design codes, building codes

Structure Requirements

- strength & equilibrium
  - safety
  - stresses not greater than strength
  - adequate foundation

- efficiency
  - economy of materials

- construction

- cost

- other

Structural Requirements

- serviceability
  - strength
  - deflections

- efficiency
  - economy of materials

- construction

- cost

- other
Structure Requirements

- economy and construction
  - minimum material
  - standard sized members
  - simple connections and details
  - maintenance
  - fabrication/erection

Design Procedure

- planning
- preliminary structural configuration
- determination of loads
- preliminary member selection
- analysis
- evaluation
- design revision
- final design

Design Procedure

- planning to establish
  - function of structure
  - criteria for optimum design
  - code jurisdiction
- preliminary structural configuration
  - arrangement of elements within form
    - columns
    - beams
    - joists
    - trusses

Design Procedure

- determination of loads
  - structure weight
  - moving loads
  - severe, rare loads
  - building codes

- preliminary member selection
  - based on configuration, determine loads on individual elements
  - determine internal forces & stresses
  - choose section to satisfy primary strength requirement
Design Procedure

- analysis
  - actual structure weight
  - with other loads
  - based on structural system / modeling
    • elements – columns, beams...
    • connections
    • systems – frames, trusses
  - deflections and deformations
    • different load combination?
    • pattern loading

Design Procedure

- evaluation
  - measure results against criteria
    • strength?
    • deflections?
    • economy?

- revise design
  - any criteria NOT met
  - change member sizes, material, arrangement

Design Procedure

- final design
  - analyze revised design
  - evaluate and meets requirements
  - draw structural plan

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
Building Codes

- **occupancy**
- **construction types**
- **structural chapters**
  - loads, tests, foundations
- **structural materials, assemblies**
  - roofs
  - concrete
  - masonry
  - steel

<table>
<thead>
<tr>
<th>Building Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design &amp; Codes</strong></td>
</tr>
<tr>
<td><strong>Architectural Structures III</strong></td>
</tr>
<tr>
<td><strong>ARCH 631</strong></td>
</tr>
<tr>
<td><strong>F2008abn</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Occupancy or Use</th>
<th>Uniform (psf)</th>
<th>Concentrated (psf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Apartments (ten residential)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>2. Office</td>
<td>30</td>
<td>2,000</td>
</tr>
<tr>
<td>3. Apartment</td>
<td>100</td>
<td>2,000</td>
</tr>
<tr>
<td>4. Service and retail</td>
<td>150</td>
<td>—</td>
</tr>
</tbody>
</table>

- **adoptable codes**
  - Southern Building Code Congress International (SBCCI)
  - Building Officials & Code Administrators International (BOCA)
  - International Conference of Building Officials (UBO)
  - International Building Code (IBC)
    - attempt to get one unified code in 2000

**Code Reduction of Live Loads**

- **for (ordinary) live loads**
  - factored area supported $\geq 400$ ft$^2$
  - reduction can’t exceed
    - $0.5L_o$ (one floor) or $0.4L_o$ (more)
    - \[ L = L_o \left( 0.25 + \frac{15}{\sqrt{K_{ILL}A_T}} \right) \]

- **for live loads > 100 lb/ft$^2$**
  - live load reduction of 20% on columns

- **for (ordinary) roofs:** $L_r = L_oR_1R_2$
  - $12$ lb/ft$^2 \leq L_r \leq 20$ lb/ft$^2$

**Standards**

- **criteria for quality**
  - American National Standards Institute (ANSI)
  - American Society of Testing and Materials (ASTM)

- **materials**
  - Brick Industry Association (BIA)
  - Portland Cement Association (PCA)
  - National Concrete Masonry Association (NCMA)
**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**

- factors out of the designer’s control
  - loads
  - occurrence
- factors within the designer’s control
  - choice of material
  - “cost” of failure (F.S., probability, location)
  - economic design method
  - analysis method

**Structural Codes**

- American Concrete Institute (ACI)
- American Institute of Steel Construction (AISC)
- Precast/Prestressed Concrete Institute (PCI)
- Post Tensioning Institute (PTI)
- Structural Joist Institute (SJI)
- National Design Specifications (NDS)
  - National Forest Products Association

**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
**Design Methods**

- structures and connections see
  - shear
  - bending
  - bearing
  - axial stress
    - compression
    - tension
  - torsion

- materials have a critical stress value where they could break or yield
  - ultimate stress
  - yield stress
  - compressive stress
  - fatigue strength
  - (creep & temperature)

- material behavior

  ![Stress-strain diagram for mild steel (A36)](image)

  Figure 5.22 Stress-strain diagram for mild steel (A36) with key points highlighted.

