Achieving a USRC Gold Rating is both economical and a good investment

USRC Tiltup Seismic Retrofit Study
Contributors

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SP3 risk modeling of tilt-up designs
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Construction cost estimating
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Construction cost estimating
Damon Ho, Simpson Strong tie  
Construction cost estimating
John Lawson, Cal Poly SLO  
History of tilt-up code evolution
David McCormick, SE, SGH  
Structural engineering
Confidential, retailer  
Building layout, replacement cost and description
Objectives


- Determine the expected USRC performance rating for each of the four designs along the dimensions of SAFETY, DAMAGE and RECOVERY.

- Estimate the cost to seismically retrofit each of the buildings to achieve a USRC GOLD rating (minimum of 4 stars in each of the three dimensions)
Assumptions
Based on information provided by confidential retailer

Code: Conforms to 1973, 1976, 1991UBC or ASCE 7-10


Location: Los Angeles, CA (34.05, -118.25, Class D soil)

Construction: Concrete tilt-up with panelized plywood roof and interior steel post columns. Rectangular with no significant re-entrant corners or other irregularities.

Replacement cost: ~$142/sf = $19.2 million

Retrofit: Occurs simultaneously with major renovation/refresh schedule that includes replacing ceiling. Access to underside of roof is available. Roofing is not replaced.
Limitations

Irregularities

Many tilt-up buildings contain irregularities such as large re-entrant corners lacking collector elements. This study does not consider buildings with these features or mezzanines.

Deterioration

Concrete, steel and wood deterioration within a building can impact seismic performance. This project assumes that the building has been well maintained.

Age

Tilt-up buildings constructed in the 1950’s, 1960’s and early 1970’s may have very significant deficiencies in the anchorage of walls to foundations, panel interconnections, and wall reinforcing. This study considers only buildings designed to the 1973UBC or later when many of these design deficiencies were addressed in codes.

Soil conditions

Tilt-ups with warehouse occupancies may be located in industrial areas, near the water or other areas with poor soil conditions that can increase damage or be expensive to retrofit, in particular under wall footings and interior slabs. This study assumes a retail style building located in a suburban or urban environment without significant soil deficiencies.

Rooftop equipment

Assumed properly anchored to roof.
Typical Roof Diaphragm Details

1973 UBC
24-ft roof + 3-ft parapet, 6½” panels
Wall Anchorage: 0.20Wp(ASD)
Wall Force (out-of-plane): 0.20Wp(ASD)
Base Shear: V=0.133W (ASD)
Diaphragm: Fp=0.133Wp(ASD)

1976-1994 UBC
27-ft roof + 3-ft parapet, 7½” panels
Wall Anchorage: 0.30Wp(ASD)
Wall Force (out-of-plane): 0.30Wp(ASD)
50% increase in middle of diaphragm forces in 1991-1994 UBC
Base Shear: V=0.183W (ASD)
Diaphragm: Fp=0.183Wp(ASD)

1997 UBC and 2000+ IBC
30-ft roof + 3-ft parapet, 9¼” panels
Wall Anchorage: 0.80Wp(LRFD)
Wall Force (out-of-plane): 0.40Wp(LRFD)
Base Shear: V=0.244W (LRFD)
Diaphragm: Fp=0.25Wp(LRFD)

Assume 2:1 aspect ratio similar to subject building (500x270)

Diaphragm Nailing
Zone 1  10d@ 6, 6, 12 (Boundary, panel edges, field)
Zone 2  10d@ 4, 6, 12
Zone 3  10d@ 2-½, 4, 12
Zone 4  10d@ 2-½, 4, 12 with 3x framing at panel edges
Zone 5  2 lines of 10d@ 2-½, 4, 12 with 4x framing at panel edges
Zone 6  2 lines of 10d@ 2-½, 3 12 with 4x framing at panel edges

Diaphragm Framing
15/32” Struct I ply, panel edges align with purlins and subpurlins
2x4x8’ subpurlins @ 2’oc
4x purlins 20’ spans @ 8’oc
Glulam girders 40’ spans @ 20’oc

Credit: John Lawson, Cal Poly SLO
Approximate USRC Safety Performance

- Based on SEAONC EPRS and ASCE 41-13 (NC = Nonconforming, C=Conforming)
- Based on discussions with Dr. John Lawson and David McCormick, SE

<table>
<thead>
<tr>
<th>PC1 (Precast/Tilt-Up Concrete Shearwalls - Flexible Diaphragms)</th>
<th>EPRS Rating</th>
<th>1973 UBC</th>
<th>1976 UBC</th>
<th>1991 UBC</th>
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Approximate USRC SAFETY Rating

1 star 1 star
1 to 2 stars 4 to 5 stars

* Assumes seismic bracing of ceilings and light fixtures + racks > 6’ tall, required as part of standard remodel

