MECHANICS OF MATERIAL – II

Instructor Lab Manual

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Lab Session – 1

1.1 Objective

To determine the deflection at the mid span of a propped cantilever beam given that 3-point lads are acting on beam at equidistant from roller support using aluminum and brass and compare their results.

1.2 Apparatus

- Propped cantilever beam apparatus
- Weights
- Dial gauge
- Vernier Caliper
- Specimen
- Hangers
- Spanner

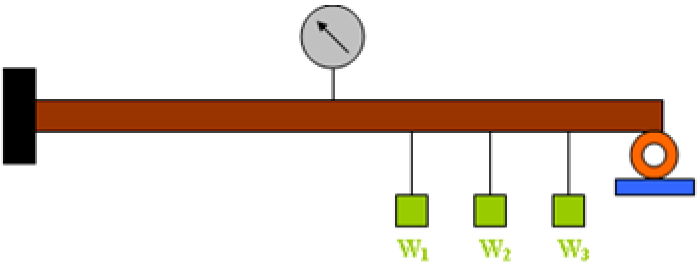


Figure 1-1: Propped Cantilever Beam

1.3 Summary of Theory

A beam is a structural element that is capable of withstanding load primarily by resisting bending.

1.4 Classification of Beams

The beams may be classified in several ways, but the commonly used classification is based on support conditions. On this basis the beams can be divided into six types:

i. Cantilever beams
ii. Simply supported beams
iii. Overhanging beams
iv. Propped beams
v. Fixed beams
vi. Continuous beams

1.4.1 Cantilever Beam

A beam having one end fixed and the other end free is known as cantilever beam, figure shows a cantilever with end 'A' rigidly fixed into its supports, and the other end 'B' is free. The length between A and B is known as the length of cantilever.

- It has 3 reaction forces
- Statically determinate

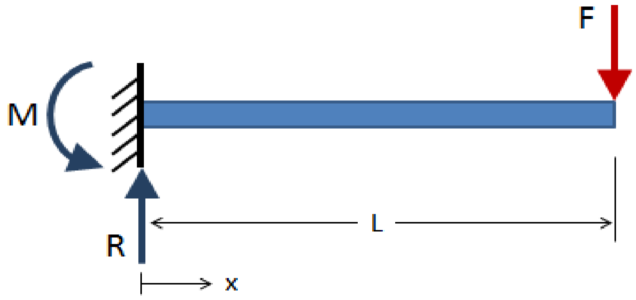


Figure 1-2: Cantilever beam

1.4.2 Simply Supported Beam

A beam having both the ends freely resting on supports is called a simply supported beam. The reaction act at the ends of effective span of the beam. Figure show simply supported beams. For such beams the reactions at the two ends are vertical. Such a beam is free to rotate at the ends, when it bends.

- It has 2 reaction forces
- Statically determinate

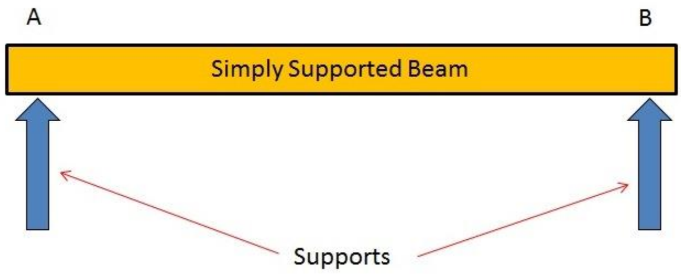


Figure 1-3: Simply supported beam

1.4.3 Overhanging Beams

A beam for which the supports re not situated at the ends and one or both ends extend over the supports, is called an overhanging beam. Figure represents overhanging beams.

- It has 4 reaction forces
- Statically indeterminate

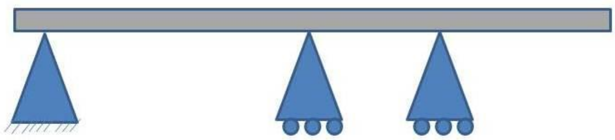
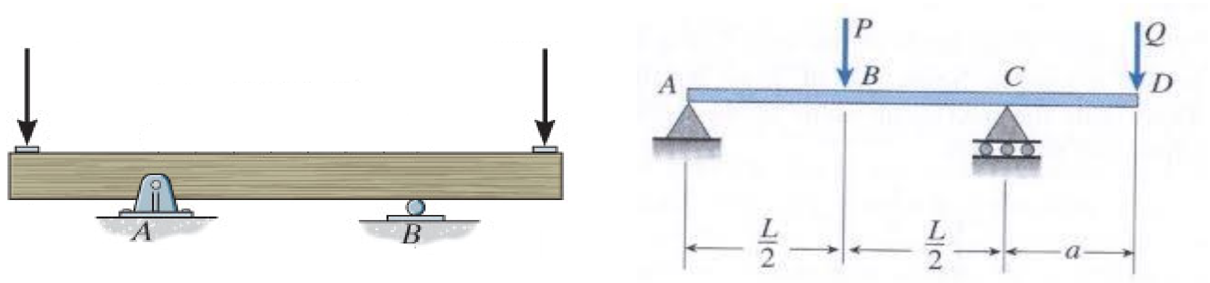


Figure 1-4: Overhanging beams



(a) (b)

Figure 1-5: (a) 2-sided overhanging beam (b) 1-sided overhanging beam

1.4.4 Propped Cantilever Beams

A cantilever beam for which one end is fixed and other end is provided support, in order to resist the deflection of the beam, is called a propped cantilever bema. A propped cantilever is a statically indeterminate beam. Such beams are also called as restrained beams, as an end is restrained from rotation.

- It has 5 reaction forces
- Statically indeterminate

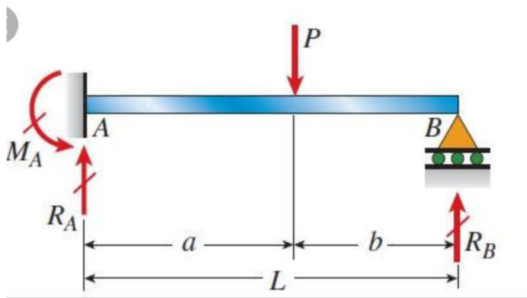


Figure 1-6: Propped Cantilever Beam

1.4.5 Fixed Beams

A beam having its both the ends rigidly fixed against rotation or built into the supporting walls, is called a fixed beam. Such a beam has four reaction components for vertical loading (i.e., a vertical reaction and a fixing moment at both ends) figure shows the fixed beam.

- It has 6 reaction forces
- Statically indeterminate

Figure 1-7: Fixed beam

1.4.6 Continuous Beam

A beam having more than two supports, is called as continuous beam. The supports at the ends are called as the end supports, while all the other supports are called as intermediate support. It may or may not have overhang. It is statically indeterminate beam. In these beams there may be several spans of same or different lengths figure shows a continuous beam.

- It has more than 3 reaction forces
- Statically indeterminate

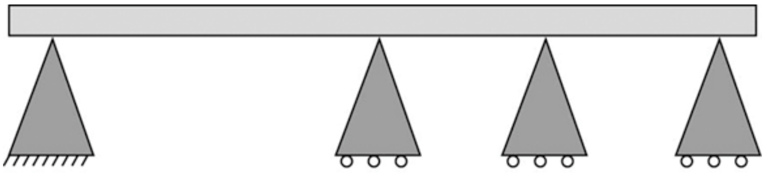


Figure 1-8: Continuous beam

1.5 Procedure

i. Measure the width and depth of the beam with the help of scale to find the moment of inertia of the beam.
ii. Set the apparatus and put the required hangers at different points.
iii. Measure the distances of each hanger from the reference end.
iv. Set the deflection dial gauge at zero after putting the hangers.
v. Take the reading of deflection after putting the loads in the hangers
vi. Repeat the process for different loads
vii. Find the theoretical deflection and compare with the experimental values by showing on a graph

1.6 Observations and Calculations (Aluminum)

Width of Beam = b = 25.4 mm

Depth of beam = d = 5.5 mm

Length of beam = 610mm

Moment of Inertia for rectangular metal bar = I = $bd^3/12$= 504.46 mm^4

Modulus of Elasticity = E = 70 GPa

Least count of dial gauge = 0.01mm

Table 1-1: Variation in deflection with loads

No. of Obs.	Loads (N)			Deflection (mm)		δ exp (Mean) (mm)	δ th $=\frac{W}{192EI}$ (mm)	%age Error
	W_1	W_2	W_3	**Loading**	**Un-loading**			
1	1	1	1	0.24	0.4	0.32	0.29	9.3%
2	2	1	1	0.58	0.725	0.6525	0.589	9.6%
3	2	2	2	0.89	0.98	0.935	0.884	5.45%
4	4	2	2	1.16	1.27	1.215	1.17	3.70%
5	4	4	2	1.49	1.49	1.49	1.47	1.34%

1.7 Graph

On graph, plot the deflection against load for the theoretical & practical results. Draw the best-fit straight lines through the points

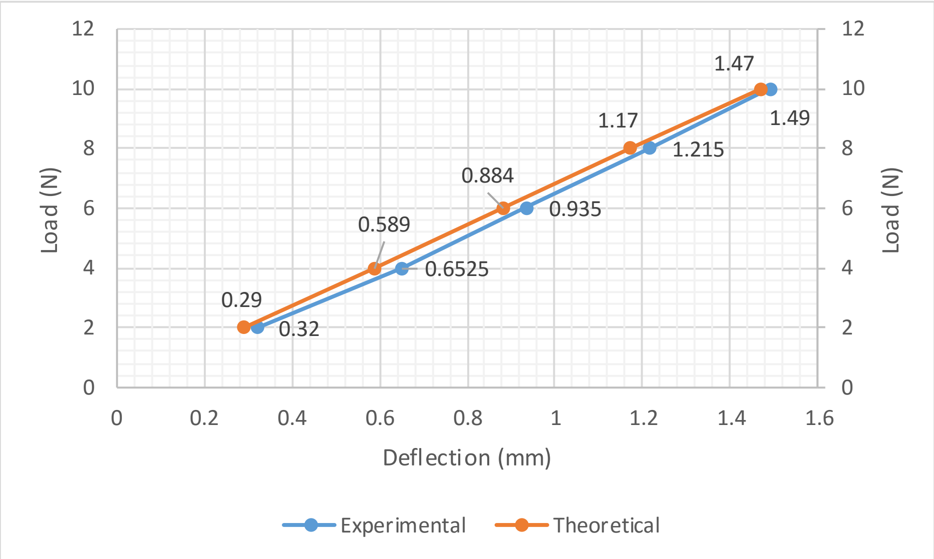


Figure 1-9: Graph between deflection and loads

1.8 Observations and Calculations (Brass)

Width of Beam = b = 9 mm

Depth of beam = d = 18 mm

Moment of Inertia for rectangular metal bar = I = $bd^3/12$= 4374 mm^4

Modulus of Elasticity = E = 70 GPa

Table 1-2: Variation in deflection with loads

Ob. No	Loads (N)			Deflection		δ exp (Mean)	$\delta_{th} = \frac{5357\,W}{EI}$	%age Error
	W_1	W_2	W_3	Loading	Un-loading			
1	1	1	1	0.26	0.26	0.26	0.189245	27
2	2	1	1	0.47	0.47	0.47	0.37849	19
3	2	2	2	0.71	0.71	0.71	0.567734	20
4	4	2	2	0.98	0.98	0.98	0.756979	22
5	4	4	2	1.50	1.50	1.50	0.946224	36

1.8.1 Graph

On graph, plot the deflection against load for the theoretical & practical results. Draw the best-fit straight lines through the points

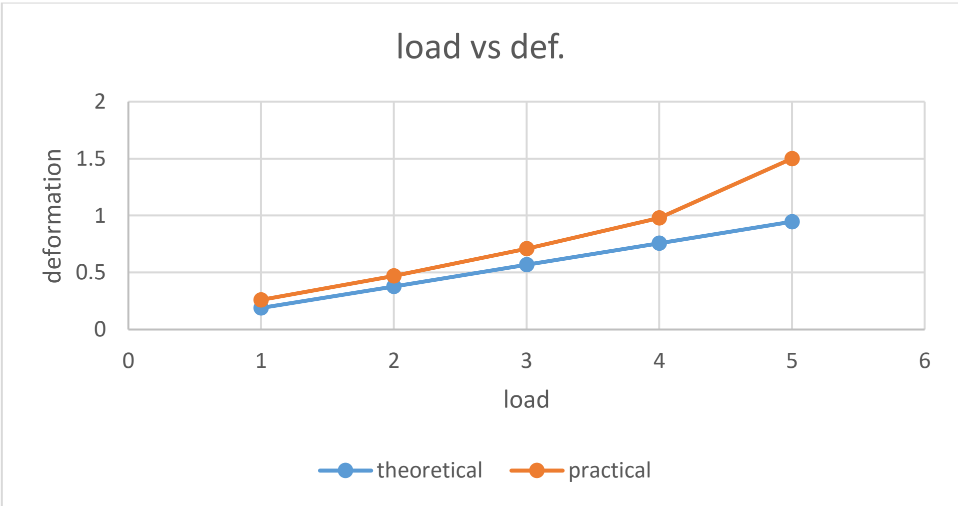


Figure 1-10: Graph between deformation and load

1.9 Industrial Applications

The are some industrial applications of loading beams

- Heavy duty beam trolleys
- Concrete beam construction
- Residential construction
- Supporting the heavy loads

1.10 Statistical Analysis

The mean value of the deflection is:

$$\bar{X} = \frac{0.26 + 0.47 + 0.71 + 0.98 + 1.50}{5}$$

$$= 0.784$$

Standard Deviation is**:**

$$\boldsymbol{S.D} = \sqrt{\frac{(0.784 - 0.26)^2 + (0.784 - 0.47)^2 + (0.784 - 0.71)^2 + (0.784 - 0.98)^2 + (0.784 - 1.50)^2}{5 - 1}}$$

$$= 0.482$$

1.11 Conclusion

We have learned a great deal about how the bending of a beam depends on the beam's load, material properties, cross section, and manner of support. We use the static beam equation and the ideas that we have explored as a basis for understanding the static deformations of more complicated structures. Deflection of Aluminum is more as compared to brass.

1.12 Comments

There are a few valid reasons to make this experiment more accurate

- Beam is made of aluminum, which shows more deflection
- We can use steel beams which is harder material than aluminum
- Steel beam will show the same properties for imposed loads which includes live loads
- It will also bear the wind loads, earthquake loads and snow loads

Lab Session – 2

2.1 Objective

To determine what levels of a combine bending and torsion cause elastic failure in different materials and compare them with various theories of failure.

2.2 Apparatus

- Bending & torsion apparatus
- Weights
- Hanger
- Dial Gauge
- Vernier Caliper
- Spanner
- Specimen

Figure 2-1: Combine bending and torsion apparatus

2.3 Theory

In this experiment we have to find out the effects of the bending and torsion on the specimen under the observation. These things become the failure of materials. The apparatus consists of a specimen **"necked"** between the base plate and the other end is joined with the counter balanced circular loading plate.

Regular interval graduations on the loading plate allow a special hanger to locate. The hanger enables us to measure the pure bending, the pure torsion or combined effect of the bending and torsion, depending upon its position. The specimen deflection is measured by a dial gauge mounted diametrically opposite load point.

This simple machine uses inexpensive test specimens made from round bar. The specimen is clamped at one end to the base bracket and at the other to a counterbalanced circular loading plate. This plate is graduated in 15° intervals. A special hanger enables pure bending, pure torque or combined loads to be applied depending on the position of the plate. The specimen deflection is measured by a dial gauge mounted diametrically opposite the load point. In the event of a specimen failure safety is ensured by set screws.

2.3.1 Necking

Necking, in engineering or materials science, is a mode of tensile deformation where relatively large amounts of strain localize disproportionately in a small region of the material. The resulting prominent decrease in local cross-sectional area provides the basis for the name "neck". Because the local strains in the neck are large, necking is often closely associated with yielding, a form of plastic deformation associated with ductile materials, often metals or polymers. The neck eventually becomes a fracture when enough strain is applied. Necking results from an instability during tensile deformation when a material's cross-sectional area decreases by a greater proportion than the material strain hardens.

