Finite Element Analysis of Composite Material Using ANSYS

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Abstract— The use of composite materials has been increased in strengthening of concrete structures in recent years. Composite materials have interesting properties such as high strength to weight ratio, ease of fabrication, good electrical and thermal properties compared to metals. A laminated composite material consists of several layers of a composite mixture consisting of matrix and fibers. Each layer may have similar or dissimilar material properties with different fiber orientations under varying stacking sequence. There are many open issues relating to design of these composites. Analysis of such composite materials starts with estimation of resultant material properties. Both classical theory and numerical methods such as finite element modeling may be employed in this line. The obtained constants are validated with an ANSYS model, where the laminate stacking sequence is built and the member is subjected to a uniform strain at free end, while the reaction stress at the fixed end is predicted. The developed interface simplifies the design process to some extent. In this paper technique for upgrading reinforced concrete column have been analysed with the application of composite material like FRP. Linear analysis of column specimen was accomplished using ANSYS. The analysis done will be useful for determining deformation of concrete column reinforced with FRP bar. The dynamic analysis in terms of fundamental linear analysis is illustrated by using ANSYS these overall material constants as of analysis.

Key words: Fibre reinforced polymer (FRP), linear analysis, ANSYS

I. INTRODUCTION

Increasing concern about global warming and depleting petroleum reserves have made scientists to focus more on the use of natural fibres such as bagasse, coir, sisal, jute etc. This has resulted in creation of more awareness about the use of natural fibres based materials mainly composites. Dramatic development of new structural materials has followed the way of substituting metals for composite in various industries, such as aviation, ship building chemical-petroleum, civil engineering etc. Fiber reinforced composite materials have been increasingly used as structural members in many structures such as airplane, which in flight condition undergoes temperature as low as -60°C or in acryogenic tank which may be exposed to temperature below -150°C. The advantages of these materials arederived from their high strength, stiffness and damping together with low specific weight. On the other hand, composite materials have the potential of reducing costs in construction, operation and development while improving structural reliability and enhancing safety. Because of these unique specifications, they are widely used in high technology structural applications, such as aeronautic and aerospace.

Composite is a mixture of two or more constituents with different properties at the macroscopic or microscopic scale. In general composites have two or more constituents, fiber and matrix. Composites are classified by the geometry of the reinforcement: particulate, flake, and fibers or by the type of matrix: polymer, metal, ceramic, and carbon. The basic idea of the composite is to optimize material properties of the composite, i.e., the properties of the matrix are to be improved by incorporating the reinforcement phase. Fibers are the principal load-carrying constituents while the surrounding matrix helps to keep them in desired location and orientation and also act as a load transfer medium between them.The advanced composite materials such as Graphite, Carbon and Glass with suitable resins are widely used because of their high specific strength and high specific modulus. The most common types of FRP are aramid, glass, and carbon; AFRP, GFRP and CFRP respectively.So, the purpose of this research is to study the behavior of reinforced concrete columns with CFRP.

II. LITERATURE REVIEW

A. Composites

A composite material is made by combining two or more materials to give a unique combination of properties, one of which is made up of stiff, long fibres and the other, a binder or 'matrix' which holds the fibres in place and very clearly stated that the composites should not be regarded simple as a combination of two materials. In the broader significance; the combination has its own distinctive properties. In terms of strength to resistance to heat or some other desirable quality, it is better than either of the components alone or radically different from either of them. It is defined as "The composites are compound materials which differ from alloys by the fact that the individual components retain their characteristics but are so incorporated into the composite as to take advantage only of their attributes and not of their short comings, in order to obtain improved materials. It explained composite materials as heterogeneous materials consisting of two or more solid phases, which are in intimate contact with each other on a microscopic scale. They can be also considered as homogeneous materials on a microscopic scale in the sense that any portion of it will have the same physical property.

B. Composites Properties

Composites consist of one or more discrete phases embedded in a continuous phase to produce a multiphase material which possesses superior properties that are not obtainable with any of the constituent materials acting alone. These constituents remain bonded together but retain their identity and properties. The continuous phase which is present in greater amount in composites is termed as matrix. The discrete phase is generally harder and stronger than the continuous phase and is called the reinforcement or reinforcing material. The geometry of the reinforced phase is one of the major parameter in determining the effectiveness of the reinforcement.

