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

## U20ASCJ04 Advanced 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, skilful, 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) - 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** | **Determine** the displacement and forces acting in the members of statically determinate truss. **(Apply)** |
| **CO2** | **Calculate** the slope and deflection of statically indeterminate beams. **(Apply)** |
| **CO3** | **Calculate** the deflection and strain energy of statically determinate structures using energy method. **(Apply)** |
| **CO4** | **Compute** the bending stress distribution of unsymmetrical section beam and crippling strength of thin plates **(Apply)** |
| **CO5** | **Estimate** the shear flow distribution and shear center in open and closed thin-walled sections. **(Apply)** |
| **CO6** | **Carry out** elementary mechanical coupon testing of materials as per the given procedure**. (Imitation)** |
| **CO7** | **Acquire** data using the available measuring devices**. (Manipulation)** |
| **CO8** | **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 | | | M | | | | | | | H | H | |
| **CO2** | H | M | | | M | | | | | H | | H | H | |
| **CO3** | H | M | | | M | | | | | H | | H | H | |
| **CO4** | H | M | | | M | | | | | | | H | H | |
| **CO5** | H | M | | | M | | | | | | | H | H | |
| **CO6** | H | M | | L | | | | H | H | H | | H | H | |
| **CO7** | H | M | | L | | | | H | H | H | | H | H | |
| **CO8** | H | M | | L | | | | H | H | H | | H | H | |

(Tick mark or level of correlation: H-High, M-Medium, L-Low)

## LIST OF EXPERIMENTS:

| S.No | Name of Experiment | Course Outcome |
|---|---|---|
| 1. | Determination of deflection in indeterminate beams | CO6,CO7,CO8 |
| 2. | Verification of Maxwell's reciprocal theorem | CO6,CO7,CO8 |
| 3. | Unsymmetrical Bending of a Beam | CO6,CO7,CO8 |
| 4. | Wagner beam-Tension field beam | CO6,CO7,CO8 |
| 5. | Determine shear centre of open sections | CO6,CO7,CO8 |
| 6. | Determine shear centre of closed sections | CO6,CO7,CO8 |

| | |
|---|---|
| **EXP NO : 1**<br><br>**DATE :** | **DETERMINATION OF DEFLECTION IN INDETERMINATE BEAMS** |

**Aim:**

To find the deflection and flexural stiffness of the fixed fixed beam with symmetric load and compare the theoretical results with the experimental results.

**Apparatus required:**

1) Beam made up brass, steel aluminum etc.

2) Dial gauge – 3 nos.

3) Magnetic dial stands.

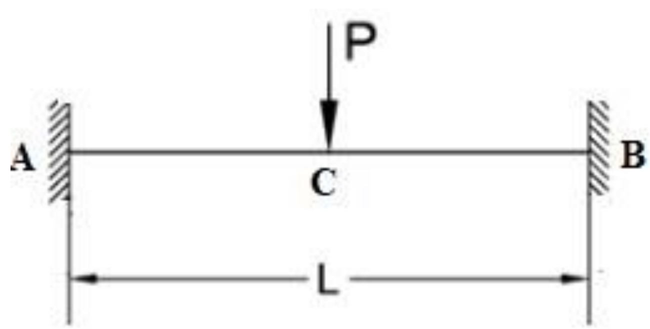
4) Beam supporting stand.

5) Loads.

6) Vernier caliper.

7) Steel scale (1 m length).

**Diagram:**



**Formula used:**

$$y_c = \frac{PL^3}{192EI} = \underline{\hspace{3cm}} \text{ (mm). (theoretical)}$$

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 C. (mm)

**Procedure:**

1) Place the given beam on the supporting stand.
2) Measure the length of the beam between the supports and mark the equal lengths of the beam for symmetric load.
3) In the unstretched position, check whether the pointer of the dial gauges is showing zero mark.
4) Place the dial gauges at the middle of the beam and both sides at symmetrical distances.
5) Adjust the dial gauges show that it is showing some reading in the undeflected state of the beam.
6) Note down these readings as initial reading.
7) Apply the loads at the symmetric distances from the both sides of the beam.
8) Note down the deflection from the dial gauges for both loading and unloading.
9) Compare the theoretical results with the experimental results.

