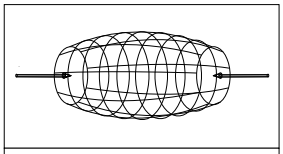
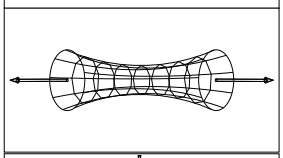
Stress and Strain

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

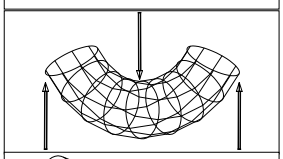
$$\sigma = \frac{P}{A}$$



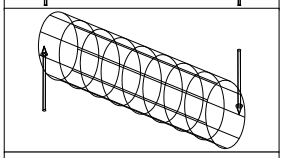
$$\sigma = \frac{P}{A}$$



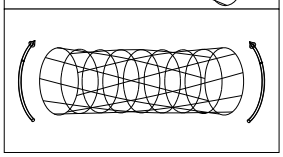
$$\sigma = \frac{M\ c}{I}$$



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



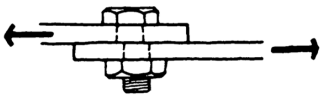
$$\tau = \frac{T\ r}{J}$$

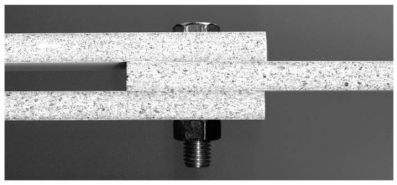


Stress

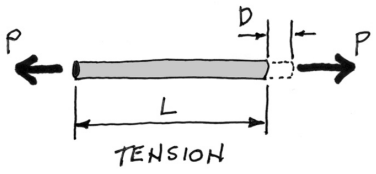
Stress is the result of some force being applied to an area of some material.

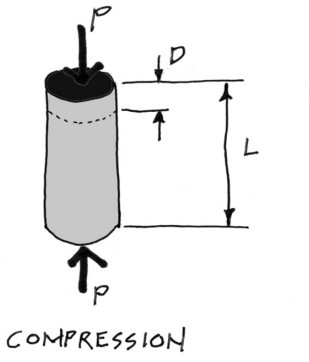
$$\sigma = \frac{P}{A} \quad \frac{\text{LOAD}}{\text{AREA}}$$





Shear Stress

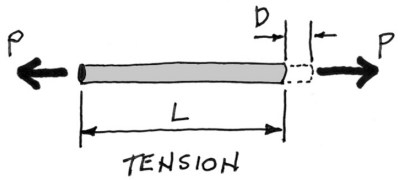




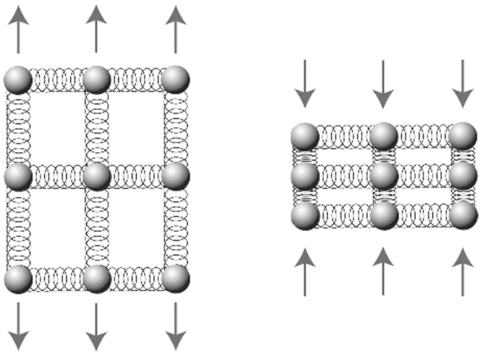
Strain

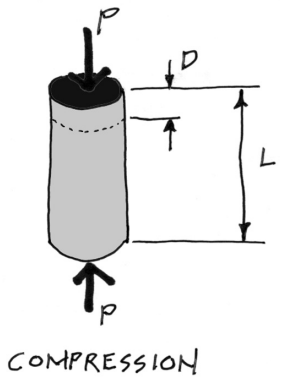
Strain is the amount of deformation in the material, per unit length.

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



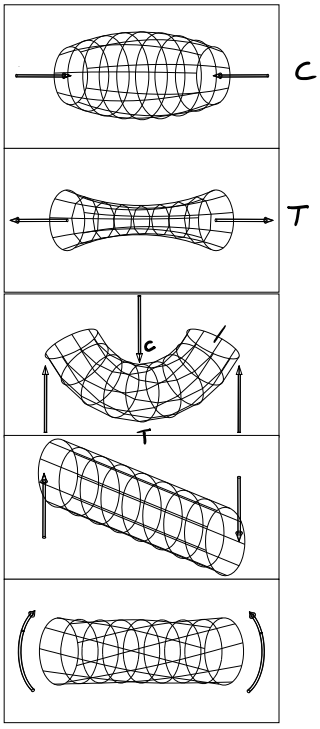
Deformation occurs either in stretching (tension) or in compressing (compression) but not always at the same rate.





