Rajshahi University of Engineering & Technology

Department of Civil Engineering

Subject : Mechanics of Materials Sessional-II

Course Code : CE 2214

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Submitted By

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Section : C

Class : 2^{nd} Year Even Semester

Session : 2018-19

Submitted To

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Roll No: 1800131
Section: C
Session: 2018-2019

Experiment No: 01
Name of Exp: Determination of tensile strength of Mild steel (MS) bar.

Subject: Mechanics of Materials Sessional - II
Course No: CE-2214
Date of Exp: 28-03-2021
Date of Submission: 04-08-2021

Experiment No: 01
Experiment Name: Determination of tensile strength of Mild Steel (MS) bar.

Introduction:

Elascity and Plasticity: Elasticity is the property of
~~metal~~ material deformed under
virtue of which a ~~metal~~ material deformed under
the load is removed. If a body regains completely
its orginal shape it is said to be perfectly elastic.

The characteristics of material by which it undergoes inelastic strain beyond those of the elastic limit is known as plasticity.

Stress: Stress is the intensity of internal force developed when an external force is applied on an engineering material. It is symbolically expressed as:

$$\sigma = \frac{P}{A}$$

Strain: Strain is a measurment of deformation produced by the application of external load on deformation per unit length. It is symbolically expressed as:

$$\varepsilon = \frac{\Delta}{L}$$

Propotional limit: It is the limiting value of the stress up to which stress is proportional to strain.

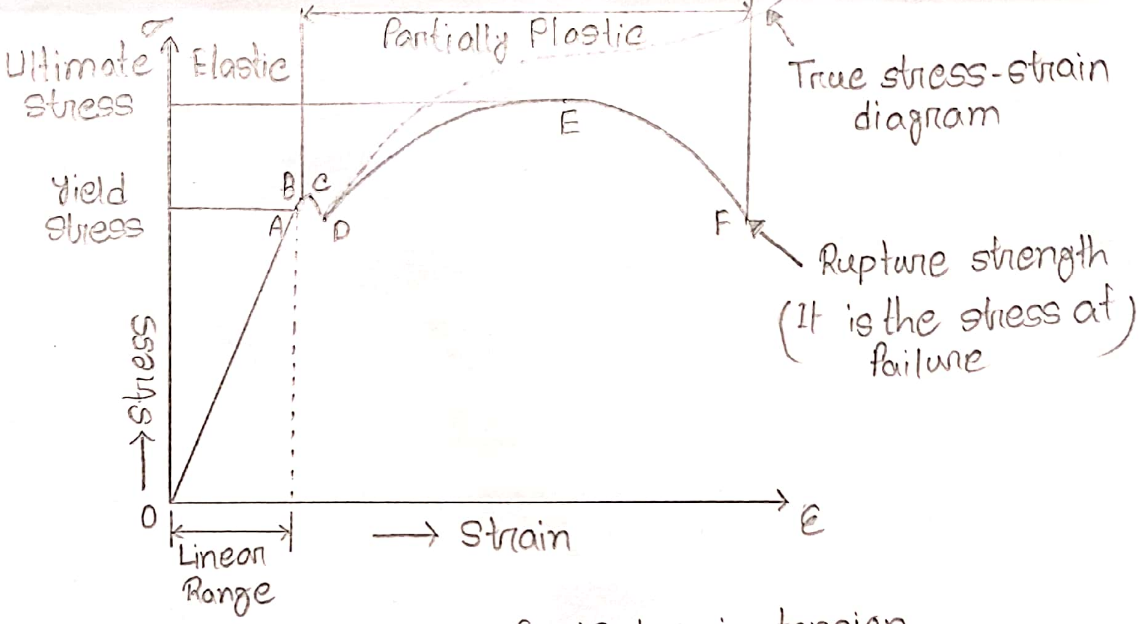

Figure: Stress-strain diagram of MS bar in tension

Elastic limit: (Point B) This is the limiting value of stress and then released, strain disappear completely and the orginal length is regained. This portion follow Hooks' law.

Elastic recovery: The recovered deformation after removal of load.

Yield stress: (Point C and D) The yield point of a material defined as that will cause an increase in deformation without increase in load. When the yield stress is reached elongation and a return to the orginal shape of the test piece is impossible.

Ultimate strength/ Tensile strength (Point E): The ~~u~~ ultimate strength represents the highest point in the stress-strain diagram and is equal to maximum load carried by the specimen devided by the orginal cross-sectional area.

Modulus of Rapture: The work done on a unit volume of material, as a simple tensile force is gradually increased from zero to the value causing rapture is defined as modulus of rapture.

Hook's law: A law stating that the strain in a solid is proportional to the applied stress, within the elastic limit of that solid. Mathematically.

$$\sigma \propto \varepsilon \Rightarrow \sigma = E\varepsilon$$

$$\Rightarrow E = \frac{\sigma}{\varepsilon}$$

Here, E is the slope of stress-strain and is called the modulus of elasticity.

Necking: In the vicinity of the ultimate stress, the reduction in area of the bar becomes clearly visible and a pronounced necking of the bar occurs.

Rapture Strength: (Point F) The stress at which the specimen finally fails is called rapture point. For structural steel, rapture strength is somewhat lower than the untimate strength.

Modulus of Rigidity: The stress at which the specimen finally fails is called rapture point. For structural steel, rapture strength is some

Objectives:
1. To determine the average yield stress of MS bar.
2. To determine the average untimate stress of MS bar.
3. To determine the actual diameter of MS bar.
4. To determine the unit weight of MS bar.
5. To determine the elongation of MS bar.
6. To determine the bending and rebending of MS bar.

Apparatus:
1. Mild steel simple bar.
2. Slide calipers
3. Digital balance
4. Scale
5. Universal testing machine (UTM)

Procedure:
1. The length of the MS bar was measured with scale.
2. The diameter of the MS bar sample was measured with slide calipers.
3. The whole steel bar was weighted by ~~to~~ balance.
4. The mild steel was ready to measured its tensile stregth and placed in universal Testing Machine after making in 8inch gap.
5. From the machine, the reading of yield point was recorded.

6. The maximum load was recorded and load was applied till the sample broke.
7. The final length between the gauge marks was taken by fitting the two ends of the broken pieces together.

Data table:

Tensile strength test of Mild Steel Bar

Group No	01	02	03
Nominal Diameter (cm)			
Length of the Bar (cm)	100·2	100·0	99·90
Weight of the Bar (gm)	905	889	886
Initial Gauge Length (cm)	20·32	20·32	20·32
Final Gauge Length (cm)	24·13	23·75	24
Yield Load (KN	50·729	51·750	49·708
Yield stress (MPa)	441·12	466·21	470·72
Ultimate Load (KN)	75·237	73·195	60·991
Ultimate stress (MPa)	654·234	659·41	577·09
Bending	Ok.	Ok.	Ok.
Rebending	Ok.	Ok.	Ok.

Calculations:

Length of the steel bar, $L = 100.2\,cm$

Weight of the steel bar, $W = 905\,gm$

Specific gravity of MS steel, $\gamma = 7.85\,gm/cm^3$

Cross-sectional area of the MS Bar, $A = \frac{W/\gamma}{L}$

$= \frac{905/7.85}{100.2}\,cm^2$

$= 1.15\,cm^2$

Actual Diameter of the mild steel bar, $d = \sqrt{\frac{A}{\pi/4}} = \sqrt{\frac{1.15}{\pi/4}}$

$= 1.21\,cm$

Machine load for yield stress, $P_{My} = 52\,KN$

Actual load for yield stress, $P_{Ay} = \{(1.0212 \times 52) - 2.3739\}$

$= 50.729\,KN$

Machine load for ultimate stress, $P_{MU} = 75.97\,KN$

Actual load for ultimate stress, $P_{AU} = (1.0212 \times 75.97 - 2.3739)$

$= 75.237\,KN$

Yield stress $= \frac{50.729 \times 1000}{1.15 \times 1000} = 441.12\,MPa$

Ultimate stress $= \frac{75.237 \times 1000}{1.15 \times 100} = 654.234\,MPa$

Unit weight of mild steel bar, $w = \frac{W}{\pi/4\, d^2 L}$

$= \frac{4 \times 905}{\pi/4 \times (1.21)^2 \times 100.2}$

$= 7.85\,gm/cm^2$

Initial gauge length, $L_1 = 20.32$ cm
Final gauge length, $L_2 = 24.13$ cm

Elongation, $\Delta = L_2 - L_1 = (24.13 - 20.32) = 3.81$ cm

$$\text{Strain}, \varepsilon = \frac{\Delta}{L} = \frac{3.81}{20.32} = 0.1875$$

Pargentage of strain $= 0.1875 \times 100\% = 18.75\%$

$$\text{Average yield stress} = \frac{441.2 + 466.21 + 470.72}{3} \text{ MPa}$$
$$= 459.35 \text{ MPa}$$

$$\text{Average ultimate stress} = \frac{654.239 + 659.41 + 577.09}{3}$$
$$= 630.24 \text{ MPa}$$

$$\text{Average Actual diameter} = \frac{1.21 + 1.19 + 1.16}{3} \text{ cm}$$
$$= 1.18 \text{ cm}$$

$$\text{Average Unit weight} = \frac{7.85 + 7.94 + 7.91}{3} \text{ gm/cm}^3$$
$$= 7.9 \text{ gm/cm}^3$$

$$\text{Average elongation} = \frac{3.81 + 3.45 + 3.68}{3} \text{ cm}$$
$$= 3.64 \text{ cm.}$$

Results:

The average yield stress = 459.35 MPa
The average ultimate stress = 630.24 MPa
The average actual diameter = 1.18 cm
The average unit weight = 7.90 gm/cm^3
The average elongation = 3.64 cm

Bending Test = Ok.
Re-bending test = Ok.

