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# Experimental Structural and Dynamic Analysis of Delaminated Fibre Reinforced Polymer Beam

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**Abstract:**

*The phenomenon of Delamination is common in composite beams as the composite beams are having laminate structures. Delamination leads to development of cracks and reduces the strength of the material.*

*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 fractural effect of symmetric Fiber reinforced polymer beams are analyzed using Ansys software. The composite material considered is S-Glass. Structural and modal analysis is done on the FRP beam by varying the delamination length with same thickness.*

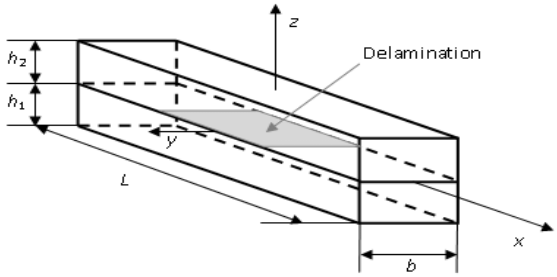


Fig: Delamination

**Introduction to beam**

A beam is an auxiliary component that is fit for withstanding load principally by opposing twisting. The bending power initiated into the material of the beam because of the outside burdens, claim weight, span and external responses to these heaps is known as a Bowing Minute.

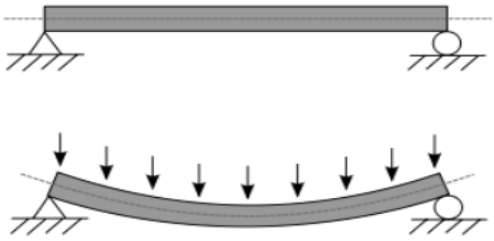

Fig A statically determinate beam, bending (sagging) under an evenly distributed load

**Delamination**

Delamination is a method of disappointment for composite materials. Methods of disappointment are otherwise called 'Failure Mechanisms'. In overlaid

materials, rehashed cyclic anxieties, effect, et cetera can make layers separate, forming a mica-like structure of particular layers, with huge loss of mechanical toughness. Delamination also happens in strengthened solid structures subject to fortification erosion, in which case the oxidized metal of the support is more noteworthy in volume than the first metal. The oxidized metal along these lines requires greater space than the first strengthening bars, which causes a wedge-like weight on the solid. This force eventually overcomes the generally feeble rigidity of cement, bringing about a partition (or delamination) of the solid above and underneath the fortifying bars.

Stuns, effect, loadings or rehashed cyclic burdens can make the overlay isolate at the interface between two layers, framing a mica-like structure of partitioned layers, with huge loss of mechanical sturdiness. This condition is known as delamination. Delamination is extremely basic in composite due to they are made as overlay. Fundamentally, it happens in light of fractional holding, non holding or debonding between the diverse layers of composite. Incomplete holding and non holding are fabricating imperfection while debonding happens in light of sudden effect or rehashed cyclic anxiety. Delamination disappointment might be identified in the material by its sound; strong composite has brilliant sound, while delaminated part sounds dull. Other nondestructive testing strategies are utilized; including installing optical filaments combined with optical time space reflect meter testing of their state, testing with ultrasound, radiographic envisioning, and infrared imaging.

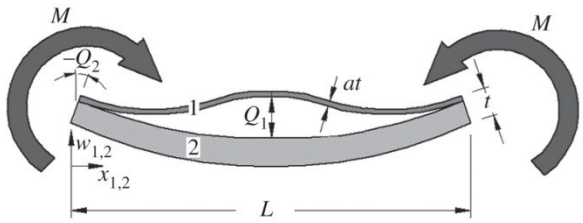


Fig: bending force on delamination beam

**COMPOSITE MATERIALS**

Composite materials have been generally used to enhance the execution of different sorts of structures. Contrasted with traditional materials, the primary points of interest of composites are their better firmness than mass proportion and also high quality to weight proportion. On account of these focal points, composites have been progressively fused in basic segments in different modern fields. A few cases are helicopter rotor cutting edges, airplane wings in aviation design, and extension structures in structural building applications. A portion of the fundamental ideas of composite materials are examined in the accompanying segment to better familiarize ourselves with the conduct of composites.

**Basic Concepts of Composite Materials:**

Composite materials are fundamentally cross breed materials framed of numerous materials so as to use their individual basic focal points in a solitary auxiliary material. The constituents are joined at a plainly visible level and are not dissolvable in each other. The key is the naturally visible examination of a material wherein the segments can be distinguished by the exposed eye. Distinctive materials can be consolidated on a minuscule scale, for example, in alloying of metals, yet the subsequent material is, for every single down to earth reason, visibly homogeneous, i.e. the segments can't be recognized by the bare eye and basically acts together. The upside of composite materials is that, if all around planned, they typically display the best characteristics of their segments or constituents and regularly a few

qualities that neither one of the constituents has. A portion of the properties that can be enhanced by shaping a composite material are quality, weakness life, solidness, temperature-subordinate conduct, consumption protection, warm protection, wear protection, warm conductivity, engaging quality, acoustical protection and weight. Normally, not these properties are enhanced in the meantime nor is there generally any prerequisite to do as such. Indeed, a portion of the properties are in struggle with each other, e.g., warm protection versus warm conductivity. The goal is only to make a material that has just the attributes expected to play out the outlined undertaking. There are two building hinders that constitute the structure of composite materials. One constituent is known as the fortifying stage and the one in which it is implanted is known as the grid. The strengthening stage material might be as strands, particulates, pieces. The framework stage materials are by and large consistent. Cases of composite frameworks incorporate cement fortified with steel, epoxy strengthened with graphite filaments, and so on.

