Engineering Structures and Materials

- ***Mechanics of materials*** is a branch of applied mechanics that deals with the behavior of solid bodies subjected to various types of loading
- A thorough understanding of mechanical behavior is essential for the safe design of all structures
- ***Mechanics of materials*** is a basic subject in many engineering fields

Mechanics of Material
Earthquakes

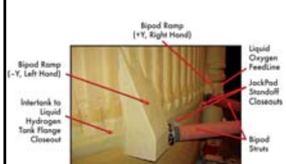
The **2017 Central Mexico earthquake** struck at 13:14 on September, 19 2017 with a magnitude estimated to be M_w 7.1 and strong shaking for about 20 seconds.

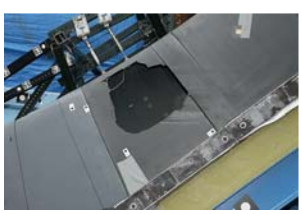
Mechanics of Material
Earthquakes

Mechanics of Material
Space Shuttle Columbia

The Space Shuttle Columbia disaster occurred on February 1, 2003, when the Space Shuttle Columbia disintegrated over Texas during re-entry into the Earth's atmosphere.

Mechanics of Material
Space Shuttle Columbia





The loss of Columbia was a result of damage sustained during launch when a piece of foam insulation the size of a small briefcase broke off the Space Shuttle external. The debris struck the leading edge of the left wing, damaging the Shuttle's thermal protection system.

Mechanics of Material
I-35W Mississippi River Bridge

The I-35W Mississippi River bridge catastrophically failed during the evening rush hour on August 1, 2007, collapsing to the river and riverbanks beneath.

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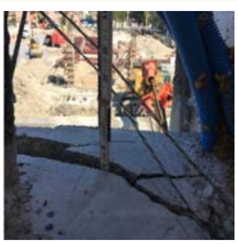
Mechanics of Material
FIU Pedestrian Bridge

On March 15, 2018, a 175-foot-long (53 m), recently-erected section of the FIU Sweetwater University City pedestrian bridge collapsed onto the Tamiami Trail (U.S. Route 41). Eight vehicles were crushed underneath, which resulted in six deaths and nine injuries.

Mechanics of Material
FIU Pedestrian Bridge



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Engineering Structures and Materials

The historical development of mechanics of materials is a fascinating blend of both theory and experiment

- Leonardo da Vinci (1452–1519)
- Galileo Galilei (1564–1642) performed experiments to determine the strength of wires, bars, and beams

Engineering Structures and Materials

- Leonhard Euler (1707–1783)
  Developed the mathematical theory of columns and calculated the theoretical critical load of a column in 1744, long before any experimental evidence existed to show the significance of his results.

Engineering Structures and Materials

- Numerical problems require that you work with ***specific units of measurements.***
- The two accepted standards of measurement are the ***International System of Units (SI)*** and the ***U.S. Customary System (USCS).***
- As you know ***significant digits*** are very important in engineering.
- In our work in this section, ***three significant digits*** provides enough accuracy.

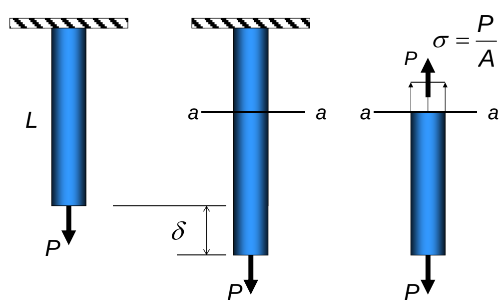
Stress and Strain

- The fundamental concepts of

  stress and **strain**

  can be illustrated by considering a prismatic bar that is loaded by axial forces *P* at the ends
- A ***prismatic bar*** is a straight structural member having constant cross section throughout its length
- In this illustration, the axial forces produce a uniform stretching of the bar; hence, the bar is said to be in ***tension***

Stress and Strain



Stress

- The tensile load *P* acts at the bottom end of the bar
- At the top of the bar are forces representing the action of the removed part of the bar
- The intensity of force (that is, the force per unit area) is called the

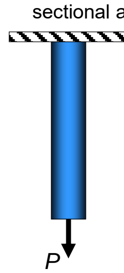
STRESS

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

(commonly denoted by the Greek letter σ).

