Module 1, Lecture 4: Stress, Strain, Elastic Behavior

Types of Forces:

- Bending
- Shear
- Axial
- Tension
- Compression

- Test a 6 inch diameter by 12 inch high concrete cylinder.
- Fails at 115,000 pounds
- What load can a 24 inch x 24 inch column carry?

\[
\frac{115,000 \text{ lb}}{\pi \left(\frac{6}{2}\right)^2} = \frac{F_{\text{column}}}{24 \times 24 \text{ in}}
\]

\[
F_c = 2,340,000 \text{ lb} = 2,340 \text{ kips}
\]

Stress and Strain

**Stress**

\[
\sigma = \frac{F}{A}
\]

SI unit of stress: N/m² = Pa

\[
\rho S i = \frac{1005}{6}
\]

**Strain**

\[
\varepsilon = \frac{\Delta L}{L}
\]

Clipping Ropes: The maximum elongation for single ropes is 0.8% when an 80 kg mass is hung from the rope.

\[
\Delta L = L_f - L_0
\]

For a Linear Elastic material, Hooke's Law applies:

\[
\sigma = E \varepsilon
\]

\(E\) is Young's Modulus, the Elastic Modulus, or the Modulus of Elasticity.

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EF 152 2015 Lecture 1-4
Stress-Strain curves: Steel and Aluminum

- **Structural steel**
  1. Ultimate Strength
  2. Yield Strength
  3. Rupture
  4. Strain hardening region
  5. Necking region

- **Aluminum**
  1. Ultimate Strength
  2. Yield strength
  3. Proportional Limit Stress
  4. Rupture
  5. Offset Strain (typically 0.2%)
Example: Neyland Stadium

A steel column supporting the upper deck of Neyland Stadium has an area of 24.7 in², a length of 128 ft, and supports 250 fans. \((E_{\text{steel}} = 29 \times 10^6 \text{ psi})\)

How much does the column compress on a football Saturday?

Order of magnitude? Weight of average Vol fan?

\[ \Delta L = \frac{F L}{AE} = \frac{10^2 (10^2)(10^3)}{10 (10^7)} = 0.1 \text{ in} \]

\[ = \frac{250 \text{ fans} (180 \text{ lb/} \text{fan}) (128 \text{ ft})}{2.9 \times 10^6 (29 \times 10^6 \text{ lb/} \text{in}^2)} = 0.0965 \text{ in} \]

Example: Dangling iPod

While listening to “Rocky Top” on your iPod Touch, you accidently drop the iPod, and it is dangling by the ear buds wire. Find the stress in the copper and PVC insulation.

Copper wire: \(E = 110 \text{ GPa}, 0.404 \text{ mm dia}\)
PVC insulation: \(E = 2.8 \text{ GPa}, 1.00 \text{ mm outer dia}\)

What quantity is the same for both the copper and the insulation?

\[ \sigma_{\text{copper}} = \frac{F_{\text{copper}}}{A_{\text{copper}}} = \frac{0.998 \text{ N}}{0.128 \text{ mm}^2} = 7.78 \text{ MPa} \]
\[ \sigma_{\text{ins}} = \frac{F_{\text{ins}}}{A_{\text{ins}}} = \frac{0.130 \text{ N}}{0.128 \text{ mm}^2} = 1.98 \text{ MPa} \]
Factor of Safety

\[ FS = \frac{\text{Strength}}{\text{Load}} \]

Allowable Load = \( \frac{\text{Strength}}{F.S.} \)

What does factor of safety depend on?
Importance factors
Uncertainty in materials used
Variation in load
Cost
Mode of failure

What are typical values for factor of safety?

1.5 - 4
Example: Hanging Sign

The force in the cable is 114 lb. Use a factor of safety of 2.5

7 x 7 strand core

<table>
<thead>
<tr>
<th>Dia</th>
<th>Breaking Strength, lbs</th>
<th>Per Ft</th>
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</thead>
<tbody>
<tr>
<td>3/64&quot;</td>
<td>270</td>
<td>$0.20</td>
</tr>
<tr>
<td>1/16&quot;</td>
<td>480</td>
<td>$0.23</td>
</tr>
<tr>
<td>3/32&quot;</td>
<td>920</td>
<td></td>
</tr>
</tbody>
</table>

What diameter cable should we use?
1. 3/64"
2. 1/16"
3. 3/32"

\[
F.S. = \frac{\text{strength}}{\text{load}}
\]

\[
\text{Load (F.S.)} = 114 \text{ lb} \times 2.5 = 285 \text{ lb}
\]