Bharath

INSTITUTE OF HIGHER EDUCATION AND RESEARCH

Declared as **Deemed-to-be-University** u/s 3 of the UGC Act, 1956

B.Tech- Aerospace Engineering

U20ASCJ02 -Fundamentals of Aerospace Structures

Lab Manual

Vision of the institute

“Bharath Institute of Higher Education & Research (BIHER) envisions and constantly strives to provide an excellent academic and research ambience for students and members of the faculties to inherit professional competence along with human dignity and transformation of community to keep pace with the global challenges so as to achieve holistic development.”

Mission of the institute

- To develop as a Premier University for Teaching, Learning, Research and Innovation on par with leading global universities.
- To impart education and training to students for creating a better society with ethics and morals.
- To foster an interdisciplinary approach in education, research and innovation by supporting lifelong professional development, enriching knowledge banks through scientific research, promoting best practices and innovation, industry driven and institute oriented cooperation, globalization and international initiatives.
- To develop as a multi-dimensional institution contributing immensely to the cause of societal advancement through spread of literacy, an ambience that provides the best of international exposures, provide health care, enrich rural development and most importantly impart value based education.
- To establish benchmark standards in professional practice in the fields of innovative and emerging areas in engineering, management, medicine, dentistry, nursing, physiotherapy and allied sciences.
- To imbibe human dignity and values through personality development and social service activities.

B.Tech- Aerospace Engineering

Vision of the Department

Department of Aeronautical Engineering will endeavor to accomplish worldwide recognition with a focal point of Excellence in the field of Aeronautics by providing quality Education through world class facilities, enabling graduates turning out to be Professional Experts with specific knowledge in Aeronautical & Aerospace engineering.

Mission of the Department

- To be the state of art Teaching and Learning center with excellent infrastructure and empowered Faculties in Aeronautical & Aerospace Engineering.
- To foster a culture of innovation among students in the field of Aeronautics and Aerospace with updated professional skills to enhance research potential for sponsored research and innovative projects.
- To Nurture young individuals to be knowledgeable, skillful, and ethical professionals in their pursuit of Aeronautical & Aerospace Engineering.

B.Tech- Aerospace Engineering

Program Educational Objectives Statements (PEO)

PEO 1: Demonstrate a solid grasp of fundamental concepts in Mathematics, Science, and Engineering, essential for effectively addressing engineering challenges within the Aerospace industry.

PEO 2: Involve in process of designing, simulating, fabricating, testing, and evaluating in the field of Aerospace.

PEO 3: Obtain advanced skills to actively engage in research and development endeavors within emerging domains, while also pursuing further education opportunities.

PEO 4: Demonstrate efficient performance both as independent contributors and as valuable team members in diverse multidisciplinary projects.

PEO 5: Embrace lifelong learning and career advancement while adapting to the evolving social demands and needs.

B.Tech- Aerospace Engineering

Programme Outcomes (PO's)

PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and Engg. Specialization to the solution of complex engineering problems.

PO2: Problem analysis: Identify, formulate, research literature, and analyze engineering problems to arrive at substantiated conclusions using first principles of mathematics, natural, and engineering sciences.

PO3: Design/development of solutions: Design solutions for complex engineering problems and design system components, processes to meet the specifications with consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: Use research-based knowledge including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and teamwork: Function effectively as an individual, and as a member or leader in teams, and in multidisciplinary settings.

PO10: Communication: Communicate effectively with the engineering community and with society at large. Be able to comprehend and write effective reports documentation. Make effective presentations and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team. Manage projects in multidisciplinary environments.

PO12: Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

B.Tech- Aerospace Engineering

Program Specific Outcomes (PSO) - R2018

PSO1: Create, Select, and Apply aerospace modelling, analysis, and design, as well as team working skills in the design and integration of Spacecraft systems.
PSO2: Apply principles of aerodynamics, space propulsion, aerospace structures and control systems to design and analyze aircraft and spacecraft with desired performance characteristics.

Program Specific Outcomes (PSO) - R2020

PSO1: Design and analyze aerospace components/systems for aerospace industries.

