Finite Element Analysis of Twisted Steel fiber Reinforced Concrete Flexure Members

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ABSTRACT

Numerical analysis using finite element techniques is carried out using ANSYS to evaluate the load carrying capacity of the flexural members. The maximum stresses obtainedare corresponding values of ANSYS Eight node, solid 65 element (brick element) with 3 DOF per each node is adopted. Element type selection solid 85, material properties input from stress-strain data, mechanical properties input data, material models input data, provision of input data for steel pads, analysis type selection static structural analysis

Keywords: Numerical, data, mechanical, steel

INTRODUCTION

Cement concrete continues to remain as the most favored construction material all over the world even on this day. The advantages of cement concrete are multifold like its affordability, feasibility, durability etc.[1-3] The construction material was called Plain cement concrete (PCC). However, though cement concrete is strong in compression it is very weak in tension. Due to this reason, steel was introduced into concrete at locations where tension was anticipated, called reinforced cement concrete (RCC)[4,5]. The concept of reinforced cement concrete design was developed based on this philosophy. Though this offered a feasible construction material for structural design, neglecting the portion of concrete located in tension zone was considered an expensive sacrifice.[7 - 11] The concepts of modular slabs, trussed beams etc., have come up consequently.[12] Then had arrived the concept of fiber reinforced cement concrete (FRC) elements. Very many types of fibers were tried different researchersin FRC designs [13 – 16]. FRC in principle restrict micro cracking in concrete, make the concrete dense, improve its durability and ductility. Each type of fiber has certain advantages and drawbacks with their usage. All this has led to the need to come up with a new fiber, which shall make the FRC designs feasible, economical yet durable.[17]

Finite Element Analysis

The beam is modeled in ANSYS through graphic user interface. Concrete is modelled using the Solid 65 isoparametric eight-noded brick element. This element has 3 degrees of freedom in translation per node.The bearing steel plates are modelled with Solid 185 isoparametric eight-noded brick elements. This element has 3 degrees of freedom in translation per node. Solid 65 and Solid185 elements have three translations namely u, v and w in the mutually perpendicular axes in cartesian coordinate system respectively.

Element section

The properties of the beam element are represented by the stress strain curve. To study the fracture and crush behaviour of the element under static stress, the beam is represented using solid elements. The results of the static structural analysis are influenced by the selection of appropriate elements for the static structural analysis, such as the geometry of the model, kind of loading, location, and nature of loading applied.The volumetric geometry of three-dimensional element best suits the model for concrete.The element's bending behaviour is properly anticipated by supplying appropriate inputs such as section characteristics to accurately simulate the cross-sectional form.Because the Solid65 3D element is capable of cracking in tension and crushing in compression, it may be utilized for concrete with and without reinforcement. The element evaluates the concrete's crushing, plastic deformation, and creep qualities, as well as its cracking behavior, in three mutually perpendicular directions.The analysis type selection and meshed model of the beam is shown in Fig.1.

