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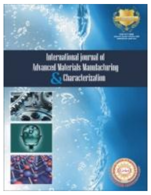

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# Non-Linear Analysis of Composite Beams

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A B S T R A C T

When a structure deforms, under a load its stiffness changes. Depending upon the amount of change in the stiffness, the field variables are calculated using linear or nonlinear approaches. In this paper linear and geometric non-linear analysis of a FRP composite beam is carried out using two-dimensional finite element method by simulating the problem in commercial software ANSYS. Influence of the parameters (i) span to height ratios(s) and (ii) Load on geometrical non-linear behavior of the beam for a fixed width-to-height ratio (b/h) of 0.2 is studied.

## Introduction

An assumption of linear elastic behavior may be used in the analysis of structures for simplifying the solution procedure. This assumption may yield results far from reality in many situations. In such cases one may arrive at either non-optimum design or failure. The basic difference between both the approaches is only in updating the geometry of the structure during load transferring.

### Types of non-linearity

Most of the non-linear behavior in product design can be categorized into one of three common types: Material, Geometric, and Boundary non-linearity

### Previous study

Namik Kemal Oztorun [1] validated a finite element formulation for the static and dynamic analysis of linear-elastic space structures composed of plate- and beam-type members. In general, finite elements can be used efficiently for the analysis of linear-elastic structures with shear walls built by the use of tunnel forms. The element considered in the present study has six degrees of freedom at each node and an in-plane rotational degree of freedom, which makes it compatible with three-dimensional (3D) beam-type finite element models. The rigidity coefficients of the element are determined analytically.

George at al [2] tested the improved geometric non-linear capability in MSC/NASTRAN version 68 on a large scale finite element model of a tie rod. The static buckling load of a tie rod is analyzed. The results of the finite element model are compared with experimental results. It is shown that MSC/NASTRAN's computed buckling load agrees well with the experimental buckling load.

Luiz A. et al [3] discussed an eight-node hexahedral element with uniform reduced integration, which is free of volumetric and shear locking and has no spurious singular modes, is implemented for geometrically non-linear static structural analysis. Numerical examples verify the computational efficiency and the potential of the three-dimensional element in the analysis of shells, plates and beams undergoing large displacements and rotations. Results are compared to those employing classical plate and shell elements.

Bassam [4] aims to clarify some of the conceptual issues which are related to the geometrically non-linear analysis of 3D framed structures, and which have been a source of previous confusion.

Yang et al [5] presents the non-linear analysis of elastic structures; the displacement increments generated at each incremental step can be decomposed into two components as the rigid displacements and natural deformations. The robustness of the procedure is demonstrated in the solution of several benchmark problems involving the post buckling response.

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Vladimr and Justn [6] deals with a new bar element with varying cross-sectional area which can be used for geometric non-linear analysis. The results obtained with new element were compared with ANSYS bar element results.

Raul [7] used Finite element models to analyze adhesive bonds in actual structures, but this takes a considerable amount of time and a high computational cost. A stress analysis of crack patch geometry is presented. A numerical simulation of the debonding of the patch is also included.

Andrzej [8] verifies the suitability of commercial engineering software for geometrically non-linear analysis of shell structures. The paper deals with the static, geometrically non-linear analysis of shells made of isotropic materials. The finite element method (FEM) has been chosen to solve the problem. The results of the ROBOBAT Millennium v.19.0 and MSC. Marc v.2005r2 commercial software is compared with the literature results.

Chandrashekhara et al [9] presents the flexural analysis of fiber-reinforced composite beams based on a higher-order shear deformation theory. The influence of boundary conditions, beam geometries, and ply orientations on the deflections and stresses of laminated beams is shown both in tabular and graphical forms.

Damian [10] developed a three-dimensional finite element model to examine the structural behavior of the Horsetail Creek Bridge in Oregon both before and after applying FRP laminates. The comparisons between ANSYS predictions and field data are made in terms of concrete strains. The analysis shows that the FE bridge model does not crack under the applied service truckloads

**Purpose of present study**

In order to identify the limitations of linear static analysis of beams, the transverse deflection and bending stresses for a width-to-height ratio of 0.2 from 2-D plane stress approach for both linear and geometric non-linear analysis options by varying span-to-height ratio of the composite beam.