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

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

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

$$F_{allowable} = \frac{F.S.}{1} \cdot f_{yield}$$

Load & Resistance Factored Design (LRFD)

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

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

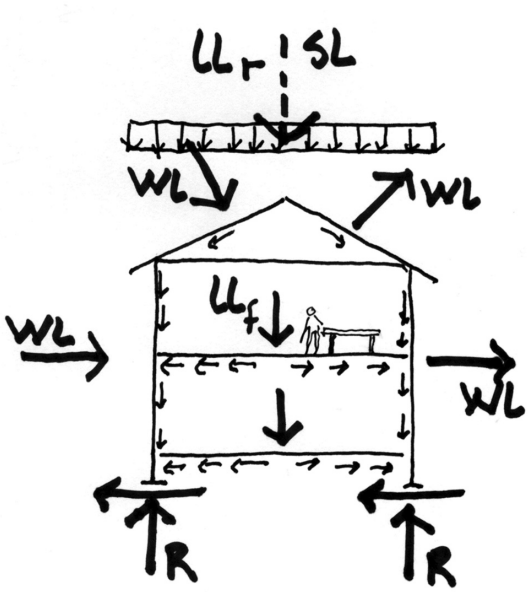
$$P_{load} = \gamma \cdot P_{applied}$$

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

ASCE – 7 Ch. 2 - Load Combinations

Load Types

- Dead Load - D
- Roof Live Load - Lr
- Floor Live Load - L
- Snow Load - S
- Wind Load - W
- Earthquake - E



Allowable Stress Design (ASD)

Not factored

- D
- D + L
- D + (Lr or S)
- D + 0.75 L + 0.75 (Lr or S)
- D + (0.6W)
- D + 0.75L + 0.75(0.6W) + 0.75(Lr or S)
- D + 0.7Ev + 0.7Eh

Strength Design (LRFD)

With gamma (γ) safety factors 2022

- 1.4 D
- 1.2 D + 1.6 L + (0.5Lr or 0.3S or 0.5R)
- 1.2 D + (1.6Lr or S or 1.6R) + (L or 0.5W)
- 1.2 D + 1.0W + L + (0.5Lr or 0.3S or 0.5R)
- 0.9D + 1.0W
- 1.2D + Ev + Eh + L + 1.5S
- 0.9D - Ev + Eh

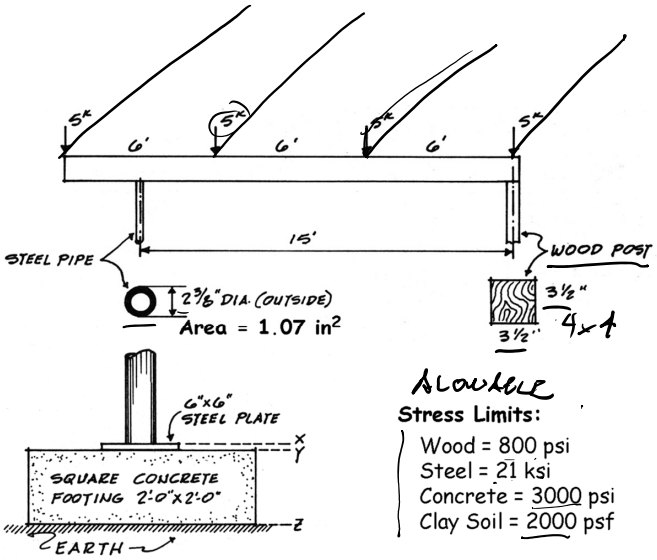
Stress Calculations

Find the stress in each material

Axial Compression

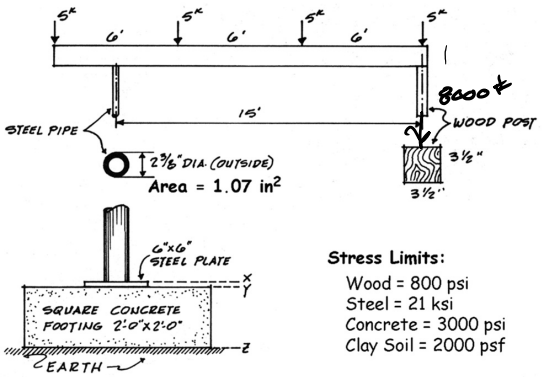
The stress equals the force spread over an area.