PSO2: Acquire the concepts of spacecraft attitude dynamics for the prediction of spacecraft motion.

Course Outcomes (COs)

CO1	**Explain** the structural components of airplane and spacecraft (**Understand**)
CO2	**Compute** the stress developed in statically determinate and indeterminate structures subjected to axial load. (**Apply**)
CO3	**Determine** power transmission and shear stress in circular shaft, and axial deformation of helical springs. (**Apply**)
CO4	**Compute** the buckling load and crippling stress of columns with different end conditions. (**Apply**)
CO5	**Determine** the principal stress induced in structural components using analytical and graphical methods. (**Apply**)
CO6	**Estimate** the bending stresses, shear stress and deflection in beams. (**Analyze**)
CO7	**Carry out** elementary mechanical coupon testing of materials as per the given procedure. (**Imitation**)
CO8	**Acquire** data using the available measuring devices. (**Manipulation**)
CO9	**Perform** basic mathematical calculation using the appropriate formulae and represent the results in form of graph and table (**Precision**)

Mapping/Alignment of COs with PO & PSO

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	H	M								H		H	H	
CO2	H	M										H	H	
CO3	H	M										H	H	
CO4	H	M										H	H	
CO5	H	M										H	H	
CO6	H	M								H		H	H	
CO7	H	M						H	H	H		H	H	
CO8	H	M						H	H	H		H	H	
CO9	H	M						H	H	H		H	H	

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low)

LIST OF EXPERIMENTS:

S.No	NAME OF EXPERIMENT	COURSE OUTCOME
1.	Uniaxial tensile testing of Aluminium specimens to determine the basic material properties.	CO6,CO7,CO8
2.	Uniaxial tensile testing of mild steel specimens to determine the basic material properties.	CO6,CO7,CO8
3.	Torsion testing of circular bar.	CO6,CO7,CO8
4.	Determination of spring constant of helical spring.	CO6,CO7,CO8
5.	Buckling of columns.	CO6,CO7,CO8
6.	Constant strength beam test.	CO6,CO7,CO8
7.	Plotting of bending stress distribution.	CO6,CO7,CO8
8.	Three-point beam bending experiment.	CO6,CO7,CO8

EXP NO: 1 DATE:	**UNIAXIAL TENSILE TESTING OF ALUMINIUM SPECIMENS TO DETERMINE THE BASIC MATERIAL PROPERTIES**

AIM

To conduct a tensile test on Aluminum rod and determine the following quantities.

1. Limit of proportionality

2. Elastic limit

3. Yield strength

4. Ultimate strength

APPARATUS REQUIRED

Following apparatus are required to conduct the above tensile test.

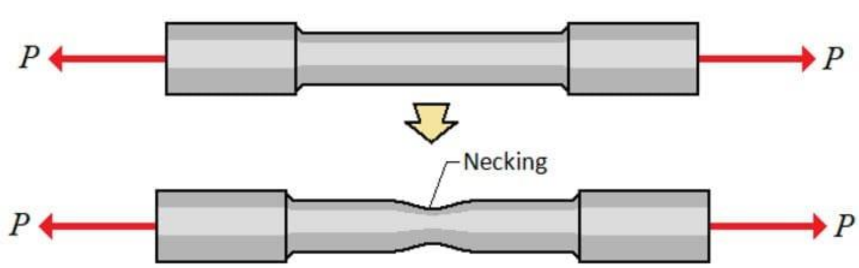
1. Universal Testing Machine (UTM)

2. Aluminum specimens

3. Steel Rule and Vernier Caliper

SIGNIFICANCE OF THE EXPERIMENT

In the tensile test of Aluminum, properties like limit of proportionality, Elastic limit, Yield strength and ultimate strength are being estimated. These properties are frequently used in the design and analysis of structural components.



