Wood Framed Tall Walls

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AIA Course

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Presentation Objectives

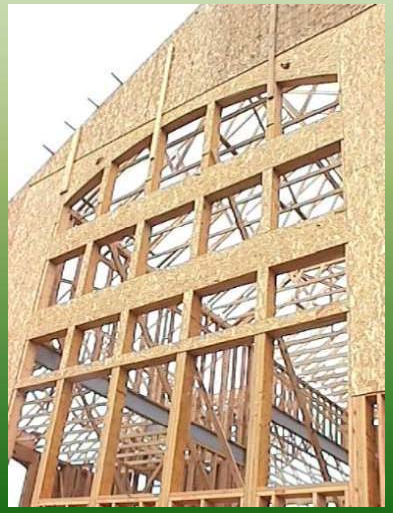
- Tall Wall Applications
- Challenges
- Thermal Performance
- Products
- Design Considerations
- Framing Details
- Fire Assemblies
- Innovative Solutions

Wood Framed Tall Wall Applications

- Residential Construction
  - Foyers
  - Great Rooms

Wood Framed Tall Wall Applications

- Light-Framed Commercial Wood Construction
  - Schools
  - Churches
  - Retail
  - Multi-Family



Challenges Associated with Tall Walls

- Large Openings
  - Maintain in-plane shear path
  - Maintaining Height to Width Ratio of Shear Walls
- Out-of-Plane Deflection
  - Protect finishes / keep building envelope in tacked
- Construction
  - Hinge points
  - Connections
  - Bracing
- Quality of material

Large Openings

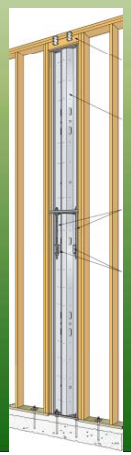
- In-Plane Shear Transfer
  - Maximum Shear Wall Dimension Ratios – Table 2305.3.4 (2006 IBC)
    - Wood Structural Panels
      - 3.5:1 for other than seismic
      - 2:1 for seismic
      - 3.5:1 for seismic if allowable shear multiplied by 2w/h

Large Openings

- In-Plane Shear Transfer
  - Pre-fabricated Shear Walls

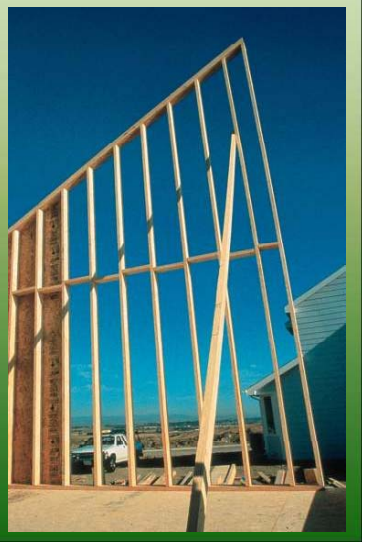
Allowable In-Plane Shear loads

- 550 lbs to 1460 lbs seismic control
- 605 lbs to 2445 lbs wind control



Out-of-Plane Deflection Limits

- Excessive Deflection
  - Walls don't feel stiff
  - Performance issues
    - Moisture intrusion
    - Exterior/Interior finish cracks and pops

