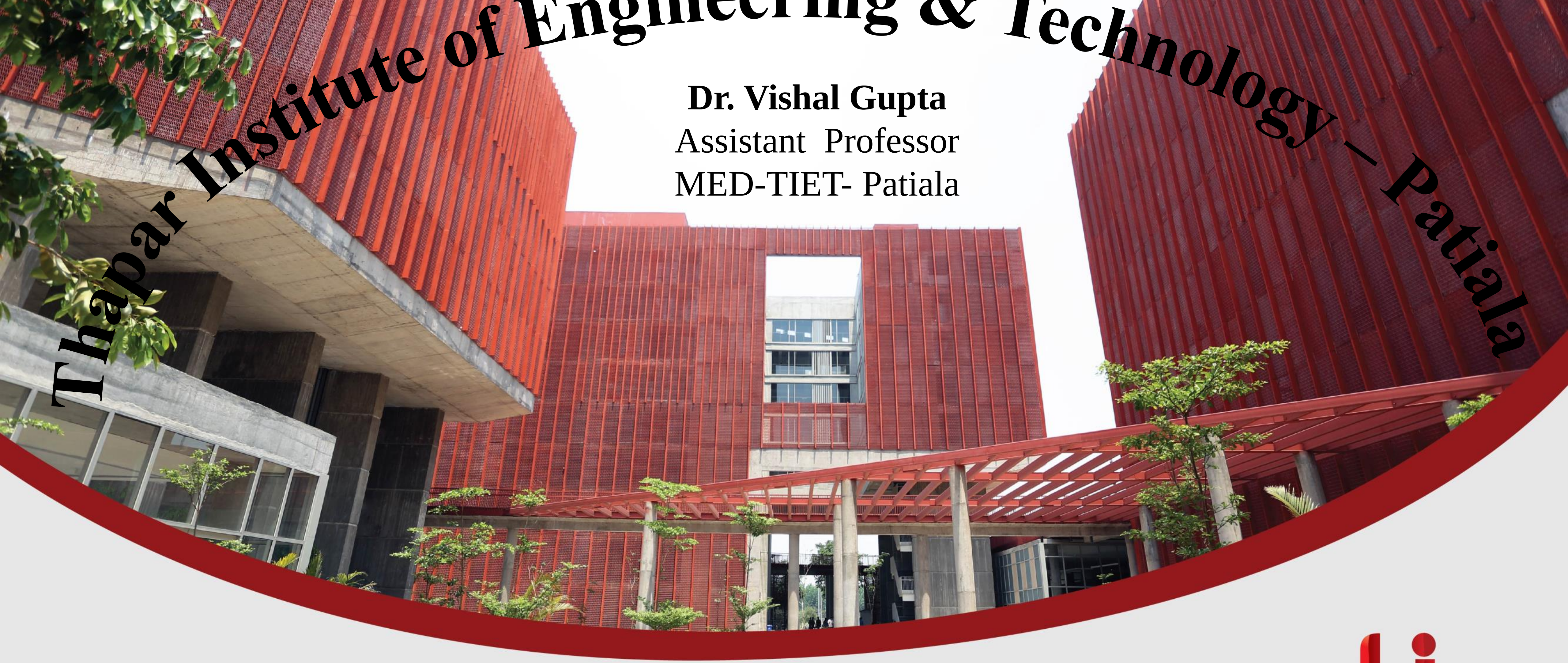

Thapar Institute of Engineering & Technology – Patiala

Dr. Vishal Gupta

Assistant Professor

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THAPAR INSTITUTE
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(Deemed to be University)

Overview of the course

Mechanical Engineering Department

Course coordinator
Dr. Vishal Gupta
Assistant Professor
Mechanical Engineering Department

Course Co-coordinator
Dr. Sachin Singh
Assistant Professor
Mechanical Engineering Department

Electronics and Communication Engineering Department

Course Coordinator
Dr. Poonam Verma
Assistant Professor
Electronics and Communication Engineering Department