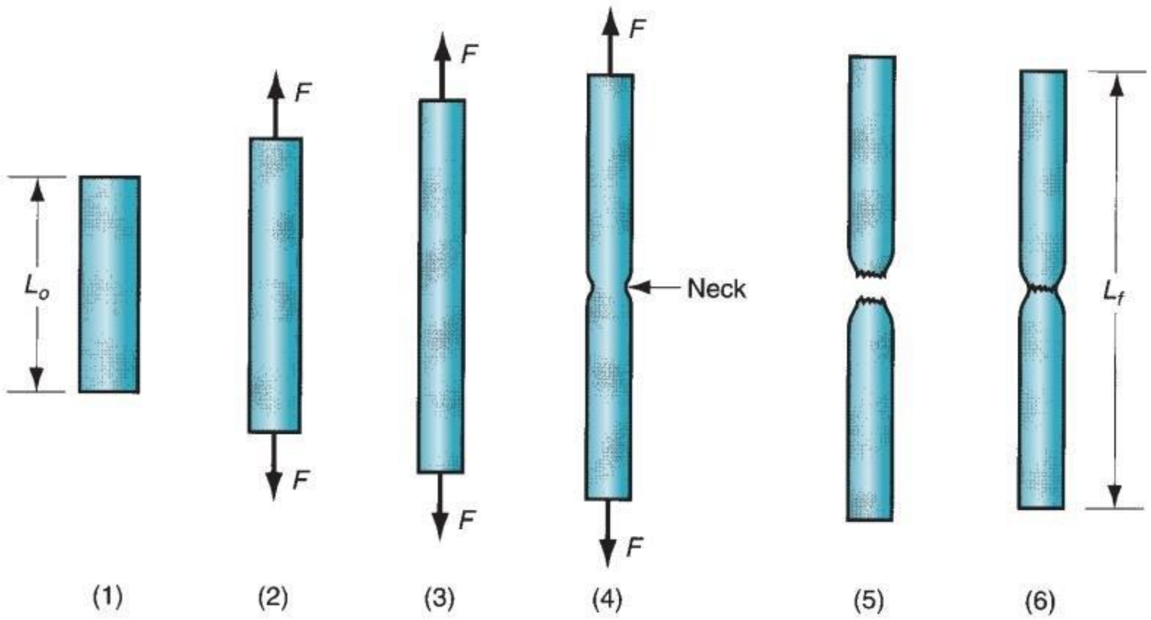


Figure 2-2: Necking

2.3.2 Bending

Bending is defined as the reaction of the loading applied perpendicular to the longitudinal axis of the element. In applied mechanics, **bending** (also known as **flexure**) characterizes the behavior of a slender structural element subjected to an external load applied perpendicularly to a longitudinal axis of the element.

Figure 2-3: Bending

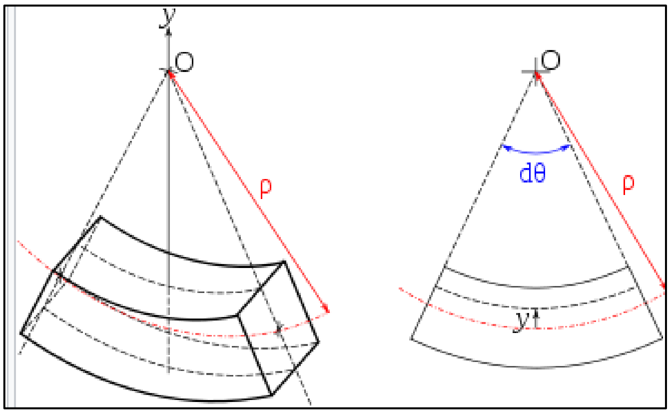


Figure 2-4: Compression and stretchness of fibers

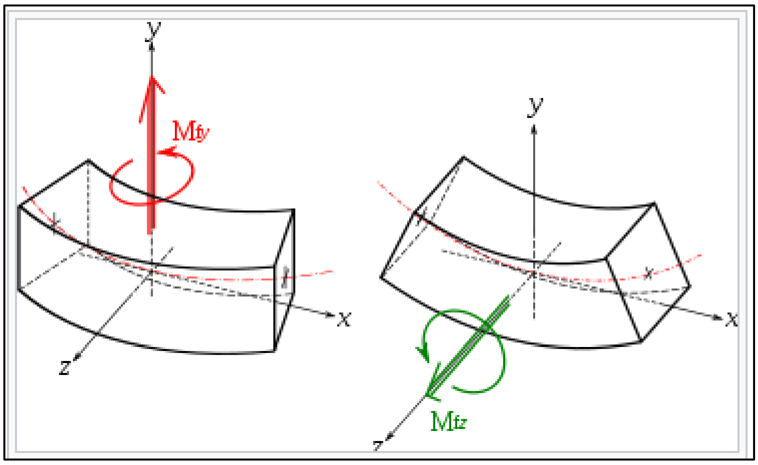


Figure 2-5: Bending moments in a beam

2.3.3 Torsion

Twisting of the object due to the applied torque on the object. Its units are per square pound. Torsion is the twisting of an object due to an applied torque. Torsion is expressed in either the Pascal (Pa), an SI unit for newtons per square meter, or in pounds per square inch (psi) while torque is expressed in newton meters (N·m) or foot-pound force (ft·lbf). In sections perpendicular to the torque axis, the resultant shear stress in this section is perpendicular to the radius.

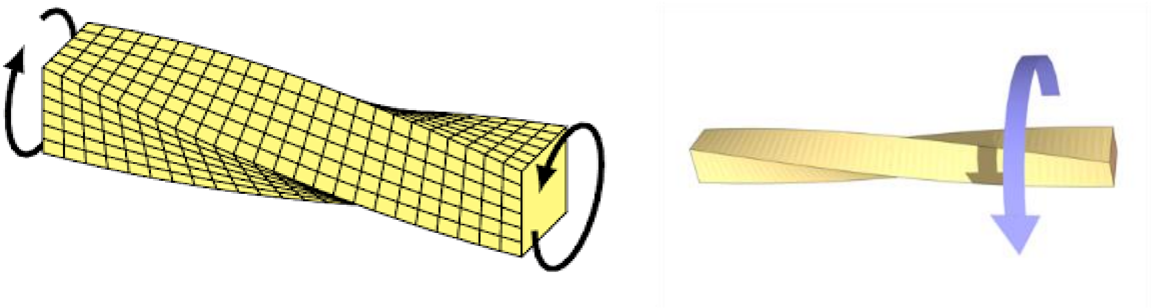


Figure 2-6: Twisting

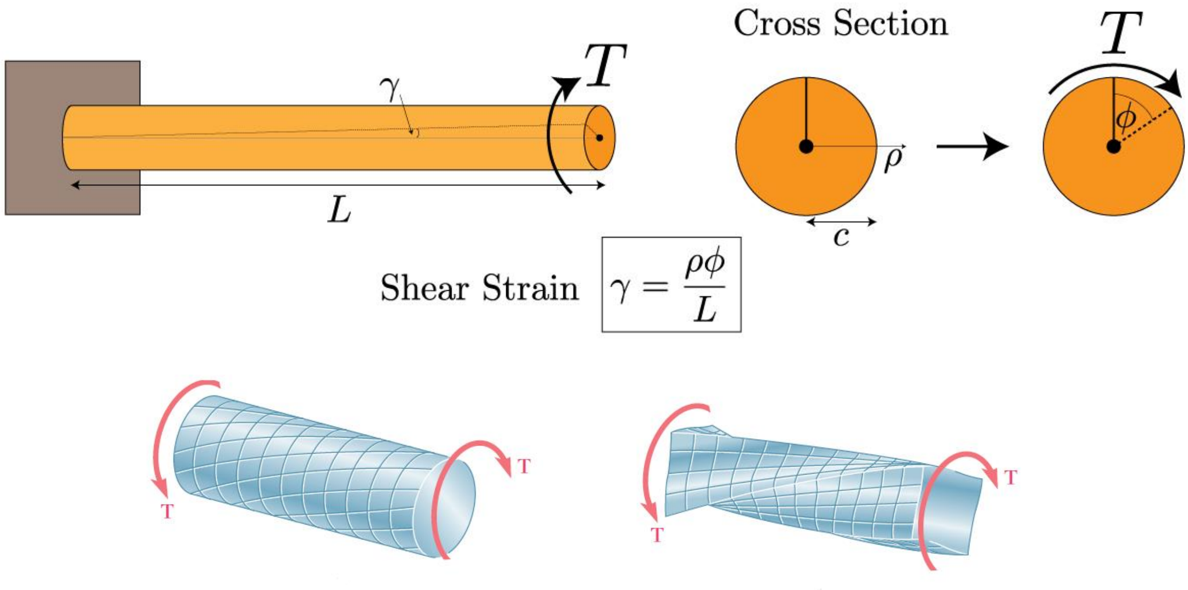


Figure 2-7: Cross Sectional view of twisting

2.3.4 Combine effect of bending and torsion

Applications of bending and torsion are very wide in our daily life routine, e.g. in shafts of the engine, in the construction beams, in the loading machines these things are applied. In designing many engineering apparatuses or in designing the weight lifting objects these things are encounter and cause the failure of the system or the structure so that the behavior of things or materials are necessary to deal. If it is ignoring, then many accidents can happen which can damage or could be very dangerous for the life of the people.

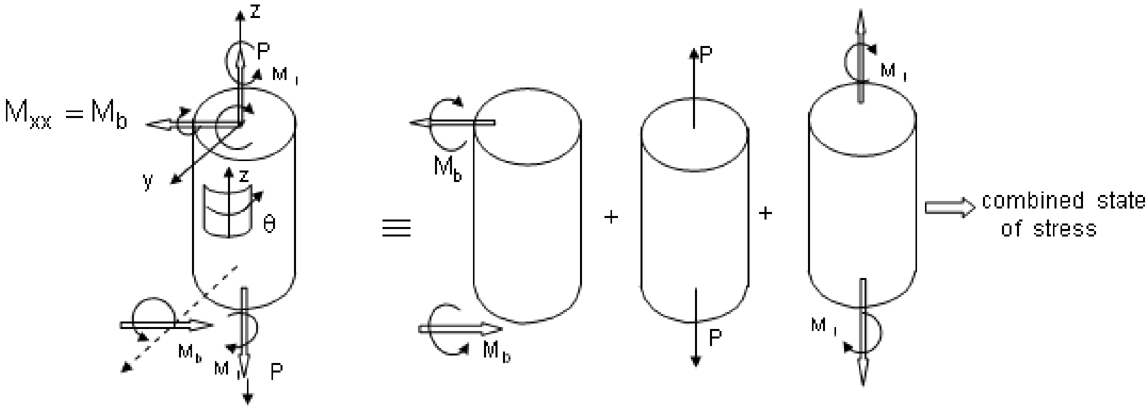


Figure 2-8: Combined Bending and torsion

2.4 Bending

2.4.1 Procedure

- Setup the apparatus on the horizontal table so can it would be able to hang the weight to the base plate.
- Set the dial gauge at the zero degree to the specimen for pure bending.
- Place the hanger at the front and opposite to the dial gauge at zero degree.
- Note the reading on the dial gauge.
- Now start moving the hanger at a place next then to the 1st place by 15^{o} and note the reading keep doing this until minimum reading is obtained at the 90^{o}.
- Keep the thing carefully and take readings neatly.

2.4.2 Observations and Calculations

Weight applied = 5N

Self-weight of hanger= 10N

Total weight = 15N

Least count of dial gauge=0.01mm

Dial position = 0^{o}

Table 2-1: Position of load vs. reading of the dial gauge in bending

Sr #	Position of the load (degree)	Reading of the dial gauge
1	0°	0.39
2	15°	0.35
3	30°	0.27
4	45°	0.18
5	60°	0.13
6	75°	0.07
7	90°	0.01

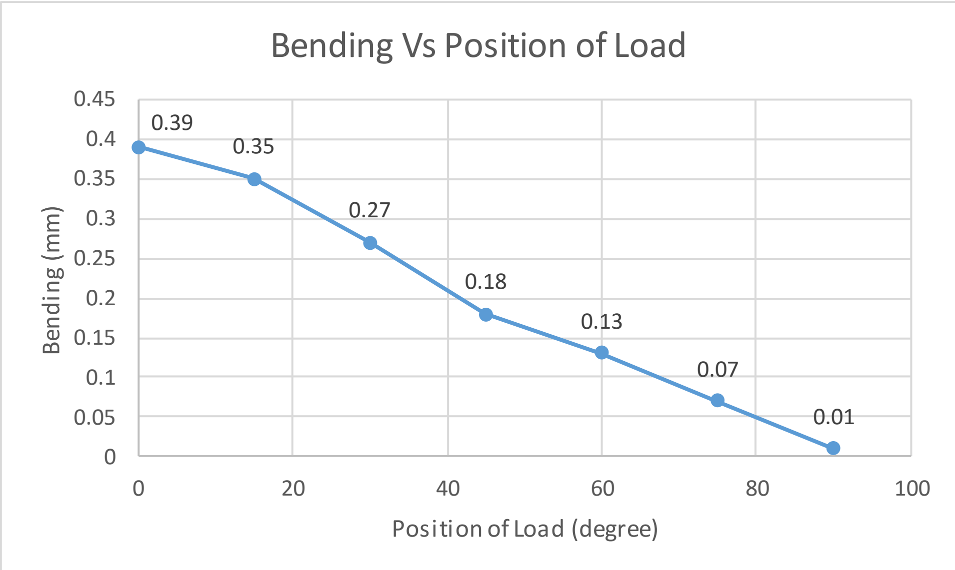


Figure 2-9: Bending vs. position of load in bending

2.4.3 Statistical Analysis

The mean value of bending is given by:

$$\textbf{M.D} = \bar{X} = \frac{0.39+0.35+0.27+0.18+0.13+0.07+0.01}{7}$$

$$= 0.2 \text{ mm}$$

$$S.D = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \bar{X})}{n-1}}$$

Standard deviation is given as,

$$= \frac{\sqrt{(0.39-0.2)^2+(0.35-0.2)^2+(0.27-0.2)^2+(0.18-0.2)^2+(0.13-0.2)^2+(0.07-0.2)^2+(0.01-0.2)^2}}{6}$$

= **0.058**

2.5 Torsion

2.5.1 Procedure

- Setup the things as in the 1st place with the difference that the dial gauge would be at 90^o rather than the zero degree.
- Place the hanger likewise in the 1st case and note the reading of the dial gauge.
- 1st at the zero degree and then proceed to the 90^o as in the 1st case.
- In this case maximum reading would be at 90^o and the minimum reading would be at the 0 degree.

2.5.2 Observations and Calculations

Weight applied = 5N

Self-weight of hanger= 10N

Total weight = 15N

Least count of dial gauge=0.01mm

Dial position = 90^o

Table 2-2: Position of load vs. reading of the dial gauge in torsion

Sr #	Position of load (degree)	Reading of dial gauge
1	0^o	0
2	15^o	0.01
3	30^o	0.05
4	45^o	0.09
5	60^o	0.11
6	75^o	0.13
7	90^o	0.14

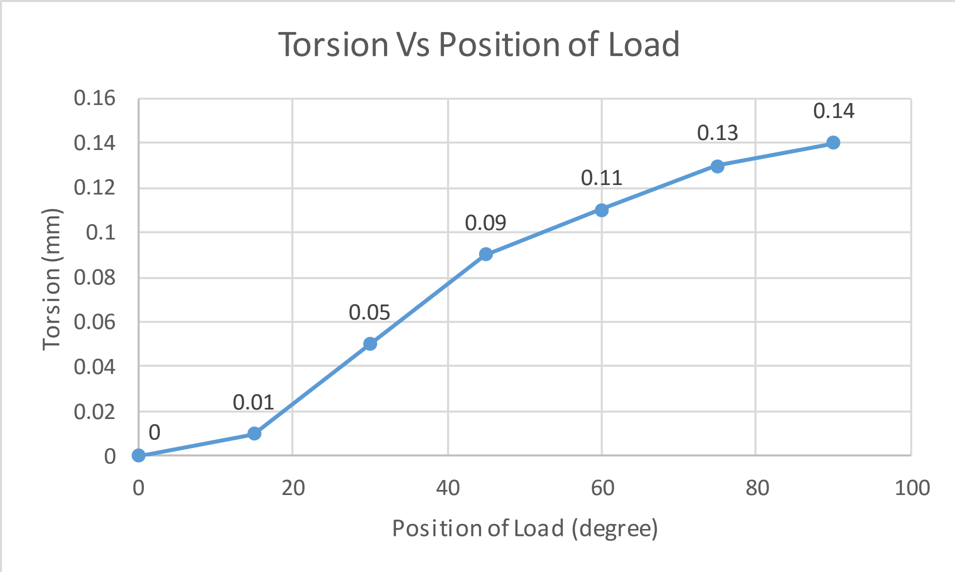


Figure 2-10: Bending vs. position of load in torsion

2.5.3 Statistical Analysis

The mean value of Torsion is given by:

$$\textbf{M.D} = \bar{X} = \frac{0+0.01+0.05+0.09+0.11+0.13+0.14}{7}$$

$$= 0.08 \text{ mm}$$

$$S.D = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \bar{X})}{n-1}}$$

Standard deviation is given as:

$$= \frac{\sqrt{(0-0.08)^2+(0.01-0.08)^2+(0.05-0.08)^2+(0.09-0.08)^2+(0.11-0.08)^2+(0.13-0.08)^2+(0.14-0.08)^2}}{6}$$

= **0.023**

2.6 Combine Effect of bending and torsion

2.6.1 Procedure

- Setup the apparatus as mention above and place the dial gauge at the 45° to the specimen.
- Place the hanger at the zero degree and note the reading
- Now start moving the hanger from 0° to the 90°.
- Take the readings at each angle.