The related research work on finite analysis are as:

1) Jun et al. introduced a dynamic finite element method for free vibration analysis of generally laminated

composite beams on the basis of first-order shear deformation theory. The influences of Poisson effect, couplings among extensional, bending and torsional deformations, shear deformation and rotary inertia are incorporated in the formulation. The dynamic stiffness matrix is formulated based on the exact solutions of the differential equations of motion governing the free vibration of generally laminated composite beam.

2) Gurban and Gupta analyzed the natural frequencies of composite tubular shafts using equivalent modulus beam theory with shear deformation, rotary inertia and gyroscopic effects has been modified and used for the analysis. The modifications take into account effects of stacking sequence and different coupling mechanisms present in composite materials. Results obtained have been compared with that available in the literature using different modeling. The close agreement in the results obtained clearly show that, in spite of its simplicity, modified EMBT can be used effectively for rotor-dynamic analysis of tubular composite shafts.
3) Rarani et al. used analytical and finite element methods for prediction of buckling behavior, including critical buckling load and modes of failure of thin laminated composites with different stacking sequences. A semi-analytical approach is first developed to calculate the critical buckling loads of square composite laminates with SFSF boundary conditions. Then, these laminates are simulated under axially compression loading using the commercial finite element software, ABAQUS. Critical buckling loads and failure modes are predicted by both eigenvalue linear and nonlinear analysis.

III. Experimental Procedure

A. *Finite Element Analysis Using ANSYS*

ANSYS is general purpose finite element analysis (FEA) software package which is engineering simulation software (computer- aided engineering, or CAE) that utilizes Finite element Analysis. It is a numerical method in which a complex system is divided into very small pieces called elements. The software uses equations that generate the behavior of these elements and solves them all.

In order to verify the longitudinal modulus obtained from classical lamination theory, a finite element model is developed in ANSYS software and further applied with a constant displacement at one end and other end is fixed. The reaction forces (stresses) are computed at fixed end and finally the longitudinal modulus and Poisson ratio are estimated. Similarly other elastic constants can be computed.

1) *Geometry*

In the present investigation both static and dynamic analysis are carried out on steel and laminated composite rail tie to study the stresses and deflection in the steel and laminated composite rail tie. Static analysis is carried out to study the maximum displacements and maximum Von-misses stresses in steel and laminated composite rail tie due to static loads and dynamic analysis is carried out to study maximum displacements. The details of testing columns were carried out in column specimens, where all columns had a square cross-section with a 450mm side and length of 3000 mm. Analyzed columns had main reinforcement(Steel, CFRP) 8#18 mm.The transverse reinforcement (Steel, GFRP) was ɸ 8 mm stirrups spaced 300 mm, characteristic compressive strength of concrete columns 30 N/mm^2.

2) *Element types*

An eight-node solid element, solid65, was used to model the concrete.A link 8 element was used to model the reinforcement Polymer bar; two nodes are required for this element. Each node has three degrees of freedom, translation in the nodal x, y, and z directions. The element is also capable of plastic deformation.

3) *Material Properties*

The input data for the concrete, CFRP, and steel properties are shown in Table I.

	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

Table 1:

IV. Application of Loading

The parametric studies included in this investigation are the reinforcement ratios and reinforcement types, and the characteristic compressive strength of concrete, ultimate load bearing capacity etc.

Col no	Reinforcement Ratio(%)	Ultimate load on column(KN)	Remark
1	0.8	2310	Steel used as reinforcement
2	0.8	4092	CFRP used as reinforcement

Table 2: Ultimate Load On Column (KN)

V. Analysis of Column Using ANSYS & Comparison of Results

A. *Linear Analysis*

Table III shows analytical results of deformations using ANSYS and also shows the comparison of deformations in columns using Steel and CFRP as a reinforcement.

Col no	Reinforcement Ratio (%)	Deformation(mm)	Remark
1	0.8	1.810	Steel used as reinforcement
2	0.8	2.615	CFRP used as reinforcement

Table 3: Ansys Results For Deformation (Linear Analysis)

VI. Conclusion

The conclusion made from this analysis are as follows**:**

– The deformation results from finite element analysis are in good agreement with the values of deformation obtained from equation of elasticity for composite material.
– In case of CFRP the ultimate load bearing capacity of the column is significantly increased.

- The CFRP is corrosion free,Weigh 1/4 th of steel,has greater tensile strength and also reduce the maintenance cost to a greater extent.
- Linear and Nonlinear Analysis and for the same reinforcementratio deformation does not change when using GFRP.

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