FORMULA USED

$$Stress = \frac{Load}{Area} \left(\frac{N}{mm^2}\right)$$

$$Strain = \frac{Change\ in\ Length\ (\Delta l)}{Orginal\ Length\ (l)}$$

$$Youngs\ modulus = \frac{Stress}{Strain} \left(\frac{N}{mm^2}\right)$$

PROCEDURE

A student should follow the given procedure step by step

1. Measure the original length and diameter of the specimen. Please ensure the specimen is free from defects.
2. Mark the gauge section on the specimen measure the gauge length.
3. Switch on the UTM, its controller PC and start interface software.
4. Enter the specimen dimension and test specifications into the GUI of the software.
5. Review UTM protection/trip values such as load limit and displacement limits.
6. Insert the specimen into grips and lock it. Move the cross-head if required.
7. Zero/Tare the load cell reading and record the grip to grip displacement.
8. Verify the displacement rate of cross-head.
9. Issue command to start the test.
10. UTM will start loading the specimen and simultaneously record load and displacement with time.
11. UTM will continue to load the specimen till its failure.
12. After failure, remove the failed specimen from the jaw and measure its final length and diameter within the gauge length.

OBSERVATION

Parameter	Gauge length	Diameter	Area (calculated)
Original dimension			
Final dimension			

CALCULATION

RESULT

Parameter	Limit of proportionality	Elastic limit	Yield strength	Ultimate Strength
Values				

EXP NO: 2 **DATE:**	**UNIAXIAL TENSILE TESTING OF MILD STEEL SPECIMENS TO DETERMINE THE BASIC MATERIAL PROPERTIES**

AIM

To conduct a tensile test on Mild Steel and determine the following quantities.

1. Limit of proportionality

2. Elastic limit

3. Yield strength

4. Ultimate strength

APPARATUS REQUIRED

Following apparatus are required to conduct the above tensile test.

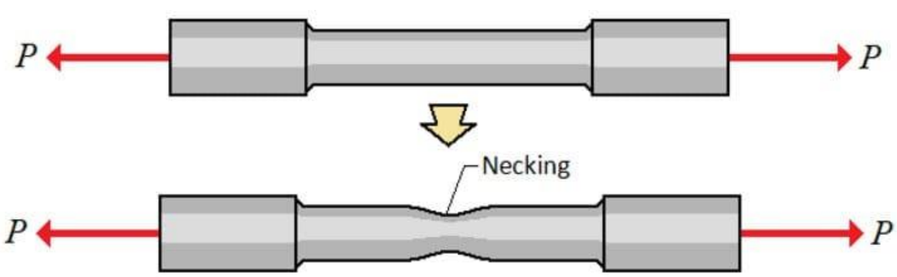
1. Universal Testing Machine (UTM)

2. Mild Steel specimens

3. Steel Rule and Vernier Caliper

SIGNIFICANCE OF THE EXPERIMENT

In the tensile test of Mild Steel, properties like limit of proportionality, Elastic limit, Yield strength and ultimate strength are being estimated. These properties are frequently used in the design and analysis of structural components.



FORMULA USED

$$Stress = \frac{Load}{Area}\ (\frac{N}{mm^2})$$

$$Strain = \frac{Change\ in\ Length\ (\Delta l)}{Orginal\ Length\ (l)}$$

$$Youngs\ modulus = \frac{Stress}{Strain}\left(\frac{N}{mm^2}\right)$$

PROCEDURE

A student should follow the given procedure step by step

1. Measure the original length and diameter of the specimen. Please ensure the specimen is free from defects.
2. Mark the gauge section on the specimen measure the gauge length.
3. Switch on the UTM, its controller PC and start interface software.
4. Enter the specimen dimension and test specifications into the GUI of the software.
5. Review UTM protection/trip values such as load limit and displacement limits.
6. Insert the specimen into grips and lock it. Move the cross-head if required.
7. Zero/Tare the load cell reading and record the grip to grip displacement.
8. Verify the displacement rate of cross-head.
9. Issue command to start the test.
10. UTM will start loading the specimen and simultaneously record load and displacement with time.
11. UTM will continue to load the specimen till its failure.
12. After failure, remove the failed specimen from the jaw and measure its final length and diameter within the gauge length.