Discussion:

1. All the measurements were observed very carefully but due to error in machine all the measurements were affected to an extent.

2. The yield point was the point where the steel bar continues to elongation and in this limit stress was proportional to strain.

3. The actual rapture stress was higher than true rupture stress because the cross-sectional area of the steel bar decreases but for the ultimate stress, the load was divided by the it initial cross sectional area.

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Experiment No: 02

Name of Exp: Determination of the direct shear test of the mild steel.

Subject: Mechanics of Materials Sessional - II

Course No: CE-2214

Date of Exp: 07-03-2021

Date of Submission: 27-06-2021

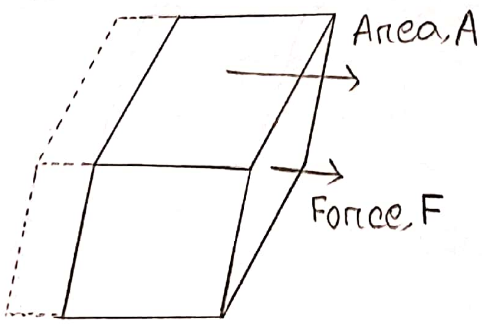
Experiment No: 02

Experiment Name: Determination of the direct shear test of the mild steel.

Introduction:

Shearing Stress: When a external force acts on an surface it undergoes deformation. If the direction of the force is parallel to the plane of the object. the deformation will be along that plane. The stress experienced by the object is shear stress or tangential stress.

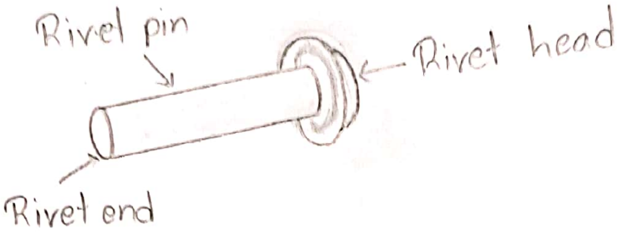
It arises when the force vector components which are parallel to the cross-sectional area of the material. In the case of normal/logitudinal stress, the force vectors will be perpendicular to the cross-sectional area on which it acts.



shear stress, $\tau = \frac{F}{A}$

Where, τ = shear stress
F = Applied force
A = Area of cross-section, that is parallel to the applied force vector.

Rivet: A ~~rev~~ rivet is a mechanical fastener composed of a head-on one end and a cylindrical stem on another (called the tail) which has the appearence of a metal pin.



Types of Riveted and Bolted joints:

There are two types of riveted and bolted joints.

i) Lap joints
ii) Butt joints

Lap joints: The components to be joined overlap each other with one rivet.

Butt joints: Additional two support joints are used to join the components face to face.

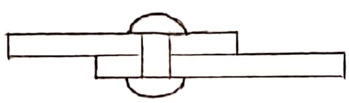


Fig: Lap joint

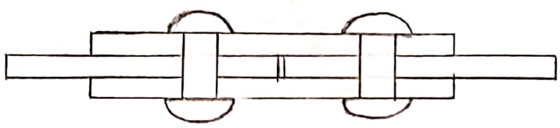


Fig: Butt joint

Type of shear:

i) Single shear: Load will be applied in one plane while one cross-section.

When single cross-section of an element in a joint takes all the shear force, it is called single shear.

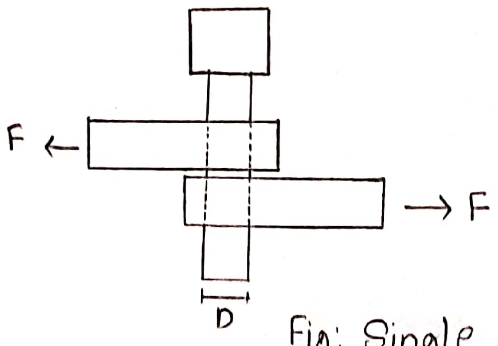


Fig: Single shear

Double shear: When two cross sections of the element takes the shear load it is called double shear.
Double shear is more safer and has higher safety factor.

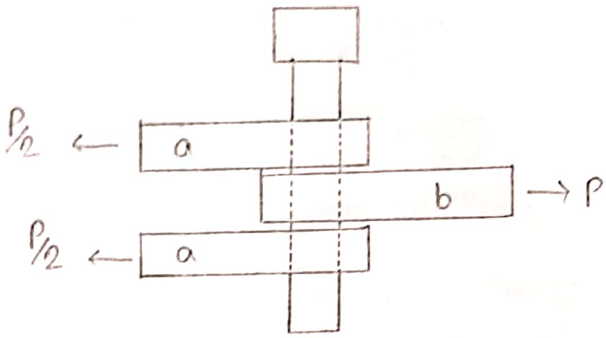


Fig: Double shear

Objectives:
i) To determine the shearing stress of rivet.

Apparatus:
i) Slide Calipers
ii) Universal Testing Machine (UTM)
iii) Hammer
iv) Rivet
v) Steel plate.
vi) Drill Machine

Procedure:
i) At first the diameter of the rivet was measured using slide calipers.
ii) According to the diameter a hole was drilled in the steel plates where the rivet was needed to be fastened.
iii) A rivet was inserted into the hole and the rivet end was hammered to lock the rivet in place.
iv) Then the two steel plate was attached ~~testing machine and load~~ to the two arm of universal testing

machine and load was applied.

v) The load was recorded which was needed to tear apart the rivet.

Observation sheet and Calculation:

Diameter of rivet, $d_1 = 9.4\,mm$

$d_2 = 9.6\,mm$

$d_3 = 9.8\,mm$

Area of rivet, $A_1 = \frac{\pi d_1^2}{4} = \frac{\pi \times (9.4 \times 10^{-1})^2}{4}\ cm^2$

$= 6.94 \times 10^{-1}\,cm^2$

$A_2 = \frac{\pi \times (9.6 \times 10^{-1})^2}{4}$

$= 7.24 \times 10^{-1}\,cm^2$

$A_3 = \frac{\pi \times (9.8 \times 10^{-1})^2}{4}$

$= 7.54 \times 10^{-1}\,cm^2$

strength of rivet, (From UTM)

$P_1 = 42\,kN$

$P_2 = 43\,kN$

$P_3 = 45\,kN$

$\therefore$ Shearing stress,

$S_{s1} = \frac{42}{6.94 \times 10^{-1}}$

$= 60.519\,kN/cm^2$

$S_{s2} = \frac{43}{7.24 \times 10^{-1}}$

$= 59.392\,kN/cm^2$

$S_{s3} = \frac{45}{7.54 \times 10^{-1}}$

$= 59.681\,kN/cm^2$

Data Table:

Sample No	Diameter of Rivet (mm)	Area (cm^2)	Load (kN)	Shearing stress S_s (kN/cm^2)	Average Shearing stress, S_s (kN/cm^2)
1	9.4	6.94×10^{-1}	42	60.519	
2	9.6	7.24×10^{-1}	43	59.392	59.86
3	9.8	7.54×10^{-1}	45	59.681	

Results: The shearing stress of the rivet is 59.86 kN/cm^2

Discussion: The test shows the shearing stress of mild steel. The diameter of the rivet was measured carefully with slide calipers. The rivet was hammered after inserting between two plates to ensure its position was locked. The plates ~~was~~ were attached tightly with UTM before loading and then the loads were recorded at which rivets got failed.

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Section: C

Session: 2018-2019

Experiment No: 03

Name of Exp: Determination of static bending test of wooden beam.

Subject: Mechanics of Materials Sessional-II

Course No: CE-2214

Date of Exp: 04-07-2021

Date of Submission: 04-08-2021

Experiment No: 03

Experiment Name: Determination of static bending test of wooden beam.