**Geometrical modeling of the problem**

A 2-D model of beam is modeled using ANSYS software by modeling longitudinal section of the beam (Fig. 1). The length of the beam is taken as 1m and cross sectional dimensions of the beam are height 'h' which varies according to different span to height ratios such as s=10, 20, 40, 60, 80, 100. The width of the beam is taken according to width to height ratio, a=0.2. The finite element mesh is generated with 8-node quadratic Plane-82 elements. For the beam simply supported boundary conditions are applied. A uniform transverse pressure of 1MPa is applied on the top surface of the beam (Fig. 1).

The details of orthotropic materials used for the analysis of composite beams (0/90/90/0) are listed in Table 1

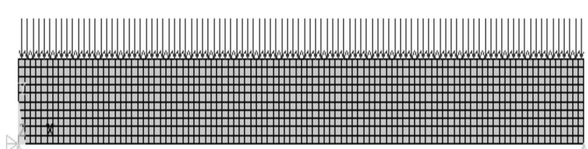


Fig. 1 2-D FE model showing meshing,

boundary conditions, and loading (s=10, a=0.2)

Table 1 Material Properties of Graphite-Epoxy at Vf =0.6 [15]

| | **θ=0°** | **θ=90°** |
|---|---|---|
| **Ex** | 141.6764GPa | 12.3857GPa |
| **Ey** | 12.3857GPa | 12.3857GPa |
| **Ez** | 12.387GPa | 141.6764GPa |
| **νxy** | 0.257 | 0.4205 |
| **νyz** | 0.4206 | 0.256 |
| **νzx** | 0.257 | 0.256 |
| **Gxy** | 4.0301GPa | 4.3592GPa |
| **Gyz** | 4.3592GPa | 4.0301GPa |
| **Gxz** | 4.0301GPa | 4.0301GPa |

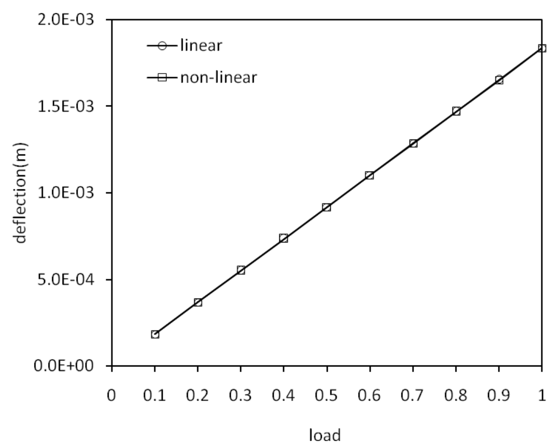
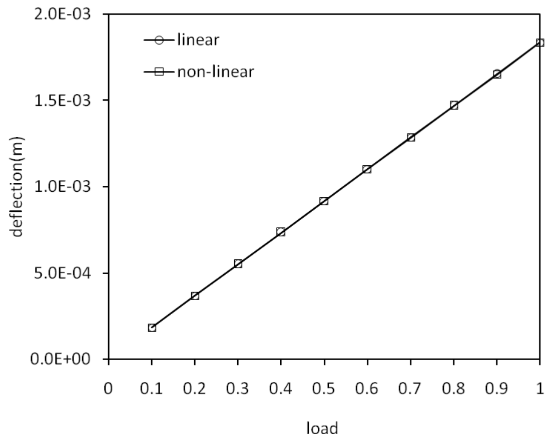



Fig. 2 Variation of deflection with respect to load



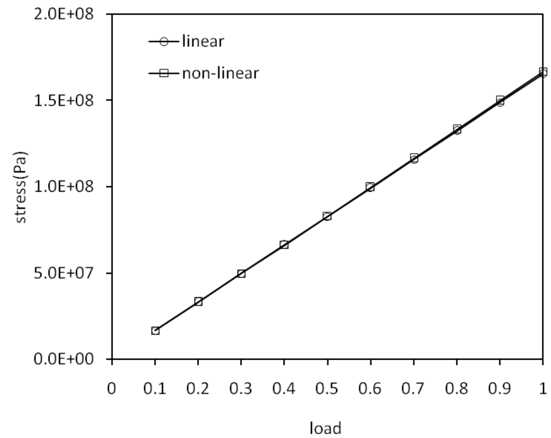
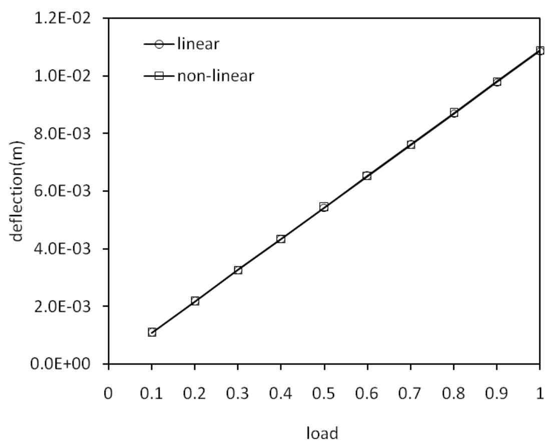