2.6.2 Observations and Calculations

Weight applied = 5N

Self-weight of hanger= 10N

Total weight = 15N

Least count of dial gauge=0.01mm

Dial position = 45º

Table 2-3: Position of load vs. reading of dial gauge in both bending and torsion

Sr #	Position of the load (degree)	Reading of dial gauge (mm)
1	0º	0.28
2	15º	0.27
3	30º	0.24
4	45º	0.21
5	60º	0.19
6	75º	0.16
7	90º	0.12

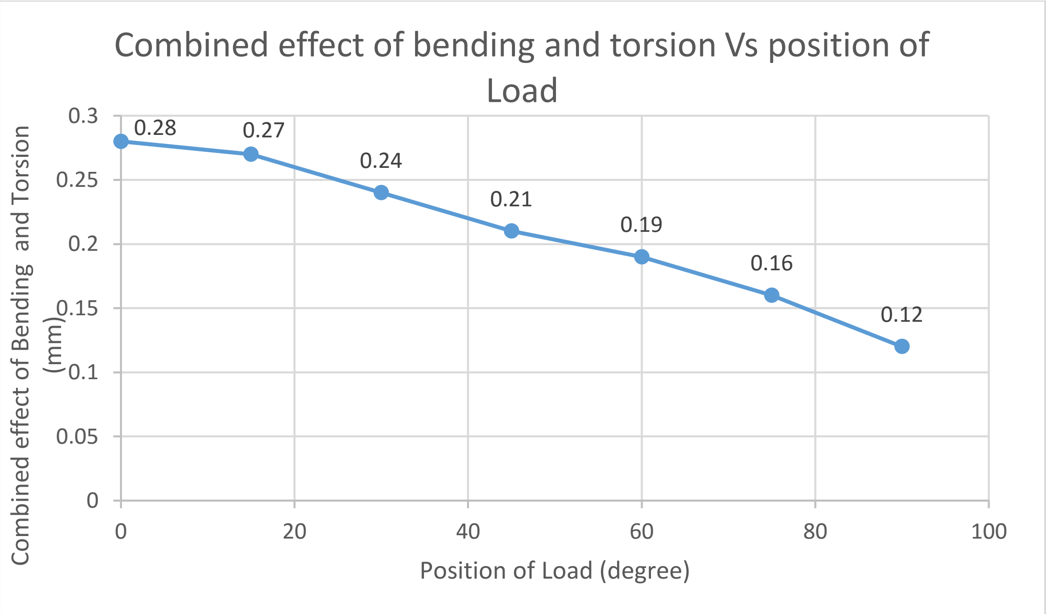


Figure 2-11: Combined effect of bending & torsion vs. position of load

2.6.3 Statistical Analysis

The mean value of Torsion is given by:

$$\mathbf{M.D} = \bar{X} = \frac{0.28+0.27+0.24+0.21+0.19+0.16+0.12}{7}$$

= 0.21mm

$$S.D = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \bar{X})}{n-1}}$$

Standard deviation is given as:

$$= \frac{\sqrt{(0.28-0.21)^2+(0.27-0.21)^2+(0.24-0.21)^2+(0.21-0.21)^2+(0.19-0.21)^2+(0.16-0.21)^2+(0.12-0.21)^2}}{6}$$

= 0.024

2.7 Industrial Applications

Some applications in which you're able to find combined bending and torsion include,

- Drive Shafts design
- Plate girders

2.8 Comments

- Under pure torsion no bending moment is induced in the shaft but due to significant Self Weight of shaft bending moment does induce in the shaft.
- Under the pure bending or pure torsion, the maximum normal stress and the maximum shear stress of the shafts are equal.
- The normal stresses are zero under pure torsion hence the normal stresses in the formulae of all failure theories are consider to be zero.

2.9 Conclusion

The value of the bending moment and torque are measured by applying different loads to the apparatus. It is observed that our practical values are very close to the mean one with the deviation of 0.21%. These deviations are caused by the vibrations and friction in the material.

Lab Session – 3

3.1 Objective

To analyze the variation in experimental and theoretical deflection both (horizontal and vertical) of a quarter circular beam.

3.2 Apparatus

i. Curved Bar Apparatus
ii. Weight
iii. Quarter circular beam apparatus
iv. Dial gauge
v. Vernier Caliper

Figure 3-1: Quarter Circular Curved Bar Apparatus

3.3 Summary of Theory:

3.3.1 Curved bars / deflection of curved bars

A body whose geometric shape is formed by the motion in space of a plane figure is called the cross section of the curved beam); its center of gravity always follows a certain curve (the axis), and the plane of the figure is normal to the curve. A distinction is made between curved beams with constant cross section (for example, the link of a chain composed of oval or circular rings) and with variable cross section (for example, the hook of a crane) and between plane beams (with a plane axis) and three-dimensional beams (with a three-dimensional axis). A special variety of curved beam is the naturally twisted curved beam, whose plane cross-sectional figure moves along its axis and simultaneously rotates around a tangent to the axis (for example, the blade of an aircraft propeller or fan).

The design of a plane curved beam (Figure 1) with a symmetrical cross section (the axis of symmetry lies in the plane of curvature) taking into account the effect of a load lying in the plane of symmetry consists in the determination of stresses normal to the cross section according to the formula.

$$\sigma = \frac{N}{F} + \frac{My}{S_z \rho}$$

where F is the area of the cross section, N is the longitudinal force, M is the bending moment in the cross section defined with respect to the axis Z0 passing through the center of gravity of the cross section (C), y is the distance from the fiber being examined to the neutral axis z, p is the radius of curvature of the fiber being examined, and Sz = Fy0 is the static moment of the cross-sectional area with respect to the axis z. The displacement Y0 of the neutral axis relative to the center of curvature of the curved beam is always directed toward the center of curvature of the curved beam and is usually determined from special tables. For a circular cross section, Y0 ≈ d2/16R; for a rectangular cross section, Y ≈ h2/12R (R is the radius of curvature of the axis of the curved beam; d and h are the diameter and height of the cross section of the beam, respectively). Normal stresses in a curved beam have their maximum values (in absolute magnitudes) near the concave edge of a beam and vary in the cross section according to a hyperbolic law. For small curvatures (R > 5h) the determination of normal stresses can be made in the same way as for a straight beam.

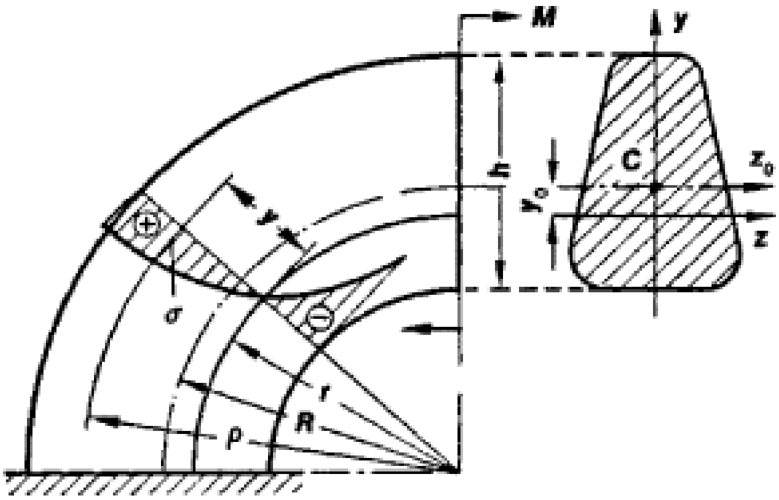


Figure 3-2: Deflection of curved bars

3.3.2 Castiglione's Theorem

Determining the deflection of beams typically requires repeated integration of singularity functions. Castigliano's Theorem lets us use strain energies at the locations of forces to determine the deflections. The Theorem also allows for the determining of deflections for objects with changing cross-sectional areas.

Whenever a load is applied to a spring it will show some deflection. This deflection is directly related to the force applied on the spring to produce that deflection. The force deflection relationship is most conveniently obtained using Castigliano's theorem. Which is stated as

“When forces act on elastic systems subject to small displacements, the displacement corresponding to any force collinear with the force is equal to the partial derivative to the total strain energy with respect to that force.”

And It is given as

$$\delta = \frac{\partial U}{\partial P}$$

In order to derive a necessary formula which governs the behavior of springs, consider a closed coiled spring subjected to an axial load W.

Let,

W = Axial Load

D = Mean Coil Diameter

d = Diameter of Spring Wire N = Number of Active Coils

l = Length of Spring

Wire = πDN

G = Modulus of Rigidity

Δ = Deflection of Spring

Φ = Angle of twist

In 1879, Alberto Castigliano’ an Italian railroad engineer, published a book in which he outlined a method for determining the displacement / deflection & slope at a point in a body. This method which referred to Catigliano’s Theorem is applied to the bodies, having constant temperature & material (homogeneous) with linear elastic behavior.

It states that “The derivative of the strain energy with respect to the applied load gives the deformation corresponding to that load. For a helical spring, the partial derivative of the strain energy w.r.t. the applied load gives the deflection in the spring i.e. $\partial U / \partial W$ = deflection.

Consider a helical compression spring made up of a circular wire and subjected to axial load W as shown in the figure above.

Strain Energy is given by:

$$U = \tfrac{1}{2} T * \Phi \qquad \text{(ii)}$$

Whereas,

$$T = ½ W * D \qquad (iii)$$

$$\Phi = Tl / JG \qquad (iv)$$

(From Torsion formula) putting the values from eqs. # (i), (iii) & (iv) in eq. # (ii) and simplifying, we get;

$$T = 4 W^2 D^3 N / d^4 G \qquad (v)$$

Now applying the castigliano' theorem by taking the partial derivative of the strain energy with respect to the applied load

$$\partial U / \partial W = \Delta = 8 WD^3 N / d^4 G \qquad (v)$$

$$W / \Delta = d^4 G / 8 D^3 N$$

3.3.3 Derivation of the Castigliano's Theorem for Quarter Circular Bar

The general expression of Castigliano's theorem is as follows:

$$\delta = \int_0^S M/EI * \frac{dM}{dW} * ds => \frac{1}{EI} * \int_0^S M * \frac{dM}{dW} * ds$$

where

M = is the moment induced by the force of loading,

E = is the elastic modulus of the beam material,

I = is the moment of inertia of the beam,

dM/dW = is the change in moment with respect to the force of loading and

ds = is the finite quantity of the beam over which integration is to take place. Because the modulus = E and the moment of inertia = I am constants, they are factored out of the integral. The work of deformation, or the moment, can be expressed as the product of the loading force, P, the radius from the center of curvature of the beam R

and the sine of the angle of curvature.

The moment can be expressed by the following equation:

$$M = PRsin\theta$$

The integrating factor ds of the general Castigliano equation can be expressed as follows:

$$ds = Rd\theta$$

The partial derivative of the work of deformation with respect to the component of the force is expressed as a function of the radius of the beam and angle of the deflected beam. For the vertical deflection, the partial derivative is written as:

$$\left(\frac{dM}{dW}\right)_V = Rsin\theta$$

and for the horizontal deflection of a curved beam, the partial derivative is written as:

$$\left(\frac{dM}{dW}\right)_H = R(1 - cos\theta)$$

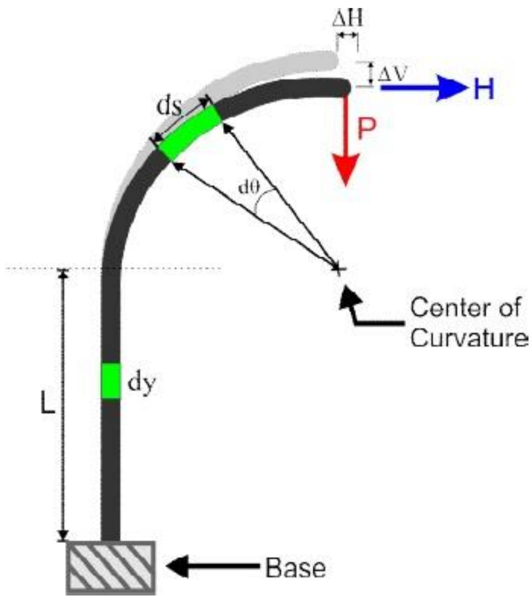


Figure 3-3: Deflection of quarter circular bar

The calculations for the vertical and horizontal deflection of the davit differs lightly from those of the semicircular beam. The davit consists of a quarter circle curved beam and a straight leg that connects to the base as seen in Figure 2. This means that the calculations of deflection must be broken into two parts: one integral for the curved section of the beam and another for the straight leg of the beam. The integration of the curved section of the davit is bound by zero and π/2 because it is a quarter -circle and the integration of the leg is bound by zero at the base of the beam and the length L of the straight segment of the beam.

To calculate the vertical deflection caused by a force of loading for a davit, the general equation of Castigliano's theorem is modified to account for the straight segment of the beam. Substitute Equations 2, 3 and 4 into the general Castigliano equation and append an integral that expresses the moment endured by the straight segment.

$$\Delta V = \frac{1}{EI} * [\int_0^{\frac{\pi}{2}} PRsin\theta * Rsin\theta * Rd\theta + \int_0^L PR * Rdy]$$

Factoring out the constants P and R yields the following expression:

$$\Delta V = \frac{1}{EI} * [PR^3 \int_0^{\pi/2} \sin^2 \theta d\theta + PR^2 \int_0^L dy]$$

Integrating with respect to theta and the y direction yields the following expression

$$\Delta V = \frac{1}{EI} * [PR^3 \left(\frac{\pi}{4}\right) + PR^2L]$$

and can be tidied up a little and the equation for the vertical deflection of the davit can be written as follows:

$$\Delta V = \frac{[\pi PR^3]}{[4EI]} + \frac{[PR^2L]}{[EI]}$$

But as in this case we are neglecting the length l of the straight segment of the beam because in our apparatus the beam is tied from the starting section of the quarter circular beam so L = 0 which will yield us the following final relation

$$\Delta V = \frac{[\pi PR^3]}{[4EI]}$$

The straight segment of the davit must be accounted for in much the same way as it was for the vertical deflection in the formulation of the horizontal deflection calculation.

$$\Delta H = \frac{1}{EI} * [\int_0^{\pi/2} [PRsin\theta + HR(1 - cos\theta)][R(1 - cos\theta)]Rd\theta$$
$$+ \int_0^L [PR + H(R + y][R + y]dy$$

Substituting Equations 2, 3 and 5 into the general expression of Castigliano's theorem and appending an integral to describe the deflection in the straight segment of the davit yields the following: Factoring out the constants P and R and letting the dummy variable H equal zero, previous Equation becomes the following:

$$\Delta H = \frac{1}{EI} * [PR^3 \int_0^{\pi/2} sin\theta - sin\theta cos\theta d\theta + P \int_0^L (R^2 + Ry)dy$$

Integrating for the curvature and straight segment yields the following expression

$$\Delta H = \frac{1}{EI} * [\frac{PR^3}{2} + PR2L + \frac{PRL^2}{2}]$$

Distributing the modulus of elasticity E and moment of inertia I into this Equation yields

$$\Delta H = \left[\frac{PR^3}{2EI}\right] + \left[\frac{PR^2L}{EI}\right] + [\frac{PRL^2}{2EI}]$$

Tidied up a little further, the equation for the horizontal deflection of a davit can be written as follows

$$\Delta H = \left[\frac{PR^3}{2EI}\right] + \left[\frac{PRL}{2EI}\right][2R + L]$$

But as in this case we are neglecting the length l of the straight segment of the beam because in our apparatus the beam is tied from the starting section of the quarter circular beam so L = 0 which will yield us the following final relation

$$\Delta H = [\frac{PR^3}{2EI}]$$

3.4 Procedure:

i. Adjust the quarter circular bar.

ii. Attach two dial gauges for finding vertical as well as horizontal deflection

iii. Load the bar for number of times by an equal amount of 1N each time and note the corresponding readings from dial gauges attached to the apparatus, for vertical and horizontal deflection.

iv. Multiply those observations with the least count of the dial gauges and note out the final deflections

3.5 Observations & Calculations:

Radius of curved bar = R = 100mm

Thickness of the bar = d = 3.175 mm

Moment of Inertia= I= 3.3×10^{-11} m^4

Modulus of Elasticity = E= 207 GN/m^2

3.5.1 Specimen calculations

P = 1 N

R = 100mm = 0.1m

E = 207 GN/m^2

I = 3.3×10^{-11} m^4

$\Delta H = PR^3 / 2EI = 1N * (0.1m)^3 / (2 * 207 * 10^9\ N/m^2 * 3.3 \times 10^{-11}\ m^4)$

Δ H = 0.0000731 m = 0.0731 mm

$\Delta V = \pi PR^3 / 4EI = 3.14 * 1N * (0.1m)^3 / (4 * 207 * 10^9\ N/m^2 * 3.3 \times 10^{-11}\ m^4)$

Δ V = 0.0001149 m = 0.1149 mm

3.5.2 Graph

On graph I plot the deflection against load for horizontal & vertical deflection for the theoretical & practical results. I Draw the best fit straight lines through the points.

