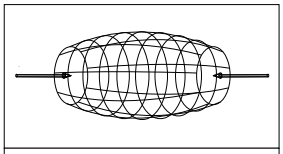
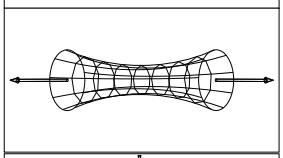
Stress and Strain

- Stress
- Strain
- Analysis – ASD vs. LRFD
- Modes of Failure

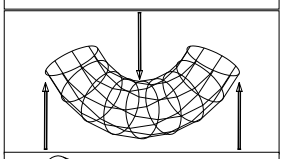
$$\sigma = \frac{P}{A}$$



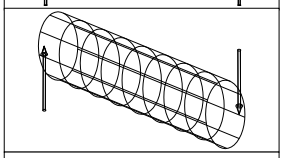
$$\sigma = \frac{P}{A}$$



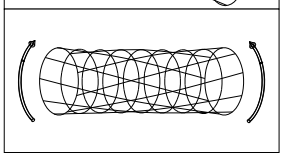
$$\sigma = \frac{M\ c}{I}$$



$$\tau = \frac{P}{A} or \frac{VQ}{Ib}$$



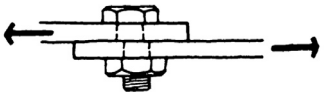
$$\tau = \frac{T\ r}{J}$$

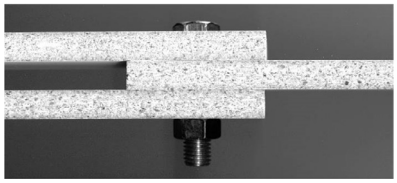


Stress

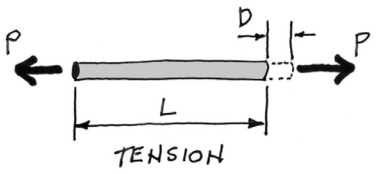
Stress is the result of a force being applied to the area of a material.

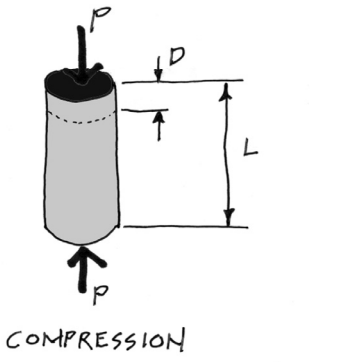
$$\sigma = \frac{P}{A}$$





Shear Stress

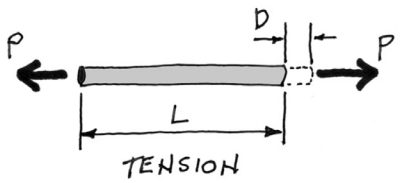




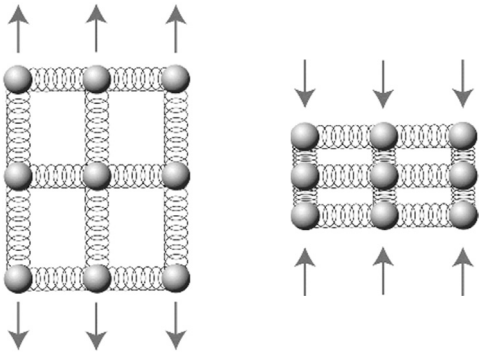
Strain

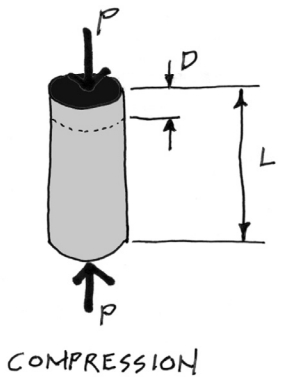
Strain is the amount of deformation in the material, per unit length.

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



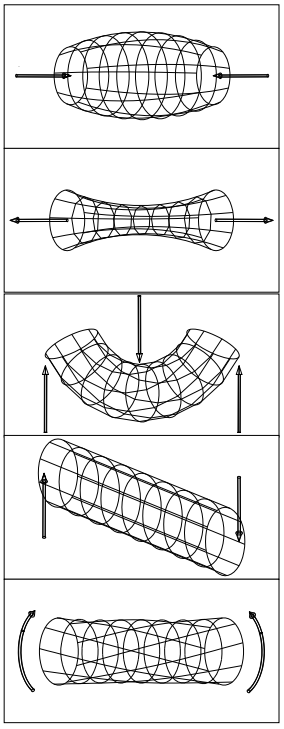
Deformation occurs either in stretching (tension) or in compressing (compression) but not always at the same rate.





