OPEN ACCESS INTERNATIONAL JOURNAL OF SCIENCE & ENGINEERING

ANALYSIS OF IMPROVEMENT OF CONCRETE TORSIONAL STRENGTH BY INCORPORATING RANDOMLY DISPERSED STEEL FIBRE IN TO THE CONCRETE BY USING SOFTWARE

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Abstract: This study investigate the effect of steel fibre on compressive strength and torsion strength of beam If external loads act far away from the vertical plane of bending, the beam is subjected to twisting about its longitudinal axis, known as torsion, in addition to the shearing force and bending moment. The current torsion design approach assumes no interaction between flexure, shear and torsion. In the present work performance of reinforced concrete beams with and without steel fibres were studied subjected to pure torsion. The experimental program consists of casting 12 reinforced concrete beams of size 150mm X150 mm and length 2m. Three of them was cast without fibres to make a comparative study with the remaining beams; The group of three beam are casted with 5% fibre ,10% fibre & 15% fibre. The longitudinal reinforcement with 4 # 8 mm diameter and 6 mm stirrups at 150 mm spacing was kept constant for all beam. The same specimen data is analysed by using ansis software. The results concluded that the cracking torsional strength and ultimate torsional strength goes on increasing as the percentage of Steel fiber goes on increasing as the mentioned above.

Keywords: Steel Fibres, Aspect ratio, Reinforced Concrete, Beam, Compressive strength, Torsional strength.

I.INTRODUCTION

The purpose of FE Analysis is to model the behaviour of the structure under a system of load. In order to perform the analysis all influencing factors must be considered and determined whether their effects are considerable or negligible on the final results. The degree of accuracy to which any system can be modelled is very much dependent on the level of planning that has been carried out. All the parameters and factors have to be accounted while planning the analysis. Planning an Analysis' is directly deals with the improving the results under specified condition. The analysis is carried out in following three stages - Pre-Processing, Solution, Post Processing.

Pre processing:

In this stage, the model of test setup has been prepared using CATIA V5. Meshing and solution is obtained using ANSYS.

CAD modeling:

CAD model is created using CATIA V5 software. CAD model of whole assembly is exported in STEP format and STEP file generated is imported in ANSYS for further processing.

II.SCOPE AND OBJECTIVES

a. To investigate experimentally torsional moment of steel fibre reinforced concrete with varying
b. To study the effect of fiber inclusion in concrete. proportions of steel fibres 5%, 10%, 15% in concrete for M30 & M40 grade of concrete.
c. To compare results of torsional moment of stee
d. l fibre reinforced concrete with the conventional concrete.

III.METHODOLOGY

Finite Element Modeling:

A continuous region is divided discrete region called elements in FE analysis. This procedure is called discretization or meshing. Initial designed FE mesh cannot hold its original shape and it is distorted due to severe plastic deformation during load application processes.

The distortion causes convergence rate and numerical errors. To handle with this problem a new FE mesh must be generated in means of changing the size and distribution of the mesh. This is called adaptive mesh procedure. One of adaptive mesh procedure is re-meshing technique and it includes the generation of a completely new FE mesh out of the existing distorted mesh. Second one is called refinement technique which is based on increasing the local mesh density by reducing the local element size as shown in Figure 5.1.

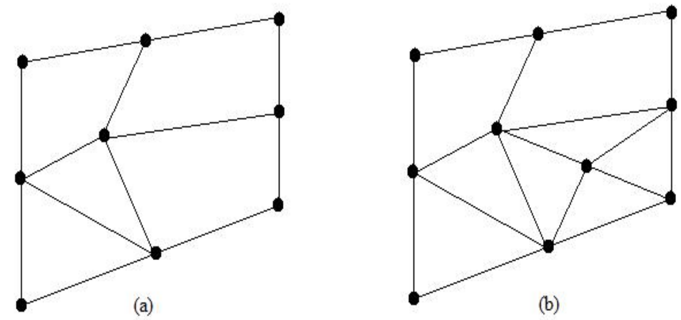


Fig.5.1. : Refinement: (a) Initial local mesh, (b) Reducing element size

The last adaptive mesh technique is smoothing which includes reallocating the nodes to provide better element shapes as shown in Figure5.2.2 (b).

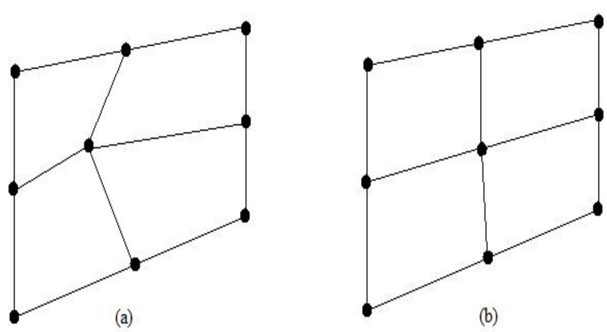


Fig.5.2. : Smoothing: (a) Initial local mesh, (b) Reallocating of the nodes

The adaptive mesh procedure decreases solution errors during calculation therefore it increases the accuracy of the simulation. For these reasons, the adaptive mesh procedure must be used in FE simulations including severe plastic deformation such as metal cutting and metal forming.

Manual meshing is long and tedious process for models with any degree of geometric complication, but with useful tools in a ANSYS, the task is becoming easier. Automatic mesh generation in a ANSYS is very useful and popular.

CAD model exported from CATIA V5 is imported in ANSYS for further procedure. Initially geometry cleanup is performed to make the geometry free from all reference lines, points and plane used in modelling. Once the geometry cleanup operation is completed Mesh parameters are defined to generate the mesh. The square blocks, the I-section and lateral steel sections are meshed using SOLID 186 elements, Concrete beam, Steel rods and steel fibers , supporting bar are meshed with second order tetra SOLID 187 elements. The welding joints are also modelled so as to capture appropriate behaviour. In order to get more accurate results, the beam is meshed with higher density.

