Learning Objectives

At the end of this program, participants will be able to:

1. Identify the primary structural components of post-frame (PF) building systems
2. Identify two PF structural design methodologies
3. Understand how to conduct structural design of PF systems without diaphragm action
4. Understand how to conduct structural design of PF systems with diaphragm action
5. Identify post-frame design resources available to architects and engineers
LEARNING OBJECTIVES

- Identify the primary structural components of post-frame (PF) building systems
- Identify two PF structural design methodologies
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- Identify post-frame design resources available to architects and engineers
POST OR PIER FOUNDATIONS

PF BUILDING DESIGN: FEATURES

• Diaphragm design procedures are unique, but well formulated and documented
• Sidewall framing often uses mechanically or glued laminated sidewall and endwall posts
• Embedded wood posts or concrete piers often serve as the building foundation

PRIMARY PF DESIGN METHODS

• 2-dimensional frame design method
  – Without diaphragm action
• 3-dimensional diaphragm design method
  – With diaphragm action

PF SYSTEMS WITHOUT DIAPHRAGM ACTION
PF SYSTEM WITH DIAPHRAGM ACTION

LATERAL LOADS: WITHOUT DIAPHRAGM ACTION

LATERAL LOADS: WITH DIAPHRAGM ACTION

ADVANTAGES OF DIAPHRAGM DESIGN

- Smaller sidewall posts
- Shallower post or pier embedment depths
- Benefits:
  - More economical design
  - Greater structural integrity
  - More durable post-frame structures
FULL-SCALE PF BUILDING TESTS

29 ga ribbed steel sheathing

Hydraulic cylinder
Temporary steel tube
Load cell
Pin
Cable
Steel or plywood pad
6" compacted gravel floor

40 ft W x 80 ft L x 16 ft H

DIAPHRAGM VS NO DIAPHRAGM ACTION

WHEN TO USE 2-D FRAME DESIGN METHOD

- Side or endwalls are open, or not sheathed
- PF Building with L:\W \( \geq 2.5:1 \)
- Connections and other structural detailing don’t develop a continuous load path for transfer of in-plane shear forces
  - Through the roof sheathing
  - Between the diaphragm and the top of the endwall
  - Through the endwall or shearwall
  - Between bottom of the endwall and the endwall foundation

EMBEDDED POST/PIER FOUNDATIONS

- Common post-soil fixity models for embedded post or pier foundations:
  - Constrained post or pier
  - Unconstrained post or pier
POST/PIER EMBEDMENT DESIGN

- ½-inch horizontal movement permitted

- Horizontal movement prevented by floor and connection

POST FOUNDATIONS: UNCONSTRAINED MODEL

- Embedded into the ground
- Not constrained from displacing horizontally at the ground line
- Pin located 0.1d above the bottom of the embedded post and a vertical roller located about \( \frac{1}{3} \) the embedment depth below the ground line

POST FOUNDATIONS: CONSTRAINED SOIL-POST MODEL

- Embedded into the ground
- Horizontal displacement prevented by properly designed connection between the post and floor slab at the ground line
- Soil interaction is modeled with a vertical roller 0.7d below ground line and with a pin at the ground line

DESIGN METHODS: 2-D POST FRAME

- Each frame is designed to carry its full tributary lateral and gravity loads
- Post-to-truss connections usually modeled as a pin
- The post-to-ground reaction is modeled consistent with post embedment details
2-D DESIGN ANALYSIS

ASCE-7 Governing Load Combinations

- Dead + ¾ snow + ¾ wind (or seismic)
  or
- 0.6 dead + wind (or seismic)
  – Usually controls post design
- Dead + snow
  – Usually controls roof-framing design

DIAPHRAGM DESIGN METHOD

- Incorporates in-plane shear strength and stiffness of the roof and wall sheathing to transfer design lateral loads to the foundation
- Three-dimensional structural analysis method
- Significantly decreases wall-post size and post-foundation embedment depth
DIAPHRAGM TEST PANEL

CANTILEVER TEST CONFIGURATION

DIAPHRAGM TEST RESULTS, IN-PLANE STRENGTH & STIFFNESS

DIAPHRAGM DESIGN-TEST VS. ROOF PANEL

Sheathing/cladding
Rafter or truss top chord (strut)
Purlin (chord)