**Fibers:**

Fibers are the primary constituent in a fiber-strengthened composite material. They involve the biggest volume part in a composite cover and offer the real bit of the heap following up on a composite structure. Legitimate choice of the sort, sum and introduction of strands is critical, on the grounds that it impacts the accompanying attributes of a composite overlay.

- Specific gravity
- Tensile strength and modulus
- Compressive strength and modulus
- Fatigue strength and fatigue failure mechanisms
- Electric and thermal conductivities
- Cost

The various types of fibers currently in use are:

- Glass Fibers
- Carbon Fibers
- Aramid Fibers
- Boron Fibers
- Silicon Carbide Fibers

**Matrix:**

In a composite material the filaments are encompassed by a thin layer of network material that holds the strands forever in the coveted introduction and disperses a connected load among every one of the filaments. The grid additionally assumes a solid part in deciding the ecological soundness of the composite article and in addition mechanical factors, for example, sturdiness and shear quality.

The framework ties the strands together, holding them adjusted in the essential focused on bearings. The lattice should likewise seclude the strands from each other with the goal that they can go about as partitioned elements. The network ought to shield the strengthening fibers from mechanical harm (e.g. scraped spot) and from ecological assault. A flexible lattice will give a methods for backing off or ceasing breaks that may have started at broken strands; on the other hand, a fragile network may rely on the filaments to go about as framework split plugs. Through the nature of its "grasp" on the strands (the interfacial bond quality), the lattice can likewise be a vital methods for expanding the sturdiness of the composite.

**Classification of Composites:**

Composite Material:

A material composed of 2 or more constituents is called composite material.

Composites comprise of at least two materials or material stages that are consolidated to create a material that has better properties than those of its individual constituents. The constituents are joined at a perceptible level as well

as not dissolvable in each other. The principle contrast amongst composite and a combination are constituent materials which are insoluble in each other and the individual constituents hold those properties on account of composites, though in compounds, constituent materials are dissolvable in each other and structures another material which has diverse properties from their constituents.

**Advantages of Composites:**

The benefits of composites over the ordinary materials are: High quality to weight proportion, high solidness to weight proportion, high effect protection, better weakness protection, Improved erosion protection, Good warm conductivity, Low Coefficient of warm extension. Accordingly, composite structures may show a superior dimensional security over a wide temperature go, high damping limit.

**Limitations of Composites:**

The impediments of composites are: Mechanical portrayal of a composite structure is more mind boggling than that of a metallic structure, the outline of fiber strengthened structure is troublesome contrasted with a metallic structure, essentially because of the distinction in properties in bearings, the manufacture cost of composites is high, improve and repairing are troublesome, they don't have a high blend of quality and break durability when contrasted with metals and they don't really give higher execution in all properties utilized for material choice.

Composite materials with everything taken into account are arranged in light of the kind of strongholds or the enveloping matrix. There are four regularly recognized sorts of composite materials in light of strongholds

- Fibrous composite materials that involve fibers in a cross section.
- Laminated composite materials that involve layers of various materials.
- Particulate composite materials that are made out of particles in a system.
- Combinations of a couple or most of the underlying three sorts. Also, the significant composite classes based on basic arrangement of the lattice are:
- Polymer-Matrix Composites
- Metal-Matrix Composites
- Ceramic-Matrix Composites
- Carbon-Carbon Composites
- Hybrid Composites

**Applications of Composite Materials:**

The normal utilizations of composites are expanding step by step. These days they are utilized as a part of medicinal applications as well. Some different fields of utilizations are:

- Automotive: Drive shafts, grip plates, fiber Glass/Epoxy leaf springs for substantial trucks and trailers, rocker arm covers, suspension arms and course to steer framework, guards, body boards and entryways.
- Aerospace: Drive shafts, rudders, lifts, course, landing gear entryways, boards and floor materials of planes,
- Payload straight entryways, remote controller arm, high pick up receiving wire, reception apparatus ribs and struts and so forth.
- Marine: Propeller vanes, fans and blowers, adapt cases, valves &strainers, condenser shells.
- Chemical Industries: Composite vessels for fluid flammable gas for elective fuel vehicle, racked bottles for flame benefit, mountain climbing, underground stockpiling tanks, channels and stacks and so on.

- Electrical and Electronics: Structures for overhead transmission lines for railroads, Power line encasings, Lighting posts, Fiber optics ductile individuals and so on.

**CRPF COMPOSITES**

CFRP Composites are lightweight, strong materials used in the manufacturing of numerous products used in our daily life. Carbon Fiber Reinforced Polymer Composites, or CFRP Composites for short, is a term used to depict a fiber strengthened composite material that utilizations carbon fiber as the essential auxiliary segment. It ought to be noticed that the "P" in CFRP can likewise remain for "plastic" rather than "polymer."

All in all, CFRP composites utilize thermosetting gums, for example, epoxy, polyester, or vinyl ester. Albeit thermoplastic pitches are utilized as a part of CFRP Composites, "Carbon Fiber Reinforced Thermoplastic Composites" regularly pass by their own particular acronym, CFRTP composites.

When working with composites or inside the composites business, it is imperative to comprehend the terms and acronyms. All the more vitally, it is important to comprehend the properties of FRP composites and abilities of the different fortifications, for example, carbon fiber.

