design codes, building codes

Structure Requirements

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

Structural Requirements

- serviceability
  - strength
  - deflections
- efficiency
  - economy of materials
- construction
- cost
- other

Figure 1.16 Equilibrium and Stability?—sculpture by Richard Eyer. Photo by author.

Figure 1.15 Stability and the strength of a structure—the collapse of a portion of the UW Husky stadium during construction (1987) due to a lack of adequate bracing to ensure stability. Photo by author.
Structure Requirements

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

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

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

Design Procedure

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

- 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

Building Codes

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

Code Reduction of Live Loads

- for (ordinary) live loads
  - factored area supported $\geq 400 \text{ ft}^2$
  - 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: $L_r = L_o R_1 R_2$
  - $12 \text{ lb/ft}^2 \leq L_r \leq 20 \text{ lb/ft}^2$

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)
  – American Wood Council

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

Design Methods

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

Design Methods

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

Design Methods

- material behavior

Design Methods

- allowable stress design
  - elastic range
  - factor of safety (F.S.)
    \[ f_{\text{actual}} = \frac{P}{A} \leq f_{\text{allowed}} = \frac{f_{\text{capacity}}}{\text{F.S.}} \]
  - 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

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

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

Loads

- gravity acts on mass (F=m*\(g\))
- 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

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
Load Paths

- openings & pilasters
  
  ![Image](image1.png)
  ![Image](image2.png)
  ![Image](image3.png)

Load Paths

- foundations
  
  ![Image](image4.png)
  ![Image](image5.png)
  ![Image](image6.png)

Load Paths

- deep foundations
  
  ![Image](image7.png)
  ![Image](image8.png)
  ![Image](image9.png)

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>Description</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 or S or R)</td>
<td></td>
</tr>
<tr>
<td>D + 0.75L + 0.75(L_r or S or R)</td>
<td></td>
</tr>
<tr>
<td>D + (0.6W or 0.7E)</td>
<td></td>
</tr>
<tr>
<td>D + 0.75L + 0.75(0.6W or 0.7E) + (0.75L_r or S or R)</td>
<td></td>
</tr>
<tr>
<td>0.6D + (0.6W or 0.7E)</td>
<td></td>
</tr>
</tbody>
</table>

### LRFD Load Combinations

<table>
<thead>
<tr>
<th>Description</th>
<th>ASCE-7 (2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4D</td>
<td></td>
</tr>
<tr>
<td>1.2D + 1.6L + 0.5(L_r or S or R)</td>
<td></td>
</tr>
<tr>
<td>1.2D + 1.6(L_r or S or R) + (L or 0.5W)</td>
<td></td>
</tr>
<tr>
<td>1.2D + 1.0W + L + 0.5(L_r or S 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>
</tbody>
</table>

- 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)