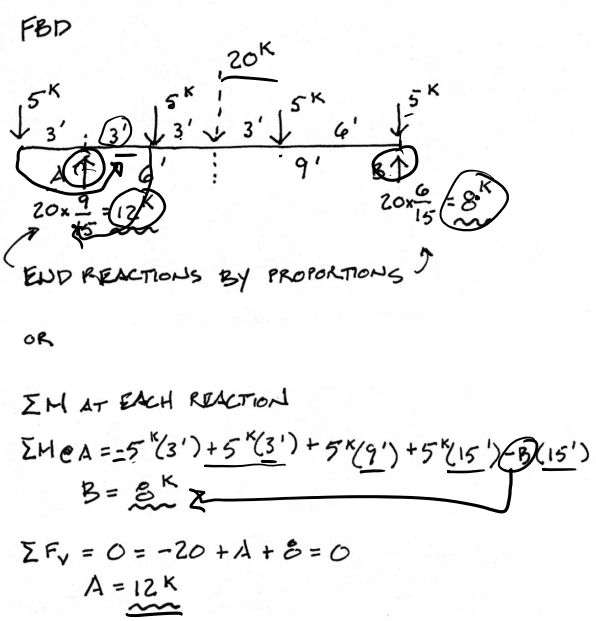
$$\sigma = \frac{P}{A}$$



Stress Calculations

FBD – reactions

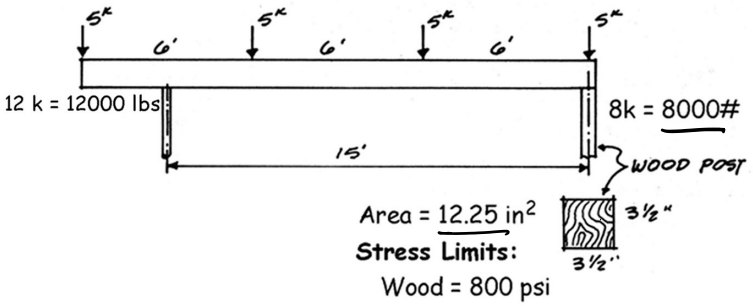




Stress Calculations

The stress equals the force spread over an area.

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



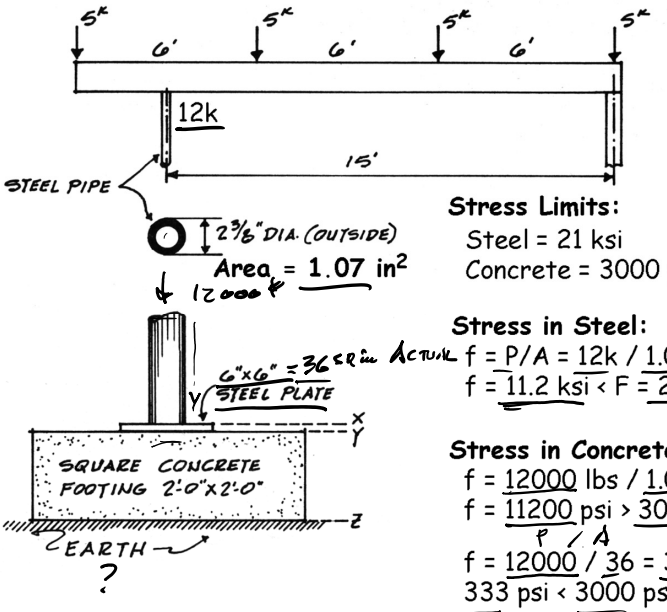
Stress in Wood:

ACTUAL
f = P/A
f = 8000lbs/12.25 in²
f = 653 psi
→ F = 800 psi CAPACITY ✓
f < F ok ✓

Stress Calculations

The stress equals the force spread over an area.

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



Stress Limits:
Steel = 21 ksi
Concrete = 3000 psi

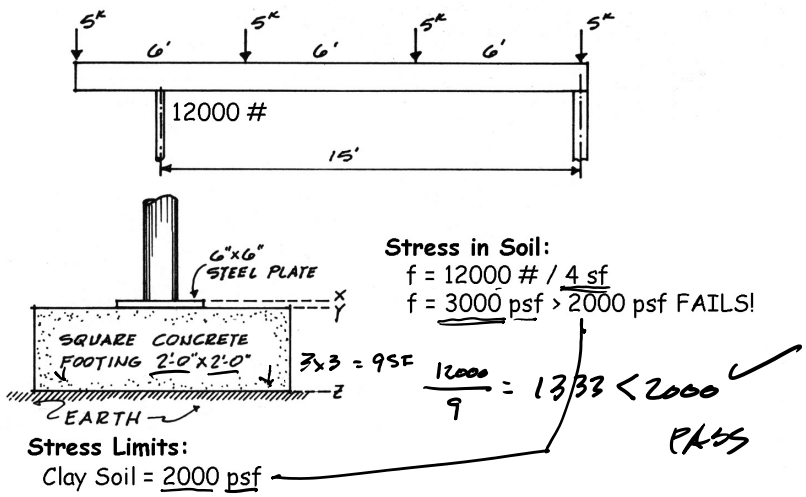
Stress in Steel:
f = P/A = 12k / 1.07 in²
f = 11.2 ksi < F = 21 ksi ok ✓
A-36

Stress in Concrete:
f = 12000 lbs / 1.07 in²
f = 11200 psi > 3000 psi FAILS!
P / A
f = 12000 / 36 = 333 psi
333 psi < 3000 psi ok

Stress Calculations

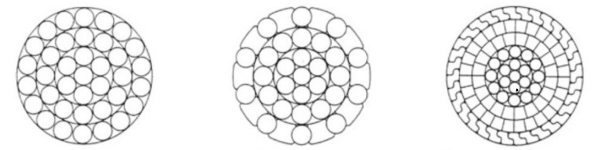
The stress equals the force spread over an area.