The global mesh setting for setup is shown in table shown below:

Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Fun...	Off
Relevance Center	Coarse
Element Size	Default
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	3.0 mm
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Advanced	
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)
Extra Retries For Assem...	Yes

Fig.5.3. :Finite Element Global Mesh Menu

The refinement technique of meshing is used to mesh the model. The finite element model is shown in figure 5.3. having 381688 elements and 251927 nodes.

In order to achieve higher accuracy in the results and to represent the curvatures, proximity and second order elements are used for meshing. Second order elements have mid-node on each edge. The contact between concrete beam and steel rods is considered as bonded. Frictional contact is defined between concrete beam and end supports through which the twist is applied to beam.

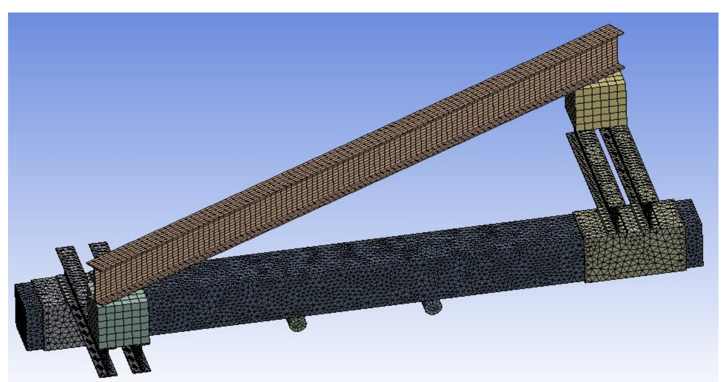
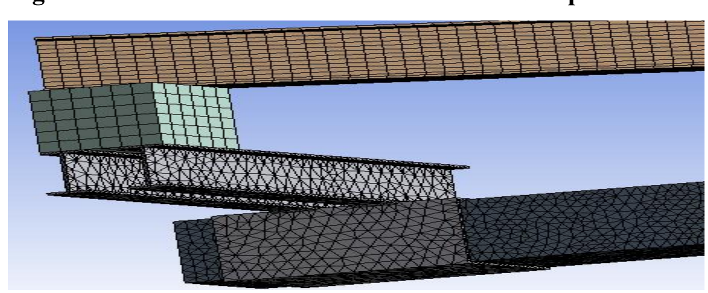


Fig.5.4. :Finite Element Model of Beam Test Setup



Nodes	381688
Elements	251927

Fig.5.5. :Block and I-Section

Material properties

The properties of different parts material have a tremendous influence on their contribution in structural strength. For example, the materials moduli determines the range of the stiffness offered against deformation of the part. Therefore, these material properties have to be determined for the computer simulation. The summaries of Mechanical properties used are shown in figure 5.6.

Properties of Outline Row 4: Structural Steel

	A		B	C
1	Property		Value	Unit
2		Density	7.85E-09	tonne mm^-3
3	⊞	Isotropic Secant Coefficient of Thermal Expansion		
6	⊟	Isotropic Elasticity		
7		Derive from	Young's M...	
8		Young's Modulus	2E+05	MPa
9		Poisson's Ratio	0.3	
10		Bulk Modulus	1.6667E+05	MPa
11		Shear Modulus	76923	MPa
12	⊞	Alternating Stress Mean Stress	Tabular	
16	⊞	Strain-Life Parameters		
24		Tensile Yield Strength	250	MPa
25		Compressive Yield Strength	250	MPa
26		Tensile Ultimate Strength	460	MPa
27		Compressive Ultimate Strength	0	MPa

Fig.5.6. : Mechanical Properties Structural Steel

Properties of Outline Row 3: Concrete

	A		B	C
1	Property		Value	Unit
2		Density	2.548E-09	tonne mm^-3
3	⊞	Isotropic Secant Coefficient of Thermal Expansion		
6	⊟	Isotropic Elasticity		
7		Derive from	Young's M...	
8		Young's Modulus	49500	MPa
9		Poisson's Ratio	0.2	
10		Bulk Modulus	27500	MPa
11		Shear Modulus	20625	MPa
12		Tensile Yield Strength	0	MPa
13		Compressive Yield Strength	0	MPa
14		Tensile Ultimate Strength	5	MPa
15		Compressive Ultimate Strength	41	MPa

Fig.5.7. : Mechanical Properties Concrete

TEST PROCEDURE

The loading may be in the form of a point load, a pressure load or a displacement in a stress (displacement) analysis, a temperature or a heat flux in a thermal analysis and a fluid pressure or velocity in a fluid analysis. The loads may be applied to a point, an edge a surface or an even a complete body.

The loads are applied in the same units as the model geometry and material properties specified. Remote Force (Direction of application updates with the deformation) is applied on 300mm Diameter disk Patch, disk is not considered in the analysis so as to reduce the number of elements and analysis time. Density of all parts has been defined to consider their self-weight in the analysis.

Boundary Conditions and Load Steps :

Once the element matrices are obtained, they are assembled to form the set of linear simultaneous equations, the solution of which yields the displacement field. The assembly is based on the principle of maintaining the continuity of the primary variable, in this case displacement and the equilibrium of the secondary variables, here forces and weights.

The two types of boundary conditions are used:

1. Essential or geometric boundary conditions which are imposed on the primary variable like displacements, and

2. Natural or force boundary conditions which are imposed on the secondary variable like forces.

The force boundary conditions are imposed during the evaluation of the element matrices itself while the prescribed displacement boundary conditions are imposed after the assembly of the element matrices. Then the global system of linear equations is solved by any numerical technique to get the displacements at global nodes.

Ends of the bars on which the beam is supported are fixed at the ends. Reduced sections of the bars are considered to reduce number of elements and reduce solution time.

