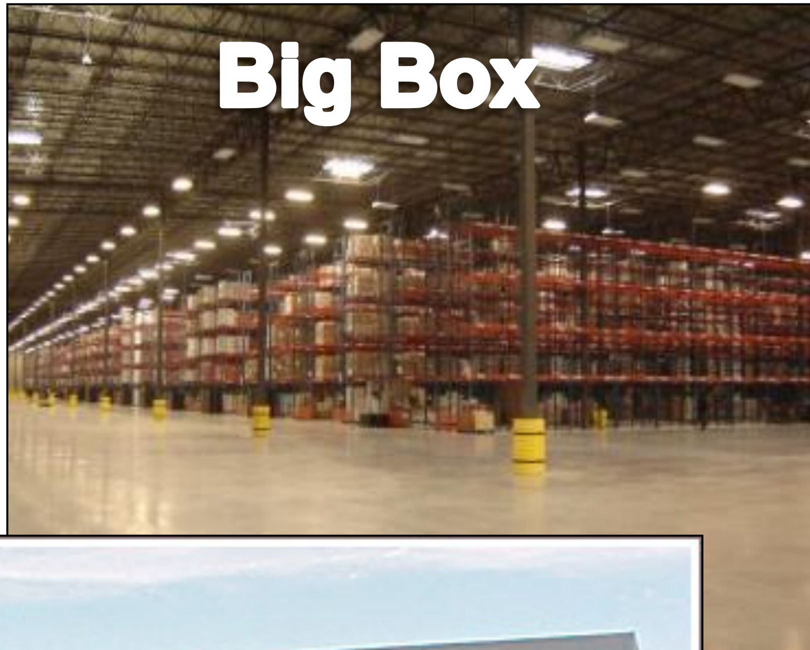
The Case for Wood Tilt-up Walls

A more efficient way of constructing industrial buildings

Photos by Woodworks

Low-Rise Tilt-up Construction



- Warehouses
- Industrial

Designed by Structural Design Group

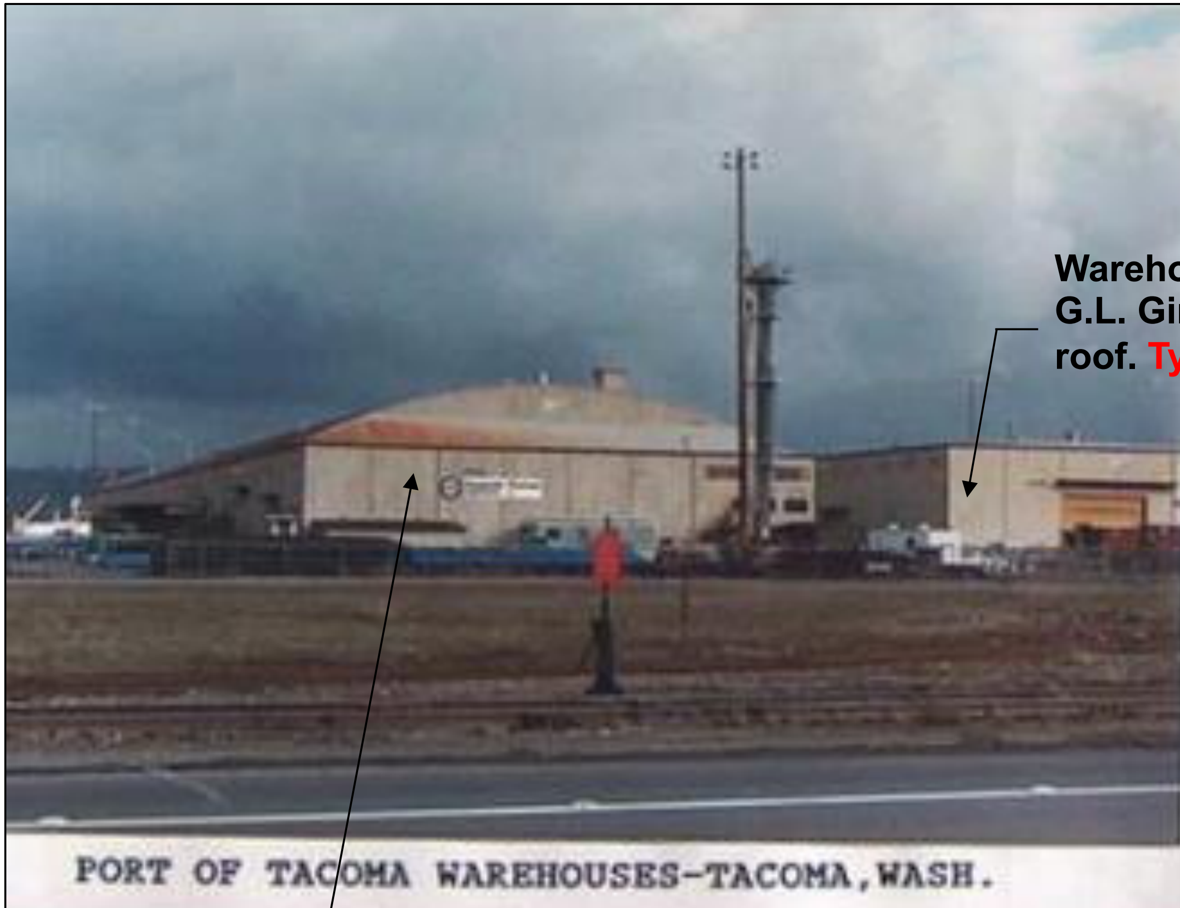
- Research Centers
- Manufacturing

Getting Past the Mind-Set

Concrete isn't the only option for tilt-up construction. Wood can be used as well!

Wood Tilt-up Walls is not a new concept

Prototypes



Warehouse 2: 120'x480' G.L. Girders w/ panelized roof. Type V construction

Warehouse 1: 160'x640' Bow-string trusses. Type V construction

Building Components

Roofs

Roofs

Walls

Relevant Code Sections

Tilt-up construction:

- **Large square footage**
- **Typically one or two story of unusual height**
- **Building height and number of stories are typically not an issue.**
- **IBC Code Sections:**

  506.2.1 Single occupancy, one-story buildings

  506.2.2 Mixed occupancy, one-story buildings

  506.3 Frontage increases

  507 Unlimited Area Buildings

  Table 506.2 – Allowable Area

503.1.1 Special Industrial Buildings and structures designed to house special industrial processes that require large areas and unusual building heights to accommodate craneways or special machinery and equipment, including, among others, rolling mills, structural metal fabrication shops and foundries; or the production and distribution of electric, gas or steam power, shall be exempt from the height, number of stories and building area limitations specified in Sections 504 and 506.

507.4 Sprinklered, one story buildings-The area of a Group A-4 building no more than one story above grade plane of other than Type V construction, or the area of a Group B, F, M or S building no more than one story above grade plane of any construction type, shall not be limited where the building is provided with an automatic sprinkler system throughout in accordance with Section 903.3.1.1 and is surrounded and adjoined by public ways or yards not less than 60 feet in width.

Fire Resistance Ratings

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A	B	A	B	HT	A	B
Primary structural frame[f] (see Section 202)	3[a]	2[a]	1	0	1	0	HT	1	0
Bearing walls Exterior[e,f] Interior	 3 3[a]	 2 2[a]	 1 1	 0 0	 2 1	 2 0	 2 1/HT	 1 1	 0 0
Nonbearing walls and partitions Exterior					See Table 602			Post and beam system	
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and associated secondary members (see Section 202)	$1^1/_2$[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

Note: FRT = Fire Retardant Treated

Firewall Used to Increase Area

Benefits:

- **Can double or triple the allowable area.**
- **Can reduce diaphragm shear/nailing significantly if also used as shear wall.**
- **Wood framed or CLT fire walls can reduce the number of trades on a job.**

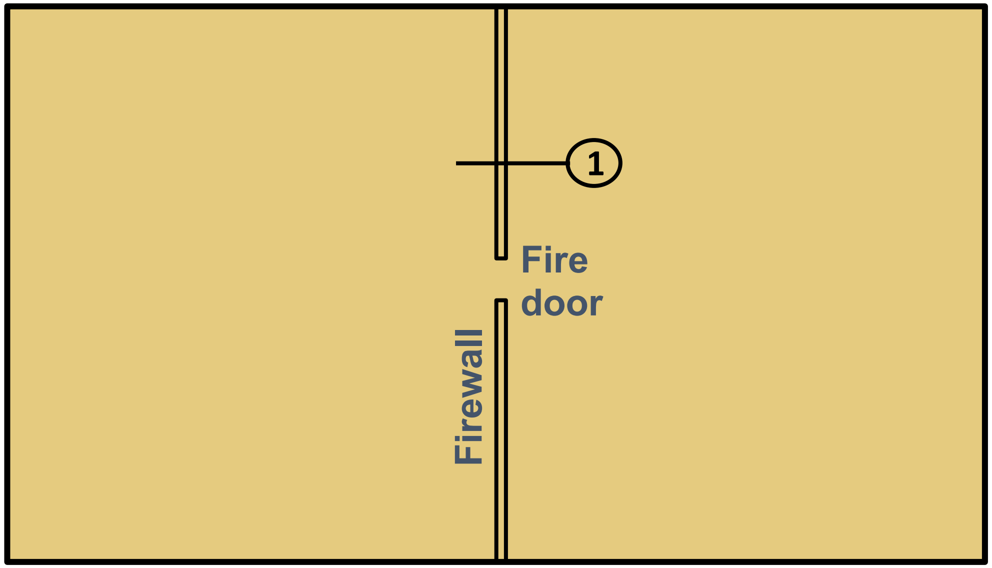
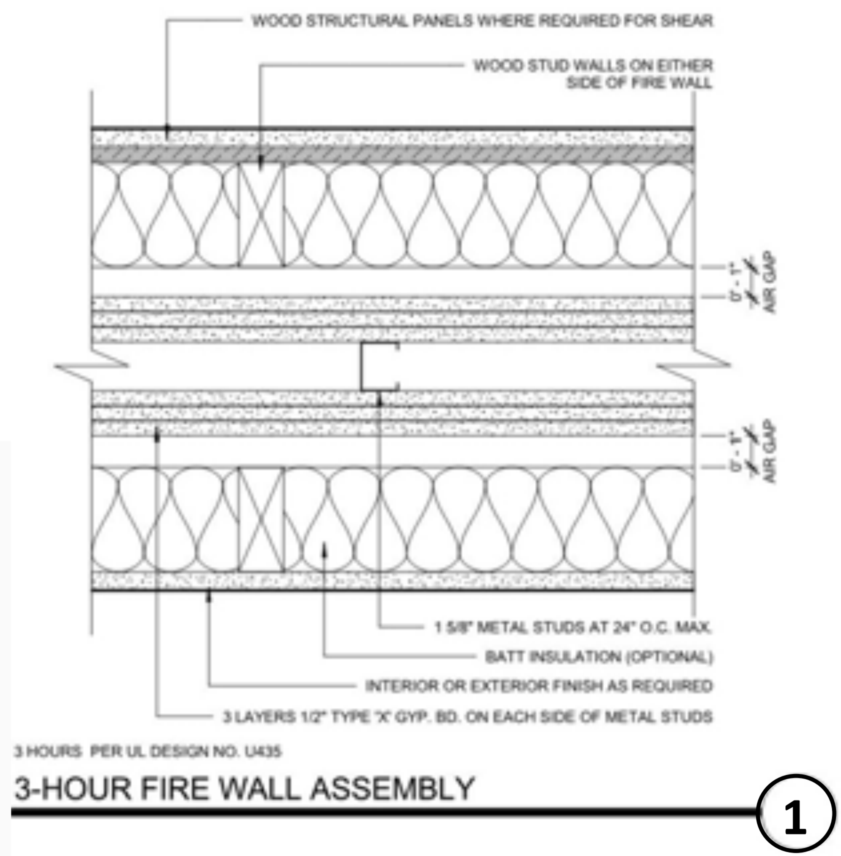


TABLE 706.4
FIRE WALL FIRE-RESISTANCE RATINGS

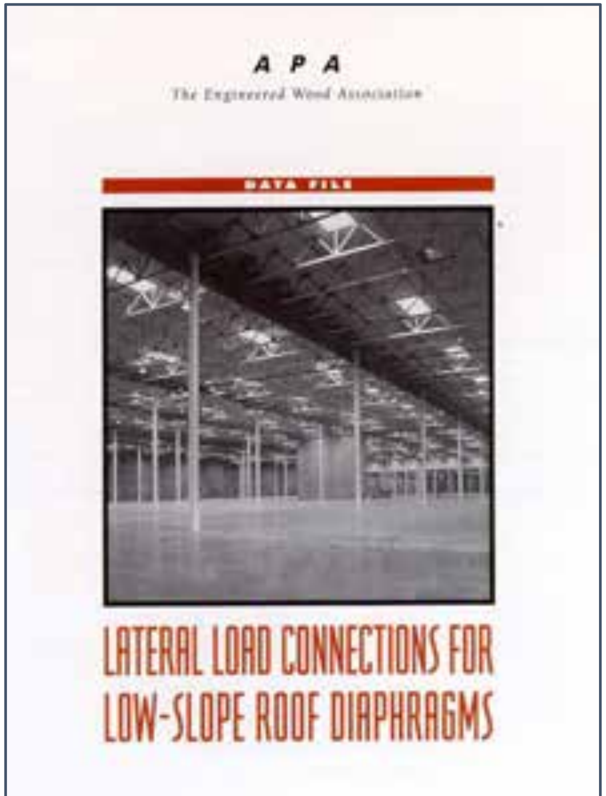
GROUP	FIRE-RESISTANCE RATING (hours)
A, B, E, H-4, I, R-1, R-2, U	3[a]
F-1, H-3[b], H-5, M, S-1	3
H-1, H-2	4[b]
F-2, S-2, R-3, R-4	2

a. In Type II or V construction, walls shall be permitted to have a 2-hour fire-resistance rating.

b. For Group H-1, H-2 or H-3 buildings, also see Sections 415.6 and 415.7.