Introduction:

Deflection: Deflection is defined as the vertical displacement of a point on a loaded beam. It is also defined as the movement of a beam from its original position. This deplacement or movement is occured by forces and loads being applied to the body. The formula of deflection is—

$$\delta = \frac{PL}{AE}$$

Modulus of Elasticity: The modulus of elasticity is a quantity that measures an object or substance's resistance to being deformed elastically when a stress is applied to it. It is the ratio of the ratio of the stress and the strain in which stress is proportional to strain. It is denoted by E. Mathematically.

$$E = \frac{\text{Stress}}{\text{Strain}} = \frac{\sigma}{\epsilon}$$

Bending moment: Bending moment is defined as the algebric sum of the moments of the forces about the section. taken an either side of the section. It is also defined as the reaction induced in a structural element when an external force is applied to the element causing the element to bend.

Shearing stress: The stress caused by shear force is called shearing stress. It is developed due to sliding of one portion of a beam fiber upon another section. It is denoted by τ which may be represent as:

$$\tau = \frac{VQ}{Ib}$$

Where, τ = Shear stress

V = Shear force at the specified section

I = Moment of Inertia about neutral axis.

b = Width of section at the point of shear stress.

$Q = A\bar{y}$

A = Area of the section above the point of shear stress.

$\bar{y}$ = Distance of centroid of area from neutral axis.

Flexural stress: The stress caused by bending moment is called flexural stress. It is denoted by σ. In general,

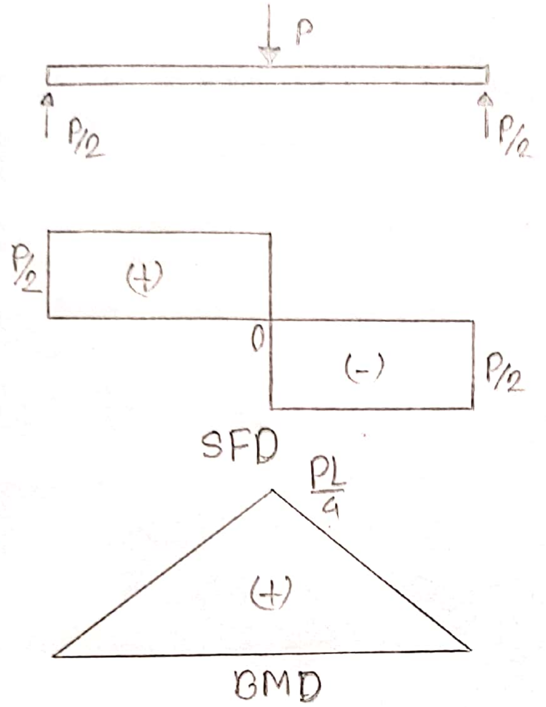
$$\sigma = \frac{My}{I}$$

For maximum flexural stress, $\sigma_{max} = \frac{Mc}{I}$

Where, M = Internal moment in the beam

c = Distance of the extreme fibre of section from the centroidal axis.

I = ~~Momemen~~ Moment of Intertia



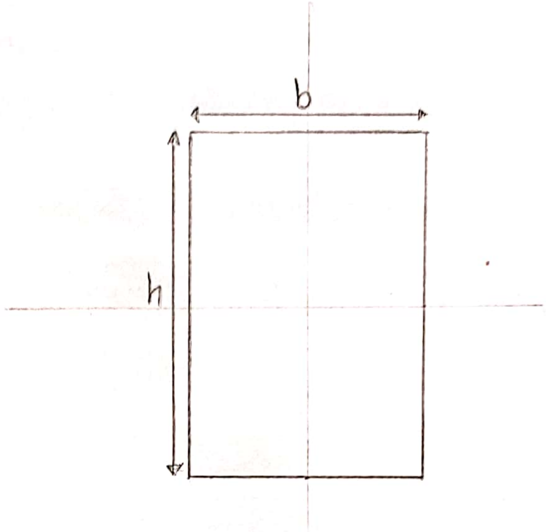


Figure : Cross Section of Beam.

Objectives:

1. To determine the maximum deflection
2. To determine the maximum bending moment.
3. To determine the maximum bending stress
4. To determine the maximum shearing stress
5. To determine the modulus of Elasticity.
6. To determine the modulus of elasticity from the graph.

Apparatus:

1. Slide calipers
2. Universal Testing Machine (UTM)
3. Dial gauge
4. Steel scale
5. Sample of wooden beam
6. Arrangement of simple support.

Procedure:

1. The cross-sectional of the beam was measured by scale.
2. The length of the mid span between the two supports was measured after fixing the beam on the support.
3. The load was applied on the middle of the two support span.
4. Then the load was increased and the deflection was measured.
5. The reading was recorded.

Observation Sheet:

Span Length between two support, L = 18 inch

Breadth of the cross section, b = 2.25 inch

Height of the cross section, h = 3 inch

Cross sectional area, $A = bh = (2.25 \times 3) = 6.75 \text{ in}^2$

Moment of inertia about Neotral axis,

$$I = \frac{bh^3}{12} = \frac{2.25 \times 3^3}{12} = 5.06 \text{ in}^4$$

Deflection gauge constant = 0.001 in

Data Table:

No of Obs	Load, P (kN)	Load, P (lb)	Gauge reading in deflection	Deflection, d (inch)
01	2.5	561.83	15	0.015
02	5.0	1123.66	25	0.025
03	7.5	1685.49	36	0.036
04	10.0	2247.32	52	0.052
05	12.5	2809.15	73	0.073
06	15.0	3370.98	98	0.098

Calculations:

1. Maximum Deflection, $\delta = 0.098$ inch

2. Maximum Bending Moment $BM = \frac{PL}{4} = \frac{3370.98 \times 18}{4}$

$[P = 15kN = 3370.98 lb]$

$= 15169.4 \, lb \cdot inch$

3. Maximum bending stress,

$$\sigma_{max} = \frac{Mc}{I}$$
$$= \frac{15169.4 \times 1.5}{5.09}$$
$$= 4496.89 \, lb/inch^2$$

$$c = \frac{h}{2} = \frac{3}{2} = 1.5 \text{ inch}$$
$$I = 5.06 \, in^4$$

4. Maximum Shearing Stress,

$$\tau = \frac{VQ}{Ib}$$
$$= \frac{1685.5 \times 2.53}{5.06 \times 2.25}$$
$$= 374.56 \, lb/inch^2$$

$$V = \frac{P}{2} = \frac{3370.98}{2} = 1685.51 \, lb$$
$$I = 5.06 \, in^4$$
$$b = 2.25 \text{ inch}$$

5. Modulus of Elasticity,

$$E = \frac{PL}{A\delta}$$
$$= \frac{3370.98 \times 18}{2.25 \times 3 \times 0.098}$$
$$= 91727.35 \, lb/inch^2$$
$$= 9.172735 \times 10^4 \, lb/inch^2$$

$$Q = A\bar{y}$$
$$= b \times \frac{h}{2} \times \frac{h}{4}$$
$$= \frac{bh^2}{8}$$
$$= \frac{2.25 \times 3^2}{8}$$
$$= 2.53 \, in^3$$

Load vs Deflection Graph

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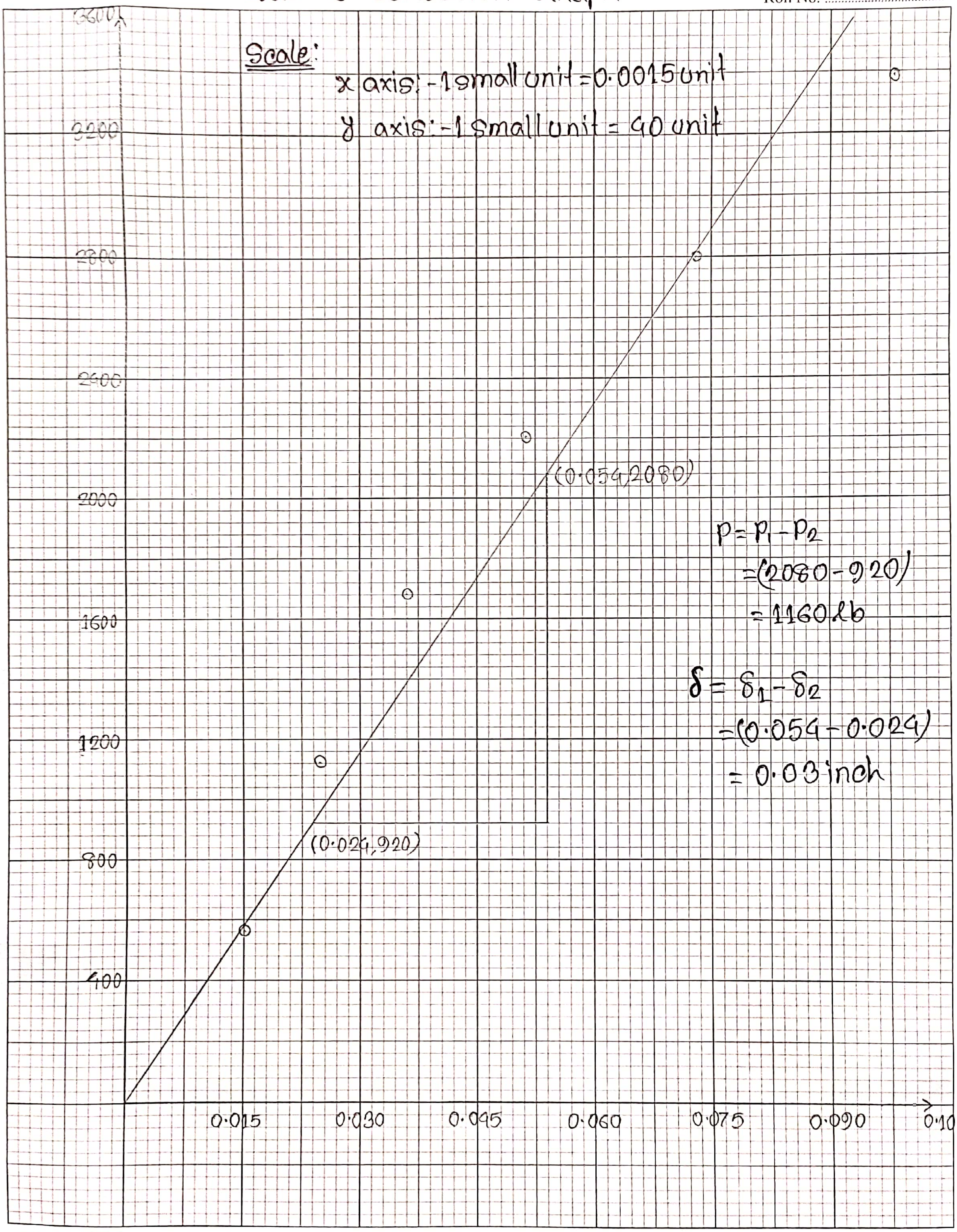

