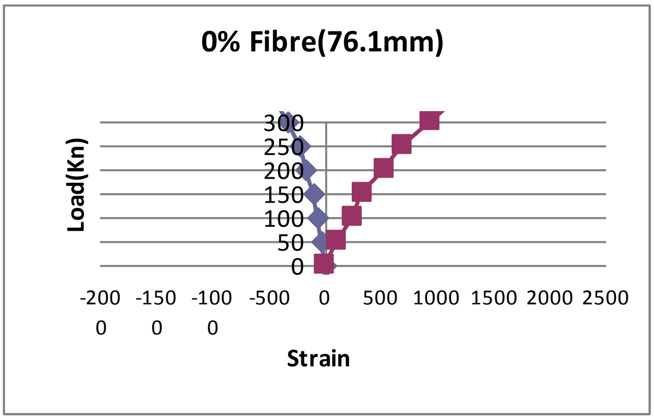
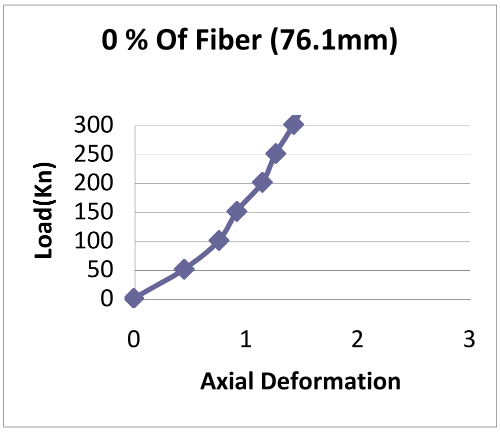
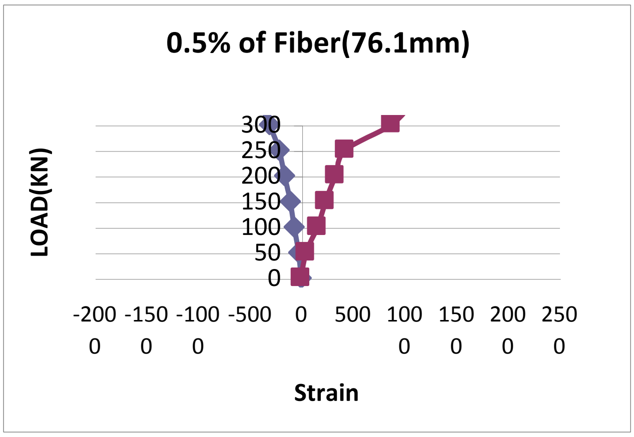
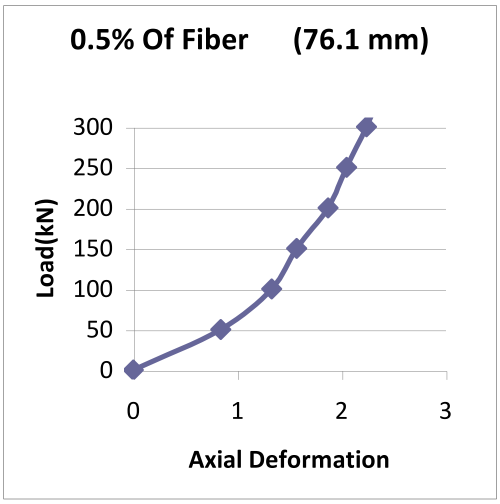