P = applied force
Truss top chord

P = ultimate strength

Ultimate Strength = \( P_{\text{ult}} \)
Design shear strength = 0.4 \( P_{\text{ult}} \)
C = design shear stiffness (slope)

\( b_{\text{s}} \) = Slope length (roof diaphragm length)

Building length = \( L_B \)
Test panel length, \( b \)
Test panel width, \( a \)
Test panel
End wall
Roof<Slide span

Building width
**DIAPHRAGM DESIGN METHOD – ROOF PANEL STIFFNESS**

- Shear stiffness of a roof diaphragm panel
  - test panel stiffness, \( c \)
  - roof panel width, \( a_p \)
  - roof panel roof slope length, \( b_{sp} \)
  - roof slope, \( \Theta \)

\[
c_{h} = c \left( \frac{a}{b} \right) \left( \frac{b_{sp}}{a_p} \right) \cos^2 \Theta
\]

**DIAPHRAGM DESIGN METHOD-ROOF PANEL STRENGTH**

- In-plane strength is a linear function of diaphragm length, \( b_{sp} \)

\[
V = [\text{unit shear}] (\text{roof diaphragm length})
V = [0.4(P_{ult}/b)](b_{sp})
\]

**DIAPHRAGM DESIGN METHOD-BARE FRAME STIFFNESS. K**

- PF diaphragm design procedures based on:
  1. Compatibility of post-frame and roof panel eave deformations and
  2. Equilibrium of horizontal forces at each eave

**DIAPHRAGM DESIGN METHOD**

- \( k = P_{f} / \Delta_{f} \)
- Depth and embedment structural analog varies with site conditions
- \( \Delta_{f} = \Delta_{x} \) Shear wall
DIAPHRAGM DESIGN METHOD

• Equilibrium of forces at each PF eave

\[ P_i = P_{fi} + P_{ri} \]

- \( P_i \) = design eave load in \( i \)th PF
- \( P_{fi} \) = portion of the design eave load carried by the \( i \)th PF
- \( P_{ri} \) = portion of the design eave load carried by the roof diaphragm panel at the \( i \)th PF

DIAPHRAGM DESIGN METHOD

• Compatibility of roof and PF deformations at each PF eave

\[ \Delta_{ri} = \Delta_{fi} \]

- \( \Delta_{ri} \) = roof panel eave deformation at the \( i \)th PF (dependent upon \( c_i, k_i, \) and \( P_i \))
- \( \Delta_{fi} = \frac{P_{fi}}{k_i} \)

DAFI COMPUTER PROGRAM

• Windows based program
• Calculates portion of lateral load carried by:
  - Each post frame
  - Roof diaphragm
• Available at no cost at www.postframeadvantage.com

DAFI COMPUTER PROGRAM

• DAFI program calculates
  - Eave displacement of each post frame
  - Portion of eave load carried by each post frame
  - Shear forces carried by each roof diaphragm panel in the building system
DAFI INPUTS

- Total number of bays in the building
- Design eave loads at each post frame, $P_i$
- Bare frame stiffness of each post frame, $k_i$
- In-plane shear stiffness of each roof diaphragm panel, $c_{hi}$

DIAPHRAGM DESIGN METHOD

Panel/PF structural analog of a 3-bay building

DAFI: UNDEFORMED POSITION
DAFI: DEFORMED EQUILIBRIUM POSITION

Cardinal

Datum

Datum

1

2

3

4

DAFI COMPUTER PROGRAM

\[ P_f^1 \]

\[ P_f^2 \]

\[ P_f^3 \]

\[ P_f^4 \]

DAFI: HIGHLY FLEXIBLE

• Can be used for post-frame building systems where:
  – Stiffness, \( k_i \), of the post frame elements are not the same
  – Stiffness, \( c_{hi} \), of the diaphragm panel elements are not the same
  – Stiffness, \( k_i \), of the two endwalls are not the same

• Available at no cost to designers at PostFrameAdvantage.com
DAFI: MINI DEMONSTRATION