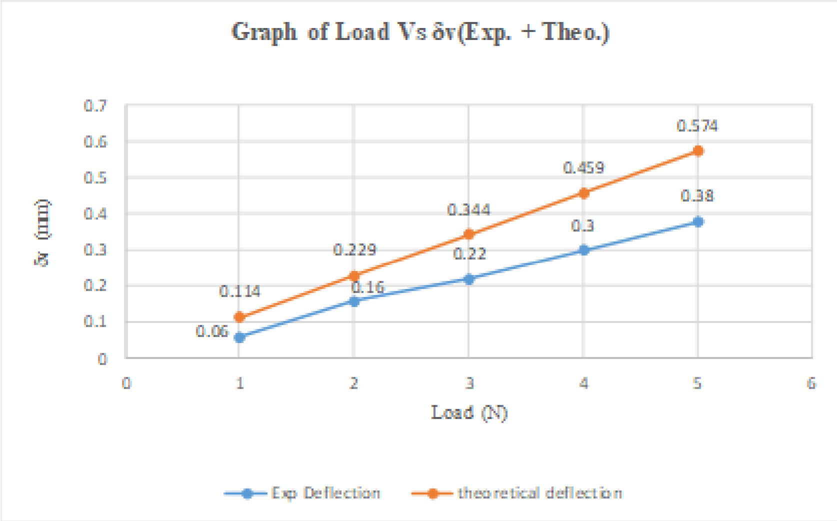


Figure 3-4: Graph between load and vertical deflection

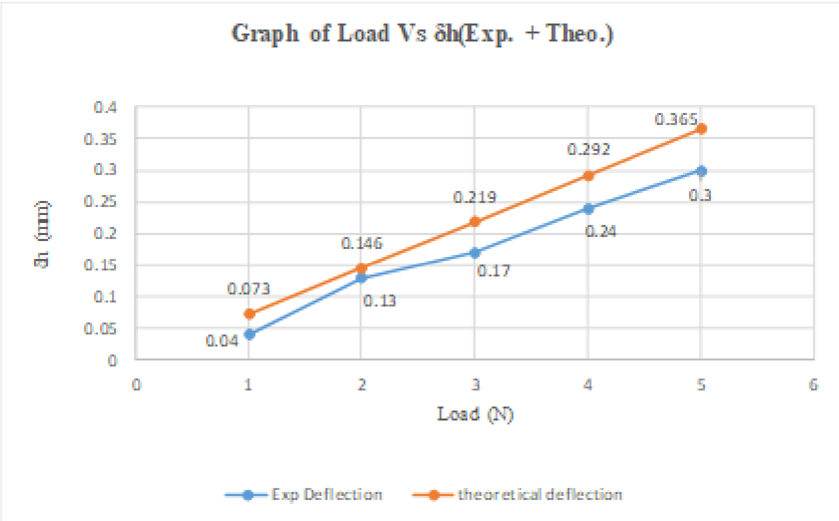


Figure 3-5: graph between load and horizontal deflection

Table 3-1: Calculation of horizontal and vertical deflection with load

Sr. No.	**Load W (N)**	**Dial gauge reading**		**Experimental deflection (mm)**		**Theoretical deflection (mm)**	
		H	*V*	*Δh*	*Δv*	*Δh*= $wr^3/2ei$	*Δv*=$\pi wr^3/4ei$
1	1	4	6	0.04	0.06	0.073	0.114
2	2	13	16	0.13	0.16	0.146	0.229
3	3	17	22	0.17	0.22	0.219	0.344
4	4	24	30	0.24	0.30	0.292	0.459
5	5	30	38	0.30	0.38	0.365	0.574

3.6 Statistical Analysis

$$X_{av} = \frac{1}{n}(x_1 + x_2 + x_3)$$

$$S_x = \sqrt{\frac{1}{n-1}((x_1 - x_{av})^2 + (x_2 - x_{av})^2 + (x_3 - x_{av})^2)}$$

$\delta H_{avg} = 0.12166$

$\delta V_{avg} = 1.83$

$S_H = 0.102$

$S_V = 1.65$

3.7 Industrial Applications:

i. Chains
ii. Hooks
iii. Loops
iv. Bridges

3.8 Comments

i. Vertical Deflection are very high as compared to the horizontal deflections.
ii. The Reason of large vertical deflections is the weight is being applied vertically.
iii. The gravity is also acting in this direction.
iv. Applying a horizontal load will cause deflections in horizontal deflections more prominent

Lab Session – 4

4.1 Objective

To find out the horizontal and vertical deflection of semicircular beam loaded by vertical load using the curved beam apparatus.

4.2 Apparatus

- Curved Bar Apparatus
- Weight
- Semicircular beam apparatus
- Dial gauge
- Vernier Caliper.

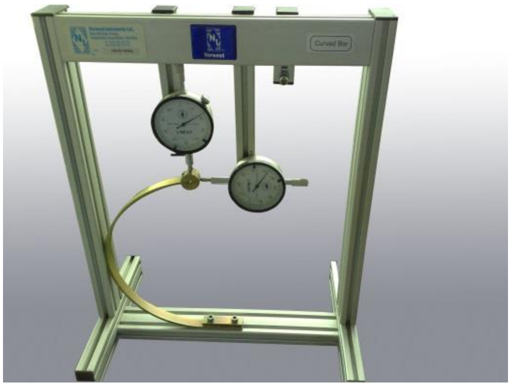


Figure 4-1: Semi Circular Curved Bar Apparatus

4.3 Summary of Theory:

4.3.1 Curved Bars

A body whose geometric shape is formed by the motion in space of a plane figure (called the cross section of the curved beam); its center of gravity always follows a certain curve (the axis), and the plane of the figure is normal to the curve. A distinction is made between curved beams with constant cross section (for example, the link of a chain composed of oval or circular rings) and with variable cross section (for example, the hook of a crane) and between plane beams (with a plane axis) and three-dimensional beams (with a three-dimensional axis). A special variety of curved beam is the naturally twisted curved beam, whose plane cross-sectional figure moves along its axis and simultaneously rotates around a tangent to the axis (for example, the blade of an aircraft propeller or fan).

The design of a plane curved beam (Figure 1) with a symmetrical cross section (the axis of symmetry lies in the plane of curvature) taking into account the effect of a load lying in the plane of symmetry consists in the determination of stresses normal to the cross section according to the formula.

$$\sigma = \frac{N}{F} + \frac{M}{S_z}\frac{y}{\rho}$$

where F is the area of the cross section, N is the longitudinal force, M is the bending moment in the cross section defined with respect to the axis Z0 passing through the center of gravity of the cross section (C), y is the distance from the fiber being examined to the neutral axis z, p is the radius of curvature of the fiber being examined, and Sz = Fy0 is the static moment of the cross-sectional area with respect to the axis z. The displacement Y0 of the neutral axis relative to the center of curvature of the curved beam is always directed toward the center of curvature of the curved beam and is usually determined from special tables. For a circular cross section, Y0 ≈ d2/16R; for a rectangular cross section, Y ≈ h2/12R (R is the radius of curvature of the axis of the curved beam; d and h are the diameter and height of the cross section of the beam, respectively). Normal stresses in a curved beam have their maximum values (in absolute magnitudes) near the concave edge of a beam and vary in the cross section according to a hyperbolic law. For small curvatures (R > 5h) the determination of normal stresses can be made in the same way as for a straight beam.

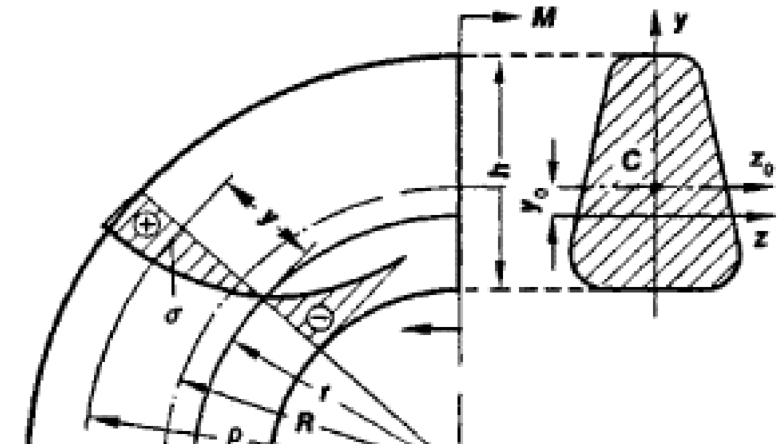


Figure 4-2: Deflection of curved bar

4.4 Derivation of formulae

4.4.1 Derivation of the Castigliano's Theorem for Semi-Circular Bar

The general expression of Castigliano's theorem is as follows:

$$\delta = {}_{0}\int^{s} M/EI * dM/dW * ds \rightarrow 1/EI * {}_{0}\int^{s} M * dM/dW * ds$$

Where;

M ► is the moment induced by the force of loading,

E ► is the elastic modulus of the beam material,

I ► is the moment of inertia of the beam,

dM/dW ► is the change in moment with respect to the force of loading and

ds ► is the finite quantity of the beam over which integration is to take place. Because the modulus ► E and the moment of inertia ►I are constants, they are factored out of the integral. The work of deformation, or the moment, can be expressed as the product of the loading force, P, the radius from the center of curvature of the beam R
and the sine of the angle of curvature.

The moment can be expressed by the following equation:

$$M = PR\sin\theta$$

The integrating factor ds of the general Castigliano equation can be expressed as follows:

$$ds = R\, d\theta$$

The partial derivative of the work of deformation with respect to the component of the force is expressed as a function of the radius of the beam and angle of the deflected beam. For the vertical deflection, the partial derivative is written as:

$$(dM/dW)_V = R\sin\theta$$

and for the horizontal deflection of a curved beam, the partial derivative is written as:

$$(dM/dW)_H = R(1 - \cos\theta)$$

To calculate the vertical deflection of a semicircular beam, substitute Equations 2,3 and 4 into the general expression of Castigliano's theorem (Equation 1). The integration is bounded by zero and π because the beam is a semicircle. This process will yield the following equation.

$$\Delta V = 1/EI * {}_{0}\int^{\pi} PR\sin\theta * R\sin\theta * R\, d\theta \rightarrow PR^3/EI\ {}_{0}\int^{\pi} \sin^2\theta\, d\theta$$

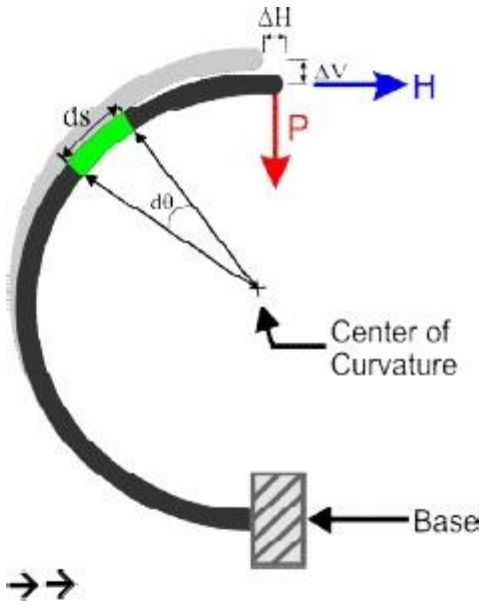


Figure 4-3: Deflection of semi-circular bar

The loading force P, the radius R, the elastic modulus E and the moment of inertia I, are all constants and can be factored out of the integral. Integrating with respect to theta yields the following equation for the vertical deflection of semicircular beam:

And thus, the final relation will be

$$\Delta V = [\pi P R^3] / [2EI]$$

To calculate the horizontal deflection of a semicircular beam, a dummy variable H must m employed as seen in Figure 1. H represents a fictitious loading force in the horizontal direction. Inserting the dummy variable allows for the integration in the horizontal direction. Substituting Equations 2, 3 and 5 into the general expression of Castigliano's theorem yields the following expression.

$$\Delta H = 1/EI * \int_0^{\pi} [PR\sin\theta + HR(1-\cos\theta)][R(1-\cos\theta)]\ R\ d\theta$$

Factoring out the constants P and R, and letting H equal zero, this equation becomes:

$$\Delta H = 1/EI * \int_0^{\pi} PR^3[\sin\theta - \sin\theta\cos\theta)]\ d\theta \rightarrow PR^3/EI \int_0^{\pi} [\sin\theta - \sin\theta\cos\theta)]\ d\theta$$

Integrating this equation with respect to theta yields the equation for the horizontal deflection of a curved beam.

And thus, the final relation will be

$$\Delta H = 2PR^3/EI$$

4.5 Procedure

i. Adjust the semicircular bar.
ii. Attach two dial gauges for finding vertical as well as horizontal deflection
iii. Load the bar for number of times by an equal amount of 1N each time and note the corresponding readings from dial gauges attached to the apparatus, for vertical and horizontal deflection.
iv. Multiply those observations with the least count of the dial gauges and note out the final deflections

4.6 Observations & Calculations

Radius of curved bar = R = 100mm

Width of the bar = b = 3.3 x 10-11 m4

Thickness of the bar = d = 207 GN/m2

Modulus of Elasticity = E= 12.7mm

Moment of Inertia= I= 3.175 mm

4.6.1 Specimen calculations

P = 1 N

R = 100mm = 0.1m

$E = 207\ GN/m^2$

$I = 3.3 \times 10^{-11}\ m^4$

$\Delta H = PR^3 / 2EI = 1N * (0.1m)^3 / (2 * 207 * 10^9\ N/m^2 * 3.3 \times 10^{-11}\ m^4)$

$\Delta H = 0.0000731\ m = 0.0731\ mm$

$\Delta V = \pi PR^3 / 4EI = 3.14 * 1N * (0.1m)^3 / (4 * 207 * 10^9\ N/m^2 * 3.3 \times 10^{-11}\ m^4)$

$\Delta H = 0.0001149\ m = 0.1149\ mm$

Table 4-1: Variation of deflection with load of a semi-circular beam

Sr. No.	**LOAD W (N)**	**Dial Gauge Reading**		**Experimental Deflection (mm)**		**Theoretical Deflection (mm)**	
		H	*V*	*δH*	*δV*	*δH*= $7WR^3/4EI$	*δV*== $\Pi WR^3/2EI$
1	1	1	2	0.01	0.02	0.02	0.02
2	2	9	19	0.09	0.19	0.05	0.04
3	3	13	26	0.13	0.26	0.07	0.06
4	4	19	35	0.19	0.35	0.1	0.08
5	5	20	49	0.20	0.49	0.13	0.1

4.6.2 Graph

On graph plot the deflection against load for horizontal & vertical deflection for the theoretical & practical results. Draw the best fit straight lines through the points.

