sbm STRIK BALDINELLI MONIZ
CIVIL • STRUCTURAL ENGINEERS

STRUCTURAL DESIGN & OPTIMIZATION OF MIDRISE LIGHT WEIGHT WOOD FRAMED BUILDINGS

PRESENTER: MIKE BALDINELLI, P.ENG, MESC, PRINCIPAL

PRESENTATION OUTLINE

- COMPANY INTRODUCTION AND WOOD DESIGN EXPERIENCE
- STRUCTURAL DESIGN AND OPTIMIZATION OF MIDRISE WOOD BUILDINGS
- CASE STUDIES & COST ANALYSIS

FIRM :STRIK BALDINELLI MONIZ

- 2004 Practice Opened, Civil, Structural , Mechanical and Electrical Engineering, Office's in Waterloo and London

- **Office Staffing:** 50 Staff Members, 12 P.Eng's, 5 with Masters Education, 1 PhD

- **Wood Design Experience:** Designed over 45+ , commercial wood framed buildings, 1-6 stories Focus on Light Weight Wood Framed Buildings (LWWF)

- Guest speaker at Ontario Wood Work Council seminars.

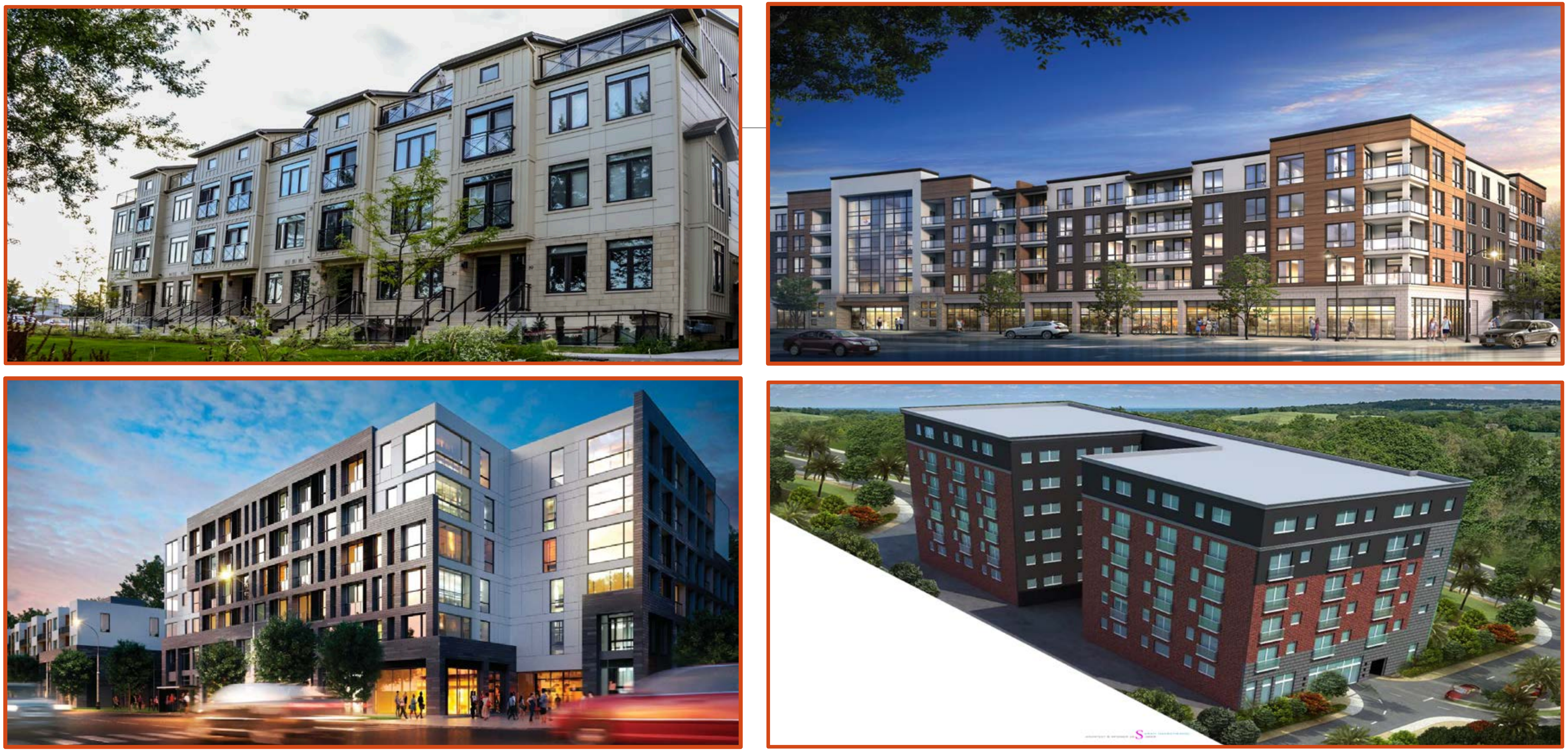
- Published in several industry magazines on the topic of "Structural Design of Wood Framed Buildings' such as: *Ontario Home Builders, Canadian Construction, Ontario Wood Works and Canadian Home Builders Magazines.*