Types of Stress

- Compression $\sigma = \frac{P}{A}$
- Tension $\sigma = \frac{P}{A}$
- Flexure $\sigma = \frac{M\ c}{I}$
- Shear $\tau = \frac{P}{A} or \frac{VQ}{Ib}$
- Torsion $\tau = \frac{T\ r}{J}$



Stress Analysis

Allowable Stress Design (ASD)

- use applied loads (no F.S. on loads)
- reduce stress by a Factor of Safety F.S.

$$f_{actual} \leq F_{allowable}$$

$$f_{actual} = \frac{P}{A}$$

$$F_{allowable} = F.S. \cdot f_{yield}$$

Load & Resistance Factored Design (LRFD)

- Use loads with safety factor γ
- Use factor on nominal strength ϕ

$$P_{load} \leq P_{resisting}$$

$$P_{load} = \gamma \cdot P_{applied}$$

$$P_{resisting} = \phi \cdot P_{material}$$

Stress Calculations - example

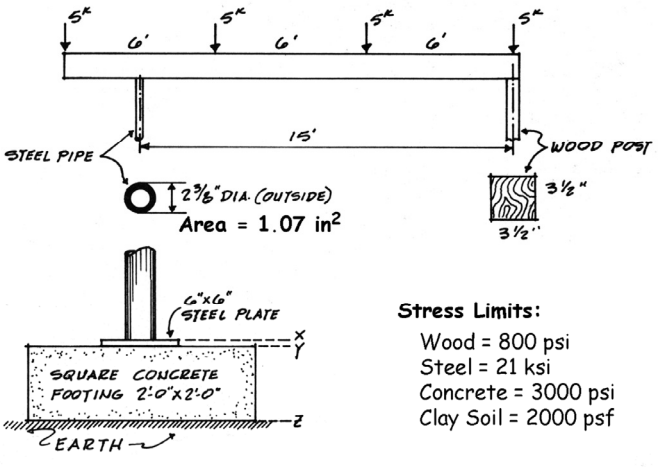
Find the stress in each material:

- wood
- steel
- concrete
- soil

Axial Compression

The stress equals the force spread over an area.

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



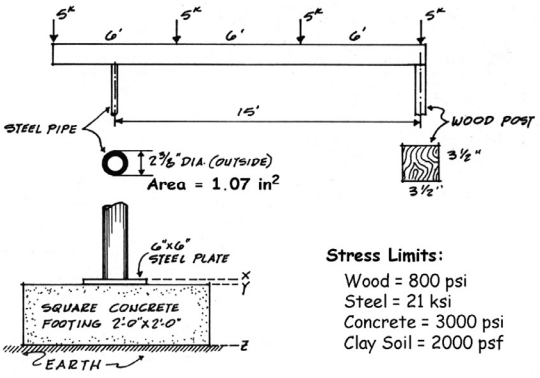
Stress Limits:

Wood = 800 psi
Steel = 21 ksi
Concrete = 3000 psi
Clay Soil = 2000 psf

Stress Calculations

Find the force on the members

FBD to find the end reactions



Stress Limits:
Wood = 800 psi
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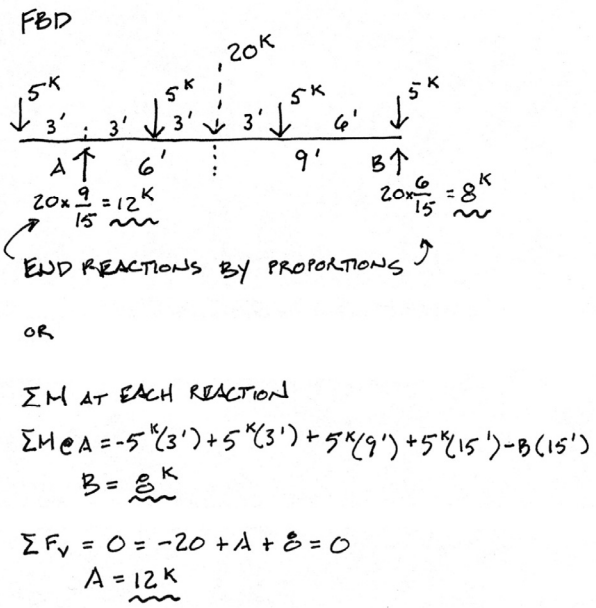
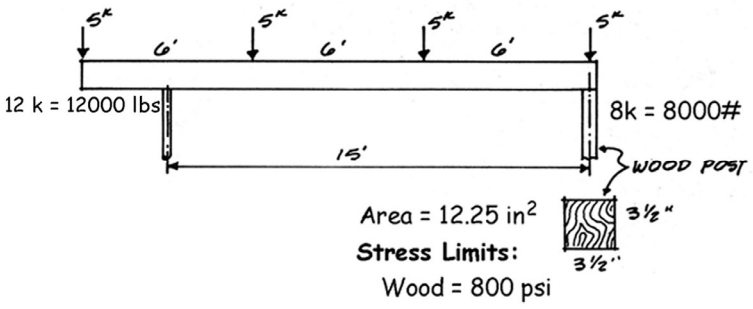


Stress Calculations

for the right side (wood)

The stress equals the force on the member, spread over the sectional area of the member.

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



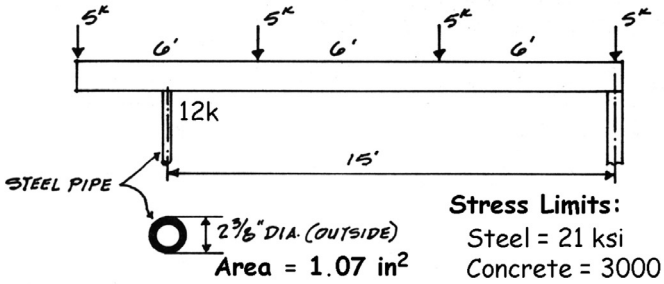
Stress in Wood:
f = P/A
f = 8000lbs/12.25 in²
f = 653 psi
F = 800 psi
f < F ok

Stress Calculations

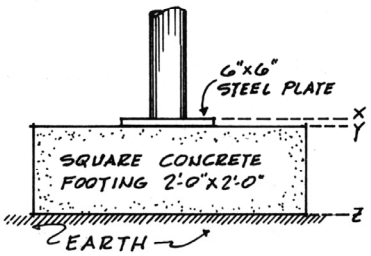
for the left side (steel pipe)

The stress equals the force spread over the area.

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



Stress Limits:
Steel = 21 ksi
Concrete = 3000 psi



Stress in Steel:
f = P/A = 12k / 1.07 in²
f = 11.2 ksi < F = 21 ksi ok

Stress in Concrete:
f = 12000 lbs / 1.07 in²
f = 11200 psi > 3000 psi FAILS!

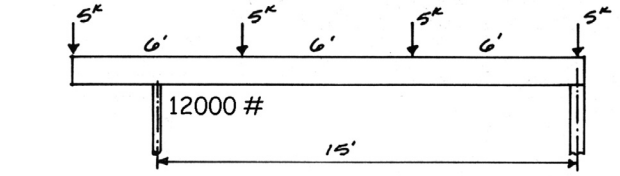
f = 12000 / 36 = 333 psi
333 psi < 3000 psi ok

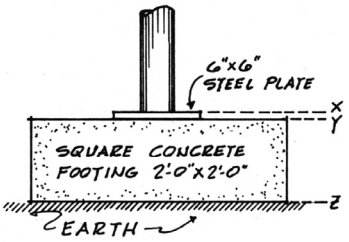
Stress Calculations

for the left side (foundation)

The stress equals the force spread over an area.

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





Stress in Soil:
f = 12000 # / 4 sf
f = 3000 psf > 2000 psf FAILS!

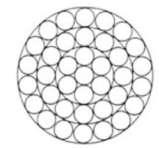
Stress Limits:
Clay Soil = 2000 psf

Stress Calculations

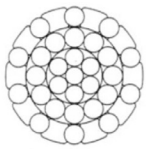
Axial Tension

The stress equals the force spread over an area.

