Architectural Structures: Form, Behavior, and Design
ARCH 331
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lecture four

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.

Sign suspended from a strut and cable.
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
Truss Structures

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

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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

\[ b = 21 \quad n = 12 \quad 2n - 3 = 2(12) - 3 = 21 \]
(a) Determinate.

\[ b = 16 \quad n = 10 \quad b = 16 < 2(10) - 3 = 17 \]
(Too few members—square panel is unstable)
(c) Unstable.

\[ b = 18 \quad n = 10 \quad b = 18 > 2(10) - 3 = 17 \]
(Too many members)
(b) Indeterminate.
Trusses

- common designs

- [Diagram of common truss designs including King post, pitched Pratt truss, pitched Howe truss, pitched Fink truss, parallel chord Pratt truss, parallel chord Howe truss, and crossed-diagonal truss]
Trusses

- common designs

![Diagram of common truss designs](image)
Trusses

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

- “pins”

Figure 4.8: Truss joints.

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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**

![Diagram showing joint cases]

- Two bodies connected, equal force, equal and 0 force.
Joint Cases

- three bodies with two in line

![Diagram showing joint cases in architectural structures]

- Three bodies with two in line, as shown in the diagram.
Joint Cases

- crossed
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