

Structural design: Whose responsibility is it?

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A recent case before the Delaware Association of Professional Engineers brought to light a potential problem that could bring a black eye to the post-frame building industry. I became aware of this case after reading an article, “The Prostituting of Pole Buildings in Delaware — Owners and Permitting Agencies Beware,” which was published in the winter 2004 newsletter of the Delaware Association of Professional Engineers. In this article, the author suggested that pole buildings cannot be code conforming or meet accepted engineering practices. The article stated this about pole buildings:

“When subjected to code mandated snow and wind loads, their critical building connections don’t hold up, the building is too light to overcome overturning uplift forces without added forms of restraint, the columns become overstressed and/or the ground surrounding the columns yields under the excessive lateral pressure induced thereon.”

I was greatly alarmed by this article, as it was published by an association of my peers and stated that post-frame buildings are non-code conforming.

After digging into the background of this article, I became aware of a case that was before the Delaware Association of Professional Engineers of an engineer that certified plans without performing adequate structural calculations or review of the building system. I was afforded the opportunity to go before the Board and testify to the code conforming



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nature of post-frame construction and the accepted engineering practices that apply to post-frame building design.

At the conclusion of my testimony, I had an opportunity to speak with the author of the above referenced article. He said he was concerned about the frequent occurrence of engineers certifying plans with little or no structural design prepared prior to certifying the plans. His purpose for writing the article was to raise a few eyebrows and attract attention to the problem of plan stamping. His article certainly “raised the eyebrows” of staff at the National Frame Builders Association headquarters and others throughout the country.

The purpose of this article is to make it clear that post-frame buildings can be code conforming and structurally designed to meet the building code. This structural design is based upon accepted engineering practice that has been thoroughly researched and documented. This article also will review the minimum standards required to be part of a set of structural specifications for any building design prior to being certified with an engineer’s stamp (seal, mark, etc.).

The National Frame Builders Association has published the “Post-Frame Building Design Manual”, which brings together and references many of the national standards that apply to the structural design of post-frame buildings. It is my recommendation that any designer who is certifying a post-frame building design be well familiar with all of the standards that are included in this manual. Specifically unique to post-frame buildings are the footings, which should be designed following the American Society of Agricultural and Biological Engineers (ASABE, formerly ASAE) standards EP486 “Shallow Post Foundation Design” and EP484 “Diaphragm Design of Metal-Clad, Post-Frame Rectangular Buildings.” At the core

of any wood-frame building design is “National Design Specifications for Wood Construction,” published by the American Forest and Paper Association, which establishes the standards for structural sizing of members and connections in wood frame buildings. Associations such as the Wood Truss Council of America, Truss Plate Institute, Southern Pine Inspection Bureau, APA—The Engineered Wood Association, and many other groups publish standards referenced by the building code for the structural design of wood frame members and systems for post-frame buildings.

An engineer has liberty to include whatever he deems necessary to convey the results of his structural calculations in a building blueprint. However, there is a minimum amount of information that should be included in a structural plan. Many states have minimum requirements for structural plans. The Pennsylvania Uniform Construction Code provides a “UCC Plan Review Checklist” Form UCC-2. This checklist includes a section referring to structural plans with 19 items to be included, if applicable, in a structural plan. Other states have similar checklists included in their state building codes.

In addition to including this minimum information in a structural plan, Table 1 is a sample outline of post-frame building design data that may assist post-frame engineers.

Table 1. Suggested Outline for Gathering Post-Frame Building Design Data

I. Structural Loading

A. Determine Governing Code: IBC 2003, ASCE 7, etc.

1. Use Group Classification
2. Type of Construction

B. Dead Loads

1. Roof ___ psf
2. Floor ___ psf
3. Other ___ psf

C. Live Loads

- 1. Roof (see also Snow Loads) ___ psf
- 2. Floor ___ psf
- 3. Other ___ psf

D. Truss Loads

- 1. Top Chord Live ___ psf
- 2. Top Chord Dead ___ psf
- 3. Bottom Chord Live ___ psf
- 4. Bottom Chord Dead ___ psf

E. Snow Loads

- 1. Ground Snow (Pg) ___ psf
- 2. Flat Roof Snow (Pf) ___ psf
- 3. Snow Exposure Factor (Ce) ___ psf
- 4. Snow Load Importance Factor (I) ___ psf
- 5. Unbalanced Snow
 - a) Windward roof ___ psf
 - b) Leeward roof ___ psf

F. Wind Load

- 1. Basic Wind Speed (V) ___ mph
- 2. Wind Load Importance Factor (I)
- 3. Wind Exposure Category

