

Finite Element Analysis of RCC Beams and Slabs Using COMSOL Multiphysics

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Abstract—In the construction of buildings and other civil engineering structures where loads must be transferred from the superstructure to the support members, such as columns and foundations, reinforced concrete beams and slabs are fundamental structural components. The traditional analytical design techniques used to analyse reinforced concrete beams and slabs typically rely on the assumptions of uniform stress distribution, ideal boundary conditions, and linear elastic behaviour of the material. These assumptions are frequently very different from how the structures actually behave under real loading conditions. A computational technique called Finite Element Analysis (FEA) was created to mimic the actual behaviour of reinforced concrete structures while taking into account the three-dimensional stress distribution mechanism. The COMSOL Multiphysics program is used in the current study to conduct the finite element analysis of reinforced concrete beams and slabs. The Solid Mechanics module of the COMSOL software is used to analyse the structural reactions of the reinforced concrete beams and slabs, including bending stress, shear stress, deflection, and the distribution of the applied load. The analytical findings from the classical theory of structural mechanics are contrasted with the outcomes of the numerical simulation of the reinforced concrete structures. Because there is little discrepancy between the analytical and numerical findings, it can be shown that the results from the finite element analysis are fairly accurate. This study demonstrates the effectiveness of COMSOL Multiphysics in analysing and validating the behaviour of reinforced concrete slabs and beams.

Index Terms—Finite Element Analysis, Reinforced Concrete Beams, RC Slabs, COMSOL Multiphysics, Structural Analysis

I. INTRODUCTION

Because of its high compressive strength, durability, affordability, and versatility, reinforced concrete is regarded as one of the primary building materials utilised in contemporary civil engineering. Several structural elements are utilised in reinforced concrete, they are regarded as essential elements for guaranteeing stability in buildings and other infrastructures, including beams and slabs. The purpose of reinforced concrete beams is to endure shear stresses and bending moments brought on by applied loads, while reinforced concrete slabs are thought of as horizontal structural elements that distribute loads from floors and roofs to beams, columns, and walls. For constructions

to be safe, serviceable, and long-lasting, the analysis and design of certain structural elements have been deemed essential.

Traditionally, traditional analytical techniques based on the theory of R.C. structures and the mechanics of structures are used to analyse how R.C. beams and slabs behave under loads. The theory of elastic beams and plates, which makes the assumptions of homogenous materials, linear elastic behaviour, and uniform stress distribution, has typically served as the foundation for the development of analytical techniques for R.C. structures. Simplified formulas for calculating bending moments, shear pressures, stresses, and deflections in R.C. structures are provided by IS 456:2000. Despite the fact that analytical techniques for R.C. structures have been created to analyse R.C. structures efficiently, they have not been able to demonstrate how R.C. structures behave in real-world working conditions. Nonlinear behaviour, concrete cracking, stiffness degradation, and concrete-steel interaction have all been observed in R.C. structures. The Finite Element Method (FEM) has emerged as one of the most effective numerical techniques for analysing complicated structural systems in recent decades. With FEM, engineers may break down a given structure into numerous small components and use numerical computations to examine the structure's stress, strain, and deformation properties at each component. By taking into account the geometrical aspects, material qualities, and loading conditions, FEM allows engineers to simulate realistic structures. Because of the non-linear material properties and stress distribution, FEM has significantly improved the accuracy of structural analysis, especially for reinforced concrete structures.

A number of software programs for the finite element analysis of structural systems are now accessible thanks to developments in computational tools. COMSOL Multiphysics is one of the software programs that may be used to solve different finite element challenges because of its capacity to handle numerical modelling and multiphysics issues. A software program called COMSOL Multiphysics enables the integrated solution of many physical problems, such as fluid dynamics, heat transfer, and structural mechanics, to solve complicated engineering problems. Engineers can now examine the structural behaviour of many kinds of reinforced concrete



structures using COMSOL Multiphysics' Solid Mechanics Module. For instance, the software's three-dimensional numerical simulation capabilities can be used to assess the structural behaviour of various kinds of reinforced concrete beams and slabs.

