Course Objectives

- The intent of this course is to...
  1. To gain a clear understanding of structural loads, load paths, and site conditions.
  2. To outline common framing and other structural errors in residential construction.
  3. To clearly define the braced wall provisions of the IRC.

Seminar Format

1. Loads & Load Paths
2. Site Conditions
3. Structural Concerns
4. Trusses
5. Wall Bracing
6. Open Discussion
**Design Criteria (R301.1)**

- “…shall be constructed to safely support all loads, including dead loads, live loads, roof loads, flood loads, snow loads, wind loads and seismic loads as prescribed by this code.”
- “The construction… shall result in a system that provides a complete load path…”

**Load Paths**

- **Newton’s 3rd Law:**
  - “To every action there is an equal and opposite reaction.”
- **Load Path:**
  - How the loads are transferred from the point of origin to where they are resisted.

**Load Paths**

- **What causes vertical loads?**
  - Gravity
- **What causes lateral loads?**
  - Wind
  - Seismic
- **What resists these loads?**
  - Ground

**Parts of Structure**

- Connections, connections, connections
- Beams, columns, headers
- Diaphragms, shear walls, collectors
- Footings, foundations, soil
Not Part of Structure

- Interior partitions
- Drywall and other finishes
- Roofing, insulation, MEP

Gravity Load Path

- What loads need to be considered?
  - Dead loads
  - Live loads
  - Snow loads
  - Soil loads
  - Hydrostatic loads
  - Rain loads
  - Flood loads

Gravity Load Path

- Concentrated vs. Uniform Loads

Gravity Load Path

- The load path is pretty easy to follow.
- What are some common problems?
Lateral Load Path

- Not as easily understood
- What loads need to be considered?
  - Wind
  - Seismic

Lateral Load Path

- Wind:
  - Wind acts against the sides of a building like the sail on a boat.
  - The majority of forces are transferred up into the roof/floor while the rest into the foundation.

Lateral Load Path

- Seismic:
  - Ground shaking causes the structure's mass to be accelerated back and forth.
  - Forces are developed where the structures mass is the largest.

Lateral Load Path

- Structure & foundations must resist:
  - Sliding
  - Overturning
Lateral Load Path

- **Sliding Load Path:**
  - Sliding Load Path (cont.)

- **Sliding Load Path (cont.)**
  - Restrained sliding is typically less severe than rocking.
  - Restrained sliding is more likely to occur in one direction than the other.
  - Use of non-restrained sliding is discouraged in areas of high seismic demand.

- **Sliding Load Path (cont.)**
  - Restrained sliding is less likely to cause damage than rocking.
  - Restrained sliding is more common in areas of moderate seismic demand.
  - Use of non-restrained sliding is discouraged in areas of low seismic demand.
Lateral Load Path

- Overturning Load Path:

How important are the connections?
Lateral Load Path

- Special attention should be paid to structural irregularities.
- The ideal structure would have no irregularities.

PART 2
Site Conditions

Geotechnical Report

- **Is a geotechnical report required per IRC?**
  - R106.1 – “Submit documents consisting of construction documents, and other data…”
  - R401.2 – Fill soils that support footings and foundations
  - R401.4 – Where expansive soils, compressible soils, shifting soils or other questionable soil characteristics are likely present.
  - Table R401.4.1, Footnote ‘b’ – Where allowable bearing capacity of less than 1,500psf is likely present
  - IBC 1803 notes any project in SDC “C” or above
  - When can this requirement be waived?
Geotechnical Report

IBC 1803.6: Report should provide...
- A plot showing locations of borings
- Complete record of soil borings
- Record of soil profile
- Elevation of water table
- Recommendations for...
  - Foundation type
  - Bearing capacity
  - Mitigation measures for expansive soils
- Expected total & differential settlement
- Compacted fill properties

Additional items for SDC ‘D’ or above...
- Seismic lateral earth pressure ➔ 6-feet
- Potential for liquefaction
- Assessment of liquefaction consequences
- Liquefaction mitigation measures

Deep Foundations (IBC 1803.5.5):
- Recommended deep foundation types
- Recommended center-to-center spacing
- Driving criteria
- Installation procedures
- Field inspection & reporting procedures
- Load test requirements
- Reductions for group action
### Geotechnical Report

**Is it okay to assume Soil Site Class 'D'?**
- 'D' = stiff soil
- 'E' = soft clay
- 'F' = liquefiable/collapsible

### Geotechnical Report

**IBC 1809.13:** Site Class E & F soils in high seismic regions require all footings to have "seismic ties".

### Sloped Lots

**Footings on Slopes:** Steeper than 1V:3H
- IRC Figure R403.1.7.1
- or...
- Ascending Slopes (R403.1.7.1) → steeper than 1V:1H
- Descending Slopes (R403.1.7.2) → steeper than 1V:1H
- or...
- Alternate setbacks & clearances allowed by the Building Official (R403.1.7.4)

### Sloped Lots

**Footings on Slopes (cont.)**
- IRC Figure R403.1.7.1
- Descending: H/3, but not greater than 40-feet
- Ascending: H/2, but not greater than 15-feet
**Sloped Lots**

- **Footings on Slopes (cont.)**
  - Ascending Slopes (R403.1.7.1)

- **Descending Slopes (R403.1.7.2)**

**Geologic Hazards**

- **Are their other geologic hazards at your site?**

**Seismic Hazard Maps:**

- Liquefaction:
  - High
  - Moderate
  - Low
  - Very Low
- Active Faults
  - Require “Special Surface Fault Rupture Hazard Study”
Flood Hazards

- Flooding:
  - National Flood Insurance Program (NFIP)
  - Flood Insurance Rate Maps (FIRM)
  - Flood Hazard Area (FHA) → Zones A & V
  - Base Flood Elevation (BFE) → “100-year flood”
  - Regulatory Floodway → area reserved to discharge base flood without increasing water surface elevation

Special Snow Loads

- Snow Drift:
  - Exceptions:
    - Projection < 15 feet
    - $P_f < 20$ psf

- Snow Drift:
  - What to look for on the plans…
Special Snow Loads

- **Unbalanced Snow:**
  - Essentially equal to ground snow load if rafter length is < 20 feet.