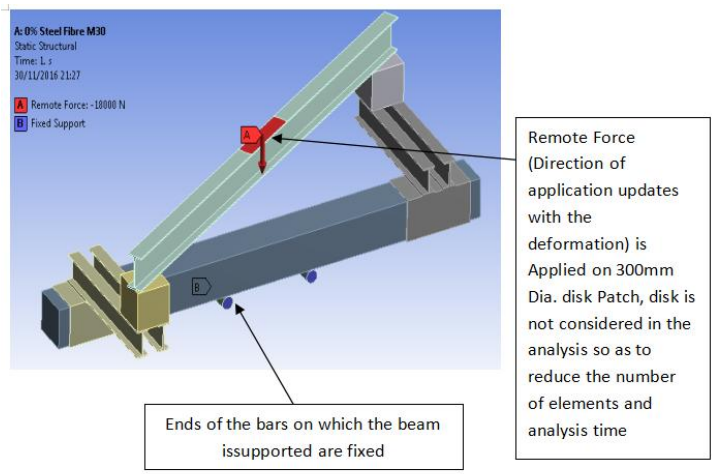


Fig.5.8. : Boundary conditions

Solution:

The model which has been pre-processed is cross checked for all contacts , loads and boundary conditions and analysis is started simply by clicking right mouse button and selecting solve using option from 'Solution' drop down menu.

During execution, several other files are generated and stored at the output path selected output path. Also, screen messages are issued to report on progress of the solution phase. A listing of all printed output is stored in filename. msg. This file contains the input data, all numerical output, and any error messages issued during execution. Several additional files are created for use by the output processor. The nodal displacement and element stress data is stored in filename.res.

Post-processing:

After completion of the analysis the result files are generated as per the preparation of the deck. The .res file is generated which contains all the binary plots of the solution. This file containing all the results is opened in the post-processor (ANSYS Solution Menu) for analyzing and plotting the results. Displacement results can be displayed as a plot of the deformed element mesh superimposed over a plot of the unreformed model. Displacements can be scaled such that the deformed shape is exaggerated for clarity. For two-dimensional solid models, stress components can be displayed as contour plots. The stress components available from the solution are the normal, shear, and Von-Mises stress components for plane stress and plane strain, and the radial, axial, shear, and hoop stress components for axi-symmetric models. For models using truss or beam elements, stress components are plotted as in table no.5.1, and 5.2.To obtain torsional strength of reinforced concrete beam shear stress are used and theory of pure torsion.

Deformation and stress plots for the Vertical Carousal Machine are shown below.

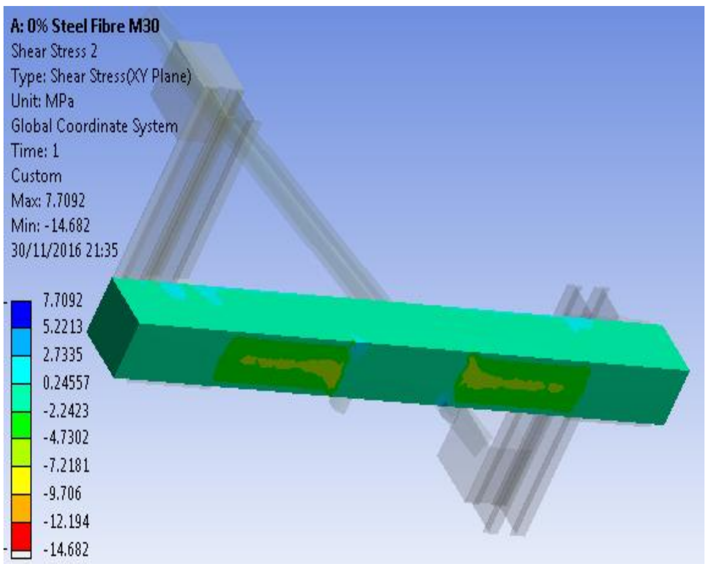


Fig.5.9. : Snapshot of beam model (0% steel fiber) of M30 grade modelled and analysed using ANSYS software

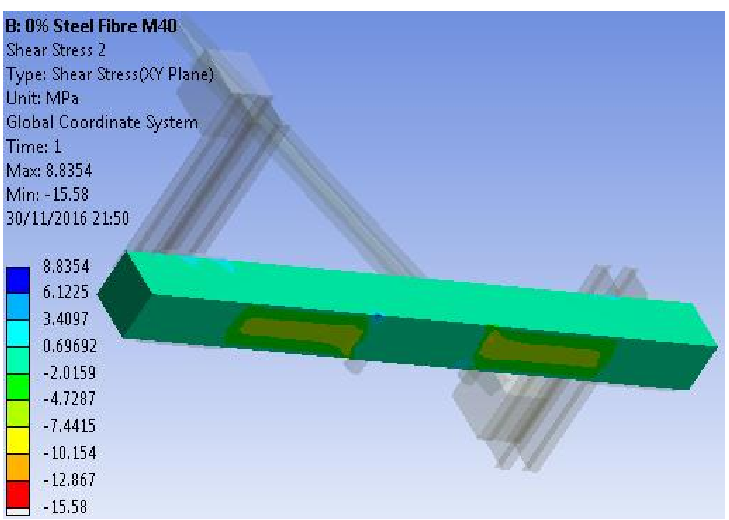


Fig.5.10. : Snapshot of beam model (0% steel fiber) of M40 grade modelled and analysed using ANSYS software

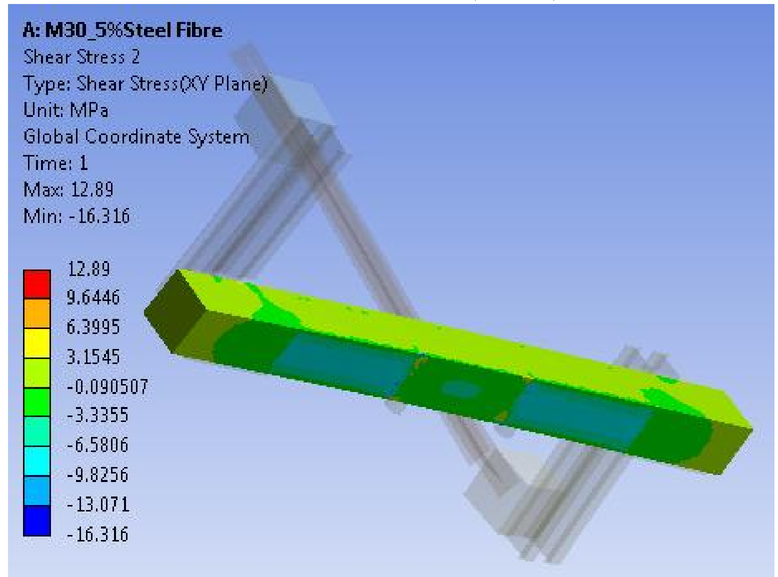


Fig.5.11. : Snapshot of beam model (5% steel fiber) of M30 grade modelled and analysed using ANSYS software