Several scholars have simulated the structural behaviour of reinforced concrete structural members using the finite element approach. Razavi and Özdenefe simulated the thermo-mechanical behaviour of vented reinforced concrete slabs using COMSOL Multiphysics software. The scientists simulated the thermo-mechanical behaviour of reinforced concrete slabs using the COMSOL Multiphysics software's heat transfer and structural mechanics modules. Ventilation significantly reduces temperature gradients and thermal stresses in reinforced concrete slabs, enhancing their structural performance, according to computational data derived using COMSOL Multiphysics software [1]. Robles et al. simulated reinforced concrete slabs with internal delamination faults using COMSOL Multiphysics software and a three-dimensional finite element model. The authors simulated reinforced concrete slabs with internal delamination faults using numerical modelling and electrical resistivity measurements. Experimental data from lab specimens was used to validate the numerical results generated with COMSOL Multiphysics software. The interior behaviour of reinforced concrete slabs and structural damage can be accurately simulated using numerical modelling approaches, according to the numerical results obtained using COMSOL Multiphysics software [2].

The behaviour of reinforced concrete beams has also been extensively studied using finite element analysis. Karmaker et al. used the COMSOL multiphysics software to create a numerical model of cracked reinforced concrete beams and examined how structural deterioration affected the beam's modal properties. The findings showed that the natural frequencies of the reinforced concrete beams are greatly reduced by the presence of cracks because of stiffness degradation; the numerical results from the finite element model were found to agree with the experimental data [3]. In order to analyse the mechanical behaviour of concrete structural components, Sambucci additionally provided a multiphysics finite element model and experimental validation of the findings. In order to produce accurate finite element results for concrete structures, the results demonstrated the importance of precisely modelling the material properties, boundary conditions, and mesh refinement procedures [4].

In order to compare the outcomes with analytical and experimental techniques, researchers have also employed the finite element method. A thorough experimental and numerical investigation of reinforced concrete beams under load was conducted by Sinaei et al. Particularly in the elastic and early cracking stages, the investigation demonstrated a correlation between the load-deflection curves produced experimentally and the finite element method [5]. Bhaskar et al. investigated reinforced concrete beams using the finite element approach. The study demonstrated that the FEM can reliably forecast the stress, deflection, and cracking behaviour of reinforced concrete beams exposed to by contrasting the observed findings with the analytical solution derived from classical beam theory under different load settings [6].

In addition to the behaviour of reinforced concrete beams, the finite element method has been used in a number of additional investigations on the structural behaviour of reinforced concrete slabs. Verma and Gupta's study looked at how static loading circumstances affected the structural behaviour of reinforced concrete slabs. Analytical results from the classical slab theory were contrasted with numerical results from the finite element approach. In contrast to the analytical method, the study claims that the finite element method can provide a realistic pattern of stress distribution in the slab [7]. The structural behaviour of reinforced concrete beams was modelled in the Chen et al. study using the nonlinear finite element approach, and the finite element method's conclusions were verified through experimentation. The study indicates that if the right material and boundary conditions are applied in the finite element model, the 3D finite element model can yield correct results [8]. Determining the precision and dependability of COMSOL Multiphysics software as a tool for finite element analysis of reinforced concrete structural components is the main goal of this study. This study attempts to demonstrate how finite element analysis may replicate genuine behaviour and offer a greater understanding of the performance of reinforced concrete beams and slabs by contrasting numerical results with analytical solutions. The findings of this research will help us better understand structural analysis techniques and their advantages, particularly with regard to numerical modelling.

II. METHODOLOGY

In order to gain insight into the structural behaviour of reinforced concrete beams and slabs under different loading circumstances, the current work uses the finite element method for numerical analysis. In this sense, the COMSOL Multiphysics software, which is effective for performing three-dimensional structural analysis, is used to model the structural behaviour of reinforced concrete beams and slabs. A thorough three-dimensional model that closely resembles the real structure is created in this work for the reinforced concrete beam and slab system. The COMSOL Multiphysics software's Solid Mechanics module, which is effective for assessing the stress, strain, and deformation properties of structural members, is used to achieve this.

A. General

The current study's methodology involves using both finite element analysis and analytical computations to examine the structural behaviour of reinforced concrete slabs and beams. In this work, the COMSOL multiphysics program with the solid mechanics module is used to generate a three-dimensional finite element model for the beam and slab system. The finite element analysis's procedures include defining the geometry of the structure, defining the material characteristics, defining the boundary conditions, defining the loading conditions, creating a mesh, and simulating the structure using the finite element method. The analytical computations verify the outcomes of the finite element analysis.

