ARCHITECTURAL STRUCTURES: FORM, BEHAVIOR, AND DESIGN

ARCH 331

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SUMMER 2014

lecture three

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
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 Diagram]
Truss Structures
• statically determinate
• indeterminate
• unstable

(b) Indeterminate.

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

(c) Unstable.

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

(a) Determinate.

\[ b = 21 \]
\[ n = 12 \quad 2(n) - 3 = 2(12) - 3 = 21 \]
Trusses

• common designs

- King post truss
- Queen post truss
- Parallel chord truss
- Pitched Pratt truss
- Pitched Howe truss
- Pitched Fink truss
- Warren trusses
- Crossed-diagonal truss
Trusses

- common designs
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
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
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

case 1

- \( \text{equal} \)

or

- \( \text{equal and 0} \)
Joint Cases

- three bodies with two in line

![Diagram showing joint cases with three bodies, two in line, and forces at equilibrium](image-url)
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