Credit: SEAONC, ASCE
**Expected Seismic Performance**

- Based on information provided by HB-Risk, ASCE 41-13 and SEAONC EPRS
- 500’ x 270’ floor plate
- Based on Design Level event with return period in Los Angeles ~711 years

<table>
<thead>
<tr>
<th>CODE LEVEL</th>
<th>SAFETY*</th>
<th>DAMAGE</th>
<th>RECOVERY**</th>
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<tbody>
<tr>
<td>1973 UBC</td>
<td>1 star</td>
<td>28% (2 star)</td>
<td>99 days (3 star)†</td>
</tr>
<tr>
<td>1976 UBC</td>
<td>1 star</td>
<td>26% (2 star)</td>
<td>95 days (3 star)†</td>
</tr>
<tr>
<td>1991 UBC</td>
<td>1 to 2 stars</td>
<td>21% (2 star)</td>
<td>86 days (3 star)†</td>
</tr>
<tr>
<td>ASCE 7-10</td>
<td>4 to 5 stars</td>
<td>8% (4 star)</td>
<td>15 days (4 star) ††</td>
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</tbody>
</table>

* Based on ASCE 41-13 and SEAONC EPRS

** Assumes retailer has a BORP program and financing in place

† Assumes at least some structural damage that may produce a Yellow Tag, where city closes building until structural repairs are completed following issuance of a permit (8wk permitting delay as per REDi)

†† Minimal structural damage and Green Tag expected, allowing for occupancy while repairs are ongoing, so no permitting delay. Recovery time based on time required to restore basic functionality
Retrofit

- Based on results from HB-Risk study, **1997UBC and later designed buildings, can achieve a USRC GOLD rating** so long as rapid response measures are put in place: post event inspection, retainers with contractors, and adequate financing. For national big-box retailers all three are well within their capabilities. This eliminates REDi impeding factors that can substantially extend repair times.

- Therefore, the retrofit expectation will be that pre 1997UBC buildings will be brought into conformance with the 1997UBC/2000IBC.

- The HB-Risk study indicates that little damage occurs in the tilt-up walls themselves, either in- or out-of-plane, at the design level event, so that retrofit will be limited to the roof diaphragm and its connections to the walls.

- Assumption is also that in a major renovation/refresh for retailer, the existing ceiling is dropped and replaced with a current code compliant ceiling, including grid and light fixture bracing.
Retrofit Assumptions

- Per the study by John Lawson, requirements for concentric wall and crosstie anchors appeared in the 1997UBC.
- 1973UBC – Assume old style wall-roof, subdiaphragm and crosstie connections will be completely replaced because of eccentric connections and low design forces.
- 1976-1994UBC – Assume wall-roof and crosstie connections will be doubled up in order to become concentric. The increase in wall anchorage forces from 0.30Wp (ASD) to 0.80Wp (LFRD) would be achieved by the additional anchors.
- 1976-1994UBC – Assume subdiaphragm details are all replaced in direction parallel to 4x purlins, and use newer style detail with block between subpurlins.
- All nailing augmentation done from below roof.
- Plywood is oriented with panel edges aligned with 2x4 subpurlins and 4x purlins so that supplementary blocking is not needed.
- (E) 2x4 subpurlins need to be doubled where panel edge nailing requires 3x or 4x elements.
Retrofit Details

1973UBC brought to compliance with 1997UBC

Wall anchors
Parallel to girders: Use (e) 4x14 purlins (DETAIL D) @ 8'oc
Perp to girders: Space at 8’ oc use block between purlins 16’ back (DETAIL B) 4x block with Simpson 2-HUC hanger, 5/8”x16’ rod and 3” pl

Crossties
On girders at 20'OC: Ties at 40' girder span (DETAIL F)
On purlins at 40'OC: Ties at 20' purlin span (DETAIL G)

Girder to wall ties
At 20'OC parallel to long direction (DETAIL E)

Sub diaphragms
Parallel to girders: use (e) 4x14 purlins with std wall anchors (DETAIL D)
Perp to girders: space at 8' oc use block between purlins 16' back (DETAIL B)

Diaphragm nailing augmentation
Calculate average boundary nailing for 1973 and 1997 UBC designs and augment nailing with clips to achieve equivalent average spacing (DETAIL H).
- Simpson A35 clips with #6x1/2” screws to underside of plywood deck or as a preferred alternative, re-nail from above when roofing is replaced. The nailing will be lower cost when done from above.
- Assume (e) ledgers at wall edges are 3x or 4x Where 1997 UBC panel edge requirements require 3x or 4x at subpurlins, double up (e) 2x4.