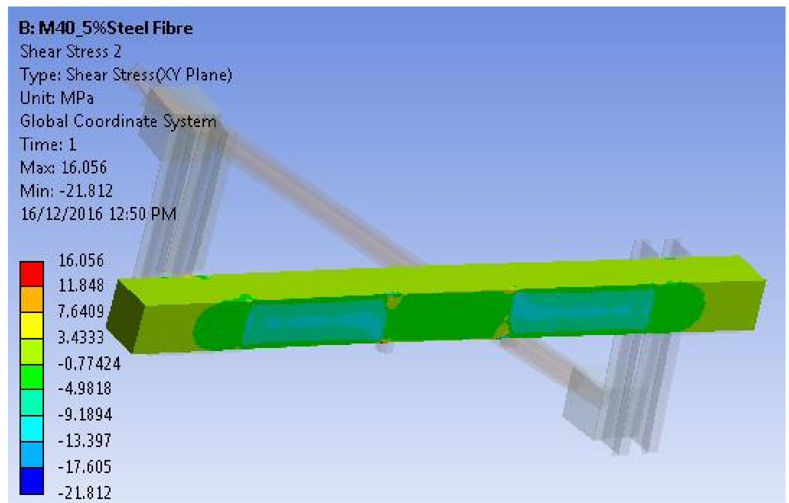


Fig.5.12. : Snapshot of beam model (5% steel fiber) of M40 grade modelled and analysed using ANSYS software

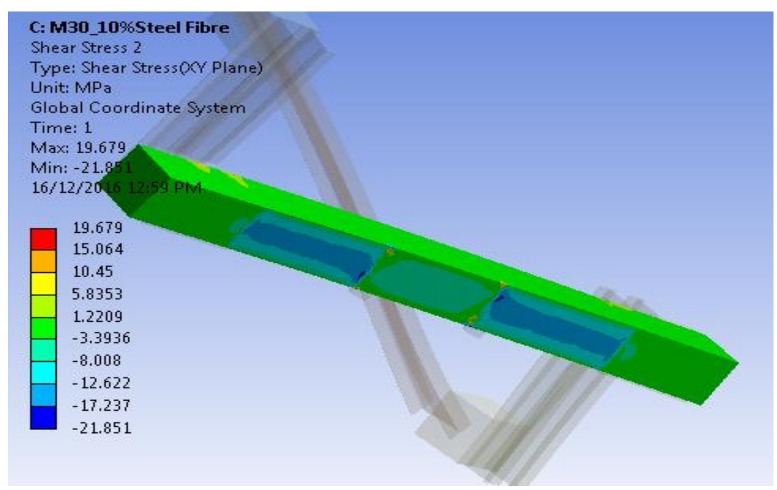


Fig.5.13. : Snapshot of beam model (10% steel fiber) of M30 grade modelled and analysed using ANSYS software

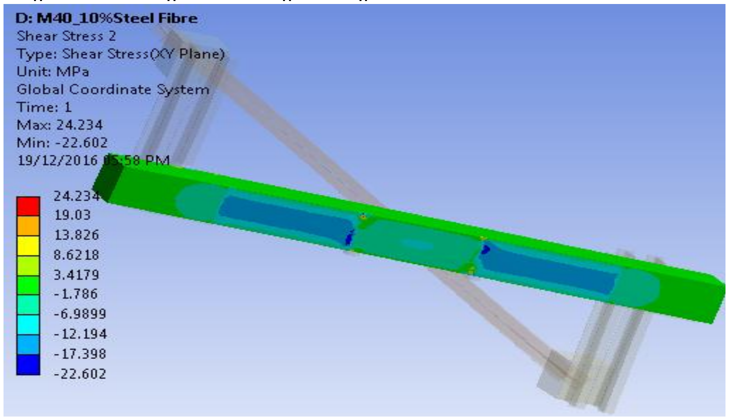


Fig.5.14. : Snapshot of beam model (10% steel fiber) of M40 grade modelled and analysed using ANSYS software

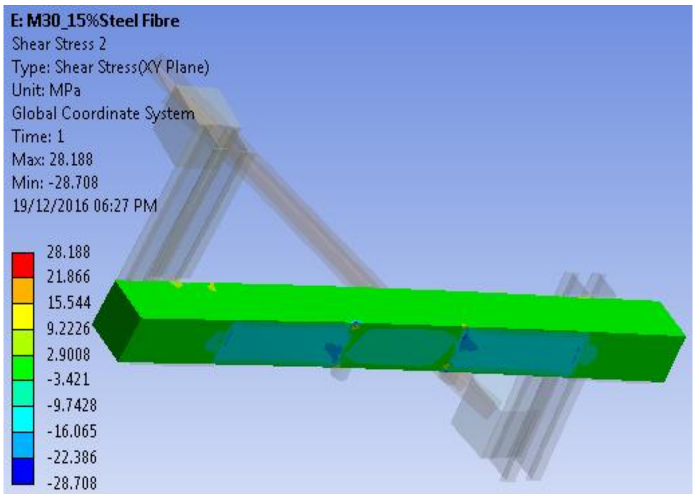


Fig.5.15. : Snapshot of beam model (15% steel fiber) of M30 grade modelled and analysed using ANSYS software