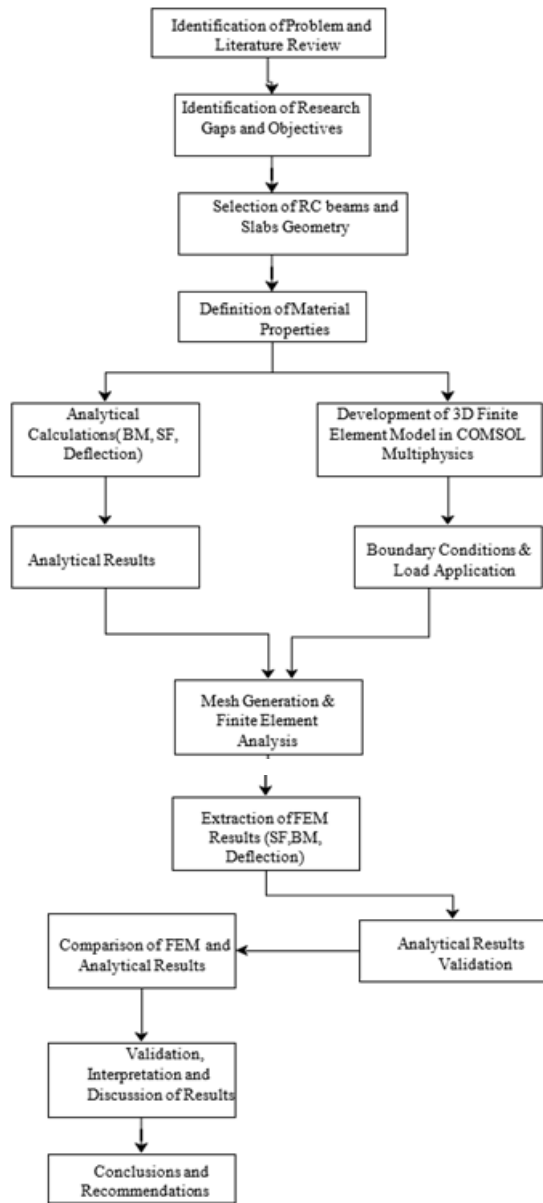


Fig. 1. Flowchart of the research methodology.

B. Selection of Structural Geometry

The first step in the analysis is the definition of the structural geometry of the reinforced concrete beam and the slab. The definition of the structural geometry is based on the conventional design practices for reinforced concrete structures to ensure the realistic modelling of the structural components. The beam model is defined as a prismatic structural component based on the length, width, and depth of the beam. The model for the slab is defined based on the conventional design practices for a reinforced concrete plate, considering the length and width of the plate and the thickness of the plate. The geometry is defined within the COMSOL Multiphysics platform to ensure the realistic modelling of the beam and the slab.

C. Material Properties

When determining the structural behaviour of reinforced concrete elements, material qualities are crucial. In the context of finite element analysis, the concrete in this study is taken to behave as a homogenous and isotropic. Important material characteristics including density, Poisson's ratio, and modulus of elasticity are defined in compliance with the general design guidelines for reinforced concrete members. The finite element model for the beam and slab domains defines these material properties. For a realistic simulation of the stress-strain behaviour in structural members, the determination of material properties is crucial. To keep the two approaches consistent, the analytical computations also make use of the material attributes.

D. Analytical Calculations

Analytical calculations are made to find the theoretical structural response of reinforced concrete beams and slabs. Classical structural mechanics concepts are used for these calculations. In the case of reinforced concrete beams, analytical expressions based on Euler-Bernoulli beam theory are used to find the shear force, bending moment, and deflection under applied loading conditions. In the case of reinforced concrete slabs, analytical solutions based on classical plate theory concepts are used to find the bending moment and deflection under uniformly distributed loads. Standard structural analysis equations, which are frequently utilised in the design of reinforced concrete structures, are applied in these computations. The numerical findings from FEA are validated using the analytical results from these computations.

E. Finite Element Modeling in COMSOL

The COMSOL Multiphysics program is used to model the reinforced concrete beam and slab using finite elements. The structural elements are modelled in three dimensions using the Solid Mechanics module. The modelling environment defines the beam and slab geometry and assigns the previously specified material attributes to the structural domains. The equilibrium equations controlling the system's structural behaviour under the imposed loads are then solved using the finite element method.

F. Boundary Conditions

The finite element model simulates the realistic boundary conditions of reinforced concrete structures, such as reinforced concrete slabs and beams. Simply supported boundary conditions are applied to reinforced concrete beams by limiting the vertical displacement of the beam's support locations while permitting the beam's ends to rotate. When it comes to reinforced concrete slabs, the boundary conditions are implemented by limiting the slab's vertical displacement.