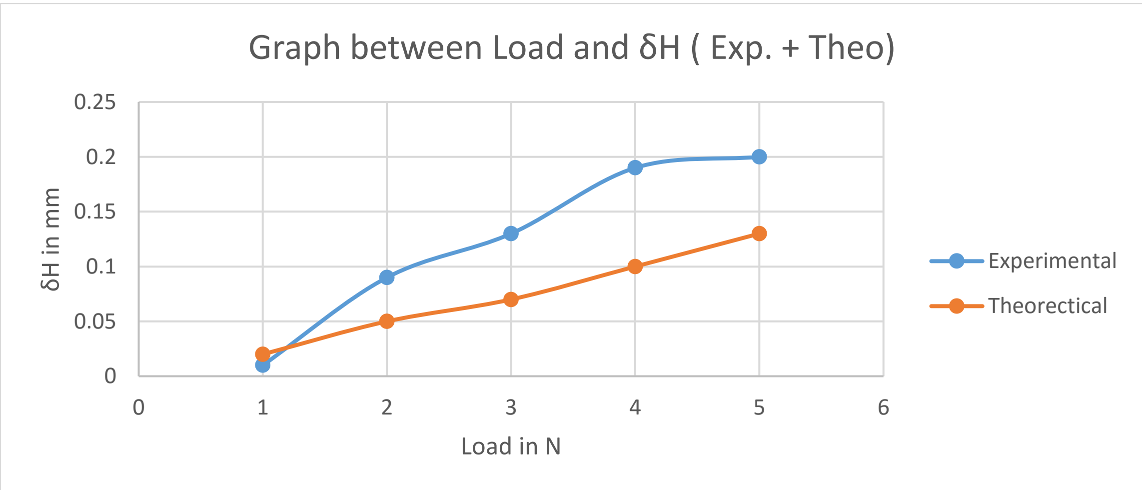


Figure 4-4: Graph between horizontal deflection and load

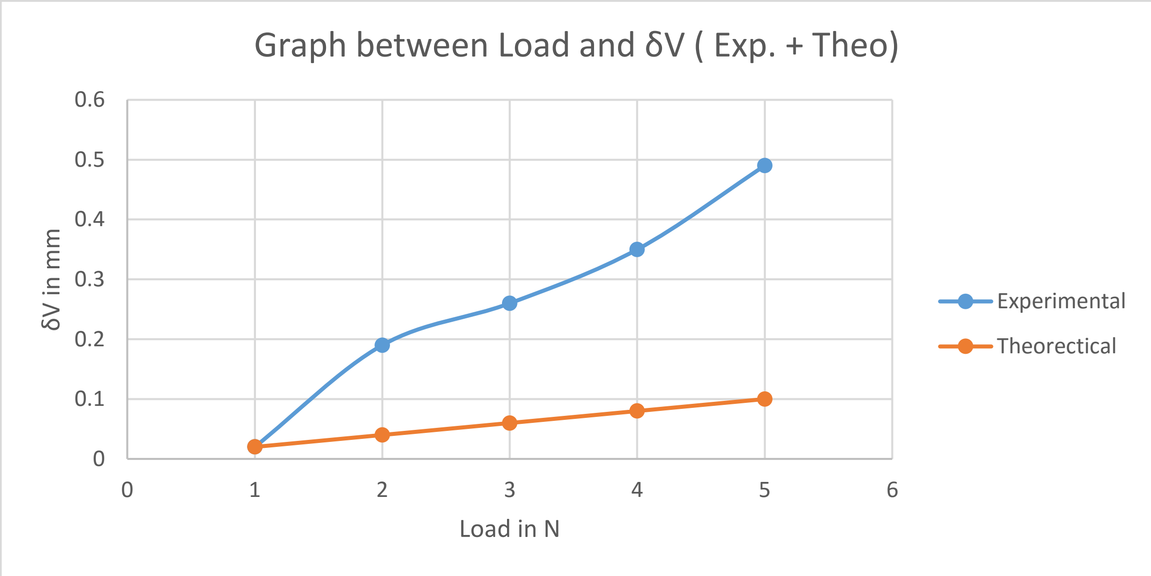


Figure 4-5: Graph between vertical deflection and load

4.7 Statistical Analysis

$$X_{av} = \frac{1}{n}(x_1 + x_2 + x_3)$$

$$S_x = \sqrt{\frac{1}{n-1}((x_1 - x_{av})^2 + (x_2 - x_{av})^2 + (x_3 - x_{av})^2)}$$

X $_{\Delta h}$ $=0.27$

X $_{\Delta v}$ $=0.18$

S $\Delta h = 0.26$

S $\Delta v = 0.15$

4.8 Industrial Applications

- Chains.
- Links.

4.9 Comments

- From analytical values it was observed that, as the load increases horizontal and vertical deflections both increase significantly.
- The horizontal deflection is more compared to vertical deflection.

- With using the Castiglia no’s Theorem Method in calculate the bar deflection, it easier if compared with other method.
- The result of deflection value is not far between experimental and theoretical.
- This experiment is successful that is the deflection bar formula according to the Castiglia no’s Theorem can be approved it punctuality for getting the beam deflection

Lab Session – 5

5.1 Objective

To study the Rockwell hardness testing machine and perform Rockwell hardness test on HRA and HRC materials by using diamond indenter.

5.2 Apparatus

- Rockwell Hardness Testing machine
- Specimen (Material Hardness Code 91.3 HR15N N 122-703)

Figure 5-1: Rockwell Testing Machine

Figure 5-2: Specimen Material

5.3 Theory

5.3.1 Hardness Tests

There are mainly 5 hardness tests that are used for non-destructive testing of materials. Hardness test is performed to evaluate the properties of materials such as strength, ductility and wear resistance and so it helps to determine whether a material treatment or use of that material is suitable for the specific purpose.

5.3.2 Rockwell Hardness Test

Rockwell hardness test is the simplest and the most cost-effective test which involves applying a specific load on material using an indenter and measuring how far indenter penetrates.

Working

Rockwell hardness test uses a conical diamond as an indenter. Initially minor load is applied. An additional major force is then applied for a predetermined period known as Dwell Period and then reduced to minor load state.

5.3.3 Brinell Hardness Test

The Brinell hardness test method as used to determine Brinell hardness, is defined in ASTM E10. Most commonly it is used to test materials that have a structure that is too coarse or that have a surface that is too rough to be tested using another test method, e.g., castings and forgings.

Working

Brinell testing often use a very high-test load (3000 kgf) and a 10mm diameter indenter so that the resulting indentation averages out most surface and sub-surface inconsistencies.

The Brinell method applies a predetermined test load (F) to a carbide ball of fixed diameter (D) which is held for a predetermined time period and then removed. The resulting impression is measured with a specially designed Brinell microscope or optical system across at least two diameters – usually at right angles to each other and these results are averaged (d). Although the calculation can be used to generate the Brinell number, most often a chart is then used to convert the averaged diameter measurement to a Brinell hardness number.

5.3.4 Vickers Hardness Test

The Vickers hardness test method consists of indenting the test material with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136 degrees between opposite faces subjected to a load of 1 to 100 kgf.

Working

The full load is normally applied for 10 to 15 seconds. The two diagonals of the indentation left in the surface of the material after removal of the load are measured using a microscope and their average calculated. The area of the sloping surface of the indentation is calculated. The Vickers hardness is the quotient obtained by dividing the kgf load by the square mm area of indentation.

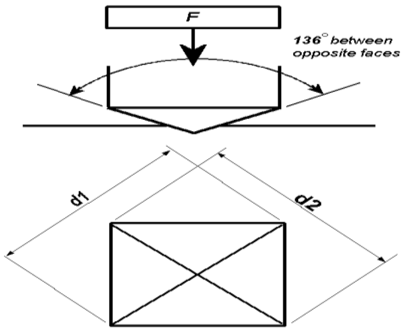


Figure 5-3: Vickers Hardness Test

5.3.5 Knoop Hardness Test

The Knoop hardness test method, also referred to as a microhardness test method, is mostly used for small parts, thin sections, or case depth work.

Working

The Vickers method is based on an optical measurement system. The Microhardness test procedure, ASTM E-384, specifies a range of light loads using a diamond indenter to make an indentation which is measured and converted to a hardness value. It is very useful for testing on a wide type of materials as long as test samples are carefully prepared.

5.3.6 Meyer Hardness Test

The Meyer hardness test is a rarely used hardness test based upon projected area of an impression. This is a more fundamental measurement of hardness than other hardness tests which are based on the surface area of an indentation. The principle behind the test is that the mean pressure required to test the material is the measurement of the hardness of the material. The mean pressure is calculated by dividing the load by the projected area of the indentation. The result is called the Meyer hardness, which has units of megapascals (MPa).

5.3.7 Destructive and Non-Destructive Test

Table 5-1: Diff. B/W Destructive& non-destructive test

Non-Destructive Test	Destructive Test
Used for finding out defects of material	Used for finding out the properties of the material
Load is not applied on the material	Load is applied on the material
No load applications, so no chance for material damage	Due to load application, material get damaged
No requirement of special equipment’s	Special equipment’s are required
Non expensive	Expensive
Less skill	Skill is required
e.g. dye penetrate test, ultrasonic, radiography, etc.	e.g. tensile test, compression test, hardness test, etc.

5.4 Procedure

- I chose one of the given specimens and noted down the code written on it.
- I put the sample material on the anvil and let the instructor do the rest.
- Instructor put the sample material on the anvil at right place and raised the anvil till the indenter just touched the material.
- Instructor set the Rockwell Measuring Scale as per according to material which was HR15N and then set the dwell period up-to 6 seconds.
- Then exchange scale was set which was HRC.
- Then the instructor pressed the start button and testing started.
- One of the group students recorded the video of whole test to measure the value of Major Load, Minor Load, exchange scale value.
- Then, the whole group noted down the value of major load and minor load.
- We also noted down the value of Hardness of material.

5.5 Observations and Calculations

Sr#	Rockwell Measuring scale	Indenter	Major Load(kgf)	Minor Load(kgf)	Hardness	Exchange Scale Value

1.	HR15N	DIAMOND TIP	15	2.98	81	41.2 HRC
2.	HRB	DIAMOND TIP	100	10	91.8	
3.	HR30T	DIAMOND TIP	30	2.98	1.8	
4.	HR30N	DIAMOND TIP	30	3	53.1	32.8 HRC
6.	HRC	DIAMOND TIP	150	10	2.0	0 HRB

5.6 Comments

- Different materials have different hardness.
- Value of hardness is measured in different scales.
- One scale value can be obtained in exchange scale.

Lab Session – 6

6.1 Objective

To study the Rockwell hardness testing machine and perform Rockwell hardness test on HRB material by using Ball indenter.

6.2 Apparatus

- Rockwell Hardness Testing machine
- Specimen

Figure 6-1: Rockwell Testing Machine

Figure 6-2: Specimen Material Sample

6.3 Theory

6.3.1 Hardness Tests

There are mainly 5 hardness tests that are used for non-destructive testing of materials. Hardness test is performed to evaluate the properties of materials such as strength, ductility and wear resistance and so it helps to determine whether a material treatment or use of that material is suitable for the specific purpose.

6.3.2 Rockwell Hardness Test

Rockwell hardness test is the simplest and the most cost-effective test which involves applying a specific load on material using an indenter and measuring how far indenter penetrates.

Working

Rockwell hardness test uses a conical diamond as an indenter. Initially minor load is applied. An additional major force is then applied for a predetermined period known as Dwell Period and then reduced to minor load state.

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The Brinell hardness test method as used to determine Brinell hardness, is defined in ASTM E10. Most commonly it is used to test materials that have a structure that is too coarse or that have a surface that is too rough to be tested using another test method, e.g., castings and forgings.

Working

Brinell testing often use a very high-test load (3000 kgf) and a 10mm diameter indenter so that the resulting indentation averages out most surface and sub-surface inconsistencies.

The Brinell method applies a predetermined test load (F) to a carbide ball of fixed diameter (D) which is held for a predetermined time period and then removed. The resulting impression is measured with a specially designed Brinell microscope or optical system across at least two diameters – usually at right angles to each other and these results are averaged (d). Although the calculation can be used to generate the Brinell number, most often a chart is then used to convert the averaged diameter measurement to a Brinell hardness number.

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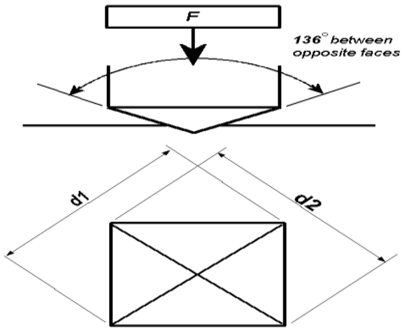
Working

The full load is normally applied for 10 to 15 seconds. The two diagonals of the indentation left in the surface of the material after removal of the load are measured using a microscope and their average calculated. The area of the sloping surface of the indentation is calculated. The Vickers hardness is the quotient obtained by dividing the kgf load by the square mm area of indentation.



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Working

The Vickers method is based on an optical measurement system. The Microhardness test procedure, ASTM E-384, specifies a range of light loads using a diamond indenter to make an indentation which is measured and converted to a hardness value. It is very useful for testing on a wide type of materials as long as test samples are carefully prepared.

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The Meyer hardness test is a rarely used hardness test based upon projected area of an impression. This is a more fundamental measurement of hardness than other hardness tests which are based on the surface area of an indentation. The principle behind the test is that the mean pressure required to test the material is the measurement of the hardness of the material. The mean pressure is calculated by dividing the load by the projected area of the indentation. The result is called the Meyer hardness, which has units of megapascals (MPa).

6.3.7 Destructive and Non-Destructive Test

Table 6-1: Diff. B/W Destructive& non-destructive test

Non-Destructive Test	Destructive Test
Used for finding out defects of material	Used for finding out the properties of the material
Load is not applied on the material	Load is applied on the material
No load applications, so no chance for material damage	Due to load application, material get damaged
No requirement of special equipment's	Special equipment's are required
Non expensive	Expensive
Less skill	Skill is required
e.g. dye penetrate test, ultrasonic, radiography, etc.	e.g. tensile test, compression test, hardness test, etc.

6.4 Procedure

- I chose one of the given specimens and noted down the code written on it.
- I put the sample material on the anvil.
- I placed the sample material on the anvil at right place and raised the anvil till the indenter just touched the material.
- I set the Rockwell Measuring Scale as per according to material which was HRB and then set the dwell period up-to10 seconds.
- Then exchange scale was set which was HRB.
- I repeated the same procedure for 8 second dwell period and HRC exchange scale.
- Then, the whole group noted down the value of major load and minor load.
- We also noted down the value of Hardness of material.

6.5 Observations and Calculations

Sr#	Rockwell Measuring scale	Indenter	Major Load(kgf)	Minor Load(kgf)	Hardness	Exchange Scale Value
1.	HRB	Ball Indenter	100	10	77.4	77.4 HRB
2.	HRB	Ball Indenter	100	10	78.0	0.00 HRC

6.6 Comments

- Different materials have different hardness.
- Value of hardness is measured in different scales.
- One scale value can be obtained in exchange scale.
- Ball indenter is basically used for soft materials.
- Diamond tip indenter is basically used for harder materials.
- Variation in the value of hardness is due to inexperience.

Lab Session – 7

7.1 Objective

To perform tensile test on a specimen of mild steel (MS) by using universal testing machine (UTM)

7.2 Apparatus

- Specimen (Plain Steel)
- Universal Testing Machine Control Unit
- Computer System to compile the results

7.3 Theory

7.3.1 Universal Testing Machine

A machine used to test specimens for tensile strength, compressive strength, shear strength and to perform bend test along other important laboratory tests. The primary use of the testing machine is to create the stress strain diagram. Universal testing machine (UTM) is called so because of the versatility of its application. The following tests can be performed with it

- Tension Test
- Compression Test
- Bending Test

Figure 7-1: Universal Testing Machine for mild steel

7.3.1.1 Parts of Universal Testing Machine

The Universal Testing Machine consists of two main parts

1. The loading unit
2. The control panels

Loading Unit

In this unit actual loading of the specimen takes place - consists of three cross heads namely upper head, middle head and lower head. Using appropriate cross heads tensile, compressive, shear, bending load with the help of different attachment can be applied. Loading unit of a UTM consists of:

1. Upper cross head
2. Lower cross head
3. Table Upper Cross Head

It is used to clamp testing specimen from top

Lower Cross Head

It is used to clamp testing specimen from below

Table

It is used to place the specimen, used for compression test

Elongation Scale

An elongation scale, which measures the relative movement between the lower table and the lower cross-head, is also provided with the loading unit.

Control Unit

These include the electric control devices, the hydraulic control devices and the load indicating devices.

Electric Control Devices

These are in the form of four switches set on the left side of the panel face. The upper and lower push switches are for moving the lower cross-head up and down respectively. The remaining two are the ON and OFF switches for the hydraulic pump.

Hydraulic Control Devices

These are a pair of control valves set on the table or the control panel.

These are:

- The right control valves
- The left control valves

The right control valve is the inlet valve and the left control valve is the return valve.

Load indicating Devices

A means of providing the test result is needed. Some older machines have dial or digital displays and chart recorder. Many newer machines have a computer interface for analysis and printing.

Extensometer

An instrument used to measure elongation in the material

Necking

At a certain maximum value of the load the diameter of a portion of the specimen begins to decrease, because of local instability. This phenomenon is known as necking. To visualize the necking effect of a material, a tensile test is conducted on a specimen of the material. The test specimen is placed in a testing machine which is used to apply a centric load P. At a certain maximum stress, the diameter of a portion of the specimen start to decrease at the weaker point and the material shows necking effect as shown in figure.