**Properties:**

Composite materials, strengthened with carbon fiber, are not quite the same as other FRP composites utilizing customary materials, for example, fiberglass or aramid fiber. The properties of CFRP composites which are invaluable incorporate

**Light Weight** - A customary fiberglass strengthened composite utilizing ceaseless glass fiber with a fiber of 70% glass (weight of glass/add up to weight), will usually have a thickness of .065 pounds for every cubic inch. In the interim, a CFRP composite, with the same 70% fiber weight, may ordinarily have a thickness of .055 pounds for every cubic inch

**Stronger** - Are carbon fiber composites lighter weight, as well as CFRP composites are considerably more grounded and stiffer per unit of weight. This is genuine when contrasting carbon fiber composites with glass fiber, however considerably more so when contrasted with metals

For instance, a better than average general guideline when contrasting steel with CFRP composites is that a carbon fiber structure of equivalent quality will frequently measure 1/fifth that of steel. You can envision why all the car organizations are researching utilizing carbon fiber rather than steel.

When contrasting CFRP composites with aluminum, one of the lightest metals utilized, a standard presumption is that an aluminum structure of equivalent quality would likely weigh 1.5 times that of the carbon fiber structure.

Obviously, there are numerous factors that could change this correlation. The review and nature of materials can be unique, and with composites, the assembling procedure, fiber engineering, and the quality should be considered.

**Disadvantages of CFRP composites**

**Cost** - Although amazing materials, there is a motivation behind why carbon fiber isn't utilized as a part of each and every application. Right now, CFRP composites are taken a toll restrictive in many occurrences. Contingent upon the present economic situations (free market activity), the kind of carbon fiber (aviation versus business review), and the fiber tow estimate, the cost of carbon fiber can fluctuate drastically.

Crude carbon fiber on a cost for each pound can be anyplace between 5-times to 25-times more costly than fiberglass.

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**Conductivity** - This can be both leverage to carbon fiber composites, or an impediment relying upon the application. Carbon fiber is greatly conductive, while glass fiber is insulative. Numerous applications utilize glass fiber, and can't utilize carbon fiber or metal, entirely in view of the conductivity.

For instance, in the utility business, numerous items are required to utilize glass filaments. It is additionally one reason why steps utilize glass fiber as the stepping stool rails. In the event that a fiberglass stepping stool were to interact with an electrical cable, the odds of electric shock are much lower. This would not be the situation with a CFRP stepping stool.

Despite the fact that the cost of CFRP composites still stays high, new mechanical progressions in assembling are proceeding to take into consideration more financially savvy items.

Ideally, in our lifetime we will have the capacity to see financially savvy carbon fiber utilized as a part of an extensive variety of buyer, mechanical, and car applications.

**SOLID WORKS**

Solid Works is mechanical outline computerization programming that exploits the commonplace Microsoft Windows graphical UI.

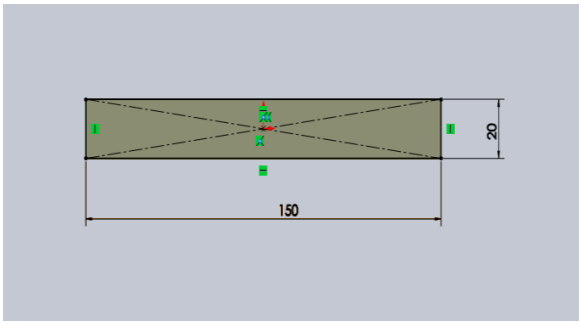
It is a simple to-learn instrument which makes it workable for mechanical creators to rapidly outline thoughts, try different things with highlights and measurements, and deliver models and nitty gritty illustrations.

A Solid Works show comprises of parts, gatherings, and illustrations. Typically, we start with a draw, make a base element, and after that add more highlights to the model. (One can likewise start with a transported in surface or strong geometry).

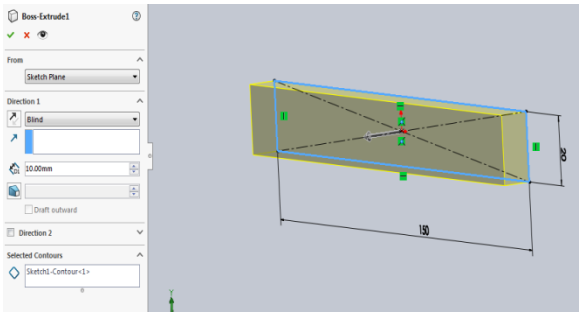
**DESIGN OF DELAMINATED BEAMS:**

**150mm length:**

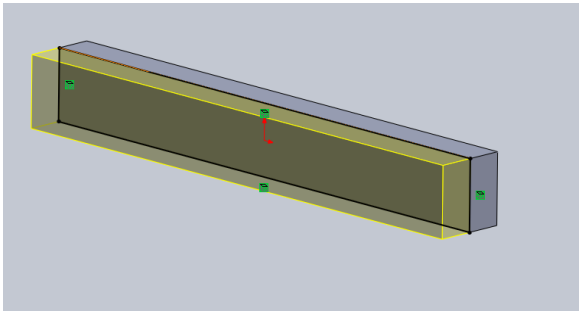
Draw 2d sketch as according following dimensions

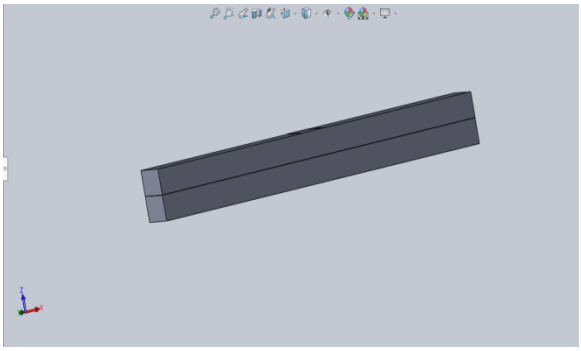



Extrude the sketch according required thickness




With as dimensions and thickness draw one more beam on previous one, without merge result to make a delamination.

