Design Methods

- different approaches to meeting strength/safety requirements
  - allowable stress design (elastic)
  - ultimate strength design
  - limit state design
  - plastic design
  - load and resistance factor design
- assume a behavior at failure or other threshold and include a margin of safety

Load Types

- \( D \) = dead load
- \( L \) = live load
- \( L_r \) = live roof load
- \( W \) = wind load
- \( S \) = snow load
- \( E \) = earthquake load
- \( R \) = rainwater load or ice water load
- \( T \) = effect of material & temperature
- \( H \) = hydraulic loads from soil (F from fluids)
**Weight of Materials**

- for a volume
  - \( W = \gamma V \) where \( \gamma \) is weight/volume
  - \( W = \gamma tA \) for an extruded area with height of \( t \)

**Building Codes**

- documentation
  - laws that deal with planning, design, construction, and use of buildings
  - regulate building construction for
    - fire, structural and health safety
  - cover all aspect of building design
  - references standards
    - acceptable minimum criteria
    - material & structural codes

**Prescribed Loads**

- ASCE-7
  - live load (not roof) reductions allowed
- International Building Code
  - occupancy
  - wind: pressure to static load
  - seismic: shear load function of mass and response to acceleration
  - fire resistance
Code Reduction of Live Loads

- for (ordinary) live loads
  - factored area supported $\geq 400 \text{ ft}^2$
  - reduction can't exceed
    - $0.5L_o$ (one floor) or $0.4L_o$ (more)

$$L = L_o \left( 0.25 + \frac{15}{\sqrt{K_{LL}A_T}} \right)$$

- for live loads $> 100 \text{ lb/ft}^2$
  - live load reduction of 20% on columns

- for (ordinary) roofs: $L_r = L_o R_1 R_2$
  - $12 \text{ lb/ft}^2 \leq L_r \leq 20 \text{ lb/ft}^2$

Structural Codes

- prescribe loads and combinations
- prescribe design method
- prescribe stress and deflection limits
- backed by the profession
- may require design to meet performance standards
- related to material or function

Design Methods

- probability of loads and resistance
- material variability
- overload, fracture, fatigue, failure
- allowable stress design
  $$f_{\text{actual}} = \frac{P}{A} \leq f_{\text{allowed}} = \frac{f_{\text{capacity}}}{F.S.}$$
- limit state design
  - design loads & capacities
Allowable Stress Design

• historical method
• a.k.a. working stress, strength design
• stresses stay in ELASTIC range

ASD Load Combinations

• \( D \)
• \( D + L \)
• \( D + (L_r \text{ or } S \text{ or } R) \)
• \( D + 0.75L + 0.75(L_r \text{ or } S \text{ or } R) \)
• \( D + (0.6W \text{ or } 0.7E) \)
• \( D + 0.75L + 0.75(0.6W \text{ or } 0.7E) + (0.75L_r \text{ or } S \text{ or } R) \)
• \( 0.6D + (0.6W \text{ or } 0.7E) \)

Limit State Design

• a.k.a. strength design
• stresses go to limit (strain outside elastic range)
• loads may be factored
• resistance or capacity reduced by a factor
• based on material behavior
• “state of the art”

Limit State Design

• load and resistance factor design (LRFD)
  – loads:
    • not constant,
    • possibly more influential on failure
    • happen more or less often
  – UNCERTAINTY
    \[ \gamma_D P_D + \gamma_L P_L \leq \phi P_u \]
  \( \phi \) - Resistance factor
  \( \gamma \) - Load factor for (D)ead & (L)ive load
**LRFD Load Combinations**  
ASCE-7 (2010)

- $1.4D$
- $1.2D + 1.6L + 0.5(L_r$ or $S$ or $R)$
- $1.2D + 1.6(L_r$ or $S$ or $R) + (L$ or $0.5W)$
- $1.2D + 1.0W + L + 0.5(L_r$ or $S$ or $R)$
- $1.2D + 1.0E + L + 0.2S$
- $0.9D + 1.0W$
- $0.9D + 1.0E$
  
  - $F$ has same factor as $D$ in 1-5 and 7
  - $H$ adds with 1.6 and resists with 0.9 (permanent)

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**Load Tracing**

- **how loads are transferred**
  - usually starts at top
  - distributed by supports as **actions**
  - distributed by **tributary areas**

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**Load Tracing**

- **tributary load**
  - think of water flow
  - “concentrates” load of area into center

\[ w = \left( \frac{\text{load}}{\text{area}} \right) \times (\text{tributary width}) \]
Load Paths

• wall systems

- Load Paths

• openings & pilasters

- Load Paths

• foundations
Load Paths

• deep foundations