G. Equipment Load

- 1. Fire Suppression Systems
- 2. Lights, Heaters, HVAC units

H. Stored Material Loads

- 1. Equivalent Fluid Density (EFD) ___

pcf

I. Earthquake Design Data (analysis based on equivalent lateral force procedure)

- 1. Spectral Response Acceleration at 1 sec, S
- 2. Spectral Response Acceleration at short periods, S

J. Seismic Use Group



- 1. Occupancy Importance Factor, I
- 2. Site Class

K. Basic Structural System

- 1. Light Framed Walls with Shear Panels
- 2. Response Modification Factor (R)
- 3. Deflection Amplification Factor (Cd)

L. Structural Calculations

- 1. Loads and Load Combinations Used
- 2. Load Paths Used to Resist Forces from Applied Loads and/or Load Combinations
- 3. Methodology Used to Determine

- Adequacy of the Components Specified
- 4. Stiffness of Components and Systems
- 5. Main Frame Member Design
 - a) Truss
 - b) Posts
 - c) Foundations
 - d) Diaphragm
 - e) Connections
- 6. Secondary Member Design
 - a) Girts
 - b) Purlins
 - c) Connections

- d) Sheathing Loaded Perpendicular to Plane
- 7. Bracing
 - a) Load that the Brace will Carry
 - b) Load Path for the Brace

System

- c) Stability of the Bracing Components

M. Structural Analysis for Other

Items

1. Floor System Design
2. Window and Door Framing
3. Large Door Headers
4. Roof, Wall, and Ceiling Coverings (If they are part of the diaphragm system or transfer-applied load to the secondary or main framing)

II. Footings

A. Compaction & Leveling of Footing Sub Grade after Footing Holes are Augered

B. Type of Concrete to Use based on Structural Load Application & Current Temperature

C. Slump

D. PSI

E. Mixture

F. Size, Based on

1. Soil Bearing Capacity
2. Applied Building Live Loads
3. Applied Building Dead Loads

G. Depth

1. Embedment
2. Below Frost Line
3. Building Height

H. Re-Rod Mat Reinforcement (typically used to reduce the thickness of the footing)

1. Size
2. Grade
3. Placement of Rod
4. Field Ability to Place Mat at the Proper Location

III. Columns*

A. Spacing - Examples: 8', 9', 10', 12'

B. Type of Column - Examples: Solid Sawn, Nail Laminated, Glue Laminated, Nail & Glue Laminated, Concrete Base

C. Size - Examples: 4x6, 6x6, 3-ply 2x6, 4-ply 2x6, 3-ply 2x8, 4-ply 2x8

D. Species & Grade of Lumber -

Examples: SYP, MSR, #1, #2, Select Structural

E. Treatment Levels - Examples: .40 Pcf, .60 Pcf, .80 Pcf

F. Treatment Use Group - Examples: Ground Contact (4A), Fresh Water/Ground Embedment (4B), Permanent Wood Foundation/Severe Environments (4C)

G. Type of Treatment - Examples: ACQ, Copper Azole, CCA

H. Length of Treatment - Examples: for Laminated Columns, 6', 7' or Full Column Treatment

I. Fabrication Requirements, for Field-Fabricated Columns

1. Fastener Type
2. Fastener Size
3. Fastener Spacing

J. Column Uplift Anchors - Examples: Treated Blocks, Tie Clips to Footings,

etc.

Some Available Documents

From NFBA - www.nfba.org

- "Spotlight on Architecture: Post-Frame Buildings" video
- Fire Test Manual
- 1996 Diaphragm Test Kit
- Post-Frame Building Design Manual
- Post-Frame "Beautiful Buildings Brochure"
- Framing Tolerances Standard
- Metal Panel & Trim Installation Tolerances Standard

From ASABE - www.asabe.org

- EP484.2 Diaphragm Design of Metal-Clad, Wood-Framed Rectangular Buildings
- EP558 Load Test for Metal-Clad, Wood-Framed Diaphragms
- EP559 Design Requirements, and Bending Properties for Mechanically Laminated Post
- EP486.1 Shallow Post Foundation Design
- Paper #01-4012 Uplift Resistance of Post Foundations