**Observation Table:**

| S. No | Load (P) in Kg | Deflection at C in mm | | | Theoretical Deflection ($y_{theory}$) in mm | Percentage error % |
|---|---|---|---|---|---|---|
| | | Loading | Unloading | Average ($y_{exp}$) in mm | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

**Calculation:**

Length of the beam (L) = __________ (mm).

Breadth of the beam (b) = _________ (mm).

Depth of the beam (d) = ___________ (mm).

Moment of Inertia (I) = $\frac{b\,d^3}{12}$ = __________ ($mm^4$).

**Result:**

Thus, the deflection test on the fixed fixed beam is conducted and theoretical results compared with the experimental results.

At C,

1) Experimental value = ___________ (mm).

2) Theoretical value = _____________ (mm).

3) Percentage error = _____________%.

| EXP NO : 2<br><br>DATE : | VERIFICATION OF MAXWELL'S RECIPROCAL THEOREM |
|---|---|

## Aim:

To verify the Maxwell's reciprocal theorem using simply supported beam.

## Apparatus required:

1) Beam made up brass, steel aluminum etc.
2) Dial gauge
3) Magnetic dial stands
4) Beam supporting stand
5) Loads
6) Vernier caliper
7) Wooden scale (1 m length)

## MAXWELL'S RECIPROCAL THEOREM:

$$\delta_{AB} = \delta_{BA}$$

Where,

**$\delta_{AB}$-** deflection at point A due to load on point B.

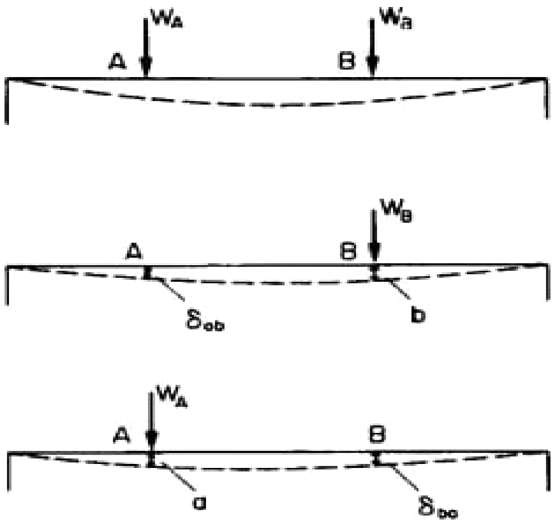
**$\delta_{BA}$ -** deflection at point B due to load on point A

## Theory:

The following are the three versions of Maxwell's reciprocal theorem.

1) The deflection at point B due to unit load at point A is equal to deflection at point A due to unit load at point B.
2) The slope at point B due to unit moment at point A is equal to the slope at the point A due to unit moment at point B.
3) The slope at point B due to unit load at point A is equal to the deflection at the point A due to unit moment at point B.

**Diagram :**




$\delta_{ab}$ = deflection at A with load at B
$\delta_{ba}$ =deflection at B with load at A

**Precautions:**

- Make sure that dial gauge tip should just touch the beam under the stand.
- The dial gauge needle should be adjusted to zero before taking the initial reading.

**Procedure:**

1) The given wooden beam or steel rod is placed on the knife-edge to form a SSB.
2) The 2 points are separated by a distance is taken as A and B on the SSB.
3) The dial gauge is placed at point A through the magnetic stand.
4) The hanger is placed on point B. the dial gauge is adjusted for zero without taking any load on the SSB. Then the weights are added in 100 gms. The deflection at point A is noted for every 100 gms.
5) The load and dial gauge are interchanged (i.e) the loads are added at point A and dial gauge at point B.
6) Readings are taken for every 100 gms of weight.
7) A graph between load applied and deflection is drawn for both the cases i.e deflection at A due to load at B and deflection at B due to load at B due to load at B and deflection at B due to load at A.
8) The slopes of two graphs are obtained and the slopes are found to be the same, which means Maxwell’s theorem is true.

## Tabulation:

**Load at A, deflection at B ($\delta_{BA}$ )** **Least count =**

| **Sl.no** | **Load in g** | **Deflection (div)** | **Deflection × L.C in mm** |
|---|---|---|---|
| 1. | | | |
| 2. | | | |
| 3. | | | |
| 4. | | | |
| 5. | | | |
| | | | |

**Load at B, deflection at A ( $\delta_{AB}$ )** **Least count =**

| **Sl.no** | **Load in g** | **Deflection (div)** | **Deflection × L.C in mm** |
|---|---|---|---|
| 1. | | | |
| 2. | | | |
| 3. | | | |
| 4. | | | |
| 5. | | | |

## Calculation:

**Result:**

Thus the Maxwell's reciprocal theorem is verified.