$P = P_1 - P_2$
$= (2080 - 920)$
$= 1160$ lb

$\delta = \delta_1 - \delta_2$
$= (0.054 - 0.024)$
$= 0.03$ inch

MICRO

N.P. 8 Inch x 10 Inch

Calculation from Graph:

$$P_1 = 2080\,lb \quad , \quad P_2 = 920\,lb$$

$$P = (P_1 - P_2) = (2080 - 920)$$
$$= 1160\,lb$$

$$\delta_1 = 0.054\text{ inch} \quad ; \quad \delta_2 = 0.024\text{ inch}$$

$$\delta = \delta_1 - \delta_2 = (0.054 - 0.024)\text{ inch}$$
$$= 0.03\text{ inch}$$

∴ The modulus of Elasticity.

$$E = \frac{PL}{A\delta}$$

$$\Rightarrow E = \frac{1160 \times 18}{2.25 \times 3 \times 0.03}$$

$$\Rightarrow E = 10.311 \times 10^9\ lb/inch^2$$

Result:

1. The maximum deflection = 0.098 inch
2. The maximum bending moment = 15169.4 lb-inch
3. The maximum bending stress = 4496.89 $lb/inch^2$
4. The modulus of Elasticity from calculation = 9.172735×10^9 lb/~~e~~inch
5. The modulus of Elasticity from graph = $10.311 \times 10^9\ lb/inch^2$

Discussion:

Dial gauge was placed bottom of member. marked the pointer as zero. Then reading was ~~m~~ noticed very carefully. As a result, the modulus of Elasticity was in range.

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Experiment No: 04
Name of Exp: Determination of Impact test of Mild steel.

Subject: Mechanics of Materials Sessional-II
Course: CE-2214
Date of Exp: 04-07-2021
Date of submission: 04-08-2021

Experiment No: 04
Experiment Name: Determination of impact test of Mild steel.

Introduction:

Impact: A high force or shock over a short time period. In mechanics, an impact is a high force or shock applied over a short time period when two or more bodies collide.

Impact test: Impact testing - ASTM E23 and ISIBS standard, The impact test is a method for evaluating the toughness and notch sensitivity of engineering materials. It is usually used to test the toughness of materials.

Charpy impact test: A test specimen 'B' machined to a 10 mm × 10 mm cross-section, with either a 'V' or 'U' notch. Subsize specimens are used where the material thickness is restricted. The specimen can be tested down the cryogenic temperature.

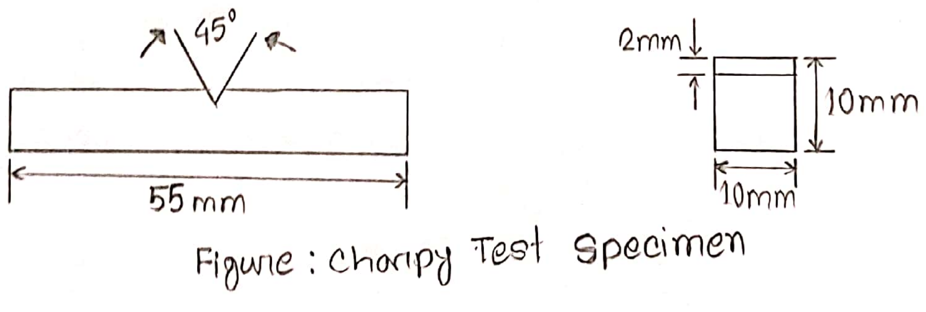


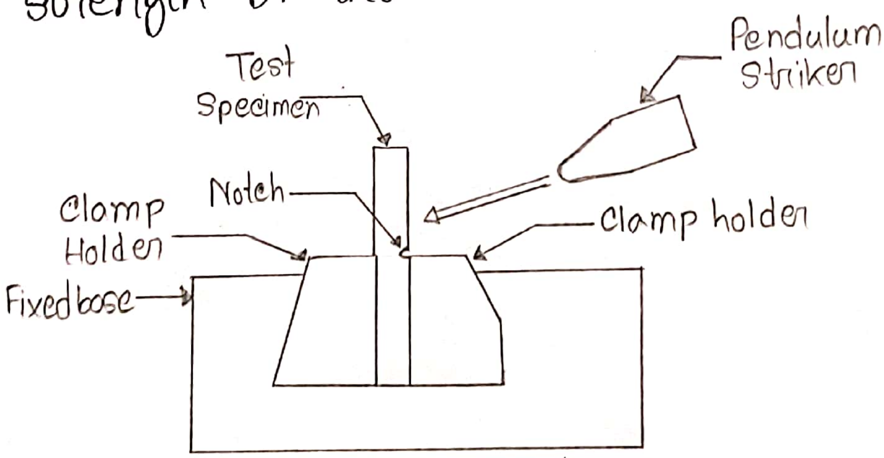
Figure: Charpy Test Specimen

Principle: The charpy impact test is a dynamic test piece U-notched or V-notched in the middle and supported at each end, is broken by a single blow of a freely swinging pendulum.

Then the energy is measured by the impact strength of materials. The impact test helps to measure the energy absorbed.

Izod Impact Test: The test specimen is machined to a square or round section, with either one, ~~too~~ two, or three notches. The specimen is clamped vertically on the anvil with the notch facing the hammer.

Principle: The Izod in which a test piece, V-notched test piece gripped vertically, is broken by a single blow of freely, swinging pendulum. The blow is struck on the safe as the notch and at the fixed height above it. The energy absorbed is measured. The absorbed energy is a measure of the impact strength of the material.



Notched Izod impact test

Fig: Izod Impact Test Specimen

Difference between the charpy Impact test and Izod Impact test:

Charpy Impact Test	Izod Impact Test
The specimen is set to be simply supported.	The specimen is set to be cantilever.
Both 'V' notch and 'U' notch is used.	Only 'V' notch is used.
The length of the specimen is 55mm and the notch is equidistance from both ends.	The length of the specimen is 75mm and the notch is 47mm from one end ~~28~~ and 28mm from the other end.
V-notch or U-notch is set in position in the opposite direction of load.	V-notch is set in position in the direction of food.

Objectives:

- To detemine the absorbed energy capacity of mild steel.

Apparatus:

1. Specimen of steel
2. Scale
3. Slide Calipers
4. Shaper machine
5. Izod impact test
6. The charpy test machine.

Procedure:

For the charpy impact test:

1. The first sample of required dimensions was taken.
2. A V-notch was made equidistance from both ends by using a shaper machine.
3. Before setting the specimen to the charpy imput test machine, the hammer was to fall freely from the starting point and the maximum reading was taken.
4. The difference between the starting point and maximum reading was calculated.
5. The specimen was set and the hammer was again allowed to fall from the starting point and the reading of the ~~m~~ needle of the machine was taken
6. Again the difference between the maximum point and the starting point was calculated.
7. The first difference was initial reading and the 2nd difference was the final reading.
8. The difference between the initial and final reading was calculated which was the energy absorption capacity of the specimen.

For the Izod impact test:

1. At first, the specimen of required dimensions was taken.
2. V-notch was made, as shown in the figure using a shaper machine.