G. Loading Conditions

The loading conditions are specified in the finite element model, which represents the actual loading conditions that occur in reinforced concrete beams and slabs. In the beam model, the loading conditions are applied either in the form of a concentrated load or a uniformly distributed load along the length of the beam, which represents the actual loading conditions that occur in structural elements. In the case of the slab model, a uniformly distributed load is applied along the surface of the slab, which represents the actual loading conditions that occur in floors of buildings. These loading

conditions cause bending moments, shear forces, and deflections in the structural elements, which are determined using finite element analysis in COMSOL Multiphysics software.

H. Mesh Generation

Because it directly affects the precision and dependability of the numerical findings, mesh production is a crucial stage in finite element analysis. Using the mesh generation capability in COMSOL Multiphysics software, the geometric models of the reinforced concrete beams and slabs were discretised into a finite number of tiny elements for this study. The structural domains of the beam and slab models were discretised using the three-dimensional tetrahedral elements. In regions like the loading and support points where significant stress gradients and deformations are anticipated, the mesh density is refined. This maintains computing efficiency while improving the accuracy of the numerical findings.

I. Finite Element Analysis

The Finite Element Method (FEM) interface in COMSOL Multiphysics is used for finite element analysis in order to assess the structural characteristics of slabs and beams made of reinforced concrete. Static structural analysis is carried out under the given loads and boundary conditions using a stationary solver. Stress distribution, deformation patterns, bending moments, and shear forces created in the structural elements are all covered in depth by the numerical solution derived from the finite element method. The accuracy and dependability of the finite element model are assessed by comparing these findings with analytical computations after they have been retrieved using COMSOL Multiphysics' post-processing tools.

III. RESULTS AND DISCUSSION

Using COMSOL multiphysics software and finite element analysis, the structural behaviour of reinforced concrete beams and slabs is examined. To evaluate the dependability of the created finite element model, the outcomes of simulating the structure using the finite element approach are contrasted with analytical results. Major metrics like bending stress, shear stress, and the structure's deflection at key points are compared.

A. Finite Element Evaluation of Beam Deflection

The variation in displacement throughout the beam's length under loading conditions is represented by the contour of the deflection. The cantilever beam's maximum deflection happens at the free end and is zero at the fixed end, according to the Euler-Bernoulli beam theory. Both the elasticity of the beam and the accurate modelling of the boundary conditions are confirmed by the fluctuation of the beam's deflection as seen in the finite element solution. The degree of deformation is shown by the contour plot's colour variation. The colour is more intense close to the beam's free end.

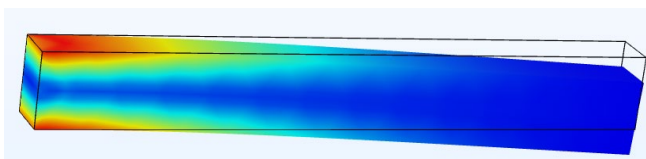


Fig. 2. Deflection contour of reinforced concrete beam obtained under applied loading using COMSOL Multiphysics.

B. Comparison of Analytical and COMSOL Results

The numerical findings from the finite element analysis program COMSOL Multiphysics are compared with the analytical calculation results. The purpose of the comparison is to evaluate the created finite element model's accuracy and dependability in predicting the structural behaviour of reinforced concrete slabs and beams. For comparison, the important structural behavior—bending stress, shear stress, and deflection—is taken into account.

The COMSOL Multiphysics program is used to compare the analytical calculation results with the numerical results of the finite element analysis. In order to assess the constructed finite element model's correctness and dependability in predicting the structural behaviour of the reinforced concrete beams and slabs, a comparison is made. For comparison, the three main structural behaviors—bending stress, shear stress, and deflection—are taken into account.

C. Beam Analysis Results

COMSOL Multiphysics and analytical computations were used to analyse the cantilever beam under uniformly distributed load (UDL) and concentrated point load. At three separate points along the beam span—L/4, L/2, and 3L/4—the response parameters, including deflection, shear force, and bending moment, were assessed. With relatively minor percentage differences, the finite element analysis findings closely match the analytical values. This shows that the structural behaviour of the beam under both UDL and point load situations is precisely predicted by the COMSOL model.

