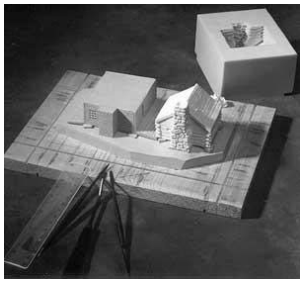
APPLIED ARCHITECTURAL STRUCTURES:
STRUCTURAL ANALYSIS AND SYSTEMS
ARCH 631
DR. ANNE NICHOLS
FALL 2013

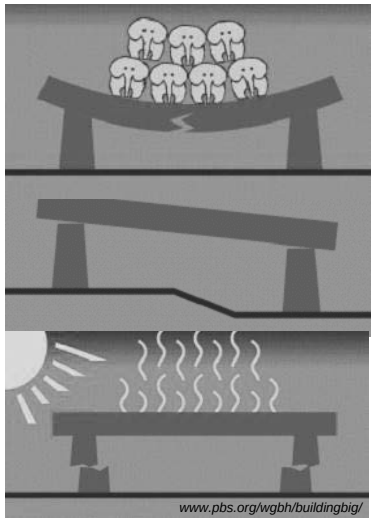
lecture
three



design codes, building codes

Structural Requirements

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



www.pbs.org/wgbh/buildingbig/

Structure Requirements

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

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

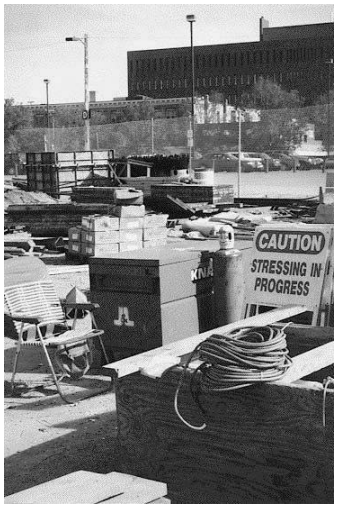
Structure Requirements

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

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*

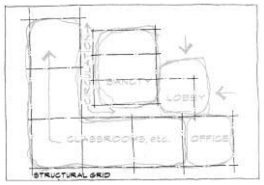


Design Procedure

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

Design Procedure

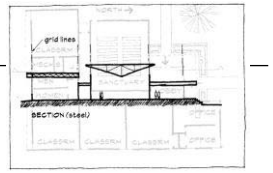
- *planning to establish*
  - *function of structure*
  - *criteria for optimum design*
  - *code jurisdiction*
- *preliminary structural configuration*
  - *arrangement of elements within form*
    - *columns*
    - *beams*
    - *joists*
    - *trusses*



Design Procedure

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

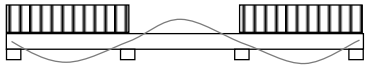
} *building codes*



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

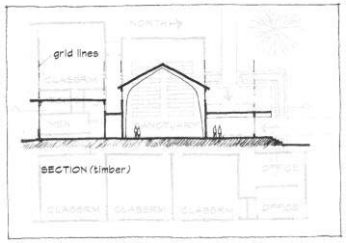
Design Procedure

- *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*



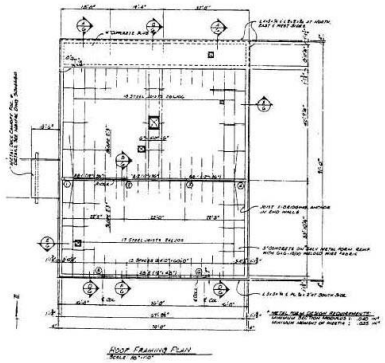
Design Procedure

- *evaluation*
  - *measure results against criteria*
    - *strength?*
    - *deflections?*
    - *economy?*
- *revise design*
  - *any criteria NOT met*
  - *change member sizes, material, arrangement*



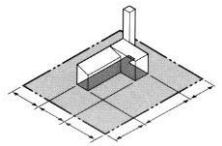
Design Procedure

- *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 <u>all</u> aspect of building design*
  - *references standards*
    - *acceptable minimum criteria*
    - *material & <u>structural</u> codes*



Building Codes

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

OCCUPANCY OR USE	UNIFORM (psf)	CONCENTRATED (lbs.)
1. Apartments (see residential)	—	—
2. Access floor systems		
Office use	50	2,000
Computer use	100	2,000
3. Armories and drill rooms	150	—
4. Assembly areas and theaters		
Fixed seats (fastened to floor)	60	
Lobbies	100	
Movable seats	100	—
Stages and platforms	125	
Follow spot, projections and control rooms	50	
Catwalks	40	

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

- *for (ordinary) live loads*
  - *factored area supported* ≥ 400 *ft²*
  - *reduction can't exceed*
    - $0.5L_o$ *(one floor) or* $0.4L_o$ *(more)*

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

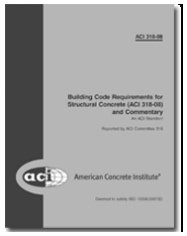
- *for live loads > 100 lb/ft²*
  - *live load reduction of 20% on columns*
- *for (ordinary) roofs:* $L_r = L_o R_1 R_2$
  - 12 *lb/ft²* $\leq L_r \leq 20$ *lb/ft²*