3. Before setting the specimen, the hammer of the Izod impact test specimen machine was allowed to fall freely from starting point and the maximum deflection was taken. The difference between these two points was noted as initial reading.

4. Then the specimen was set as discussed in the introduction and the hammer was allowed to fall from the starting point and the maximum deflection was noted. as the final reading.

5. The difference between the initial and final reading was calculated which was the energy absorption capacity of the specimen.

Calculation:

For charpy Impact test:

Initial reading (without specimen) = (220 - 0) lb-ft
= 220 lb-ft

Final reading (with specimen) = (220 - 180) lb-ft
= 40 lb-ft

Energy absorption capacity of a specimen = (220 - 40)
= 180 lb-ft

For Izod Impact test:

Initial reading (without specimen) = (220 - 0) lb-ft
= 220 lb-ft

Final reading (with specimen) = (220 - 120) lb-ft
= 100 lb-ft

Energy absorption capacity of specimen = (220-100)
= 120 lb-ft

Result:

- Energy absorption(Charpy Impact test) = 100 lb-ft
- Energy absorption(Izod Impact test) = 120 lb-ft

Discussion:

1. The face of the notch is the most important factor to be kept in right direction to break or to fail.

2. The specimen supported for the two testing machines were also important. Because its absorption capacity would be changed for its supporting system.

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Session: 2018-19

Experiment No: 05

Name of Exp: Determination of the properties of the Helical spring.

Subject: ~~Meh~~ Mechanics of Materials Sessional-II

Course No: CE-2214

Date of exp: 20-06-2021

Date of submission: 27-06-2021

Experiment No: 05

Experiment Name: Determination of the properties of the helical spring.

Introduction:

Spring: A spring is defined as an elastic body whose function is to distort when loaded and to recover its orginal shape when the load is removed.

Spring is an elastic machine element that can deflect under the application of load. When the load is removed it regains orginal position. In other words, spring is a mechanical object made up of material having very high yield strength to restore elastic. It is used in various mechanics to absorb shocks or it also resist to transfer shocks and vibrations on various critical machine member.

Spring materials: The material used to made springs are called a spring steel. Spring stell are mostly low-alloy manganese, low carbon steel or high carbon steel with very high yield strength. Examples of spring materials are as follows.

- Oil tempered steel
- Stainless steel
- Elgiloy
- Carbon value
- Iconel
- Monel

- Titanium
- Chrome silicon

Types of spring in mechanical: Based on the shape of the spring, it can be broadly classified into following type-

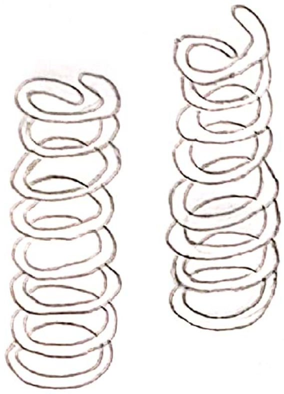


Figure: Helical Compression spring.

Figure: Helical extension spring

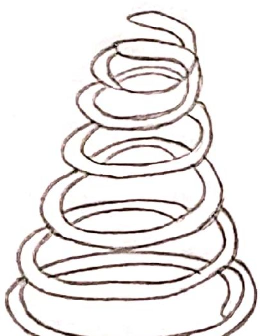


Figure: Conical Spring

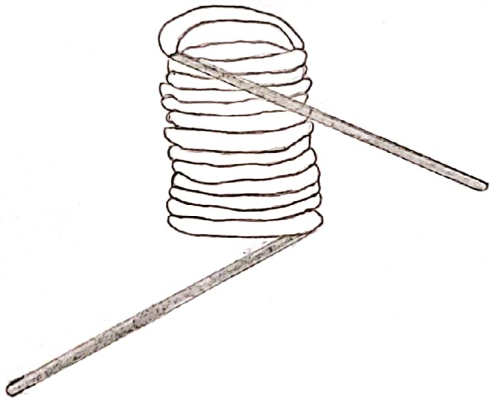


Figure: Torsion spring.

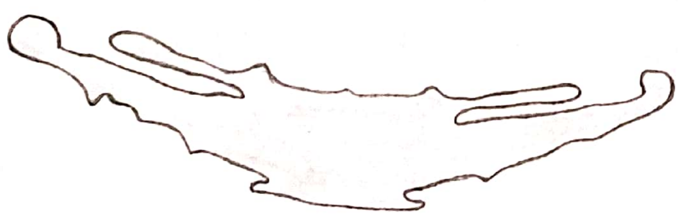


Figure: Laminated or Leaf spring

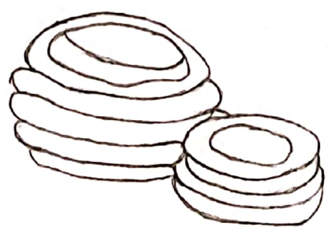


Figure: Disc or belleville spring

Why we need a mechanical spring:- springs are very usefull machine element. There are various regions to use spring. Some of them are given below:

- To absorb shock load
- To store energy
- To measure force
- To motive power
- To return motion
- To control of vibrations
- To retaining of rings

Helical spring:- The helical springs are made of a wire called in the form of a helix and are priminary intended for compresive or tensile loads and torque forces.

According to loading condition, helical springs are clasified into following four types.

a. Open coil springs or compression helical springs.
b. Closed coil springs or tension helical springs.
c. Torsio spring
d. Spiral spring

a. Compression spring: These springs are open coil helical spring. A helical coil is pressed or squeezes by load. It resists compression or push forces. It also shows resistance to linear compressive forces

Applications:

- Motorcycle's suspensions
- Pen
- lock
- Couches
- Lighter

b. Tension spring: Tension springs are also called as extension springs. Pull force is applied, resulting in extension of the spring. These type of springs have hook or extended eyes either one or both ends.

Application:

- Lever mechanisms
- Counterbalancing of garage doors
- Weighing machine
- Vise-grip pilers
- Garage door assemblies.

c. Torsion Spring: In this types of springs, the load applied to coil is a torque or twisting force. In other words, helical springs which can hold and release angular energy or these springs try to hold a system in place. After twisting, the helical coil applies propor-tional force to opposite direction. The torsion springs are used in application which rotates less than 360 degree. These springs have either clockwise or anticlock wise rotation.

Application:

- Mouse trap
- Rocker switches
- Door hinges
- Clothes pin
- Automobile starters.

d. Spiral spring: spiral spring is also known as clock spring or constant force spring. A number of times bond of steel wrapped around it to form this type of springs. This types of springs releases are used in machines that need to rotate a number of times and the same time has to release same amount of load constantly. These types of springs are used when more power is required. Some of these springs are with thicker bond so that they can give fever rotation. These types of springs are used in heavy duty applications.

Application:

- Automotive seat recliners
- Alarm timepiece
- Watch
- Window regulators
- DC motors

Leaf springs: Leaf springs are also called as semi-elliptica spring or cart spring. It is one of the oldest forms springs. Leaf springs are long and flat slender one shaped. These types of springs are used in vechile suspensions. Location from axel is center of the are. And either end of loop is attached to the vechile. It spread the load over vechile chassis.

Advantages:

- Leaf springs are easy to construct.
- These springs are strong.
- No need for separate linkage to hold the axel in position, leaf springs works as a linkage.

- Rear axel location helps in reducing the extra wight.
- Axel damping is controlled by leaf springs.
- It reduces cost by eliminating the need testing arm and pan hand rod.

Applications:

- Automobile suspensions
- Used by blacksmiths (due to its relatively high quality steel.)

Belleville Spring: A belleville spring is also known as a coned disc spring, conical spring washer, disc spring, belleville washer or cupped spring washer. Belleville washers are mostly coin shape spring with a hole in center. This disc springs are dynamically or statically loaded to its axis. This spring required less space for installation but can bear a very large load. These springs have more advantages compare to other springs.

Applications:

- Slip clutch
- Overload clutcher
- High pressure valve
- Drill bit shock absorber

Volute and conical spring: These springs are conical shape compression springs. Conical springs are also known as tapered spring. These springs used to provide stability and reduce solid height.

Special purpose spring: As the name suggest this springs are made for special purpose use. Special purpose springs are made up from different types of material all together such as air and water.