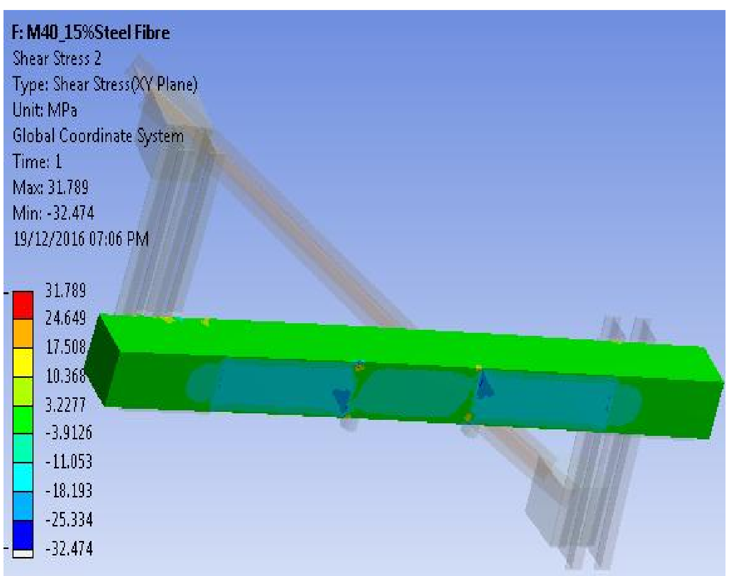


Fig.5.16. : Snapshot of beam model (15% steel fiber) of M40 grade modelled and analysed using ANSYS software

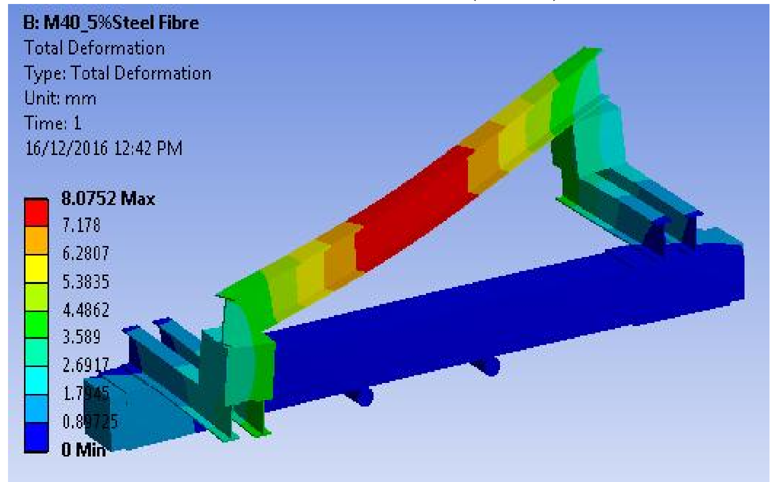


Fig.5.17. : Snapshot of deformed shape of I section of M30 grade model

(5% steel fiber)

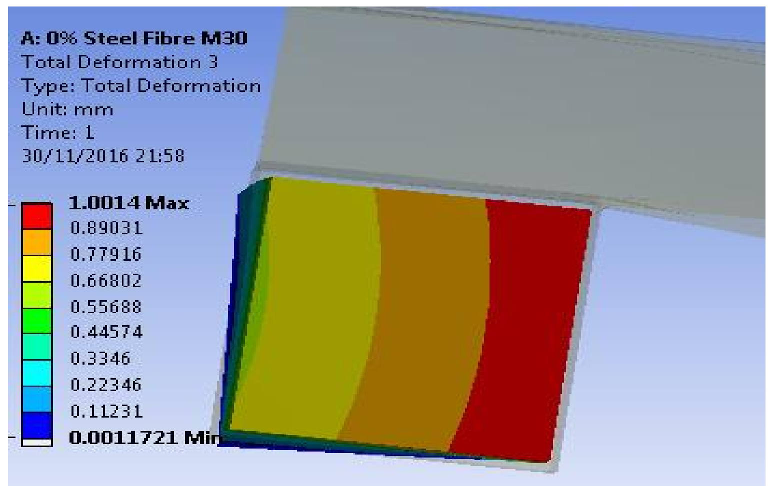


Fig.5.18. : Snapshot of twisted shape of R.C. beam model for M30 grade model (0% steel fiber)

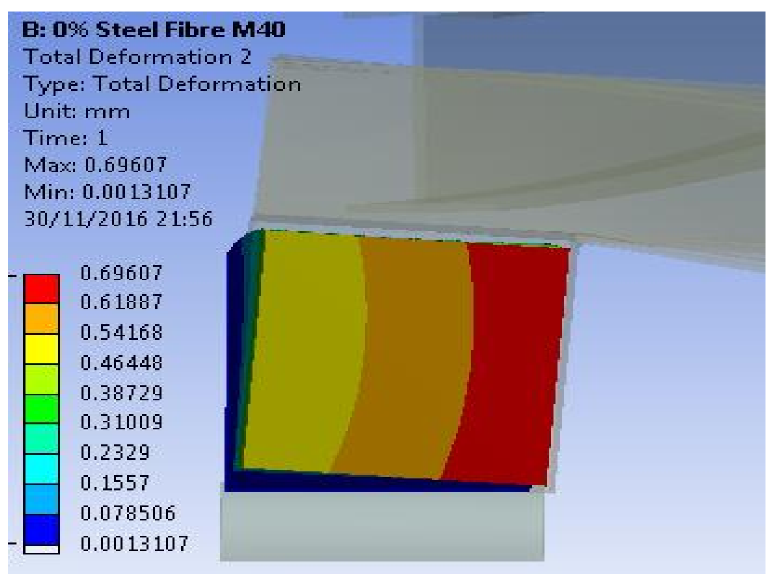


Fig.5.19. : Snapshot of twisted shape of R.C. beam model for M40 grade model (0% steel fiber)

