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Structural and vibration analysis of delaminated composite beams

[1]Narra.Sowjanya, [2]Mulluri.Haritha
[1] PG student, Department of Mechanical Engineering, Qis College of engineering & technology
[2] Guide (Asst.prof), Department of Mechanical Engineering, Qis College of engineering & technology, Ongole

ABSTRACT:

Delamination is a mode of failure for composite materials. Modes of failure are also known as 'failure mechanisms'. In laminated materials, repeated cyclic stresses, impact, and so on can cause layers to separate, forming a mica-like structure of separate layers, with significant loss of mechanical toughness. Some manufacturers of carbon composite bike frames suggest to dispose of the expensive frame after a particularly bad crash, because the impact could develop defects inside the material. Due to increasing use of composite materials in aviation, delamination is increasingly an air safety concern, especially in the tail sections of the airplanes.

In this thesis, the effects of delamination length on the stresses and natural frequency of symmetric composite beams are analyzed using Ansys software. The composite material considered is carbon fiber. Structural and Frequency analysis are done on the composite beam by varying the delamination lengths.

I. INTRODUCTION

- **Introduction to beam**

A beam is a structural element that is capable of withstanding load primarily by resisting bending. The bending force induced into the material of the beam as a result of the external loads, own weight, span and external reactions to these loads is called a bending moment.

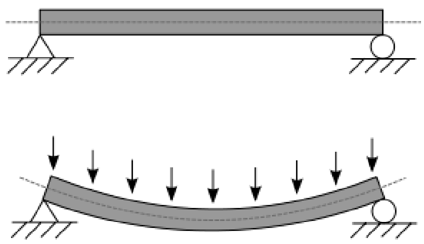


Figure 1. Beam figure

A statically determinate beam, bending (sagging) under an evenly distributed load

- **Overview**

Historically beams were squared timbers but are also metal, stone, or combinations of wood and metal such as a flitch beam. Beams generally carry vertical gravitational forces but can also be used to carry horizontal loads (e.g., loads due to an earthquake or wind or in tension to resist rafter thrust as a tie beam or (usually) compression as a collar beam). The loads carried by a beam are transferred to columns, walls, or girders, which then transfer the force to adjacent structural compression members. In light frame construction joists may rest on beams.

In carpentry a beam is called a plate as in a sill plate or wall plate, beam as in a summer beam or dragon beam.

- **Delamination**

Delamination is a mode of failure for composite materials. Modes of failure are also known as 'failure mechanisms'. In laminated materials, repeated cyclic stresses, impact, and so on can cause layers to separate, forming a mica-like structure of separate layers, with significant loss of mechanical toughness. Delamination also occurs in reinforced concrete structures subject to reinforcement corrosion, in which case the oxidized metal of the reinforcement is greater in volume than the original metal. The oxidized metal therefore requires greater space than the original reinforcing bars, which causes a wedge-like stress on the concrete. This force eventually overcomes the relatively weak tensile strength of concrete, resulting in a separation (or delamination) of the concrete above and below the reinforcing bars.

II. DELAMINATION LENGHTS

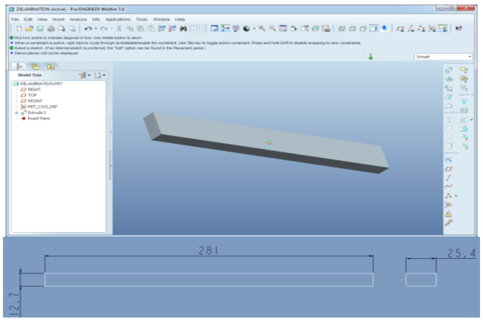
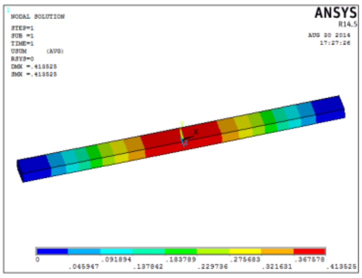
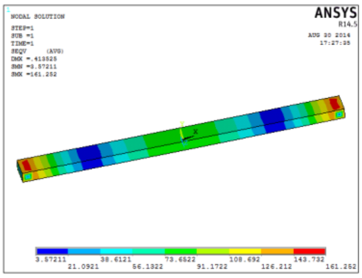