Note: Based on cost estimates provided by Simpson Strongtie variation as a function of the precise size of the hold down anchors is relatively small compared with the average material and installation cost. Therefore, the selection of specific anchor was based on simplified calculations.
Retrofit Details

1976 and 1991 UBC brought to compliance with 1997 UBC

Wall anchors
Parallel to girders: Use (e) 4x14 purlins (DETAIL D), assuming 1-sided connection already exists. Single Simpson HDU4-SDS2.5 with 5/8" rod.
Perp to girders: Space at 8' oc use block between purlins 16' back (DETAIL B). 4x block with Simpson 2-HUC hanger, 5/8"x16' rod and 3" plate.

Diaphragm crossties
On girders at 20'OC: Ties at 40' girder span (DETAIL F), assuming 1-sided connection already exists. Single Simpson HCSTR4 with 3/4" bolts.
On purlins at 40'OC: Ties at 20' purlin span (DETAIL G), assuming 1-sided connection already exists. Single Simpson HHDQ11 with 1" rod.

Girder to wall ties
At 20'OC parallel to long direction (DETAIL E), assuming 1-sided connection already exists. Single Simpson HHDQ11 with 1" rod.

Sub diaphragms
Parallel to girders: use (e) 4x14 purlins with std wall anchors (DETAIL D). Wall anchors achieve this.
Perp to girders: space at 8' oc use block between purlins 16' back (DETAIL B). Wall anchors achieve this.

Diaphragm nailing augmentation
Calculate average boundary nailing for 1976 and 1997 UBC designs and augment nailing with clips to achieve equivalent average spacing (DETAIL H). Augmentation would be slightly less for 1991 UBC where higher forces in middle half of diaphragm were assumed.
- Simpson A35 clips with #6x1/2" screws to underside of plywood deck or as a preferred alternative, renail from above when roofing is replaced. The nailing will be lower cost when done from above.
- Assume (e) ledgers at wall edges are 3 or 4x. Where panel edge requirements require 3 or 4x at subpurlins, double up (e) 2x4.
## Retrofit Quantities

1973UBC brought to compliance with 1997UBC

<table>
<thead>
<tr>
<th>Connection</th>
<th>Piece*</th>
<th>Rod</th>
<th>Other</th>
<th>Detail</th>
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<tr>
<td>Purlin to tiltup wall anchors (epoxied into 6” wall)</td>
<td>(246) HDU4-SDS2.5</td>
<td>(246) 5/8” rod x 18”</td>
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<td>D</td>
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<tr>
<td>Subpurlin to tiltup wall anchors (epoxied into 6” wall)</td>
<td>(132) HUC hangers</td>
<td>(66) 5/8”dia x 16'</td>
<td>(66) 3” bearing pl.</td>
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<td>Girder crossties</td>
<td>(288) HCSTR4 w/ ¾” bolts</td>
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<td>Purlin crossties</td>
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<td>(50) HHDQ11</td>
<td>(50) 1” rods x 18”</td>
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<td>Diaphragm strengthening</td>
<td>(25,000) A35</td>
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<td>PH6-121 screws to plywood deck</td>
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<td>Subpurlin augmentation</td>
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* (x) Refers to the total number of pieces, not the total number of detail locations
## Retrofit Quantities

1973 and 1991UBC brought to compliance with 1997UBC

<table>
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<tr>
<th>Connection</th>
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<td>(123) 5/8&quot; rod x 18&quot;</td>
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<td>(epoxied into 6&quot; wall)</td>
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<td>(123) 5/8&quot; rod x 18&quot;</td>
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<td>Purlin crossties</td>
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<td>(144) 1&quot; rods x 24&quot;</td>
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* (x) Refers to the total number of pieces, not the total number of detail locations
** 1991 and 1994UBC increased OOP forces at middle half of diaphragm so this retrofit would be a bit conservative
Retrofit Details
From FEMA 547

Credit: FEMA

Through bolt as lower cost alternative

Through bolt as lower cost alternative

Figure 16.4.2.3: Enhanced Girder Connection at Pilaster
Retrofit Details
From FEMA 547 and Simpson Strongtie

Figure 22.2.3-1A: Roof Plan with Diaphragm Cross-Tie System Using Subdiaphragms, Shown for Wood Diaphragm

Diaphragm nailing augmentation
Replacement or patching of roofing and nailing from above as preferred alternative

Credit: FEMA
Credit: Simpson
Retrofit Pricing

- Price includes materials, installation and inspections
- General conditions, profit and overhead included.
- Mobilization and demolition of ceilings not included because during renovation and refresh process, contractor will already incur these costs.
- Costs are averaged from estimates provided by Simpson Strongtie, Optimum Seismic and Concrete West.