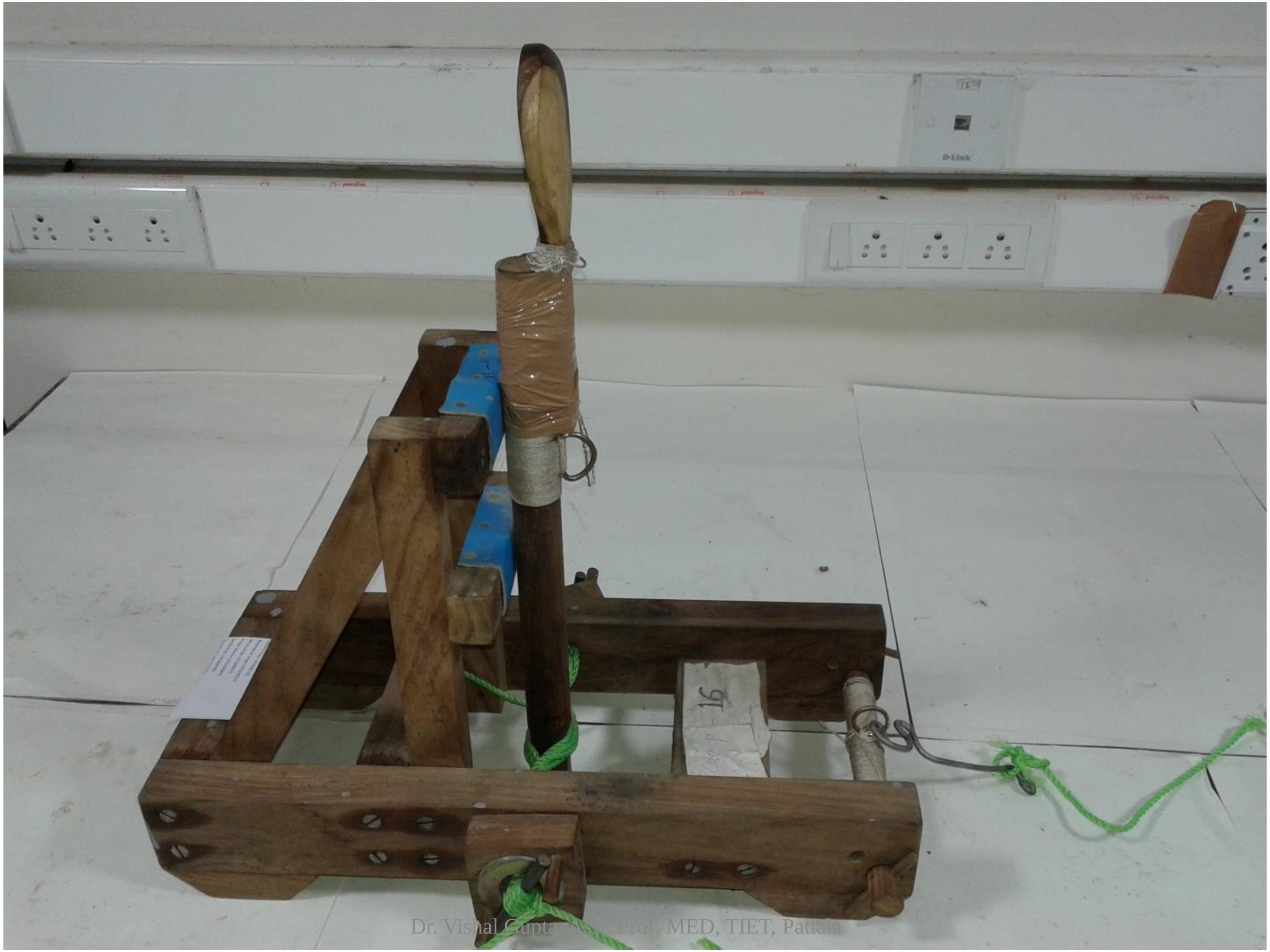
ENGINEERING DESIGN PROJECT-I
UTA016

Lecture - 3

How Structures Fail

Instructional objective

- Failure Modes – Axial members
- Failure Modes-Beams
- Factor of safety
- Failure Modes (TORSION)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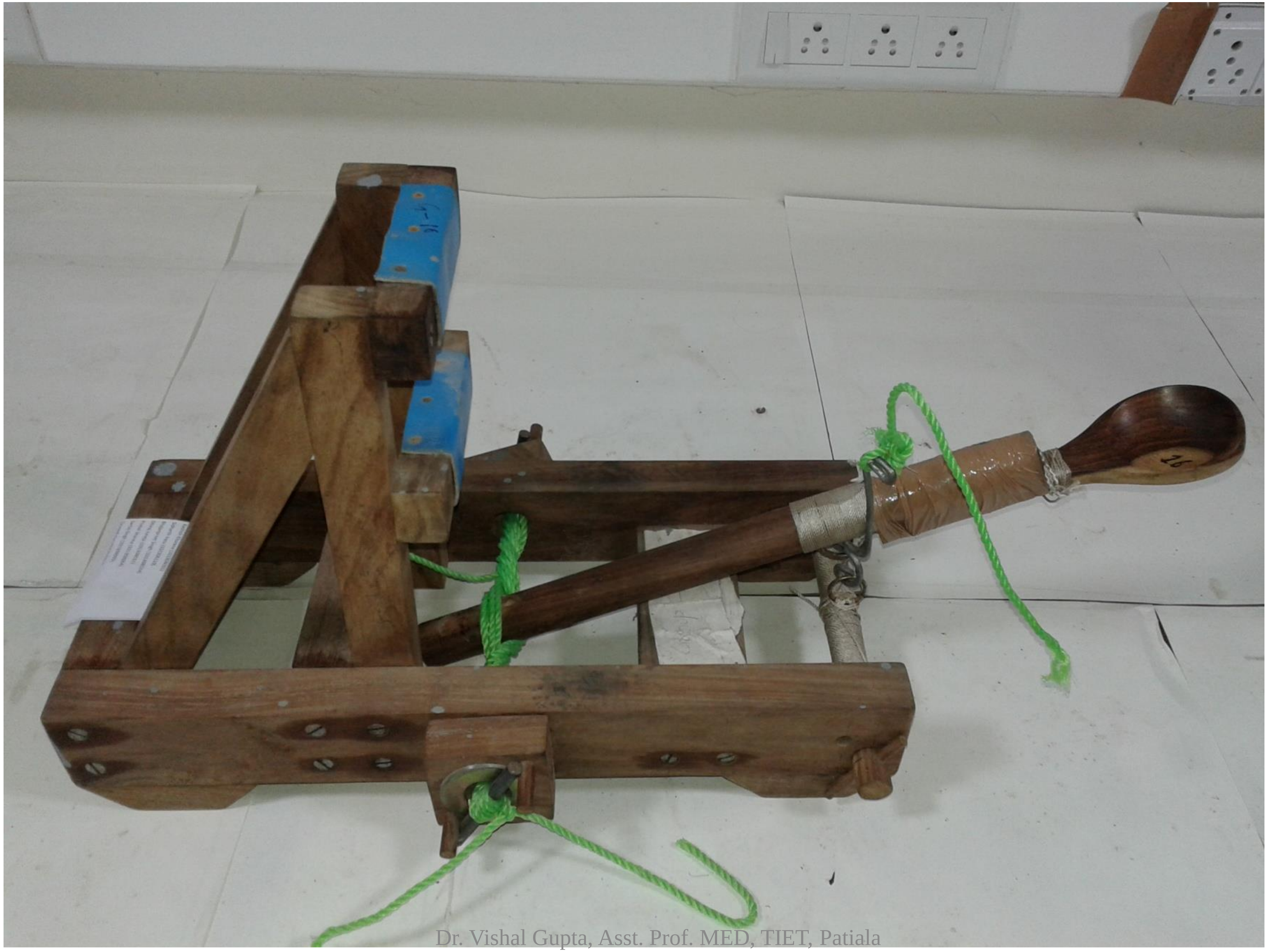
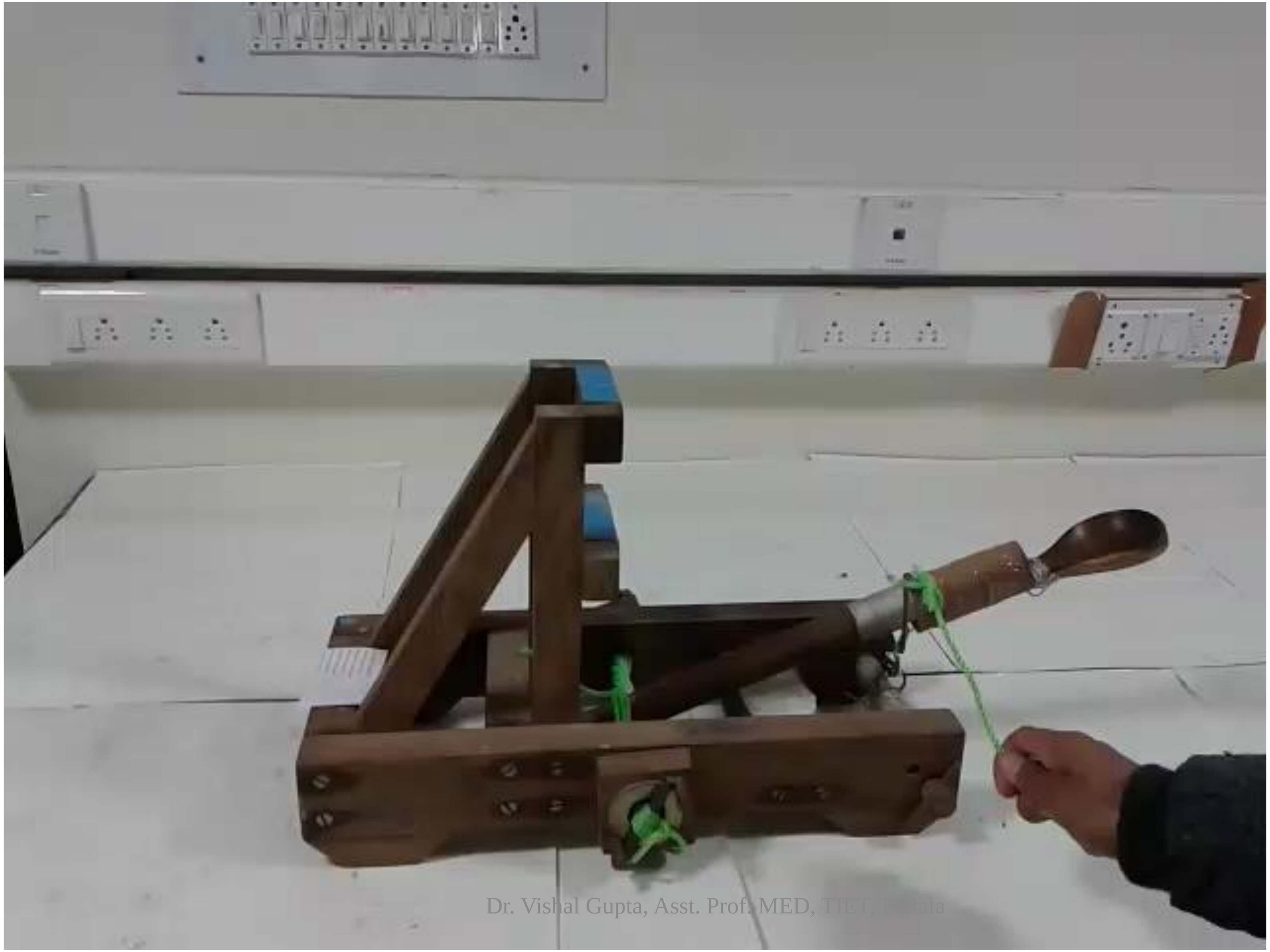