It is observed that Principle of Superposition holds good for beam bending.

$$\boldsymbol{\delta_{AB} = \delta_{BA}}$$

| EXP NO : 3<br><br>DATE : | **UNSYMMETRICAL BENDING OF A BEAM** |
|---|---|

**Aim:**

To perform unsymmetrical bending and determine the shear centre for the given Z section

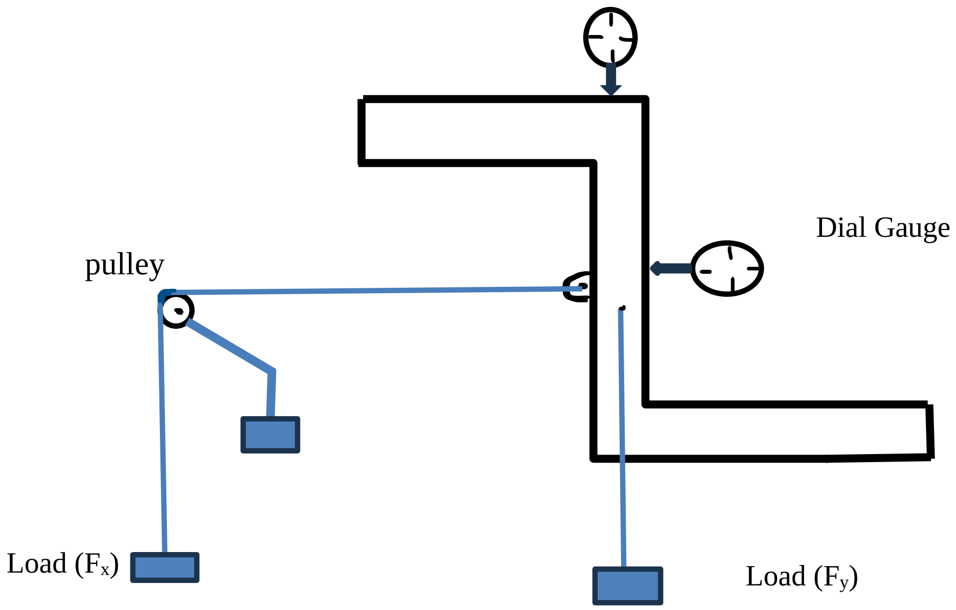
**Apparatus Required:**

1. Beam of Z-channel section.
2. Known Weights with loading hook and.
3. Dial gauge with magnetic base.
4. Vernier Caliper

**Procedure:**

1) Measure the length, breadth, thickness of the given unsymmetrical section and calculate the values of $I_{xx}$, $I_{yy}$ & $I_{xy.}$
2) The given Section hang two weights $F_y$ and $F_x$ ,And fix two dial gauges in which one is to measure the vertical deflection in the top of the flange and another is to measure horizontal defelection in the middle of web.
3) Keeping values of $F_y$ constant and Variying values of $F_x$ ,note the corresponding deflection values of dx and dy.
4) Determine the value of $\boldsymbol{\theta_a}$ & $\boldsymbol{\theta_b}$ using the force of deflection along X and Y direction.
5) Plot the graph $\boldsymbol{\theta_a}$ in Y- axis & $\boldsymbol{\theta_b}$ in X – axis , Calculate the value of Ø from the graph.
6) Find the error percentage between the experimental and theoretical values.

**Diagram:**




**Formulae Used**

For theoretical

$$\tan 2\emptyset = \frac{2I_{xy}}{I_{yy} - I_{xx}}$$

For experimental

1) $\tan\theta_a = \frac{F_y}{F_x}$

2) $\tan\theta_b = \frac{d_y}{d_x}$

Where:

| | | |
|---|---|---|
| $\theta_a$ | = | The angle of the plane of loading |
| $\theta_b$ | = | The angle of the plane of Displacement |
| $F_x$ | = | Force applied in x-direction |
| $F_y$ | = | Force applied in y-direction |
| $d_x$ | = | Displacement in x-direction |
| $d_y$ | = | Displacement in y-direction |
| $\emptyset$ | = | Principal plane |