Fig.2 Delamination lengths

1.1 Structural analysis of delaminated beam

2.1.1 Carbon fiber





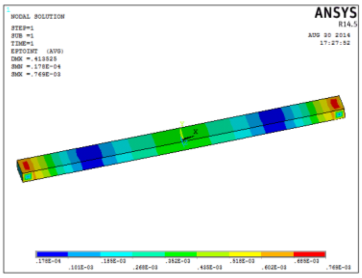
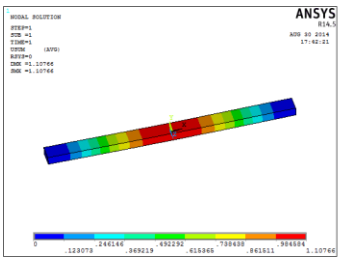
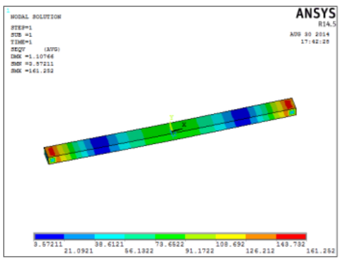


Figure 2.Displacement **Figure 3.Stress** **Figure 4.Strain**

2.1.2 Kevlar





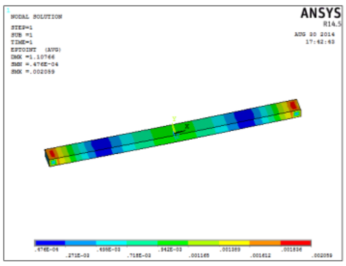
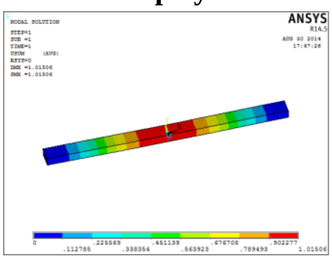
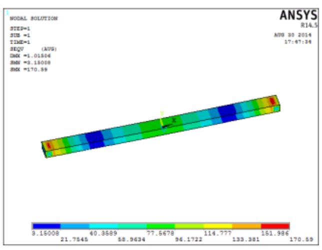