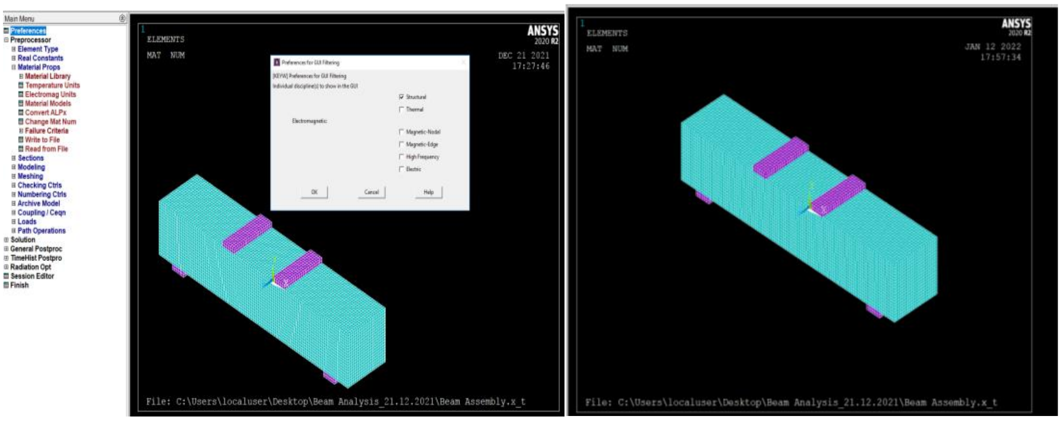

Fig.1 Analysis type selection and Meshed model of the beam

Material properties of model

The material characteristics of the concrete were designed in such a way that they perfectly mirror the concrete's real behaviour.The stress-strain curve generated in the experimental programmeis used for the concretein this study.

Meshing

The modelled beam volumemeshedthrough thestandardmeshingoptioninANSYS.Meshing is defined through different ways in ANSYS. The mesh size effects the results significantly. The convergence of the solution, its calculation time are strongly influenced by the mesh pattern. To acquire a converged solution in a suitable amount of time while calibrating with the experimental data, a number of meshing procedures are used.

Loads and boundary condition

Modeling the beam shape, element selection, material attributes assignment based on physical circumstances, boundary condition, and loads were all described in this chapter.Boundary conditions are used to limit displacement and constrain the model, resulting in a unique solution based on the experimental environment.Boundaryconditionsare imposed on the FE model in order to have convergence of the results. The boundary conditions and external loads onto steel pads are shown in Fig.2

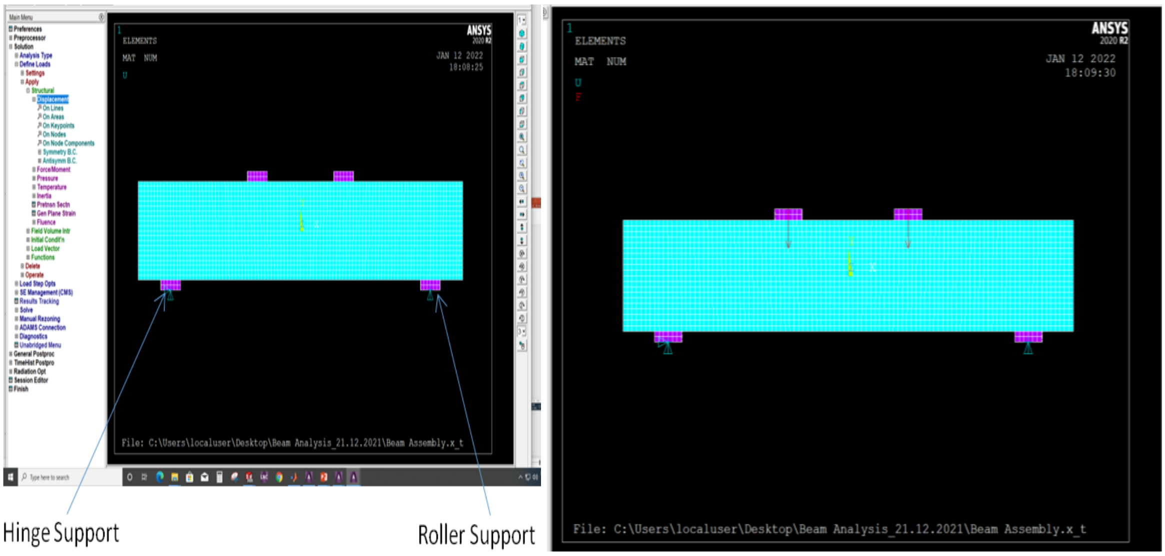

Fig.2 Boundary conditions and external loads onto steel pads

Convergence criteria

The convergence criteria for the reinforced concrete solid elements were based on force and displacement. The convergence tolerance limits were initially selected by analysis program. It was observed that the convergence of solutions for the SFRC beam models was difficult to achieve due to the nonlinear behaviour of the reinforced concrete. Therefore, the convergence tolerance limits were increased to a maximum of four times that the default tolerance limits (0.5% for force checking and 3.5% for displacement checking) in order to obtain the convergence of the solutions. The FEA model was independent of mesh size.