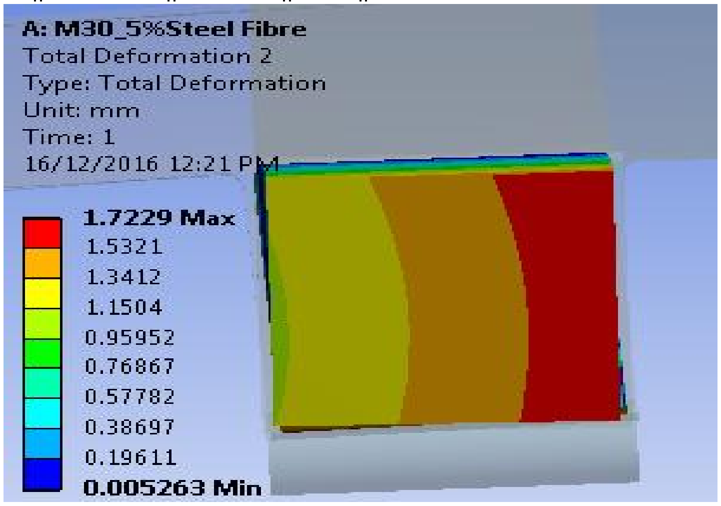


Fig.5.20. : Snapshot of twisted shape of R.C. beam model for M30 grade model (5% steel fiber)

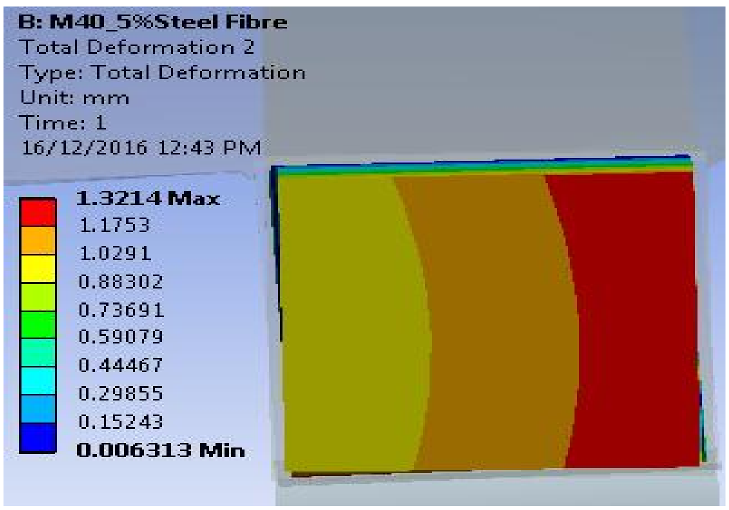


Fig.5.21. : Snapshot of twisted shape of R.C. beam model for M40 grade model (5% steel fiber)

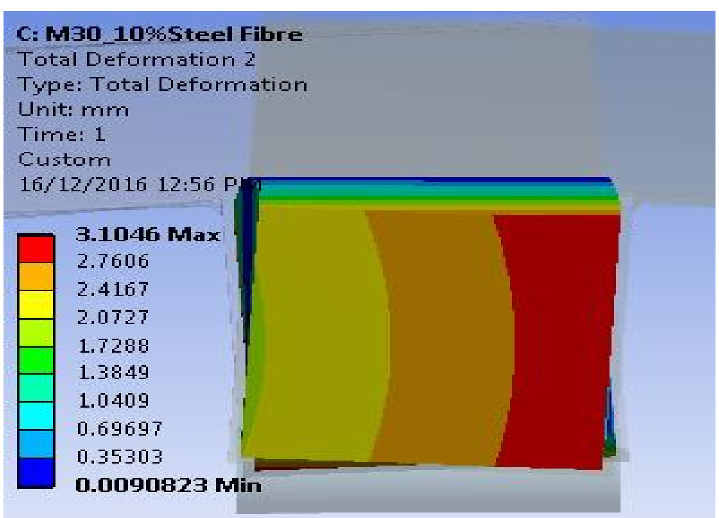


Fig.5.22. : Snapshot of twisted shape of R.C. beam model for M30 grade model (10% steel fiber)

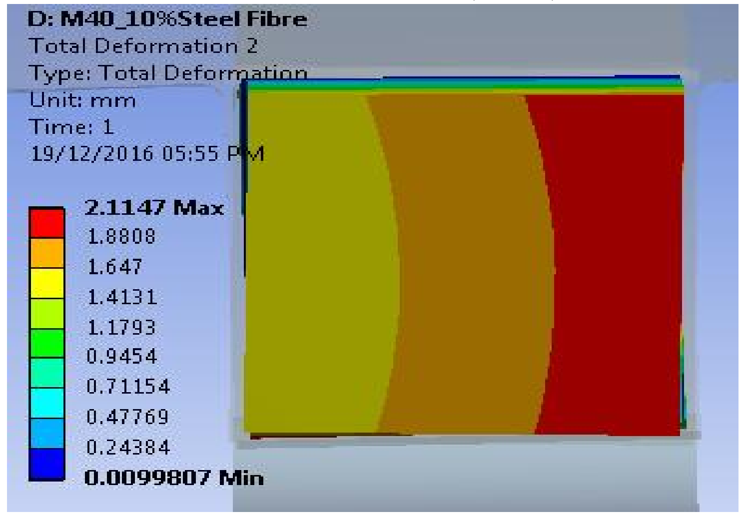


Fig.5.23. : Snapshot of twisted shape of R.C. beam model for M40 grade model (10% steel fiber)

Fig.5.24. : Snapshot of twisted shape of R.C. beam model for M30 grade model (15% steel fiber)

