lecture four

ARCHITECTURAL STRUCTURES: FORM, BEHAVIOR, AND DESIGN
ARCH 331
DR. ANNE NICHOLS
FALL 2013

point equilibrium and planar trusses

http://nisee.berkeley.edu/godden
Equilibrium

- balanced
- steady
- resultant of forces on a particle is 0
Equilibrium on a Point

- analytically

\[ R_x = \sum F_x = 0 \]
\[ R_y = \sum F_y = 0 \]

- Newton convinces us it will stay at rest
Equilibrium on a Point

- **collinear force system**
  - ex: cables

\[ \sum F_{\text{in-line}} = 0 \]

\[
\begin{align*}
R_x &= \sum F_x = 0 \\
R_y &= \sum F_y = 0
\end{align*}
\]
Equilibrium on a Point

- concurrent force system
  - ex: cables

\[
R_x = \sum F_x = 0
\]

\[
R_y = \sum F_y = 0
\]
Free Body Diagram

- **FBD (sketch)**
- **tool to see all forces on a body or a point including**
  - external forces
  - weights
  - force reactions
  - internal forces
Free Body Diagram

- **determine point**
- **FREE it from:**
  - ground
  - supports & connections
- **draw all external forces acting ON the body**
  - reactions (supporting forces)
  - applied forces
  - gravity

FBD of concurrent point B.
Free Body Diagram

• sketch FBD with relevant geometry
• resolve each force into components
  – known & unknown angles – name them
  – known & unknown forces – name them
• are any forces related to other forces?
• for the unknowns
• write only as many equilibrium equations as needed
• solve up to 2 equations
Free Body Diagram

• solve equations
  – most times 1 unknown easily solved
  – plug into other equation(s)

• common to have unknowns of
  – force magnitudes
  – force angles
Truss Structures

• ancient (?) wood
  – Romans 500 B.C.
• Renaissance revival
• 1800’s analysis
• efficient
Truss Structures

– analogous to cables and struts

(a) STABLE: pinned supports resist thrust

(b) UNSTABLE: substitution of roller support eliminates thrust resistance

(c) STABLE: wood strut resists thrust internally to form simple truss
Truss Structures

- comprised of straight members
- geometry with triangles is stable
- loads applied only at pin joints
Truss Structures

• **2 force members**
  - forces in line, equal and opposite
  - compression
  - tension

• **3 members connected by 3 joints**

• **2 more members need 1 more joint**
  \[ b = 2n - 3 \]
Truss Structures

- compression and tension
Truss Structures

• statically determinate
• indeterminate
• unstable

(a) Determinate.

(b) Indeterminate.

(c) Unstable.

n = 10  b = 16 < 2(10) - 3 = 17
(Too few members—square panel is unstable)

n = 10  b = 18 > 2(10) - 3 = 17
(Too many members)
Trusses

- common designs

- King post
- Inverted king post

- Queen post
- Inverted queen post

- Parallel chord
- Warren trusses

- Pitched Pratt truss

- Pitched Howe truss

- Pitched Fink truss

- Constant forces in upper chords and no forces in diagonals (normally built with rigid joints if diagonals are omitted).

- Parallel chord
- Pratt truss

- Parallel chord
- Howe truss

- Parallel chord
- Crossed-diagonal truss
Trusses

- common designs

- Bowstring truss
- Lenticular truss
- "Scissors" truss
- Cantilevered truss (funicularly shaped)
- Northlight trusses
- Monitors with clerestories
Trusses

- uses
  - roofs & canopies
  - long spans
  - lateral bracing
Truss Connections

- “pins”

Figure 4.8: Truss joints.

http://nisee.berkeley.edu/godden
Sainsbury Center, Foster 1978
Sainsbury Center, Foster 1978

two pin-connection supports
(typical of all trusses)

see detail

third pin connection
at end trusses only
(makes truss and supporting columns
behave as a rigid frame
to minimize movement
around end glazing)

tubular steel
prism columns
are cantilevered
from foundation
(rigid base connection)

prism (3-sided)
roof trusses

tubular cross-bracing
between columns
Truss Analysis

• visualize compression and tension from deformed shape

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Truss Analysis

- **Method of Joints**
- **Graphical Methods**
- **Method of Sections**

- all rely on equilibrium
  - of bodies
  - internal equilibrium
Method of Joints

• isolate each joint
• enforce equilibrium in $F_x$ and $F_y$
• can find all forces

• long
• easy to mess up
Joint Cases

• *two bodies connected*

![Joint Cases Diagram]

- A \(\rightarrow\) B \(\rightarrow\) C
- A \(\rightarrow\) B \(\rightarrow\) C

\[ \text{equal} \]
\[ \text{equal} \]
\[ \text{and} \]
\[ \text{0} \]
Joint Cases

- three bodies with two in line
Joint Cases

- crossed

![Joint Cases Diagram]

- equal
Tools – Multiframe

• in computer lab
Tools – Multiframe

• frame window
  – define truss members
    • or pre-defined truss
  – select points, assign supports
  – select members, assign section & assign pin ends

• load window
  – select points, add point load
Tools – Multiframe

• to run analysis choose
  – Analyze menu
    • Linear

• plot
  – choose options

• results
  – choose options