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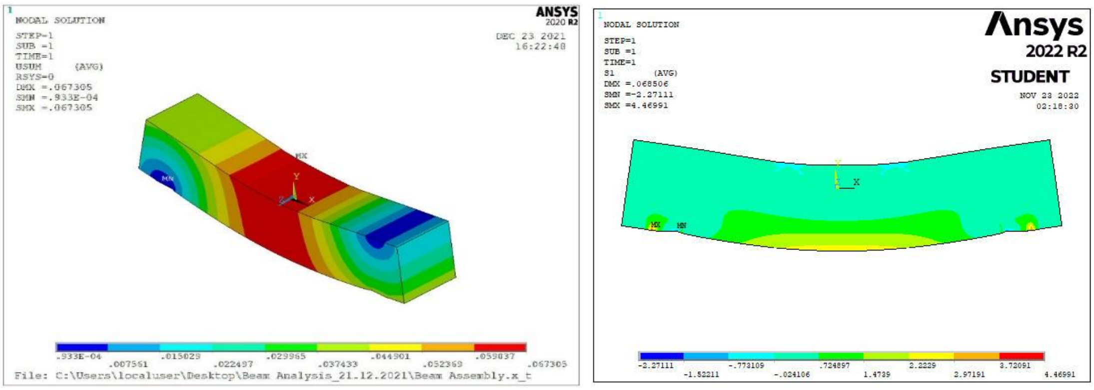

Fig.3 Ultimate deflection and principal stress for M20 grade concrete with 0% fibers

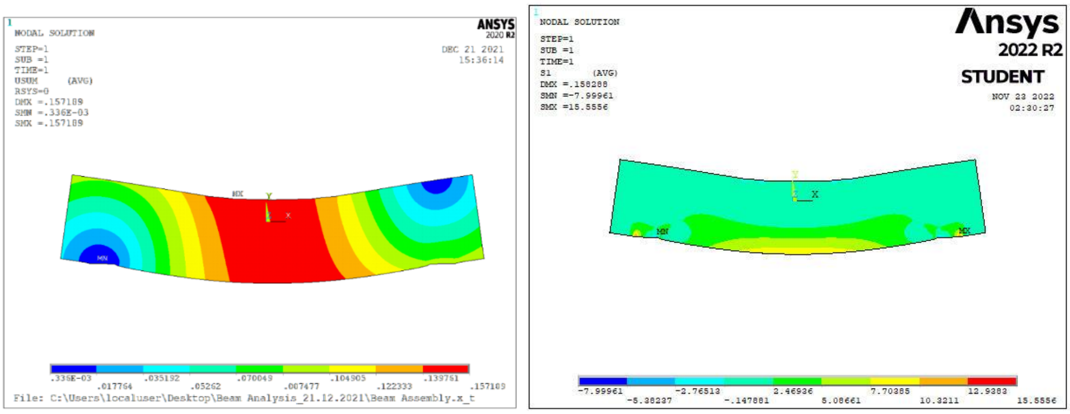

Fig.4 Ultimate deflection and principal stress for M20 grade concrete with 0.15% fibers