**Technical Data:**

**For Z-section**

Length of the section =

Top flange width =

Bottom flange width =

Height of the web =

Thickness of the section =

**Tabulation:**

| Sl.no | $F_y$ (kg) | $F_x$ (kg) | $d_x$ (mm) | $d_y$ (mm) | $\tan\theta_a$ | $\tan\theta_b$ | $\theta_a$ | $\theta_b$ |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |

**Calculation:**

**Result:**

Thus the principal plane of the unsymmetrical Z – Section beam is inclined at angle of ,

( Theoretically = ……………………)

( Graphically = ……………………)

The error percentage is = …………………….

| EXP NO: 4<br><br>DATE: | **WAGNER BEAM – TENSION FIELD BEAM** |
|---|---|

**Aim:**

To determine the allowable stress for the given diagonal tension beam section

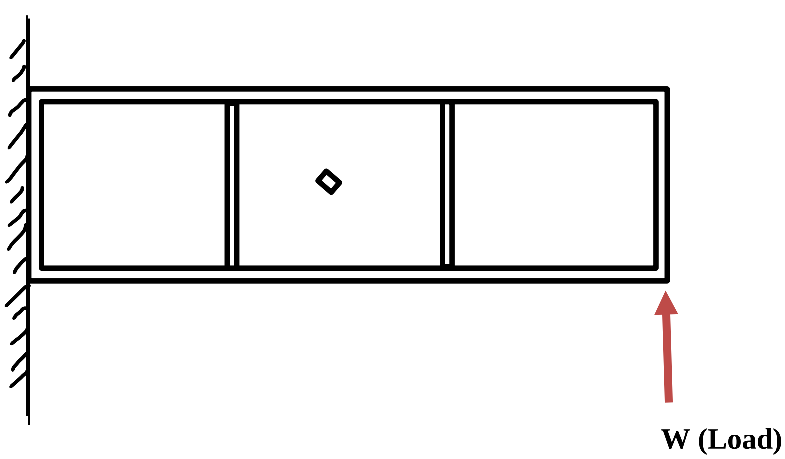
**Apparatus Required**

1. Diagonal tension channel
2. Strain gauges
3. Digital strain indicator
4. Load cell
5. Load indicator
6. Hydraulic jack

**Theory**

Diagonal-tension shear beams, in applications where the web buckles well before the ultimate load is reached, have long proven to be efficient forms of construction. Although the basic behavior of diagonal-tension beams is well understood, neither the complex stress distributions that result after this web has not buckled nor the ultimate strength of these beams may be predicted accurately by pure theory.

## Diagram:




Wagner beam setup

## Tabulation

| SI no | W (kg) | $\varepsilon$ t | $\varepsilon$ s | $\sigma t= E*\varepsilon t$ | $\sigma s= E*\varepsilon s$ |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

## Procedure

1. Initially note the strain value in Digital Strain indicator
2. Place a .5 kg on the hook
3. Record the corresponding digital load indicator and strain indicator reading

## NOTE

Do not load diagonal tension panel more than 10 kg

## Technical data

Length of the beam =

Difference between centroid of the flange rivet h =

Thickness of the web =

W= Weight

$\alpha$ = angle of web buckle = $45^{\cdot}$

E = young's Modulus

**Experimental**

$\sigma s = W/ht$

$\sigma t = 2W/ht \times 1/\sin 2\alpha$

**Result:**

Stress in the web by theoretically……………
Stress in the web by experimentally……………

| | |
|---|---|
| **EXP NO: 5**<br><br>**DATE:** | **DETERMINE SHEAR CENTER OF OPEN SECTION** |

## Aim:

To determine the shear centre for the given open channel section

## Apparatus Required:

1. Beam of channel section.
2. Known Weights with loading hook and.
3. Dial gauge with magnetic base.
4. Vernier caliper

## Theory:

Shear centre is defined as that unique point on the beam cross section where the application of the shear force does not produce the beam to twist. The channel section has a horizontal axis of symmetry and the experiment is to determine its location on axis since angular twisting moment causes a twist, it is simply a matter of placing the shear force at a point on the cross section where the shear force and the shear centre combine to produce a zero tensional moment about all points on a plane of beam cross section

## Procedure:

1) Mount two dial gauges on the flange at a known distance, preload the dial gauge and set it to zero.

2) Place a total of 500-gram load at A note down the dial gauge readings.

3) Now remove one load piece from hook A and place it on B, thus the total vertical load on this section remains 500 grams.