From Wood Truss Council of America - www.woodtruss.com

- BCSI-B1 Guide for Handling, Installing and Bracing of Metal Plate Connected Wood Trusses
- BCSI-B2 Truss Installation & Temporary Bracing
- BCSI-B3 Web Member Permanent Bracing/Web Reinforcement
- BCSI-B4 Construction Loading
- BCSI-B5 Truss Damage, Jobsite Modifications & Installation Errors
- BCSI-B6 Gable End Frame Bracing
- BCSI-B7 Temporary & Permanent Bracing for Parallel Chord Trusses
- BCSI-B9 Multi-Ply Girders
- BCSI-B10 Post-frame Truss Installation & Bracing
- BCSI-B11 Fall Protection & Wood Trusses
- 1-03 Guide to Good Practice for Handling, Installing & Bracing of Metal Plate Connected Wood Trusses
- a) Commentary for Permanent Bracing of Metal Plate Connected Wood Trusses
- b) Informational Series of Documents Titled "Truss Technology in Building"

K. Column Embedment - Examples: 4' Deep, 5' Deep

*Design Note: Not all solid-sawn and laminated columns are equal to each other

IV. Wall Girts

A. Size - Examples: 2x4, 2x6, 2x8

B. Spacing - Examples: 16", 24", 36"

C. Species & Grade - Examples: #2 Spruce Pine Fir, #2 Southern Yellow

Pine

D. Connection Requirements

1. Nails
 - a) Size - Example: Shank Diameter and Length
 - b) Type - Examples: Ring Shank, Spiral Shank, Common
 - c) Quantity & Location
 - d) Coating - Approved Hot-Dipped Galvanized or Stainless Steel (if in treated wood)

V. Supports (Truss Carriers)

A. Size - Examples: 2x6, 2x8, 2x10, 2x12, LVL

B. Species & Grade - Examples: Select

Structural Hem Fir, #1 Southern Yellow Pine

C. Quantity - Examples: 2, 3, 4, 5, 6 Members

D. Connection Requirements of Members (connection to column, connection to each other)

1. Nails
 - a) Size - Example: Shank Diameter and Length
 - b) Type - Examples: Ring Shank, Spiral Shank
 - c) Quantity & Location
 - d) Coating - Approved Hot-Dipped Galvanized or Stainless Steel (if in treated wood)
2. Bolts
 - a) Size
 - b) Hardness
 - c) Quantity & Location
 - d) Coating - Approved Hot-Dipped Galvanized or Stainless Steel (if in treated wood)
 - e) Note: Not all the Same Size Dimensional Lumber is Equal
 - (1) Base Design Value

for 2x12 #2 Doug Fir
Larch - $F_b=900$
(2) Base Design Value for
2x12 Select Structural
Hem Fir - $F_b=1400$
 F_b = Allowable Extreme
Fiber Stress in Bending

Source: *Western Lumber Product Use Manual 5-01*
The fiber stress values, along with other design
values, are used to determine what the 2x12
will support.

VI. Bearing Blocks

**A. Used for Additional Connection
Fasteners when there is Not Enough
Space in the Supports (Truss Carriers)
for the Total Number of Required
Fasteners**

**B. Blocks, Width of Column, Placed
Below Supports (truss carriers)**

C. Species and Grade Requirements

**D. Length Requirements of Bearing
Block**

E. Connection Requirements

1. Quantity of Fasteners
2. Type of Fasteners

VII. Roof Trusses

A. Loads

1. Top Chord Live Load (Snow)
 - a) Formula from ASCE 7 to
Determine Top Chord Live Load
 - (1) $P_f=0.7C_eC_tI_pg$
 - (2) C_e =Exposure Factor
 - (3) C_t =Thermal Factor
 - (4) I_p =Importance Factor

- (5) P_g =Ground Snow
- b) Slope Factor (C_s)
- c) Unbalanced Loads (wind-
ward, leeward)
- d) Step Roof Condition (if
applicable)
- e) Top Chord Pitch - Examples:
4:12, 5:12, etc.

2. Top Chord Dead Load
 - a) Roofing Material
 - b) Roof Top Equipment
3. Bottom Chord Live Load
 - a) Attic Storage Loads, if
applicable

4. Bottom Chord Dead Load
 - a) Ceiling material
 - b) Lights
 - c) Mechanical Equipment
 - d) Ceiling Insulation

B. Additional Design Factors & Loads

1. Centers - Examples: 2', 4', 8', etc.
2. Bearing Width at Heel
3. Bottom Chord & Web Lateral
Bracing Location (provided by
truss fabricator)

C. Permanent Truss Bracing & Connections (designed by building designer)

1. Truss X-Bracing
2. Wind Bracing
3. Connection Requirements of
Bracing (by building designer)
4. Truss Connection Requirements
for Uplift (truss print will
show uplift reactions)
 - a) Anchored to Column,

Direct Bearing on Column at
Bearing Wall
b) Anchored to Truss Supports
(Carriers) by Using:

- (1) Tie Down Blocks
 - (2) Steel Anchor Clips
 - (3) Steel Straps
- c) Bolts & Nails
- (1) Type - Examples:
Hardened Bolts, Ring
Shank or
Spiral Shank Nails
 - (2) Size of Fasteners
 - (3) Quantity of Fasteners

D. Equipment Loads

1. Concentrated Loads on Top or
Bottom Chords
2. Location of Equipment Loads

E. Transferring Loads

1. Transferring the Roof Loads &

the

Equipment Loads:

- a) To the Truss Supports
(Carriers)
- b) To the Columns
- c) To the Footings
- d) To the Connections &

Fasteners of Each Component

VIII. Roof Purlins (if required)

**A. Size of Material - Examples: 2x4,
2x6, 2x8**

B. Spacing - Examples: 16", 19.2", 24"

1. Configuration
2. Flat
3. On Edge
4. In Hangers (Note: If hangers are

required, specify hanger type)

C. Species & Grade - Examples: #2 Spruce Pine Fir, #1 Southern Yellow Pine

D. Connection Requirements

- a) Size - Examples: Shank Diameter and Length
- b) Type - Examples: Ring Shank, Spiral Shank
- c) Quantity & Location
- d) Fasteners Required for Hangers

IX. Permanent Building Bracing

A. Wall Bracing

- 1. Corner
- 2. Mid-Point (depending on building length, may require additional sets of bracing)

B. Roof Bracing (coordinate with truss design)

- 1. End
- 2. Mid-Point (depending on building length, may require additional sets of bracing)

C. Material

- 1. Pre-Punched Galvanized Steel Banding
- 2. Dimensional Lumber

D. Connection Requirements

- 1. Size - Examples: 10d, 16d
- 2. Type - Examples: Ring Shank, Spiral Shank
- 3. Quantity & Location
- 4. Fasteners Required for Pre-Punched Galvanized Steel Banding

E. Diaphragm Design

- 1. Exterior Walls & Roof

- 2. Wood Structural Panel Sheathing, Metal Panels
- 3. Fastener Requirements

X. Door Headers

A. Bearing Wall Headers

- 1. Glue-Laminated Beams
- 2. Stack Dimensional Lumber
- 3. LVL (Laminated Veneer Lumber)
- 4. Size, Species & Grade of Material
- 5. Connection & Fastener Requirements
 - a) To Columns
 - b) Field-Fabricated, Stacked Dimensional Material

B. Non-Bearing Wall Headers

- 1. Dimensional Lumber
 - a) Size - Examples: 2x6, 2x8, 2x10, 2x12
 - b) Species & Grade of Material
 - c) Connection & Fastener Requirements

XI. Door Framing

A. Overhead & Track (Slider) Doors

- 1. Side Jambs, Back Jambs
- 2. Using Jambs as a Bearing Member of Door Header (if applicable)

B. Walk Doors

- 1. Vertical Framing
- 2. Column
- 3. Header

C. Above Components

- 1. Size, Species & Grade of Material
- 2. Connection & Fastener Requirements

XII. Window Framing

A. Framing Requirements

- 1. Headers, Sills, Jambs
- 2. Size, Species & Grade of Material

B. Connection & Fastener Requirements

C. Elevation of Windows

D. Transition Requirements from Siding to Window

XIII. Walk Doors

A. Manufacture or Equal

B. Size - Examples: 30/68, 60/68

C. Type - Examples: Economy, Thermo Break, Heavy Duty, Fire Rated

D. Hardware Set

- 1. Locksets
- 2. Closers
- 3. Dead Bolts
- 4. Kick Plates
- 5. Panic Bars

E. Door Windows - Examples: Half, Full, 9-Lite, Narrow

XIV. Siding (Exterior Finish)

A. Steel (Metal Panel)

B. Manufacture

C. Panel Profile

D. Gauge

E. Yield Strength, Ultimate Strength, or Both

F. Paint System

G. Trims

- 1. Hemmed, Exposed Edges
- 2. Soffit - Vented or Smooth, Aluminum or Steel

H. Other Options

- 1. Brick Wainscot
- 2. EIFS
- 3. Wood

- 4. Vinyl Siding
- 5. Many more

I. Connection & Fastener Requirements of Siding Components (usually provided by siding manufacturer)
J. Barrier between Metal Panel Siding and Treated Framing Components
(Examples: Ice & Water Shield, Vycor Plus, Vycor Deck Protector)