Special Snow Loads

- **Sliding Snow:**
  - Slippery: > ⅛:12 pitch
  - Non-slippery: > 2:12 pitch
  - \( W = \) ridge-to-eave
  - Distribute onto lower roof 15’
  - Sliding load: \( \frac{0.4 \times Pf \times W}{15'} \)

**Example:**
- Assume Pf = 30psf
- Sliding load ≈ 10psf
Wind Exposure

- Three exposures outlined in the IRC
  - Exposure B: Urban & suburban areas with closely spaced obstructions having the size of single-family dwellings.

Seismic Hazard

- Seismic Design Category
  - Figure R301.2.2.1
  - Table R301.2.2.1.1, or
  - IBC Methodology

Wind Exposure

- Exposure C: Open terrain with scattered obstructions typically < 30-feet in height
- Exposure D: Flat, unobstructed areas exposed to wind flowing over open water for a distance of at least 1 mile.

Seismic Hazard

- How many of you verify ground motions?
  - Multiple options, such as ...
    - ATC Hazards by Location (seismic, wind, snow, tornado)
    - SEAOC Seismic Design Map Tool (seismic only)
    - ASCE 7 Hazard Tool (seismic, wind, rain, flood, ice, snow & tsunami)
  - The others are fading out with the introduction of ASCE 7-22.
  - For that reason, we will use the ASCE 7 Hazard Tool as an example.

https://ascehazardtool.org
Introduction

- Multiple topics based upon...
  - Survey of licensed S.E.’s
  - APA’s “Top 10 Framing Errors”
  - Multiple APA Publications

Incomplete Load Path

Gravity Load Path:
- Verify that loads have a path to the foundation.

Gravity Load Path (cont.)
- Example: Girder Truss support

Lateral Load Path:
- Follow loads through members & connections from the roof to the foundation.
- Forces will concentrate at the end of the path provided.
Incomplete Load Path

- Lateral Load Path (cont.)
  - Example: Interior shearwalls

Notches / Holes

- Dimension Lumber joists and beams shall...
  - Not exceed 1/6 of member depth
  - Not be longer than 1/3 member depth
  - Not be located in middle 1/3 of span

Eave Blocking

- Notches at the ends shall be ≤ 1/4 of the member depth.
Notches / Holes

- Diameter of holes bored or cut into joists and beams shall...
  - Not exceed 1/3 of member depth
  - Not be closer than 2” from bottom of member or any other hole or notch

Notches / Holes

- Notches:
  - Exterior ≤ 25% width
  - Bearing ≤ 25% width
  - Partition ≤ 40% width

- Holes:
  - Edge ≥ 5/8”
  - Ø ≤ 40% width (single)
  - Ø ≤ 60% width (double)

Notches / Holes

- If > 50% of top plate width is notched/drilled...
  - Provide a 1.5” wide x 16ga, galvanized metal tie
  - Fasten to either side w/ (8) 10d nails

Notches / Holes

- Cantilevered Rafters:
  - No more than 1/4 the depth, but not less than 3.5”
  - 24-inch maximum cantilever
Notches / Holes

- **Tapered Ceiling Joists:**
  - No more than 1/4 joist depth at inside face of support

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Notches / Holes

- **I-Joists:**
  - APA – Form No. Z725F
  - Notch in Top Flange: Weyerhauser TB-818
  - Holes Near Bearing: Weyerhauser TB-817
  - Rafter Cuts: Weyerhauser TB-805

---

Notches / Holes

- **I-Joists:**
  - Weyerhauser TB-818
    - Original joists are properly designed
    - Adjacent joists are undamaged
    - Uniform loads
    - 1 side-flange notch

---

Notches / Holes

- **I-Joists:**
  - Weyerhauser TB-817

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Notches / Holes

- **Notches & Holes:**
  - I-Joists: APA – Form No. Z725F
  - Notch in Top Flange: Weyerhauser TB-818
  - Holes Near Bearing: Weyerhauser TB-817
  - Rafter Cuts: Weyerhauser TB-805

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Notches / Holes

- **I-Joists:**
  - Weyerhauser TB-817
**Notches / Holes**

- **I-Joists:** Weyerhauser TB-805

- **Notches & Holes:**
  - LVLs: APA – Form No. EWS G535A
  - GLBs: APA – Form No. EWS S560H

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**Improper Fasteners**

- Model Codes have specified *“common”* nails for more than 40 years.
- Most gun nails are box nails (also cooler & sinker)
- 8d common → 0.131 shank
- 8d box → 0.113 shank
- ≈ 15% reduction in shank

---

**Improper Fasteners**

- ESR-1539 – International Staple, Nail and Tool Association

---

**Notches / Holes**

- LVLs: APA – Form No. EWS G535A
- GLBs: APA – Form No. EWS S560H
Improper Fasteners

- **APA TT-087B:**
  - Using ESR-1539 and NDS equations → 25% reduction in capacity
  - SDPWS lists “common or hot-dip galvanized box”
  - “Available test results suggest similar shear wall performance between walls constructed with 8d common and 8d box nails.”

Overdriven Fasteners

- **IBC 2304.10.2:**
  - Nails “…shall be driven so that their head or crown is flush with the surface of the sheathing.”