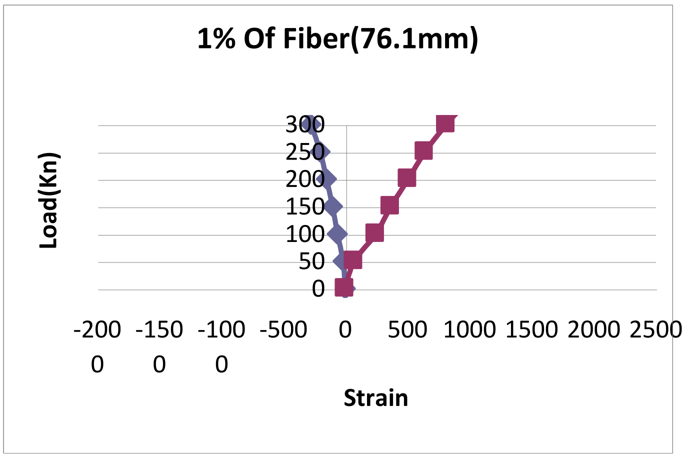
6) Load Versus Axial Deformation



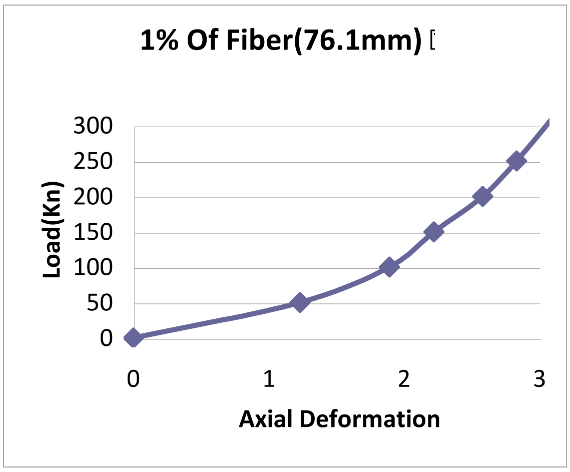




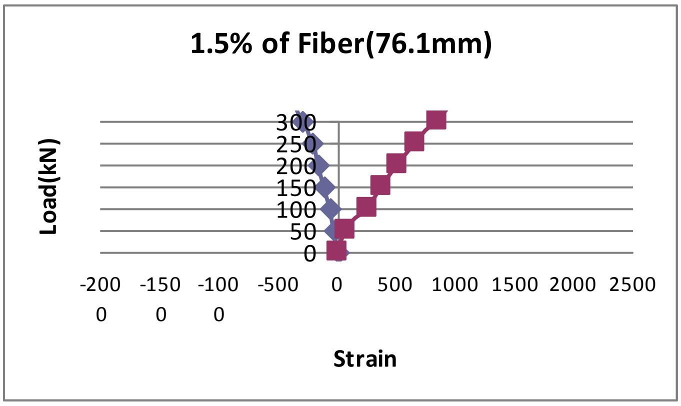


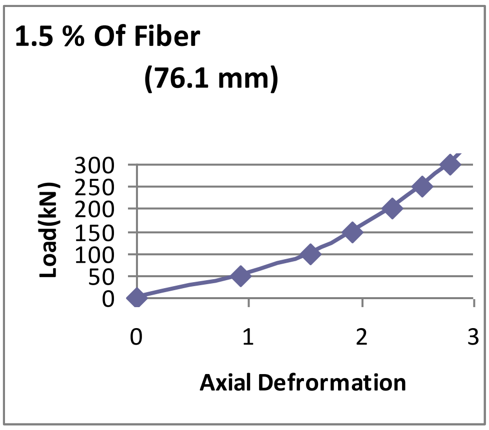


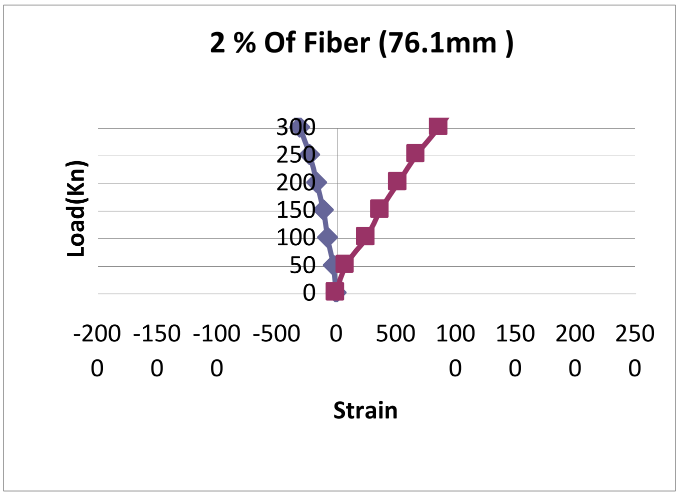
5) Graph Load (Y axis) vs. linear(-)and lateral strain(+)