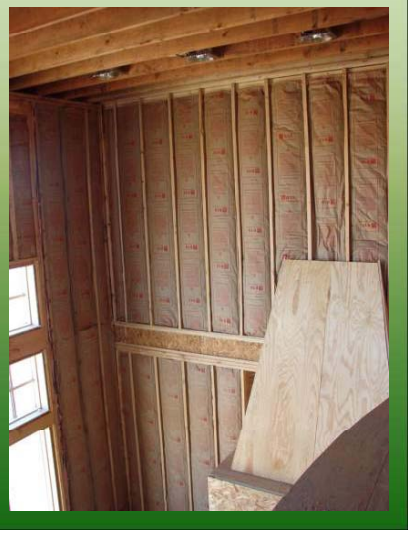


Out-of-Plane Deflection Limits

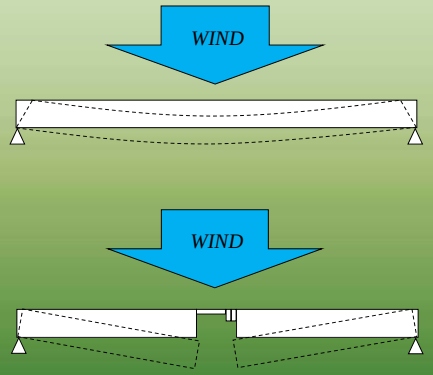
- IBC Table 1604.3
  - Flexible Finishes: H/120 (2009 IBC – H/180)
  - Brittle Finishes: H/240
  - The wind load is permitted to be taken as 0.70 times the "component and cladding" loads for the purpose of determining deflection limits
- IBC Section 2403.3
  - Mullions: L/175 up to ¾"
- 2006/2009 IRC Table R301.7
  - Plaster/Stucco Surfaces: H/360

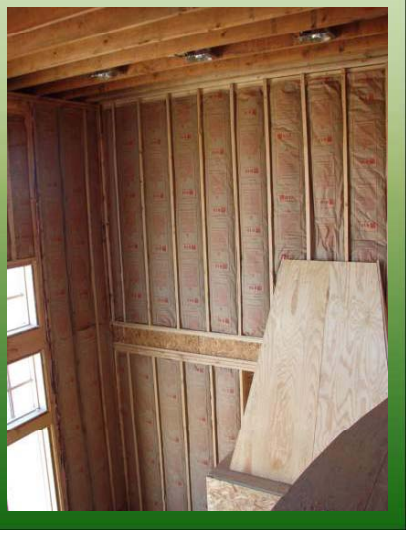
Construction

- Not Straight
  - Bowing, twisting and warping of solid-sawn lumber
- Limited Material Lengths
  - "Hinge Point" creates a structural weakness in the wall

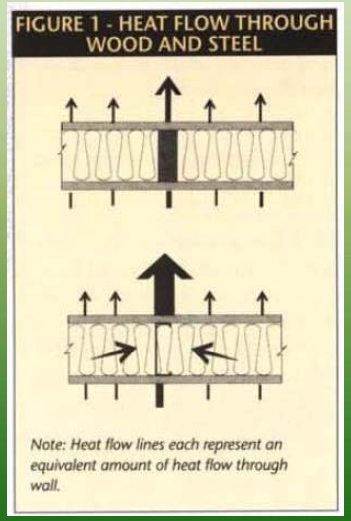


Construction



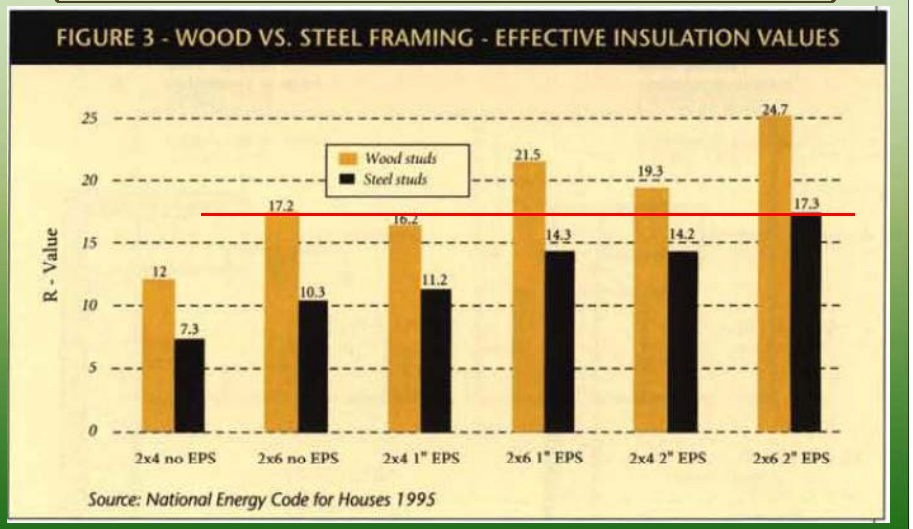


Thermal Performance



Source: The Thermal Performance of Light-Frame Assemblies, Canadian Wood Council

Thermal Performance



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Products

- Dimension Lumber
  - Studs, Headers, Built-up Columns
  - Solid Sawn
    - 2x4 to 2x14 (20ft to 26ft)
  - Finger-Jointed
    - Vertical Stud Use Only (12ft)
      - 2x3 to 2x6
    - Structural Finger Joint (32ft to 40ft)
    - HRA or Non- HRA
    (Heat Resistant Adhesive)
      - 2x3 to 2x12