- **APA TT-012C:**
  - Reduction in capacity is not required if...
    - All are overdriven ≤ 1/16” in dry conditions
    - If ≤ 20% of edge fasteners are overdriven ≤ 1/8”
    - Panels used are thicker than required
Overdriven Fasteners

- **APA TT-012B:**
  - If > 20% are overdriven by > 1/16”, or…
  - If any are overdriven by > 1/8”, then…
  - **One** additional fastener must be driven **for each two** overdriven.
  - If nails were originally used and are spaced too close for additional nails, approved staples should be used to reduce the potential for splitting.

Shear Walls

- **Braced Walls:**
  - All framing members and blocking shall be ≥ 2x
  - 8d common at 6”o.c. edge nailing and 12”o.c. field nailing
- **Engineered Shear Walls:**
  - All panels shall have 2x blocking
    - 3x required when edge nailing is 2”o.c., or…
    - 10d nails and 3”o.c., or…
    - Panels applied to each face and are not offset

Shear Walls (cont.)

- **Shear Walls:**
  - Allowable aspect ratios
    - Without reduction → 2:1
    - With reduction → 3.5:1 (e.g. 8’-0” x 2’-3”)
  - Example: 9-foot wall
    - 2:1 → 4.5 feet
    - 3.5:1 → 2.57 feet
  - 43% reduction in capacity!
  - Look for shear wall widths that have been changed in the field!

Shear Walls (cont.)

- **Perforated Shear Walls**
Shear Walls

Shear Walls (cont.)
- Perforated Shear Walls

Table 4.2.3.8 Shear Capacity Adjustment Factor, $C_v$

<table>
<thead>
<tr>
<th>Percent Full-Height Sheathing (Blocking)</th>
<th>Percent Wall Area Openings (A_o / A_W)</th>
<th>Shear Capacity Ratio, C_v</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0% 1% 10% 20% 30% 40% 50% 60% 70% 80%</td>
<td>1.00 1.00 0.97 0.77 0.53 0.45 0.44 0.42 0.40 0.39</td>
</tr>
</tbody>
</table>

- Force-Transfer Shear Walls
  - Design & Detailing:
    - Each wall pier ≥ 2-feet
    - Full-height segment at each end
    - No out-of-plane offsets
    - Collectors shall be full length
  - Requires rational analysis
  - Must define blocking, straps and holdowns

Shear Walls

Shear Walls (cont.)
- Force-Transfer Shear Walls

Holdown Straps

Case 1: Improper locations
- Engineered specified retrofit anchor required.
Holdown Straps

Case 2: Spalling at embed straps
- If < 1", load capacity is not affected.
- If < 4", holdown capacity is reduced by 10%.
- If > 4", Engineered retrofit holdown is required.

Holdown Straps

Case 3: Offsets
- Creates slack in the line.
- Only a 5/8" offset is permitted.
- If over sheathing, slightly notching the panel edge will keep strap from bulging and wall movement to a minimum.
- More than a single 90° bend is not allowed.

Holdown Straps

Case 4: Holdowns at Rim Joists
- Is proper holdown being used at rim joists?
- The holdown will need to be replaced.

Holdown Straps

Case 5: Improper Holdown Used
- Plans often state “Simpson xxx, or approved equal”
- Is the replacement holdown equivalent?
- Has the replacement holdown been approved by the EOR?
- Does it have a current ICC-ES, IAPMO, or other report?
Foundation Walls

- **IRC R404.1.1: Walls must be engineered if...**
  - Subject to hydrostatic pressure from ground water, or...
  - Support > 4 feet of unbalanced backfill and do not have permanent lateral support

- **Inadequate Foundation Drainage**
  - IRC R405.1: “Drains shall be provided around concrete or masonry foundations that retain earth and enclose habitable or usable spaces located below grade.”
    - Exception: Well-drained ground

Foundation Walls

- **Inadequate Foundation Drainage (cont.)**
  - Foundation Drain (**R405.1**):
    - At or below top of footing or below the bottom of the slab
    - Gravel drain:
      - 12” beyond outside edge of footing
      - Top at least 6” above footing
      - Cover with approved filter material
      - Perforated pipe w/ filter membrane
      - Pipe placed on at least 2” gravel
      - Surround pipe with 6” of gravel

- **Inadequate Foundation Drainage (cont.)**
  - Foundation Drain (cont.):
    - Must discharge by gravity or mechanical means into an approved drainage system.
Foundation Walls

- Are foundation walls restrained?
  - Prescriptive Tables include this footnote: "Where walls retain more than 4 feet or more of unbalanced backfill, they shall be laterally supported at the top and bottom before backfilling."
  - R404.1.3.2: "Concrete foundation walls shall be laterally supported at the top and bottom."

- How is a foundation wall considered restrained?
- Are walkout basements restrained?

Foundation Walls

- Are foundation walls restrained? (cont.)
  - SDC ‘D or above’
  - At least 4 vertical bars
  - $\rho_{\text{min}} = 0.005$
  - $\rho = 0.005$
  - #4 ≤ 14”Ø
  - #5 ≤ 17”Ø
  - #6 ≤ 21”Ø
  - #7 ≤ 24”Ø

Concrete Piers

- Vertical Reinforcement (IBC 1810.3.9.4.2):
Concrete Piers

- **Enclosed Ties (IBC 1810.3.9.4.2)**
  - #3 bar if ≤ 20”Ø
  - Otherwise #4 bar
  - Spacing shall be least of...
    - 12d, vertical bar;
    - 1/2 least dimension of compression member; and...
    - 12 inches
  - #4 vert → 6"
  - #5 vert → 7.5"
  - #6 vert → 9"
  - #7 vert → 10.5"

- **Seismic Hooks (IBC 1810.3.2.1.1)**
  - Required in SDC ‘C’ or above
  - ACI 318:
    - Bend not less than 135°
    - 6db extension (i.e. #4 bar → 3”)

