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

Big Box

Retail

- Research Centers
- Manufacturing

Designed by Structural Design Group
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 1: 160’x640’ Bow-string trusses. Type V construction

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

Roofs

Roofs

Walls
Relevant Code Sections
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.

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

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)**

<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>TYPE I</th>
<th>TYPE II</th>
<th>TYPE III</th>
<th>TYPE IV</th>
<th>TYPE V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>HT</td>
</tr>
<tr>
<td>Primary structural frame&lt;sup&gt;f&lt;/sup&gt; (see Section 202)</td>
<td>3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Bearing walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior&lt;sup&gt;e&lt;/sup&gt;,&lt;sup&gt;f&lt;/sup&gt;</td>
<td>3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Interior</td>
<td>3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Exterior</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Interior</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor construction and associated secondary members (see Section 202)</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Roof construction and associated secondary members (see Section 202)</td>
<td>1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1</td>
</tr>
</tbody>
</table>

Note: FRT = Fire Retardant Treated

**Post and beam system**

See Table 602
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 RATING

<table>
<thead>
<tr>
<th>GROUP</th>
<th>FIRE-RESISTANCE RATING (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, B, E, H-4, I, R-1, R-2, U</td>
<td>3a</td>
</tr>
<tr>
<td>F-1, H-3b, H-5, M, S-1</td>
<td>3</td>
</tr>
<tr>
<td>H-1, H-2</td>
<td>4b</td>
</tr>
<tr>
<td>F-2, S-2, R-3, R-4</td>
<td>2</td>
</tr>
</tbody>
</table>

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

Examples (Concrete tilt-up walls):

- Sub-diaphragms
- Continuous cross-ties
- Anchorage details
Wall Panel Options

Concrete

Light Framed

CLT
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 one way to construct the walls. Design loads are based on Woodworks papers:

Wind Design of Timber Panelized Roof Structures

Seismic Design of Timber Panelized Roof Structures
Panel to footing embeds

4x4 bearing plate

Embed plates typ.

Steel angle ledger/ diaphragm chord. (Optional embeds and rebar for diaphragm chord)

Wood or steel open-web truss girders

Concrete panel w/ single or double vertical and horizontal layers of rebar

Panel to panel and panel to footing embeds as required.

Panel perimeter rebar

4x4 bearing plate w/ WHS or bolts as required

Embed plates and out-of-plane connectors

Cont. ledger

Wood or steel open-web truss girders

Panelized roof

WSP sheathing

Hgt. as required

Parapet as req’d.

Typical tilt-up panel

Wall thickness (varies)
• Standard wall design
• Slender wall analysis

WSP sheathing

Panel perimeter rebar

Panel to footing embeds

Cont. conc. Ftg. As req’d.

Example Panel w=51.5 kips

Typical Concrete Tilt-up Panel without Openings

Bearing Wall System, Site-cast R=4
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 \( R=7 \)

Panel width 12’ max

For manuf. and transportation

2x horiz. girts

W/ joist hangers.

Short panel widths allows for smaller girt sizes and transportation

GL or steel tube columns sized and spaced per design

Wood or steel open-web girder trusses

CC column cap

GL diaphragm chord

Extend panel end members above as req’d. if parapet

Double glue-lam, LVL or PSL columns bolted together at ea. end of panel per design

Panelized roof

Example Panel \( w=6.2 \) kips

Typical tilt-up panel

Typical tilt-up Panel with Parapet

Panelized roof

WSP sheathing

Blocking or bridging as required

Double glue-lam, LVL or PSL columns bolted together at ea. end of panel per design

Cont. turn-down ftg.

Spread ftg at columns
WSP sheathing

Panelized roof panels

Diaphragm chord

FRT WSP over exterior face (not req’d if Type V)

Glue-lam columns - size for charring or steel columns at grid spacing

ECC or ECCO column cap as required

Glue-lam columns or steel columns at grid spacing

FRT WSP (not req’d if Type V)

Cont. turn-down ftg

Spread conc. Ftg

Example Panel w=8 kips

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

- Optional stem wall
- Concealed connector
- Moisture barrier
- Dowel pin
- Optional stem wall
- Toenail or screw connection
- Pressure treated plate
Typical Wall Splice Detail

Lap Joint

Prescriptive connectors- both sides

Butt Joint

Prescriptive connectors- (1) or both sides

Typical Connections Details per 2021 SDPWS Table CB-2
Typical Framing Plan

Possible High Chord Force Detail

Possible Post and Beam Detail

Panelized roof panels

2x ripped plate

Prescriptive shear clips

Diaphragm boundary nailing

Panelized roof panels

Bolt at center of each panel.

Diaphragm GL Chord (inside)

Prescriptive shear clips

Diaphragm GL Chord (outside)

Bolt at center of each panel.

Preferred

2x ripped plate

Panelized roof panels

Bolt at center of each panel.

Diaphragm GL Chord

Prescriptive shear clips between posts
Panelized roof panels over Blocking

- Diaphragm boundary nailing
- Glue-lam BM as required for grid
- ECC column cap as required
- Glue-lam columns or steel columns at grid spacing

Diaphragm boundary nailing

- Shear clips as required
- Bolt or lag screw at center of each panel.
- Glue-lam BM as required for grid
- Prescriptive shear clips
- Direct bearing on wall panel as allows

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, $\Omega_0 = 2.5$, $Cd = 2$.

Proposed CLT Shear Wall Balloting

ASCE 7-22 proposal:

- CLT shear wall system:
  (a) CLT shear walls: $R = 3$, $Cd = 3$, and $\Omega_0 = 3$; and
  (b) CLT shear walls with shear resistance provided by high aspect ratio panels only: $R = 4$, $Cd = 4$, and $\Omega_0 = 3$.