OBSERVATION

Parameter	Gauge length	Diameter	Area (calculated)
Original dimension			
Final dimension			

CALCULATION

RESULT

Parameter	Limit of proportionality	Elastic limit	Yield strength	Ultimate Strength
Values				

EXP NO: 3 **DATE:**	**TORSION TESTING OF CIRCULAR BAR**

AIM

To conduct torsion test on a circular bar and to determine its modulus of rigidity.

APPARATUS REQUIRED

- Torsion Testing Machines with necessary measuring devices
- Mild Steel Specimen
- Steel Rule & Vernier Caliper

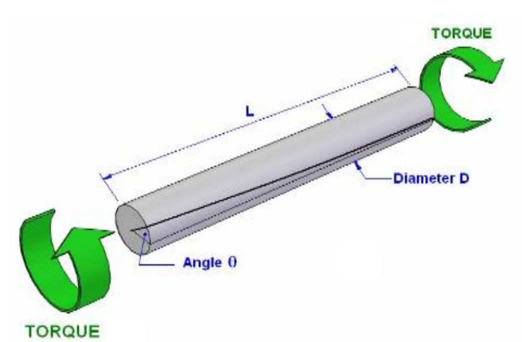
PRACTICAL USES

An aircraft's wing is subjected to bending as well as torsion loads due the aerodynamic loads acting on the wing. These loads will induce shear stresses that have a tendency to rip the wing off. Hence, during design of an airplane's wing we need to analyze the effect of torsion and also, the value of modulus of rigidity is also important in design.

FORMULA USED

$$Torsion\ Equation,\qquad \frac{T}{J} = \frac{G\theta}{L} = \frac{\tau}{R}$$

T	-	Applied Torque (Nm)
R	-	Radius of the specimen (m)
L	-	Length of the Specimen (m)
G	-	Modulus of Rigidity (N/m^2)
J	-	Polar Moment of Inertia (m^4) = $\pi d^4/32$
τ	-	Shear Stress (N/m^2)
θ	-	Angle of Twist (rad)



PROCEDURE

- Measure the diameter and length of the mild steel specimen
- Fix the mild steel rod into the torsion testing machine
- Reset the indicators to zero
- Apply torque in steps by operating the lever that moves the pendulum connected to the shaft and note down the corresponding angle of twist values
- Plot a graph of T against θ

OBSERVATION

d	-	Specimen Diameter (mm)	=
L	-	Length of the Specimen (mm)	=

TABULATION

Sl. No.	Applied Torque (in divisions)	Applied Torque (Nm)	Angle of Twist				Modulus of Rigidity (N/m^2)
			θ_A (deg)	θ_B (deg)	$\lvert \theta_A - \theta_B \rvert$ (deg)	$\lvert \theta_A - \theta_B \rvert$ (rad)	

CALCULATION

RESULTS

The modulus of rigidity of circular rod material is found.

EXP NO: 4 DATE:	**DETERMINE SPRING CONSTANT OF HELICAL SPRING**

AIM

To determine the stiffness of spring and the modulus of rigidity of the spring wire for an open coil helical spring

APPARATUS REQUIRED

- Spring Test Setup
- Open Coil Helical Spring
- Dial Gauge
- Steel Rule & Vernier Caliper
- Weights

PRACTICAL USES

An open coil helical spring is used to take up compression loads and store the energy in the form of strain energy. Open coil springs play a very important role in aircraft landing gears and other automobile suspension units. Hence, knowledge of their design is essential.