Concrete Piers

- **Exceptions (IBC 1810.3.9.4)**
  - Not required in R-3 of 2-stories or less when...
  - Element is not subject to lateral loads, or...
  - Only supports posts from decks and patios and the calculated lateral does not exceed 200#
  - In these cases a single #4 vertical bar must be provided without ties or spirals

Deep Foundations

- **Caisson Footings (IBC 1810.3.5)**
  - Common for areas with expansive or collapsible soils
  - Cased:
    - “Permanent”
    - 8”Ø minimum
    - 1” concrete cover
  - Uncased:
    - 12”Ø minimum
    - Length ≤ 30”Ø
    - 2.5” concrete cover
Deep Foundations

- **Caisson Footings (cont.)**
  - Minimum of 4 vertical bars
  - Enclosed seismic hooks w/ spacing of...
    - 12 longitudinal $d_b$
    - 1/2 least dimension of element
    - 12 inches
  - Reinforced length is greatest of...
    - One-half element length;
    - 10-feet;
    - Three times least element dimension

Sill Plate Anchorage

- **IBC §1905.1.8:**
  - In-plane shear strength to comply with the NDS
  - Maximum 5/8-inch diameter
  - Minimum 7-inch embedment
  - Min. concrete edge distance of 1-3/4”
  - Placed w/in 15ø of end of concrete foundation
  - 2x, 3x sill plates or 33-mil to 68-mil tracks

Deep Foundations

- **What is wrong with this detail?**

  ![Diagram of deep foundations]

Sill Plate Anchorage

- **IRC R403.1.6:**
  - 1/2” diameter min.
  - 7” embedment min.
  - Placed in middle third of plate
  - 2 per plate min.
  - Max 12” from end
  - Min. 7db from end
Sill Plate Anchorage

- **IRC R403.1.6.1 - SDC ‘D’:**
  - 3”x3”x0.229” plate washers are required
  - 2021 SDPWS requires the edge of the square plate washer to extend within 1/2-inch of the sheathed edge.

Post-Installed Anchors

- **Post-Installed Anchors:**
  - Expansion, epoxy, screw, etc.
  - Must be approved for proposed application
  - Special inspection is often required!!!

Upside-down Glulams

- If glulams are cambered the top will be marked.
- If the critical tension laminations are on the bottom than this builds deflection into the structure.

Rock Walls

- Slope protection, not a retaining wall
- Why should we worry about these walls?
Rock Walls

1/20/2013 – A 63-year-old St. George woman was sent to hospital with a broken jaw and sternum from a runaway boulder.

5/14/2010: An article stated that “…a building inspector could have, and should have, detected and prevented the disaster at any stage, but didn’t.”

Rock Walls

What should we be looking for in a rock wall submittal?

Prescriptive Handouts:
- Seattle, WA
- Sparks, NV
- Southern Nevada B.O.A.
- FHWA

Standard Items:
- Dimensioned site plan
- Cross section of wall (rock size for each lift, maximum height, backfill, drainage, slope of ground, batter, and embedment)
- If > 4-feet: Structural Analysis & Soils Report
- Base rock must be embedded 12-inches
- Minimum batter of 1H:4V (i.e. 15%)
- Graded so water cannot flow over top
- …
Rock Walls

- **Standard Items (cont.):**
  - Lower half should consist of 4-man or larger rocks with upper half being progressively smaller with minimum 2-man rocks.
  - Void spaces shall be “chinked” or tightly filled
  - Landscape materials cannot have detrimental effect

<table>
<thead>
<tr>
<th>Size</th>
<th>Weight</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-man</td>
<td>58 - 210 lbs</td>
<td>0.4 - 1.3 cubic ft</td>
</tr>
<tr>
<td>2-man</td>
<td>265 - 580 lbs</td>
<td>1.6 - 3.6 cubic ft</td>
</tr>
<tr>
<td>3-man</td>
<td>760 - 1,850 lbs</td>
<td>4.7 - 11.2 cubic ft</td>
</tr>
<tr>
<td>4-man</td>
<td>3,000 - 4,900 lbs</td>
<td>18.4 - 24.5 cubic ft</td>
</tr>
<tr>
<td>5-man</td>
<td>5,000 lbs</td>
<td>30.7 cubic ft</td>
</tr>
<tr>
<td>6-man</td>
<td>7,000 lbs</td>
<td>42.9 cubic ft</td>
</tr>
</tbody>
</table>

Narrow Sheathing

- **APA Publication R275:**
  - > 16”-24” → block lower edge or provide 2 clips
  - ≥ 12”-16” → block lower edge
  - < 12” → block upper and lower edges

Gaps in Sheathing

- **APA** recommends a minimum 1/8” gap between sheathing panels
Gaps in Sheathing

- **APA’s spacing hint:**
  - Use 10d box nail to gauge 1/8-inch spacing between panels.
  - Spacer-type panel clips may be used for roof sheathing applications.

Steel Moment Frames

- **Many residential designers do not understand how to design and detail a steel moment frame.**
  - Ordinary Moment Frame (OMF) → R = 3.5
  - Special Moment Frame (SMF) → R = 8.0
  - Wood Shearwalls → R = 6.5 (OMF = 54% capacity)

Steel Moment Frames

- The design within the wall line of the OMF → R = 3.5
- Several Prefabricated Moment Frames (i.e. Simpson Strong Frame®)

IAPMO ER-164:

- Calculations by Simpson Strong-Tie are to be submitted to the code official.
- Calculations by the EOR must be provided showing that the design loads do not exceed those allowed in ER-164.
- Special inspections are required unless conventional construction has been met.
Full-Depth Blocking

- Shall be provided at...
  - Ends of joists
  - Intermediate supports (SDC D\textsubscript{0}, D\textsubscript{1}, and D\textsubscript{2} only)
  - At 8-feet on center (> 2"x12" dimension lumber)

Full-Depth Blocking

- Same for I-joists...

