Experimental And Numerical Study on Dynamic Behaviour of Composite Beams With Different Cross Section

P.Balalrishna[1], Sampath Kumar.K[2]
[1, 2] Dept of civil engg
[2]Head of Dept, Dept of civil engg
[1, 2] Newton's Institute of Science & Technology,Macherla,India

Abstract- *The increasing use of composite materials across various fields such as aerospace, automotive, civil, naval and other high performance engineering applications are due to their light weight, high specific strength and stiffness, excellent thermal characteristic, ease in fabrication and other significant attributes. The present study deals with experimental investigation on free vibration of laminated composite beam and compared with the numerical predictions using finite element method (FEM) in ANSYS environment. A program is also developed in MATLAB environment to study effects of different parameters. The scope of the present work is to investigate and understand the effect of different parameters including cross sectional shape on modal parameters like modal frequency, mode shapes. Experimental investigation is carried out by Impulsive frequency response test under fixed- free and fixed-fixed boundary conditions. Composites Beams are fabricated using woven glass fabric and epoxy by hand layup technique. Modal analysis of various cross sectional beams were reported, compared and discussed. The finite element modelling has been done by using ANSYS 14 and compared with the experimental results. Two-node, finite elements of three degrees of freedom per node and rectangular section are presented for the free vibration analysis of the laminated composite beams in this work.*

Keywords- GGBFS, Mortar Cubes, SSHM.

I. INTRODUCTION

The widespread use of composite structures in aerospace applications has stimulated many researchers to study various aspects of their structural behavior. These materials are particularly widely used in situations where a large strength-to-weight ratio is required. Similarly to isotropic materials, composite materials are subjected to various types of damage, mostly cracks and delamination. These result in local changes of the stiffness of elements for such materials and consequently their dynamic characteristics are altered. This problem is well understood in case of constructing elements made of isotropic materials, while data concerning the influence of fatigue cracks on the dynamics of composite elements are scarce in the available literature.

A. Purpose and Objectives of Study

The main objective of this thesis is to study and compare the numerical and experimental result of free vibration analysis of composite Fibre Reinforced Polymer (FRP) beam. The present investigation mainly focuses on the study of vibration of industry driven woven fiber glass/epoxy composite beams. A first order shear deformation theory based on finite element model is developed for studying the free vibration, The influence of shape of the beams, boundary conditions, number of layers, fiber orientations and aspect ratio on the free vibration of composite beams are investigated experimentally also examined numerically.

II. LITERATURE REVIEWS

Ostachowicz & Krawczuk (1999) presented a method of analysis of the effect of two open cracks upon the frequencies of the natural flexural vibrations in a cantilever beam. Two types of cracks were considered: double-sided, occurring in the case of cyclic loadings, and single-sided, which in principle occur as a result of fluctuating loadings. It was also assumed that the cracks occur in the first mode of fracture: i.e., the opening mode. An algorithm and a numerical example were included.

Krawczuk (2004) formulated a new beam finite element with a single non-propagating one-edge open crack located in its mid-length for the static and dynamic analysis of cracked composite beam-like structures. The element includes two degrees of freedom at each of the three nodes: a transverse deflection and an independent rotation respectively. He presented the exemplary numerical calculations illustrating variations in the static deformations and a fundamental bending natural frequency of a composite cantilever beam caused by a single crack.

Krawczuk & Ostachowicz (2005) investigated eigen frequencies of a cantilever beam made from graphite- fiber reinforced polyimide, with a transverse on-edge non-propagating open crack. Two models of the beam were presented. In the first model the crack was modeled by a massless substitute spring Castigliano

"sthefinite element method. The undamaged parts of the beam were modeled by beam finite elements with three nodes and three degrees of freedom at the node. The damaged part of the beam was replaced by the cracked beam finite element with degrees of freedom identical to those of the non-cracked done. The effects of various parameters the crack location, the crack depth, the volume fraction of fibers and the fibers orientation upon the changes of the natural frequencies of the beam were studied. Computation results indicated that the decrease of the natural frequencies not only depends on the position of the crack and its depth as in the case of isotropic material but also that these changes strongly depend on the volume fraction of the fiibers and the angle of the fibers of the composite material.

Ghoneam (2006) presented the dynamic characteristics laminated composite beams (LCB) with various fiber orientations and different boundary fixations and discussed in the absence and presence of cracks. A mathematical model was developed, and experimental analysis was utilized to study the effects of different crack depths and locations, boundary conditions, and various code numbers of laminates on the dynamic characteristics of CLCB. The analysis showed good agreement between experimental and theoretical results.

III. MATHEMATICAL FORMULATIONS

A. Introduction

This chapter represents the theory and finite element formulation (FEM) for free vibration, static and dynamic analysis of the composite beam of different cross sections. The basic configuration of the problem investigated here is a composite beam of any boundary condition, however, a typical cantilever composite beam, which has tremendous applications in aerospace structures and high-speed turbine machinery, is considered.

B. The Methodology

The governing equations for the vibration analysis of the composite beam are developed. The stiffness matrix and mass matrix of composite beam element is obtained by Krawczuk & Ostachowicz (2004).

C. Mathematical Modelling

The model chosen is a cantilever composite beam of uniform cross-section A, The width, length and height of the beam are B, L and H, respectively in Fig1. The angle between the fibers and the axis of the beam is ‘α’.