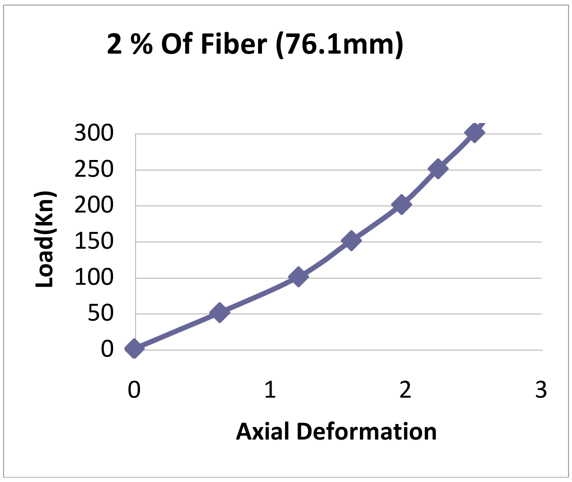


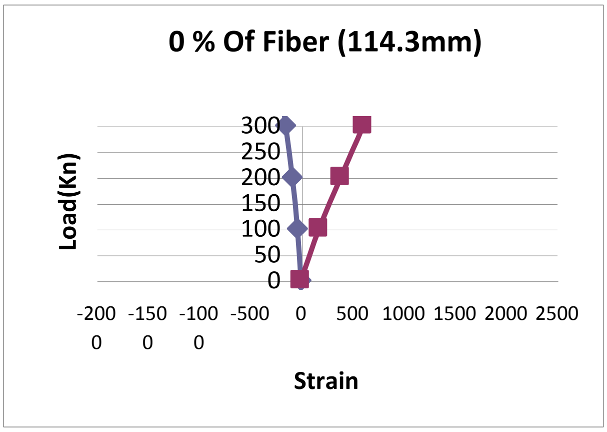
6) Load Versus Axial Deformation



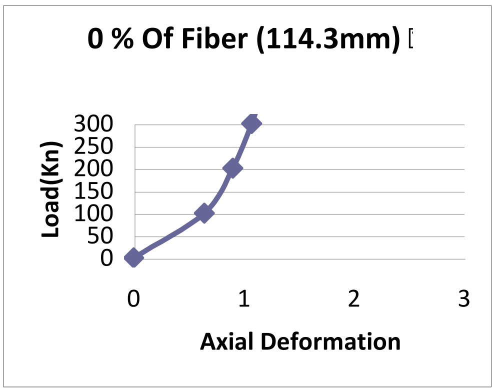




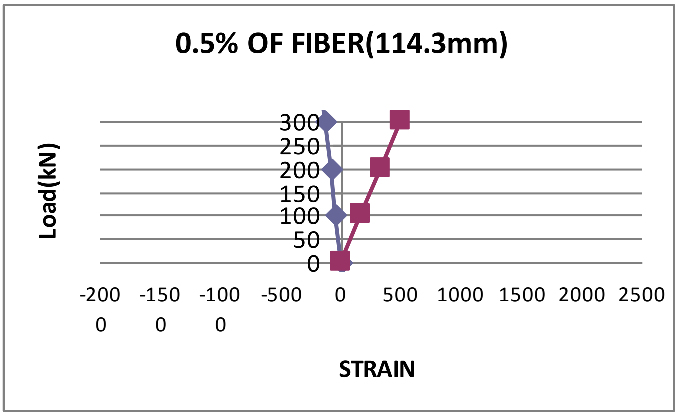


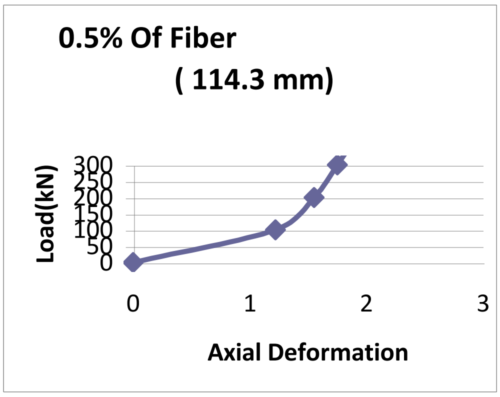


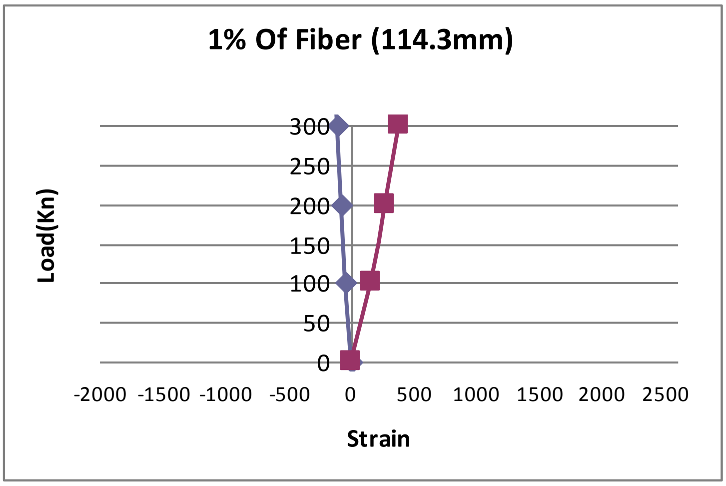
5) Graph Load (Y axis) vs. linear(-)and lateral strain(+)



