Design Criteria

• Structural Safety & Integrity
  – Buildings shall resist all lateral (wind & earthquake) and vertical structural loads thru a continuous load path transmitting them ultimately to the ground

• Structural Serviceability
  – Portions of buildings shall limit vertical deflections & lateral drift (movements)
  – Problems can usually be identified by material fatigue, such as exterior veneer or interior wall cracks or squeaky floors

• Durability
  – Specified materials and construction methods will result in a long-lasting building
Construction Terms
Loading Types

- Dead Load
- Live Load
- Cold Weather Load
- Soil Load
- Wind Load
- Earthquake Load
  - Not required in NC for typical residential home
Dead Loads

- Defined as the Weight of Permanent Portions of a Building
- Typically includes all Construction Materials
Dead Loads, cont’d

Typical Weights of Horizontal Systems

- **Roof Construction**
  - Asphalt Shingles ~ 15 psf (pounds per sq. foot)

- **Ceiling Construction**
  - Gypsum (Sheetrock) finish ~ 10psf

- **Floor Construction**
  - Carpet or Vinyl ~ 10 psf
  - Hardwood Floor ~ 12 psf
  - Ceramic Tile ~ 15 psf
Dead Loads, cont’d

Typical Weights of Vertical Systems

• Timber wall, wood sheathing, & gypsum interior finish, with:
  – Vinyl Siding ~ 8 psf
  – Thin Coat Stucco ~ 11 psf
  – Standard Brick Veneer ~ 45 psf

• 8 inch Masonry Wall fully grouted ~ 75 psf

• 8 inch Concrete Wall ~ 96 psf
Live Loads

- Non-Permanent Weight
- Includes:
  - Occupants
  - Furniture
  - Appliances
  - Storage

<table>
<thead>
<tr>
<th>APPLICATION</th>
<th>UNIFORM LOAD (psf or plf)</th>
<th>CONCENTRATED LOAD (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope ≥ 4:12</td>
<td>15 psf</td>
<td>250 lbs</td>
</tr>
<tr>
<td>Slope &lt; 4:12</td>
<td>20 psf</td>
<td>250 lbs</td>
</tr>
<tr>
<td>Attics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>without storage¹</td>
<td>10 psf</td>
<td>250 lbs</td>
</tr>
<tr>
<td>with storage²</td>
<td>20 psf</td>
<td>250 lbs</td>
</tr>
<tr>
<td>Floors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bedroom areas</td>
<td>30 psf</td>
<td>300 lbs</td>
</tr>
<tr>
<td>Other areas</td>
<td>40 psf</td>
<td>300 lbs</td>
</tr>
<tr>
<td>Garages</td>
<td>40 psf</td>
<td>2,000 lbs</td>
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<tr>
<td>Decks &amp; Balconies³</td>
<td>60 psf</td>
<td>300 lbs</td>
</tr>
<tr>
<td>Stairs</td>
<td>40 psf</td>
<td>300 lbs</td>
</tr>
<tr>
<td>Guardrails &amp; Handrails</td>
<td>20 plf</td>
<td>200 lbs</td>
</tr>
<tr>
<td>Grab bars</td>
<td>n/a</td>
<td>250 lbs</td>
</tr>
</tbody>
</table>
Cold Weather Loads

Snow
• Typically applied to exposed roofs or decks
• Ground snow load commonly ~ 10 psf
• Usually roof live load governs unless snow drifts are considered

Frost Heave
• Condition where soil under footing freezes and exerts upward movement on the foundation
• Bottom of Footings must be below frost depth to avoid this issue, commonly 12 inches in the Charlotte and Surrounding areas – refer to IBC for exact values
Soil Load

- Soil Backfill exerts pressure on walls
- Based on height of wall and restraint
- Typical Wall Force per ft
  - Basement
    - $18h^2$ (lb/ft of wall)
  - Retaining
    - $30h^2$ (lb/ft of wall)

$$P = qh \text{ (psf)}$$
Wind Loads

- Based on 90 mph wind speed
- Roughly 20 psf
- Based on ASCE 7-05
Wind Force Resisting System

- Portions of structure that keeps building from failure under wind loading
- Diaphragms include Floors & Roofs
- Shear Walls include Timber & Masonry Walls
  - Not all Walls are Shear Walls
- Load Path
  - Wind Hits Wall → Enters Diaphragm → Shear Walls Resist Movement → Foundations Hold Shear Walls