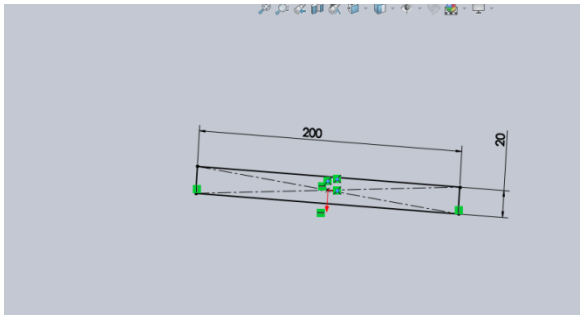




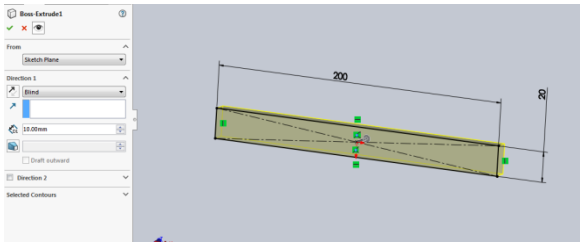
Final view of delaminated beam with 150mm length

**200mm length:**

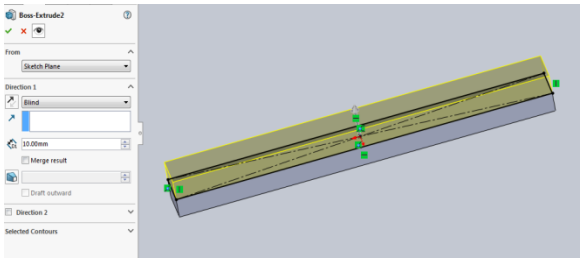
Draw 2d sketch as according following dimensions.

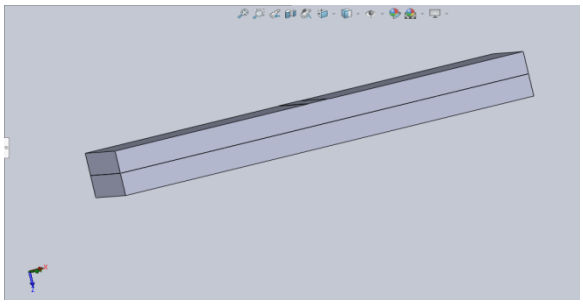



Extrude the sketch according required thickness




With as dimensions and thickness draw one more beam on previous one, without merge result to make a delamination.



Final view of delaminated beam with 200mm length

**Finite Element Analysis**

**Introduction**

Finite Element Analysis (FEA) is a PC based numerical strategy for ascertaining the quality and conduct of designing structures. It can be utilized to figure redirection, stretch, vibration, clasping conduct and numerous other marvels. It additionally can be utilized to dissect either little or substantial scale redirection under stacking or connected removal. It utilizes a numerical procedure called the limited component technique (FEM).

**INTRODUCTION TO SIMULATION**

Simulation is a plan investigation framework. Simulation gives recreation answers for straight and nonlinear static, recurrence, clasping, warm, weakness, weight vessel, drop test, direct and nonlinear dynamic, and streamlining investigations.

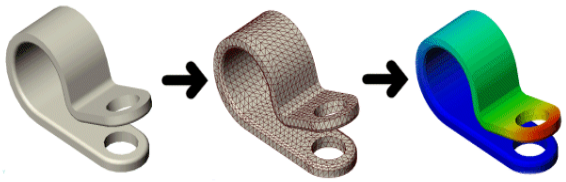


Figure: simulation example

**ANSYS**

ANSYS delivers imaginative, sensational recreation innovation propels in each significant Physics teach, alongside changes in registering pace and improvements to empowering advancements, for example, geometry dealing with, lattice and post-preparing.

These headways alone speak to a noteworthy advance ahead on the way ahead in Simulation Driven Product Development.

**ANALYSIS OF DE LAMINATED BEAM:**

**Static structural**

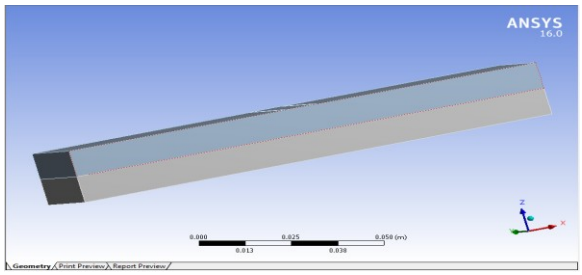
Material properties

Properties of Outline Row 5: S Glass

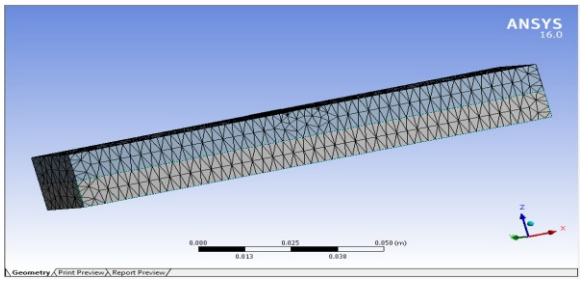
| | A | B | C |
|---|---|---|---|
| 1 | Property | Value | Unit |
| 2 | Density | 2460 | kg m^-3 |
| 3 | Isotropic Elasticity | | |
| 4 | Derive from | Young's Modulus a... | |
| 5 | Young's Modulus | 8.69E+10 | Pa |
| 6 | Poisson's Ratio | 0.22 | |
| 7 | Bulk Modulus | 5.1726E+10 | Pa |
| 8 | Shear Modulus | 3.5615E+10 | Pa |