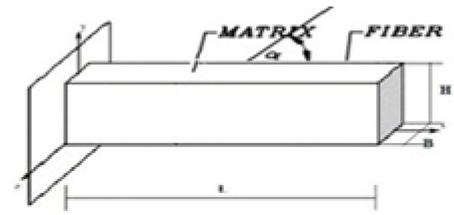

Fig1. Schematic diagram cantilever composite beam.

IV. EXPERIMENTAL PROGRAMME

This chapter deals with the details of the experimental works conducted on the static analysis and free vibration of industry driven woven roving composite beams. Therefore composite beams are fabricated for the aforementioned experimental work and the material properties are found out by tensile test as per ASTM D3039/ D3039M (2008) guidelines to characterize the composite beams. The experimental results are compared with the analytical or numerical predictions. The experimental work performed is categorized in three sections as follows,

A. Bending test

The most commonly used test for ILSS is the short beam strength (SBS) test under three point bending. The SBS test was done as per ASTM D 2344/ D 2344 M (2006) by using the INSTRON 1195 material testing machine. The specimens were tested at 2, 50, 100, 200 and 500 mm/minute cross head velocities with a constant span of 34 mm to obtain interlaminar shear strength (ILSS) of samples. Before testing, the thickness and width of the specimens were measured accurately. The test specimen was placed on the test fixtures and aligned so that its midpoint was centered and its long axis was perpendicular to the loading nose. The load was applied to the specimen at a specified cross head velocity. Breaking load of the sample was recorded. About five samples were tested at each level of experiment and their average value along with standard deviation (SD) and coefficient of variation (CV) were reported in result part. The interlaminar shear strength was calculated using the formula,

$$S = (0.75Pb)/bd \text{ as per ASTM D 2344}$$

Where Pb is the breaking load in kg; b is the width in mm and d is the thickness in mm.

Fig2. Three point bend test setup and fixture.

A. Requirement Specification

This step is done in pre-processing in ANSYS. In this work the beam element model used know was SHELL93 and it was specification at the pre-processing stage. The SHELL93 element is applicable to this model for the structural meshing and boundary condition applications. The parameter specified in the table above indicated that only vertical direction analysis was carried on the beam. This is applicable to the modal analysis experiment in the previous section.

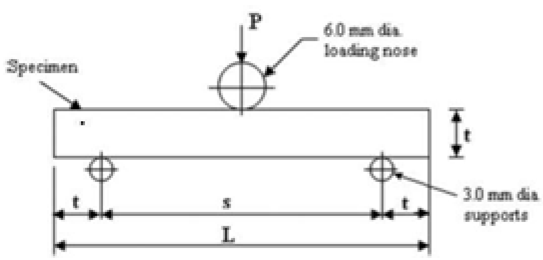

Fig3. Schematic diagram of three point bend test.

V. MODELING IN ANSYS

The finite element simulation was done by FEA package known as ANSYS. The FEA software package offerings include time-tested, industry-leading applications for structural, thermal, mechanical, computational fluid dynamics, and electromagnetic analyses, as well as solutions for transient impact analysis. ANSYS software solves for the combined effects of multiple forces, accurately modelling combined behaviours resulting from "multiphysics" interactions. This is used to perform the modelling of the beam and calculation of natural frequencies with relevant mode shapes.This is used to simulate both the linear & nonlinear effects of structural models in a static or dynamic environment. The advanced nonlinear structural analysis includes large strain, numerous nonlinear material models, nonlinear buckling, post- buckling, and general contact. Also includes the ANSYS Parametric Design Language (APDL) for building and controlling user-defined parametric and customized models.The purpose of the finite element package was utilised to model the Fibre reinforced polymer (FRP) beam in 3-D as SHELL93 (8node93). This package enables the user to investigate the physical and mechanical behavior of the beam.

A. Procedure in Modelling ANSYS

There are major and sub important steps in ANSYS model, pre-processing, solution stage and post- processing stage.

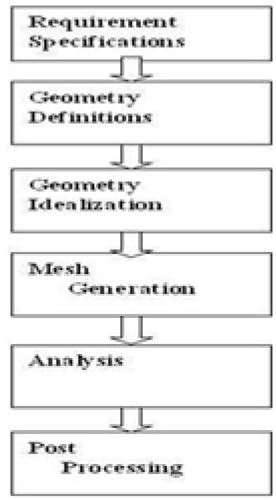

Fig4. FE-Analysis Steps.

Geometry Definition	Values
Thickness	3.57e-4m
Young modulus	1.46e9
Density	1660
Width	0.05m
Length of the beam	0.40m
Poisson Ratio	0.3

Table2. Input data for Modelling of the beam

VI. CONCLUSION

The following conclusions can be made from the present investigations of the box and channel shaped composite beam finite element. This element is versatile and can be used for static and dynamic analysis of a composite or isotropic beam.The natural frequencies of different boundary conditions of composite beam have been reported. The program result shows in general a good agreement with the existing literature.It is found that natural frequency is minimum for clamped –free supported beam and maximum for clamped-clamped supported beam. Mode shape was plotted for differently supported laminated beam with the help of ANSYS to get exact idea of mode shape. Vibration analysis of laminated composite beam was also done on ANSYS to get natural frequency and same trend of natural frequency was found to be repeated. There is a good agreement between the experimental and numerical results.The Finite Element method defined previously is directly applied to the explained examples of generally laminated composite beams to obtain the natural frequencies, the impact of Poisson effect, slender ratio, material anisotropy, shear deformation and boundary conditions on the natural frequencies of the laminated beams are analyzed. And it is found that the present results are in very good agreement with the theoretical results of references.

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