Lateral load analysis must be conducted along both axes of structure.
Wind Force Resisting System, cont’d

• Prevents Sliding

• Prevents Overturning
Diaphragms Types

Blocked Diaphragm

Unblocked Diaphragm

ACCOMMODATING RIDGE VENTS WITH BLOCKED DIAPHRAGMS

Edge nail spacing

Unblocked

Blocked

Half of edge nail spacing

(Not to scale)
Timber Shear Walls

Prescriptive

• Most Common
• Cost Effective

• Does Not Require Engineering Analysis
• Limited in Applications
Timber Shear Walls, cont’d

Engineered
• Stronger
• Designed by Engineer
• Requires Specific Knowledge to Install
Vertical Load Path

- Roof Load
- Second Floor Load
- First Floor Load
- Wall + Floor Load
- Soil-bearing Reaction (≈ Roof + 2 Walls + 2 Floors + Foundation Wall Load)

**Diagram Details:**
- Double Top Plate
- Header
- Jamb Stud
- King Stud
- Window Sill
- Stud
- Cripple Stud
- Wall (R1) and Header (R2) Reactions

**Load Path Details:**
- Roof + Wall + Floor Load
- Structure System "Seen" by Roof + Wall Load
- Floor Load
- Structural System "Seen" by Floor Load

**Load Calculations:**
- Net Roof Uplift Load (Wind - Dead Load)
- Uplift > Gravity
- Equilibrium (Wind Uplift = Total Dead Load)*
- Uplift < Gravity

**Notes:**
- Equilibrium point varies depending on magnitude of wind uplift load and dead load. Codes require that only part of the dead load be considered when determining uplift forces.
- Caution: Depending on magnitude of uplift force at various points in the load path, metal connectors may be required, particularly in hurricane-prone coastal regions.

*Note: Equilibrium point varies depending on magnitude of wind uplift load and dead load. Codes require that only part of the dead load be considered when determining uplift forces.
Lateral Load Path

NOTE: IF STIFFNESS OR LOAD IS NONS YMMETRICAL, BUILDING ROTATION OCCURS ($\Delta_1 \neq \Delta_2$) AND LOADS ARE DISTRIBUTED BY TORSION ($\Delta_4$) AS WELL AS BY DIRECT SHEAR IN THE DIRECTION OF THE LATERAL FORCE. THIS CONDITION VARIES BUT IS A REALITY FOR MOST DESIGNS. $\Delta_2$ IS THE BENDING DEFORMATION OF THE HORIZONTAL DIAPHRAGM (I.E., ROOF).

= LATERAL SHEAR (HACKING) LOAD FROM WIND PRESSURE ON WINDWARD AND LEWARD (NOT SHOWN) TRIBUTARY AREAS. THE TRIBUTARY SURFACE PRESSURE LOADS ARE TRANSFERRED TO THE WALLS THROUGH THE FLOOR AND ROOF BY DIAPHRAGM ACTION.

NOTE: WHILE LATERAL LOADS ARE SIMILARLY TRANSFERRED TO WALLS BY DIAPHRAGM ACTION, SEISMIC FORCES ORIGINATE FROM THE TRIBUTARY MASS OF THE BUILDING (I.E., PLAN AREA), NOT THE EXTERIOR SURFACE AREA AS IS SHOWN FOR WIND.
Foundations

- Vary depending on local conditions
- Most Common are the crawl space, basement, & monolithic
- Foundation must resist vertical and horizontal loads
Floor & Wall Systems
Roof System

Typical Framing

- Sheathing
- Ridge Board
- Rafter
- Ceiling Joist
- Gable End
- Lookout
- Fly Rafter
- Overhang
- Roof Sheathing
- Rafter
- Lookout
- Soffit Fascia
- Eave Overhang (Rafter)
- Truss
- Lookout
- Soffit Fascia
- Eave Overhang (Truss)
Residential Design Conclusions

- This presentation was intended for a simple overview of the loading and design of residential homes.
- When structural elements are in question, please contact a registered professional engineer to determine its integrity and safety.
- Please refer to our other presentations for additional information located at: www.structural-design-solutions.com