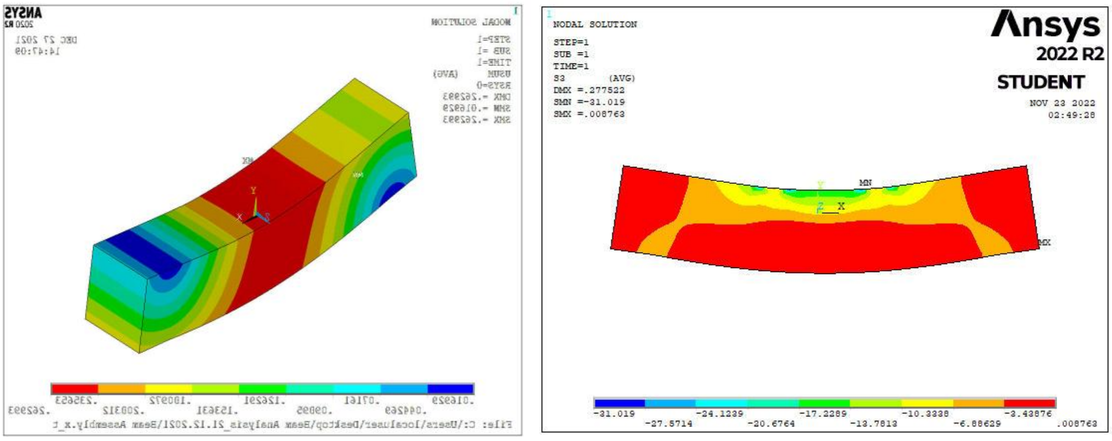

Fig.5 Ultimate deflection and principal stress for M20 grade concrete with 0.3% fibers

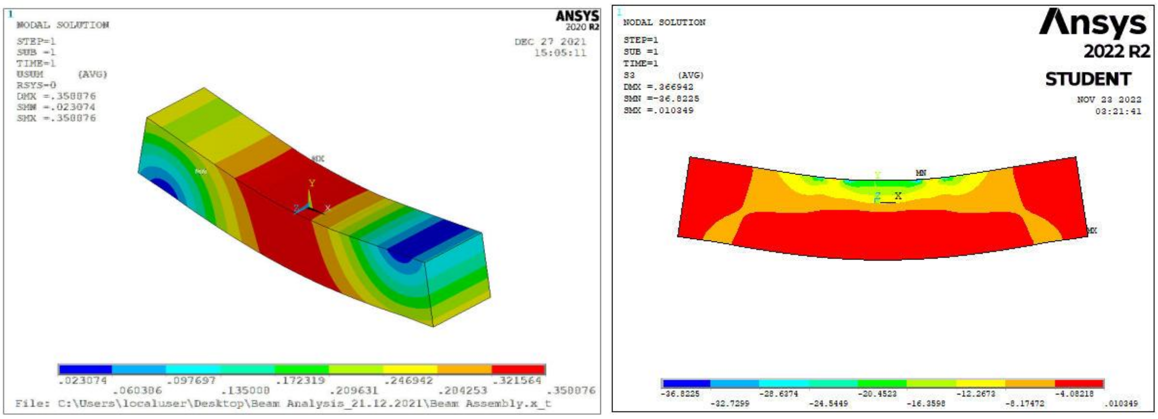

Fig.6 Ultimate deflection and principal stress for M20 grade concrete with 0.45% fibers

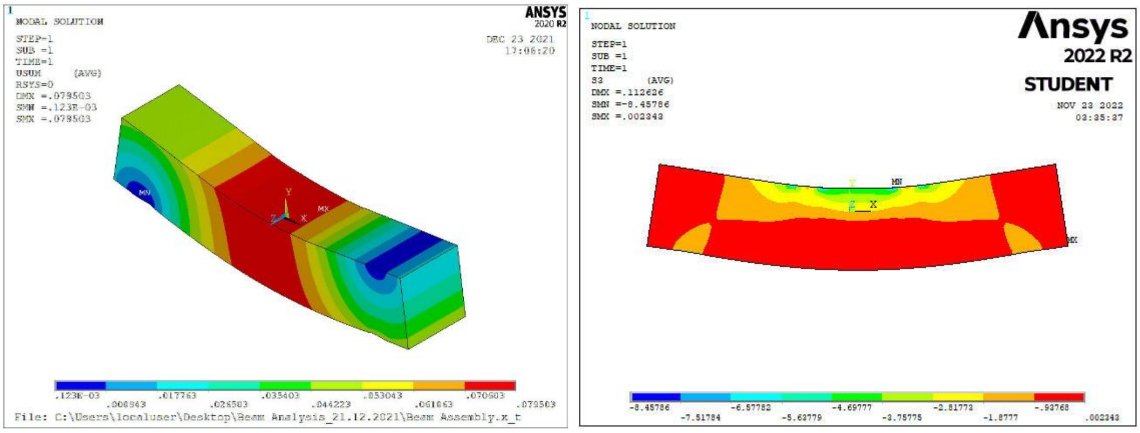

Fig.7 Ultimate deflection and principal stress for M25 grade concrete with 0% fibers