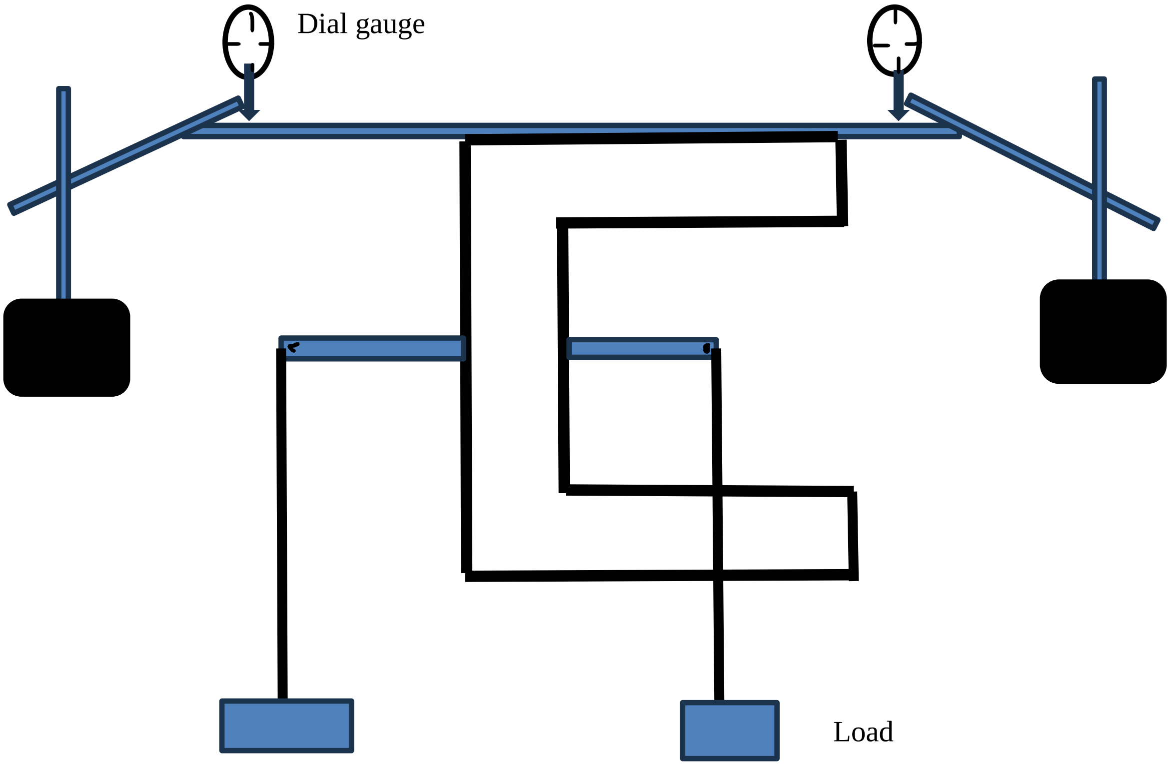
4) Record the dial gauge reading.

5) Transfer all the load pieces one by one to hook B, and note down the dial gauges readings.

6) For every load case calculate the algebraic different between the dial gauge readings as measure of angle of twist θ suffered by the section.

7) Plot a graph with ‘e’ value on x-axis and d1 – d2 value on y-axis, the meeting point of the straight line with x-axis determine the shear centre.

**Diagram :**




**Formulae Used:**

For theoretical

$$e = \frac{3b^2}{(h + 6b)}$$

For experimental

$$\mathbf{e = AB\ (W_A - W_B)\ /\ (2W_T)}$$

Where:

| | | |
|---|---|---|
| H | = | height of the specimen |
| b | = | width of the specimen |
| AB | = | distance between load point |
| $W_A$ | = | load at point A |
| $W_B$ | = | load at point B |
| $W_T$ | = | total load |

**Tabulation:**

| Sl.no | $W_A$ | $W_B$ | $D_1$ | $D_2$ | $D_1$-$D_2$ | $e_{exp}$ | $e_{the}$ | $\theta$ |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |