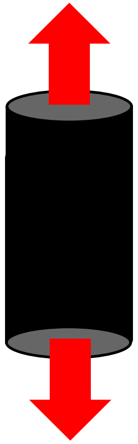
FIRING A MANGONEL

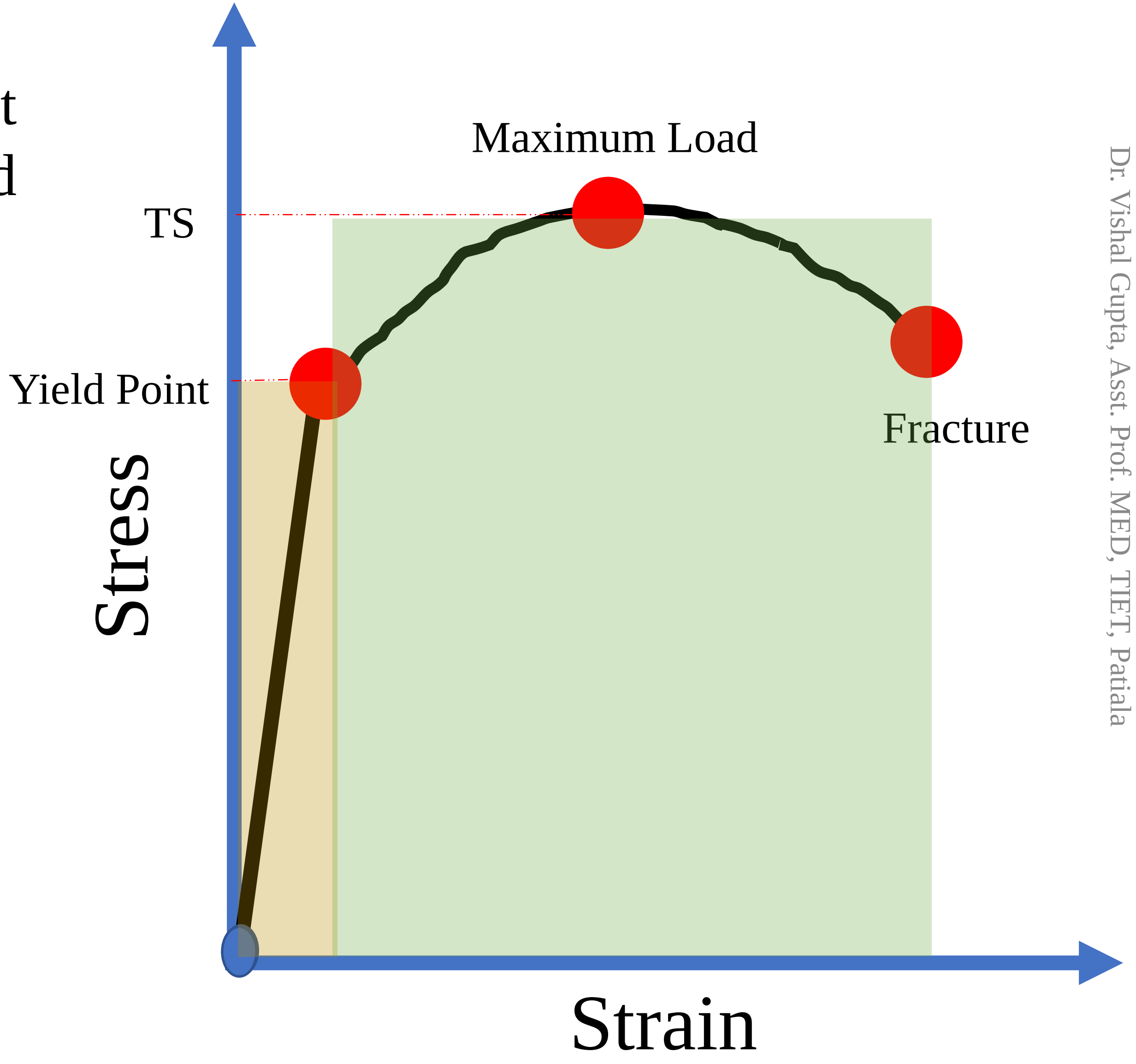


Failure Modes – Axial members

ENGINEERING STRESS–STRAIN

The engineering stress and strain in a tensile test are defined relative to the original area and length of the test specimen.





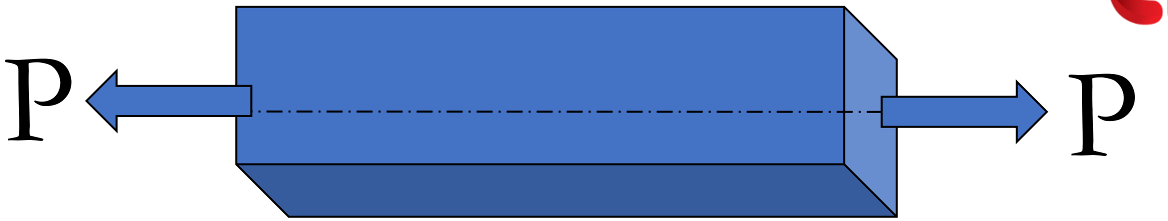
Elastic Region

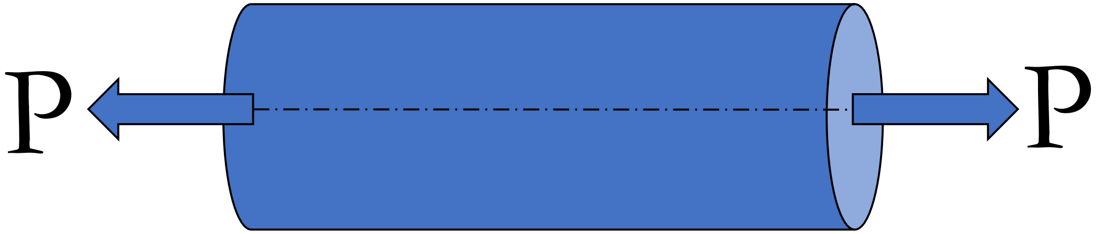
Plastic Region

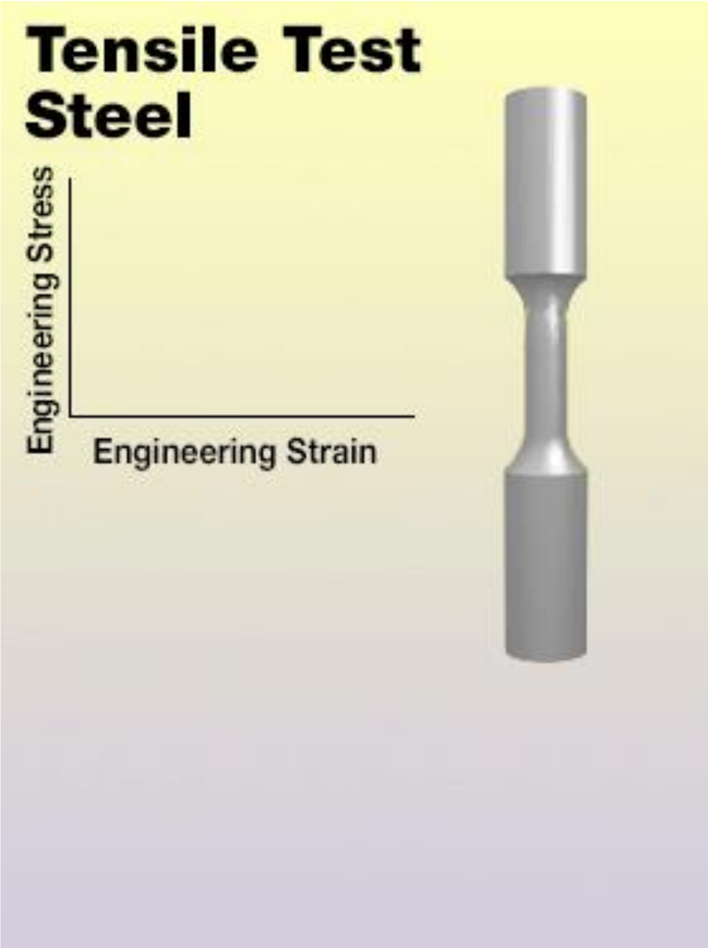
Dr. Vishal Gupta, Asst. Prof. MED, TIET, Patiala

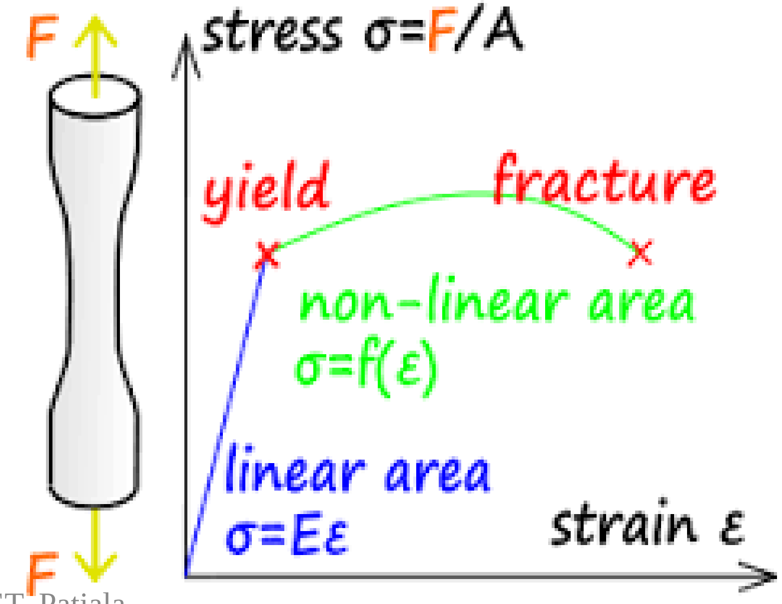
TENSION IN A MEMBER

1. AXIAL STRESS
2. EXTENSION LEADING TO STRAIN









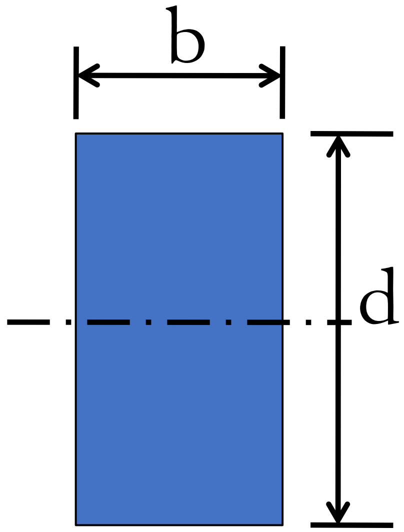
Failure Modes – Axial members

STRESS= FORCE /FAILURE AREA (MPa or N/mm²)