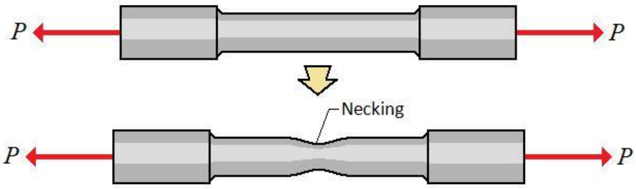


Figure 7-2: Necking Phenomenon for mild steel

7.4 Procedure

- Measure the length of the specimen by a Vernier Caliper Fix the specimen between jaws of UTM
- Apply tensile load on the specimen by the hydraulic system
- Increase the load gradually up to the point at which the specimen deforms Record the load and extension or compression of the specimen

7.5 Observations and Calculations

Length of specimen = 120mm

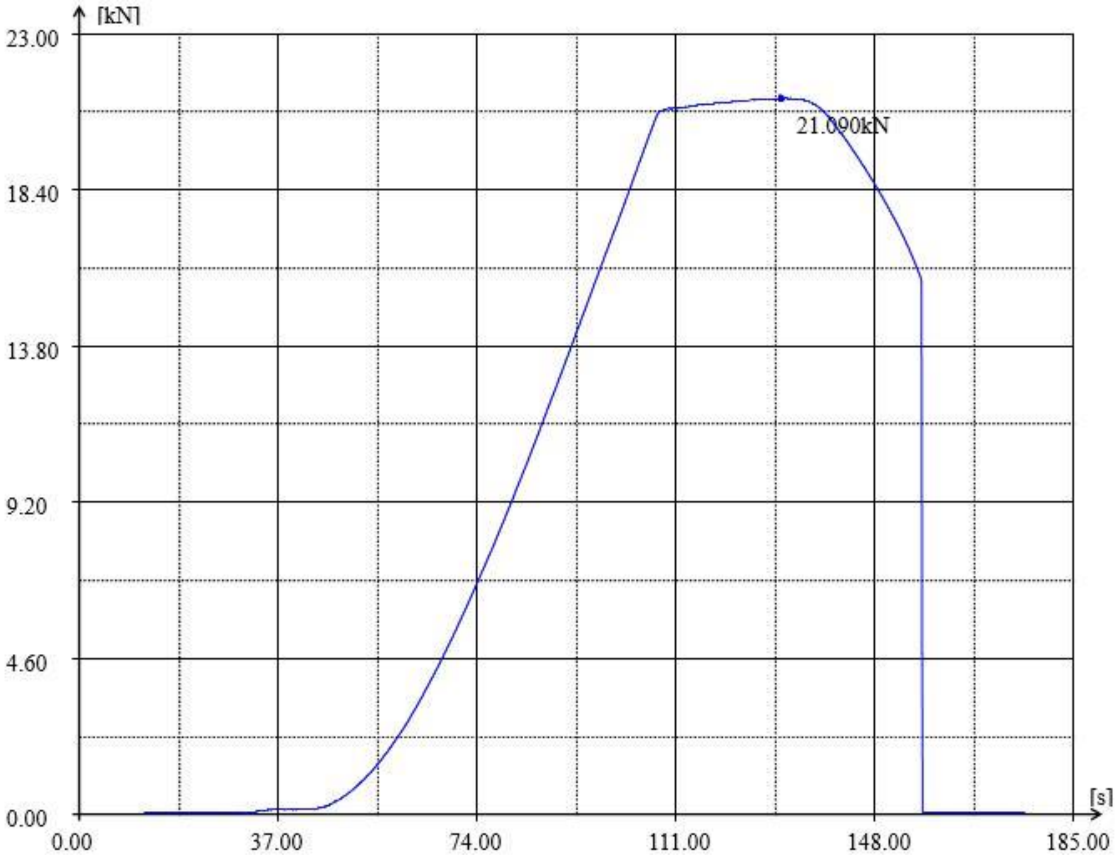
Length of the holding section = 50mm Area of the specimen= πr^2 = 33.2mm^2

Diameter of specimen = 6.50mm Diameter of the holding section = 9.30mm

Table 7-1: Calculations for Mild Steel

Serial #	Specimen Material	Diameter of the specimen (mm)	Breaking Load (kN)	Breaking Strength (Pa)
1	Plain Steel	6.50	21.1	630

7.6 Graph



7.7 Comments

Due to poor finishing of the specimen, the results and graph obtained were not accurate.

Lab Session – 8

8.1 Objective

To perform tensile test on a specimen of aluminum (Al) by using universal testing machine (UTM).

8.2 Apparatus:

- Specimen (Mild Steel)
- Universal Testing Machine Control Unit
- Computer System to compile the results

8.3 Theory

8.3.1 Universal Testing Machine

A machine used to test specimens for tensile strength, compressive strength, shear strength and to perform bend test along other important laboratory tests. The primary use of the testing machine is to create the stress strain diagram. Universal testing machine (UTM) is called so because of the versatility of its application. The following tests can be performed with it: -

- Tension Test
- Compression Test
- Bending Test

Figure 8-1: Universal Testing Machine for Aluminum

8.3.1.1 Parts of Universal Testing Machine

The Universal Testing Machine consists of two main parts

1. The loading unit
2. The control panels.

Loading Unit

In this unit actual loading of the specimen takes place - consists of three cross heads namely upper head, middle head and lower head. Using appropriate cross heads tensile, compressive, shear, bending load with the help of different attachment can be applied. Loading unit of a UTM consists of:

1. Upper cross head
2. Lower cross head
3. Table Upper Cross Head

It is used to clamp testing specimen from top

Lower Cross Head

It is used to clamp testing specimen from below

Table

It is used to place the specimen, used for compression test

Elongation Scale

An elongation scale, which measures the relative movement between the lower table and the lower cross-head, is also provided with the loading unit.

Control Unit

These include the electric control devices, the hydraulic control devices and the load indicating devices.

Electric Control Devices

These are in the form of four switches set on the left side of the panel face. The upper and lower push switches are for moving the lower cross-head up and down respectively. The remaining two are the ON and OFF switches for the hydraulic pump.

Hydraulic Control Devices:

These are a pair of control valves set on the table or the control panel.

These are:

- The right control valves
- The left control valves

The right control valve is the inlet valve and the left control valve is the return valve.

Load indicating Devices

A means of providing the test result is needed. Some older machines have dial or digital displays and chart recorder. Many newer machines have a computer interface for analysis and printing.

Extensometer

An instrument used to measure elongation in the material

Necking

At a certain maximum value of the load the diameter of a portion of the specimen begins to decrease, because of local instability. This phenomenon is known as necking. To visualize the necking effect of a material, a tensile test is conducted on a specimen of the material. The test specimen is placed in a testing machine which is used to apply a centric load P. At a certain maximum stress, the diameter of a portion of the specimen start to decrease at the weaker point and the material shows necking effect as shown in figure.

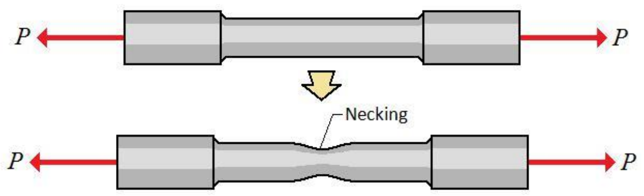


Figure 8-2: Necking Phenomenon for aluminum

Procedure:

- Measure the length of the specimen by a Vernier Caliper Fix the specimen between jaws of UTM
- Apply tensile load on the specimen by the hydraulic system
- Increase the load gradually up to the point at which the specimen deforms Record the load and extension or compression of the specimen

8.4 Observations and Calculations:

Length of specimen = 110mm

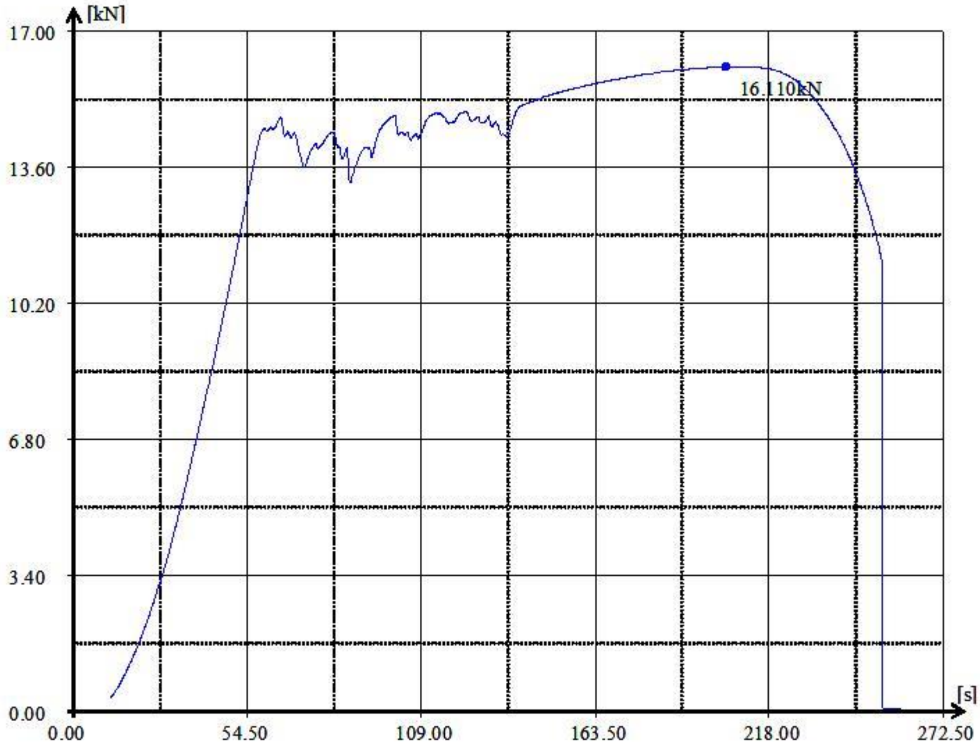
Length of the holding section = 50.0mm Area of the specimen= πr^2 = 44.2mm^2

Diameter of specimen = 7.50mm Diameter of the holding section = 9.30mm

Table 8-1: Calculations for Aluminium

Serial #	Specimen Material	Diameter of the specimen (mm)	Breaking Load (kN)	Breaking Strength (MPa)
1	Mild Steel	7.50	16.1	364

8.5 Graph



8.6 Comments

Due to some error in the UTM, the results were not accurate as expected. Moreover, the graph obtained is not according the expected results.

Lab Session – 9

9.1 Objective

To perform tensile test on a specimen of copper (Cu) by using universal testing machine (UTM).

9.2 Apparatus

- Specimen (Aluminum)
- Universal Testing Machine Control Unit
- Computer System to compile the results

9.3 Theory

9.3.1 Universal Testing Machine

A machine used to test specimens for tensile strength, compressive strength, shear strength and to perform bend test along other important laboratory tests. The primary use of the testing machine is to create the stress strain diagram. Universal testing machine (UTM) is called so because of the versatility of its application. The following tests can be performed with it: -

- Tension Test
- Compression Test
- Bending Test

Figure 9-1: Universal Testing Machine for copper

9.3.1.1 Parts of Universal Testing Machine

The Universal Testing Machine consists of two main parts

1. The loading unit
2. The control panels

Loading Unit

In this unit actual loading of the specimen takes place - consists of three cross heads namely upper head, middle head and lower head. Using appropriate cross heads tensile, compressive, shear, bending load with the help of different attachment can be applied. Loading unit of a UTM consists of:

1. Upper cross head
2. Lower cross head
3. Table Upper Cross Head

It is used to clamp testing specimen from top

Lower Cross Head

It is used to clamp testing specimen from below

Table

It is used to place the specimen, used for compression test

Elongation Scale

An elongation scale, which measures the relative movement between the lower table and the lower cross-head, is also provided with the loading unit.

Control Unit

These include the electric control devices, the hydraulic control devices and the load indicating devices.

Electric Control Devices

These are in the form of four switches set on the left side of the panel face. The upper and lower push switches are for moving the lower cross-head up and down respectively. The remaining two are the ON and OFF switches for the hydraulic pump.

Hydraulic Control Devices:

These are a pair of control valves set on the table or the control panel.

These are:

- The right control valves
- The left control valves

The right control valve is the inlet valve and the left control valve is the return valve.

Load indicating Devices

A means of providing the test result is needed. Some older machines have dial or digital displays and chart recorder. Many newer machines have a computer interface for analysis and printing.

Extensometer

An instrument used to measure elongation in the material

Necking

At a certain maximum value of the load the diameter of a portion of the specimen begins to decrease, because of local instability. This phenomenon is known as necking. To visualize the necking effect of a material, a tensile test is conducted on a specimen of the material. The test specimen is placed in a testing machine which is used to apply a centric load P. At a certain maximum stress, the diameter of a portion of the specimen start to decrease at the weaker point and the material shows necking effect as shown in figure.

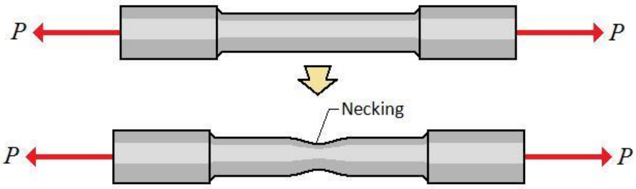


Figure 9-2: Necking Phenomenon for copper

9.4 Procedure

- Measure the length of the specimen by a Vernier Caliper Fix the specimen between jaws of UTM
- Apply tensile load on the specimen by the hydraulic system
- Increase the load gradually up to the point at which the specimen deforms Record the load and extension or compression of the specimen

9.5 Observations and Calculations

Length of specimen = 68.0mm

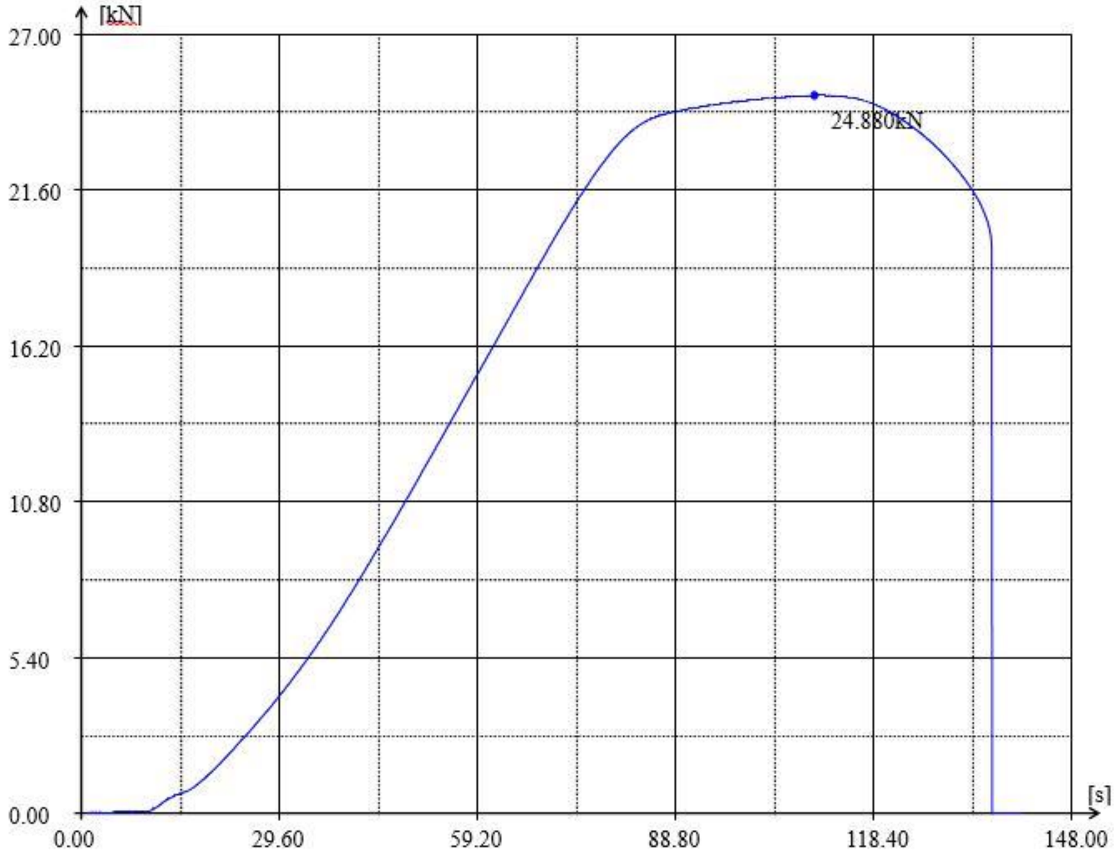
Length of the holding section = 50.0mm Area of the specimen= πr^2 = 28.3mm^2

Diameter of specimen = 6.00mm Diameter of the holding section = 9.2mm

Table 9-1: Calculations for Copper

Serial #	Specimen Material	Diameter of the specimen (mm)	Breaking Load (kN)	Breaking Strength (MPa)
1	Aluminum	6.00	24.9	880

9.6 Graph



9.7 Comments

The finale results obtained were close to the theorized results. The graph shows minimal distortion

Lab Session – 10

10.1 Objective

To perform tensile test on a specimen of brass by using universal testing machine (UTM).