APA I-Joist Blocking

- Web Stiffeners:
  - Where web is in jeopardy of buckling out-of-plane
  - Heavy loads that cause web to knife through flange
  - Support hanger does not extend to top flange

APA I-Joist Blocking

- Web Stiffeners (cont.)
  - Bearing stiffeners: Located at the reactions when required
  - Load stiffeners: Located between supports where significant point loads are applied to top flange
APA I-Joist Blocking

- **Squash Blocks:**
  - Purpose is to carry a point load that would otherwise be carried by the joist.

- **Filler Blocks:**
  - Used to fill space between a pair of I-joists acting as a single bending member.
  - Helps to transfer load from one member to the next.
  - Must be placed the full length of the I-joist.

Miscellaneous Items

- **Decks**
  - IBC 1604.8.3: Positively attached for vertical & lateral loads
  - AWC DCA 6

- **Post Frame Buildings**
  - AWC DCA 5

- **Log Structures**
  - ICC 400

PART 4
Trusses
Truss Package

- Inconsistencies are common between the initial design and the truss package.
- What are some common issues that arise?
- When do you review the truss package?

Deferred Submittal (IBC 107.3.4.1)
- Required for structural components in which the structural design has not been submitted.
- Must be allowed by jurisdiction.
- Must be listed on the construction documents.
- Prior to submittal to the city, designs must be submitted to, and approved by, the EOR.
- None of the deferred submittal items shall be installed until submittal is approved by the AHJ.

What is included? (IBC 2303.4.1.1)
- Design per ANSI/TPI 1
- Placement diagram & individual truss drawings
- Design professional → where required
- Permanent individual truss member restraint (PITMR)
  - Who is responsible for specifying?

Truss Design Drawings (IRC R502.11.4 & IBC 2303.4.1.1)
- Slope/depth, span and spacing;
- Locations of all joints;
- Required bearing widths;
- Design loads;
- Adjustments for conditions of use;
- Each reaction force and direction;
- Joint connector type, size, etc.;
- Lumber size, species & grade of wood; …
Truss Package

- **Truss Design Drawings (cont.)**
  - Truss connections (truss-to-girder, ply-to-ply, splices);
  - Calculated and allowable deflections;
  - Maximum axial and tension forces;
  - Permanent bracing locations, methods & details

Truss Bracing

- Trusses require lateral support to perform in the manner they are intended.
- Very narrow in relation to their depth and span.
- **Bracing...**
  - Prevents out-of-plane buckling
  - Maintains spacing
  - Resists and transfers lateral loads

Let’s Test Our Knowledge!

- Who is required to specify the truss bracing?
- What is the difference between temporary and permanent truss bracing?
- How is the permanent truss bracing typically accomplished?
Truss Bracing

- **IRC R502.11.2**
  - Shall be specified on construction documents.
  - In the absence of providing, refer to BCSI Good Practice for Handling, Installing & Bracing of Metal Plate Connected Wood Trusses.

Locations shown on individual truss drawings

**IBC 2303.4.1.2:** Clarifies what is already required

- Member restraint (PITMR) in “green”
- Diagonal bracing (PITMDB) at each PITMR in “red”

IBC 2303.4.1.2 (cont.)

- When the truss plans call for PITMR, it must be provided by one of the following:
  - PITMR & PITMDB shall be provided using standard industry lateral restraint and diagonal bracing details per TPI, accepted engineering practice, or Figures 2303.4.1.2(1), (3), and (5).
  - Buckling reinforcement is added to individual truss per truss drawings, or per Figures 2303.4.1.2 (2) and (4).
  - Project-specific PITMR and PITMDB design by EOR.
Truss Bracing

- **Bracing Installation:**
  - Minimum size member → 2x4
  - Continuous bracing to overlap 2-feet.
  - Use at least two 10d, 12d, or 16d nails into each truss
  - Nails to be flush or double-headed for easy removal

PART 5
Wall Bracing

- **Items to Cover**
  - Conventional Limits
  - Wall Bracing (Chapter 6)
  - Examples
  - Load Paths
  - Miscellaneous
A. Conventional Limits

- **Prescriptive (i.e. “Cookbook”) method.**
- **Provided in IRC, IBC Section 2308, WFCM, ICC 400 & AISI S230**
- Several limitations, especially in high-seismic or high-wind regions

**A. Conventional Limits**

- **Wind Limitations (R301.2.1.1):**
  - Figure R301.2(5)B: > 140mph
  - Vancouver, WA: 125mph, Exp. B
  - Clark County, WA: 135mph, Exp. B

**A. Conventional Limits**

- **Seismic Provisions (R301.2.2):**
  - Applies to Seismic Design Categories D₀, D₁, & D₂
  - Also applies to townhomes in SDC ‘C’
  - SDC ‘E’ shall comply with the IBC.
A. Conventional Limits

- **Snow Loads (R301.2.3):**
  - Ground Snow Load ($P_g$) ≤ 70psf
  - Vancouver, WA: 25psf (20psf if < 150ft MSL)
  - Clark County, WA: 30psf

- **Other Limitations:**
  - Floodplain Construction (R301.2.4)
  - Weight limitations for concrete, masonry & metal stud
  - In SDC 'D' or greater…
    - ≤ 3 stories
    - ≤ 2 stories if Structurally Insulated Panels (SIP)
    - Anchored masonry veneer (R702.1 and R703)
    - Masonry chimneys (Chapter 10)

A. Conventional Limits

- **Irregular Buildings (R301.2.2.6)**

A. Conventional Limits

- **Item #1:** Out-of-plane offsets
A. Conventional Limits

- Item #2: Floors or roofs without lateral support on all sides.

- Item #3: End of braced wall segment occurring more than 1-foot over an opening below.

