design codes, building codes

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

Structure Requirements
- stability & stiffness
  - stability of components
  - minimum deflection and vibration
  - adequate foundation
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

- 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

- 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

- 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>OCCUPANCY OR USE</th>
<th>UNIFORM</th>
<th>CONCENTRATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartments (not residential)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Office</td>
<td>100</td>
<td>2,000</td>
</tr>
<tr>
<td>Amusements, theaters</td>
<td>150</td>
<td>—</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ANTIMICROBIAL AND DETERGENTS</th>
<th>LIMITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washed with detergent</td>
<td>100</td>
</tr>
<tr>
<td>Washed by hand</td>
<td>125</td>
</tr>
<tr>
<td>Detergent</td>
<td>40</td>
</tr>
</tbody>
</table>

Building Codes

- 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 (ALTERNATIVE)

- now allowed for ordinary roofs
- for live loads ≤ 100 lb/ft²
  - area supported ≥ 150 ft²
  - not a garage
  - reduction of 0.08% /ft² allowed
  - reduction can’t exceed
    - 60% or 40%
    - \[ R = 23.1 \left( 1 + \frac{D}{L_o} \right) \]
- for live loads > 100 lb/ft²
  - live load reduction of 20% on columns

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

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

- 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

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

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

Design Methods

- **loads on structures are**
  - not constant
  - can be more influential on failure
  - happen more or less often
  - **UNCERTAINTY**
  \[ \gamma_D P_D + \gamma_L P_L \leq \phi P_u \]
  - \(\phi\): Resistance factor
  - \(\gamma\): Load factor for (D)ead & (L)ive load

Loads

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

- **wall systems**
Load Paths

• openings & pilasters

• foundations

Load Paths

• deep foundations

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

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

LRFD Load Combinations

- $1.4D$
- $1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$
- $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (L \text{ or } 0.5W)$
- $1.2D + 1.0W + L + 0.5(L_r \text{ or } S \text{ or } R)$
- $1.2D + 1.0E + L + 0.2S$
- $0.9D + 1.0W$
- $0.9D + 1.0E$

- $0.9D + 1.0E \text{ F has same factor as } D \text{ in 1-5 and 7}$
- $H \text{ adds with 1.6 and resists with 0.9 (permanent)}$