Products

- Engineered Lumber Products
  - Studs
    - Laminated Veneer Lumber (LVL)
    - Laminated Strand Lumber (LSL)
    - Glue Laminated Lumber
  - Headers and Columns
    - Structural Composite Lumber (SCL)
      - LSL, LVL, Glu-Lam, Parallel Strand Lumber (PSL)
    - Glue Laminated Lumber

Products

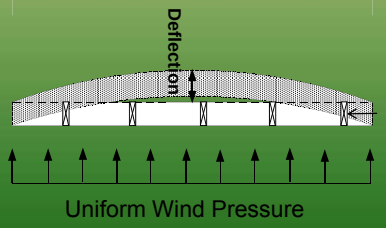
- Engineered Lumber Products
  - Code Evaluation Reports
    - AC202 – Acceptance Criteria for Wood-Based Studs
    - 6.0 Evidence Submitted

      Ex.: 6.2 Data in accordance with the ICC-ES Acceptance Criteria for Wood-based Studs (AC202), dated June 2009.

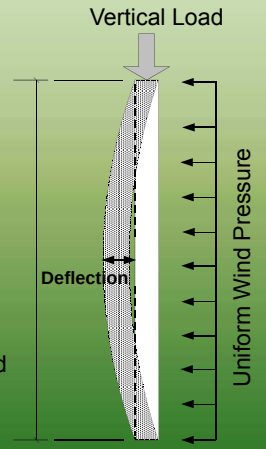
Design Considerations

Combined Loads

- Vertical Load
  - Roof/Snow and dead
- Lateral Load
  - Wind load (⊥ to wall plane)
  - Wind and Seismic (// to wall plane)



Top View of Wall Header



Stud or Column

Design Considerations

Buckling Height Limits

- Every column has a height limit to prevent buckling
- Max height = 50d (d= depth in inches)

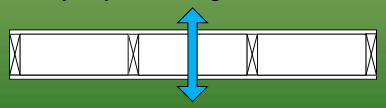
1½": 8' height limit between blocking…

3½" (2x4) Max Height: 14'

5½" (2x6) Max Height: 22'-6"

7¼" (2x8) Max Height: 30'

Stud or column in a sheathed wall is braced against buckling in this direction.



Stud or column in a sheathed wall is not braced against buckling in this direction.

Design Considerations

- National Design Specification (NDS)
- Eqn 15.4-1

$$\left[\frac{f_c}{F'_c}\right]^2 + \frac{f_{b1} + f_c(6e_1/d)[1+0.234(f_c/F_{cE1})]}{F'_{b1}[1-(f_c/F_{cE1})]} + \frac{f_{b2} + f_c(6e_2/d_2)\left\{1+0.234(f_c/F_{cE2})+0.234\left[\frac{f_{b1}+f_c 6e_1/d_1}{F_{bE}}\right]^2\right\}}{F'_{b2}\left\{1-(f_c/F_{cE2})-\left[\frac{f_{b1}+f_c 6e_1/d_1}{F_{bE}}\right]^2\right\}} \le 1.0$$

- Eqn 3.7-1

$$c_p = \frac{1+\left[\frac{F_{cE}}{F_c^*}\right]}{2c} - \sqrt{\left(\frac{1+\left[\frac{F_{cE}}{F_c^*}\right]}{2c}\right)^2 - \frac{\left[\frac{F_{cE}}{F_c^*}\right]}{c}} \le 1.0$$

- Eqn 15.3-1 – multiple Cp by K_f for built-up columns

Design Considerations

- NDS notations
  - C_P
    - c = 0.9 for SCL and GLB
    - c = 0.8 for sawn lumber

$$c_p = \frac{1+\left[\frac{F_{cE}}{F_c^*}\right]}{2c} - \sqrt{\left(\frac{1+\left[\frac{F_{cE}}{F_c^*}\right]}{2c}\right)^2 - \frac{\left[\frac{F_{cE}}{F_c^*}\right]}{c}} \le 1.0$$