AXIAL STRESS

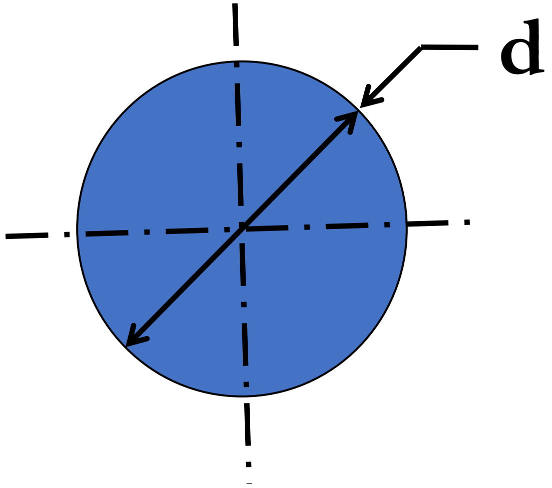
For rectangular cross-section

$$\sigma_a = \frac{P}{b \times d}$$



For circular cross-section

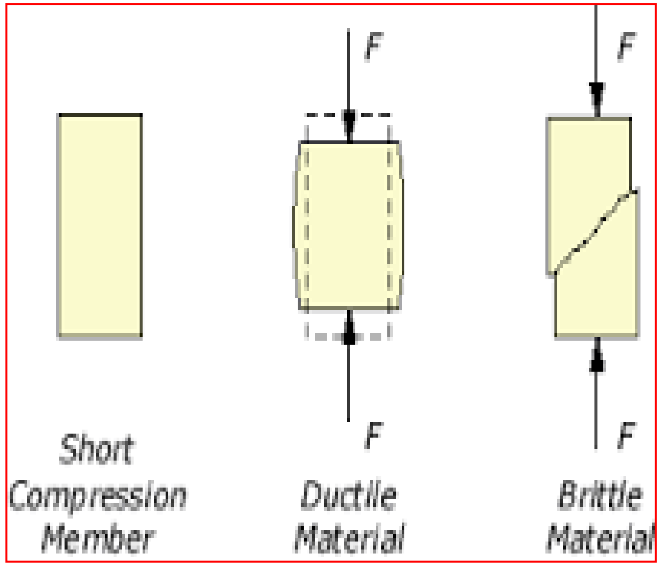
$$\sigma_a = \frac{P}{\frac{\pi}{4} d^2} = \frac{4P}{\pi d^2}$$

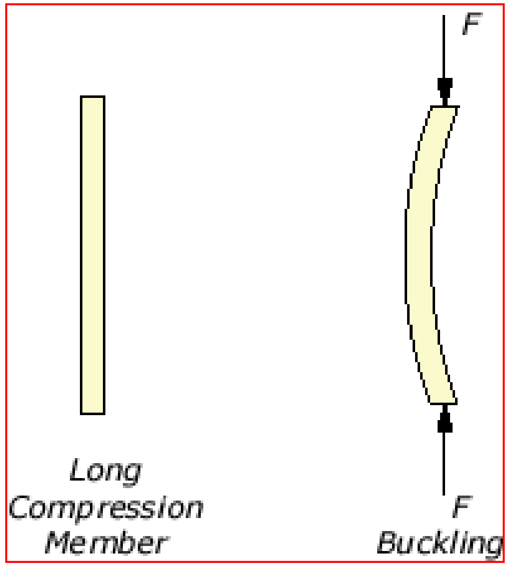


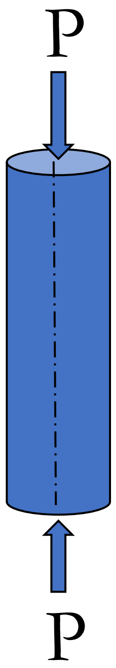
BUCKLING IN COMPRESSION

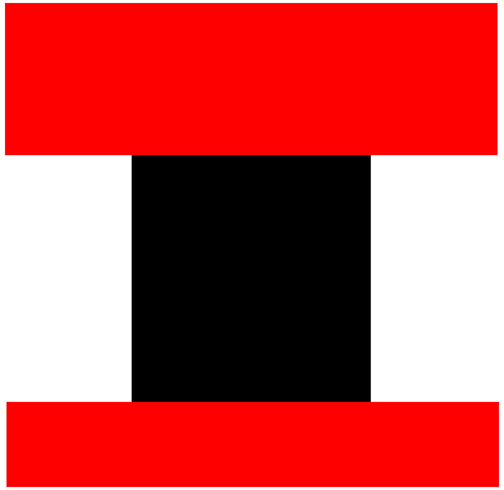
- ELASTIC
- PLASTIC

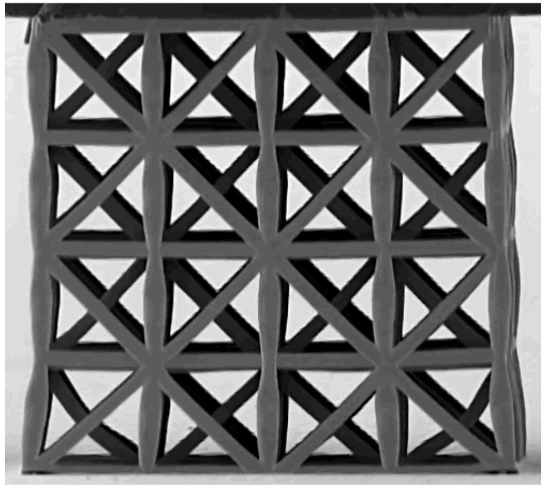
STRESS= FORCE /FAILURE AREA











SHORT COLUMN: a column which fails in compression

$$\sigma_a = \frac{P}{b \times d}$$

LONG COLUMN: a column which buckles before full compression strength is reached

$$\sigma_{cr} = \frac{P_{cr}}{A}$$

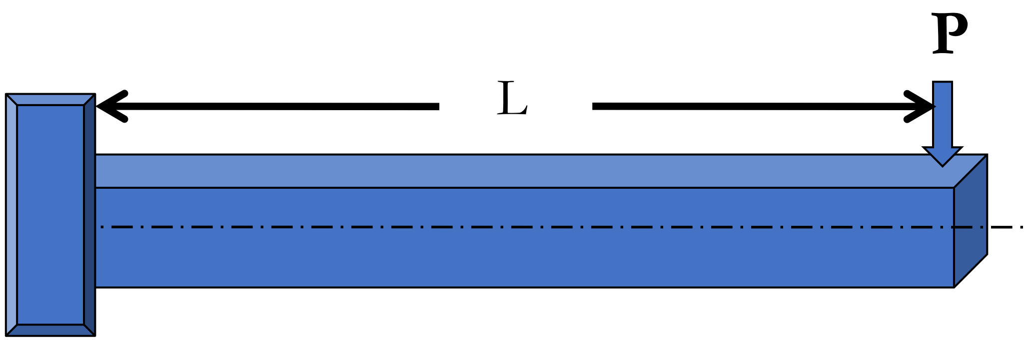
Where:

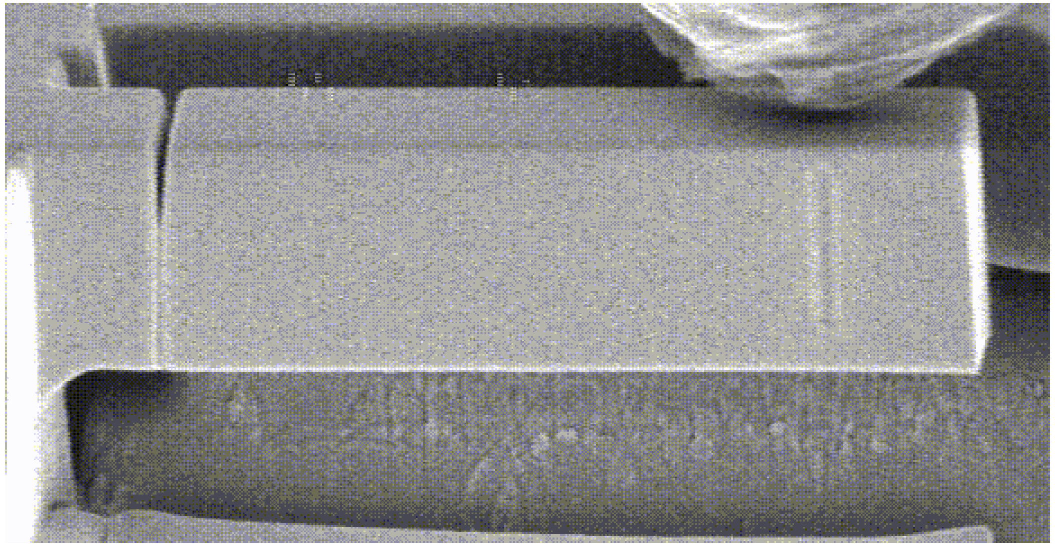
$$P_{cr} = \frac{\pi^2 EI}{L^2}$$

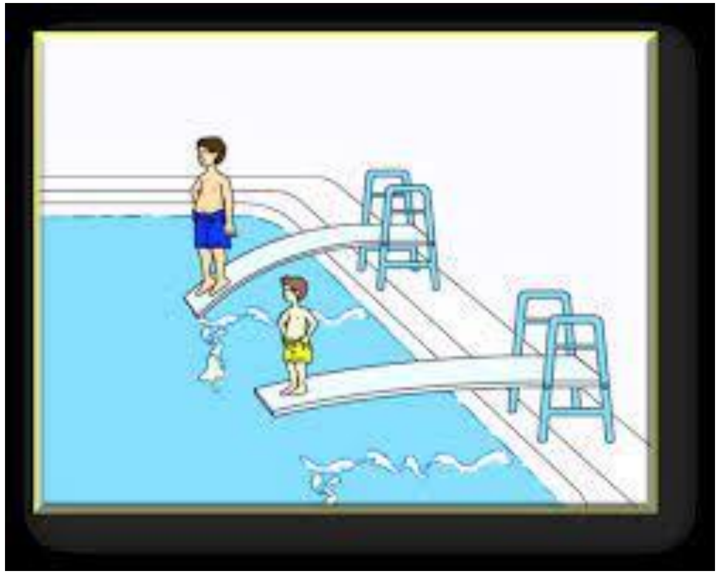
Failure Modes-Beams

TYPES OF BEAMS

1. CANTILEVER BEAM

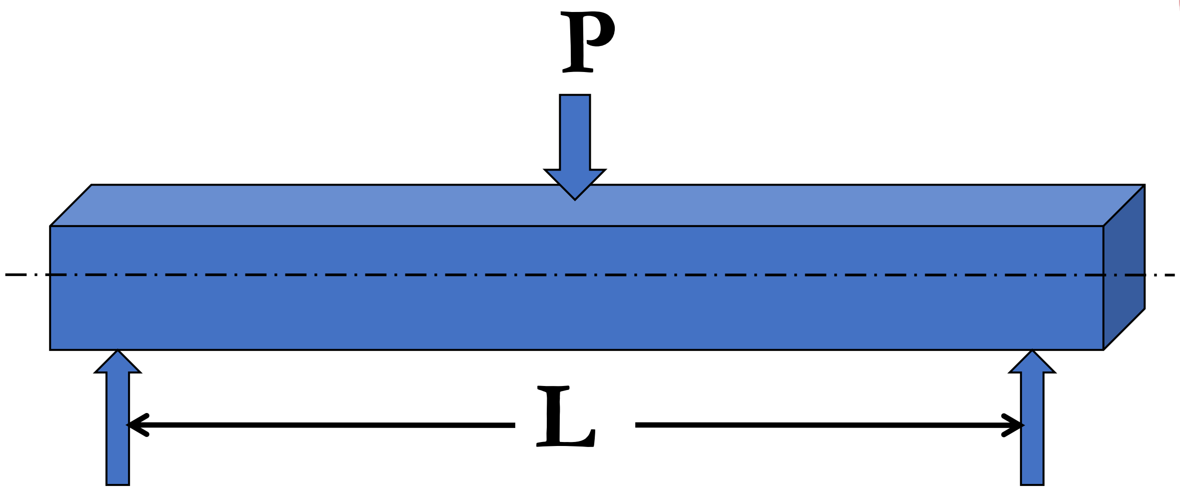


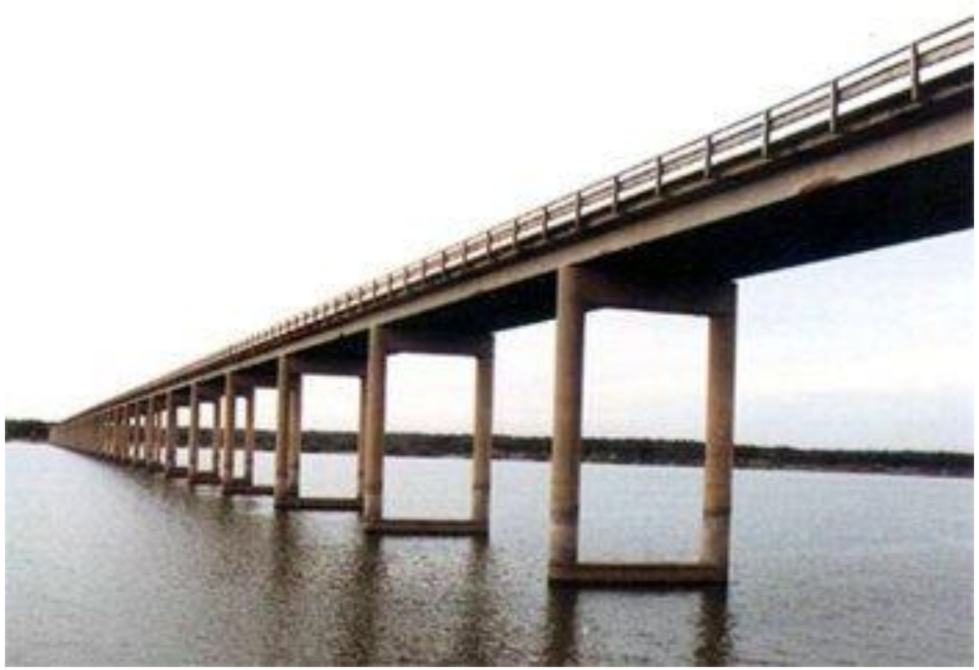


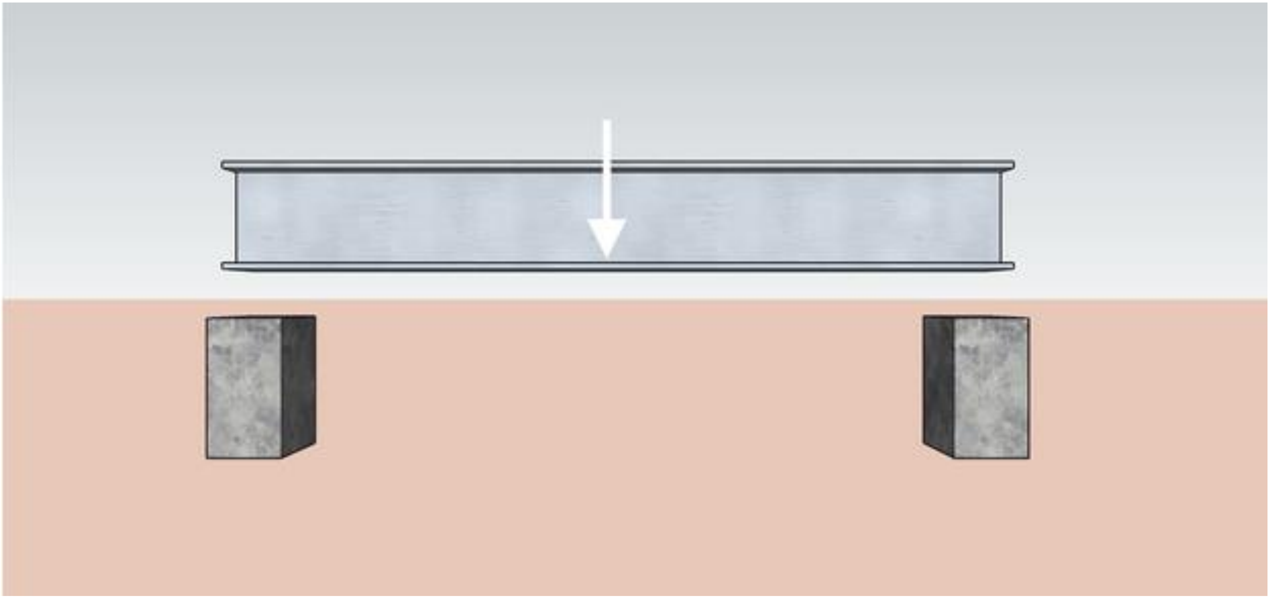


TYPES OF BEAMS

2. SIMPLY SUPPORTED BEAM

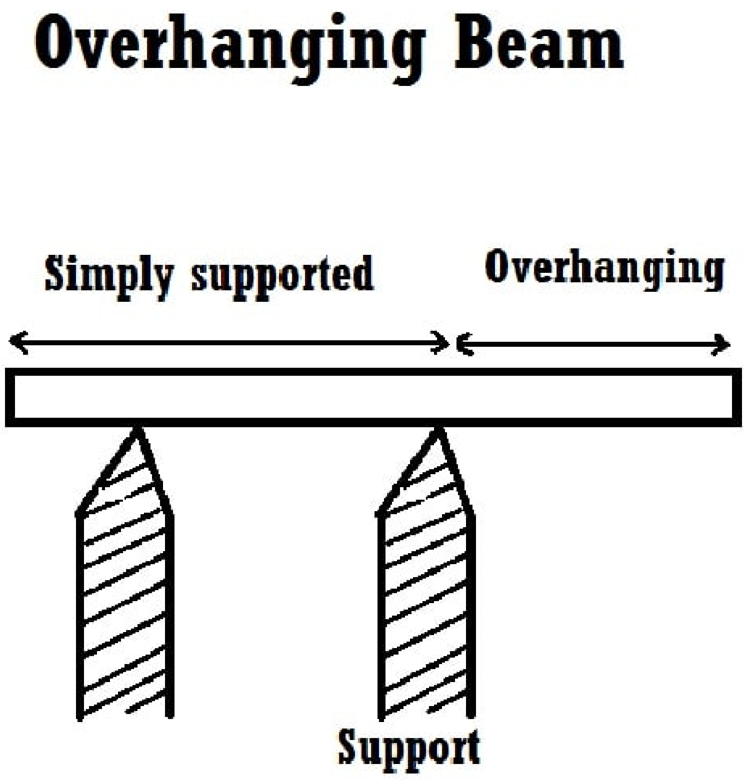






TYPES OF BEAMS

3. OVERHANG BEAM

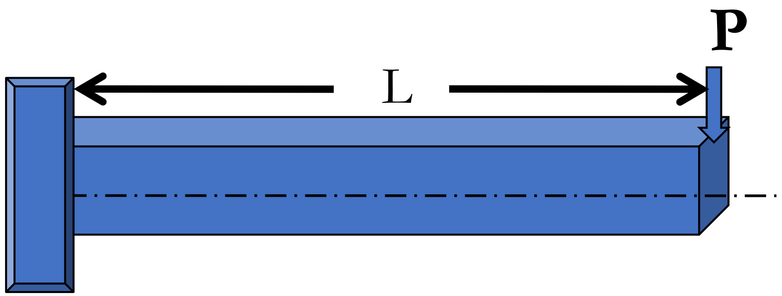


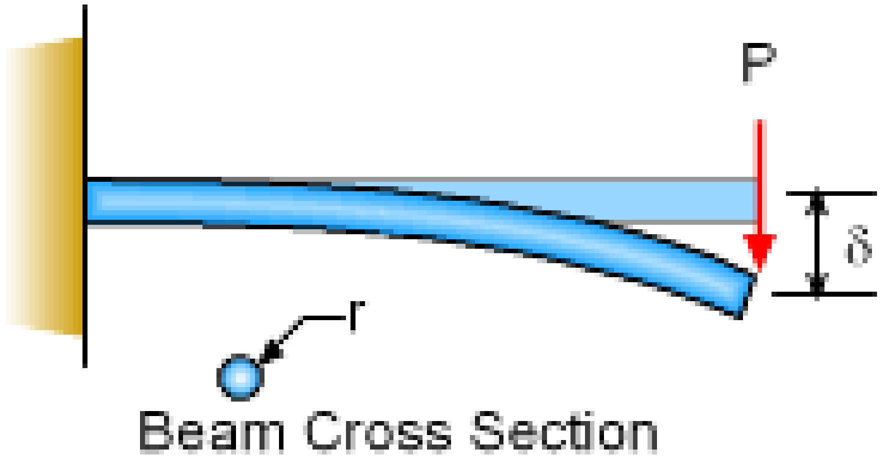
Failure Modes-Beams

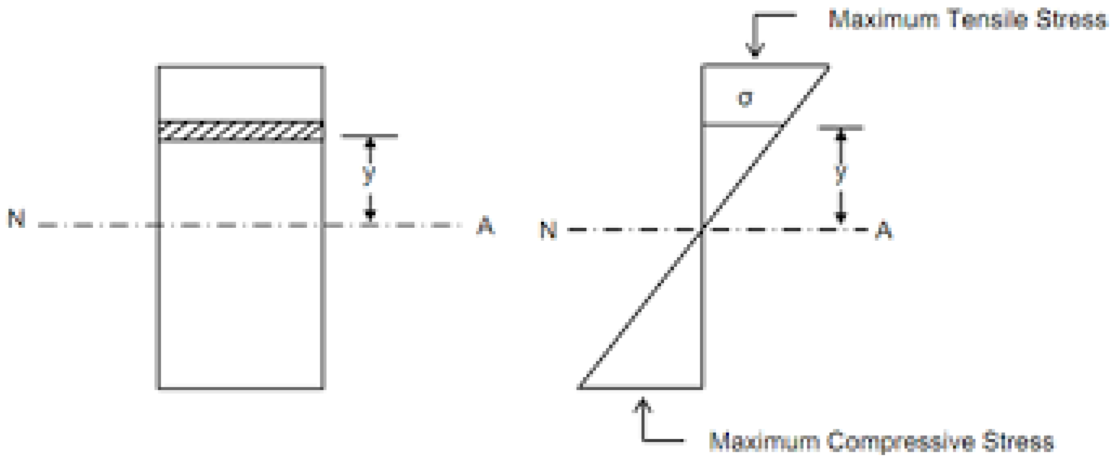
BENDING OF A BEAM