**150mm length:**

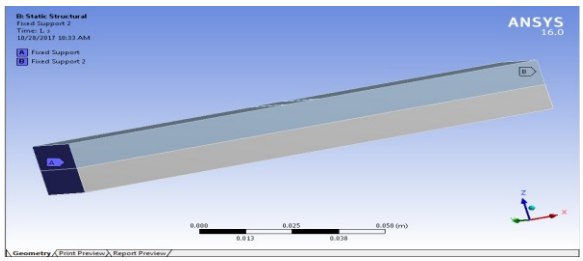
Modal



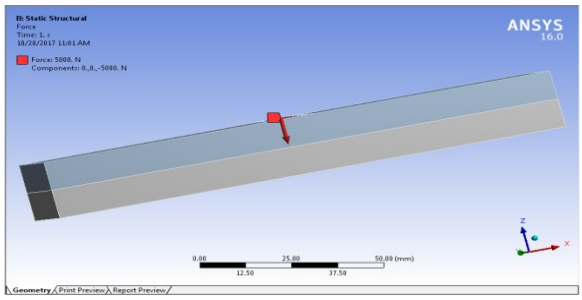

Mesh



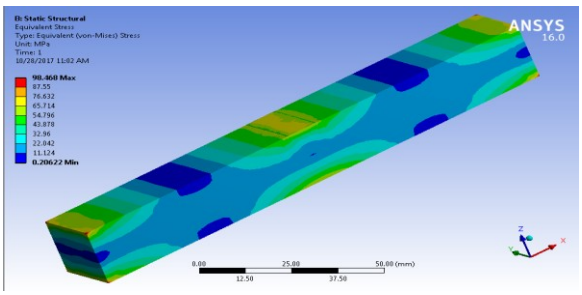

Fixed support



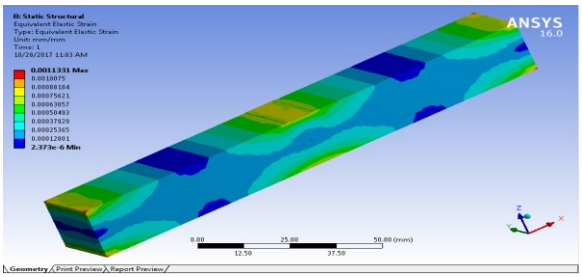

Load



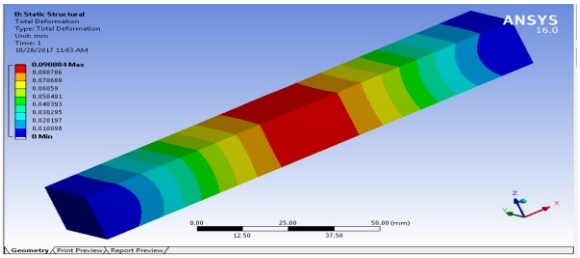

Stress




Strain

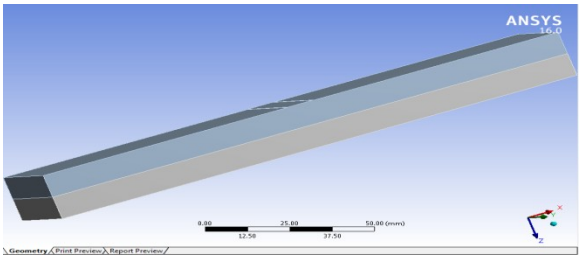



Deformation

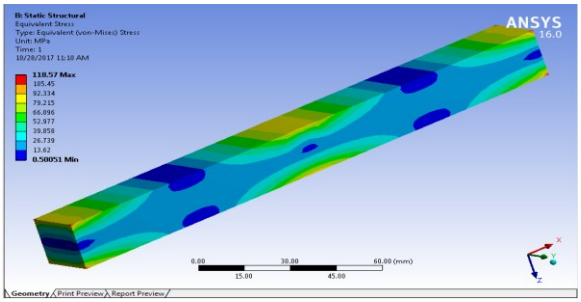



**200mm length:**

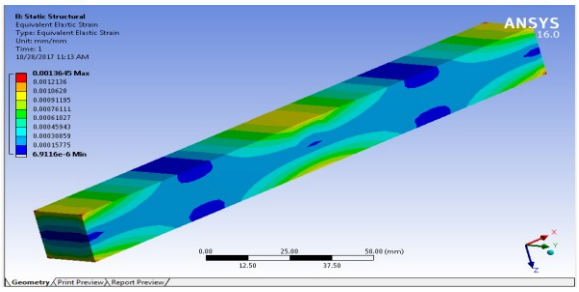
Modal



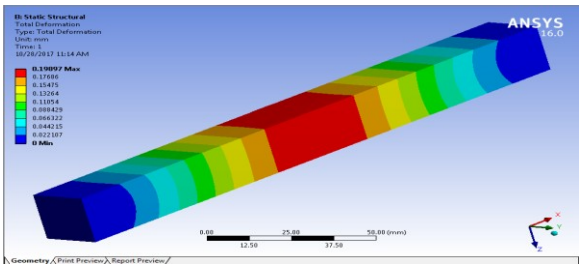

Stress



Strain



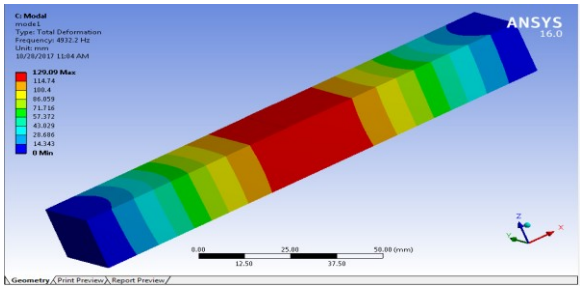

Deformation



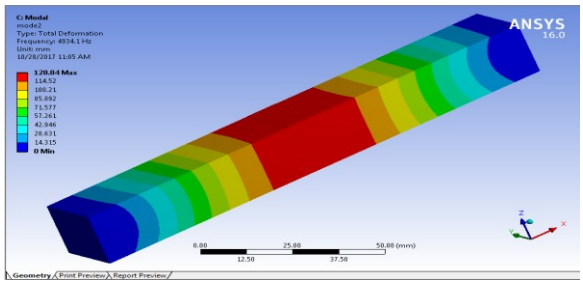