- **Michael Baldinelli,** awarded "Wood Engineer Advocate, 2016" Ontario Wood Council


VARIETY
BROCK
VARIETY
COFFEE CAFE


ALBERT

WOODLAND VILLAGE, London, Ontario
Winner, “2013 Best Multi-Level Wood Building in Ontario”
Ontario Wood Works Award



TEMPLAR FLATS:

First 6 storey wood framed building completed in Ontario.

Winner, “2016 Best Multi-Level Wood Building in Ontario”
Ontario Wood Works Award

Case Study: Templar Flats , CWC

Overview

- Lateral Loads on Buildings

  Calculation of Loads and how they are distributed on a wood building

- How to resist the **lateral loads and building deflections/inter-storey drift**?

- **Strik Baldinelli Moniz,** SX·N·WD Lateral Design Software

- Building Design Optimization

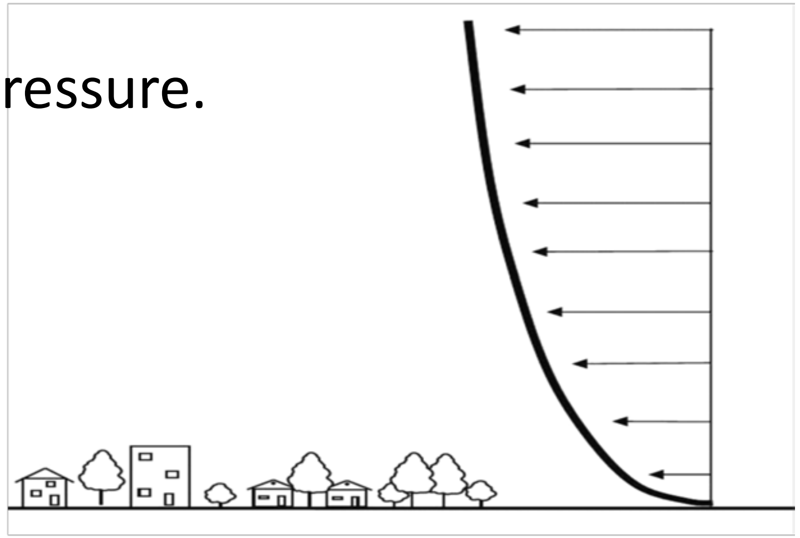
Lateral Loads on Buildings

Wind Loads: Based on building façade area and wind pressure.

$Wind\ Pressure:\ p = I_w q C_e C_g C_p$ (OBC 2012 Cl. 4.1.7.1(1))

$Exposure\ Coefficent:\ C_e = \left(\frac{h}{10}\right)^{0.2} \geq 0.9$ (OBC 2012 Cl. 4.1.7.1(5)(a))