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*

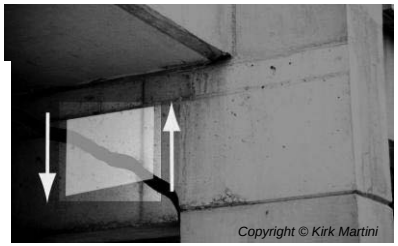
Design Methods

- *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*

http://mceer.buffalo.edu

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)

acceptance vs. failure

Design Methods

- material behavior

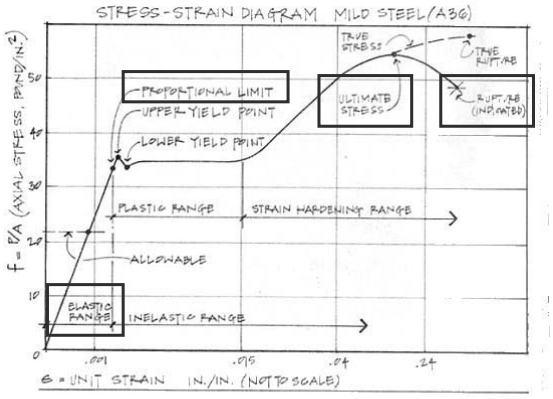
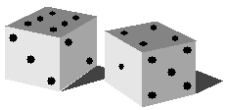


Figure 5.22 Stress-strain diagram for mild steel (A36) with key points highlighted.

Design Methods

- allowable stress design
  - elastic range
  - factor of safety (F.S.)

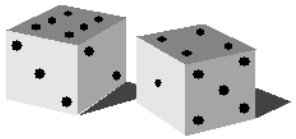


$$f_{actual} = \frac{P}{A} \leq f_{allowed} = \frac{f_{capacity}}{F.S.}$$

  - probability of loads and resistance
  - material variability
  - overload, fracture, fatigue, failure

Design Methods

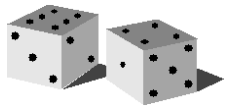
- *load and resistance factor design (LRFD)*
  - *beyond allowable stress*
- *materials aren't uniform 100% of the time*
  - *ultimate strength or capacity to failure may be different and some strengths hard to test for*
- *RISK & UNCERTAINTY*



$$f_u = \frac{P_u}{A}$$

Design Methods

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



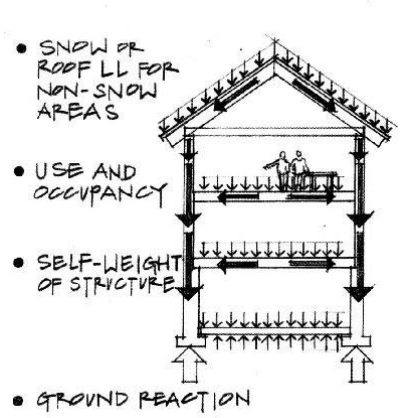
$$\gamma_D P_D + \gamma_L P_L \leq \phi P_n$$

ϕ - *Resistance factor*

γ - *Load factor for (D)ead & (L)ive load*

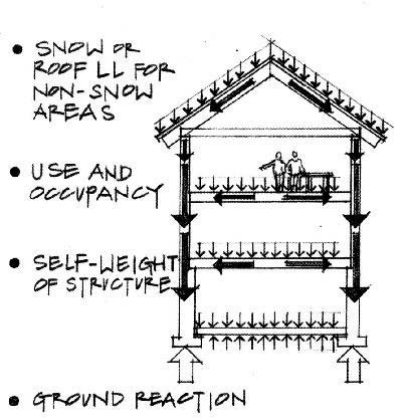
Loads

- *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*

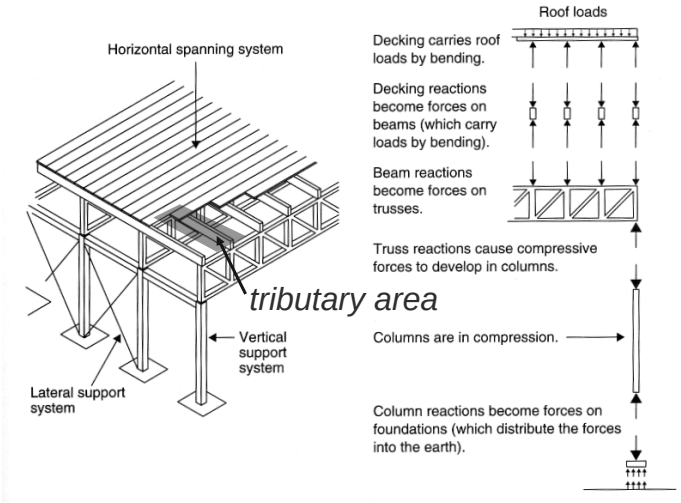


Load Tracing

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



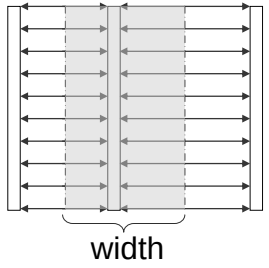
Load Tracing



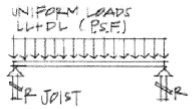
Load Tracing

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

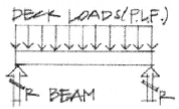
$$w = \left(\frac{load}{area}\right) \times \left(tributary\ width\right)$$



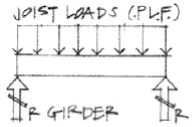
Load Paths



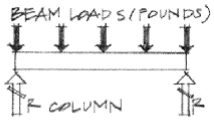
(a) FBD—decking.