**MODAL ANALYSIS**

**150mm length**

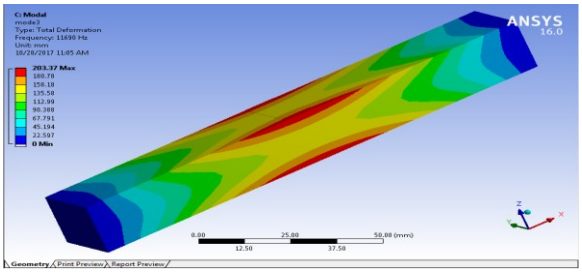
Mode1



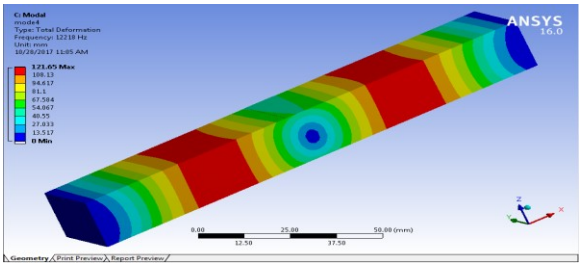

Mode2



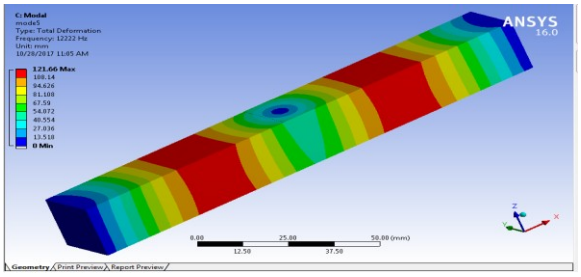

Mode3



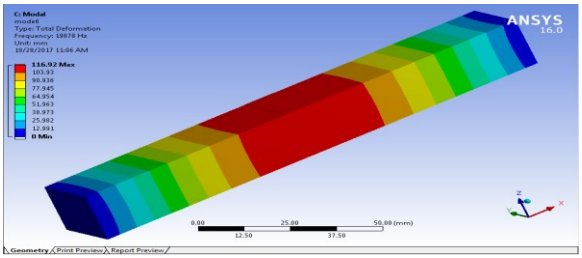

Mode4




Mode5




Mode6




The following bar chart indicates the frequency at each calculated mode.

FIGURE 5
Model (B4, C4) > Modal (C5) > Solution (C6)

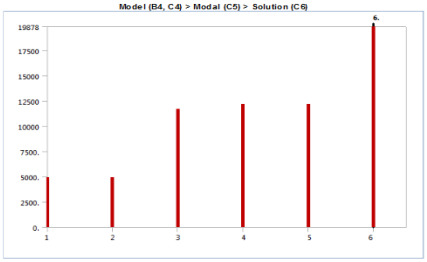
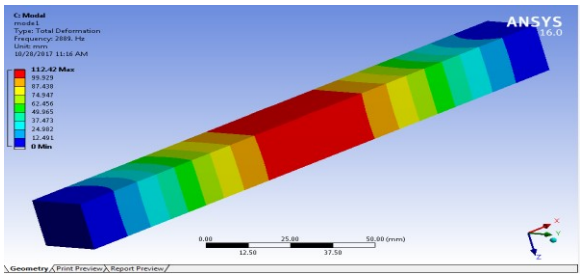



TABLE 23
Model (B4, C4) > Modal (C5) > Solution (C6)

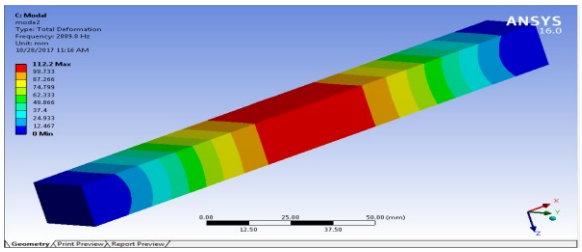
| Mode | Frequency [Hz] |
|---|---|
| 1. | 4932.2 |
| 2. | 4934.1 |
| 3. | 11690 |
| 4. | 12218 |
| 5. | 12222 |
| 6. | 19878 |