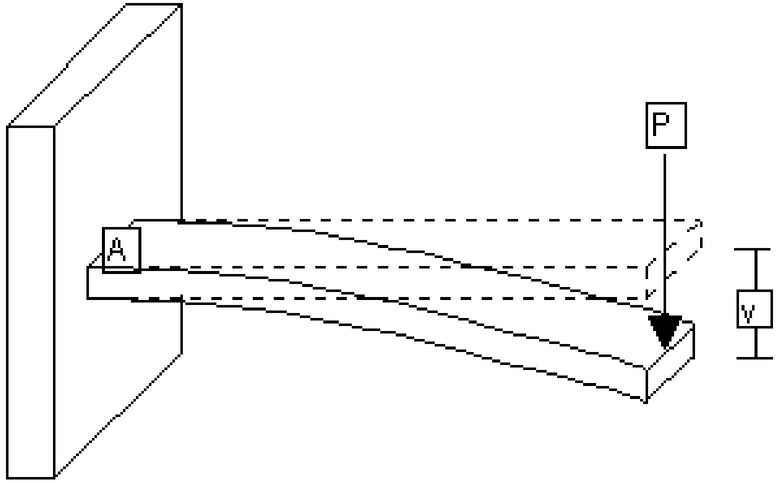
1. BENDING STRESS
2. TENSION AND COMPRESSION
3. SECOND MOMENT OF AREA
4. DEPTH V/S WIDTH
5. SECTION MODULUS

1. CANTILEVER BEAM









M = P x L (Cantilever beam)

EULER'S FLEXURE FORMULA

$$\frac{M}{I} = \frac{\sigma_b}{y} = \frac{E}{\rho}$$

BENDING OF A BEAM

BENDING STRESS

$$\sigma_b = \frac{M.y}{I}$$

WHERE:

$\boldsymbol{\sigma_b}$ = THE BENDING STRESS,

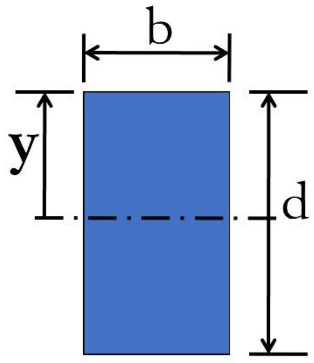
M= BENDING MOMENT,

y = DISTANCE FROM THE NEUTRAL AXIS

I = SECOND MOMENT OF AREA

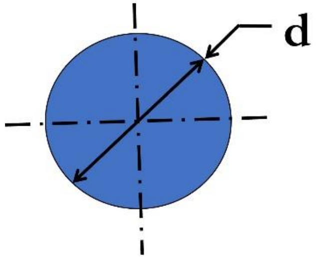
M = P x L (Cantilever beam)