Other types of springs are:

1. Constant spring
2. Variable spring
3. Variable stiffness spring
4. Flat spring
5. Machined spring
6. Serpentise spring
7. Cantilever spring
8. Hair spring or balance spring
9. V- spring
10. Gas - spring
11. Ideal spring
12. Main spring
13. Negator spring
14. Progressive rate coil spring

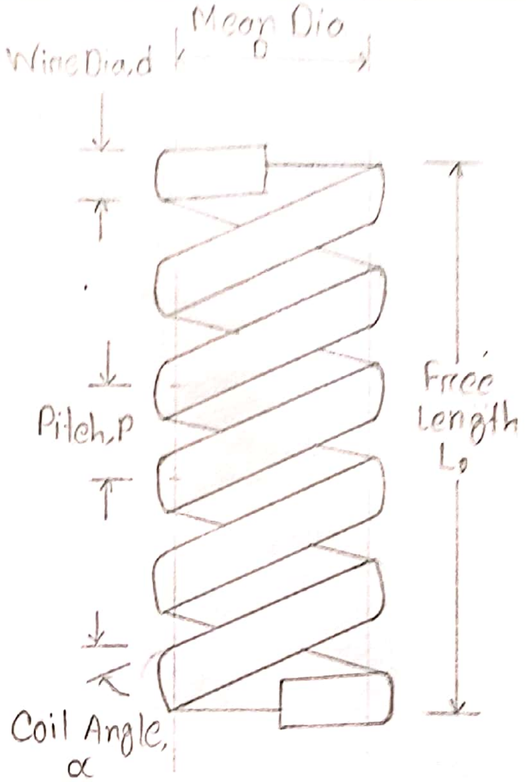
Pitch, P

Spring Constant,

$$m = \frac{D}{d}$$

Mean Radius.

$$R = \frac{D-d}{2}$$



Maximum shearing stress of helical springs:

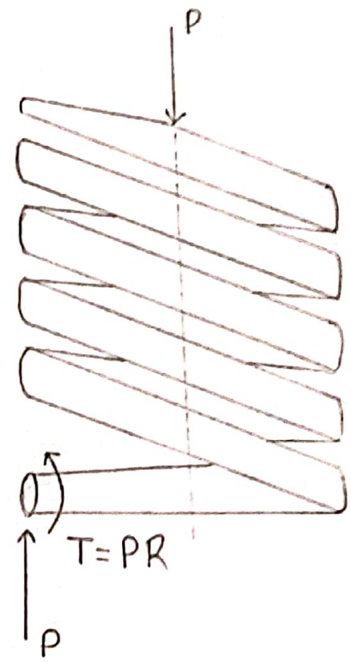
$$\tau = \tau_1 + \tau_2$$

$$= \frac{4P}{\pi d^2} + \frac{16(PR)}{\pi d^3}$$

$$= \frac{16(PR)}{\pi d^3}\left(1 + \frac{d}{4R}\right)$$

$$\tau_{max} = \frac{16(PR)}{\pi d^3}\left(\frac{4m-1}{4m-4} + \frac{0.615}{m}\right)$$

$$= \frac{16(PR)}{\pi d^3}\left(1 + \frac{0.5}{m}\right)$$



Deflection of helical springs:

$$d = \frac{64 PR^3 n}{Gd^4}$$

Objectives:

i) To determine the maximum shearing stress.
ii) To determine the maximum deflection.
iii) To determine the modulus of rigidity.
iv) To determine the spring constant m.
v) To determine the modulus of rigidity from graph.

Apparatus:

i) Helical spring machine.
ii) Slide calipers.
iii) Deflection gauge.
iv) Scale
v) Spring
vi) Balance weight

Procedure:

1.) The diameter of the spring and wire were measured with slide calipers.
The number of turns of the spring was recorded.
2.) The number of turns of the spring was set up.
3.) The helical spring machine was set up.
4.) At first a small amount of weight was hanged up and the load from the deflection gauge was recorded.
5.) Without removing the first weight another amount of weight was hanged up. By counting the weight with the addition of first and end one, the reading of the deflection gauge was recorded. This time the weight was also recorded with adding the first one.
6.) In the same way five readings were taken and in every observation cumulative reading was recorded.

Observation sheet and sample calculation:

Outer diameter of the spring, $D = 3.15\,cm = 0.0315\,m$

Inner diameter of the spring, $d = 0.30\,cm = 0.003\,m$

No of turns, $n = 8$

$\therefore$ Diameter of the spring $= (3.15 - 0.30)\,cm$
$= 2.85\,cm$

$\therefore$ Radius of spring, $R = \frac{2.85}{2}\,cm$
$= 1.425\,cm$
$= 0.01425\,m$

1 small div of dial gauge $= 0.01\,mm$
$= 10^{-5}\,m$

Calculation:

Spring constant, $m = \frac{D}{d} = \frac{0.0285}{0.003}$
$= 9.5$

Maximum shearing stress of helical spring,

$$\tau_{max} = \frac{16PR}{\pi d^3}\left[\frac{4m-1}{4m-4} + \frac{0.615}{m}\right]$$

$$= \left\{\frac{16 \times 21.96 \times 0.01425}{\pi \times (0.003)^3} \times \left(\frac{4 \times 9.5 - 1}{4 \times 9.5 - 4} + \frac{0.615}{9.5}\right)\right\} kg/m^2$$

$$= 6.67 \times 10^8\ N/m^2$$

Here,

Maximum deflection, $\delta = 1332 \times 10^{-5}\,m$
$= 0.01332\,m$

Maximum deflection, $\delta = \frac{64 PR^3 n}{G d^4}$

or, modulus of rigidity, $G = \frac{64 P R^3 n}{\delta d^4}$

$$\therefore G = \frac{64 \times 21.96 \times (0.01425)^3 \times 8}{0.01332 \times (0.003)^4} \ kg/m^2$$

$$= 3.02 \times 10^{10} \ kg/m^2$$

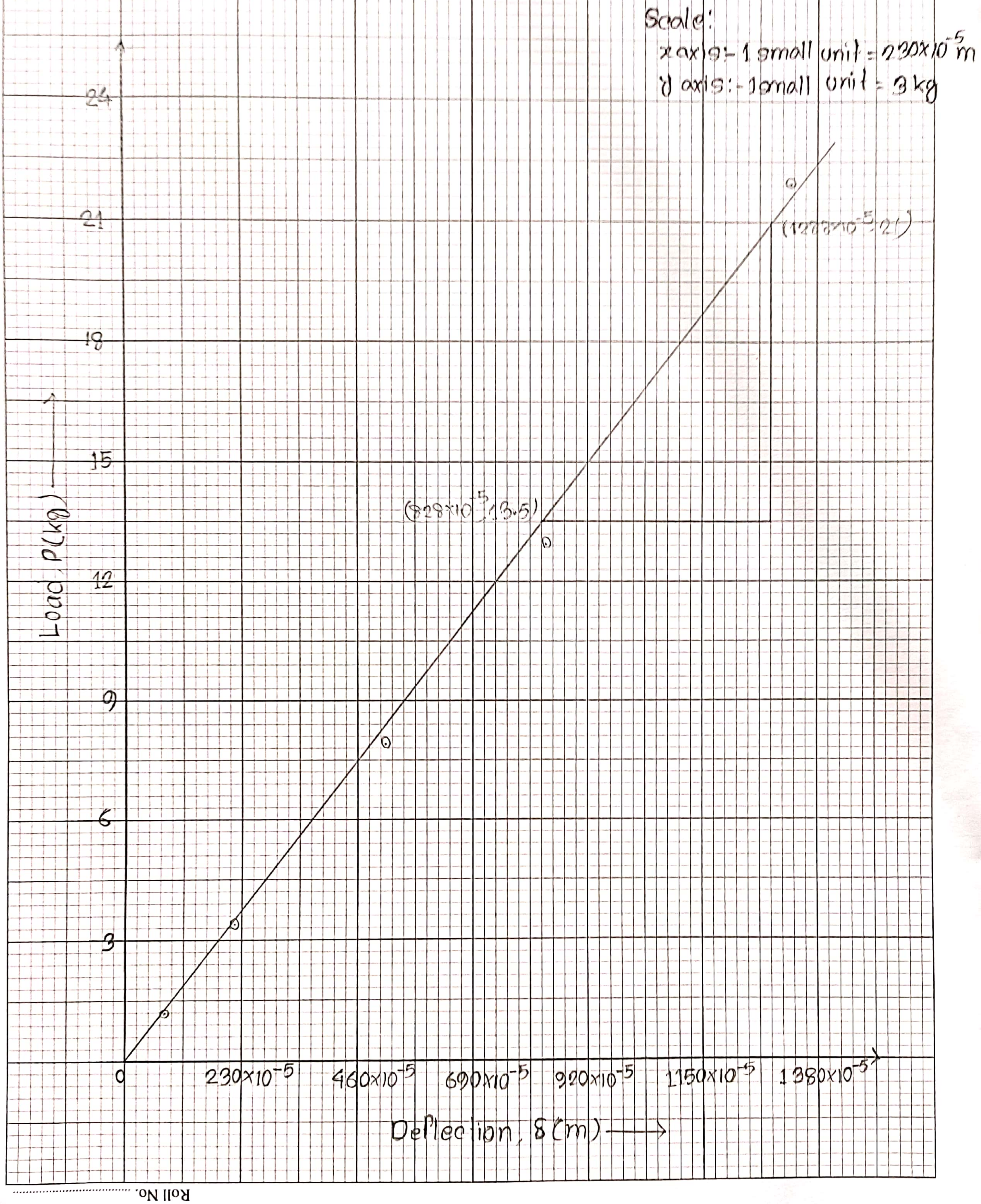
$$= 2.955 \times 10^{11} \ N/m^2$$

Data Table:

- Determination of the maximum deflection of helical spring.