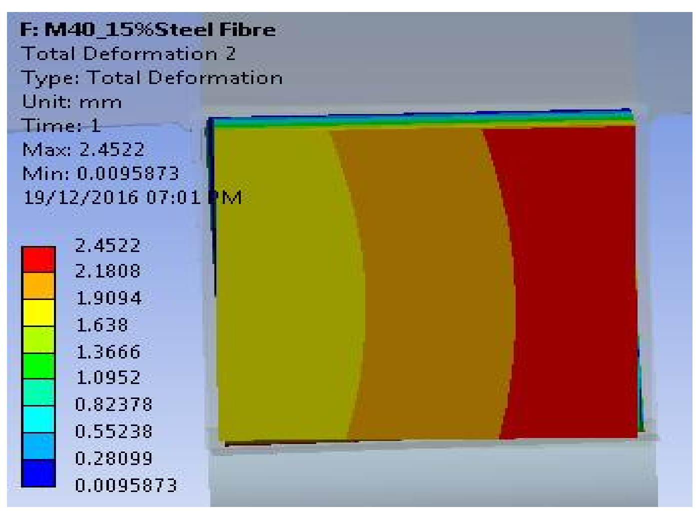


Fig.5.25. : Snapshot of twisted shape of R.C. beam model for M40 grade model (15% steel fiber)

EXPERIMENTAL RESULT

Result obtained from Finite Element Method based software :

To investigate torsional strength of casted beam specimens by analytical method. Finite Element Method based software entitled Ansys 15.0 is used. In order to understand the torsional behaviour of reinforced cement concrete beam mathematical model is developed in Ansys.

5.1 Result obtained for M30 grade of concrete beams using Ansys software :

Beam	Load (kN)	Shear Stress (N/mm^2)	Torsion (kN-m)	Deformation	
				I section	Beam
FR0	9	7.7092	8.6785	4.654	1.0014
FR5	14.95	12.89	14.5012	7.8767	1.7229
FR10	26.95	19.679	22.1388	14.2	3.1046
FR15	31.25	28.188	31.7115	15.74	3.4282

Table no. 5.1 shows result obtained for M30 grade of concrete beams using ansys software. Shear stress for concrete having 0% steel fibers is found to be 7.7092 N/mm^2 and deformation of I section is 4.654 and beam is 1.0014 and torsional strength is 8.6785 kN-m, for concrete having 5% steel fibers is found to be 12.89 N/mm^2 and deformation of I section is 7.8767 and beam is 1.7229 and torsional strength is 14.5012 kN-m, for concrete having 10% steel fibers is found to be 19.679 N/mm^2 and deformation of I section is 14.2 and beam is 3.1046 and torsional strength is 22.1388 kN-m, and for concrete having 15% steel fibers is found to be 28.188 N/mm^2 and deformation of I section is 15.74mmand beam is 3.4282mmand torsional strength is 31.7115 kN-m.

5.2 Result obtained for M40 grade of concrete beams using Ansys software:

Load (kN)	Shear Stress (N/mm^2)	Torsion (kN-m)	Deformation(mm)	
			I section	Beam
9.55	8.8354	9.9398	4.367	0.6960
17.325	16.056	18.063	8.0752	1.3214
27.74	24.234	27.3825	12.93	2.1147
32.1	31.789	35.7626	15.028	2.4522

Table no. 5.2 shows result obtained for M40 grade of concrete beams using ansys software. Shear stress for concrete having 0% steel fibers is found to be 8.8354 N/mm^2 and deformation of I section is 4.367 and beam is 0.6960 and torsional strength is 9.9398 kn-m, for concrete having 5% steel fibers is found to be 16.056N/mm^2 and deformation of I section is 8.0752 and beam is 1.3214 and torsional strength is 18.063 kN-m, for concrete having 10% steel fibers is found to be 24.234N/mm^2 and deformation of I section is 12.93 and beam is 2.1147 and torsional strength is 27.3825 kN-m, and for concrete having 15% steel fibers is found to be 31.789 N/mm^2 and deformation of I section is 15.028 mm and beam is 2.4522 mm and torsional strength is 35.7626 kN-m.

To obtain torsional strength of reinforced concrete beam shear stress are used and theory of pure torsion.

Torsional equation,

$$\tau = \frac{Mt \times r}{J}$$

Where,

τ =Shear Stress (N/mm^2).

Mt = Torsional moment(kN-m).

r = Distance from extreme compressive fiber to the neutral axis (mm).

J= Polar moment of inertia.

Comparison Results of Experimental and Analytical :

To investigate torsional strength of casted beam specimens by analytical method Finite Element Method based software in titled ANSYS 15 is used. In order to understand the torsional behaviour of Reinforced Cement Concrete beam a mathematical model is developed in ANSYS15. Table no. 6.8 and Table no. 6.9 shows the comparison resultfor Torque induced in concrete beams of M30 and M40 grade.

Table 6.8.: Comparison of results for Torque induced in concrete Beams of M30 grade

Beam	**Load (kN)**	**Experimental Torque (kN-m)**	**ANSYS software Torque (kN-m)**	**% difference**
FR0	9	4.725	4.3364	8.22
FR5	14.95	7.848	7.2506	7.73
FR10	27.05	14.201	11.069	22.05
FR15	31.25	16.327	15.8557	2.88

Table no. 6.8 shows that comparison of result Torque induced in concrete beams of M30 grade. The 0% of fiber experimental torque is 4.725 kN-m and analytical torque is 4.3364 kN-m, The 5% of fiber experimental torque is 7.848 kN-m and analytical torque is 7.2506 kN-m, The 10% of fiber experimental torque is 14.201 kN-m and analytical torque is 11.0694 kN-m,and The 15% of fiber experimental torque is 16.327 kN-m and analytical torque is15.8557 kN-m.