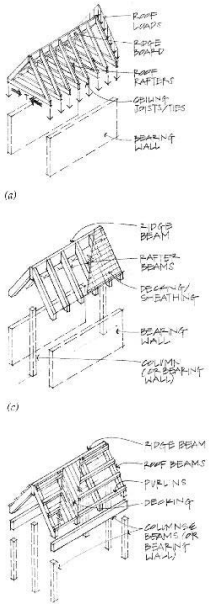
(b) FBD—joists.



(c) FBD—beams.



(d) FBD—girder.



Load Paths

- *wall systems*

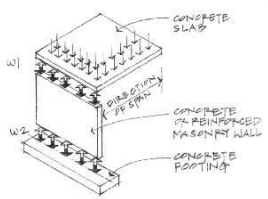


Figure 4.12 Uniform wall load from a slab.

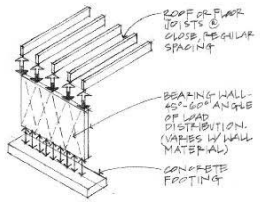


Figure 4.13 Uniform wall load from rafters and joists.

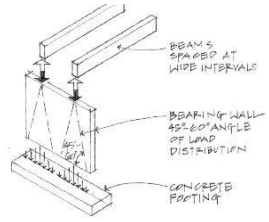


Figure 4.14 Concentrated loads from widely spaced beams.

Load Paths

- *openings & pilasters*

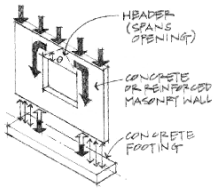


Figure 4.15 Arching over wall openings.

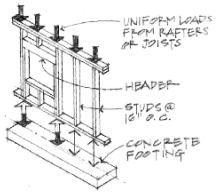


Figure 4.16 Stud wall with a window opening.

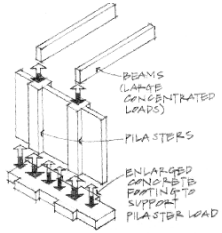


Figure 4.17 Pilasters supporting concentrated beam loads.

Load Paths

- *foundations*

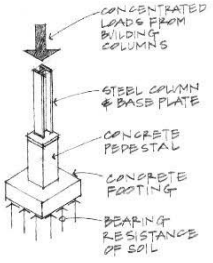


Figure 4.24 Spread footing.

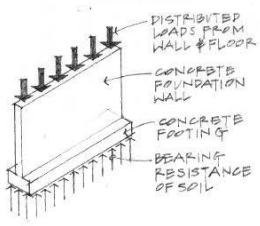


Figure 4.25 Wall footing.

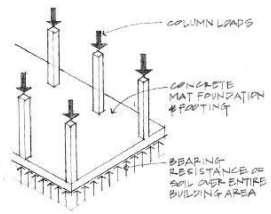


Figure 4.26 Mat or raft foundation.

Load Paths

- *deep foundations*

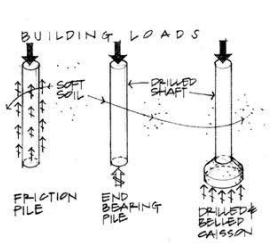


Figure 4.27 Pile foundations.

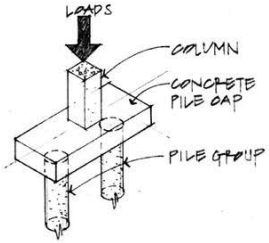


Figure 4.28 Pile cap on one pile group.

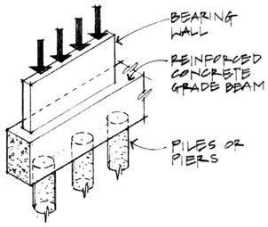


Figure 4.29 Grade beam supporting a bearing wall.

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)*

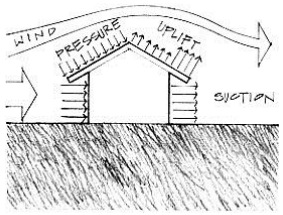


Figure 1.13 Wind loads on a structure.

ASD Load Combinations

ASCE-7 (2010)

- D
- D + L
- D + (L_r or S or R)
- D + 0.75L + 0.75(L_r or S or R)
- D + (0.6W or 0.7E)
- D + 0.75L + 0.75(0.6W or 0.7E) + (0.75L_r or S or R)
- 0.6D + (0.6W or 0.7E)

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

  - 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)