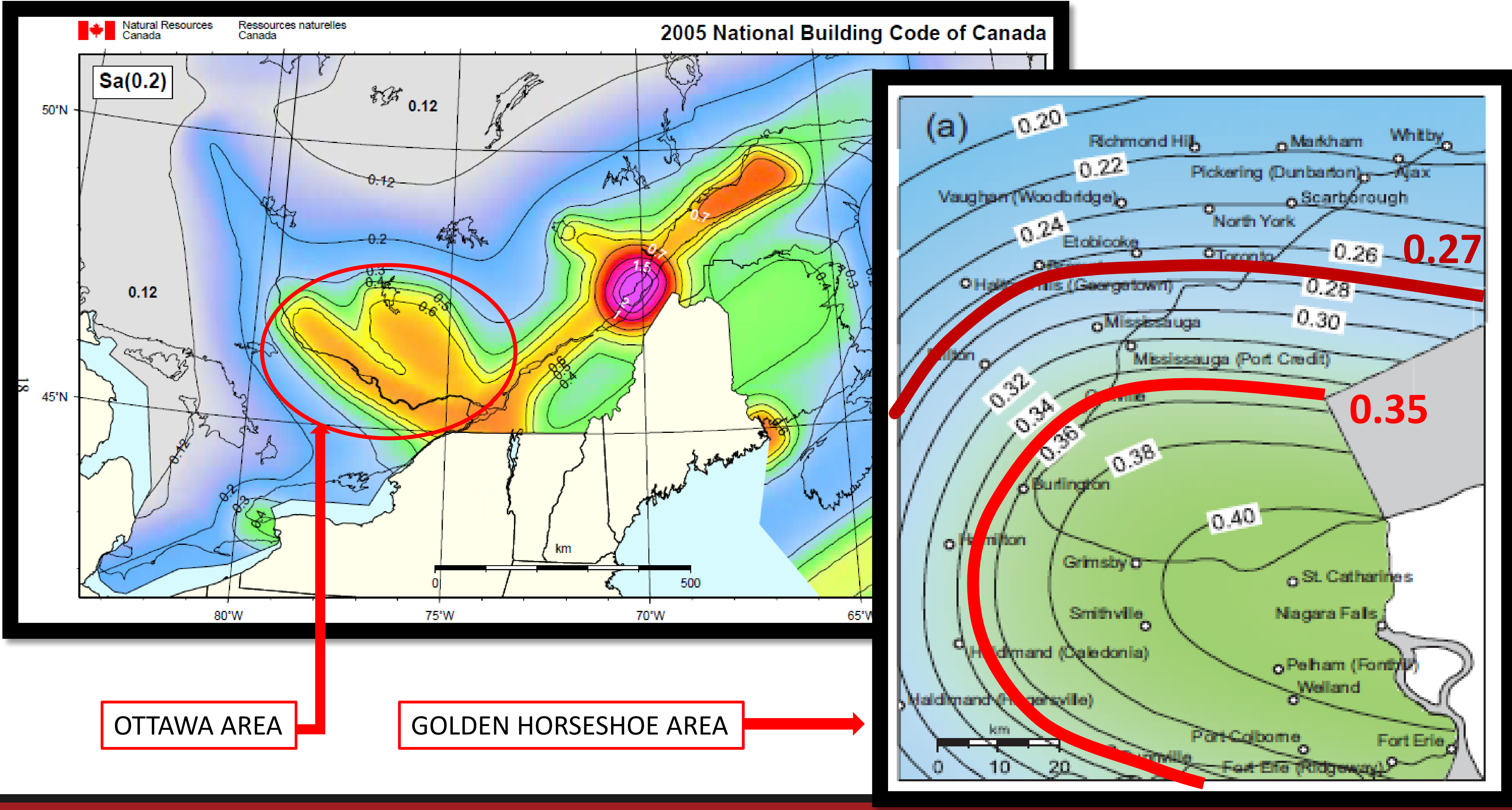
Ex. 4 storey vs 6 storey, Wind Loads increase about 15%



Seismic Loads:

$$V = \frac{S_a M_v I_E \boxed{W}}{R_d R_o}$$

Wood vs. Concrete: Concrete buildings weigh (mass) up to 3 to 4 time more than a wood building, Seismic loads are directly proportional to the mass



OTTAWA AREA

GOLDEN HORSESHOE AREA

Earthquake Loads and Ductility

Seismic loads are reduced by the ductility of the building materials.