10.2 Apparatus

- Specimen (Brass)
- Universal Testing Machine Control Unit
- Computer System to compile the results

10.3 Theory

10.3.1 Universal Testing Machine

A machine used to test specimens for tensile strength, compressive strength, shear strength and to perform bend test along other important laboratory tests. The primary use of the testing machine is to create the stress strain diagram. Universal testing machine (UTM) is called so because of the versatility of its application. The following tests can be performed with it: -

- Tension Test
- Compression Test
- Bending Test

Figure 10-1: Universal Testing Machine for Brass

10.3.1.1 Parts of Universal Testing Machine

The Universal Testing Machine consists of two main parts

3. The loading unit
4. The control panels

Loading Unit

In this unit actual loading of the specimen takes place - consists of three cross heads namely upper head, middle head and lower head. Using appropriate cross heads tensile, compressive, shear, bending load with the help of different attachment can be applied. Loading unit of a UTM consists of:

4. Upper cross head
5. Lower cross head
6. Table Upper Cross Head

It is used to clamp testing specimen from top

Lower Cross Head

It is used to clamp testing specimen from below

Table

It is used to place the specimen, used for compression test

Elongation Scale

An elongation scale, which measures the relative movement between the lower table and the lower cross-head, is also provided with the loading unit.

Control Unit

These include the electric control devices, the hydraulic control devices and the load indicating devices.

Electric Control Devices

These are in the form of four switches set on the left side of the panel face. The upper and lower push switches are for moving the lower cross-head up and down respectively. The remaining two are the ON and OFF switches for the hydraulic pump.

Hydraulic Control Devices:

These are a pair of control valves set on the table or the control panel.

These are:

- The right control valves
- The left control valves

The right control valve is the inlet valve and the left control valve is the return valve.

Load indicating Devices

A means of providing the test result is needed. Some older machines have dial or digital displays and chart recorder. Many newer machines have a computer interface for analysis and printing.

Extensometer

An instrument used to measure elongation in the material

Necking

At a certain maximum value of the load the diameter of a portion of the specimen begins to decrease, because of local instability. This phenomenon is known as necking. To visualize the necking effect of a material, a tensile test is conducted on a specimen of the material. The test specimen is placed in a testing machine which is used to apply a centric load P. At a certain maximum stress, the diameter of a portion of the specimen start to decrease at the weaker point and the material shows necking effect as shown in figure.

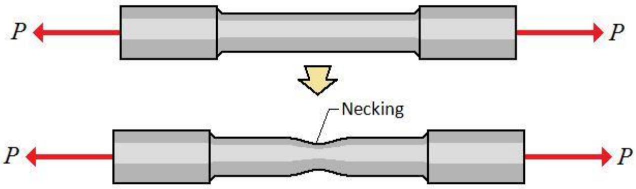


Figure 10-2: Necking Phenomenon for Brass

10.4 Procedure

- Measure the length of the specimen by a Vernier Caliper Fix the specimen between jaws of UTM
- Apply tensile load on the specimen by the hydraulic system
- Increase the load gradually up to the point at which the specimen deforms Record the load and extension or compression of the specimen

10.5 Observations and Calculations

Length of specimen = 108mm

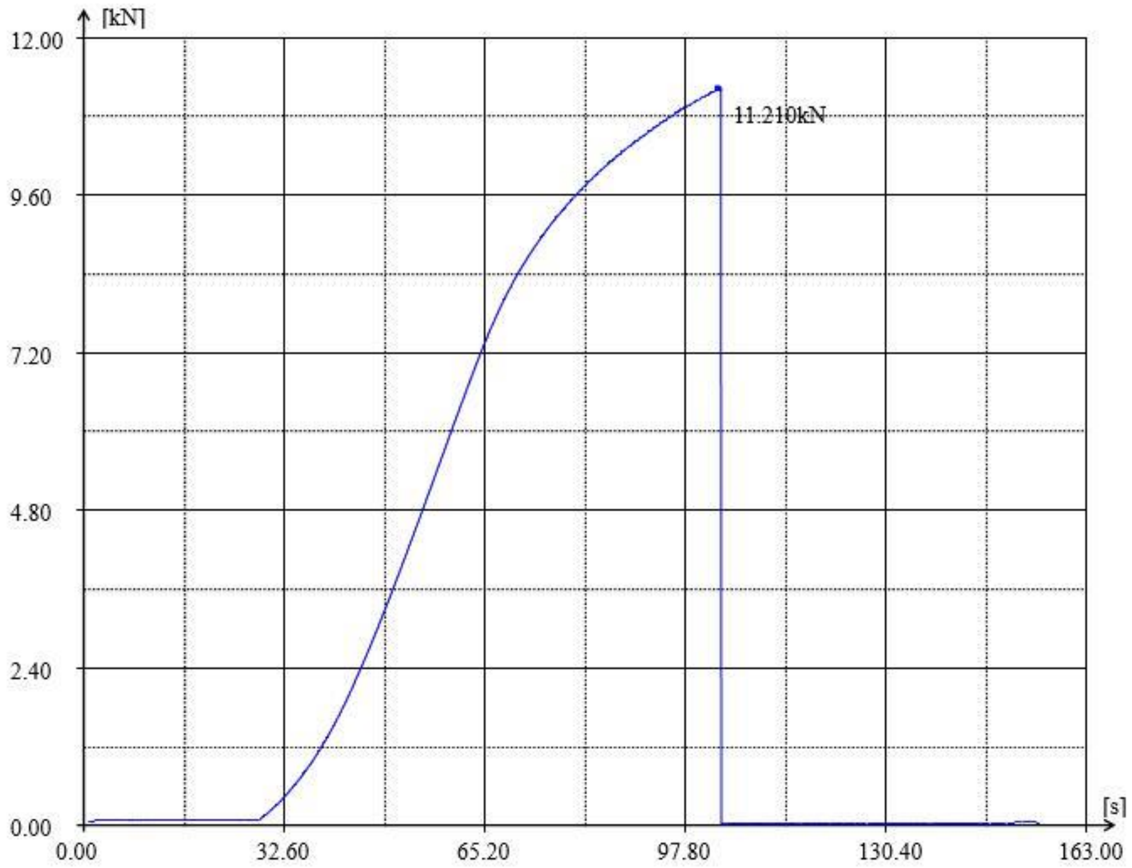
Length of the holding section = 50mm Area of the specimen= πr^2 = 38.5mm^2

Diameter of specimen = 7.00mm Diameter of the holding section = 9.30mm

Table 10-1: Calculations for Brass

Serial #	Specimen Material	Diameter of the specimen (mm)	Breaking Load (kN)	Breaking Strength (Pa)
1	Brass	7.00	11.2	290

10.6 Graph



10.7 Comments

Due to poor finishing of the specimen, the results and graph obtained were not accurate

Lab Session – 11

11.1 Objective

To perform tensile test on a specimen of plain steel alloy by using universal testing machine (UTM).

11.2 Apparatus

- Specimen (Copper)
- Universal Testing Machine Control Unit
- Computer System to compile the results

11.3 Theory

11.3.1 Universal Testing Machine

A machine used to test specimens for tensile strength, compressive strength, shear strength and to perform bend test along other important laboratory tests. The primary use of the testing machine is to create the stress strain diagram. Universal testing machine (UTM) is called so because of the versatility of its application. The following tests can be performed with it:

- Tension Test
- Compression Test
- Bending Test

Figure 11-1: Universal Testing Machine for plain steel alloy

11.3.1.1 Parts of Universal Testing Machine

The Universal Testing Machine consists of two main parts

1. The loading unit
2. The control panels

Loading Unit

In this unit actual loading of the specimen takes place - consists of three cross heads namely upper head, middle head and lower head. Using appropriate cross heads tensile, compressive, shear, bending load with the help of different attachment can be applied. Loading unit of a UTM consists of:

1. Upper cross head
2. Lower cross head
3. Table Upper Cross Head

It is used to clamp testing specimen from top

Lower Cross Head

It is used to clamp testing specimen from below

Table

It is used to place the specimen, used for compression test

Elongation Scale

An elongation scale, which measures the relative movement between the lower table and the lower cross-head, is also provided with the loading unit.

Control Unit

These include the electric control devices, the hydraulic control devices and the load indicating devices.

Electric Control Devices

These are in the form of four switches set on the left side of the panel face. The upper and lower push switches are for moving the lower cross-head up and down respectively. The remaining two are the ON and OFF switches for the hydraulic pump.

Hydraulic Control Devices:

These are a pair of control valves set on the table or the control panel.

These are:

- The right control valves
- The left control valves

The right control valve is the inlet valve and the left control valve is the return valve.

Load indicating Devices

A means of providing the test result is needed. Some older machines have dial or digital displays and chart recorder. Many newer machines have a computer interface for analysis and printing.

Extensometer

An instrument used to measure elongation in the material

Necking

At a certain maximum value of the load the diameter of a portion of the specimen begins to decrease, because of local instability. This phenomenon is known as necking. To visualize the necking effect of a material, a tensile test is conducted on a specimen of the material. The test specimen is placed in a testing machine which is used to apply a centric load P. At a certain maximum stress, the diameter of a portion of the specimen start to decrease at the weaker point and the material shows necking effect as shown in figure.

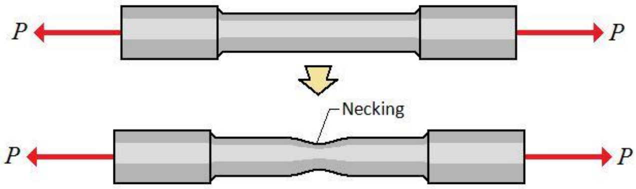


Figure 11-2: Necking Phenomenon for plain steel alloy

11.4 Procedure

- Measure the length of the specimen by a Vernier Caliper Fix the specimen between jaws of UTM
- Apply tensile load on the specimen by the hydraulic system
- Increase the load gradually up to the point at which the specimen deforms Record the load and extension or compression of the specimen

11.5 Observations and Calculations

Length of specimen = 95.0mm

Length of the holding section = 50mm

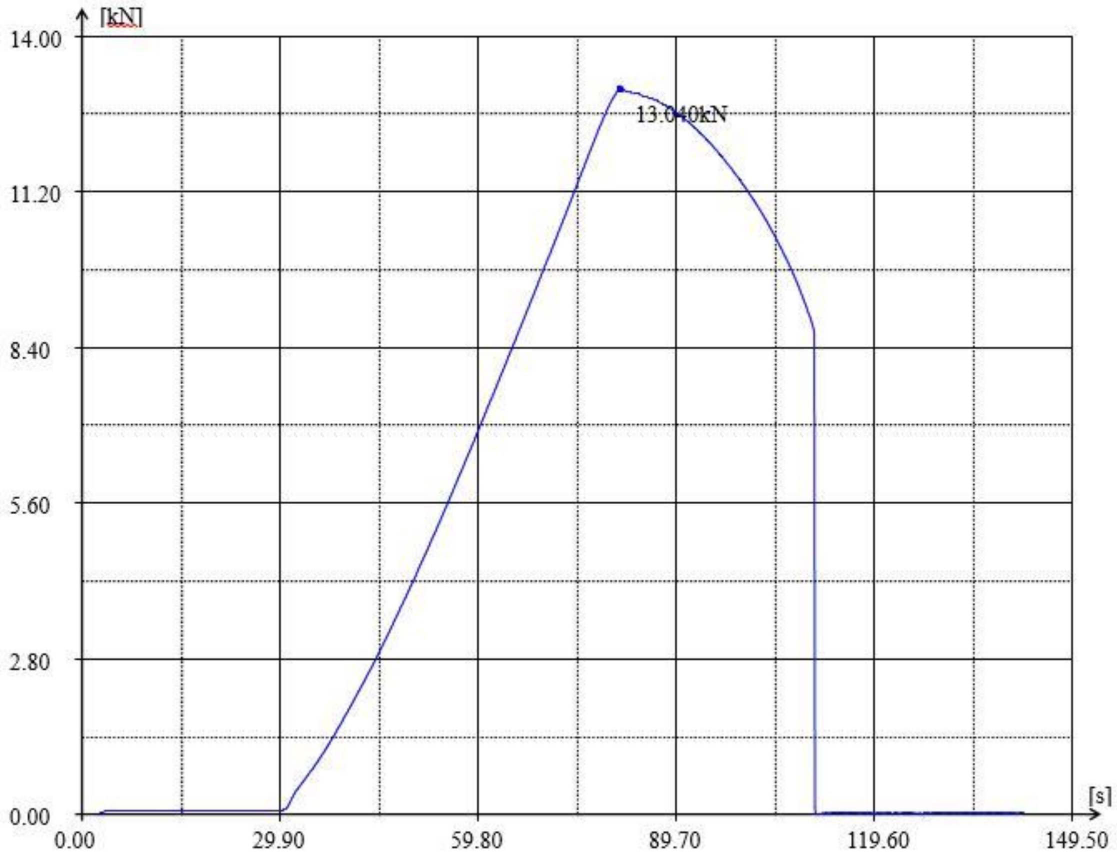
Area of the specimen= πr^2 = 28.3mm^2

Diameter of specimen = 6.00mm Diameter of the holding section = 9.00mm

Table 11-1: Calculations for Plain Steel Alloy

Serial #	Specimen Material	Diameter of the specimen (mm)	Breaking Load (kN)	Breaking Strength (MPa)
1	Copper	6.00	13.0	460

11.6 Graph



11.7 Comments

The machine error caused a few anomalies in the readings and eventually in the graph also.

Lab Session – 12

12.1 Objective

To perform tensile test on a specimen of flat plate of polypropylene materials by using universal testing machine (UTM).

12.2 Apparatus

- Specimen (Polypropylene) Universal Testing Machine Control Unit
- Computer System to compile the results

12.3 Theory

12.3.1 Universal Testing Machine

A machine used to test specimens for tensile strength, compressive strength, shear strength and to perform bend test along other important laboratory tests. The primary use of the testing machine is to create the stress strain diagram. Universal testing machine (UTM) is called so because of the versatility of its application. The following tests can be performed with it:

- Tension Test
- Compression Test
- Bending Test

Figure 12-1: Universal Testing Machine for flat plate of polypropylene

12.3.1.1 Parts of Universal Testing Machine

The Universal Testing Machine consists of two main parts

1. The loading unit
2. The control panels

Loading Unit

In this unit actual loading of the specimen takes place - consists of three cross heads namely upper head, middle head and lower head. Using appropriate cross heads tensile, compressive, shear, bending load with the help of different attachment can be applied. Loading unit of a UTM consists of:

1. Upper cross head
2. Lower cross head
3. Table Upper Cross Head

It is used to clamp testing specimen from top

Lower Cross Head

It is used to clamp testing specimen from below

Table

It is used to place the specimen, used for compression test

Elongation Scale

An elongation scale, which measures the relative movement between the lower table and the lower cross-head, is also provided with the loading unit.

Control Unit

These include the electric control devices, the hydraulic control devices and the load indicating devices.

Electric Control Devices

These are in the form of four switches set on the left side of the panel face. The upper and lower push switches are for moving the lower cross-head up and down respectively. The remaining two are the ON and OFF switches for the hydraulic pump.

Hydraulic Control Devices

These are a pair of control valves set on the table or the control panel.

These are:

- The right control valves
- The left control valves

The right control valve is the inlet valve and the left control valve is the return valve.

Load indicating Devices

A means of providing the test result is needed. Some older machines have dial or digital displays and chart recorder. Many newer machines have a computer interface for analysis and printing.

Extensometer

An instrument used to measure elongation in the material

Necking

At a certain maximum value of the load the diameter of a portion of the specimen begins to decrease, because of local instability. This phenomenon is known as necking. To visualize the necking effect of a material, a tensile test is conducted on a specimen of the material. At a certain maximum stress, the diameter of a portion of the specimen start to decrease at the weaker point and the material shows necking effect as shown in figure.