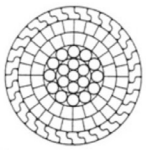
$$\sigma = \frac{P}{A}$$



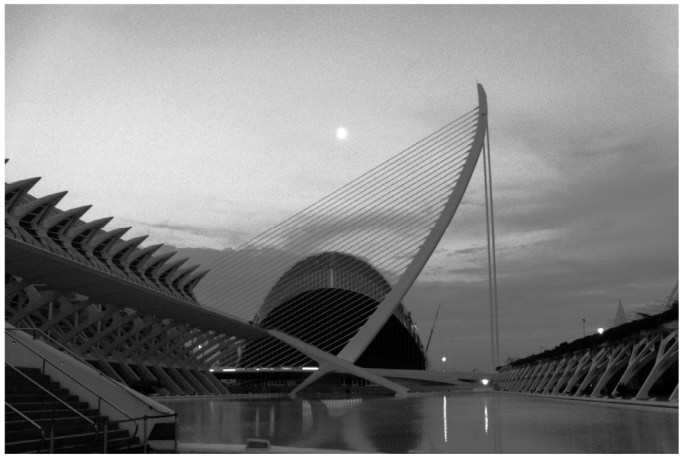
open spiral rope



half-locked rope



full-locked rope



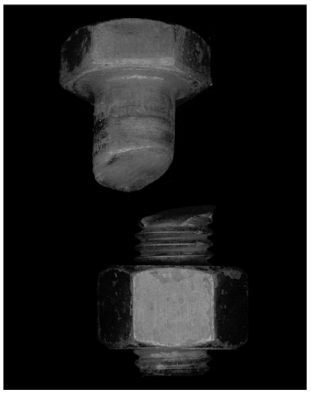
Santiago Calatrava - Serreria Bridge - Valencia 2008

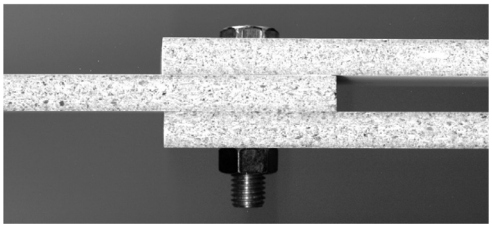
Stress Calculations

Shear

The stress equals the force spread over an area.

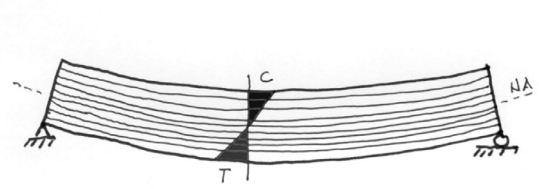
$$\sigma = \frac{P}{A}$$





Stress Calculations

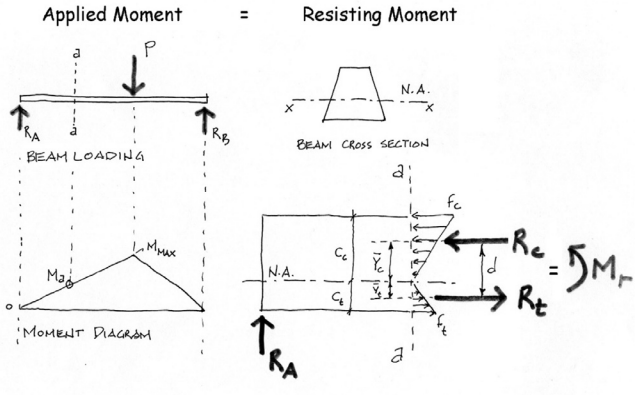
Bending



Flexure Stress

The stress is on the “fibers” or longitudinal layers

$$\sigma = \frac{M\ c}{I}$$

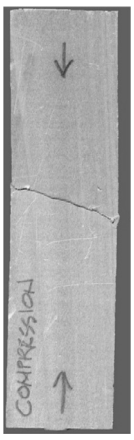


Shear Stress

The stress is between the longitudinal layers.

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

Modes of Failure



Strength
- Tension rupture
- Compression crushing

Stability
- Column buckling
- Beam lateral torsional buckling

Serviceability
- Beam deflection
- Building story drift
- cracking