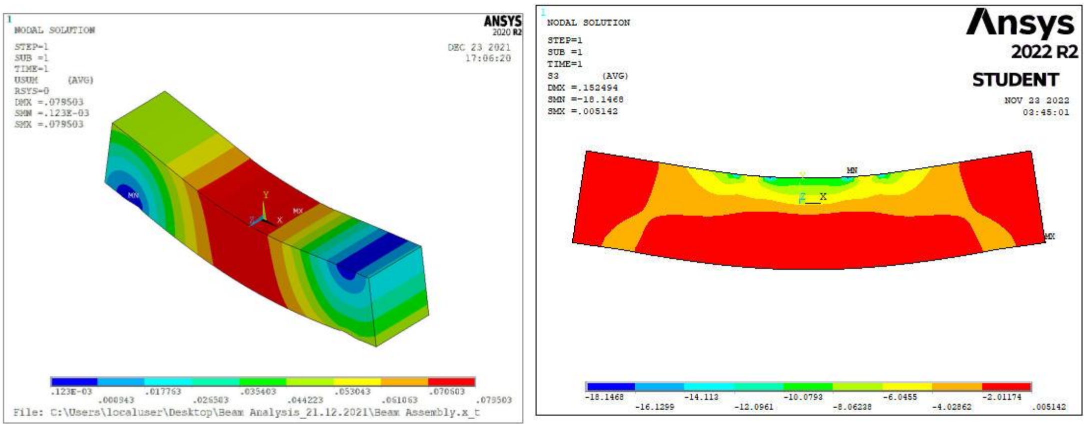

Fig.8 Ultimate deflection and principal stress for M25 grade concrete with 0.15% fibers

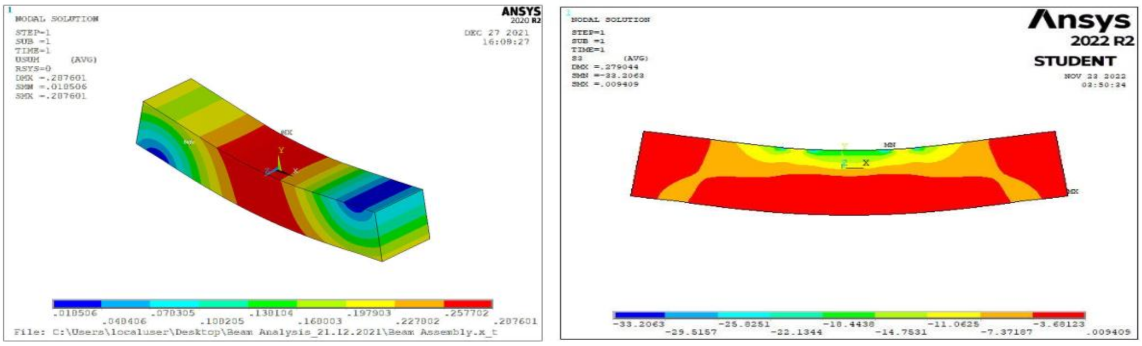

Fig.9 Ultimate deflection and principal stress for M25 grade concrete with 0.3% fibers