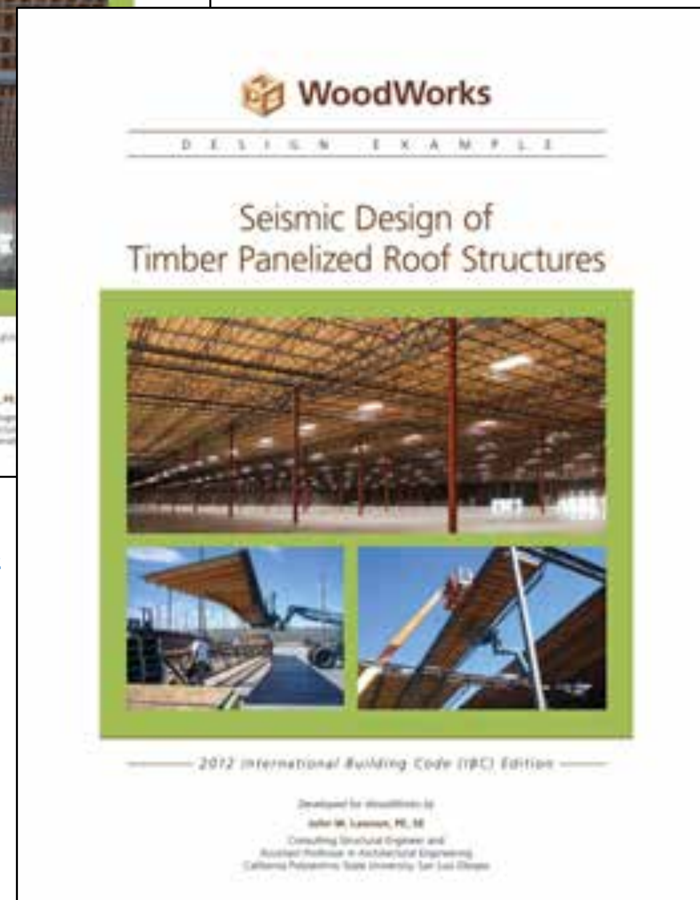


Resources



APA Publication Z350

[Wind Design of Timber Panelized Roof Structures]

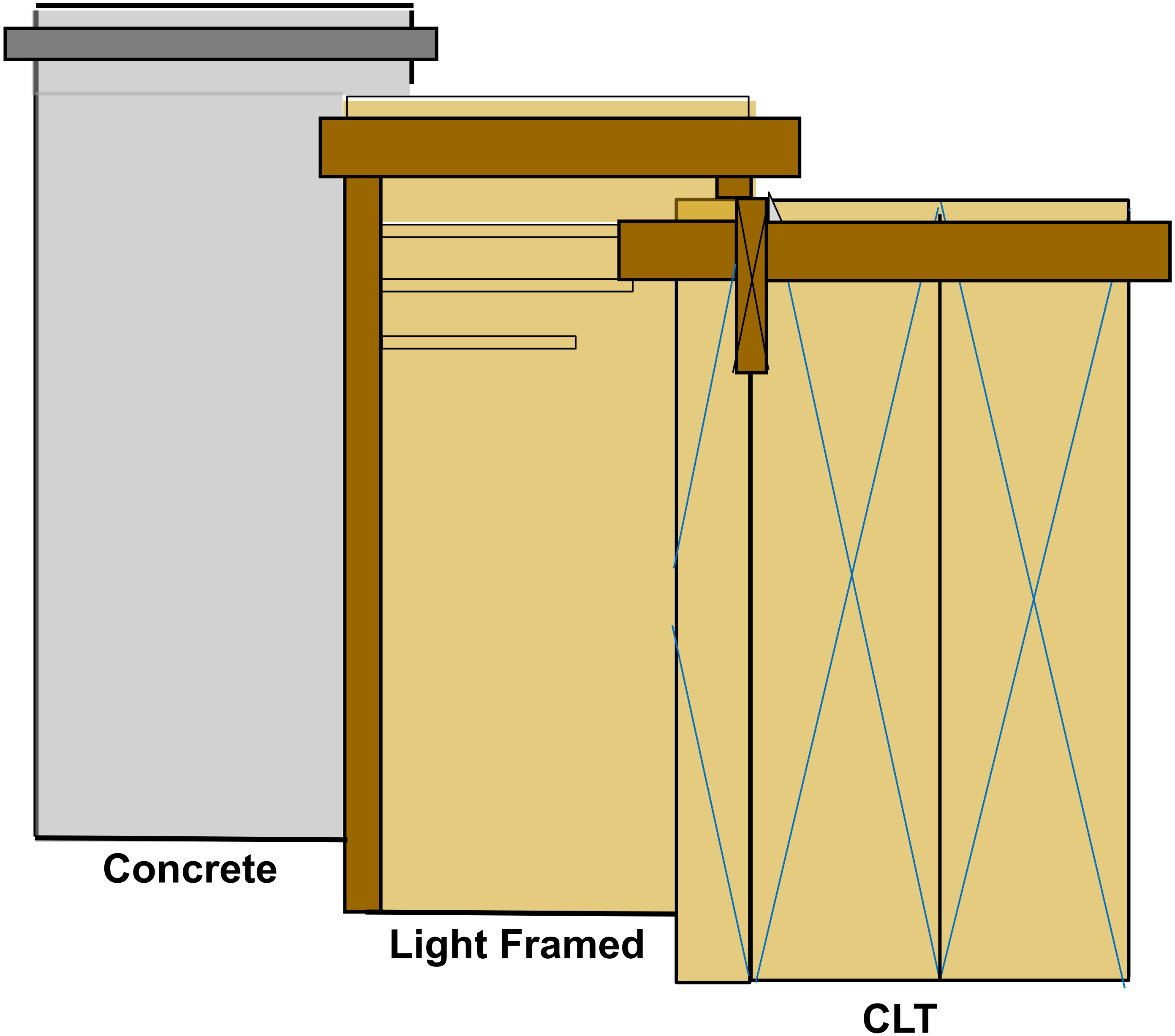


[Seismic Design of Timber Panelized Roof Structures]

Examples (Concrete tilt-up walls):

- **Sub-diaphragms**
- **Continuous cross-ties**
- **Anchorage details**

Wall Panel Options



Concrete Tilt-up Walls

Added costs, including materials, labor and construction time

- Continuous cross-ties and connections across the diaphragm are required (ASCE 7-16 Sections 12.11.2 and 12.11.2.2). If trusses are used as cross-ties, the additional axial forces could increase the cost of those trusses. SDC C-F
- Sub-diaphragms and high capacity out-of-plane wall connections are required for concrete or masonry walls. ASCE 7-16 Sections 12.11.2 and 12.11.2.2. SDC C-F
- Increased foundation sizes.
- Special inspection requirements are required for concrete construction per 2018 IBC Chapter 17, Table 1705.3
- Concrete sampling and testing is required per 2018 IBC Chapter 17, Table 1705.3
- Concrete curing time-adds to construction time and contractor time on-site.
- Scheduling, coordination for placement and lifting-adds to construction time and costs.
- Formwork, embeds, standard inserts for connections, and added rebar for are required or lifting walls. Bond breaker and other chemicals are also required.
- Cracking/shrinkage, mirror images from casting beds, finishing and repairs (patching, sand blasting and bush hammer) adds cost.

Concrete Tilt-up Walls-Cont.

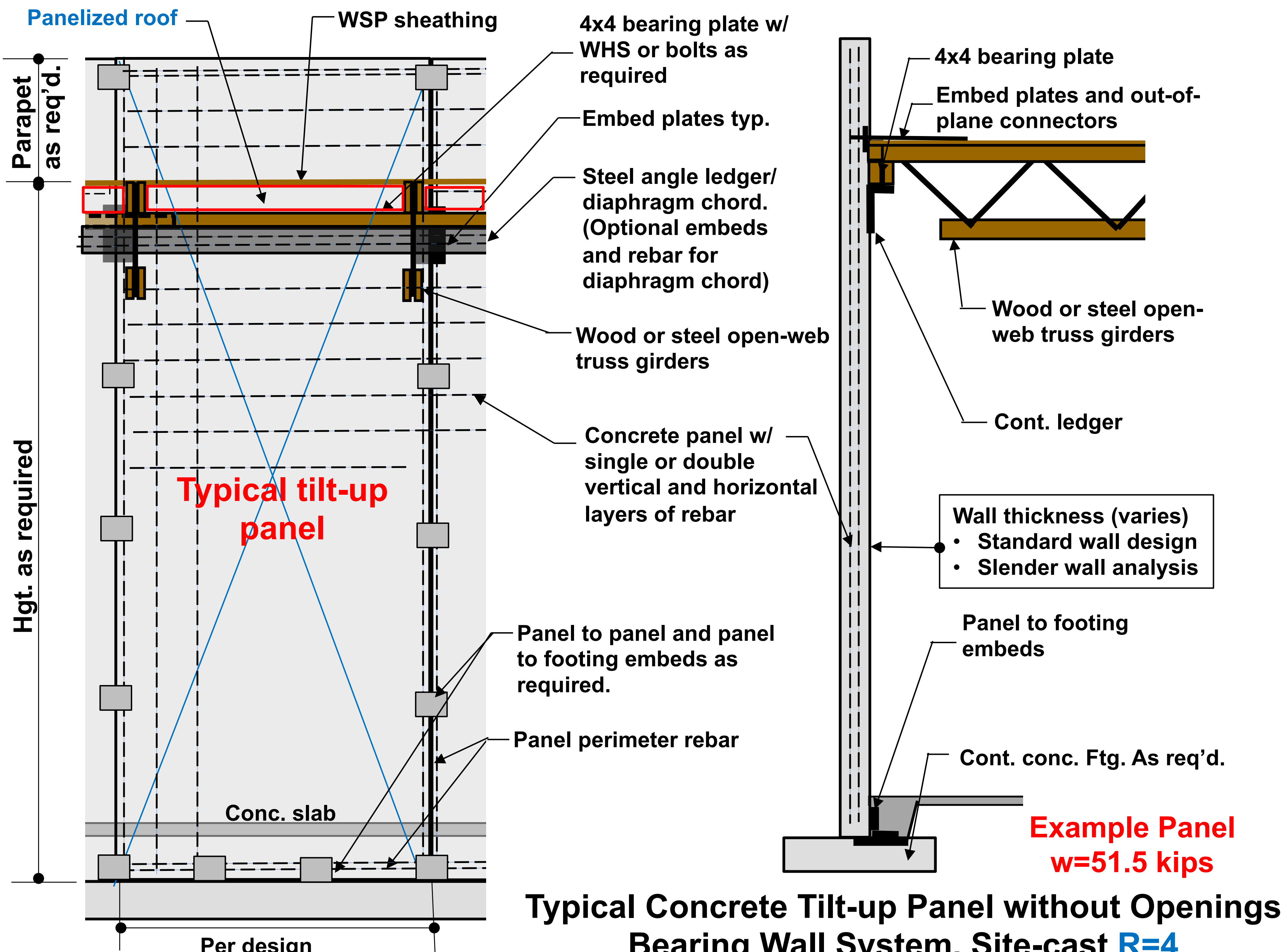
- Extra rebar is required at narrow pier sections and at large openings
- Crane sizes, require higher capacities for concrete walls
- Pilasters/plinths (cast-in-place) integration with wall panels-as occurs.
- Cold weather-hot weather concreting and concrete additives, freeze construction delays adds cost
- Wall mass seismic forces to diaphragm causes increased nailing and larger connections
- Tilt-Up Contractor - liability involved in the lifting process which increases cost