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



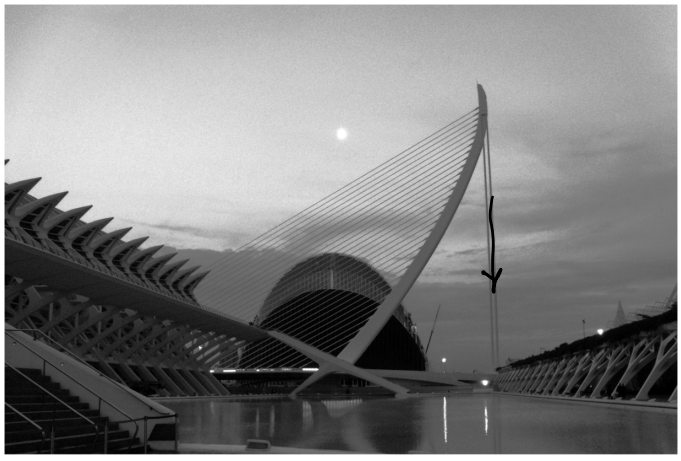
Stress Calculations

Axial Tension



The stress equals the force spread over an area.

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



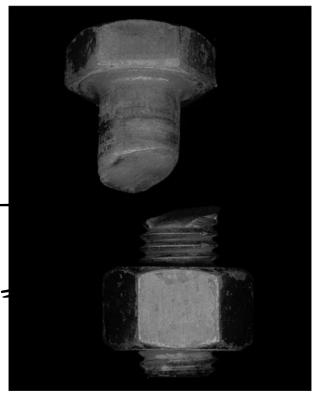
Santiago Calatrava - Serreria Bridge - Valencia 2008

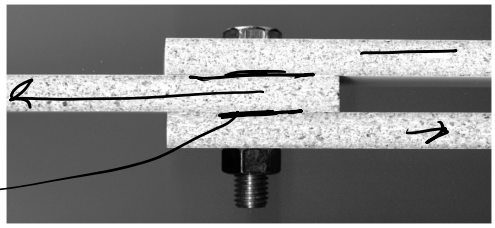
Stress Calculations

Shear

The stress equals the force spread over an area.

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

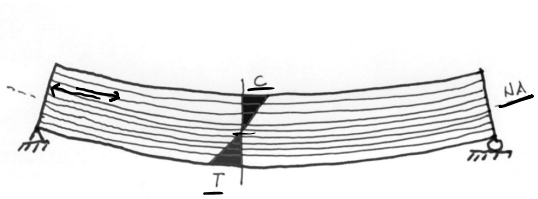




2x A_{bolt}

Stress Calculations

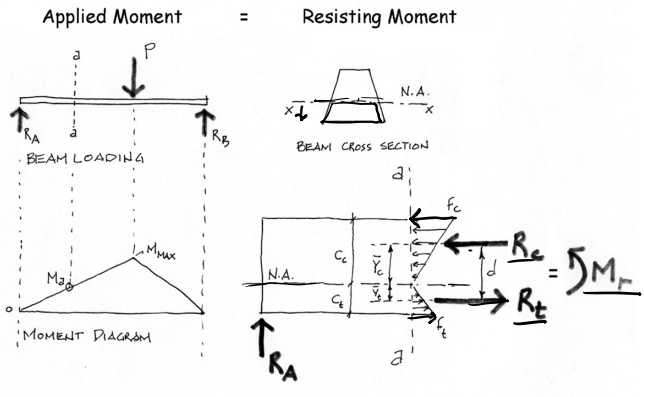
Bending



Flexure Stress

The stress is on the "fibers" or longitudinal layers

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



Shear Stress

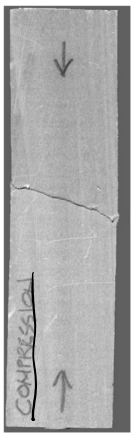
The stress is between the longitudinal layers.

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

Modes of Failure

Strength

- Tension rupture
- Compression crushing



Stability

- Column buckling
- Beam lateral torsional buckling



Serviceability

- Beam deflection
- Building story drift
- cracking