SECOND MOMENT OF AREA



$$\mathbf{y = d/2}$$

$$I = \frac{bd^3}{12}$$



$$I = \frac{\pi d^4}{64}$$

SECTION MODULUS

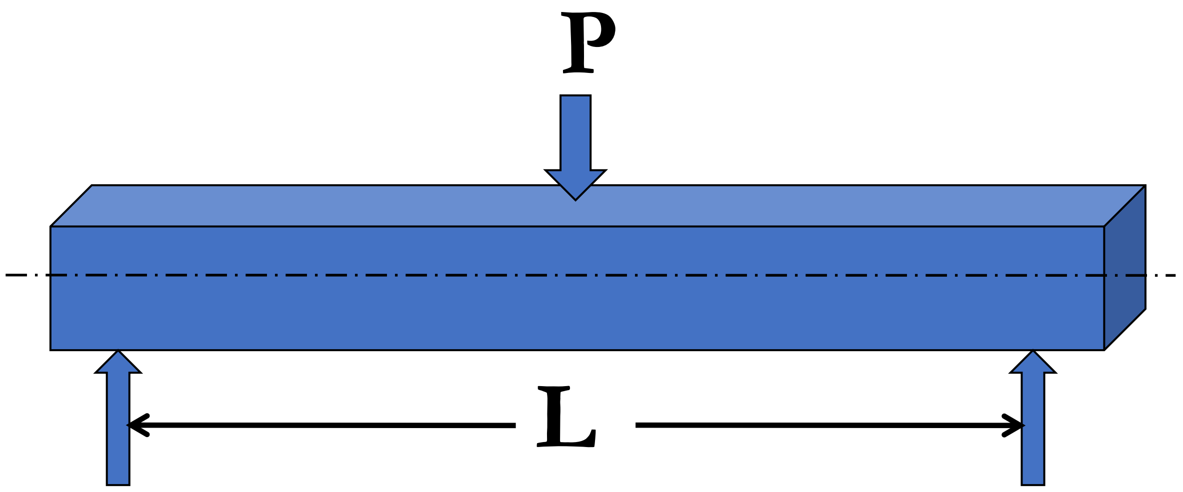
$$Z = \frac{I}{y}$$

BENDING STRESS

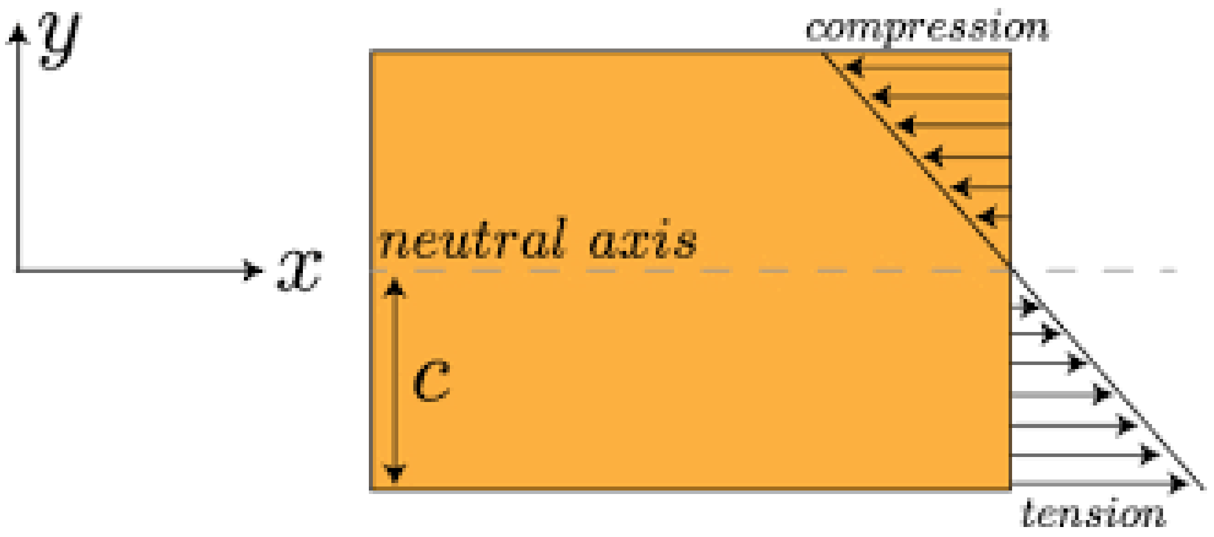
$$\sigma_b = \frac{M}{Z}$$

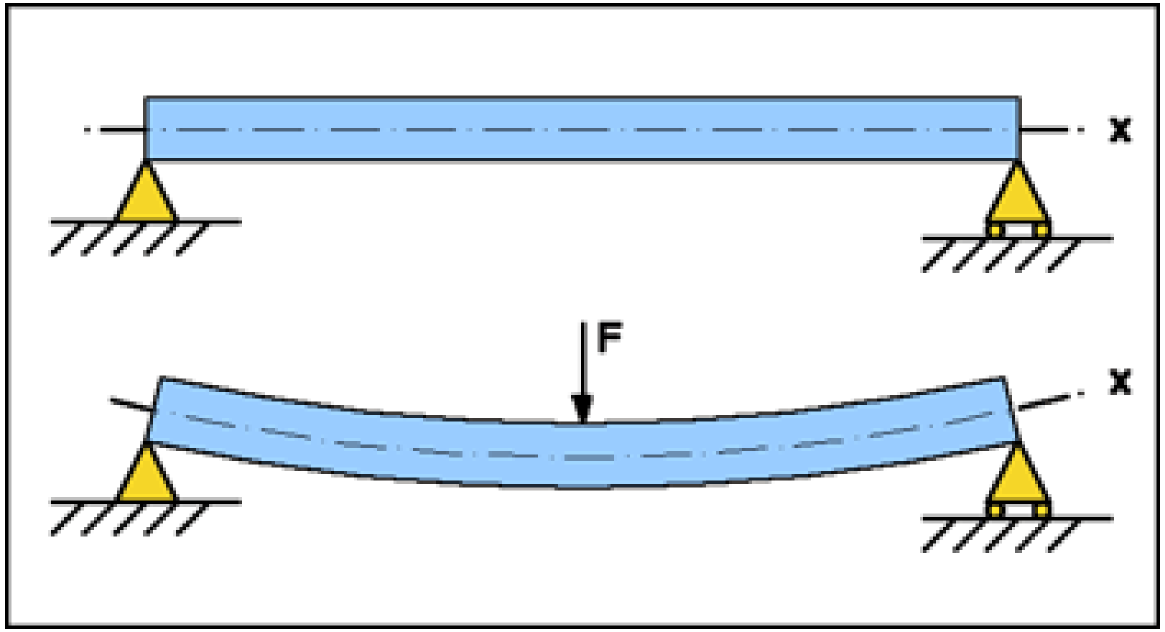
2. SIMPLY SUPPORTED BEAM

SIMPLY SUPPORTED WITH LOAD AT THE MIDDLE

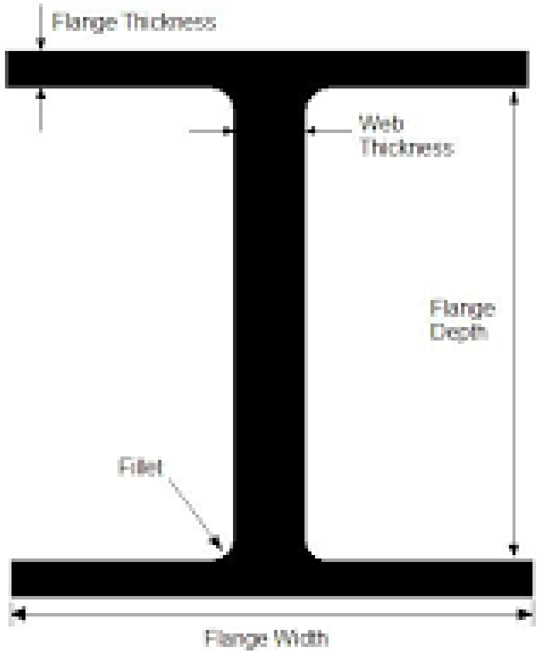


M=PL/4





BEAM CROSS-SECTION



Factor of safety

- While designing a component or a structural member, it is necessary to keep sufficient reserve strength in case of an accident.
- This is achieved by taking a suitable factor of safety (FOS)

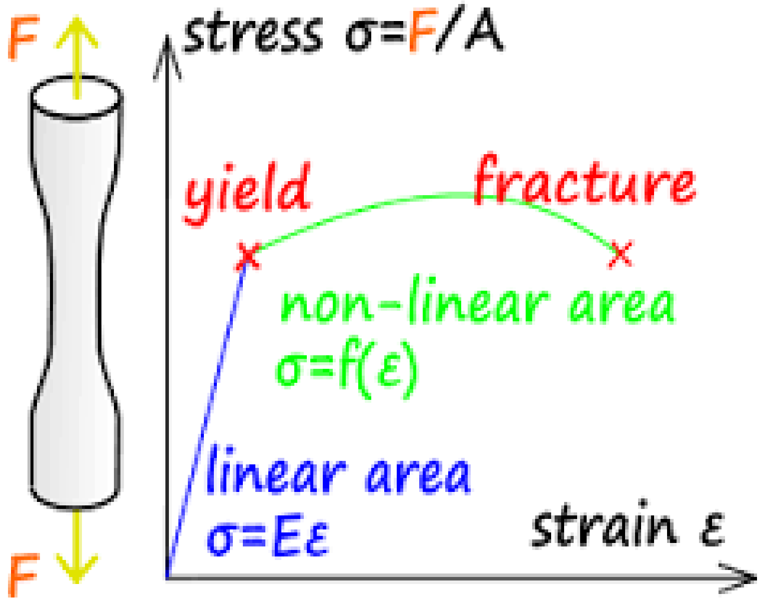
$$FOS = \frac{\text{FAILURE STRENGTH (STRESS)}}{\text{ACTUAL / ALLOWABLE STRESS}}$$

$$FOS = \frac{\text{FAILURE STRESS}}{\text{ALLOWABLE STRESS}}$$

$$FOS = \frac{\text{FAILURE LOAD}}{\text{WORKING LOAD}}$$

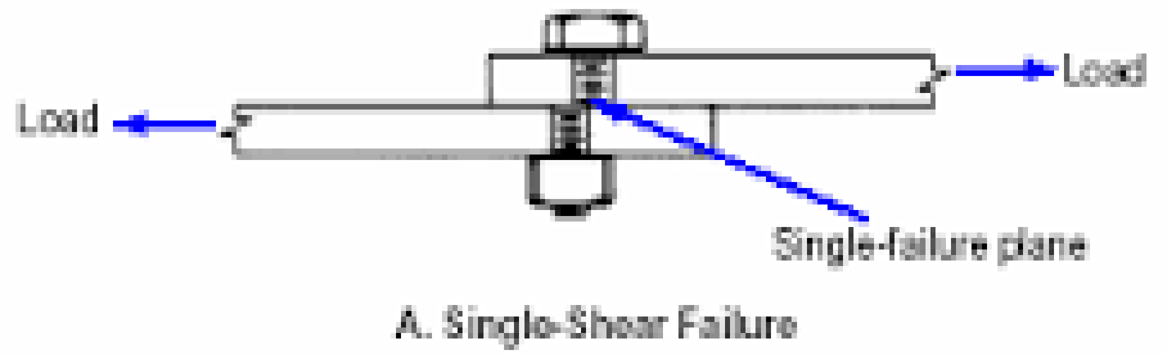
$$FOS = \frac{S_{ut} / S_{yt}}{\sigma}$$