Note:

The following wall panel details were used to get a cost comparison between the panel types, but represent only <u>one way</u> to construct the walls. Design loads are based on Woodworks papers:

<u>Wind Design of Timber Panelized Roof Structures</u>

<u>Seismic Design of Timber Panelized Roof Structures</u>

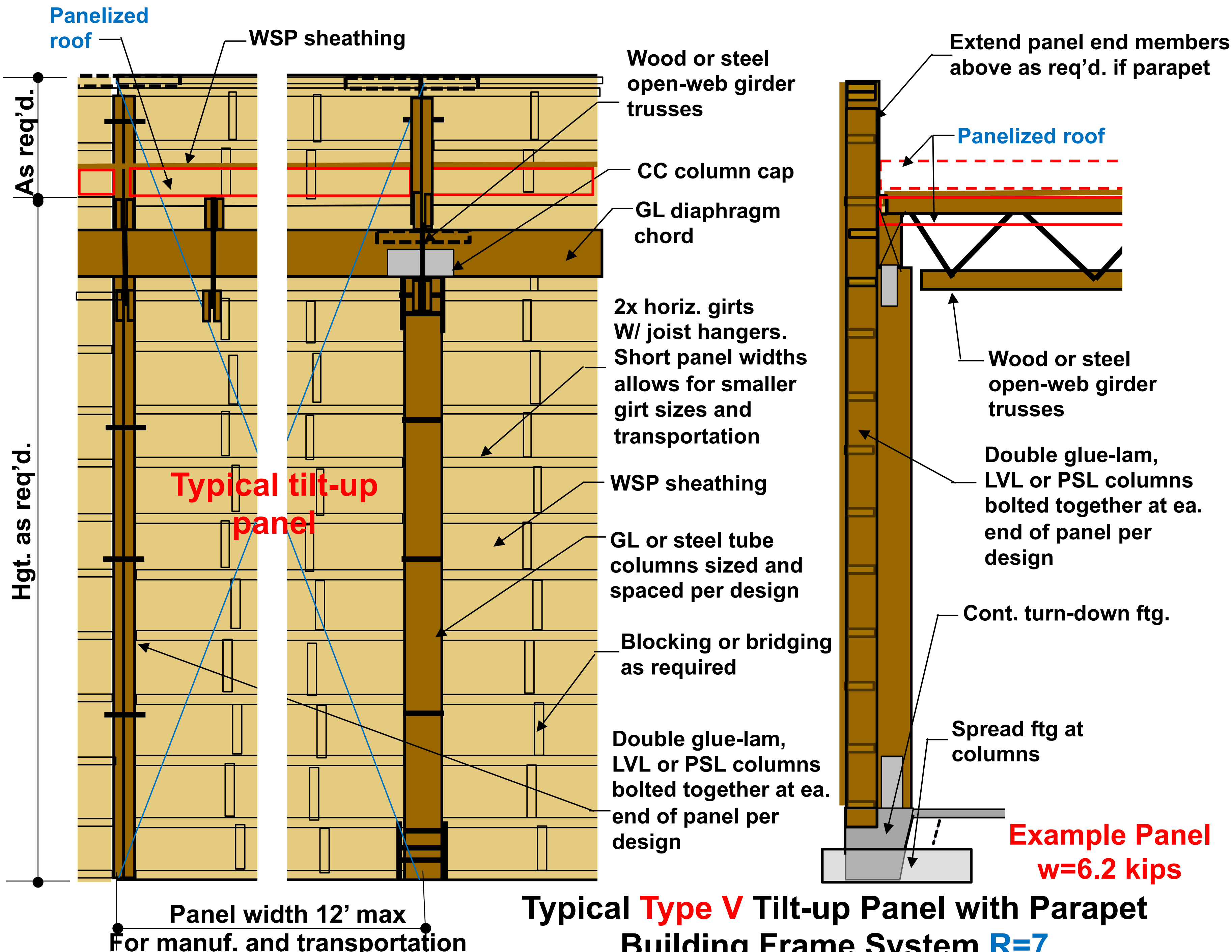


Typical Concrete Tilt-up Panel without Openings
Bearing Wall System, Site-cast R=4

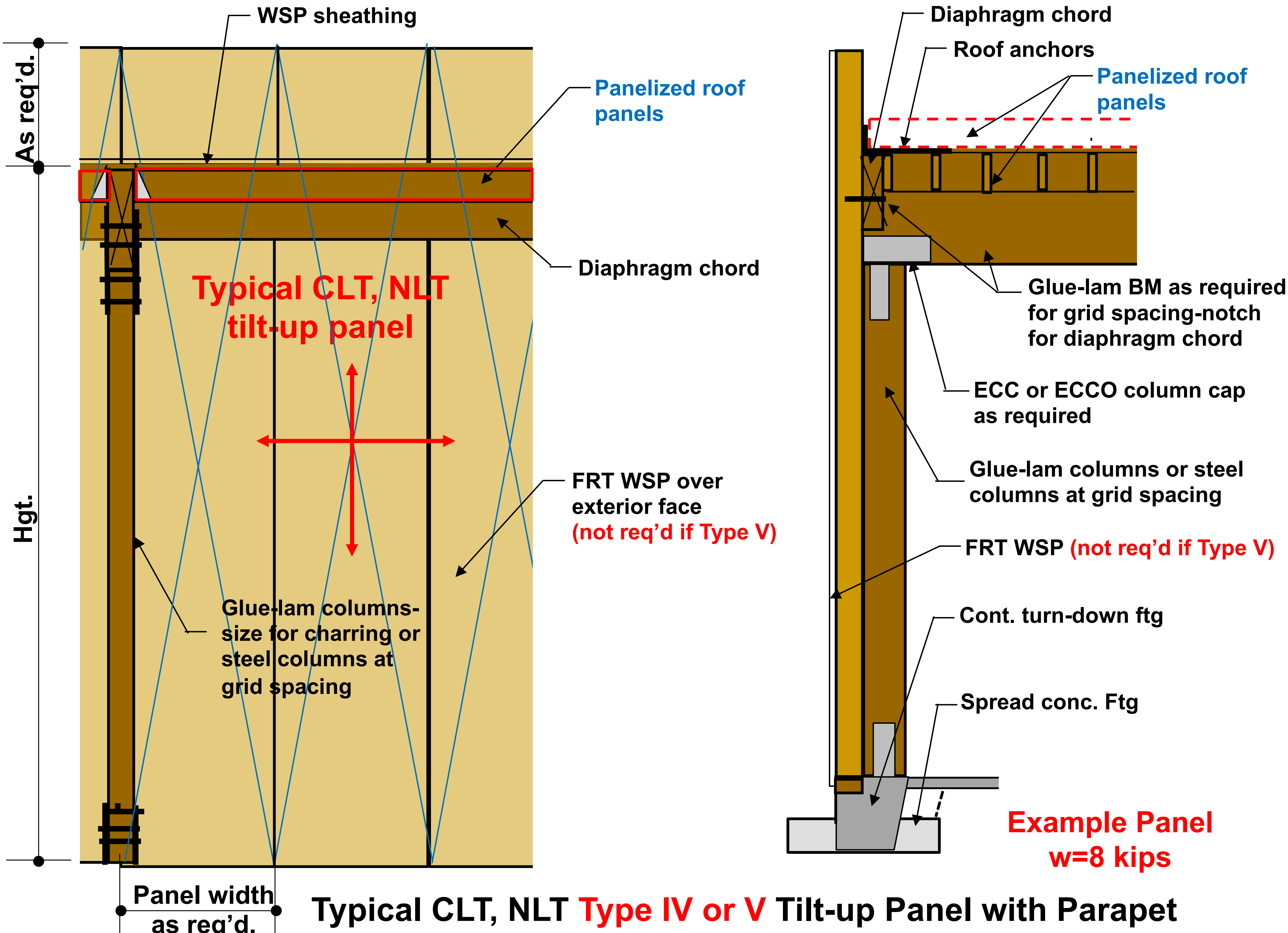
Wood Wall Panel Options and Objectives

Objectives:

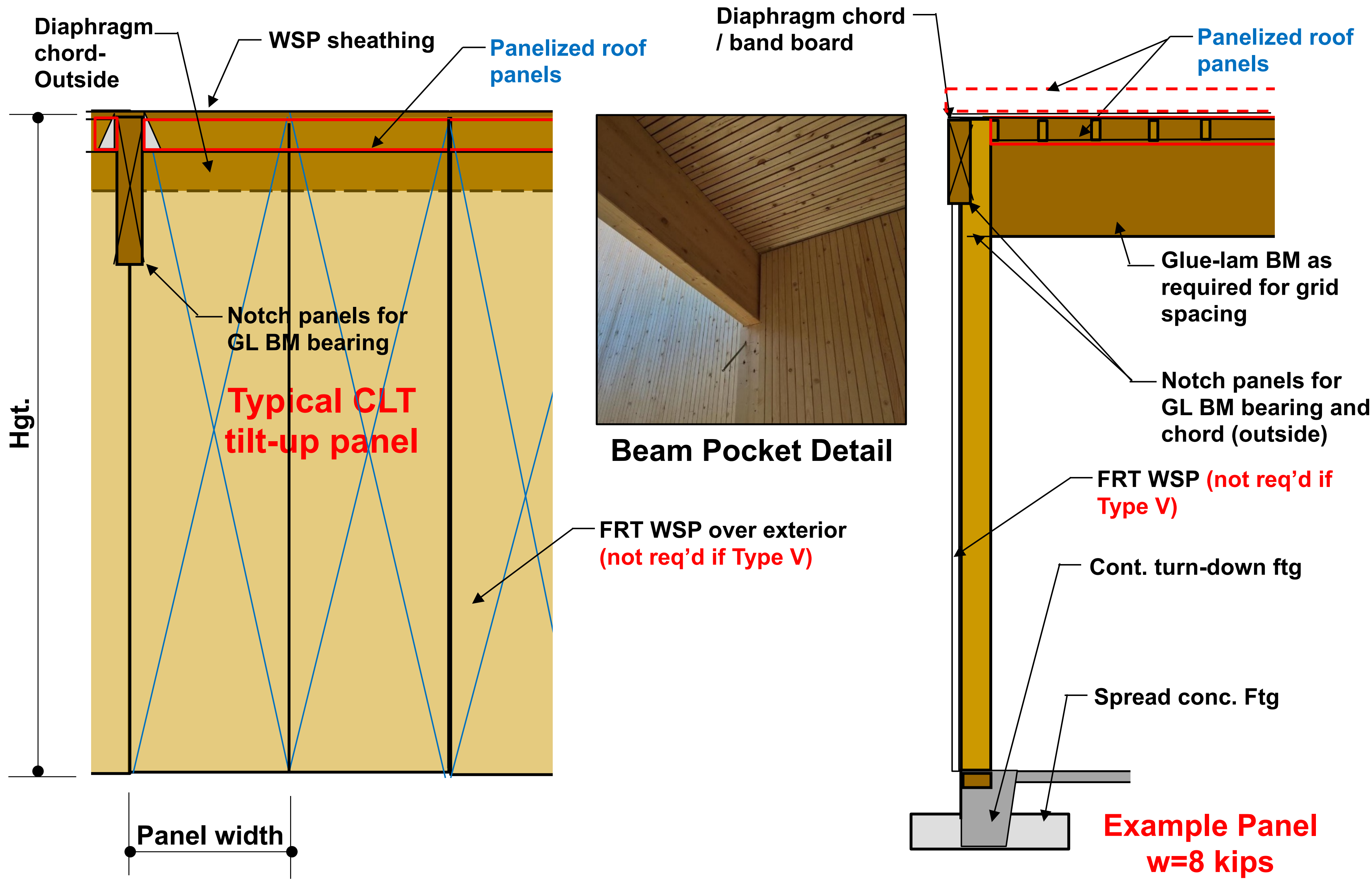
- Reduce loads to diaphragm and foundation
- Make walls non-load bearing where possible
- Use high R factor (seismic)
- Avoid high-shear diaphragms
- CLT-reduce panel thickness where possible (no. of plies)
- Framing method objective
  - Light frame-Horizontal girts reduces 2x depth vs. long vertical studs
  - GL columns allow any height of wall and creates post and beam system, R=7.
  - CLT panels- Orient strong axis to shortest support dimension