Stress

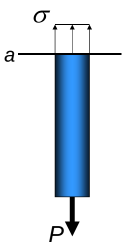
- The axial force is equal to the intensity s times the cross–sectional area *A* of the bar



$$P = \sigma A$$

- When the bar is stretched by the force ***P***, the resulting stresses are ***tensile stresses***
- If the force ***P*** cause the bar to be compressed, we obtain ***compressive stresses***

Stress

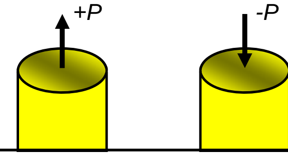


$$\sigma = \frac{P}{A}$$

- The stress acting perpendicular to the cut surface, it is referred to as a ***normal stress***
- The equation $\sigma = P/A$ will give the ***average normal stress***

Stress

- ***Sign convention*** for normal stresses is:
  (+) for tensile stresses and
  (-) for compressive stresses
- Because the normal stress s is obtained by dividing the axial force by the cross–sectional area, it has ***units*** of ***force per unit of area***

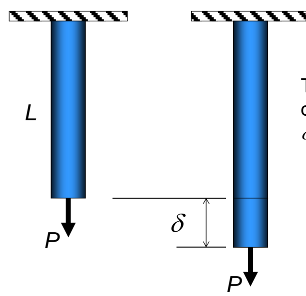


Stress

- ***In SI units:***
  Force is expressed in newtons (N) and area in square meters (m^2). A N/m^2 is a pascals (Pa).
- ***In USCS units:***
  Stress is customarily expressed in pounds per square inch (*psi*) or kips per square inch (*ksi*).

  7,000 Pa to make 1 psi

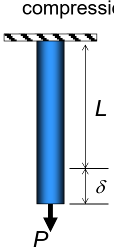
Normal Strain



The change in length is denoted by the Greek letter δ (delta).

Normal Strain

- An axially loaded bar undergoes a change in length, becoming longer when in tension and shorter when in compression



- The concept of elongation per unit length, or ***strain***, denoted by the Greek letter ε (epsilon) and given by the equation

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

Normal Strain

- If the bar is in tension, the strain is called a
  tensile strain
- If the bar is in compression, the strain is called a
  compressive strain
- Tensile strain is taken as positive (+), and compressive strain as negative (-).

Normal Strain

- The strain ε is called a ***normal strain*** because it is associated with normal stresses.
- Because normal strain ε is the ratio of two lengths, it is a ***dimensionless quantity***; that is, it has no units.

Example

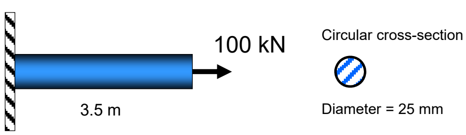
Consider a steel bar having length L of 2.0 m. When loaded in tension, the bar might elongate by an amount δ equal to 1.4 mm.

$$\varepsilon = \frac{\delta}{L} = \frac{\overline{1.4} \times 10^{-3} m}{2.0 m} = \boxed{0.000\overline{70} = \overline{7.0} \times 10^{-4}}$$

The resulting state of stress and strain is called ***uniaxial stress and strain***

Example

A prismatic bar with a circular cross section is subjected to an axial tensile force. The measured elongation is δ = 1.5 mm. Calculate the tensile stress and strain in the bar.



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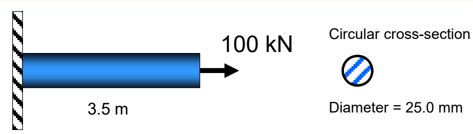
Example

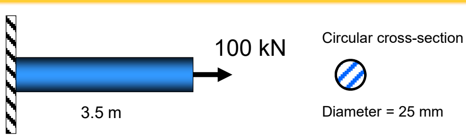


Assuming the axial force act at the center of the end cross section, then the stress is:

$$\sigma = \frac{P}{A} = \frac{100kN}{\frac{\pi(25.0mm)^2}{4}} = 203.718327 \frac{N}{mm^2} = \boxed{\overline{204} Mpa}$$

$$1{,}000 \; mm = 1 m$$

Example



The strain is

$$\varepsilon = \frac{\delta}{L} = \frac{\overline{1.5} mm}{3.5 m}\left(\frac{1m}{1{,}000 mm}\right) = 0.0004286.....$$

$$= \boxed{\overline{4.3} \times 10^{-4}}$$

Mechanics of Materials

End of Part 1

Any Questions?