Design Considerations

- NDS notations
  - C_P
    - $F_{cE} = 0.822\ E_{min}'/(\ell_e/d)^2$
      - $E_{min}' = E[1\text{-}1.645COVe](1.03)/1.66$ (D-4)
        - E = Eapparent
        - COVe = 0.25 to 0.095
      - K_e = 0.85 to 1.0 to determine ℓ_e

$$c_p = \frac{1+\left[\frac{F_{cE}}{F_c^*}\right]}{2c} - \sqrt{\left(\frac{1+\left[\frac{F_{cE}}{F_c^*}\right]}{2c}\right)^2 - \frac{\left[\frac{F_{cE}}{F_c^*}\right]}{c}} \le 1.0$$

Design Considerations

- Allowable Design Stresses

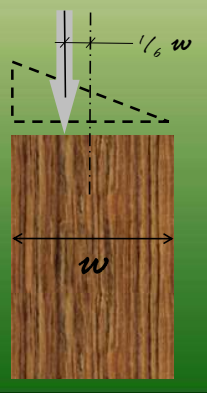
$$\left[\frac{f_c}{F'_c}\right]^2 + \frac{f_{b1} + f_c(6e_1/d)[1+0.234(f_c/F_{cE1})]}{F'_{b1}[1-(f_c/F_{cE1})]}$$

Design Stresses	DF-L #2	SP #2	ES11	ES12	LSL	24F	LVL	PSL
F_b psi	900	1250	1350	1950	1700 to 2360	2400	2250 to 2950	2900
E x 10^6 psi	1.6	1.6	1.6	1.9	1.3 to 1.6	1.6	1.5 to 2.0	2.0
F_v psi	95	90	200	200	400 to 410	190	250 to 290	290
$F_{c//}$ psi	1350	1600	1350 to 1550	1700 to 2300	1400 to 2175	1650	2350 to 3200	2900

Design Considerations

- NDS notations
  - e = eccentricity
    - $^1/_6$ of the wall thickness

$$\left[\frac{f_c}{F'_c}\right]^2 + \frac{f_{b1} + f_c(6e_1/d)[1+0.234(f_c/F_{cE1})]}{F'_{b1}[1-(f_c/F_{cE1})]}$$



Design Tools

Wall Design Wind Pressure (PSF)(1)

Exposure Category(2)	Effective Wind Area(3) (ft²)	Basic Wind Speed (mph)							
		85	90	100	110	120	130	140	150
B	≤ 10	14.5	16.2	20.1	24.3	28.9	33.9	39.3	45.1
	50	13.1	14.7	18.1	21.9	26.1	30.6	35.5	40.8
	≥ 100	12.5	14.0	17.3	20.9	24.9	29.2	33.9	38.9
C	≤ 10	20.1	22.6	27.9	33.7	40.1	47.1	54.6	62.7
	50	18.2	20.4	25.2	30.5	36.2	42.5	49.3	56.6
	≥ 100	17.3	19.4	24.0	29.1	34.6	40.6	47.1	54.0
D	≤ 10	23.7	26.6	32.9	39.8	47.3	55.5	64.4	73.9
	50	21.5	24.1	29.7	35.9	42.8	50.2	58.2	66.8
	≥ 100	20.5	22.9	28.3	34.3	40.8	47.9	55.5	63.7

(1) Tabulated pressures are based on the Analytical Procedure defined in ASCE 7-05 (**3-second gust**). Values assume a Components & Cladding (C&C) member in the interior zone of an enclosed structure, with the following factors:
- Importance factor of 1.0
- Topographical factor of 1.0
- Mean roof height of 33'

Wind Loads

Exposure 'B'

Exposure 'C'

Exposure 'D'

Design Tools

STUD LOAD TABLE

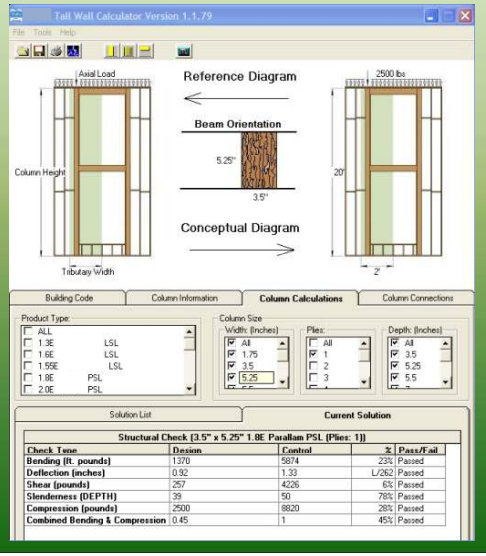
Studs—Maximum Allowable Lateral (Wind) and Vertical Load