Serial No	Applied load, P (kg)	Dial Gauge reading, (div)	Dial Gauge constant, m	Deflection, δ (m)
1.	1.13	74		74×10^{-5}
2.	3.39	216		216×10^{-5}
3.	7.91	515	10^{-3}	515×10^{-5}
4.	12.92	835		835×10^{-5}
5.	21.96	1332		1332×10^{-5}

Load vs Deflection Graph



Calculation from graph:

Here, $P_2 = 21kg$

$P_1 = 13.5kg$

$\therefore P = P_2 - P_1$

$= (21 - 13.5)kg$

$= 7.5kg$

$\delta_1 = 828 \times 10^{-5} m$

$\delta_2 = 1288 \times 10^{-5} m$

$\therefore \delta = \delta_2 - \delta_1$

$= (1288 \times 10^{-5} - 828 \times 10^{-5}) m$

$= 460 \times 10^{-5} m$

and, $R = 0.01425 m$

$d = 0.003 m$

$n = 8$

$\therefore$ Modulus of rigidity, $G = \frac{64PR^3n}{\delta d^4}$

$= \frac{64 \times 7.5 \times (0.01425)^3 \times 8}{460 \times 10^{-5} \times (0.003)^4}$

$= 2.98 \times 10^{10} kg/m^2$

$= 2.92 \times 10^{11} N/m^2$

Results:

Maximum shearing stress = 6.67×10^8 N/m^2

Maximum deflection, δ = 0.01332 m

Spring constant, m = 0.5

Modulus of rigidity (From calculation) = 2.955×10^{11} N/m^2

Modulus of rigidity (From graph) = 2.92×10^{11} N/m^2

Discussion: The reading of deflection from dial gauge for heavy weights was taken carefully as for heavy weights, the pointer deflects so quickly. The modulus of rigidity from calculation and graph are so close. that means other readings were also taken consciously as for as possible.

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Experiment No: 06

Name of Exp.: Determination of Buckling test of Slender column

Subject: Mechanics of Materials Sessional - II

Course No: CE-2214

Date of Exp: 27-06-2021

Date of Submission: 04-07-2021

Experiment No: 06

Experiment Name: Determination of buckling test of slender column.

Introduction:

Column: A column is a compression member that is so slender compared to its length that under gradually increasing loads it fails by buckling at loads considerably less than those required to cause failure by crushing.

Long columns- Fail by buckling/Excessive lateral bending ($\frac{L}{r}>100$)

Intermediate columns- Fail by combination of buckling and crushing ($\frac{L}{r}=100$)

Short columns - Fail by crushing ($\frac{L}{r}<30$)

Where, L is the length of column and r is the radius of gyration.

Slenderness ratio: The ratio $\frac{L}{r}$ is called the slenderness ratio of the column. Since an axially loaded column tends to buckle about the axis of ~~last~~ least moment of intertia, the leaste radius of gyration should be used to determine the slenderness ratio.

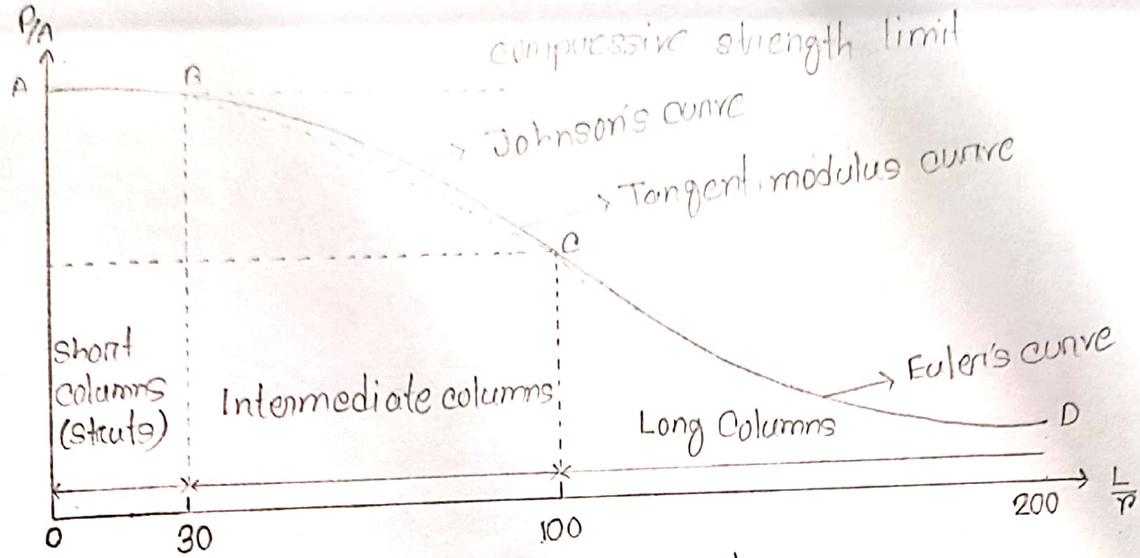


Fig: Slenderness ratio

<u>Critical Load:</u> A critical load can be interpreted as the maximum axial load to which a column can be subjected and still remain. although in such an unstable condition that a slight sideways thrust will cause it to bow out.

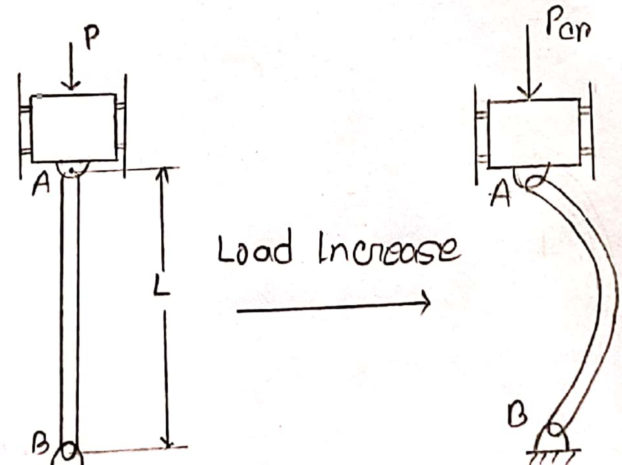


Figure: Buckling of column.

<u>Euler's formula:</u>

Figure shows the centre line of a column in equilibrium under the action of it's critical load P. The column is assumed to have hinged ends restrained against lateral moment.

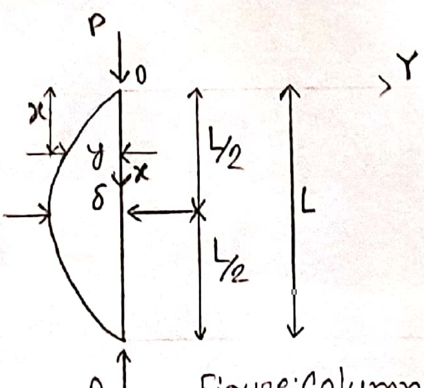


Figure: Column

The maximum deflection δ is so small that there is no applicable difference between the original length of the column and its projection on a vertical plane under these conditions the slope $\frac{dy}{dx}$ is so small that we may apply the approximate differential equation of the elastic curve of the beam,

$$EI.\frac{d^2y}{dx^2} = M = P(-y) = -Py \text{ .... } (i)$$

Also the equation of a simple vibrating body:

$$\frac{W}{g}.\frac{d^2x}{dt^2} = -kx$$

for which the general solution is,

$$x = C_1 \sin\left(t\sqrt{\frac{kg}{W}}\right) + C_2 \cos\left(t\sqrt{\frac{kg}{W}}\right)$$

Hence by analogy the solution at eqn (i) can be written at once as,

$$y = C_1 \sin\left(x\sqrt{\frac{P}{EI}}\right) + C_2 \cos\left(x\sqrt{\frac{P}{EI}}\right) \text{ .... } (ii)$$

Substituting $y=0$ at $x=0$ in eqn (ii) gives $C_2=0$.
If we apply $y=0$ at $x=L$, we can write,

$$0 = C_1 \sin\left(L\sqrt{\frac{P}{EI}}\right)$$

This is satisfied if $C_1=0$, then

$$L\sqrt{\frac{P}{EI}} = n\pi \quad \text{where, } n = 0, 1, 2, 3, \text{......}$$