TABLE I. AT QUARTER SPAN (L/4) OF CANTILEVER BEAM SUBJECTED TO UNIFORMLY DISTRIBUTED LOAD

Quantity	Span (m)	Load (N/m)	Manual	COMSOL	% Error
Deflection (mm)	3	6000	1.32×10^{-1}	1.2575×10^{-1}	4.70
	5	7000	1.07	1.0499	1.88
	6	8000	2.54	2.4477	3.63
Shear Force (kN)	3	6000	13.50	13.542	0.31
	5	7000	26.25	26.526	1.05
	6	8000	36.00	36.499	1.39
Bending Moment (N·m)	3	6000	15187.5	15190	0.02
	5	7000	49219	49677	0.93
	6	8000	81000	81764	0.94

The COMSOL findings are marginally lower than the analytical results for the quarter span, or at L/4, and the percentage difference is within a narrow range. With a small percentage error, the shear force and bending moment results from the analytical and numerical approaches are found to be in close agreement.

TABLE II. AT QUARTER SPAN (L/2) OF CANTILEVER BEAM SUBJECTED TO UNIFORMLY DISTRIBUTED LOAD

Quantity	Span (m)	Load (N/m)	Manual	COMSOL	% Error
Deflection (mm)	3	6000	4.10×10^{-1}	3.9533×10^{-1}	3.60
	5	7000	3.55	3.4433	3.01
	6	8000	8.30	8.1005	2.40
Shear Force (kN)	3	6000	9.00	8.999	0.01
	5	7000	17.50	17.164	1.92
	6	8000	24.00	23.314	2.86
Bending Moment (N·m)	3	6000	6750	6749.2	0.01
	5	7000	21875	21895	0.09
	6	8000	36000	35862	0.38

It is found that the COMSOL simulation's deflection values at mid-span, or L/2, nearly match the analytical calculation, indicating little differences caused by the simulation's realistic stiffness values.

In a similar vein, it is seen that the bending moment and shear force values computed using the two approaches correspond well. The discretisation and approximation taken into account in the finite element analysis may be the cause of the little differences.

TABLE III. AT QUARTER SPAN (3L/4) OF CANTILEVER BEAM SUBJECTED TO UNIFORMLY DISTRIBUTED LOAD

Quantity	Span (m)	Load (N/m)	Manual	COMSOL	% Error
Deflection (mm)	3	6000	7.60×10^{-1}	7.3199×10^{-1}	3.70
	5	7000	6.72×10^{-1}	6.4550×10^{-1}	3.94
	6	8000	15.67	15.224	2.85
Shear Force (kN)	3	6000	4.50	4.4985	0.03
	5	7000	8.75	8.9236	1.98
	6	8000	12.00	11.53	3.92
Bending Moment (N·m)	3	6000	1687.5	1688.7	0.07
	5	7000	5469	5298	3.13
	6	8000	9000	8836	1.82

The % error falling within acceptable bounds indicates that the results for the deflection value at the three-quarter span position (3L/4) likewise demonstrate satisfactory agreement with the analytical estimate. Although there are some variations because the finite element method can account for the three-dimensional effect of the stresses and boundary conditions, the results for the shear force and bending moment values also show similar results, with the numerical results following the same trend as those obtained using the analytical method. The finite element technique is successful in simulating the structural response of the cantilever beam under evenly distributed load, as evidenced by the good agreement between the results produced using the analytical method and the results obtained using COMSOL. The reliability and efficacy of the simulation results obtained using the COMSOL multiphysics tool for

simulating the structural response of the cantilever beam under uniformly distributed load are demonstrated by the percentage differences between the results obtained using the analytical method and those obtained using COMSOL.

TABLE IV. AT QUARTER SPAN (L/4) OF CANTILEVER BEAM SUBJECTED TO POINT LOAD

Quantity	Span (mm)	Load (kN)	Manual	COMSOL	% Error
Shear Force (kN)	3000	30	30	30.097	0.32
	4000	40	40	39.250	1.88
	5000	50	50	51.005	2.01
Bending Moment (N·mm)	3000	30	2.25×10^7	2.2503×10^7	0.013
	4000	40	1.20×10^8	1.2002×10^8	0.02
	5000	50	1.875×10^8	1.8858×10^8	0.58
Deflection (mm)	3000	30	0.406	0.421	3.70
	4000	40	1.285	1.303	1.40
	5000	50	3.04	3.161	3.98

The results of the study for shear force, bending moment, and deflection at the cantilever beam's quarter span under point load, as determined by the analytical approach and the finite element method using the COMSOL program, are shown in Table IV. As can be seen, the bending moment and shear force findings accord well with the analytical results; the percentage errors for the finite element values are less than 2%. The discrepancy between the analytical and finite element findings is acceptable for the deflection results.