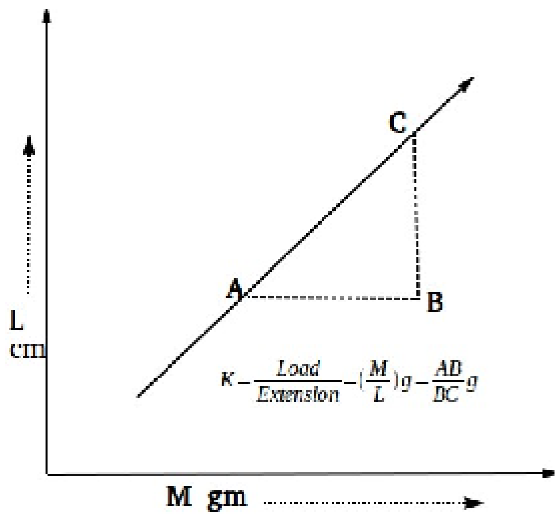
FORMULAE USED

$$Deflection, \delta = 2WR^3 n\pi sec\alpha \left[\frac{cos^2\alpha}{GJ} + \frac{sin^2\alpha}{EI}\right]$$

$$tan\alpha = \frac{(L-d)}{2\pi Rn}$$

$$Stiffness\ of\ spring, k = \frac{W}{\delta}$$

W	-	Applied Load (N)
R	-	Mean Coil Radius (mm) = (D –d)/2
D	-	Spring Coil Diameter (mm)
d	-	Spring Wire Diameter (mm)
n	-	No. of Coils
L	-	Length of the Spring (mm)
α	-	Helix angle (rad)
G	-	Modulus of Rigidity (N/mm^2)
E	-	Young's Modulus (N/mm^2)
I	-	Moment of Inertia (mm^4) = $\pi d^4/64$
J	-	Polar Moment of Inertia (mm^4) = $\pi d^4/32$
δ	-	Deflection of Spring (mm)
k	-	Stiffness of the Spring (N/mm)



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PROCEDURE

- Measure the diameter of the wire of the spring and also the diameter of spring coil.
- Note down the number of turns and measure the length of the spring.
- Insert the spring in the spring testing machine and load the spring by weights in steps and note down the corresponding axial deflections in compression.
- From the tabulated values, the modulus of rigidity of the material of the spring wire can be estimated.
- Plot a curve between load and deflection. The slope of the curve gives the stiffness of the spring.

OBSERVATION

D	-	Spring Coil Diameter (mm)	=
d	-	Spring Wire Diameter (mm)	=
R	-	Mean Coil Radius (mm) = (D –d)/2	=
n	-	No. of Coils	=
L	-	Length of the Spring (mm)	=

TABULATION

Sl. No.	Applied Load (kg)	Deflection (mm)	Modulus of Rigidity (N/mm^2)	Stiffness (N/mm)

CALCULATION

RESULTS

The modulus of rigidity of the spring wire material =
The stiffness of the spring (analytical) =
The stiffness of the spring (graphical) =

EXP NO: 5 DATE:	BUCKLING OF COLUMNS

AIM

To determine the critical load and critical stress of a given column.

APPARATUS REQUIRED

1. Column testing apparatus
2. Specimen
3. Dial gauge
4. Vernier caliper

FORMULA USED

1. The critical load of column is,

$$P_{cr} = \pi^2 EI_{\min} \big/ (KL)^2 = \pi^2 EI_{\min} \big/ L_e^2$$

where K is a constant or length factor depending on the end condition of the column

End Conditions of the Column	Length Factor, k
Hinged-Hinged	1.0
Hinged-Fixed	0.7
Fixed-Fixed	0.5
Fixed-Free (i.e., cantilever)	2.0

E- Young's modulus of the material,

I_{min}- Min. Moment of Inertia,

L_e- Effective Length of section.

2. The critical stress of column is

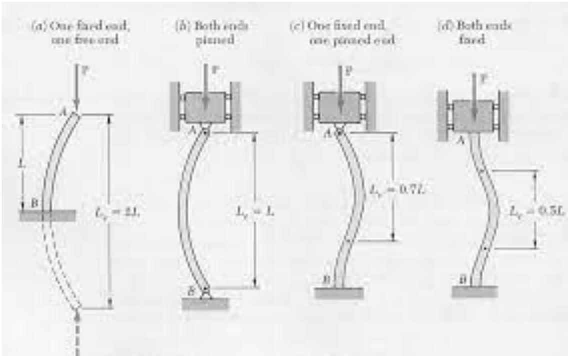
$$\sigma_{cr} = P_{cr} \big/ A = \pi^2 E(I_{\min} / A) \big/ KL^2$$

$$\sigma_{cr} = \pi^2 E \big/ (L_e / r_{\min})^2$$

$$\sigma_{cr} = \pi^2 E \big/ \eta^2$$

3. Min. Radius of gyration of column is $r_{\min} = \sqrt{(I_{\min} / A)}$
   where is A is cross sectional area of column