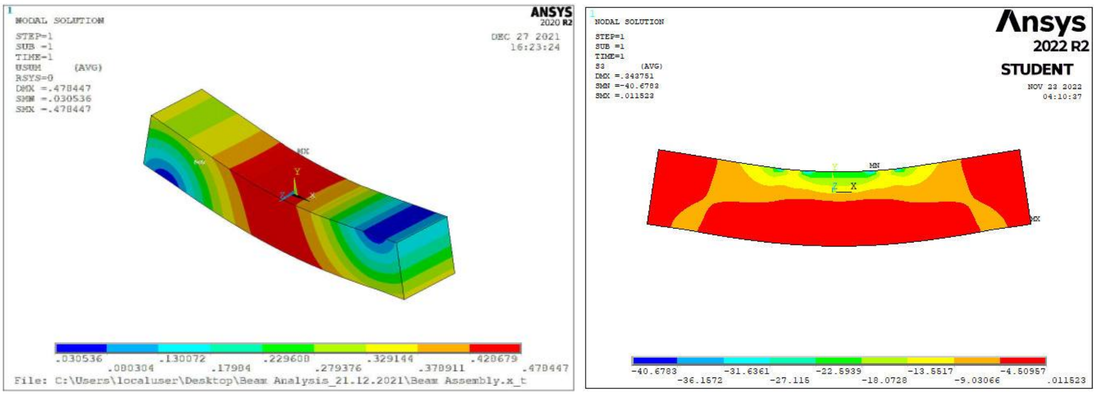

Fig.10 Ultimate deflection and principal stress for M25 grade concrete with 0.45% fibers

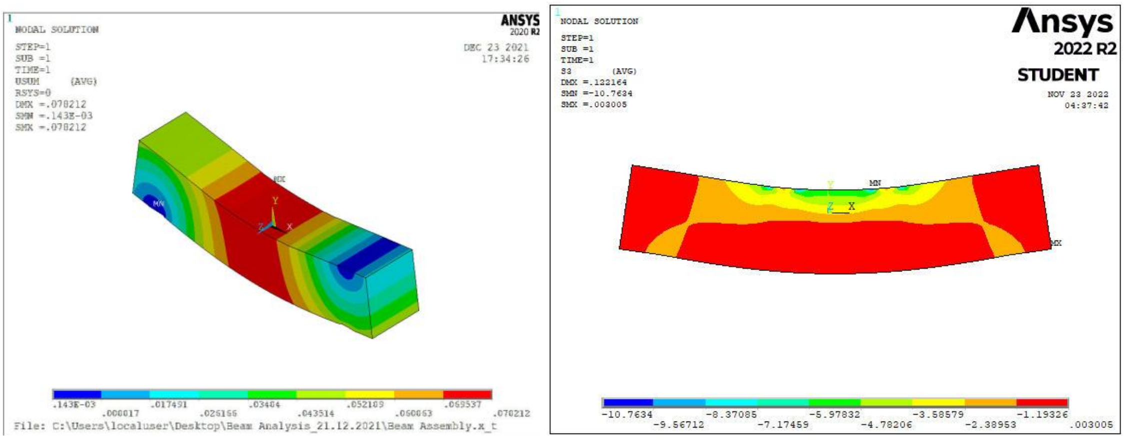

Fig.11 Ultimate deflection and principal stress for M30 grade concrete with 0% fibers

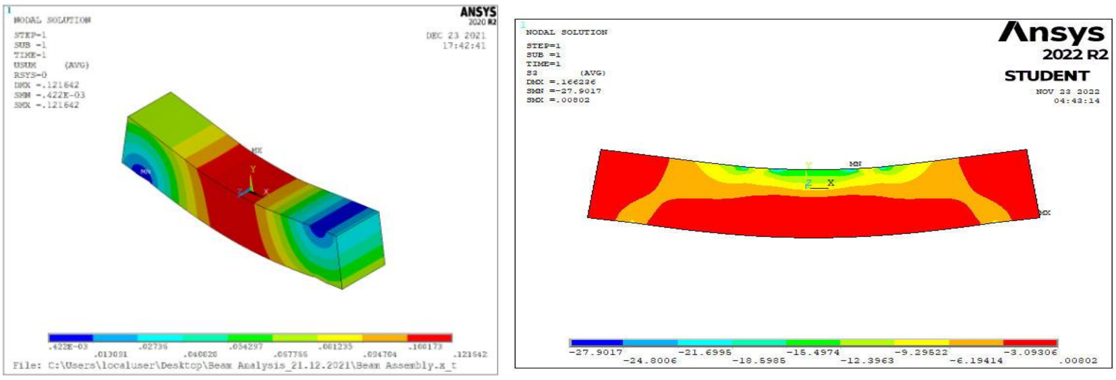

Fig.12 Ultimate deflection and principal stress for M30 grade concrete with 0.15% fibers