TABLE V. AT MID-SPAN (L/2) OF CANTILEVER BEAM SUBJECTED TO POINT LOAD

Quantity	Span (mm)	Load (kN)	Manual	COMSOL	% Error
Shear Force (kN)	3000	30	30	30.001	0.003
	4000	40	40	41.022	2.56
	5000	50	50	49.122	1.76
Bending Moment (N·mm)	3000	30	4.50×10^7	4.499×10^7	0.022
	4000	40	8.00×10^7	8.0421×10^7	0.53
	5000	50	1.25×10^8	1.2565×10^8	0.52
Deflection (mm)	3000	30	1.47	1.51	2.60
	4000	40	4.63	4.713	1.80
	5000	50	10.97	11.46	4.49

The results of the analytical technique and the COMSOL simulation for the shear force, bending moment, and deflection at the quarter span of the cantilever beam under point load are compared in Table IV. With percentage errors of less than 2%, it can be inferred that the findings for the shear force, bending moment, and deflection at the cantilever beam's quarter span under point load correspond well with the results from the analytical technique.

TABLE VI. AT THREE-QUARTER SPAN (3L/4) OF CANTILEVER BEAM UNDER POINT LOAD

Quantity	Span (mm)	Load (kN)	Manual	COMSOL	% Error
Shear Force (kN)	3000	30	30	29.992	0.03
	4000	40	40	39.683	0.79
	5000	50	50	50.308	0.62
Bending Moment (N·mm)	3000	30	6.75×10^7	6.7502×10^7	0.003
	4000	40	4.00×10^7	3.991×10^7	0.23
	5000	50	6.25×10^7	6.1765×10^7	1.18
Deflection (mm)	3000	30	2.96	3.04	2.70
	4000	40	9.47	9.528	0.60
	5000	50	22.7	23.19	2.18

Table VI shows a comparison of the analytical and COMSOL results over a three-quarter period. With an error rate of less than 1%, the shear force and bending moment values determined by the COMSOL simulation accord well with the analytical findings. The deflection findings show good agreement, indicating that the beam under loading conditions is accurately represented by the finite element model.

D. Geometric Configuration and Loading Conditions of Reinforced Concrete Slab

A typical floor slab utilised in construction structures, the reinforced concrete slab under consideration in this study is modelled as a rectangular slab with defined length, breadth, and thickness. For the structure to behave realistically, the slab is geometrically modelled using typical design proportions. The numerical model assigns realistic material parameters for the slab that are taken into account for reinforced concrete. In order to simulate the service load circumstances that are frequently encountered in structural applications, the slab is subjected to a uniformly distributed load. The slab's edges are given realistic boundary constraints that mimic the structure's supports, such as fixed or simply supported supports. The load is delivered to the top of the slab, and COMSOL Multiphysics' finite element approach is used to assess the structure's stress distribution, bending, and deflection response.

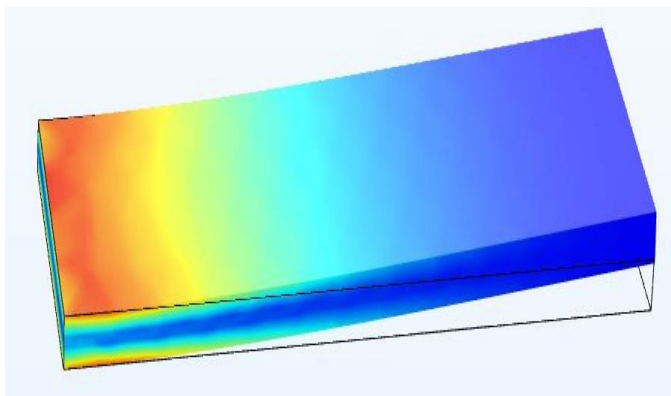


Fig. 3. Deflection contour of reinforced concrete slab obtained from finite element analysis

E. Slab Analysis Results

The COMSOL Multiphysics tool's finite element model is used to analyse the reinforced concrete slab's structural behaviour. To examine the stress distribution, bending behaviour, and deflection of the reinforced concrete slab, evenly distributed loading conditions are used. The analytical answer derived from classical plate theory and general principles of reinforced concrete design is contrasted with the numerical solution found in the aforementioned simulation. The analytical result from the aforementioned problem is utilised to comprehend the stress fluctuation and deformation pattern across the reinforced concrete slab's surface. The finite element model performs similarly to the reinforced concrete slab, as demonstrated by the satisfactory comparison between the analytical solution and the numerical solution found in the aforementioned problem.