4. Slenderness ration $\eta = \dfrac{L_e}{r_{\min}}$



PROCEDURE

1. Measure the length and the mean diameter of the column to be tested
2. Place the column in the column testing apparatus and secure it with the given end conditions
3. Apply load to the column. Give a small lateral force to deflect the column laterally. Increase the load if the column straightens back upon removal of the lateral force.
4. Continue the process until the applied load is just sufficient to hold the column in a bend condition; i.e., when the column does not straighten back after removal of lateral load. Record this load as the critical load.
5. Calculate the theoretical buckling load for each loading case.

TABULATION

Support Conditions	Column Dia (d) or Size (mm)	Cross sectional area (A) (mm^2)	Min Radius of gyration (r_{min}) (mm)	Column length (L) (mm)	Effective length (L_e) (mm)	Slenderness ratio (η)	Critical load (P_{cr}) (N)	Critical stress $\sigma_{cr} = \frac{P_{cr}}{A}$ (Expt) (N/mm^2)	Critical stress $\sigma_{cr} = \frac{\pi E}{\eta^2}$ (Theory) (N/mm^2)

CACULATION

RESULT

i. The critical stress is …………………..N/mm^2
ii. The critical load is …………………….N

EXP NO: 6 DATE:	**CONSTANT STRENGTH BEAM TEST**

AIM

To determine the stress of various location along a length of a constant strength beam and compare with the theoretical value.

THEORY

A beam in which section modulus varies along length of the beam in the same proportion as the bending moment is known as Constan strength beam. In this case the maximum stress remains constant along the Length of the beam.

Consider,

b = width of the beam

h = depth of the beam

I = length of the beam

$$\sigma = M / Z$$

Let the depth of the beam be constant and the width varies.

APPARATUS REQUIRED

1. A constant strength beam.
2. Strain gauges.
3. Strain indicator.
4. weighs with hook.

PROCEDURE

1. The constant strength beam is fixed as a cantilever
2. Strain gauges are fixed at three different locations of the beam.
3. The strain gauges are fixed both on the top surface at each location.
4. Strain indicator is used to measure the strain at each location.
5. The Strain gauge readings are noted for every 200 g at location A, B, C and tabulated as given blow

CALCULATION

RESULT

The experiment values of the stress are compared with the theoretical values.

Sl. No.	Load	Location from free end	Experiment (θ)	Theoretical (θ)
1.	A	A		
	B	B		
	C	C		
2.	A	A		
	B	B		
	C	C		
3.	A	A		
	B	B		
	C	C		

EXP NO: 7 DATE:	**PLOTTING OF BENDING STRESS DISTRIBUTION**

AIM

To plot the bending stress distribution for a simply supported beam subjected to point load.

APPARATUS REQUIRED

1. Beam with supports
2. Dial gauges with magnetic stands
3. Weight pan with slotted weights
4. Measuring scale

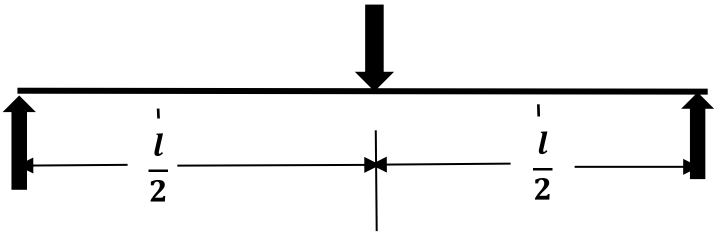
THEORY

A beam of rectangular cross-section is subjected to a bending moment M (N·m). The bending stress in the beam is calculated as

$$\sigma = 6M/bd^2 \text{ (Pa)}$$

where b is the width and d is the depth of the beam.