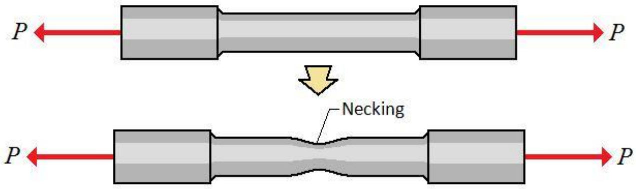


Figure 12-2: Necking Phenomenon for flat plate of polypropylene

12.4 Procedure

- Measure the length of the specimen by a Vernier Caliper Fix the specimen between jaws of UTM
- Apply tensile load on the specimen by the hydraulic system
- Increase the load gradually up to the point at which the specimen deforms Record the load and extension or compression of the specimen

12.5 Observations and Calculations

Length of specimen = 65mm

Breadth of specimen = 10.0mm

Length of the holding section = 50mm

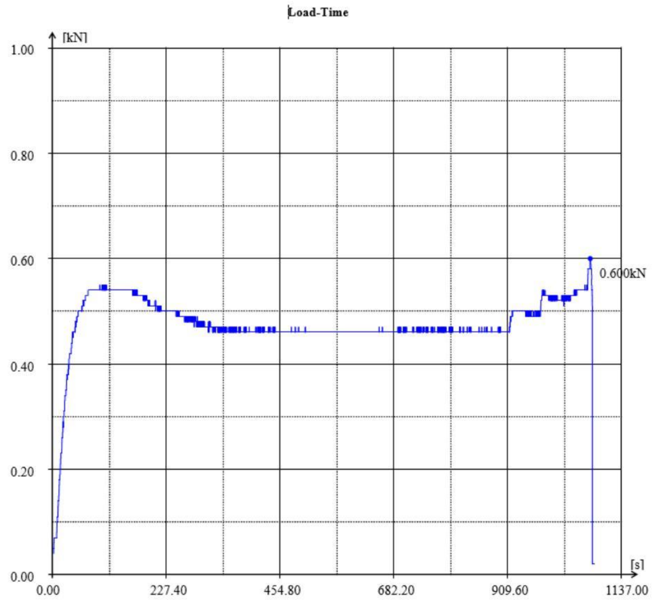
Height of specimen = 4.50mm

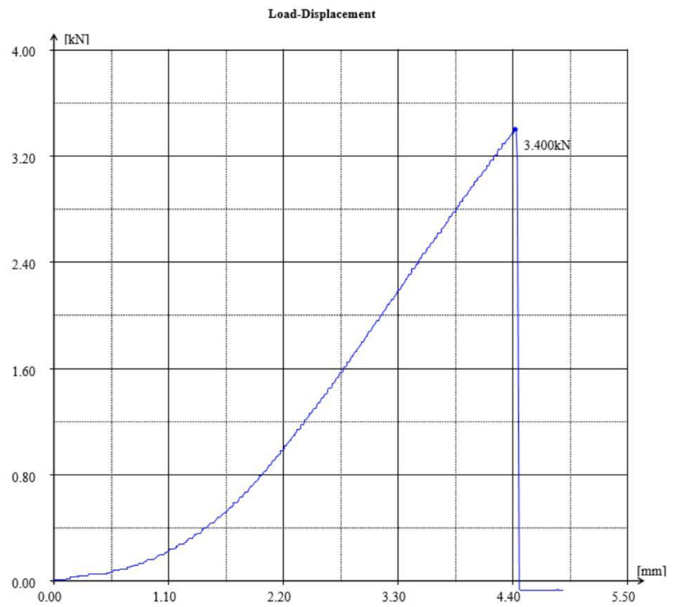
Area of the specimen= πr^2 = 45.0mm^2

Table 12-1: Calculations for Flat Plate of Polypropylene

Serial	**Specimen**	**Breadth of specimen**	**Breaking Load**	**Breaking Strength**
#	**Material**	**mm**	**(kN)**	**(Pa)**
1	Polypropylene	10.0	3.40	3.40

12.6 Graphs





12.7 Comments

Due to poor finishing of the specimen, the results and graph obtained were not accurate. And the exact value of breaking strength cannot be determined

Lab Session – 13

13.1 Objective

To perform compression test on a specimen of concrete by using universal testing machine (UTM).

13.2 Apparatus

- Specimen (Concrete)
- Universal Testing Machine Control Unit
- Computer System to compile the results

13.3 Theory

13.3.1 Universal Testing Machine

A machine used to test specimens for tensile strength, compressive strength, shear strength and to perform bend test along other important laboratory tests. The primary use of the testing machine is to create the stress strain diagram. Universal testing machine (UTM) is called so because of the versatility of its application. The following tests can be performed with it:

- Tension Test
- Compression Test
- Bending Test

Figure 13-1: Universal Testing Machine for concrete

13.3.1.1 Parts of Universal Testing Machine

The Universal Testing Machine consists of two main parts

1. The loading unit
2. The control panels

Loading Unit

In this unit actual loading of the specimen takes place - consists of three cross heads namely upper head, middle head and lower head. Using appropriate cross heads tensile, compressive, shear, bending load with the help of different attachment can be applied. Loading unit of a UTM consists of:

1. Upper cross head
2. Lower cross head
3. Table Upper Cross Head

It is used to clamp testing specimen from top

Lower Cross Head

It is used to clamp testing specimen from below

Table

It is used to place the specimen, used for compression test

Elongation Scale

An elongation scale, which measures the relative movement between the lower table and the lower cross-head, is also provided with the loading unit.

Control Unit

These include the electric control devices, the hydraulic control devices and the load indicating devices.

Electric Control Devices

These are in the form of four switches set on the left side of the panel face. The upper and lower push switches are for moving the lower cross-head up and down respectively. The remaining two are the ON and OFF switches for the hydraulic pump.

Hydraulic Control Devices

These are a pair of control valves set on the table or the control panel.

These are:

- The right control valves
- The left control valves

The right control valve is the inlet valve and the left control valve is the return valve.

Load indicating Devices

A means of providing the test result is needed. Some older machines have dial or digital displays and chart recorder. Many newer machines have a computer interface for analysis and printing.

Extensometer

An instrument used to measure elongation in the material

Necking

At a certain maximum value of the load the diameter of a portion of the specimen begins to decrease, because of local instability. This phenomenon is known as necking. To visualize the necking effect of a material, a tensile test is conducted on a specimen of the material. At a certain maximum stress, the diameter of a portion of the specimen start to decrease at the weaker point and the material shows necking effect as shown in figure.

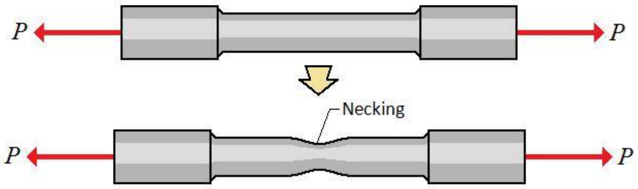


Figure 13-2: Necking Phenomenon for concrete

13.4 Procedure

- Measure the length of the specimen by a Vernier Caliper Fix the specimen between jaws of UTM
- Apply tensile load on the specimen by the hydraulic system
- Increase the load gradually up to the point at which the specimen deforms Record the load and extension or compression of the specimen

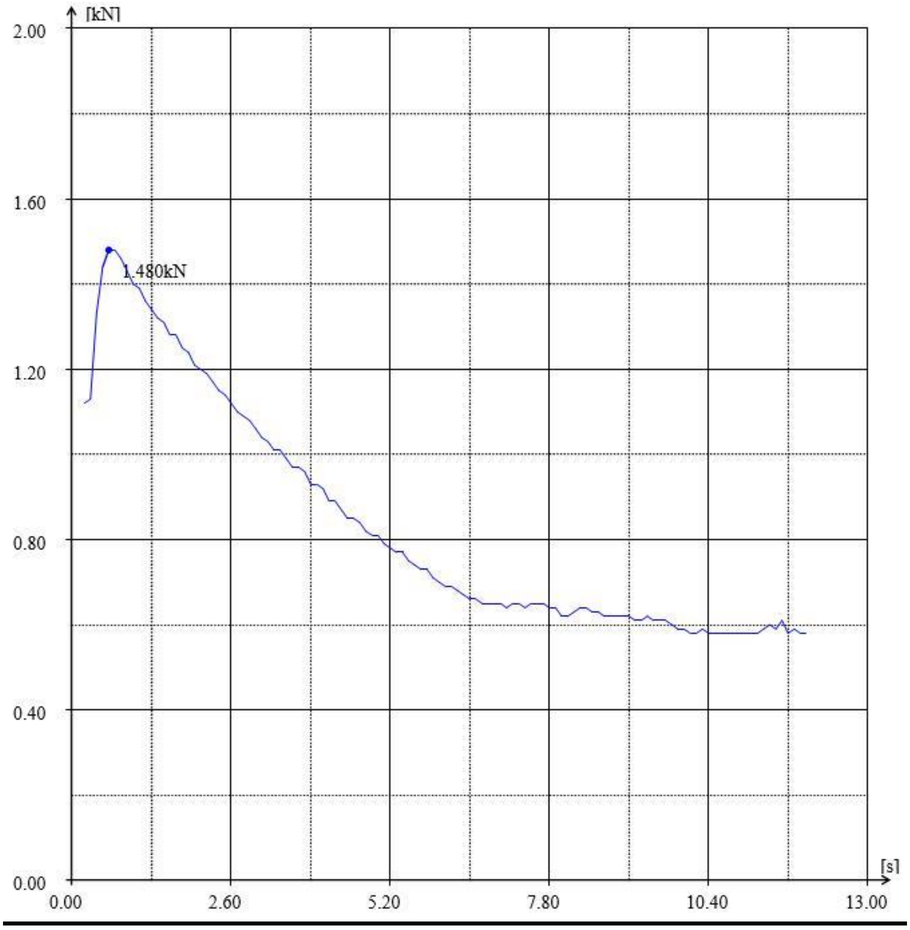
13.5 Observations and Calculations

Area of the specimen= $\pi r^2 = 1140 mm^2$

Table 13-1: Calculations for Concrete

Serial	Specimen Material	Diameter of specimen (mm)	Breaking Load (kN)	Breaking Strength (Pa)
1	Concrete	10.0	1.48	1.30

13.6 Graphs



13.7 Comments

The strength of the material is not justifiable due to large area of the specimen.

Lab Session – 14

14.1 Objective

To perform bending test on different beams of different materials by using universal testing machine (UTM).

14.2 Apparatus:

- Specimens
- Universal Testing Machine Control Unit
- Computer System to compile the results

14.3 Theory

14.3.1 Universal Testing Machine

A machine used to test specimens for tensile strength, compressive strength, shear strength and to perform bend test along other important laboratory tests. The primary use of the testing machine is to create the stress strain diagram. Universal testing machine (UTM) is called so because of the versatility of its application. The following tests can be performed with it:

- Tension Test
- Compression Test
- Bending Test

Figure 14-1: Universal Testing Machine for different beams

14.3.1.1 Parts of Universal Testing Machine

The Universal Testing Machine consists of two main parts

3. The loading unit
4. The control panels

Loading Unit

In this unit actual loading of the specimen takes place - consists of three cross heads namely upper head, middle head and lower head. Using appropriate cross heads tensile, compressive, shear, bending load with the help of different attachment can be applied. Loading unit of a UTM consists of:

4. Upper cross head
5. Lower cross head

6. Table Upper Cross Head

It is used to clamp testing specimen from top

Lower Cross Head

It is used to clamp testing specimen from below

Table

It is used to place the specimen, used for compression test

Elongation Scale

An elongation scale, which measures the relative movement between the lower table and the lower cross-head, is also provided with the loading unit.

Control Unit

These include the electric control devices, the hydraulic control devices and the load indicating devices.

Electric Control Devices

These are in the form of four switches set on the left side of the panel face. The upper and lower push switches are for moving the lower cross-head up and down respectively. The remaining two are the ON and OFF switches for the hydraulic pump.

Hydraulic Control Devices

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Necking

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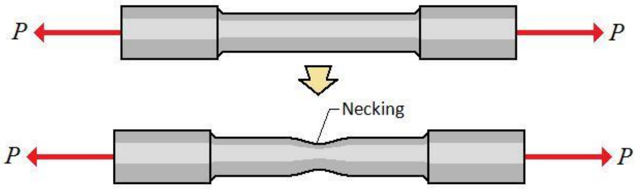


Figure 14-2: Necking Phenomenon for different beams

14.4 Procedure

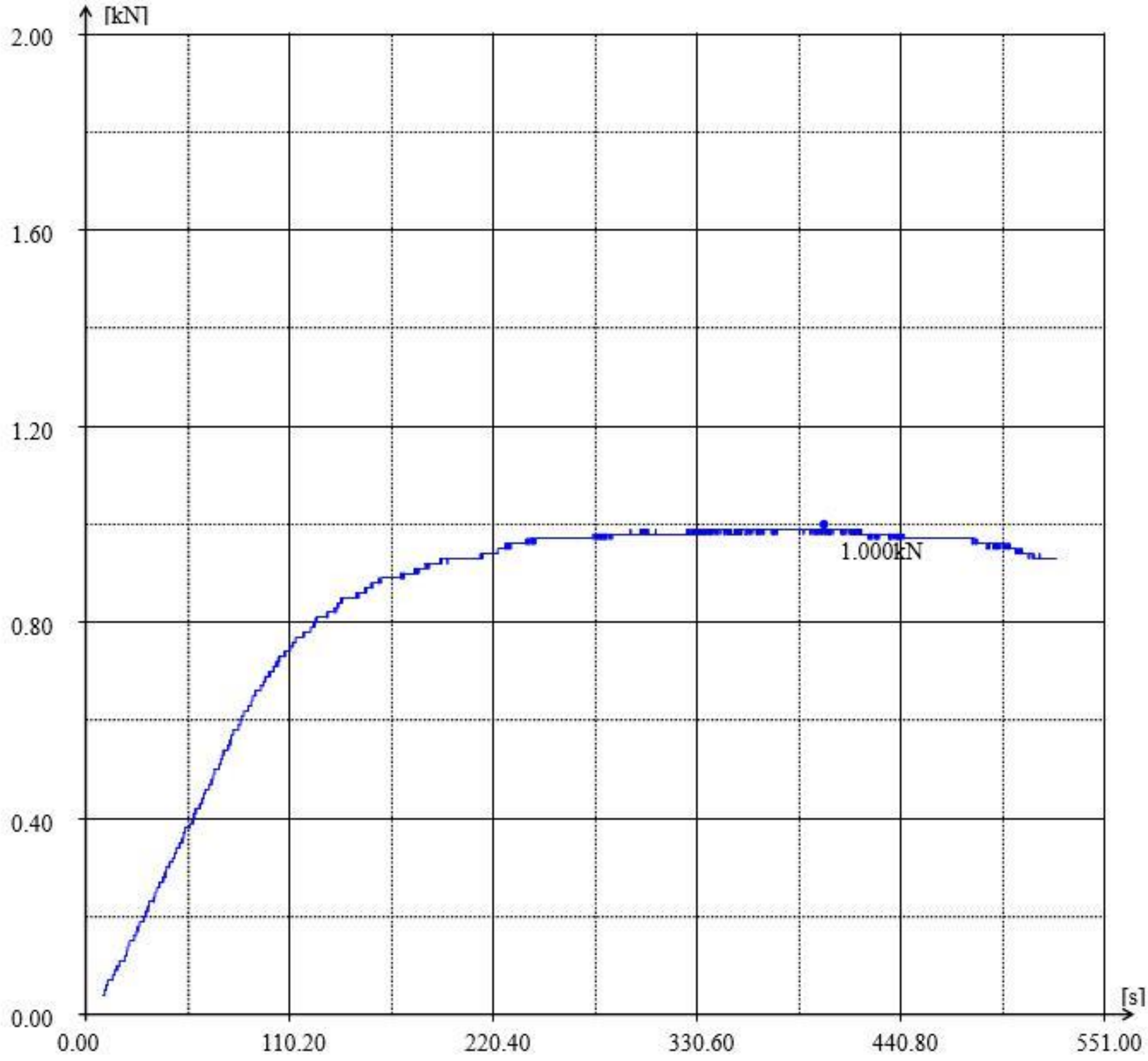
- Measure the length of the specimen by a Vernier Caliper Fix the specimen between jaws of UTM
- Apply tensile load on the specimen by the hydraulic system
- Increase the load gradually up to the point at which the specimen deforms Record the load and extension or compression of the specimen

14.5 Observations and Calculations:

Table 14-1: Calculations for different beams

Sr. No.	Specimen Material	Length of Specimen (mm)	Area of the specimen (mm^2)	Diameter or Breadth of specimen (mm)	Breaking Load (kN)	Flexural Strength (Pa)
1	Mild Steel	205	50.0	10.0	1.00	1830

14.6 Graphs



14.7 Comments

The strength of the material is not justifiable due to large area of the specimen.