- Item #4: Diaphragm openings exceeding either 12-feet or 50% of the least floor/roof dimension.

- Item #5: Floor levels with vertical offsets.
  - Exceptions:
    - Framing must be supported directly by continuous foundations at the perimeter.
    - Floor framing must be lapped or tied together as required by R502.6.1. (i.e., 3” lap and (3)10d face nails, or equivalent)
A. Conventional Limits

- **Item #6:** Braced wall lines that do not occur in two perpendicular directions.

![Braced Wall Lines Diagram](image)

- **Item #7:** Above grade masonry or concrete

![Above Grade Masonry Diagram](image)

A. Conventional Limits

- **Item #8:** Hillside – New to 2021 IRC!
  - All the following must apply...
    - Grade > 1V:5H, and...
    - Tallest cripple wall > 7-feet, and...
    - Of the total plan area below the lowest framed floor, whether open or enclosed, less than 50 percent is living space having interior wall finishes conforming to Section R702.

A. Conventional Limits

- **Weights of Materials:**
  - Roofs ≤ 15psf *
  - Floors ≤ 10psf
  - Exterior Walls ≤ 15psf
  - Interior Walls ≤ 10psf
  - 25psf allowed if...
    - 20% braced wall increase for 1-story or top story, and...
    - 10% braced wall increase for other stories
  - See Table R602.10.3(4)
A. Conventional Limits

- **Engineered Design (R301.1.3):**
  - “When a building of otherwise conventional construction contains structural elements exceeding the limits of…the IRC), these elements shall be designed in accordance with accepted engineering practice.”

B. Wall Bracing

- **Terminology:**
  - Wall Bracing
  - Braced Wall Line (BWL)
  - Braced Wall Panel (BWP)
  - Length
  - Spacing

B. Wall Bracing

- **Braced Wall Line (IRC R202):**
  - “A straight line through the building plan that represents the location of the lateral resistance provided by the wall bracing.”

- **BWL shown on plans (IRC R602.10.1):**
  - “The braced wall lines shall be designated as straight lines in the building plan placed in accordance with this section.”
B. Wall Bracing

- **BWL Length (IRC R602.10.1.1):**
  - Equals the distance between its ends
  - “The end of a BWL shall be the intersection with a perpendicular BWL, an angled BWL… or an exterior wall.”

- **BWL Locations & Permitted Offsets (IRC R602.10.1.2):**
  - BWP can be offset up to 4-feet on either side of BWL
  - \( \leq \frac{2}{3} \) of BWP length can be placed to either side of BWL (New to 2021 IRC)

- **BWL Spacing (IRC R602.10.1.3):**
  - Wind (100 mph to < 140mph) \( \leq 60\)-feet
  - SDC A – C → Use Wind Bracing (except for townhomes)
  - SDC D \( \leq 25\)-feet

**TABLE P10.1.1**

<table>
<thead>
<tr>
<th>APPLICATION</th>
<th>CONDITION</th>
<th>BUILDING TYPE</th>
<th>Maximum Spacing</th>
<th>Equivalent to Minimum Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind bearing</td>
<td>( \geq 140 \text{ mph} )</td>
<td>Detached, townhouse</td>
<td>60 feet</td>
<td>None</td>
</tr>
<tr>
<td>SDC A – C</td>
<td>Detached</td>
<td>Torsion</td>
<td>Use wind bracing</td>
<td>Use wind bracing</td>
</tr>
</tbody>
</table>
| SDC B – D | Torsion | 35 feet | Up to 15 feet when length of suspended bracing per Table R602.13.1.2 is reduced in accordance with \( \frac{1}{6} \)
| SDC E, Ei, F | Detached, townhouse, near and two stories only | 25 feet | Up to 35 feet not to exceed 15 square feet. Spacing of all other braces shall not exceed 25 feet |
| SDC F, F, G, H | Detached, townhouse, near and two stories only | 25 feet | Up to 35 feet not to exceed 15 square feet. Spacing of all other braces shall not exceed 25 feet |

>25 feet and \( \leq 30 \text{ feet} \): \( 1.2 \)
>30 feet and \( \leq 35 \text{ feet} \): \( 1.4 \)
B. Wall Bracing

- **Angled Walls (IRC R602.10.1.4):**
  - Maximum diagonal length of 8-feet
  - If > 8-feet, shall be considered a separate BWL.

B. Wall Bracing

- **Braced Wall Lines (cont.):**

B. Wall Bracing

- **Braced Wall Panel (IRC R202):**
  - “A full-height section of wall constructed to resist in-plane shear loads through interaction of framing members, sheathing material and anchors. The panel’s length meets the requirements of its particular bracing method and contributes toward the total amount of bracing required along its braced wall line in accordance with Section R602.10.1.”

B. Wall Bracing

- **Braced Wall Panels (R602.10.2):**
  - Shall be...
    - Full-height sections
    - No vertical/horizontal offsets
    - Placed along BWL
  - Location:
    - Spacing ≤ 20-feet
    - w/in 10-feet from each end
B. Wall Bracing

- **Braced Wall Panels (R602.10.2):**
  - **Location (cont.):**
    - SDC D, D1, & D2 → 10-feet from end
    - 2-foot panel on each side
    - 1,800# holdown

- **BWP – Min. Number (R602.10.2.3):**
  - BWL ≤ 16-feet → 2 BWP of any length or one 4-foot BWP
  - BWL > 16-feet → 2 BWP
  - Floors or roofs not laterally supported by braced walls: 6 feet max.