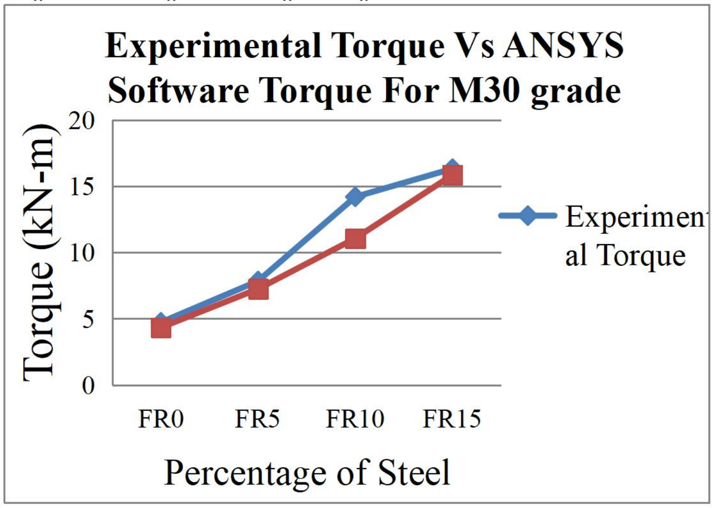


Fig. 6.6.:Graph ofexperimental torque vs ANSYS software torque for M30 grade

Table 6.9.: Comparison of results for torque induced in concrete beams of M40 grade

Beam	Load (kN)	Experimental Torque (kN-m)	ANSYS software Torque (kN-m)	% difference
FR0	9.55	5.014	4.9699	0.875
FR5	17.325	9.096	9.0915	0.709
FR10	27.74	14.563	13.6912	5.986
FR15	32.1	16.8525	17.8813	5.7534

Table no. 6.9 shows that comparison of result Torque induced in concrete beams of M40 grade. The 0% of fiber experimental torque is 5.014 kN-m and analytical torque is 4.9699 kN-m, The 5% of fiber experimental torque is 9.096 kN-m and analytical torque is 9.0915 kN-m, The 10% of fiber experimental torque is 14.563 kN-m and analytical torque is 13.6912 kN-m,and The 15% of fiber experimental torque is 16.8525 kN-m and analytical torque is 17.8813 kN-m. (see in figure 6.7).

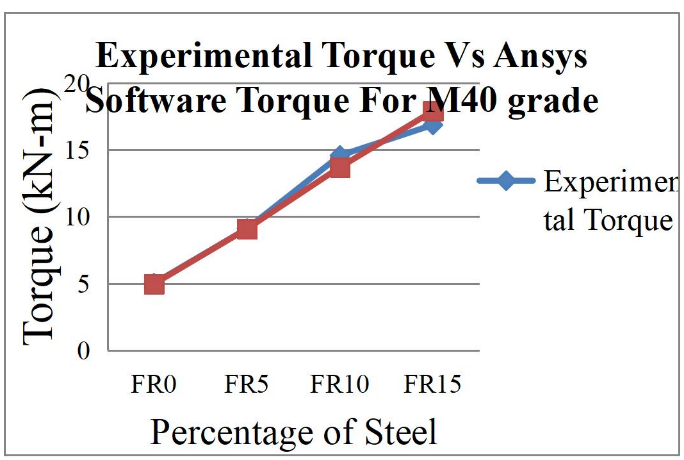


Fig. 6.7.:Graph ofexperimental torque vs ANSYS software torque for M40 grade

6.5 Comparative results of percentage increase in torsional strength :

Table 6.10.: Comparative results for percentage increase in torsional strength for M30 grade

Beam	Experimental Torque kN-m (Avg.)	% Increase in torsional capacity	Software Torque kN-m	% Increase in torsional capacity
FR0	4.834	-	4.3364	-
FR5	8.2086	69.81	7.2506	64.20
FR10	14.262	195.04	11.0694	155.26
FR15	16.73	246.09	15.8557	265.64

Table no. 6.10 shows that comparative results for percentage increase in torsional strength for M30 grade. Use of 5% of fibers in concrete results in 69.81% increase in torsional strength in experiment analysis and 64.20% by software analysis, Use of 10% of fibers in concrete results in 195.04% increase in torsional strength in experiment analysis and 155.26% by software analysis, and Use of 15% of fibers in concrete results in 246.09% increase in torsional strength in experiment analysis and 265.64% by software analysis.

Table 6.11.: Comparative results for percentage increase in torsional strength for M40 grade

Beam	Experimental Torque (kN-m) (Avg.)	% Increase in torsional capacity	Software Torque (kN-m)	% Increase in torsional capacity
FR0	5.1626	-	4.9699	-
FR5	9.4193	82.45	9.0315	100.60
FR10	14.7896	186.47	13.6912	175.48
FR15	17.1746	232.67	17.8813	259.79

Table no. 6.11 shows that comparative results for percentage increase in torsional strength for M40 grade. Use of 5% of fibers in concrete results in 82.45% increase in torsional strength in experiment analysis and 100.60% by software analysis, Use of 10% of fibers in concrete results in 186.47% increase in torsional strength in experiment analysis and 175.48% by software analysis, and Use of 15% of fibers in concrete results in 232.67% increase in torsional strength in experiment analysis and 259.79% by software analysis.

CONCLUSION

Following conclusions can be obtained from the present experimental work on effects of varying percentage of steel fibers to torsional strength.

1. For M30 grade of concrete by using steel fibers about 5% of weight of cement. It is found that the torsional strength of fiber reinforced concrete beams is increases by 60% - 70% of conventional reinforced cement concrete beams.
2. For M30 grade of concrete by using steel fibers about 10% of weight of cement. It is found that the torsional strength of fiber reinforced concrete beams is increases by 150% - 200% of conventional reinforced cement concrete beams.
3. For M30 grade of concrete by using steel fibers about 15% of weight of cement. It is found that the torsional strength of fiber reinforced concrete beams is increases by 240% - 300% of conventional reinforced cement concrete beams.
4. For M40 grade of concrete by using steel fibers about 5% of weight of cement. It is found that the torsional strength of fiber reinforced concrete beams is increases by 80% - 110% of conventional reinforced cement concrete beams.
5. For M40 grade of concrete by using steel fibers about 10% of weight of cement. It is found that the torsional strength of fiber reinforced concrete beams is increases by 150% - 200% of conventional reinforced cement concrete beams.
6. For M40 grade of concrete by using steel fibers about 15% of weight of cement. It is found that the torsional strength of fiber reinforced concrete beams is increases by 230% - 300% of conventional reinforced cement concrete beams.
7. Use Of fiber in Reinforced concrete has found very beneficial to enhance the torsional strength of RC beam subjected to pure torsion.
8. The cracking torsional strength and ultimate torsional strength goes on increasing as the percentage of steel fiber goes on increasing.

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