**Technical Data:**

**For C-section**

Length of the section =

Top flange width =

Bottom flange width =

Height of the web =

Thickness of the section =

**Calculation :**

**Result:**

The shear centre for the open section

Theoretically = ……………………

Experimentally = ……………………

| EXP NO: 6<br><br>DATE: | DETERMINE SHEAR CENTER OF CLOSED SECTION |
|---|---|

**Aim:**

To determine the shear centre for the given closed channel section

**Apparatus Required:**

1. Beam of channel section
2. Known Weights with loading hook
3. Dial gauge with magnetic base
4. Vernier caliper

**Theory:**

Shear centre is defined as that unique point on the beam cross section where the application of the shear force does not produce the beam to twist. The channel section has a horizontal axis of symmetry and the experiment is to determine its location on axis since angular twisting moment causes a twist, it is simply a matter of placing the shear force at a point on the cross section where the shear force and the shear centre combine to produce a zero tensional moment about all points on a plane of beam cross section

**Procedure:**

1) Mount two dial gauges on the flange at a known distance, preload the dial gauge and set it to zero.

2) Place a total of 500 gram load at A note down the dial gauge readings.

3) Now remove one load piece from hook A and place it on B, thus the total vertical load on this section remains 500 grams.

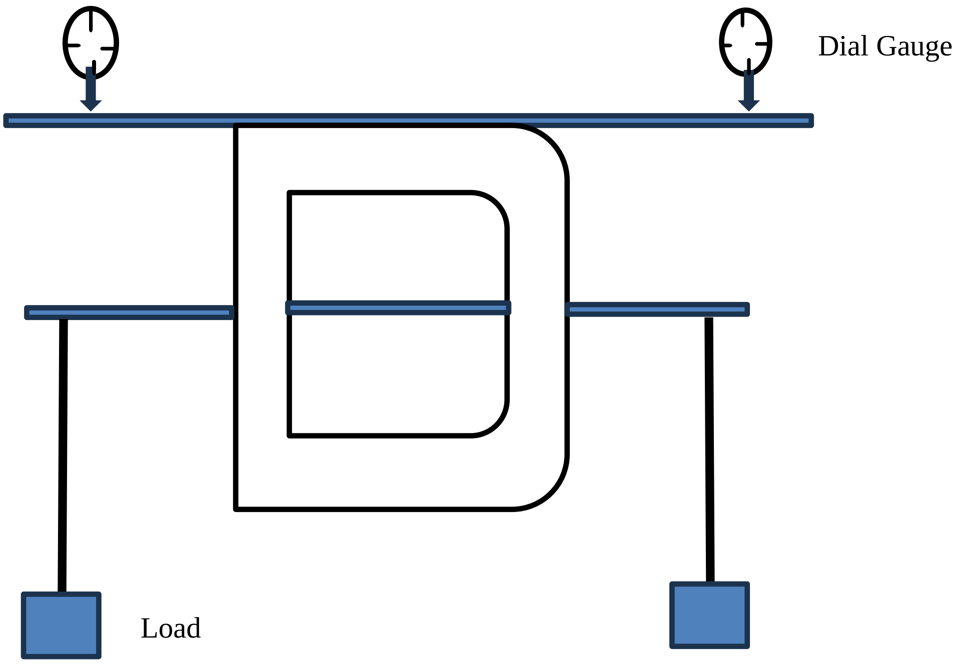
4) Record the dial gauge reading.

5) Transfer all the load pieces one by one to hook B, and note down the dial gauges readings.

6) For every load case calculate the algebraic different between the dial gauge readings as measure of angle of twist θ suffered by the section.

7) Plot a graph with 'e' value on x-axis and d1 – d2 value on y-axis, the meeting point of the straight line with x-axis determine the shear centre.

**Diagram:**




**Formulae used:**

**For theoretical**

$$e = \frac{3b^2}{h(1 - \frac{6b}{h})}$$

**For experimental**

$$\mathbf{e = AB\,(W_A - W_B) / (2W_t)}$$

Location of shear centre from original origin of scale for closed section (D-section)

$$\mathbf{e_{closed} = e + d/2}$$

Where

H = height of the specimen
b = width of the specimen
AB = distance between load point
$W_A$ = load at point A
$W_B$ = load at point B
$W_T$ = total load

**Technical Data:**

**For D-section**

Length of the section =
Top flange width =
Bottom flange width =
Half sphere diameter =
Height of the web =
Thickness of the section =

**Tabulation:**

| SI.No | $W_A$ | $W_B$ | $D_1$ | $D_2$ | $D_1$-$D_2$ | $e_{exp}$ | $e_{the}$ |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |

## Calculation:

## Result:

The shear centre for the closed section is

Theoretically = ……………………

Experimentally = ……………………