Wall Ht.	Load and Deflection	1½" x 3½" Lateral Load (plf)				1½" x 5½" Lateral Load (plf)						1½" x 7¼" Lateral Load (plf)					
		15	20	26(1)	30	15	20	26(1)	30	40	50	15	20	26(1)	30	40	50
8'	Vertical (lbs)	2,855	2,855	2,855	2,855	4,485	4,485	4,485	4,485	4,485	4,485	5,915	5,915	5,915	5,915	5,915	5,915
	Defl. Ratio	L/833	L/625	L/480	L/416	L/3142	L/2356	L/1813	L/1571	L/1178	L/942	L/6952	L/5214	L/4010	L/3476	L/2607	L/2085
9'	Vertical (lbs)	2,855	2,790	2,610	2,490	4,485	4,485	4,485	4,485	4,485	4,485	5,915	5,915	5,915	5,915	5,915	5,915
	Defl. Ratio	L/587	L/440	L/339	L/293	L/2229	L/1672	L/1286	L/1114	L/836	L/668	L/4966	L/3724	L/2865	L/2483	L/1862	L/1489
10'	Vertical (lbs)	2,375	2,220	2,035	1,915	4,485	4,485	4,485	4,485	4,485	4,485	5,915	5,915	5,915	5,915	5,915	5,915
	Defl. Ratio	L/429	L/322	L/248	L/214	L/1637	L/1227	L/944	L/818	L/613	L/491	L/3665	L/2749	L/2114	L/1832	L/1374	L/1099
11'	Vertical (lbs)	1,935	1,770	1,585	1,465	4,485	4,485	4,485	4,485	4,485	4,485	5,915	5,915	5,915	5,915	5,915	5,915
	Defl. Ratio	L/323	L/242	L/186	L/161	L/1236	L/927	L/713	L/618	L/463	L/371	L/2779	L/2084	L/1603	L/1389	L/1042	L/833
12'	Vertical (lbs)	1,580	1,415	1,230	1,110	4,485	4,485	4,485	4,485	4,485	4,485	5,915	5,915	5,915	5,915	5,915	5,915
	Defl. Ratio	L/248	L/187	L/144	L/124	L/956	L/717	L/551	L/478	L/358	L/286	L/2156	L/1617	L/1244	L/1078	L/808	L/646

General Notes

- Table is based on:
  - A load duration factor of 1.60.
  - Full-width blocking at a maximum vertical spacing of 8' on-center.
  - A buckling length coefficient of $K_e = 0.85$. For deflection, use $K_e = 1.0$.
  - Axial loads applied eccentrically, at a distance of ⅙ of the **wall thickness** dimension of the stud, measured from the stud centerline.
  - A compression perpendicular-to-grain stress of 435 psi, adjusted per NDS® 2005, 3.10.4.
  - A code-allowed repetitive-member increase of 4%.

Design Tools



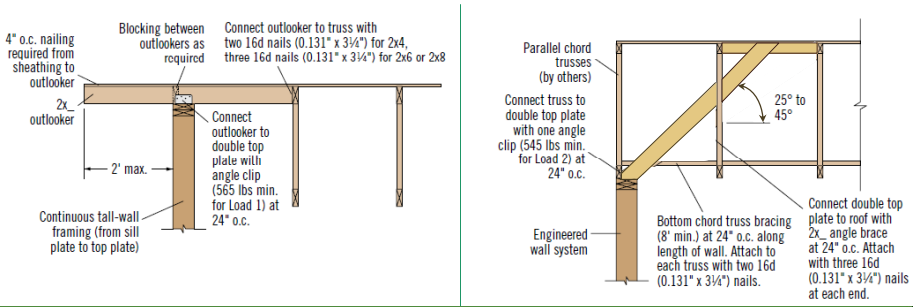
Framing Details

Framing Details

Bracing?