**200mm length**

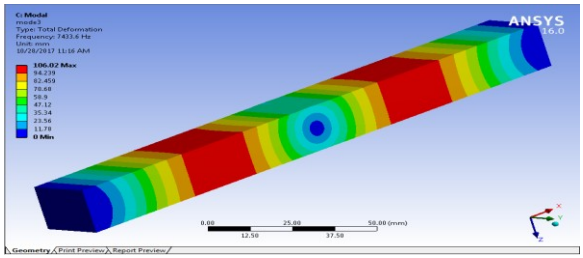
Mode1



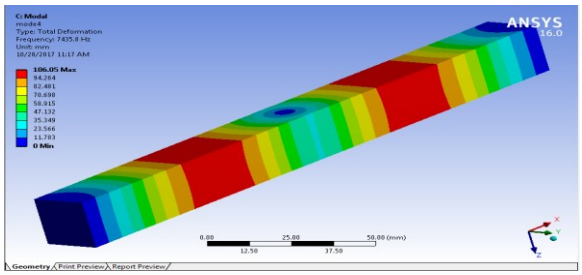
Mode2



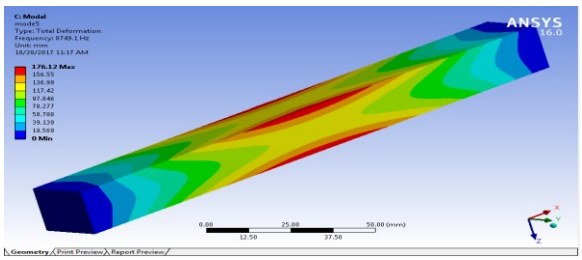
Mode3



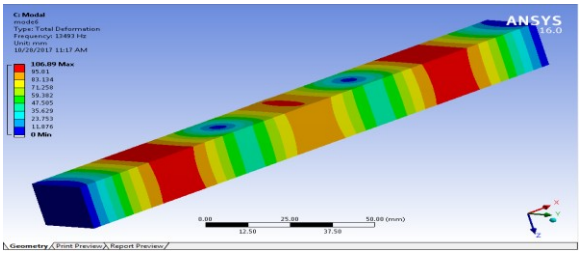
Mode4



Mode5



Mode6



The following bar chart indicates the frequency at each calculated mode.

FIGURE 5
Model (B4, C4) > Modal (C5) > Solution (C6)

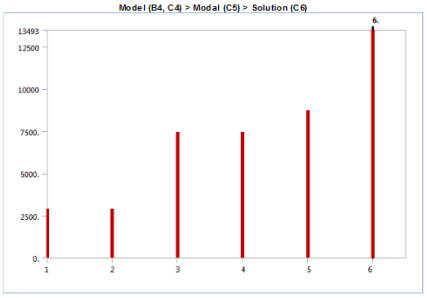



TABLE 23
Model (B4, C4) > Modal (C5) > Solution (C6)

| Mode | Frequency [Hz] |
|---|---|
| 1. | 2889. |
| 2. | 2889.8 |
| 3. | 7433.6 |
| 4. | 7435.8 |
| 5. | 8749.1 |
| 6. | 13493 |

**MATERIAL TESTING:**

Prior to manufacturing, many materials, design, and production decisions are made to ensure product reliability and proper performance. To validate these decisions, a variety of testing methods are employed. The methods are grouped into two major categories:

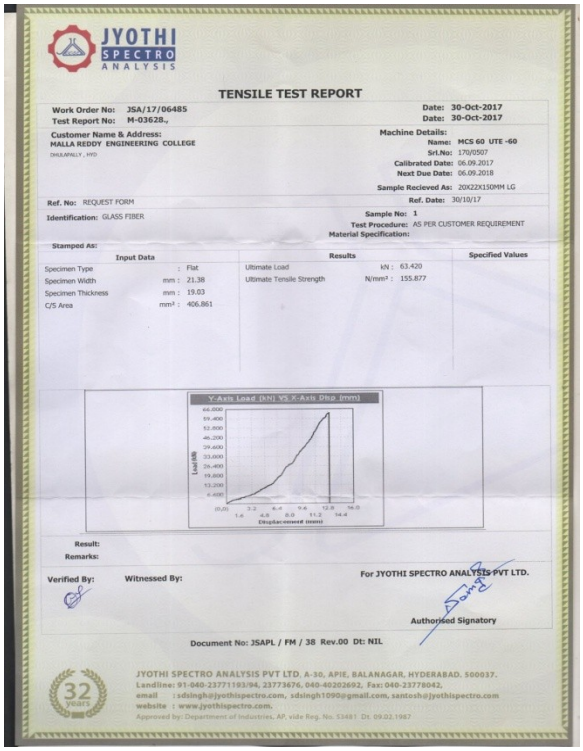
- Mechanical Testing
- Non-Destructive Testing (NDT)

**Mechanical testing**

Mechanical testing uncovers the properties of a material when drive is connected powerfully or statically. A mechanical test indicates whether a material or part is appropriate for its expected application by measuring properties, for example, flexibility, elasticity, prolongation, hardness, break strength, affect protection, stretch crack and as far as possible.