Typical Type V Tilt-up Panel with Parapet Building Frame System R=7

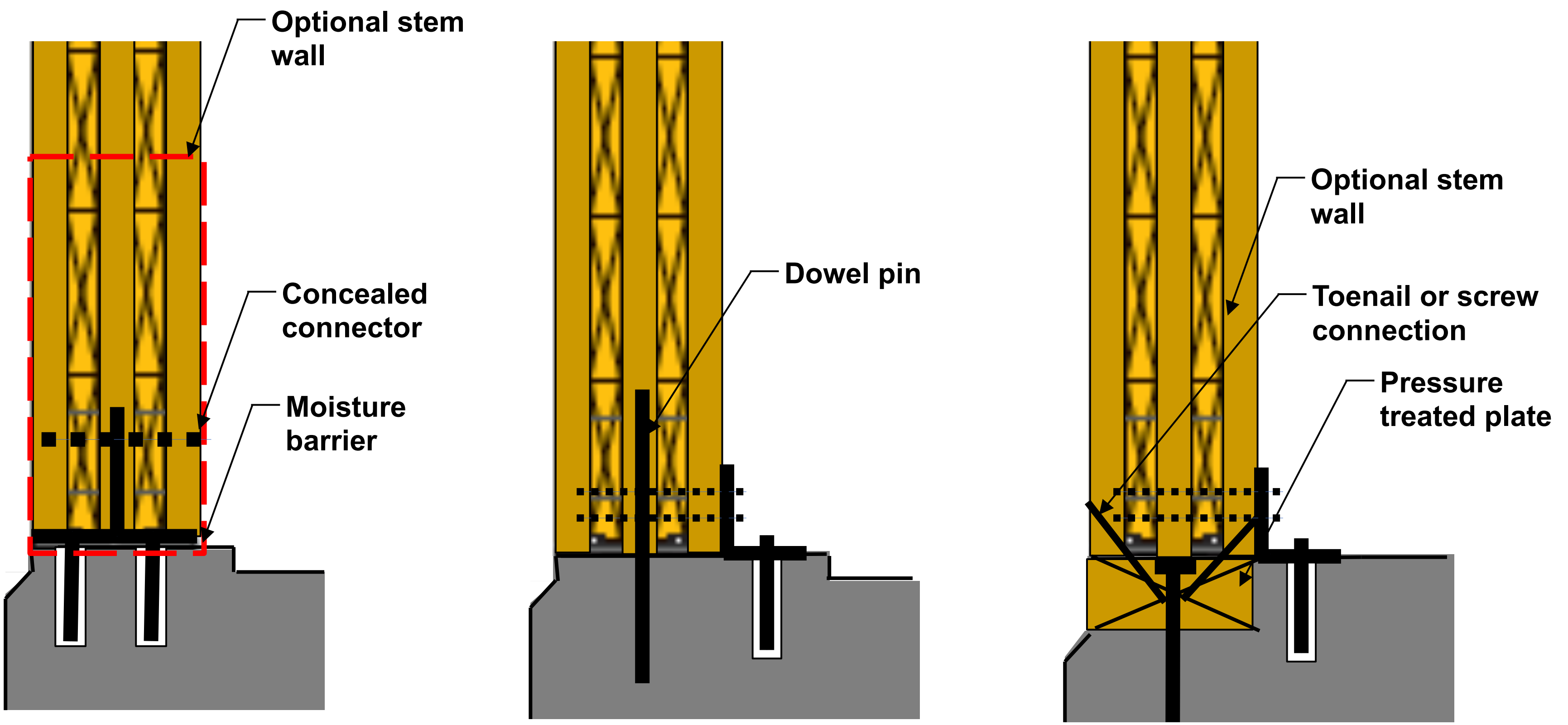


Typical CLT, NLT Type IV or V Tilt-up Panel with Parapet Post and Beam System Wind or Seismic (R=2 AMMR)

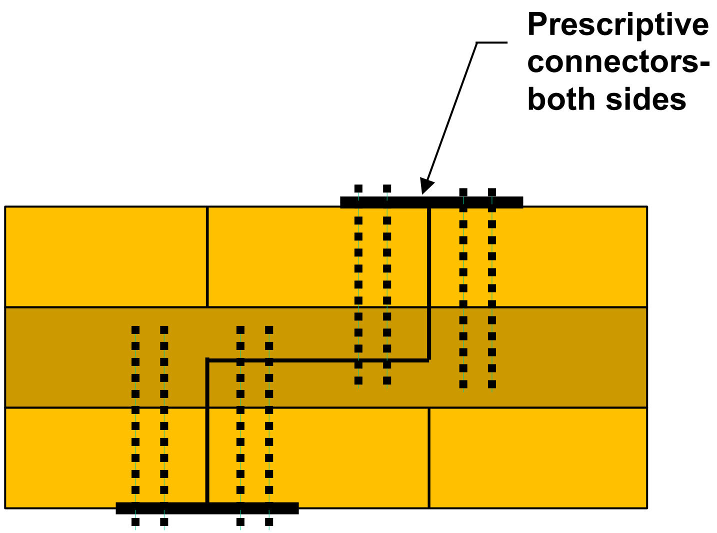


Typical CLT Type IV or V Tilt-up Panel without Parapet
Bearing wall panels Wind or Seismic (R=2 AMMR)

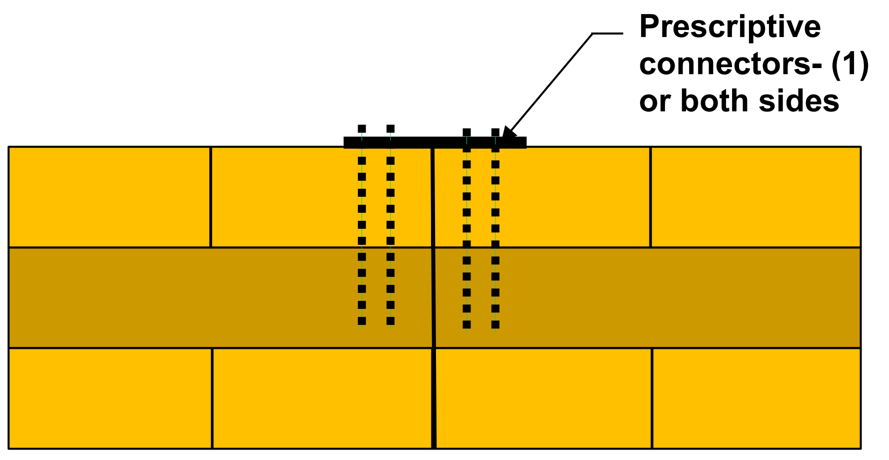
Typical Connections - Foundation



Typical Wall Splice Detail

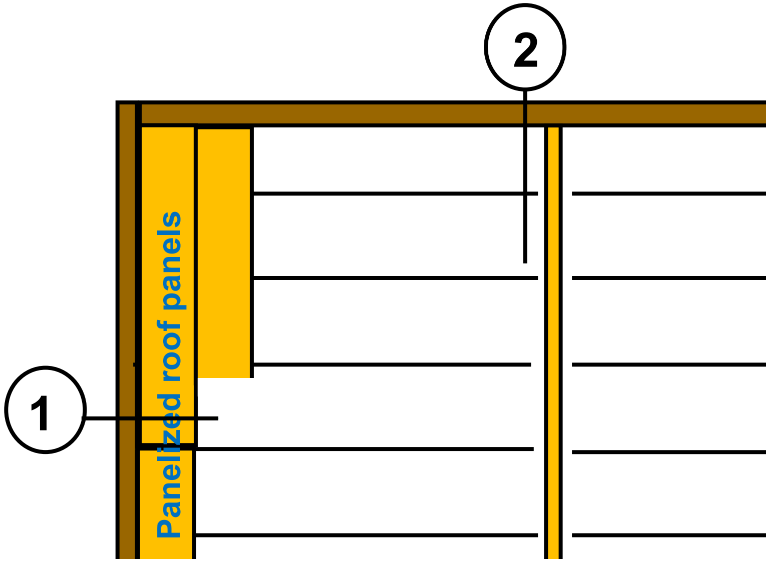


Lap Joint

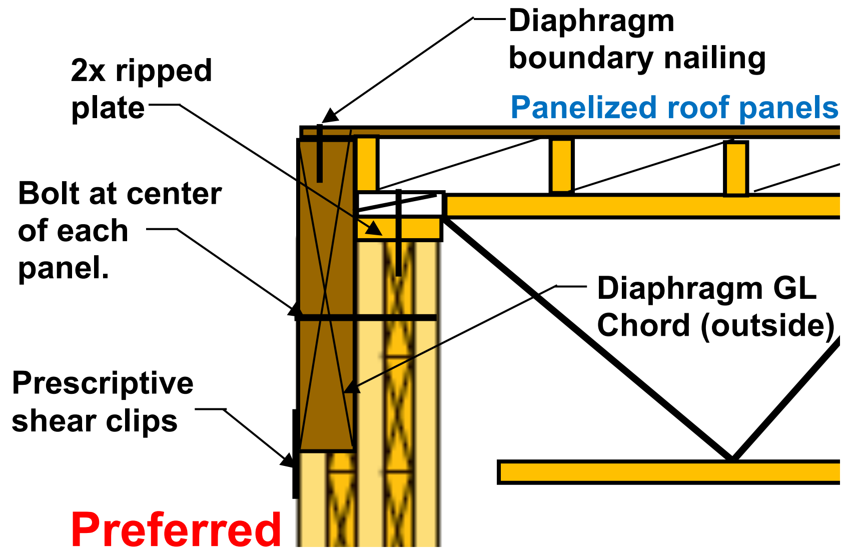


Butt Joint

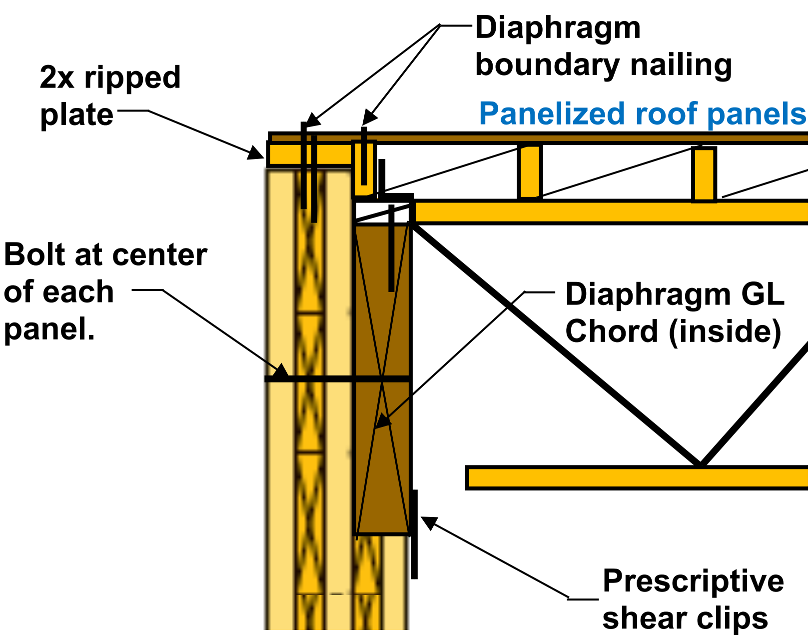
Typical Connections Details per 2021 SDPWS Table CB-2