- allowable stress design
  - elastic range
  - factor of safety (F.S.)
    \[
    f_{\text{actual}} = \frac{P}{A} \leq f_{\text{allowed}} = \frac{f_{\text{capacity}}}{F.S.}
    \]
  - probability of loads and resistance
  - material variability
  - overload, fracture, fatigue, failure
**Design Methods**

- **load and resistance factor design (LRFD)**
  - beyond allowable stress
- **materials aren’t uniform 100% of the time**
  - ultimate strength or capacity to failure may be different and some strengths hard to test for
- **RISK & UNCERTAINTY**

  \[ f_u = \frac{P_u}{A} \]

**Loads**

- gravity acts on mass \((F=m\times g)\)
- force of mass
  - acts at a point
    - ie. joist on beam
  - acts along a “line”
    - ie. floor on a beam
  - acts over an area
    - ie. people, books, snow on roof or floor

**Design Methods**

- **loads on structures are**
  - not constant
  - can be more influential on failure
  - happen more or less often
  - **UNCERTAINTY**

  \[ \gamma_D P_D + \gamma_L P_L \leq \phi P_n \]

  \(\phi\) - Resistance factor
  \(\gamma\) - Load factor for (D)ead & (L)ive load

**Load Tracing**

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

Load Paths

- wall systems

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Load Paths

- openings & pilasters

![Figure 4.15 Arching over wall openings.](image)
![Figure 4.16 Stair wall with a window opening.](image)
![Figure 4.17 Pilasters supporting concentrated loads.](image)

Load Paths

- foundations

![Figure 4.24 Spread footing.](image)
![Figure 4.25 Mat footing.](image)
![Figure 4.26 Mat or cap foundation.](image)

Load Paths

- deep foundations

![Figure 4.27 Pile foundations.](image)
![Figure 4.28 Pile cap on one pile group.](image)
![Figure 4.29 Grade beam supporting a bearing wall.](image)

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)
### ASD Load Combinations

<table>
<thead>
<tr>
<th>Combination</th>
<th>ASCE-7 (2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D$</td>
<td></td>
</tr>
<tr>
<td>$D + L$</td>
<td></td>
</tr>
<tr>
<td>$D + (L_r \text{ or } S \text{ or } R)$</td>
<td></td>
</tr>
<tr>
<td>$D + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$</td>
<td></td>
</tr>
<tr>
<td>$D + (0.6W \text{ or } 0.7E)$</td>
<td></td>
</tr>
<tr>
<td>$D + 0.75L + 0.75(0.6W \text{ or } 0.7E) + (0.75L_r \text{ or } S \text{ or } R)$</td>
<td></td>
</tr>
<tr>
<td>$0.6D + (0.6W \text{ or } 0.7E)$</td>
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</tr>
</tbody>
</table>

### LRFD Load Combinations

<table>
<thead>
<tr>
<th>Combination</th>
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</tr>
</thead>
<tbody>
<tr>
<td>$1.4D$</td>
<td></td>
</tr>
<tr>
<td>$1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$</td>
<td></td>
</tr>
<tr>
<td>$1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (L \text{ or } 0.5W)$</td>
<td></td>
</tr>
<tr>
<td>$1.2D + 1.0W + L + 0.5(L_r \text{ or } S \text{ or } R)$</td>
<td></td>
</tr>
<tr>
<td>$1.2D + 1.0E + L + 0.2S$</td>
<td></td>
</tr>
<tr>
<td>$0.9D + 1.0W$</td>
<td></td>
</tr>
<tr>
<td>$0.9D + 1.0E$</td>
<td></td>
</tr>
<tr>
<td>$0.9D + 1.0E$</td>
<td></td>
</tr>
<tr>
<td>$0.9D + 1.0E \text{ F has same factor as } D \text{ in 1-5 and 7}$</td>
<td></td>
</tr>
<tr>
<td>$H \text{ adds with 1.6 and resists with 0.9 (permanent)}$</td>
<td></td>
</tr>
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