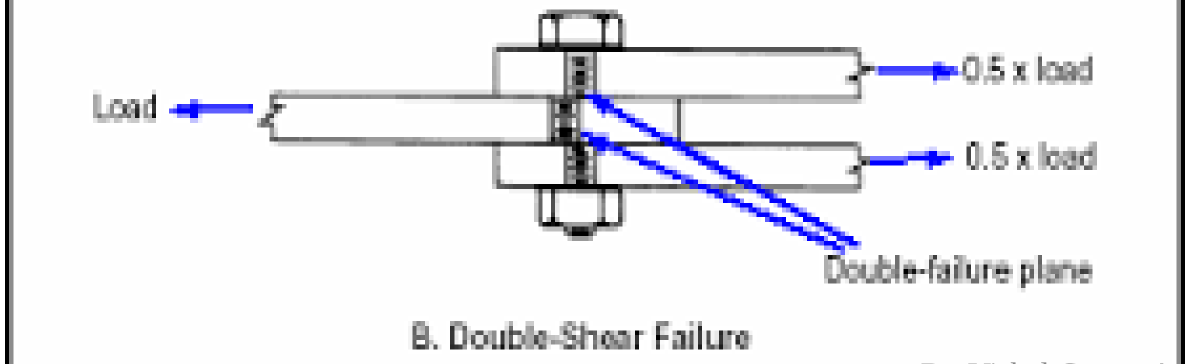
$$\sigma = \frac{S_{ut}}{FOS}$$

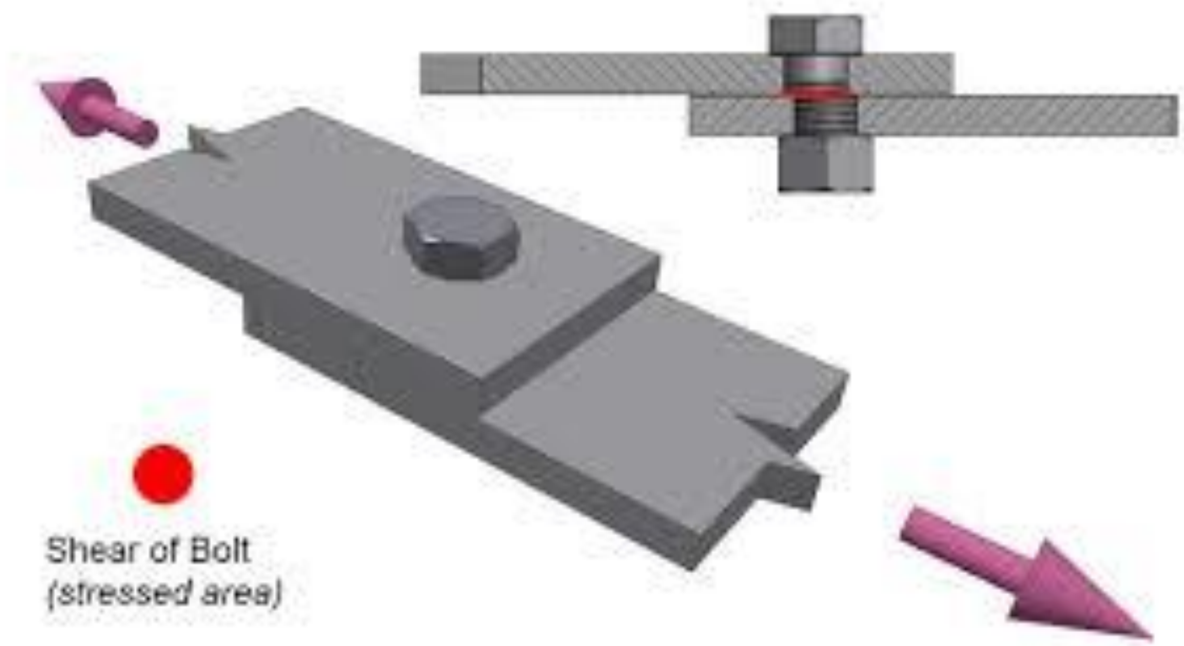


SHEAR FAILURE

BOLT FAILURE







(Single Shear)

SHEAR STRESS

$$\tau = \frac{P}{\left(\frac{\pi}{4}d^2\right)}$$

$$\tau = \frac{P}{2\left(\frac{\pi}{4}d^2\right)}$$

where 'd' is the diameter of bolt

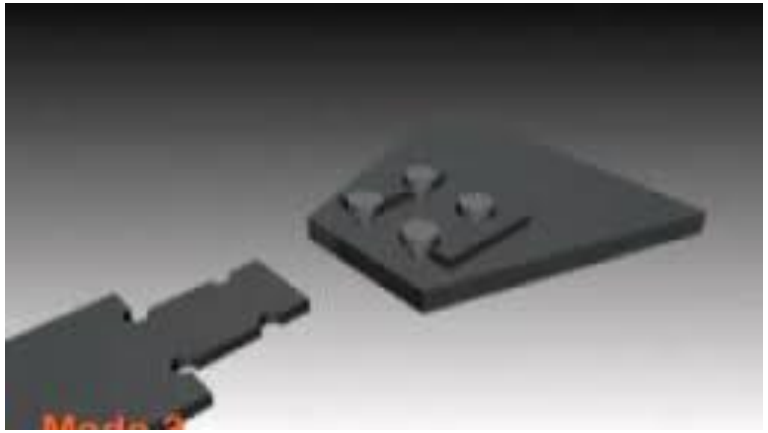
(Single Shear)

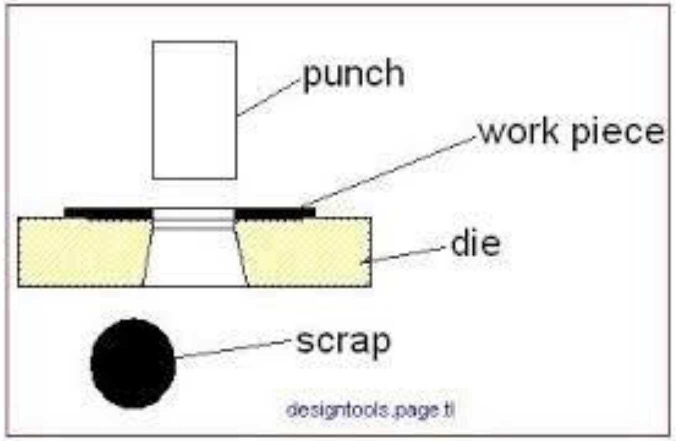
(Double Shear)

SHEAR FAILURE

OTHER EXAMPLES OF SHEAR

PLATE FAILURE

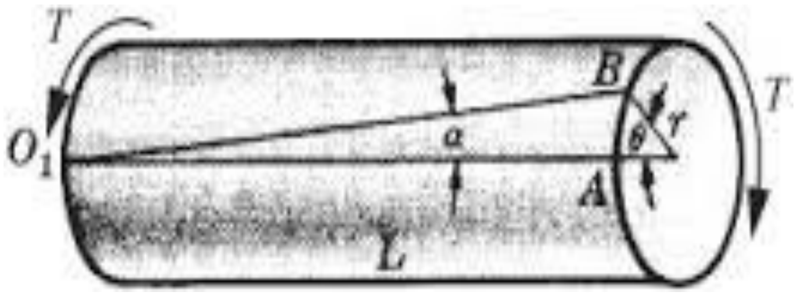


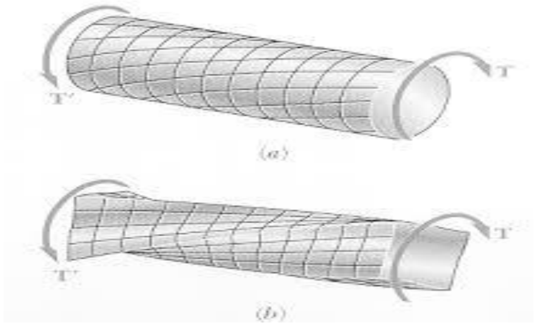


Failure Modes (TORSION)

SHAFT

$$\frac{T}{I_p} = \frac{\tau}{r} = \frac{G\phi}{L}$$





WHERE **T, I_P, τ, r, G, ϕ** AND **L** ARE, RESPECTIVELY, THE TWISTING MOMENT, POLAR MOMENT OF INERTIA, SHEAR STRESS, RADIUS OF THE SHAFT, SHEAR MODULUS, ANGLE OF TWIST AND LENGTH OF SHAFT

$$\tau = \frac{T \times r}{I_p}$$

where

$$I_p = \frac{\pi}{32} d^4$$

OTHER MODES

- CYCLIC - FATIGUE
- IMPACT
- CORROSION
- THERMAL MOVEMENT

Thanks for attending this lecture

Save Electricity Save World