- 48-ft-wide by 96-ft-long post frame
- Post frames 8-ft o.c.
- Number of bays — 12
- Post-frame stiffness (k) — 300 lbs/in.
- Endwall stiffness (k_e) — 10,000 lbs/in.
- Roof diaphragm stiffness (C) — 12,000 lbs/in.
- Horizontal eave load at interior post frame — 800 lbs
DAFI: MINI DEMONSTRATION

POST/PIER EMBEDMENT DESIGN

- Post-embedment details must resist
  - Shear force and moments from lateral loadings
  - Uplift post loads
  - Downward acting gravity loads
POST/PIER EMBEDMENT DESIGN:
UNCONSTRAINED POST; NO COLLAR

• \( d^2 = \frac{(6V_a + 8 M_a)}{d} / (S' b) \)
• \( d \) = the embedment depth
• \( V_a, M_a \) = the shear and bending moment applied to foundation at ground surface
• \( S' \) = the adjusted allowable lateral soil pressure
• \( b = 1.4B \) = the effective post width of the post or pier
• \( B \) = the narrow width of the post

POST/PIER EMBEDMENT DESIGN:
CONSTRAINED POST; NO COLLAR

Embedment depth design equation for lateral resistance for a constrained post without any partial depth attached collars or cleats

\[ d = \left[ \frac{4 M_a}{S' b} \right]^{1/3} \]

POST/PIER EMBEDMENT DESIGN:
POSTS WITH BOTTOM COLLARS

• Design equations in:

ASAE EP 486, Shallow Post Foundation Design

www.asabe.org

POST/PIER EMBEDMENT DESIGN:
UPLIFT FORCES

Mass of soil in shaded truncated cone resists post withdrawal due to uplift forces

Post must be mechanically attached to the collar or wood cleat

Mass of attached collar or wood cleat
POST/PIER FOUNDATION DESIGN: UPLIFT DESIGN

- Design Equations for Uplift Resistance of Embedded Posts with Collars

2. ASAE EP 486, Shallow Post Foundation Design (www.asabe.org)

POST EMBEDMENT DETAILS

- Place footings below frost line
- Do not use partial concrete collars immediately below ground line (top collars)
- Provide good drainage away from post holes
- Use only preservative treated wood for all wood elements in contact with the ground

PF DESIGN: SPECIAL CONSIDERATIONS

- Designer or architect should use hot-dipped galvanized or stainless steel hardware
  - In all below-ground applications
  - When hardware is in contact with preservative-treated wood

POST-FRAME TECHNICAL RESOURCES

Provides structural design procedures for post-frame building systems
PF TECHNICAL RESOURCES

- ANSI/ASAE (ASABE) EP 484  
  - Diaphragm design procedures
- ANSI/ASAE (ASABE) EP 486  
  - Shallow post foundation design
- ANSI/ASAE (ASABE) EP 559  
  - Requirements and bending properties for mechanically laminated columns
  - asabe.org or nfba.org

PF STRUCTURAL DESIGN RESOURCES

- AWC/AF&PA (2005)
- ASCE 7 (2005, 2010)
- AWPA's U1-09

OTHER PF TECHNICAL RESOURCES

- DAFI
- Framing Tolerance Guidelines
- Metal Cladding Installation Tolerance Guidelines
- Post Frame Construction Guide
- Design Documents for Engineers & Architects: Wind and Seismic
- Guide specification for PF Building Systems
- 1 hour and 3 hour PF Firewall Reports

Design No. V304 January 20, 2012
Bearing Wall Rating - 3-1/2 Hr

5/8 Gyp Board (SCX)
4 layers, both sides

Nail-lam post 4-ply, 2x6
Vertical blocking
2x4 wall girts
MORE PF DESIGN GUIDANCE?

- Visit PostFrameAdvantage.com
- Take PFMI Online University courses
  - Six 1-hour session course on engineering-based information
  - Three 1-hour session course on PF for architects
  - Free
  - CE credits available for design professionals

KEY WEBSITES FOR POST-FRAME DESIGN

- WWW.POSTFRAMEADVANTAGE.COM
- WWW.NFBA.ORG