**MECHANICAL TESTING RESULTS:**

**For 150mm**



JYOTHI SPECTRO ANALYSIS

TENSILE TEST REPORT

Work Order No: JSA/17/06485 Date: 30-Oct-2017
Test Report No: M-03628 Date: 30-Oct-2017
Customer Name & Address: MALLA REDDY ENGINEERING COLLEGE DHULAPALLY , HYD
Machine Details: Name: MCS 60 UTE -60 Srl.No: 170/0507 Calibrated Date: 06.09.2017 Next Due Date: 06.09.2018
Sample Recieved As: 20X22X150MM LG
Ref. No: REQUEST FORM Ref. Date: 30/10/17
Identification: GLASS FIBER Sample No: 1 Test Procedure: AS PER CUSTOMER REQUIREMENT Material Specification:
Stamped As:

| Input Data | | | Results | | Specified Values |
|---|---|---|---|---|---|
| Specimen Type | : Flat | | Ultimate Load | kN : 63.420 | |
| Specimen Width | mm : 21.38 | | Ultimate Tensile Strength | N/mm² : 155.877 | |
| Specimen Thickness | mm : 19.03 | | | | |
| C/S Area | mm² : 406.861 | | | | |

Y-Axis Load (kN) VS X-Axis Disp (mm)

Result:
Remarks:

Verified By: Witnessed By: For JYOTHI SPECTRO ANALYSIS PVT LTD.

Authorised Signatory

Document No: JSAPL / FM / 38 Rev.00 Dt: NIL

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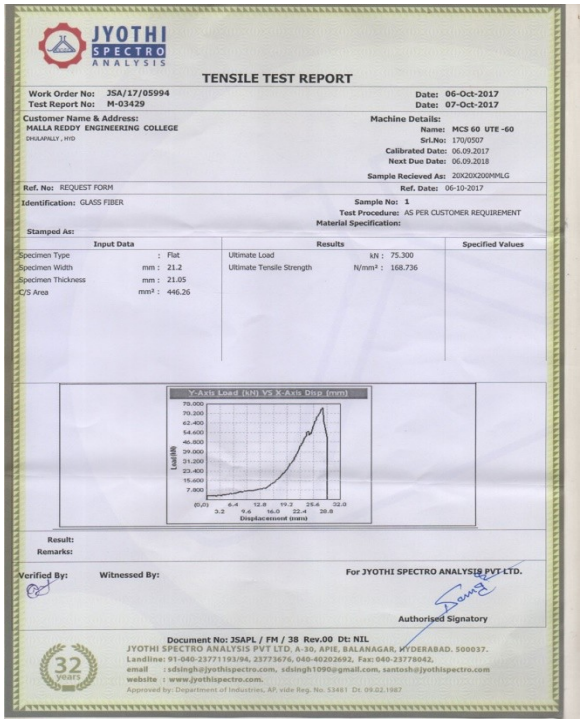
Approved by: Department of Industries, AP. vide Reg. No. 53481 Dt. 09.02.1987

**For 200mm**



JYOTHI SPECTRO ANALYSIS

TENSILE TEST REPORT

Work Order No: JSA/17/05994 Date: 06-Oct-2017
Test Report No: M-03429 Date: 07-Oct-2017
Customer Name & Address: MALLA REDDY ENGINEERING COLLEGE DHULAPALLY , HYD
Machine Details: Name: MCS 60 UTE -60 Srl.No: 170/0507 Calibrated Date: 06.09.2017 Next Due Date: 06.09.2018
Sample Recieved As: 20X20X200MMLG
Ref. No: REQUEST FORM Ref. Date: 06-10-2017
Identification: GLASS FIBER Sample No: 1 Test Procedure: AS PER CUSTOMER REQUIREMENT Material Specification:
Stamped As:

| Input Data | | | Results | | Specified Values |
|---|---|---|---|---|---|
| Specimen Type | : Flat | | Ultimate Load | kN : 75.300 | |
| Specimen Width | mm : 21.2 | | Ultimate Tensile Strength | N/mm² : 168.736 | |
| Specimen Thickness | mm : 21.05 | | | | |
| C/S Area | mm² : 446.26 | | | | |

Y-Axis Load (kN) VS X-Axis Disp (mm)

Result:
Remarks:

Verified By: Witnessed By: For JYOTHI SPECTRO ANALYSIS PVT LTD.

Authorised Signatory

Document No: JSAPL / FM / 38 Rev.00 Dt: NIL
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Approved by: Department of Industries, AP. vide Reg. No. 53481 Dt. 09.02.1987

**Analysis Results table**

**Table: Static structural analysis result**

| length of beam | Stress(Mpa) | Strain | Deformation(mm) |
|---|---|---|---|
| 150mm | 98.468 | 0.0011331 | 0.090884 |
| 200mm | 118.57 | 0.0013645 | 0.19897 |

**Table: Modal analysis result**

| Mode | Frequency(Hz) | Deformation(mm) |
|---|---|---|
| 1 | 4932.2 | 129.09 |
| 2 | 4934.1 | 128.84 |
| 3 | 11690 | 203.37 |
| 4 | 12218 | 121.65 |
| 5 | 12222 | 121.66 |
| 6 | 19878 | 116.92 |

**Conclusion:**

- Brief study about the beams, delaminated beam, composite materials done in this project.
- Mechanical Testing, design and analysis of delaminated beam is done.
- Two beams of different lengths 150mm and 200 mm of same thickness made of S-Glass prepared material machined.
- Beams are tested mechanically in universal testing machines and reports are generated.
- By using solid works software two beam of same dimension which are tested mechanically, modeled in CAD software by using different commands and features.
- Two models generated by solid works are converted to IGES file and transferred to ANSYS workbench for analysis.
- Static analysis is performed on 150mm and 200mm beam by selecting the material as S-Glass, stress, strain and deformation are noted as result and tabulated.
- According to result table, 200mm length beam showing better strength as compare to 150mm length beam because of more mass and area.

- Both the beam stress values are less than yield stress value of beam which are mechanically tested, hence design is safe.
- Modal analysis also performed on beams to study its dynamic behavior.
- Deformation based upon respective frequency, for different mode shapes are noted tabulated.

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