<table>
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<th>Connection</th>
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* All markups distributed to line items: Installation, Permits, Rentals, Inspections, GC, OH, Profit
Pricing provided from retailer for two recent Southern California projects and which includes all markups.

- Location impacts costs significantly. Urban and coastal areas are typically more expensive.
- The specific retrofit implemented was provided for Location 2. It is similar to that proposed in this study.

**Location 1**
- Range of cost is $4 to $5 per square foot
- $540,000 to $675,000
- 2.8% to 3.5% of replacement cost

**Location 2**
- $2 per square foot
- $222,000
- 1.4% of replacement cost
Retrofit Details
From Confidential Retailer

Cost Data

Hardware: $54,701
Lumber: $25,350
Labor: $142,072
Summary

To achieve a USRC GOLD rating, assuming post earthquake engineering inspection and contractor mobilization retainers are in place, and retailer has adequate financing in place so that REDi impeding factors are not triggered.

Building parameters: 135,000sf, 500’x270’ floorplan, no irregularities, $19,200,000 replacement cost, located in Los Angeles

Cost to retrofit a 1973UBC compliant building: $448,000  
$3.32 / sq.ft.  
2.3% of replacement cost

Cost to retrofit a 1976UBC through 1994UBC compliant building: $197,000  
$1.46 / sq.ft.  
1.0% of replacement cost

Cost to achieve USRC GOLD for a 1997UBC or later building: $0  
(With inspection, mobilization and financing in place)
**Return on Improved Performance**

- Older buildings retrofitted to be USRC Gold compliant
- Building replacement cost value (RCV): $19,200,000
- Average CA store revenue based on public information ~ $134,000 per day

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### DAMAGE IN A DESIGN LEVEL EVENT *

<table>
<thead>
<tr>
<th>CODE LEVEL</th>
<th>Existing</th>
<th>Retrofit</th>
<th>Savings at RCV</th>
<th>Existing</th>
<th>Retrofit</th>
<th>Revenue savings</th>
<th>Total Return</th>
<th>Retrofit Cost</th>
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<td>15</td>
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<td>$15,180,000</td>
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<td>15</td>
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<td>$9,480,000</td>
<td>$12,110,000</td>
<td>$197,000</td>
<td>61</td>
</tr>
</tbody>
</table>

* From SP3 evaluation Design Event has 711 year return period at Los Angeles site.
Return on Improved Performance to Achieve USRC Gold Rating

- Annualize ROI when older buildings retrofitted to be USRC Gold compliant
- Building replacement cost value (RCV): $19,200,000
- Average CA store revenue based on public information ~ $134,000 per day

### ANNUAL DAMAGE AND RETURNS *

<table>
<thead>
<tr>
<th>CODE LEVEL</th>
<th>Existing</th>
<th>Retrofitted</th>
<th>Savings at RCV</th>
<th>Average Annual Loss*</th>
<th>Average Annual Recovery (days)</th>
<th>Total Annual Savings (Return)</th>
<th>Retrofit Cost</th>
<th>Annual ROI</th>
<th>PV Return over 10 years**</th>
<th>BCR over 10 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973 UBC</td>
<td>0.42%</td>
<td>0.06%</td>
<td>$69,696</td>
<td>2.37</td>
<td>0.27</td>
<td>$281,264</td>
<td>$350,960</td>
<td>78%</td>
<td>$2,846,597</td>
<td>6.4</td>
</tr>
<tr>
<td>1976 UBC</td>
<td>0.38%</td>
<td>0.06%</td>
<td>$62,016</td>
<td>1.98</td>
<td>0.27</td>
<td>$228,268</td>
<td>$290,284</td>
<td>148%</td>
<td>$2,354,461</td>
<td>12.0</td>
</tr>
<tr>
<td>1991 UBC</td>
<td>0.28%</td>
<td>0.06%</td>
<td>$42,048</td>
<td>1.50</td>
<td>0.27</td>
<td>$164,974</td>
<td>$207,022</td>
<td>105%</td>
<td>$1,679,136</td>
<td>8.5</td>
</tr>
</tbody>
</table>

* From SP3 evaluation, average annual values include overall earthquake risk from multiple events on an annualized basis.
** 10 years is recommended by retailer
Design Performance Goal for New Buildings

- Buildings built to current code are likely to receive a USRC Gold Rating with no additional construction costs
- Owner needs to have in place:
  - Business Recovery program that includes engineering inspection and contractor mobilization
  - Adequate financing to complete repairs

<table>
<thead>
<tr>
<th>CODE LEVEL</th>
<th>SAFETY</th>
<th>DAMAGE</th>
<th>RECOVERY</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCE 7-10</td>
<td>4 to 5 stars</td>
<td>8% (4 star)</td>
<td>15 days (4 star)</td>
</tr>
</tbody>
</table>