Framing Details

Wind Brace



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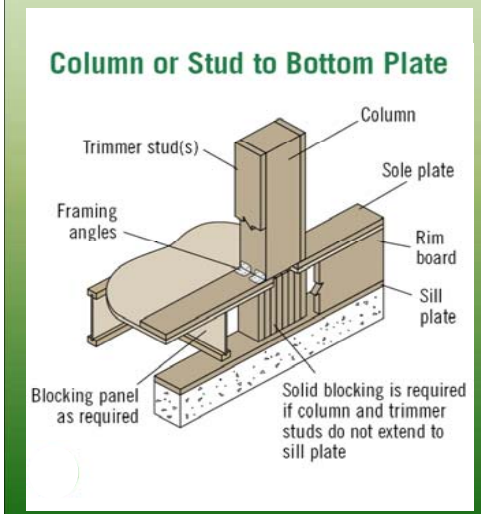

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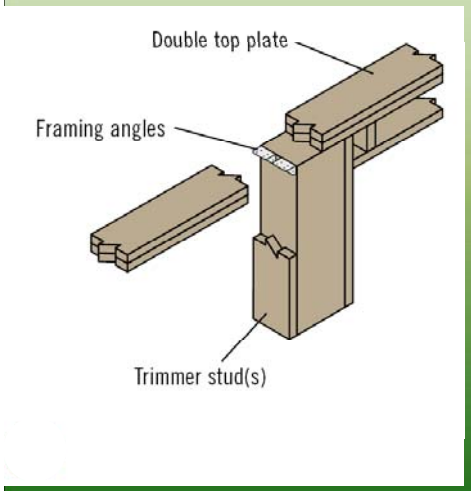

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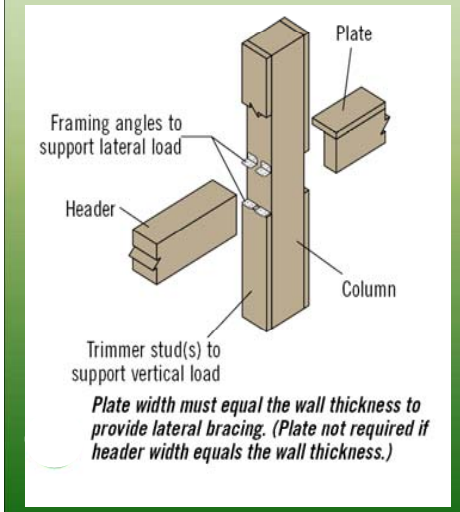
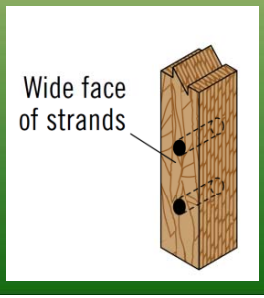


Plate width must equal the wall thickness to provide lateral bracing. (Plate not required if header width equals the wall thickness.)

Framing Details

- Nailing
  - Spacing
  - Lateral and withdrawal values
    - Dependent on specific gravity of product
    - Specific gravity varies between face and edge
- Hold-downs
  - Bolt values
  - screws



Fire

- Multiple Resources for Fire-rated assemblies
- Solid Sawn
  - IBC
  - Gypsum Association GA-600-2009 www.gypsum.org
  - American Wood Council Design for Code Acceptance 3 www.awc.org
- Finger-Jointed Stud
  - HRA mark required

Fire

- ELP
  - Check manufacturer's code evaluation report
    - May be a direct substitute in sawn lumber assemblies
    - May be reduction to allowable design stresses
    - May need additional insulation

Fire

- Fire Retardant Treatments
  - LSL, LVL, PSL check with the manufacturer
    - Most don't allow – voids warranty
  - Glue-laminated members check with manufacturer
    - Not recommended
  - Lumber
    - Allowed
  - Design Value Reductions – 0.80 to 0.98
  - Galvanized or stainless steel fasteners – reductions apply – 0.91 to 0.98

Innovative Solutions

- Tilt-up LSL wall

Innovative Solutions

- I-Joists as wall studs?
- Advantages
  - Reduced capacity for thermal bridging
  - Thicker walls / More insulation
- Disadvantage
  - Not code evaluated
  - Non-rectangular shape
  - Special detailing required
  - No load tables

Thank You