- **Required Length of Bracing (R602.10.3):**
  - Min. Length of BWP on each BWL
  - Only Table R602.10.3(1) – Wind
    - SDC A and B – All structures
    - SDC C – Detached structures (acc. or 1 family)
    - Modified by Table R602.10.3(2)
  - Both Table R602.10.3(1) and R602.10.3(3) – Wind and Seismic
    - SDC C – Townhouses
    - SDC D – All structures
    - Modified by Table R602.10.3(2) and R602.10.3(4)
B. Wall Bracing

- **Braced Wall Panels (R602.10.4):**
  - Intermittent Bracing (12 methods)
  - Continuous Sheathing (4 methods)

**Intermittent Bracing (Table R602.10.4):**

- From story to story: Any method
- From BWL to BWL: Intermittent only
- Not allowed within a BWL (SDC ‘D’ or above)

**Continuous Sheathing (Table R602.10.4):**

- See Method CS-WP
- See Section R602.10.6.4
- See Section R602.10.6.4
B. Wall Bracing

- **Braced Wall Panels (R602.10.5):**
  - Minimum Length:

<table>
<thead>
<tr>
<th>Material</th>
<th>Height</th>
<th>Width</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB</td>
<td>48</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>GB + ASN</td>
<td>35</td>
<td>42</td>
<td>50</td>
</tr>
</tbody>
</table>

**Example:** What is the minimum width of a continuous sheathed braced wall that is 10-feet tall and includes a single man door opening (i.e., height = 80")?

- **Required Bracing (R602.10.3):**
  - Each wall line must be checked for wind & seismic
  - Exceptions:
    - SDC A and B → Wind only
    - SDC C – Detached structures (accessory or 1-family) → Wind only
B. Wall Bracing

8 Steps to Verifying Bracing:

- What bracing method is being used?
- Braced length requirement – Wind
- Apply wind adjustment factors.
- Braced length requirement – Seismic
- Apply seismic adjustment factors.
- What braced wall length controls? (wind or seismic)
- BWL locations & spacing
- BWP locations & spacing

C. Examples

Example #1 – Detached Garage

Given:

- 20’x20’ footprint
- 8’ wall height
- 4:12 roof pitch
- Mfr. Trusses
- WSP
- Wind: 95mph, Exp. ‘B’
- SDC ‘D’

Example #1 – Detached Garage

Step 1: What bracing method is being used?
Example #1 – Detached Garage

**Step 2: Braced length requirement – Wind**

- **Exposed Category:** B
- **90 Foot Wind Speed Height:** 16 Foot Wall Height
- **Exposure Factor:**
  - Method 1: LW = 2.5’ x 1.0 x 0.7 x 0.9 x 1.0 = 2.2’
  - Method 2: LW = 2.5’ x 1.0 x 0.7 x 0.9 x 1.4 = 2.2’

**Step 3: Apply Wind Adjustment Factors**

- **Adjusted Braced Wall Length for Wind:**
  - LW = 2.5’ x 1.0 x 0.7 x 0.9 x 1.0 = 2.2’
  - LW = 2.5’ x 1.0 x 0.7 x 0.9 x 1.4 = 2.2’

### Table: Bracing Requirements Based on Wind Speed

<table>
<thead>
<tr>
<th>Ultimate Design Wind Speed (mph)</th>
<th>Storey Location</th>
<th>Braced Wall Line Breaking (ft)</th>
<th>Method</th>
<th>Adjustment Method</th>
<th>Code Requirement</th>
<th>Applicable Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>Less side wall</td>
<td>6.5</td>
<td>1.0</td>
<td>0.7</td>
<td>0.9</td>
<td>1.0</td>
</tr>
<tr>
<td>40</td>
<td>Less side wall</td>
<td>6.5</td>
<td>1.0</td>
<td>0.7</td>
<td>0.9</td>
<td>1.0</td>
</tr>
<tr>
<td>60</td>
<td>Less side wall</td>
<td>6.5</td>
<td>1.0</td>
<td>0.7</td>
<td>0.9</td>
<td>1.0</td>
</tr>
</tbody>
</table>

- **No Gypsum Board Required?**
- **What is the minimum width of the BWPs?**
- **How many BWP per BWL are required?**
Example #1 – Detached Garage

**Step 4: Braced length requirement - Seismic**

![Table](image)

**Step 5: Apply Seismic Adjustment Factors (cont.)**

![Diagram](image)
Example #1 – Detached Garage

Step 5: Apply Seismic Adjustment Factors (cont.)

- Adjusted Braced Wall Length for Seismic:
  \[ \text{LS} = 4.0' \times 1.0 \times 1.0 \times 1.0 \times 1.0 \times 1.5 \times 1.0 = 6.0' \text{BW L} \]

- How many BWP per BWL are required?
- What is the minimum width of the BWPs?

Step 6: What Bracing Length Controls?

- Wind: Adjusted Length = 4.9'/BWL
- Seismic: Adjusted Length = 6.0'/BWL
- → 6.0'/BWL
- While that is the calculated braced wall length, it does not control!

The last two steps (#7 & #8) are to verify the locations of the braced walls and their spacing.

Example #1 – Detached Garage

7.5'/BWL

Step 7:
- BWL Locations & Spacing

Step 8:
- BWP Locations & Spacing
Example #1 – Detached Garage

Example #1 – Double Garage

- Does this work using the WSP method?
- Can it work using the CS-WSP method?

Wall Bracing Quiz

- What is the maximum offset of BWP along a BWL?
- What is the maximum spacing, edge to edge, between BWPs within a BWL?
- How far can a BWP be from the end of a BWL?
- What is the minimum width of a WSP BWP?
- What is the minimum width of a CS-WSP BWP?
- What is the maximum spacing between centers of BWLs?
- What alternate methods can allow for narrow BWPs which are equivalent to 4-feet of braced length?