From which,

$$P = n^2 \times \frac{EI\pi^2}{L^2} \text{ ..... } (iii)$$

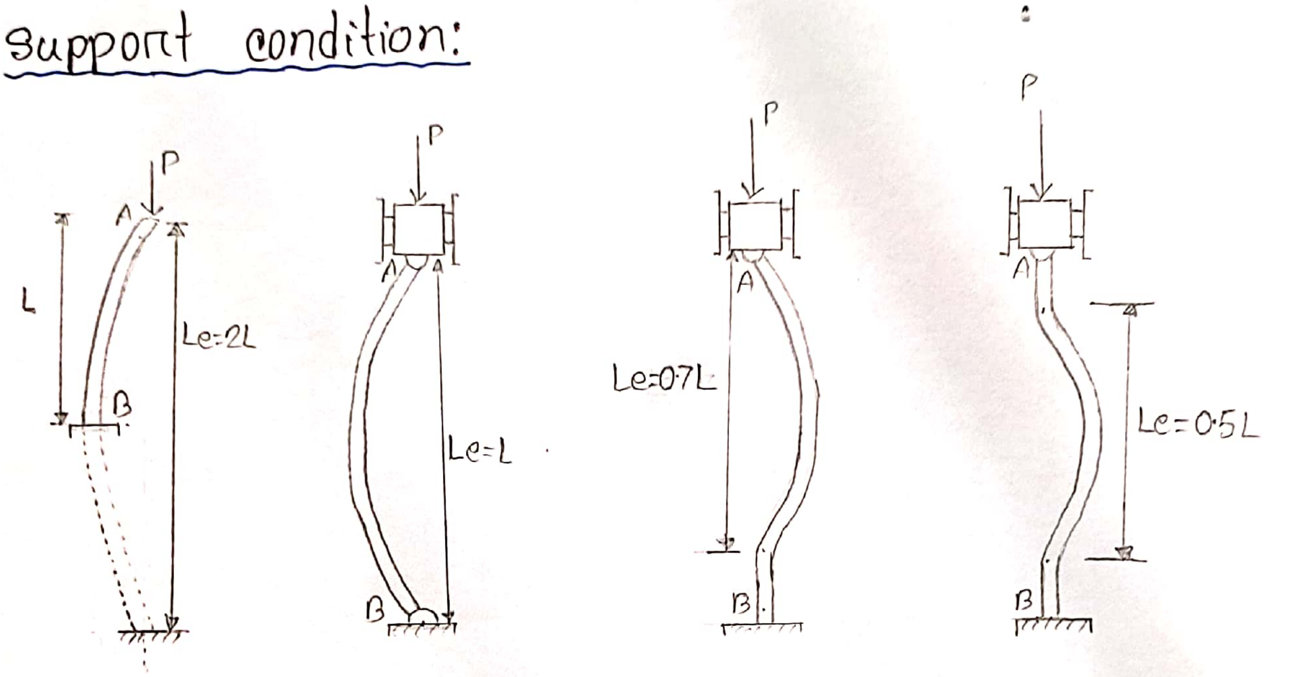
For critical Load, eqn (iii) can be written as,

$$P_{cr} = n^2.\frac{EI\pi^2}{L_e^2}$$

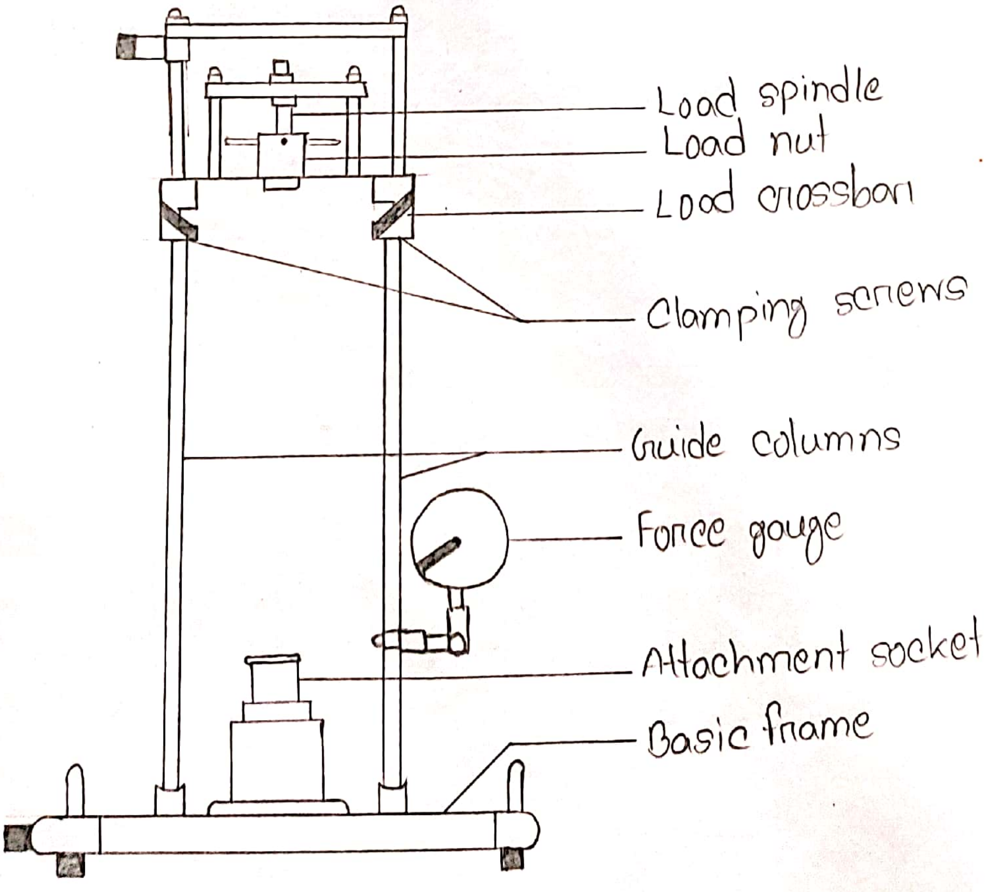
Where,
P_{cr} = Critical load
L_e = Effective length

E = Modulus of elasticity
I = Moment of inertia
n = No. of loop

Support condition:



Buckling test machine:



Objectives:

i) Determination of the critical load for different support condition of slender column.

ii) To compare the experimental critical load with that given by the Euler's equation.

Apparatus:

i) Buckling test machine

ii) Slide calipers

iii) Column

iv) Scale

v) Tape

vi) Load equipment.

Procedure:

1. The diameter of the column was measured.

2. The column was set in an experiment set up (buckling test machine) and first two ends of the column was kept fixed.

3. Load was given gradually and as soon as it was deflected, the total weight was recorded.

4. The critical length was measured by scale between two points from which deflection was started.

5. Then the beam was set by keeping one end fixed and one end hinged and by the above ways total weight for deflection and critical length was recorded.

6. After that the beam was set keeping both end hinged and by the similar way total weight of deflection was recorded.

7. The critical length was measured also.

Observation sheet and sample calculation:

Length of the column, $L = 85.5 cm = 0.855 m$

Diameter of the column, $d = 1.05 cm = 0.0105 m$

Modulus of Elasticity of steel, $E_s = 200 GPa = 200 \times 10^9 Pa$

Moment of Inertia, $I = \frac{\pi d^4}{2^4 \times 4} = \frac{\pi \times (0.0105)^4}{64}$

$= 5.967 \times 10^{-10} m^4$

Case-1: One end fixed and other end hinged →

$$P = \frac{n^2 E I \pi^2}{Le^2} = \frac{1^2 \times 200 \times 10^9 \times 5.967 \times 10^{-10} \times \pi^2}{(0.855 \times 0.7)^2}$$

[Here, $Le = 0.7L$

$= 335.19$ kg

Case-2: Both end hinged →

$$P = \frac{n^2 E I \pi^2}{Le^2} = \frac{1^2 \times 200 \times 10^9 \times 5.967 \times 10^{-10} \times \pi^2}{(0.855)^2}$$

$= 164.24$ kg

Case-3: Both end fixed →

$$P = \frac{n^2 E I \pi^2}{Le^2} = \frac{1^2 \times 200 \times 10^9 \times 5.967 \times 10^{-10} \times \pi^2}{(0.5 \times 0.855)^2}$$

$= 656.97$ kg [Here, $Le = 0.5L$]

Data table:

No.	Case	Theoretical load (kg)	Actual load (kg)
01.	One end fixed and other hinged	332·27	15·82
02.	Both end hinged	162·81	11·3
03.	Both end fixed	651·26	27·12

Results:

Theoretical critical load of slender column:

One end fixed and other hinged = 332·27 kg

Both end hinged = 162·81 kg

Both end fixed = 651·26 kg

Actual critical load of slender column:

One end fixed and other hinged = 15·82 kg

Both end hinged = 11·3 kg

Both end fixed = 27·12 kg

Discussion: This test shows the buckling test slender column. Deflection was considered from imperfect column and it wasn't measured by any machine. So the critical load wasn't recorded accurately as the deflection of the column has faults. As the buckling machine, the deflection and force weren't recorded from any deflection ~~measure~~ measuring equipment and force gauge. So, there may be some errors.