Diagram,



PROCEDURE

1. Measure the length, breadth, and depth of the given beam.
2. Mark the locations on the given beam
3. Add weights and note the deflection at marked locations.
4. Sketch the bending moment diagram
5. Calculate the bending stresses at the top layer, bottom layer and neutral axis of the beam and sketches the stress distributions

FORMULA USED

Bending stress for a rectangular section is given by

$$\boxed{\sigma = -\frac{My}{I}}$$

RESULT

Hence, the bending stress distribution for a given simply supported beam graph is plotted.

EXP NO: 8 DATE:	**THREE-POINT BEAM BENDING EXPERIMENT**

AIM

To find the deflection at various locations in a simply supported beam subjected to three-point bending. Compare the theoretical results with the experimental results.

APPARATUS REQUIRED

- Metallic beam
- Dial gauge
- Magnetic stands
- Beam supporting stand
- Loads
- Vernier caliper
- Scale/ Rule

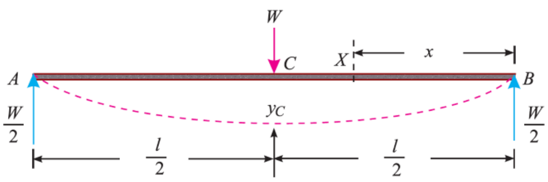
FORMULA USED

$y_c = Wl^3/48EI$ (mid-span deflection in the simply-supported beam)

$I = bh^3/12$;

Deflection equation at any section which is at a distance of x from right end,

$$E\,I.y = \frac{Wx^3}{12} - \frac{Wl^2x}{16}$$



% Error = [(y_c) theoretical - (y_c) experiment]/ (y_c) theoretical x 100

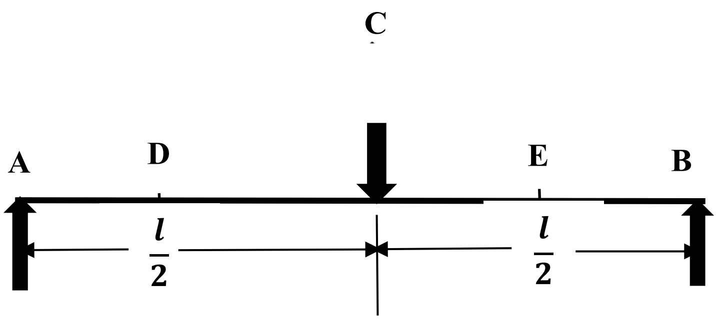
Where,

l= Length of beam. (mm);
I = Moment of inertia of the beam. (mm^4);
E = Young's modulus of the material of the beam. (N/mm^2);
y_c = vertical deflection at mid span. (mm)

OBSERVATION

l	-	Length of beam (mm)	=
b	-	Width of beam (mm)	=
h	-	Depth of beam (mm)	=
P	-	Applied load (kg)	=
y_c	-	Deflection at mid span of the beam (mm)	=

Diagram



PROCEDURE

- Place the given beam on the supporting stands for simply supported beam (three-point bending).
- Measure the length of the beam between the supports and mark the equal lengths of the beam for the center point.
- In the unstretched position, check whether the pointer of the dial gauges is showing a zero mark.
- Place the dial gauge at the mid-span(C) and the other two locations (D and E) of the beam
- Adjust the dial gauges so that it is showing some reading in the undeflected state of the beam. Note down these readings as initial readings.
- Apply the loads at the mid-span for simply supported beam
- Note down the deflection from the dial gauges in all three locations of the beam
- Compare the theoretical results with the experimental result.

TABULATION

S.No	Load at the mid-span W(kg)	Deflection at locations(mm)			
		D		E	
		Experimental	Theoretical	Experimental	Theoretical
1					
2					
3					
4					

CALCULATION

RESULT

The deflection test on the simply supported beam subjected to three-point bending is conducted and theoretical results are compared with the experimental results.