Wall Bracing

- 8 Steps to Verifying Bracing:
  - What bracing method is being used?
  - Braced length requirement – Wind
  - Apply wind adjustment factors.
  - Braced length requirement – Seismic
  - Apply seismic adjustment factors.
  - What braced wall length controls? (wind or seismic)
  - BWL locations & spacing
  - BWP locations & spacing
Wall Bracing

- **8 Steps to Verifying Bracing:**
  - What bracing method is being used?
  - Braced length requirement – Wind
  - Apply wind adjustment factors.
  - Braced length requirement – Seismic
  - Apply seismic adjustment factors.
  - What braced wall length controls? (wind or seismic)
  - BWL locations & spacing
  - BWP locations & spacing

**Rule of Thumb:** If 50% of a BWL consists of BWP’s the amount of bracing provided is likely more than sufficient.

*We need to pay attention to the details!*

**Example #2 – Simpson**

- The Kimball Shed
- Simpson’s “Wall-Bracing Length Calculator”
  - [www.strongtie.com/webapps/bracedwall/](http://www.strongtie.com/webapps/bracedwall/)
Example #2 – Simpson

Example #3 – APA

APA’s calculator → great for designer’s

www.apawood.org/calculator
D. Load Paths (The Details!)

Gravity Load Path

Lateral Load Path

 IRC R502.2.1:
- “A load path for lateral forces shall be provided between floor framing and braced wall panels located above or below a floor…”
- Connections, connections, connections!!!
Lateral Load Path

- **Braced Wall Connections (R602.10.8):**
  - Framing perpendicular to BWP
  - A rim joist, band joist, or blocking shall be provided along entire length of BWP.
  - Fastening shall be per Table R602.3(1)

- **Braced Wall Connections:**
  - Framing parallel to BWP
  - A rim joist, end joist, or other parallel framing member shall be provided directly above and below the BWP.
  - Where not possible, full-depth blocking at 16"o.c. to the parallel framing members to each side of BWP.
  - Fastening shall be per Table R602.3(1) & Figure R602.10.8(2)

- **Braced Wall Connections (R602.10.8):**
  - BWP to concrete or masonry → per IRC R403.1.6
  - Foundation anchorage (IRC R403.1.6):
    - Sill plates treated against decay and termites
    - 3/4"Ø anchor bolts having 7" minimum embedment
    - Spaced ≤ 6-feet o.c.
    - Located in middle-third of plate
    - Two minimum per plate
    - Place within 12" of end but not closer than 7db
    - Anchor bolts can be placed while concrete is still plastic → 2021 IRC change
  - Only applies to townhouses in SDC C
  - 3"x3"x0.229" plate washers for full length of BWL
  - Max. anchor spacing is 4-feet for 2-story buildings
  - Stepped cripple walls → R602.10.10
    - Bracing is limited to WSP and CSP-WSP
    - BWP spacing 14-feet max. edge-to-edge
    - May require 4"o.c. edge nailing
Lateral Load Path

- **Connections to Roof Framing (R602.10.8.2):**
  - **Top Plates:**
    - Attached to rafters and trusses per IRC Table R602.3(1)
    - Top plate splice \( \Rightarrow (8) \) 16d common nails on each side
    - Blocking (or band joist, rim, header joist, or truss) shall be provided between rafters and roof trusses at BWP.
    - Not required over openings in continuous sheathed BWL.

---

Lateral Load Path

- **Connections to Roof Framing (R602.10.8.2):**
  - **SDC A, B & C:**
    - Blocking not required if \( d \leq 9.25 \) - inches
    - If \( > 9.25 \) - inches and \( \leq 15.25 \) - inches, blocking may comply with Figure R602.10.8.2(1)

---

Lateral Load Path

- **Connections to Roof Framing (R602.10.8.2):**
  - **SDC D\textsubscript{0}, D\textsubscript{1}, & D\textsubscript{2} (cont.):**
    - If \( \leq 15.25 \) - inches, blocking may comply with Figure R602.10.8.2(1)
    - If \( > 15.25 \) - inches, there are four options:
      1. Soffit blocking panels
      2. Vertical blocking panels
      3. Truss blocking
      4. Other acceptable methods
Lateral Load Path

- **BWP Support (R602.10.9):**
  - Cantilevered floor joists → IRC R502.3.3
    - Shall not exceed nominal depth of joist
    - Alternate #1 → Table R502.3.3(1) – dimension lumber only
    - Alternate #2 → exterior balconies – dimension lumber only
  - Post- or pier-supported raised floor systems → engineered

- **BWP Support (R602.10.9):**
  - Masonry stem walls ≤ 48” long → IRC Figure R602.10.9
  - Masonry stem walls > 48” → IRC R403.1
  - Concrete stem walls ≤ 48” long, and > 12” tall and < 6” thick → IRC Figure R602.10.9

Gravity & Lateral Load Paths

- **Fastening - Table R602.3(1):**
  - #1: Blocking to top plate, toe nail (3–10d)
  - #6: Rafter or roof truss to plate, toe nail (3–16d)
  - #8: Built-up studs, face nail (10d @ 16”o.c.)
  - #9: Wall corners, face nail (16d @ 12”o.c.)
Portal Frame Options

**Intermittent Method:**
- PFH → 16” is = 48” of WSP wall bracing
- We also see these specified on engineered shear walls

**Continuous Sheathed Method:**
- CS-PF
  - SDC A, B, C: 16” is = 1.5 x Actual length (not = 48”)
  - SDC D, D1, D2: 16” is = Actual length (not = 48”)
- No foundation holdowns
- Can be used at upper floors
  - Not allowed for engineered design

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**Plan Review Tools**

International Code Council, 2018 IRC©

Applied Building Technology, IRC Wall Bracing, Research Report No. 1601-01
Plan Review Tools

Other Resources
- APA/ICC Guide to Wall Bracing
- APA → apawood.org/wall-bracing;
  Includes a 5-part webinar series on wall bracing with ICC and AIA CEUs

PART 6
Open Discussion

Any Questions?

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