XV. Roofing
A. Steel (Metal Panel)
B. Manufacture
C. Panel Profile
D. Gauge
E. Yield Strength, Ultimate Strength, or Both
F. Paint System
G. Trims
 1. Hemmed Exposed Edges
 2. Soffit - Vented or Smooth, Aluminum or Steel
H. Shingles
 1. Manufacturer
 2. Shingle Model - Examples: 3-in-1, Architectural
I. Underlayment - Examples: 15# Felt, 30# Felt, Roofers Select, Ice & Water Shield
J. Roof Decking - Examples: OSB, Plywood, Insulated Structural Panel
 1. Thickness - 1/2", 5/8", etc.
K. Spacer Clips (if required)
L. Connection & Fastener Requirements of Roofing Components (usually provided by material manufacturer)

XVI. Concrete Floor
A. Mix Specifications
B. Slump
C. Thickness
D. Air Entrained
E. Reinforcement (welded wire, fiber mesh, etc.)
F. Rodent Walls (depth & thickness)
G. Thresholds, if applicable (pipe for overhead & angle for slider doors)
H. Sealers & Curing Compounds
I. Control & Expansion Joints
J. Door Apron
 1. Size
 2. Thickness
 3. Thickened Edges

XVII. Other Items to Consider in the Building Design
A. Interior Partition Walls, Framing, Insulation, Wall Finish
B. Interior Doors, Size, Type (Fire & Finish), Swings, Hardware, etc.
C. Equipment & Fixture Blocking
D. Interior Windows, Size, Type of Glass, etc.
E. Interior Furnishings, Cabinets, etc.
F. Fire-Rated Assemblies for Walls & Ceilings (as required)
G. Temporary Construction Bracing

XVIII. For All Framing Members
A. Determine Size and Quantity of Nails Based on Species of Lumber and Reaction Loads that Each Nail Must

Support
B. Placement of Fasteners

The outline in Table 1 represents only an example of the information to be included in an engineer's plans and specifications prior to certifying a plan. The outline is not intended to be a definitive and prescriptive requirement for design, but a guideline for making designs and specifications that are as complete and accurate as possible. Each structural engineer must decide what information will be included in plans and specifications prior to applying a seal. There are many design standards and tools available that apply to structural engineering in general and for specific use with post-frame building design.

Post-frame buildings are complex three-dimensional (plane frames and diaphragms perpendicular to the plane frame) structures requiring in-depth structural analysis that relies on competent engineering. Proper and complete structural analysis will provide the information required for the "Suggested Outline for Gathering Post-Frame Building Design Data" given in Table 1.

A complete building design also will often require engineering calculations other than structural ones. The thermal insulation, ventilation, heating/cooling, moisture removal (vapor barriers and drain paths), electrical, and plumbing systems all will impact functionality of the building. These systems may require that the design engineer(s) ensure that differently-designed systems do not compromise one another. For instance, some types of roof insulation may maintain the thermal integrity of the roof system, but detract from the strength and stiffness of the roof diaphragm.

Table 1, "Suggested Outline for Gathering Post-Frame Building Design Data," is not intended as an infallible or exhaustive list of requirements for all post-frame designs. The ingenuity and creativity of design professionals today and in the future will cause incessant evolution of engineering practices. The performance-oriented design process allows post-frame to be competitive and even preferred over other types of construction that tend to be prescriptive in nature. Engineers should

remain free to come up with new ways to solve problems (designs), and to use analysis tools that show the solution created is sound from both a scientific and engineering perspective. The table is only intended to provide ideas for engineers to consider when approaching post-frame design. Therefore, the table should not be construed by any party to be a prescriptive pronouncement of an approval process or mandatory requirements for engineering any post-frame building.

The National Association of Professional Engineers creed states:

As a Professional Engineer, I dedicate my professional knowledge and skill to the advancement and betterment of human welfare.

I pledge:

To give the utmost of performance;

To participate in none but honest enterprise;

To live and work according to the laws of man and the highest standards of professional conduct;

To place service before profit, the honor and standing of the profession before personal advantage, and the public welfare above all other considerations.

In humility and with need for Divine Guidance, I make this pledge.

In order to ensure "advancement and betterment of human welfare" we must all insist that complete engineering be performed prior to providing professional certification for any project. While every item on the sample outline in Table 1 may not apply to each specific project and some projects will require engineering not listed, all projects require the highest level of professional conduct from both engineers and builders alike. ■

Tim Royer is president of Timber Tech Engineering, Inc., and serves on the NFBA Editorial Review Committee. Special recognition goes to Doug Thomsen for his work on Table 1, "Suggested Outline for Gathering Post-Frame Building Design Data."