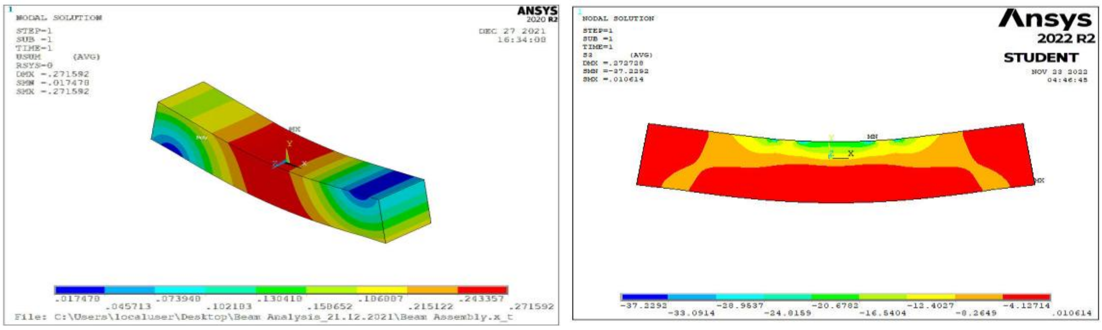

Fig.13 Ultimate deflection and principal stress for M30 grade concrete with 0.3% fibers

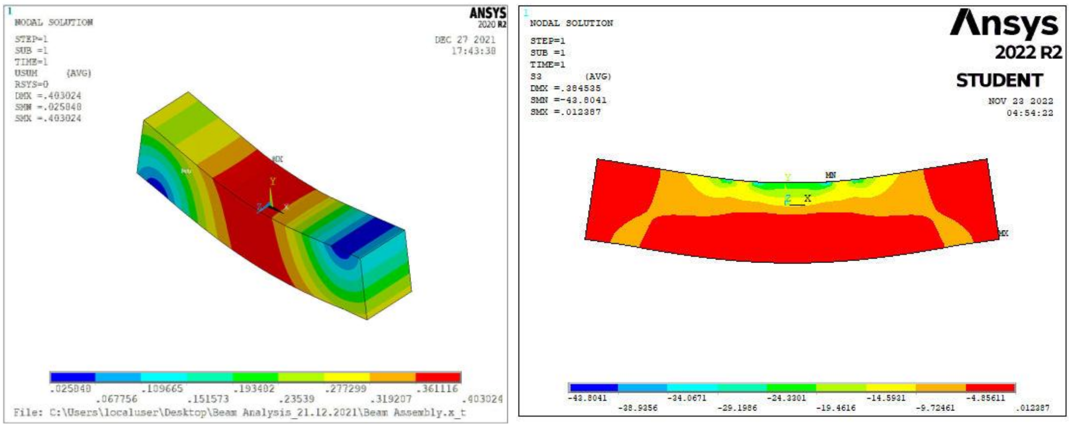

Fig.14 Ultimate deflection of prism for M30 grade concrete with 0.45% fiber

Table 1: Comparison of results for different grades

Grade	FEA, ANSYS	Grade	FEA, ANSYS	Grade	FEA, ANSYS
M20	5.34	M25	6.51	M30	8.83
	17.40		16.67		21.55
	25.56		26.70		29.57
	26.60		32.38		36.30