TABLE VII. COMPARISON OF DEFLECTION, SHEAR FORCE, AND BENDING MOMENT OF ONE-WAY REINFORCED CONCRETE SLAB UNDER UDL

Quantity	Location	Manual	COMSOL	% Error
Deflection (mm)	L/4	0.456	0.4509	1.11
	L/2	1.52	1.5044	1.03
	3L/4	2.87	2.8382	1.11
Shear Force (kN)	L/4	6.75	6.766	0.24
	L/2	4.50	4.764	5.87
	3L/4	2.25	2.284	1.51
Bending Moment (N·mm)	L/4	7.59375×10^6	7.5565×10^6	0.49
	L/2	3.375×10^6	3.3009×10^6	2.19
	3L/4	8.4375×10^5	8.5487×10^5	1.32

For the one-way cantilever slab under uniformly distributed load (UDL), the span-wise findings from analytical computations and COMSOL Multiphysics software show a high degree of agreement. With a mean percentage error of 2.54%, the shear force showed the most variation among the response parameters. The shear force at the midpoint of the span, or L/2, has the largest standard variation of 2.91% in the data. The localised stress concentrations linked to the finite element method (FEM) formulations may be the cause of the greater range in the shear force values. With a low percentage error of 1.08%, the results for the deflection demonstrated a high degree of agreement between the analytical and numerical results. Additionally, there was very little variation in the outcomes, suggesting that the serviceability effects were accurately predicted by the program COMSOL Multiphysics. With a mean percentage error of 1.33%, the results showed a moderate degree of variation, demonstrating the numerical model's dependability. The finite element method's three-dimensional effects could be the cause of slight variations in the bending moment values.

IV. CONCLUSION

The validity of the selected method for numerical modelling is ensured by the good agreement between the results of the analytical solution based on classical beam theory, classical slab theory, and IS 456:2000 and the finite element models for the reinforced concrete beam and slab created using the COMSOL

Multiphysics program. Additionally, the findings produced from the analytical solution have demonstrated percentage deviations between 0% and 3% for the shear force values at the crucial places, such as $L/4$, $L/2$, and $3L/4$. This guarantees that the results for the distribution of internal forces are accurately represented.

With a percentage variation ranging from 1 to 5%, the bending moment values obtained using COMSOL were slightly greater than those obtained using the analytical technique, especially in the areas around the fixed support and the load application. This may be because the effects of three-dimensional stresses, which are typically ignored in the analytical method, are taken into account in the finite element model. Similarly, the values of deflection calculated using the numerical method at locations $L/4$, $L/2$, and $3L/4$, as obtained from the COMSOL simulation, have demonstrated an increasing trend of being higher than the values calculated using the analytical method, with differences ranging from 4% to 10% for slabs and from 3% to 8% for beams. The accurate modelling of the stiffness of the structure, the inclusion of shear deformation, the compatibility of three-dimensional deformation, and the realistic modelling of boundary constraints have all contributed to higher deflection values calculated using the numerical technique. However, because of the assumptions made regarding the linear elastic behaviour, uniform stiffness, support conditions, and lack of stress concentrations, the analytical method yields lower values of deflection.

In comparison to the findings produced using COMSOL, the percentage variance of the results obtained for the reinforced concrete slab is between 2 and 6%. Higher deviations occur between the edges and the middle of the slab, where plate action predominates in the behaviour of the structure. Even if the analytical models, according to IS 456:2000, are shown to offer a safe and appropriate assessment of the structure's reaction, they are insufficient to simulate realistic load distribution and three-dimensional effects, as determined by finite element analysis.

The dependability of the COMSOL multiphysics tool for the study of reinforced concrete beams and slabs is validated by the percentage variation of the findings with respect to all the parameters, as obtained using the analytical approach and COMSOL, falling within acceptable bounds. According to the survey.

While the finite element technique provides precise results and insight into realistic structural behaviour, especially for the aim of serviceability evaluation of structures, the analytical method is suitable for design objectives.

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