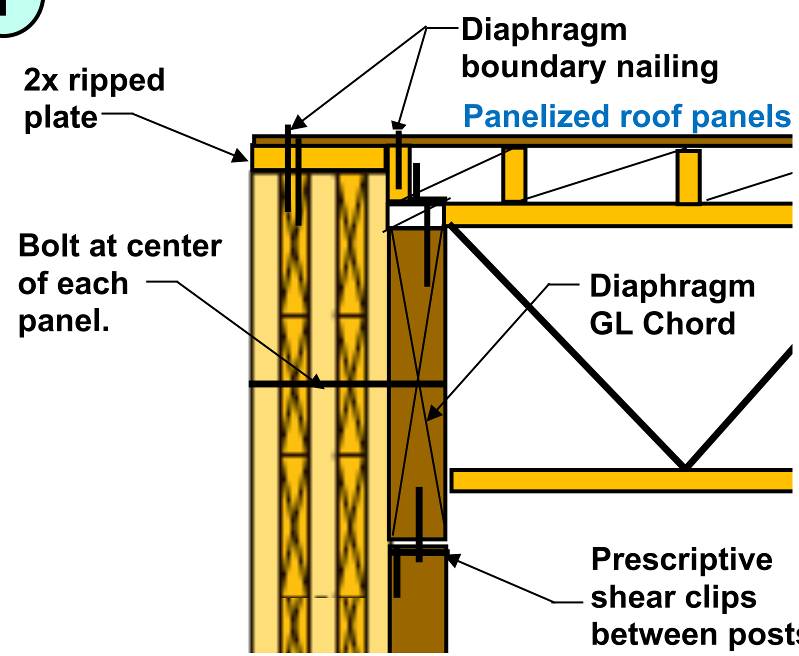
Typical Framing Plan



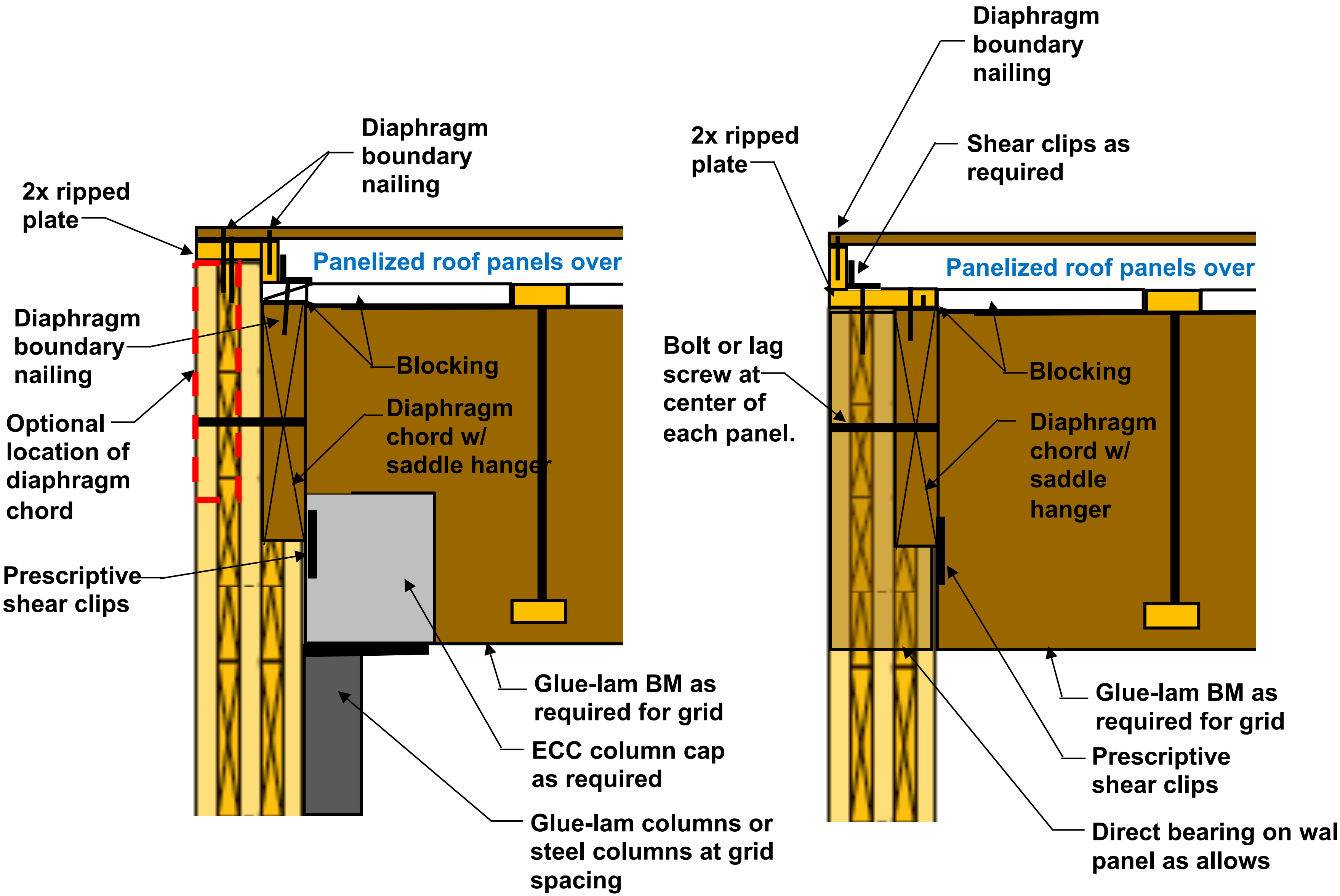
1 Possible High Chord Force Detail



1 Possible High Chord Force Detail



1 Possible Post and Beam Detail



2 Possible High Chord Force Detail

Current CLT Shear Walls

- CLT is currently not recognized in any seismic lateral force resisting systems. –Currently requires AMMR
- The US CLT Handbook provides suggested conservative seismic response value, R=2.
- Oregon has adopted values: R=2, Ω0 = 2.5, Cd = 2.

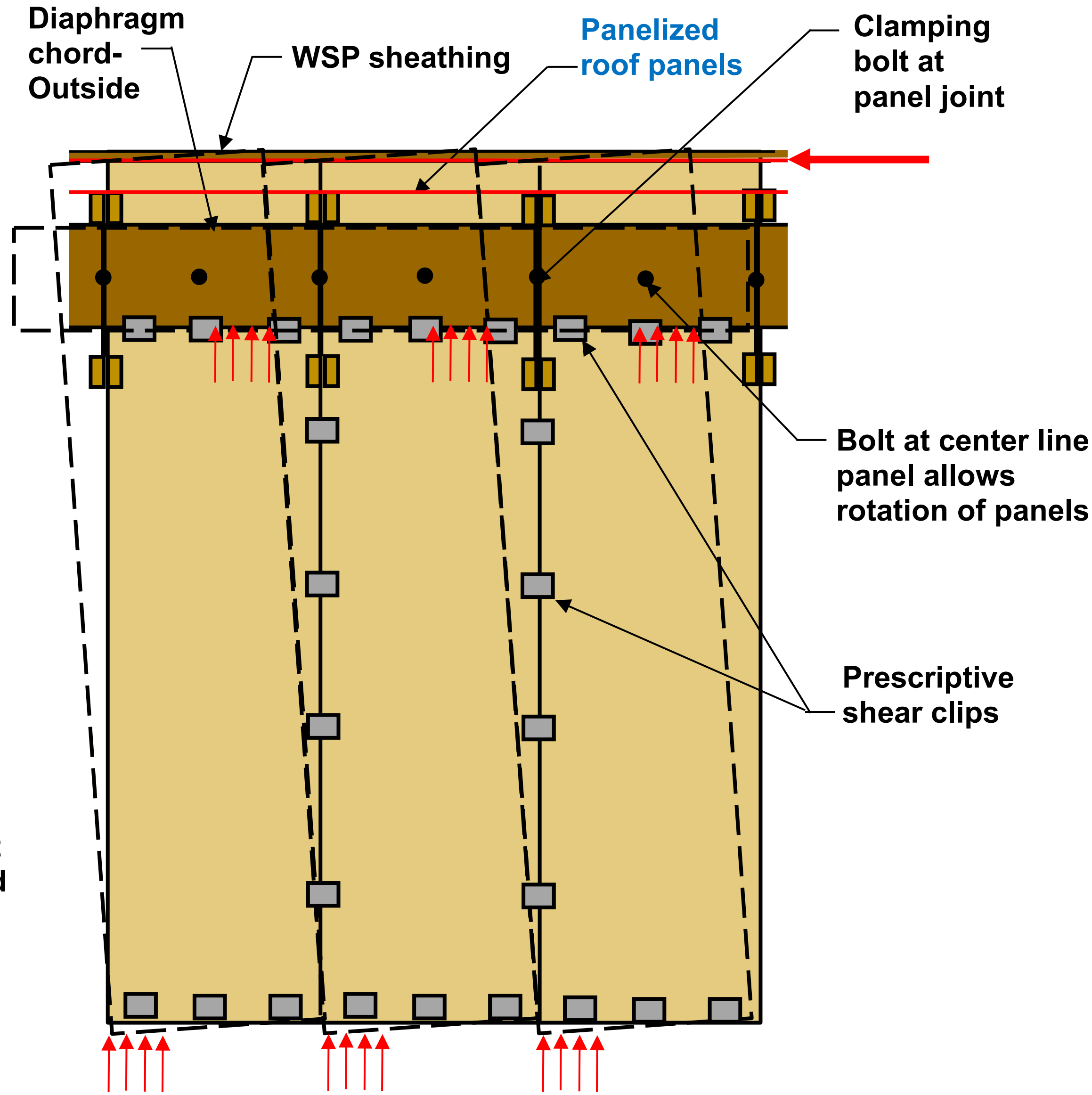
Proposed CLT Shear Wall Balloting

ASCE 7-22 proposal:

- CLT shear wall system:
  - (a) CLT shear walls: R = 3, Cd = 3, and Ω0 = 3; and
  - (b) CLT shear walls with shear resistance provided by high aspect ratio panels only: R = 4, Cd = 4, and Ω0 = 3.

2021 SDPWS Balloting

- CLT SW's shall be designed per Section 4.6.3.2 and Appendix B
- Exception: R=1.5, no special detailing

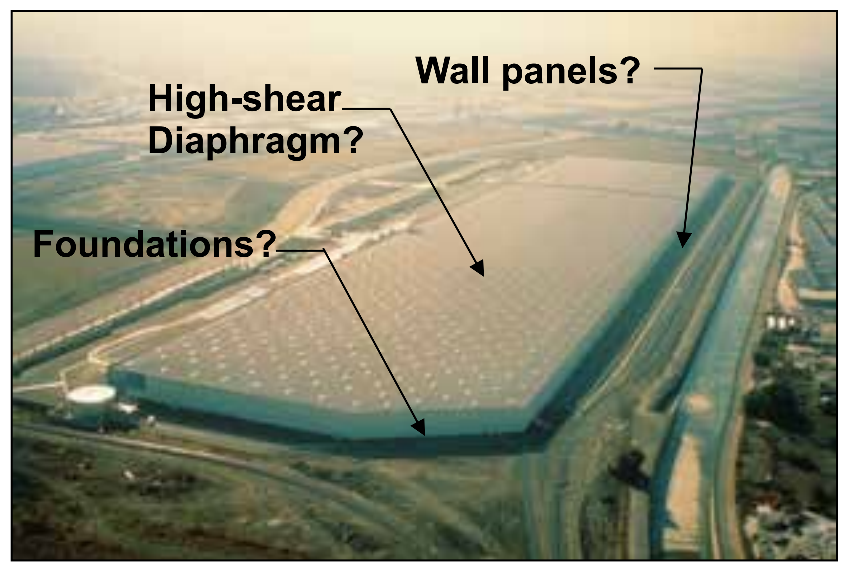


Typical CLT Type IV or V Tilt-up Panel without Parapet
Bearing wall panels Wind or Seismic

Cost Comparison Objective

- Help you understand how the reduction in lateral roof loads can effect the overall cost and reduction of design components.
- We will compare previously published design example forces for wind and seismic controlled concrete tilt-up wall construction vs. wood tilt-up wall construction.

Where’s the Money?



