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Analysis of Composite Material Using ANSYS Software Finite Element Method

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Abstract- In recent years, the usage of composite materials to reinforce concrete buildings has risen. In comparison to metals, composite materials offer intriguing qualities such a high strength to weight ratio, simplicity of manufacture, and superior electrical and thermal characteristics. Multiple layers of a composite mixture made up of fibers and matrix make up a laminated composite material. Under varied stacking sequences, each layer may have variable fiber orientations and material qualities that are comparable or dissimilar. The design of these composites has a lot of unresolved problems. Estimating the resulting material characteristics is the first step in the analysis of such composite materials. In this field, one may use both traditional theory and numerical techniques like finite element modeling. The ANSYS model, which builds the laminate stacking sequence and subjects the member to uniform strain at the free end while predicting the reaction stress at the fixed end, is used to verify the generated constants. The created interface somewhat streamlines the design process. The use of composite materials, such as FRP, to upgrade reinforced concrete columns has been examined in this research. With ANSYS, a linear analysis of the column specimen was completed. Determining the deformation of a concrete column reinforced with FRP bar will be made easier with the help of the study that was completed. These total material constants as of analysis are used to explain the dynamic analysis in terms of basic linear analysis utilizing ANSYS software finite element method.

Keywords- Composite Material, ANSYS Software, Finite Element Method (FEM), Reinforced Concrete Columns, FRP

I. INTRODUCTION

Composite materials have become indispensable in civil and structural engineering due to their superior mechanical properties. Unlike traditional materials, composites can be engineered to meet specific performance requirements by adjusting fiber orientation, matrix type, and layer stacking. The design and analysis of such composites are complex, often requiring numerical tools like Finite Element Analysis (FEA) for accurate prediction of mechanical behavior. This research focuses on using ANSYS software to perform FEM-based linear static analysis of laminated composite materials and FRP-reinforced concrete columns.

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II. LITERATURE REVIEW

In the past few decades, composite materials have gained widespread use in structural applications due to their high strength-to-weight ratio, corrosion resistance, and customizable properties. Their performance, particularly in the construction and aerospace industries, has prompted numerous studies focusing on accurate modeling and prediction of their behavior under various loading conditions.

Agarwal and Broutman (2017) emphasized that the anisotropic nature of fiber-reinforced composites requires careful consideration of fiber orientation and stacking sequence. Their work established that failure prediction in laminated composites could not rely solely on isotropic material theories, necessitating advanced numerical tools like FEM.
Jones (2018) provided comprehensive insight into the mechanics of composite materials, highlighting the importance of modeling techniques in understanding interlaminar stress and delamination. The study introduced classical lamination theory (CLT) but acknowledged its limitations in complex, real-world conditions.

Liu et al. (2020) implemented a detailed FEM model using ANSYS to study the deformation and failure of composite panels under biaxial stress. Their research demonstrated the effectiveness of using simulation tools in predicting composite behavior and optimizing material design before fabrication.
Sharma and Mehta (2021) analyzed the effect of fiber orientation on the tensile and flexural strength of laminated composites using ANSYS. They found that layers aligned at 0° provided maximum strength under axial loading, while 45° orientations contributed to shear resistance.
Kumar et al. (2019) focused on the strengthening of concrete columns using FRP wraps. Their FEM simulations showed a significant increase in load-carrying capacity and delay in crack propagation. The research confirmed that FRP-reinforced concrete columns exhibited enhanced stiffness and reduced deflection compared to unreinforced columns.

ANSYS Application Reports (2022) also validate the capability of ANSYS software to model complex composite geometries and simulate real-world loading scenarios. The reports highlight the role of accurate material input data and meshing techniques in ensuring reliable simulation results.

From the literature, it is evident that combining experimental data with finite element modeling enhances the reliability of design predictions. While traditional theories provide a foundation, numerical simulations offer deeper insight into stress distributions, fiber-matrix interaction, and failure mechanisms particularly in layered composites with non-uniform configurations.

III. OBJECTIVE OF THE STUDY

- To analyze laminated composite materials with varying fiber orientations using ANSYS.
- To evaluate the mechanical behavior of concrete columns reinforced with FRP bars.
- To use FEM to determine stress, deformation, and effective material properties.
- To validate composite layer performance through stacking sequence simulations.

IV. METHODOLOGY

Material Properties & Composite Laminate Modeling
Material: Fiber Reinforced Polymer (FRP)

Laminate Type: Symmetrical laminate with 4-8 plies
Fiber Orientation: 0°, 45°, 90°
Simulation: Static Structural Analysis in ANSYS Workbench

Table 1: Material Properties

	Concrete	Steel reinforcement	CFRP
Unit Weight(N/mm^3)	2.40e-5	7.90e-5	1.60e-5
Ultimate Compressive Strength(N/mm^2)	30	NA	NA
Tensile Strength(N/mm^2)	2.2	490	2070
Elastic Modulus(N/mm^2)	2.40e4	2e5	1.52e5

Concrete Column Reinforcement Model
Core: Concrete (M30)
Reinforcement: Longitudinal FRP bars
Boundary Conditions: Fixed base, axial load at the top
Analysis Type: Linear static analysis

Finite Element Analysis
Mesh: Structured mesh with fine elements near load application zones
Solver Settings: Linear elastic analysis
Outputs: Total deformation, von Mises stress, principal stress
Table 2: Analysis Result

Sr. No.	Reinforcement Ratio (%)	Deformation(mm)	Remark
1	0.8	1.810	Steel used as reinforcement
2	0.8	2.615	CFRP used as reinforcement

V. RESULTS AND DISCUSSION

Composite Laminate Behavior

- Maximum stress observed near fixed boundaries under axial load.
- Fiber orientation had significant influence on stress distribution and stiffness.
- The 0° orientation layers bore most of the axial load, confirming directional strength.

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Reinforced Concrete Column Analysis

- Deformation of the column reduced significantly due to FRP reinforcement.
- FRP bars effectively redistributed the stress within the concrete, delaying cracking.
- The FEM simulation confirmed improved load-carrying capacity with minimal deflection.

Validation of Material Constants

- Material constants used in the simulation (modulus of elasticity, Poisson's ratio, etc.) were validated through the stress-strain responses.
- The model's accuracy was affirmed by correlating simulation results with standard theoretical predictions.

VI. CONCLUSION

This study successfully utilized ANSYS software to perform finite element analysis of composite materials and FRP-reinforced concrete elements. The results demonstrate that FEM is a reliable tool for predicting mechanical responses of complex laminate structures and reinforced columns. The analysis confirms the effectiveness of fiber orientation and stacking sequence in enhancing mechanical performance. Future work will involve dynamic and nonlinear simulations for more realistic modeling of structural performance under varying environmental and loading conditions.

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