Figure 5.Displacement **Figure 6.Stress** **Figure 7.Strain**

2.1.3 Floura polymer





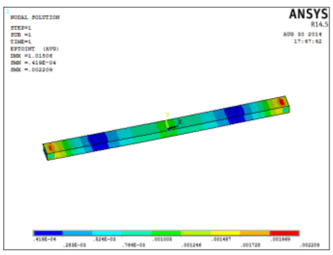


Figure 8.Displacement **Figure 9.Stress** **Figure 10.Strain**

1.2 Structural analysis of changed delaminated beam

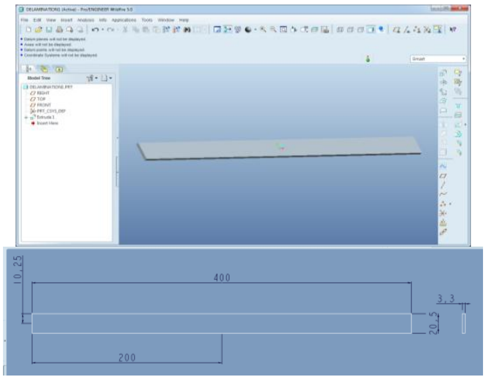


Figure 11. Change delamination lenths

2.2 Structural analysis – solid element

2.2.1 Carbon fiber

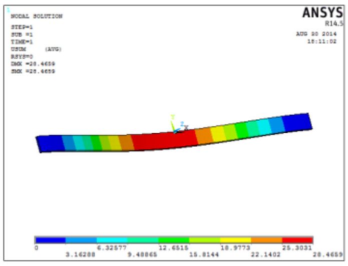


Figure 12.Displacement

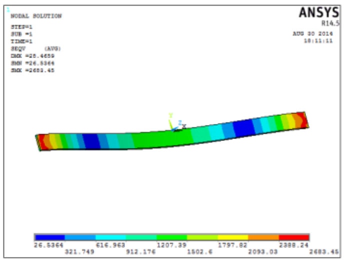


Figure 13.Stress

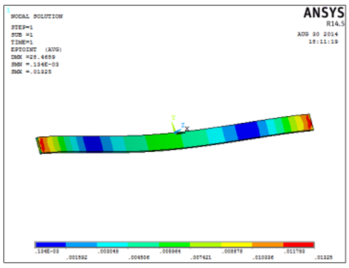


Figure 14.Strain

2.2.2 Kevlar

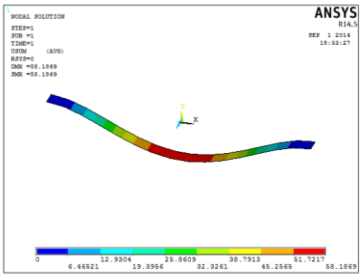


Figure 15.Displacement

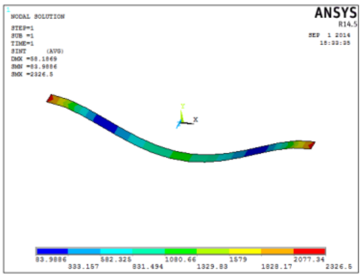


Figure 16.Stress

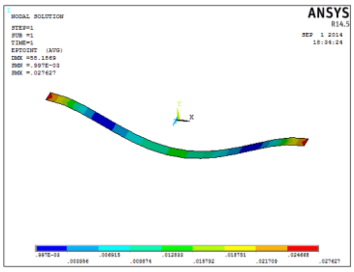


Figure 17.Strain

2.2.3 Floura polymer

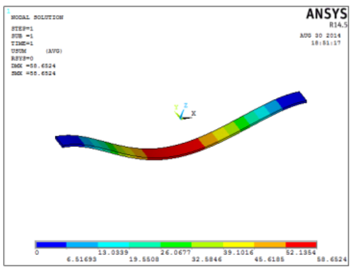


Figure 18.Displacement

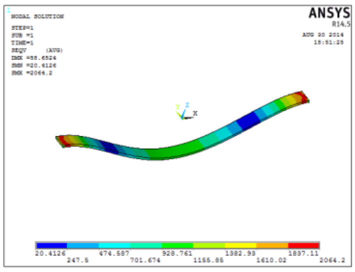


Figure 19.Stress

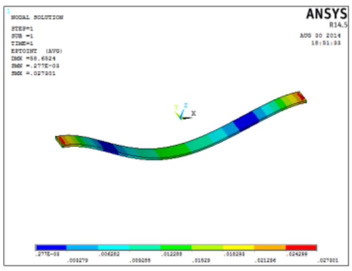


Figure 20.Strain

2.3 Shell element – 5layers

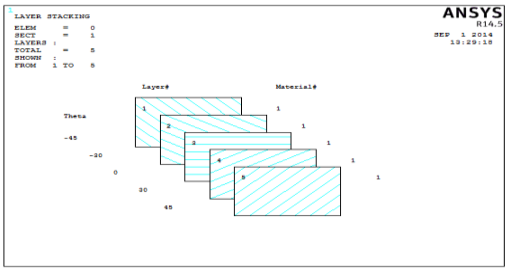


Figure 21. Layer stacking

2.3.1 Carbon fiber

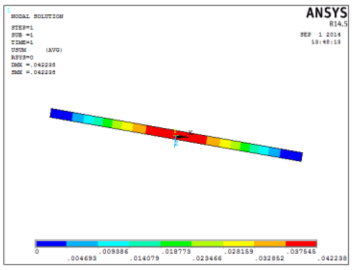


Figure 21.Displacement

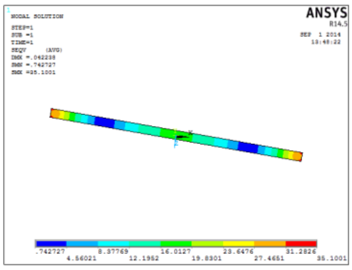


Figure 22.Stress

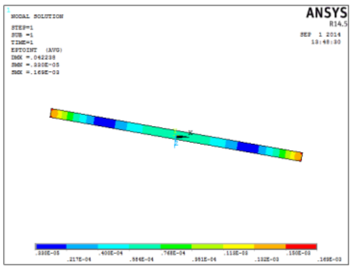


Figure 23.Strain

2.3.2 Kevlar

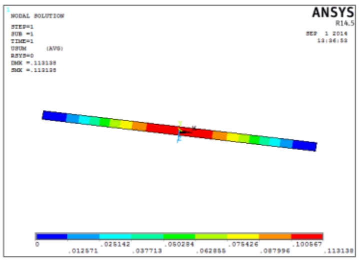


Figure 24.Displacement

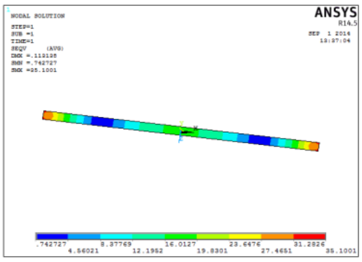