Fig. 2 Variation of deflection with respect to load

Fig. 3 Variation of stress with respect to load

**(For s=10)**



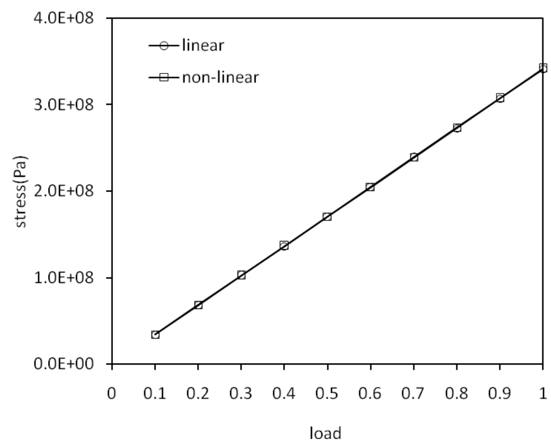
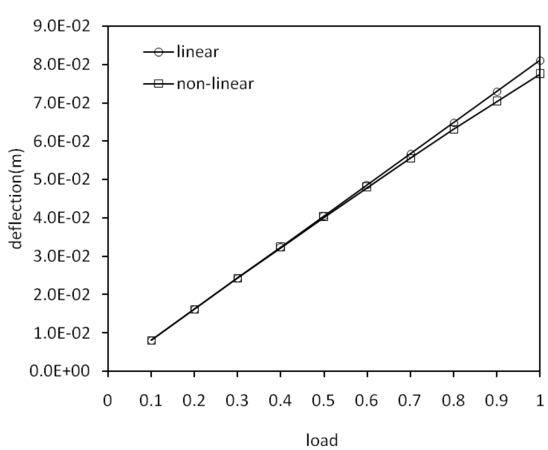