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?

Money Talks

- High-shear Diaphragm?
- Wall panels?
- Foundations?
# Example Plan Cost Comparison Tilt-up Walls

## 2019 Regionalized Cost Comparison of Panels – Material Costs Only

<table>
<thead>
<tr>
<th>Tilt-up Wall Panel Options</th>
<th>Charlotte</th>
<th>San Francisco</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost/Panel</td>
<td>Cost/SF</td>
</tr>
<tr>
<td>Typical Type V Panel-12'-0” width</td>
<td>$5850.06</td>
<td>$13.18</td>
</tr>
<tr>
<td>Typical Type III Panel-12'-0” width</td>
<td>$7191.76</td>
<td>$16.20</td>
</tr>
<tr>
<td>Typical Steel Stud Panel-12'-0” width</td>
<td>$10603.41</td>
<td>$23.88</td>
</tr>
<tr>
<td>Typical Concrete Tilt-up Panel-24'-0” width</td>
<td>$22081.68</td>
<td>$24.87</td>
</tr>
</tbody>
</table>

### 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.

Estimates by EQS Consultants May, 2019
### Approximate Typical CLT Panel Costs

<table>
<thead>
<tr>
<th>CLT</th>
<th>Furnish + Install range</th>
<th>Furnish + Install avg</th>
<th>Material + Delivery range</th>
<th>Material + Delivery avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-ply</td>
<td>$9 to $15 / sf</td>
<td>$12 / sf</td>
<td>$6 to $11 / sf</td>
<td>$9 / sf $21 /sf</td>
</tr>
<tr>
<td>5-ply</td>
<td>$15 to $24 / sf</td>
<td>$19 / sf</td>
<td>$11 to $18 / sf</td>
<td>$14 / sf $33 /sf</td>
</tr>
<tr>
<td>7-ply</td>
<td>$19 to $28 / sf</td>
<td>$23 / sf</td>
<td>$14 to $21 / sf</td>
<td>$18 / sf $41 /sf</td>
</tr>
<tr>
<td>9-ply</td>
<td>$25 to $33 / sf</td>
<td>$30 / sf</td>
<td>$19 to $24 / sf</td>
<td>$22 / sf $52 /sf</td>
</tr>
</tbody>
</table>

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.
The selection of tilt-up panel type can have a significant impact on the load distribution into a diaphragm and shear walls, which can affect 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.
You can install optional shear walls or fire walls to reduce diaphragm spans to avoid high-shear diaphragms *(Doesn’t have to be a fire wall)*.
High Shear Diaphragm Nailing

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)

Out-of-plane Connection ties

Sub-diaphragm (Typ.)

Max A/R 2.5:1

Cross ties and conn.’s

Out-of-plane ties

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:

- \( S_{DS} = 1.0 \)
- \( I_e = 1.0 \)
- \( R = \text{varies} \)

### Wind Design of Timber Panelized Roof Structures

Wind: Nominal 3 second gust

- basic wind speed = 115 mph
- Exposure C
## Seismic Design Comparisons

<table>
<thead>
<tr>
<th>Concrete Tilt-up-From example papers</th>
<th>Wood Tilt-up</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Concrete Tilt-up</strong></td>
<td><strong>Light-framed wood tilt-up walls</strong></td>
<td></td>
</tr>
<tr>
<td><strong>R=4</strong> Bearing wall-concrete shear walls</td>
<td><strong>R=7 Building Frame</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Design load coefficients</strong></td>
<td><strong>STR</strong></td>
<td><strong>ASD</strong></td>
</tr>
<tr>
<td>Cs</td>
<td>0.25</td>
<td>-----</td>
</tr>
<tr>
<td>Fpx</td>
<td>0.25</td>
<td>-----</td>
</tr>
<tr>
<td>Wn/s</td>
<td>2366 plf</td>
<td>1656 plf</td>
</tr>
<tr>
<td>Rn/s</td>
<td>596 k</td>
<td>417.2 k</td>
</tr>
<tr>
<td>Wn/s</td>
<td>2366 plf</td>
<td>1656 plf</td>
</tr>
<tr>
<td>Rn/s</td>
<td>596 k</td>
<td>417.2 k</td>
</tr>
<tr>
<td>Vd</td>
<td>1987 plf</td>
<td>1391 plf</td>
</tr>
<tr>
<td>Tn/s</td>
<td>250.4 k</td>
<td>175.3 k</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Concrete Tilt-up- example papers</th>
<th>Wood CLT Tilt-up</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design load coefficients</strong></td>
<td><strong>R=4</strong></td>
</tr>
<tr>
<td>Cs</td>
<td>STR</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
</tr>
<tr>
<td>Fpx</td>
<td>0.25</td>
</tr>
<tr>
<td>Wn/s</td>
<td>2366 plf</td>
</tr>
<tr>
<td>Rn/s</td>
<td>596 k</td>
</tr>
</tbody>
</table>

**Wn/s % increase (+)/decrease (-)***  

- 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

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

All photos and artwork by StructureCraft
Erection completed

Exterior completed

All photos and artwork by StructureCraft
Finished Interiors

All photos and artwork by StructureCraft
Case Study - StructureCraft New Shop Building, 2017

10,000 sq. ft. CLT Warehouse in Langford, British Columbia.
• 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
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 owner
• Reduced onsite waste and storage of materials
• Reduced number of trades on the job
Case Study — Port of Tacoma Warehouses, 1975

Prototypes

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

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

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

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