Figure 25.Stress

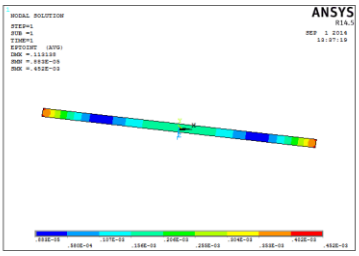


Figure 26.Strain

2.3.3 Floura polymer

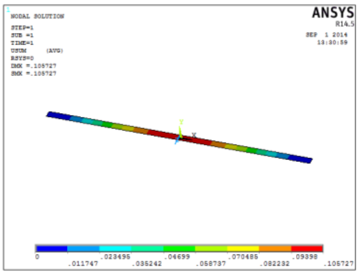


Figure 27.Displacement

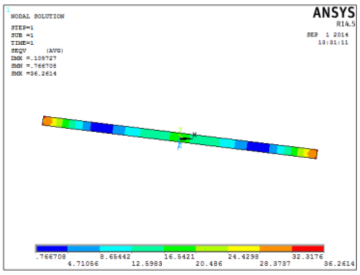


Figure 28.Stress

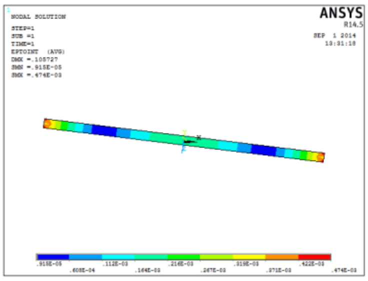


Figure 29.Strain

2.4 Changing lengths

2.4.1 Carbon fiber

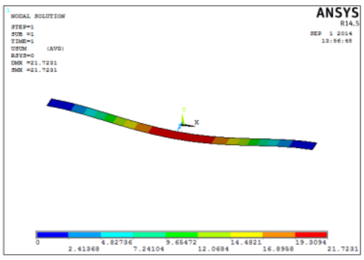


Figure 30.Displacement

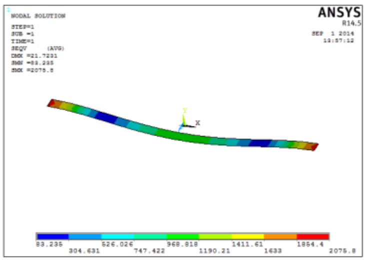


Figure 31.Stress

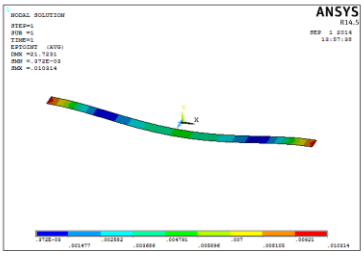


Figure 32.Strain

2.4.2 Kevlar

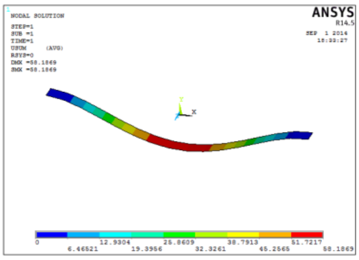


Figure 33.Displacement

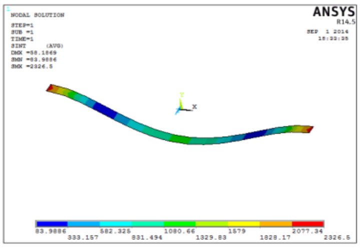


Figure 34.Stress

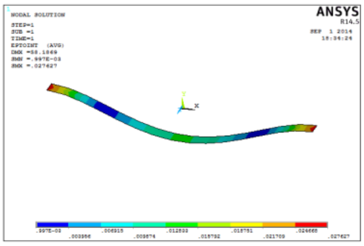


Figure 35.Strain

2.4.3 Floura polymer

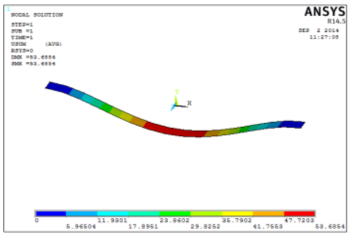


Figure 36.Displacement

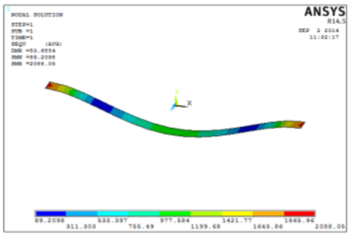


Figure 37.Stress

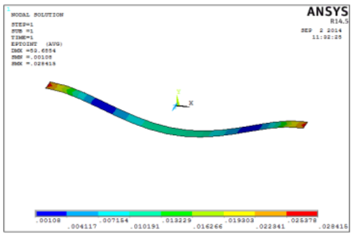


Figure 38.Strain

III. RESULTS TABLE

3.1 Delamination length – 381mm

	Carbon fiber	Kevlar	Floura polymer
Displacement (mm)	0.413526	1.10766	1.01506
Stress (N/mm^2)	161.252	161.252	170.69
Strain	0.769	0.002059	0.0002209

Table 1. Results of Displacement –Stress-Strain

	Carbon fiber	Kevlar	Floura polymer
Displacement (mm)	0.0422	0.113	0.105
Stress (N/mm^2)	35.1001	35.101	36.2614
Strain	0.000169	0.000452	0.000474

Table 2. Results of Shell element

3.2 Delamination length – 400mm

	Carbon fiber	Kevlar	Floura polymer
Displacement (mm)	28.4659	58.1869	58.6524
Stress (N/mm^2)	2683.45	2326.5	2064.2
Strain	0.01329	0.027	0.027301

Table 3. Results of Displacement –Stress-Strain

	Carbon fiber	Kevlar	Floura polymer
Displacement (mm)	21.7231	58.1869	53.6854
Stress (N/mm^2)	2075.8	2326.5	2088.05
Strain	0.01	0.027	0.28418

Table 4. Results of Shell element

IV. CONCLUSION

In this thesis, structural analysis and modal analysis is done to determine the stresses and the natural frequency of simply supported composite beam with single-edge delamination. The analysis is done by taking two delamination lengths.The delamination lengths considered are 381mm and 400mm. The analysis is done for 3 composite materials to determine the effect of delamination using solid element. Finite element analysis is done in AnsysBy observing the structural analysis results, the displacements and stresses are increased by increasing the delamination length. So the composite materials fail when the delamination increases.Modal analysis is done to determine the natural frequencies. By observing the analysis results, the natural frequencies decrease when length of delamination on the beam increase.

Analysis is also done by taking shell element by considering 5 layers. By observing the analysis results, the displacements and stresses are increased by increasing the delamination length.

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