Example Plan Cost Comparison Tilt-up Walls

2019 Regionalized Cost Comparison of Panels – Material Costs Only				
Tilt-up Wall Panel Options	Charlotte		San Francisco	
	Cost/Panel	Cost/SF	Cost/Panel	Cost/SF
Typical Type V Panel-12’-0” width	$5850.06	$13.18	$10055.19	$22.65
Typical Type III Panel-12’-0” width	$7191.76	$16.20	$12181.15	$27.44
Typical Steel Stud Panel-12’-0” width	$10603.41	$23.88	$13861.15	$31.22
Typical Concrete Tilt-up Panel-24’-0” width	$22081.68	$24.87	$32042.01	$36.08

Estimates by EQS Consultants May, 2019

Comments:

- The comparison is based on **material costs of a single panel only**, 2019 RS Means.
- Items not included:
  - Fabrication, labor and installation costs, inspection, testing, construction contingency costs, cost escalation, general requirements/conditions, bracing, and finish.
  - Professional fees, plan check fees, building permit fees.
  - Drawings provided for cost estimate created by Woodworks, Wood Products Council.
  - Panel designs based on preliminary calculations and are approximate.
  - Component/connection detailing can vary from engineering firm to firm.
  - Diaphragm cross-ties, sub-diaphragms and out-of-plane connections.
  - Construction equipment and rental costs not included.

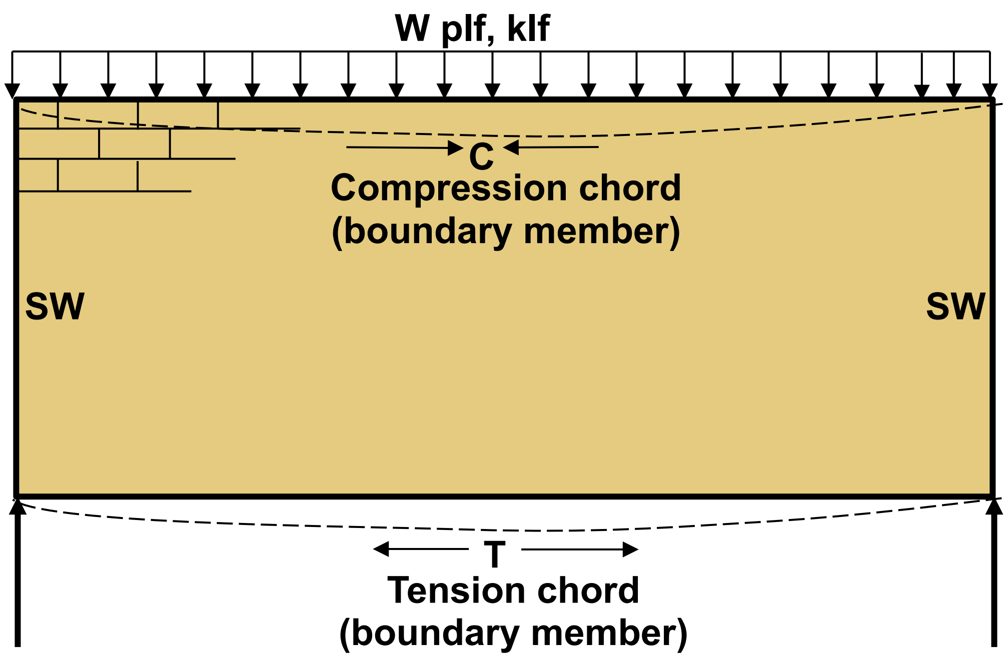
Approximate Typical CLT Panel Costs

CLT costs (approximate) - these are averages of CLT costs in the Pacific Northwest					
CLT	Furnish + Install range	Furnish + Install avg	Material + Delivery range	Material + Delivery avg	Base
3-ply	$ 9 to $15 / sf	$12 / sf	$ 6 to $11 / sf	$ 9 / sf $21/sf	———
5-ply	$15 to $24 / sf	$19 / sf	$11 to $18 / sf	$14 / sf $33/sf	-$12/sf
7-ply	$19 to $28 / sf	$23 / sf	$14 to $21 / sf	$18 / sf $41/sf	-$20/sf
9-ply	$25 to $33 / sf	$30 / sf	$19 to $24 / sf	$22 / sf $52/sf	-$31/sf

These generalized costs are approximate estimates and should NOT be use without verifying with the manufacturer. Installation is estimated as 25-35% of the material cost

Structural Engineering Considerations

Load Distribution Into a Diaphragm



The selection of tilt-up panel type can have a significant impact on the load distribution into a diaphragm and shear walls, which can effect costs.

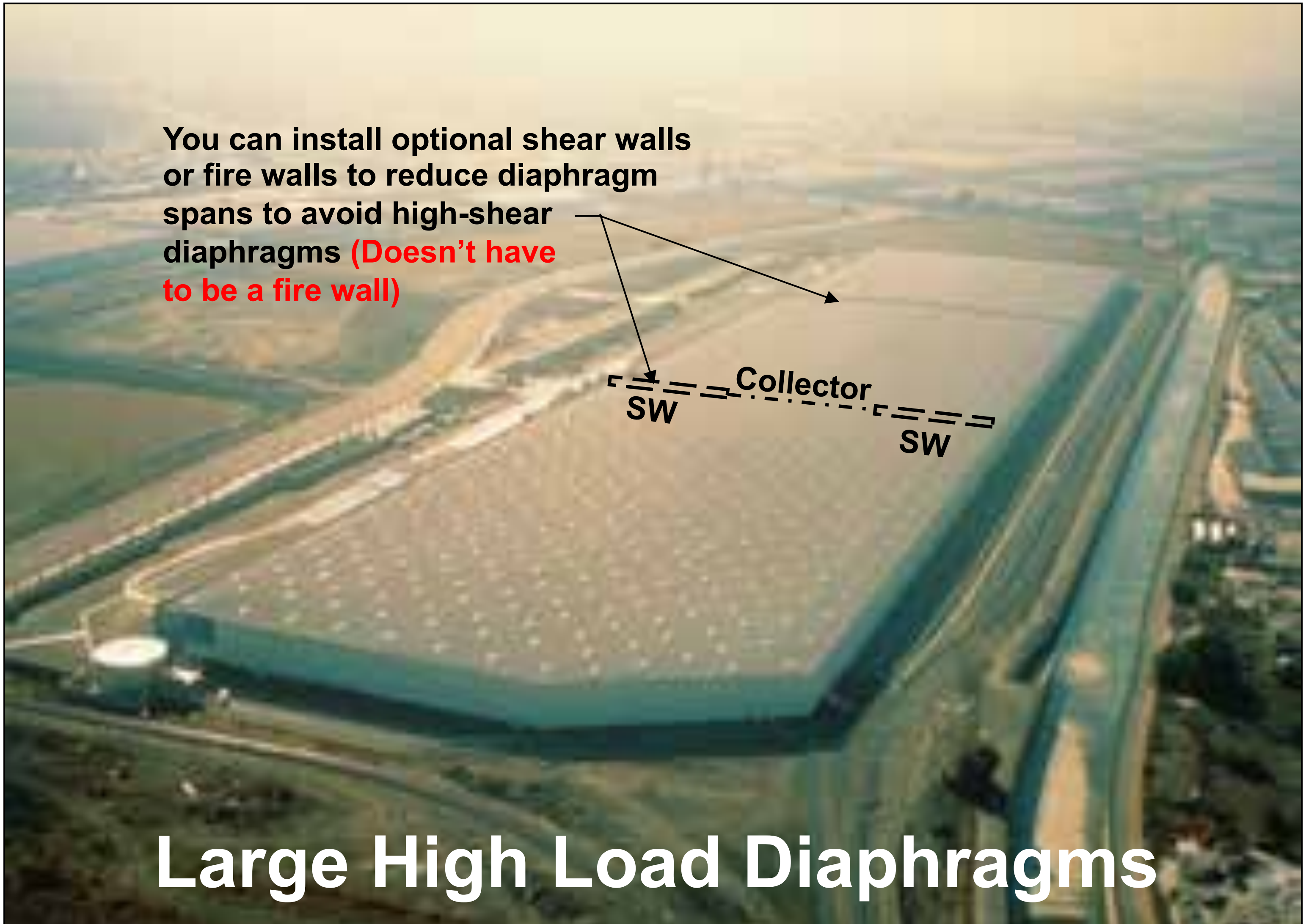
Things That Can Significantly Impact Design

- **Plan size- Required area can dictate construction type.**
- **Try to reduce diaphragm length and width or base shear to avoid or minimize high-strength diaphragms.**
- **Selection of construction Type can increase/decrease base shears**
  - **Type of lateral system:**
    - **Concrete shear walls, R=4**
    - **Bearing wall system-WSP shear walls, R=6.5**
    - **Building frame system-Post & beam w/ WSP shear walls, R=7**
    - **CLT shear walls, R=1.5, 2, 3 or 4**

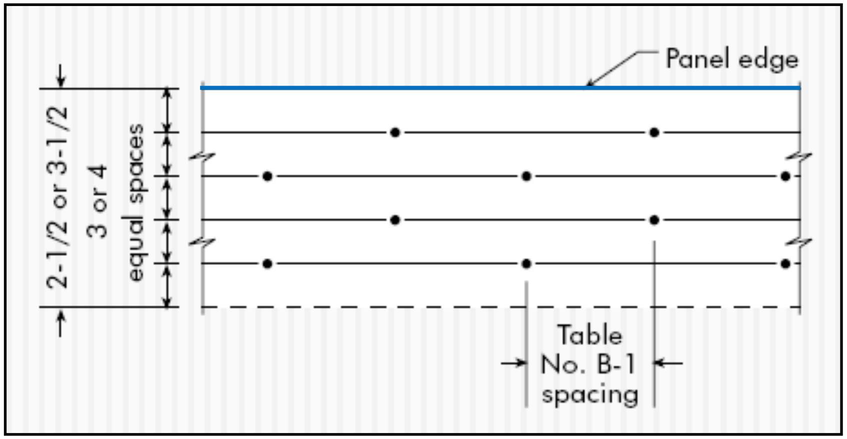
(In most cases, the larger the R factor the lower the base shear)
In this case wall weight has a large part to play

- **Wall height can increase panel thicknesses.**
- **Bearing or non-bearing walls can affect panel thicknesses**
- **Wind and seismic forces controlled designs, even if SDC B.**