Fig. 3 Variation of deflection with respect to load

Fig .4 Variation of stress with respect to load

**(For s=20)**



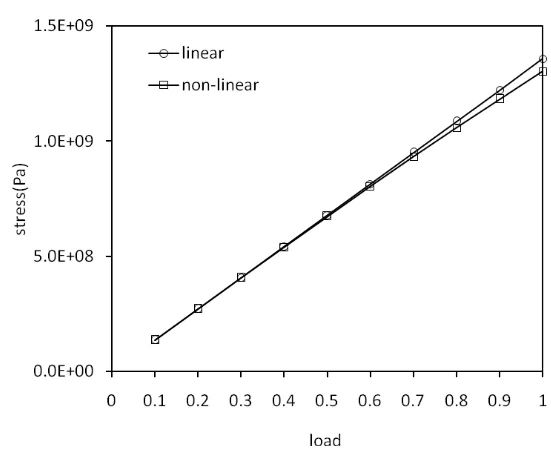




Fig. 5 Variation of deflection with respect to load

Fig. 6 Variation of stress with respect to load

**(For s=40)**

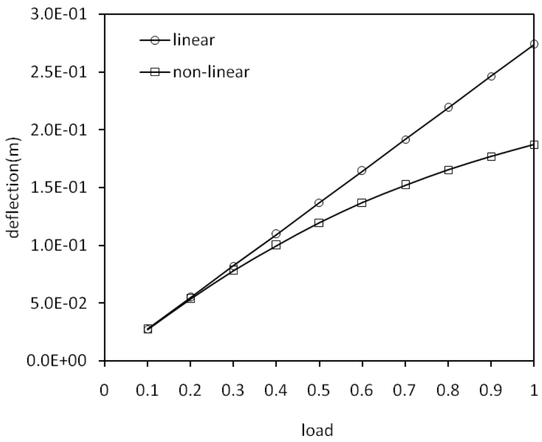



Fig. 7 Variation of deflection with respect to load

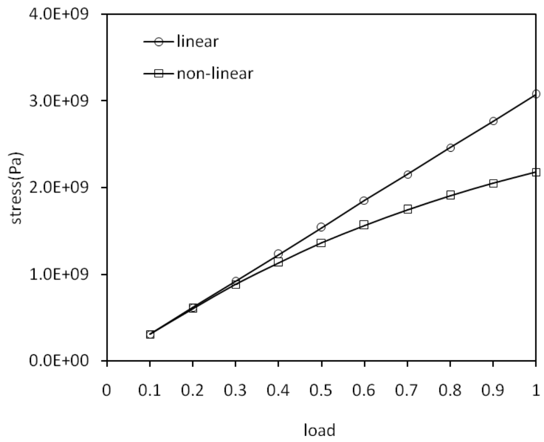



Fig. 8 Variation of stress with respect to load

**(For s=60)**

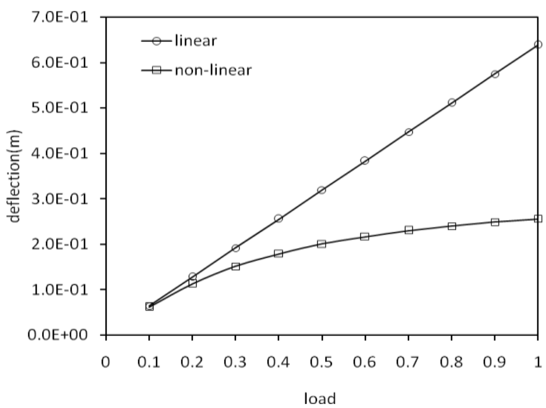



Fig. 9 Variation of deflection with respect to load

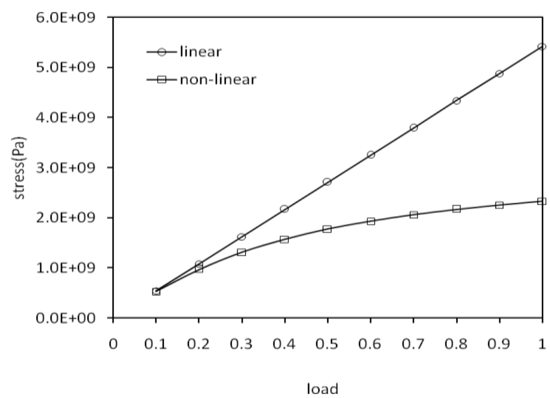



Fig. 10 Variation of stress with respect to load

**(For s=80)**

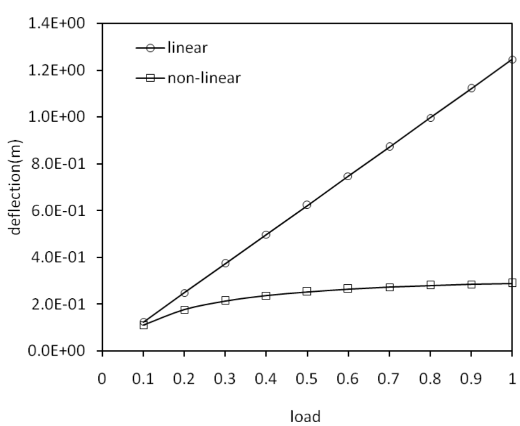



Fig. 11 Variation of deflection with respect to load

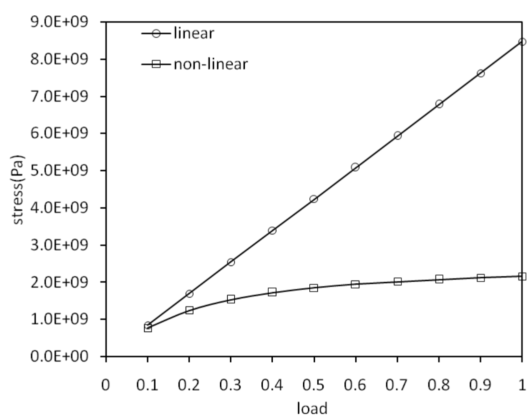



Fig. 12 Variation of stress with respect to load

**(For s=100)**

## Conclusion:

Figs. 2 to 12 show the variation of deflection and bending stress with respect to load. It can be observed that the linear assumption is valid up to S=20 for the imposed load and hence it is recommended to carryout non-linear analysis for better design of the structure when s>20.

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