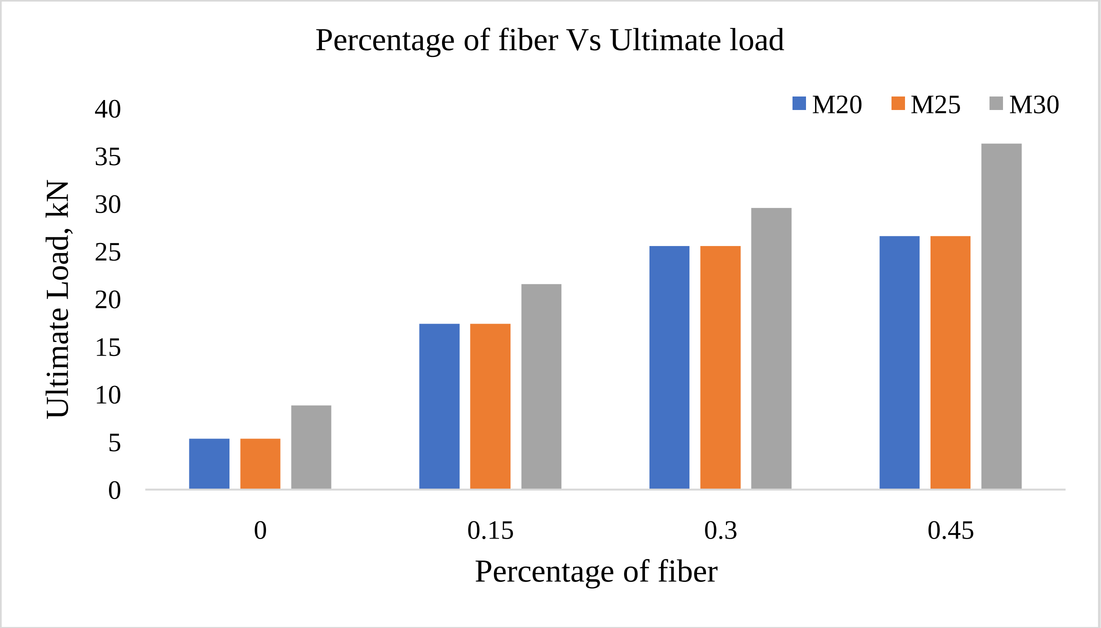

Fig.15 Comparison of FEA results for M20, M25 and M30 grade concrete

The obtained results are tabulated in the Table.1 and comparative analysis is shown in Fig.15. From finite element analysis using ANSYS, the load carrying capacity of flexural members shows a gradual increase from 5.34 to 26.6 kN for zero percent to 0.45 percent of twisted steel fibers for M20 grade concrete.Correspondingly, the values vary from 6.51 kN to 32.38 kN and 8.83 kN to 36.3 kN for M25 and M30 grades respectively.From numerical analysisusing ANSYS, a commercial code for FEA, the load carrying capacity of flexural members is found to have a gradual increase from 5.34 to 26.6 kN for zero percent to 0.45 percent of twisted steel fibers for M20 grade concrete. Correspondingly, the values range from 6.51 kN to 32.38 kNand 8.83 kNto 36.3 kN for M25 and M30 grades. The ultimate load of different concrete grades, such as M20, M25, and M30with various percentages of 0.15%, 0.3% and 0.45% of twisted steel fibers finite elementanalysis values are found to be increased as compared to zero percent twisted steel fibers.

The convergence criteria for the reinforced concrete solid elements were based on force and displacement. The convergence tolerance limits were initially selected by analysis program. It was observed that the convergence of solutions for the SFRC beam models was difficult to achieve due to the nonlinear behaviour of the reinforced concrete. Therefore, the convergence tolerance limits were increased to a maximum of four times that the default tolerance limits (0.5% for force checking and 3.5% for displacement checking) to obtain the convergence of the solutions. The FEA model must be independent of mesh size.

The increased twisted fiber content in all blends improves load bearing ability. From finite element analysis using ANSYS, the load carrying capacity of flexural members shows a gradual increase from 5.34 to 26.6 kN for zero percent to 0.45 percent of twisted steel fibers for M20 grade concrete.Correspondingly, the values vary from 6.51 kN to 32.38 kN and 8.83 kN to 36.3 kN for M25 and M30 grades respectively. The results of experimental investigations show a very close agreement with that of the numerical analysis.

CONCLUSIONS

The incorporation of twisted steel fibers into concrete significantly improves the load-carrying capacity of flexural members.As the percentage of steel fibers increases from 0% to 0.45%, the ultimate load capacity of the beams steadily rises for all concrete grades (M20, M25, and M30).This enhancement is attributed to the improved tensile strength, ductility, and energy absorption capacity of the SFRC.

The FEA results accurately predict, demonstrating the reliability of the numerical modeling approach.The numerical model can be effectively used to investigate the behavior of SFRC beams under various loading conditions and fiber configurations.The nonlinear behavior of SFRC poses challenges in achieving convergence during FEA simulations.

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