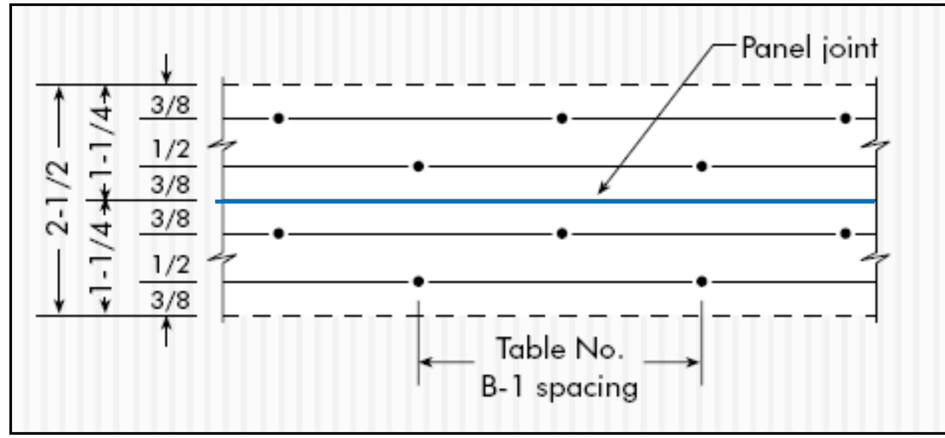
Design Issues - Concrete Tilt-up Walls



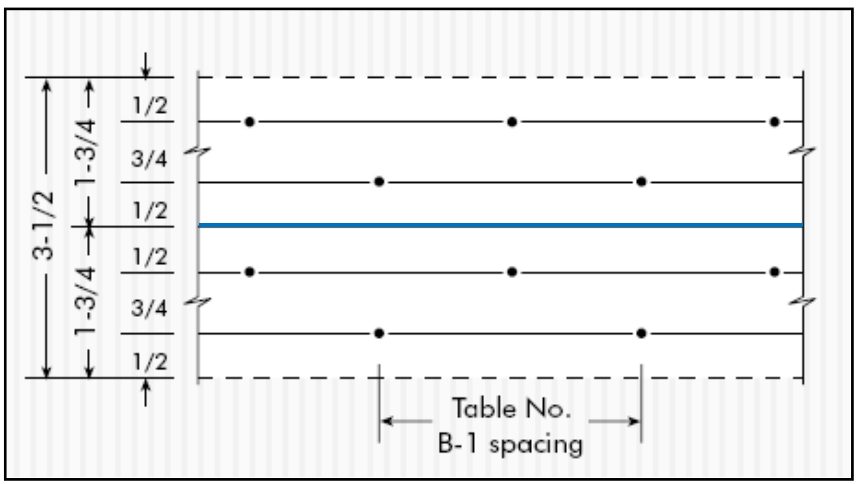
High Shear Diaphragm Nailing



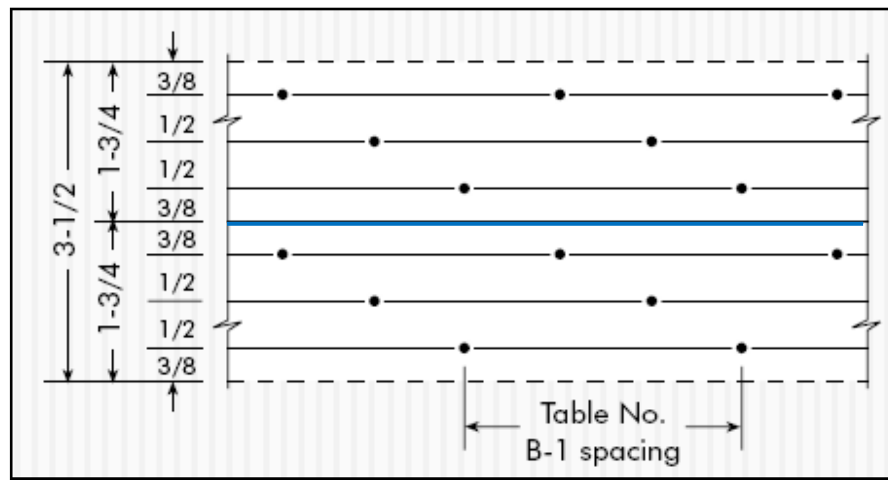
3" or 4" nominal four lines



3" nominal two lines



4" nominal, 2 fastener lines



4" nominal, 3 fastener lines

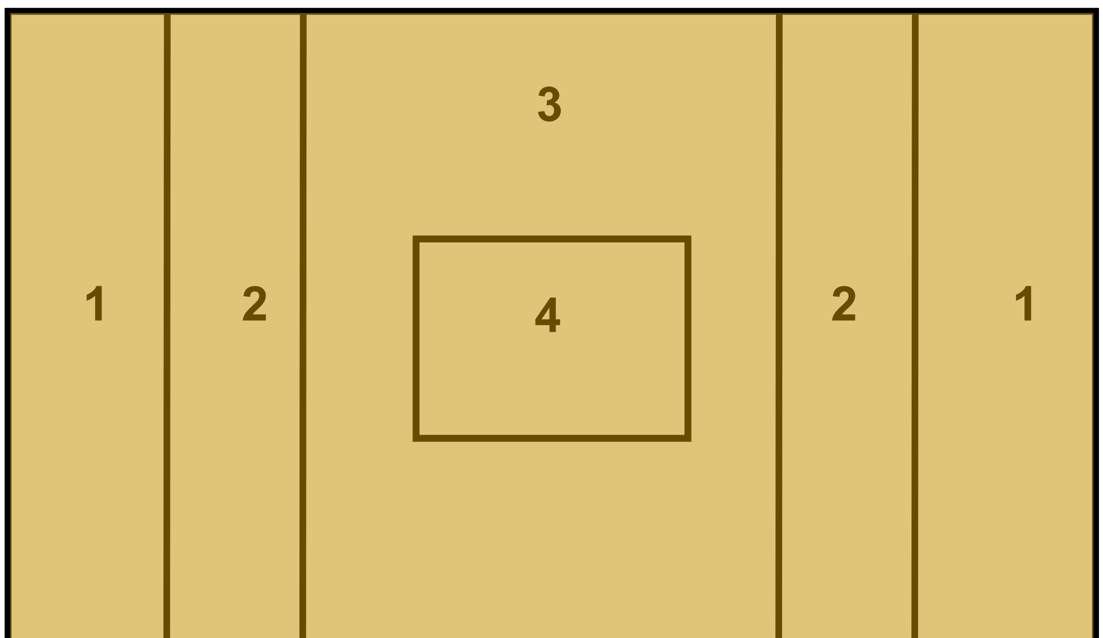
Typical Boundary Fastening (SDPWS Section 4.2.7.1.2, Figure 4B and Table 4.2B)

Note: Space panel end and edge joint 1/8". Reduce spacing between lines as necessary to maintain minimum 3/8" fastener edge margin. 1/2" is minimum distance between rows.

Multiple Nailing Zones

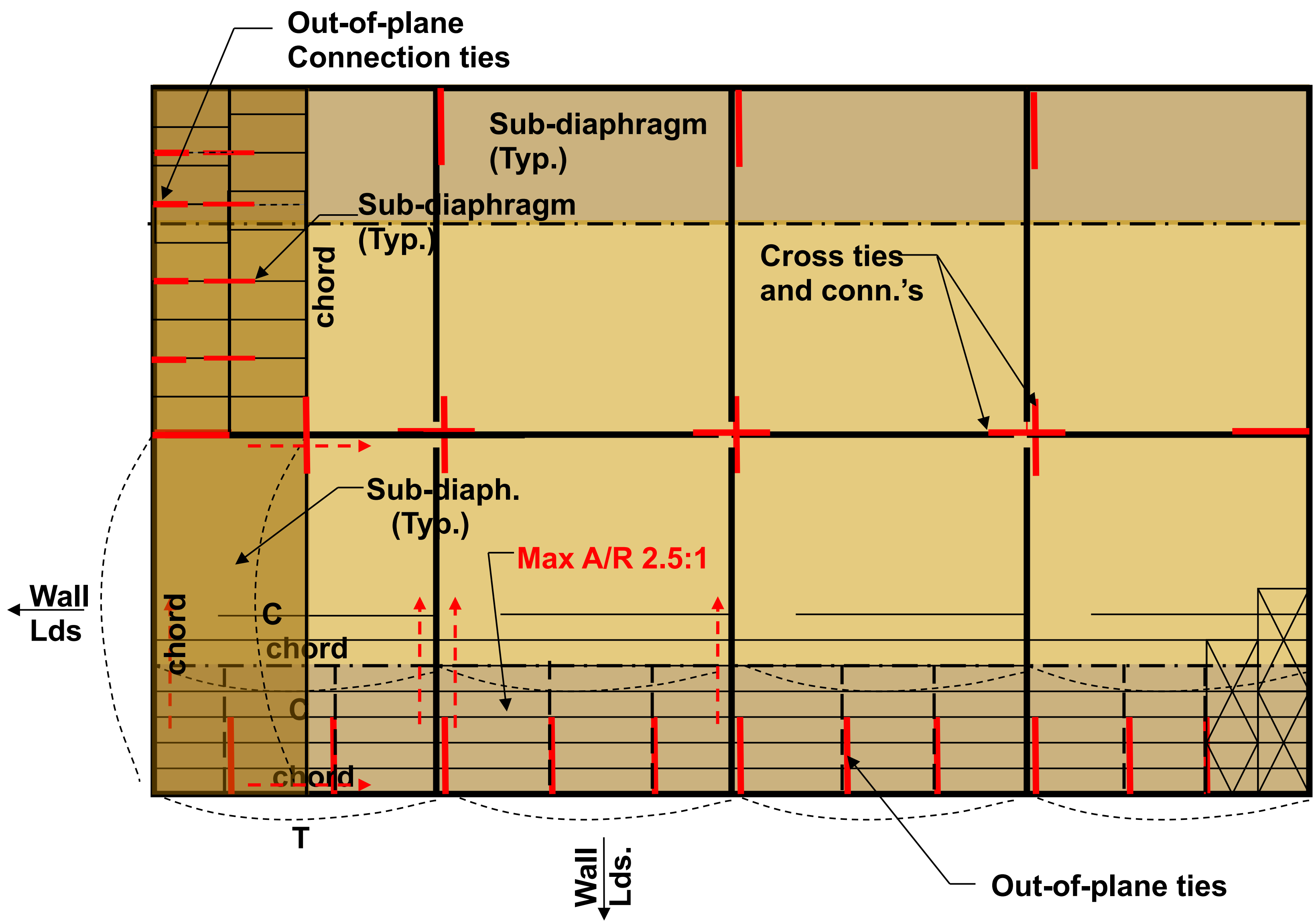
Using wood tilt-up walls helps economize on materials and construction time

- Fewer nailing zones
- Less nails and nailing time
- Smaller connections

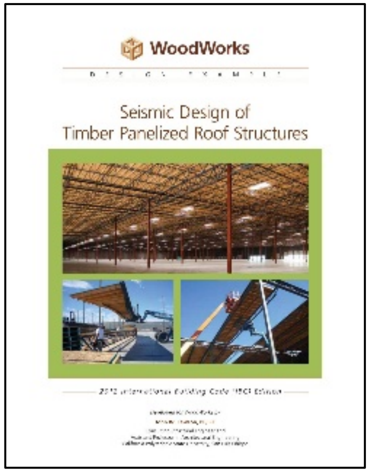


Sub-diaphragms for Seismic Loading-SDC C-F

(Not required for wood tilt-up walls)



Design Load/Force Comparison-Concrete vs. Wood walls



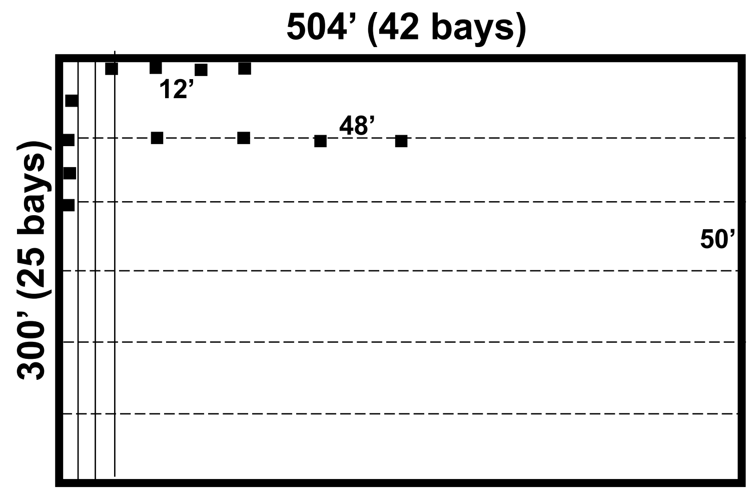
Seismic Design of Timber Panelized Roof Structures

For a single story structure

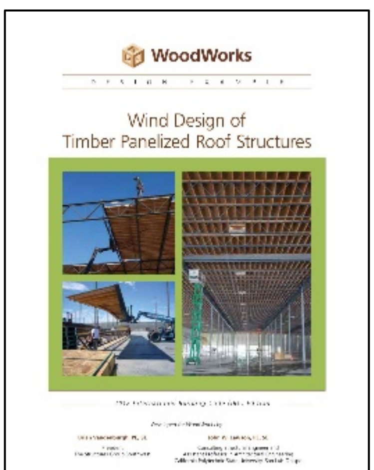
$$F_x = F_{px} = \frac{S_{DS} I_e}{R} w_{px}$$

Where:

- S_{DS}=1.0
- I_e=1.0
- R=varies

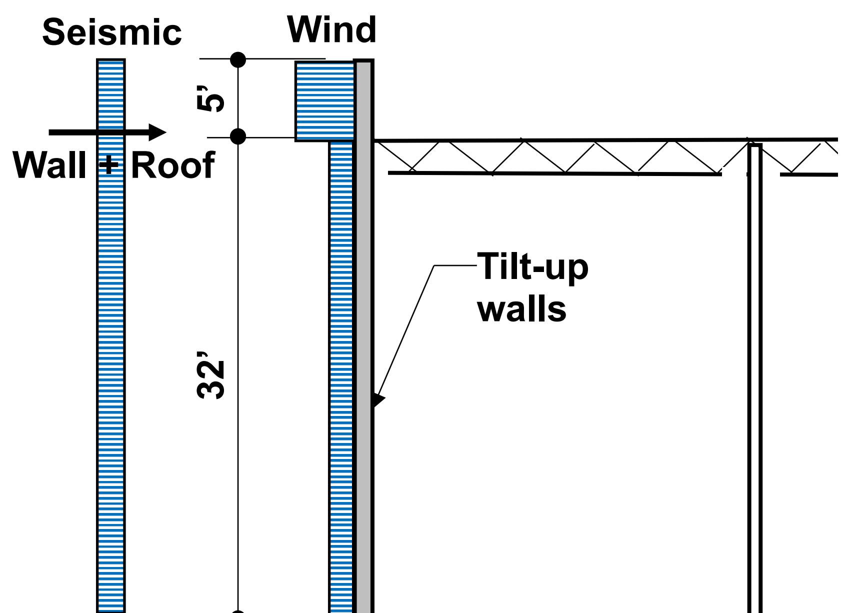


Building Plan



Wind Design of Timber Panelized Roof Structures

Wind: Nominal 3 second gust basic wind speed=115 mph Exposure C



Building Section

Seismic Design Comparisons

Concrete tilt-up
R=4 Bearing wall-concrete shear walls

Light-framed wood tilt-up walls
R=7 Building Frame

Concrete Tilt-up-From example papers			Wood Tilt-up		
	STR	**ASD**	**STR**	**ASD**	**% Reduction**
Design load coefficients					
Cs	0.25	-----	0.143	-----	-----
Fpx	0.25	-----	0.2	Minimum Fpx controlled	
Shear Walls					
Wn/s	2366 plf	1656 plf	717 plf	502 plf	69.7 %
Rn/s	596 k	417.2 k	180.7 k	126.5 k	69.7 %
Diaphragm					
Wn/s	2366 plf	1656 plf	1002.7 plf	701.8 plf	57.8 %
Rn/s	596 k	417.2 k	252.7 k	176.9 k	57.8 %
Vd	1987 plf	1391 plf	842.3 plf	589.6 plf	57.8%
Tn/s	250.4 k	175.3 k	106.1 k	74.3 k	57.8 %

Wn/s=Uniform load to diaphragm
Rn/s=Reaction (shear) to end wall

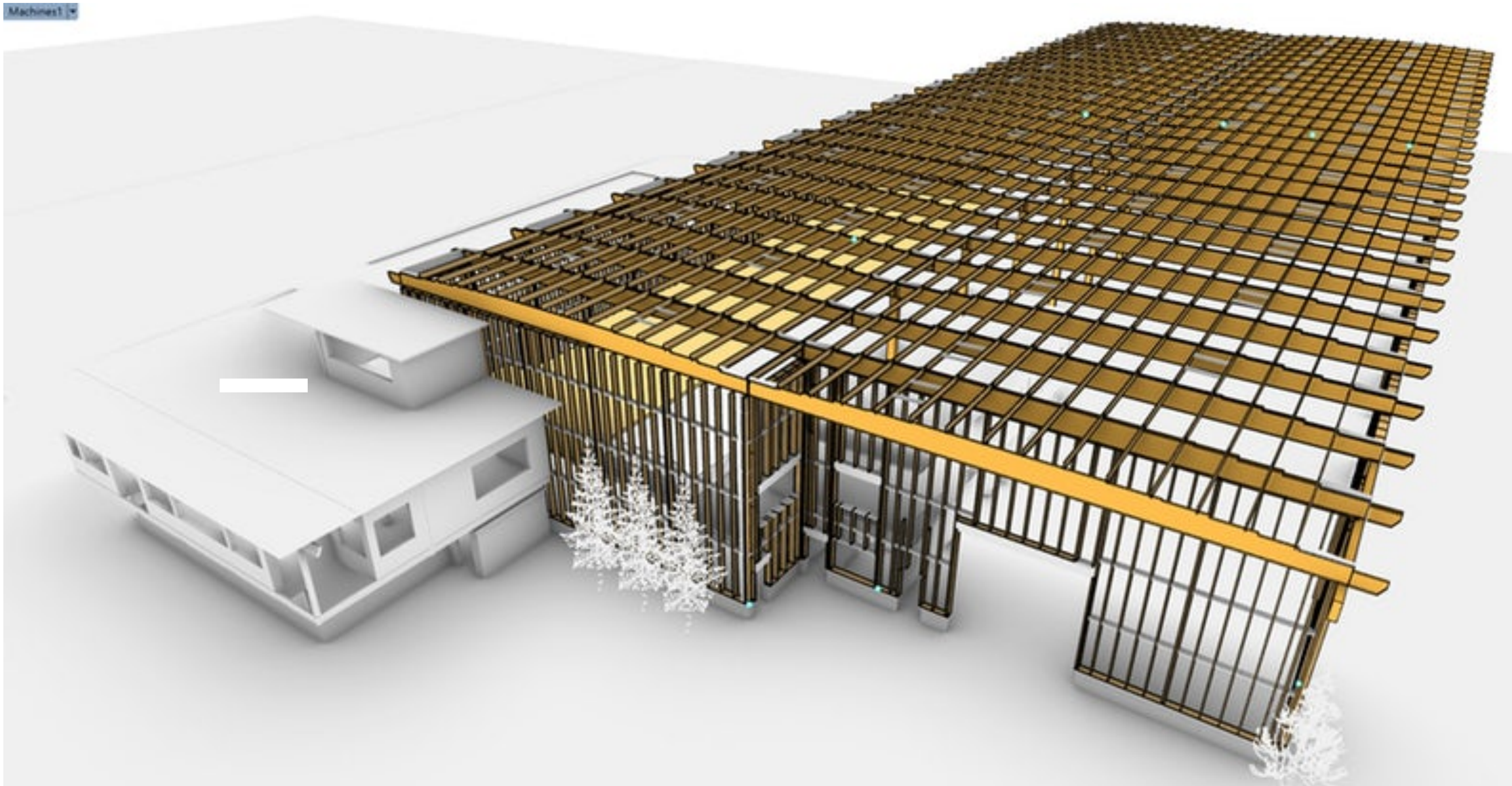
Vd=Maximum diaphragm shear
Tn/s=Maximum chord tension force

Seismic Design Comparisons-CLT

Design load coefficients	Concrete Tilt-up- example papers R=4		Wood CLT Tilt-up		
	STR	ASD	R=4	R=3	R=2
Cs	0.25	-----	0.25	0.333	0.5
Fpx	0.25	-----	0.25	0.333	0.5
Wn/s	2366 plf	1656 plf	922 plf ASD	1228 plf ASD	1844 plf ASD
Rn/s	596 k	417.2 k	232.3 k	309.5 k	464.7 k
Wn/s % increase(+)/decrease (-)			-44%	-26%	+11%

Wn/s=Uniform load to diaphragm
Rn/s=Reaction (shear) to end wall
Vd=Maximum diaphragm shear
Tn/s=Maximum chord tension force

Case Study -StructureCraft New Shop Building, 2017



All photos and artwork by StructureCraft

50,000 sq. ft. facility in Abbotsford, British Columbia.

All photos and artwork by StructureCraft

Erection of Exterior Wall Panels and Center of Building Columns

All photos and artwork by StructureCraft

NLT Beam Pocket and Closure Strip

All photos and artwork
by StructureCraft

Crane Supports added at Exterior Walls and Center Columns

All photos and artwork
by StructureCraft

Interior Office Installed

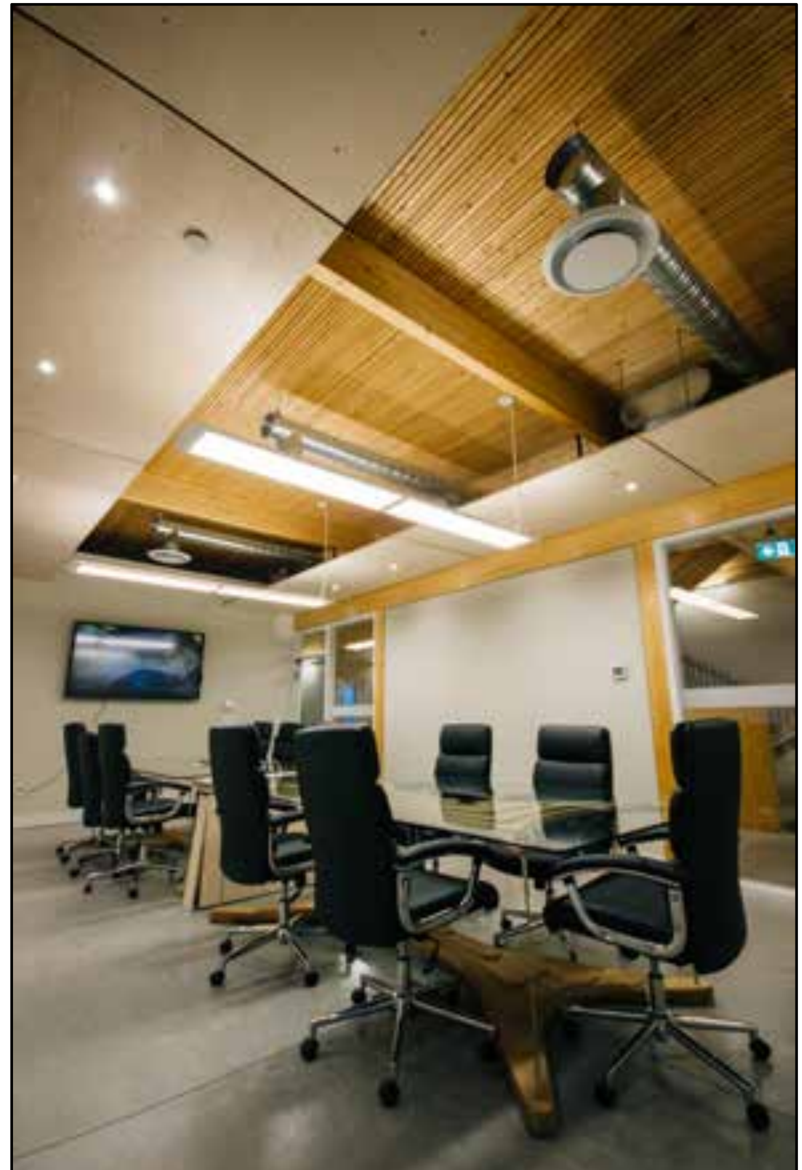
All photos and artwork
by StructureCraft

Interior Cranes, Mezzanine and Equipment Being Installed

Erection completed

All photos and artwork
by StructureCraft

Exterior completed



All photos and artwork
by StructureCraft

Finished Interiors

Case Study -StructureCraft New Shop Building, 2017

COURTESY OF STUDIO 531 ARCHITECTS

10,000 sq. ft. CLT Warehouse in Langford, British Columbia.

COURTESY OF STUDIO 531 ARCHITECTS

- **24 ft. high ceiling with open-web wood trusses**
- **CLT exterior walls and demising wall by Katerra**
- **Contractor was only experienced with concrete tilt-up construction**

COURTESY OF STUDIO 531 ARCHITECTS

Reported benefits on project:

- 5-ply CLT exterior walls and roof went up seamlessly without a hitch
- Saved significant time in erection
- Reduces cost for the contractor
- Reduced time creates earlier revenue for the for the owner
- Reduced onsite waste and storage of materials
- Reduced number of trades on the job

Case Study –Port of Tacoma Warehouses, 1975

Prototypes

Warehouse 2: 120’x480’
G.L. Girders w/ panelized roof. Type V construction

Contract requirements:

- Eliminate concrete tilt-up walls due to time constraints
- Reduce costs
- No interior columns allowed

Warehouse 1: 160’x640’
Bow-string trusses.
Type V construction

507.4 Sprinklered, one story buildings-The area of a Group A-4 building no more than one story above grade plane of other than Type V construction, or the area of a Group B, F, M or S building no more than one story above grade plane of any construction type, shall not be limited where the building is provided with an automatic sprinkler system throughout in accordance with Section 903.3.1.1 and is surrounded and adjoined by public ways or yards not less than 60 feet in width.

Questions?

This concludes Our Presentation on:

Roof and Wall Systems

WoodWorks

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