6) Load Versus Axial Deformation







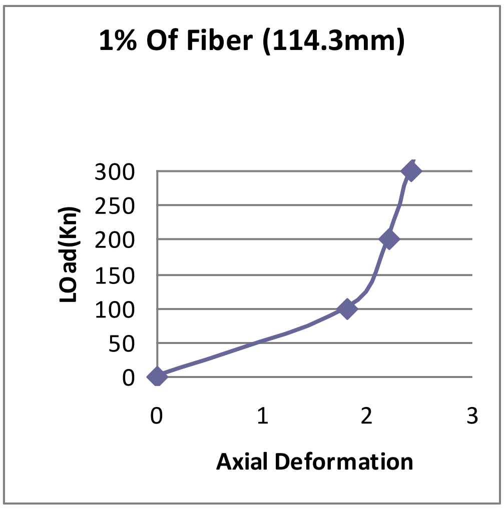
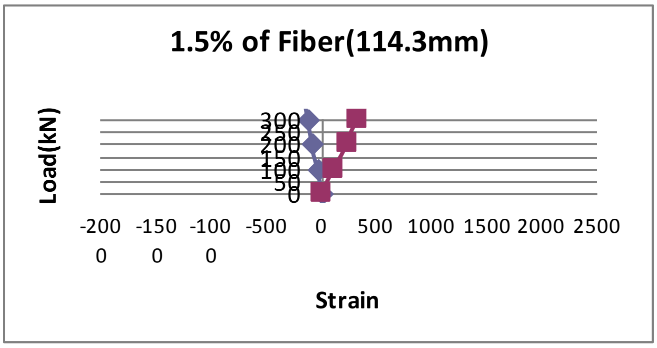
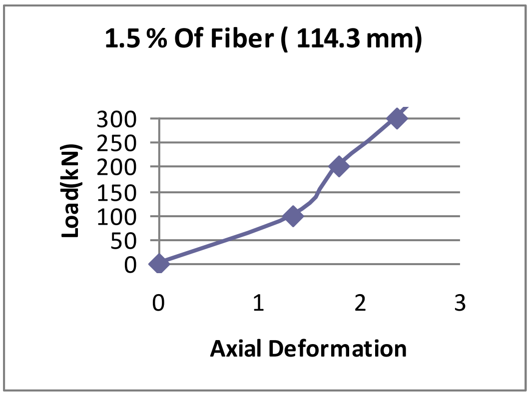


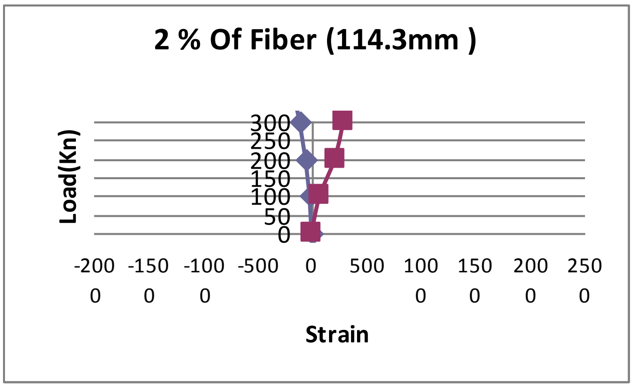
Table 14: Values Of Load Carrying Capacity Of Various Diameter Of Cft & % Of Steel Fibres

SI NO.	%of Fibre	Dia.	Thickness	Pthe (KN)	Pexp. (KN)	Pexp/Pthe	fc (N/mm^2)
		48.3	3.2	250.00	240.00	0.960	62.22
		76.1	4.5	760.00	745.00	0.980	62.22
1	0%	114.3	4.5	1120.00	1115.00	0.995	62.22
		48.3	3.2	260.00	248.00	0.954	65.77
		76.1	4.5	765.00	759.00	0.992	65.77
2	0.5%	114.3	4.5	1135.00	1124.00	0.990	65.77
		48.3	3.2	275.00	266.00	0.967	68.00
		76.1	4.5	770.00	758.00	0.984	68.00
3	1.0%	114.3	4.5	1150.00	1146.00	0.996	68.00
		48.3	3.2	278.00	269.00	0.967	70.22
4	1.5%	76.1	4.5	860.00	850.00	0.989	70.22
		114.3	4.5	1168.00	1159.00	0.992	70.22
5		48.3	3.2	265.00	251.00	0.947	64.00
		76.1	4.5	840.00	835.00	0.994	64.00
	2.0%	114.3	4.5	1130.00	1124.00	0.994	64.00

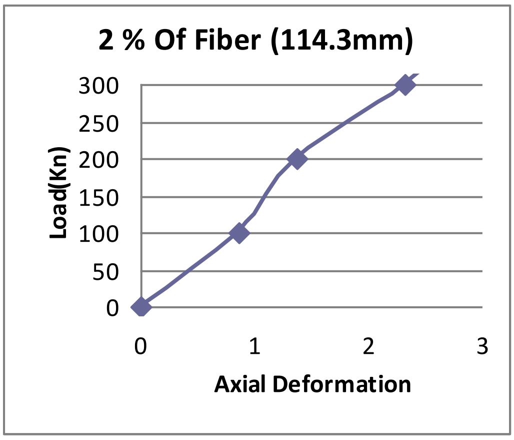




6) Load Versus Axial Deformation



5) Graph Load (Y axis) vs. linear(-)and lateral strain(+)



6) Load Versus Axial Deformation

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