Materials	R_d	R_o	R_dR_o
Wood Shear Walls	3.0	1.7	5.1
Wood Shear walls + gypsum	2.0	1.7	3.4
Masonry Shear Walls	1.5	1.5	2.25
Concrete Shear Walls	1.5	1.3	1.95

More ductile, lower load

$$V = \frac{S_a M_v I_E \boxed{W}}{R_d R_o}$$

Less ductile, higher load

What does this mean:

Concrete/Masonry buildings attract TWICE as much load vs ‘all wood buildings’

OBC 2012 –Seismic Loading

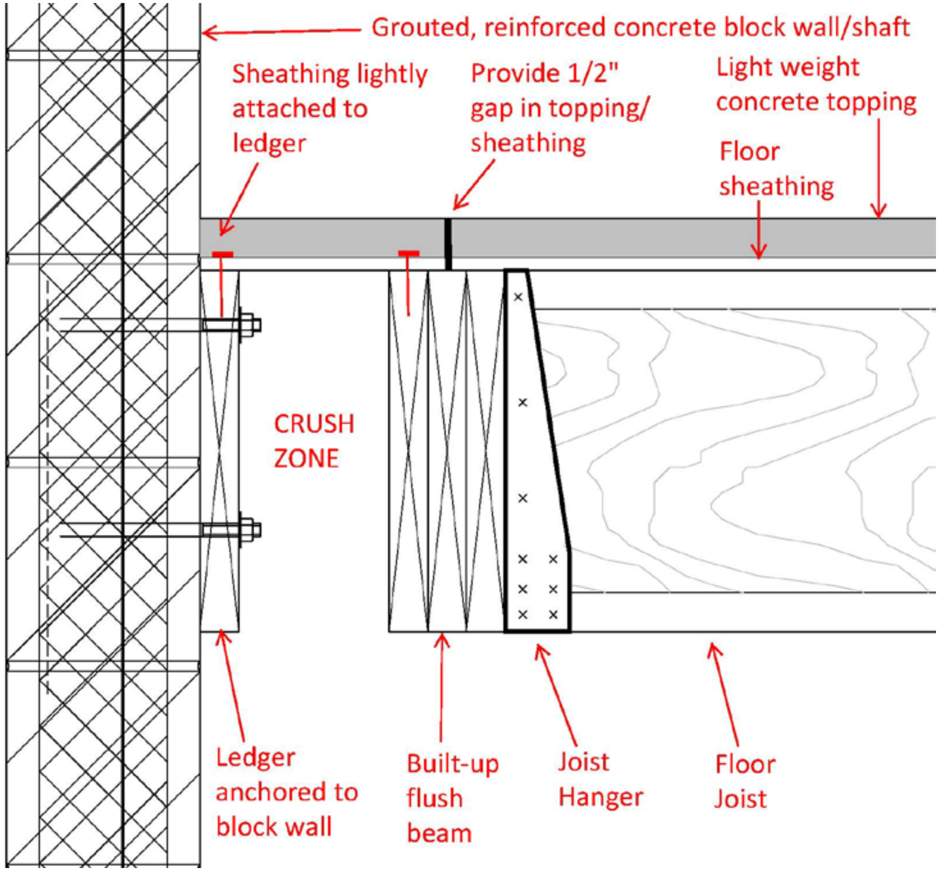
- ***Structural Separation*, 4.1.8.3 (6) (Ontario Code)**

As per OBC 2012 all stiff elements (such as concrete, masonry and precast wall panels) must be included in the seismic force resisting system, or they have to be **structurally separated from the building such that no interaction takes place as the building moves in an earthquake.**

To achieve the structural separation, OBC 2012 article 4.1.8.14 requires the adjacent structures to be separated by the square root sum of squares of their individual deflections.

For example, if the masonry shaft is calculated to deflect 3", and the wood structure is calculated to move 4", then the separation distance, d, is calculated as follows:

$$d = \sqrt{3^2 + 4^2} = 5\text{“ (Crush Zone)}$$



Resisting Lateral Loads

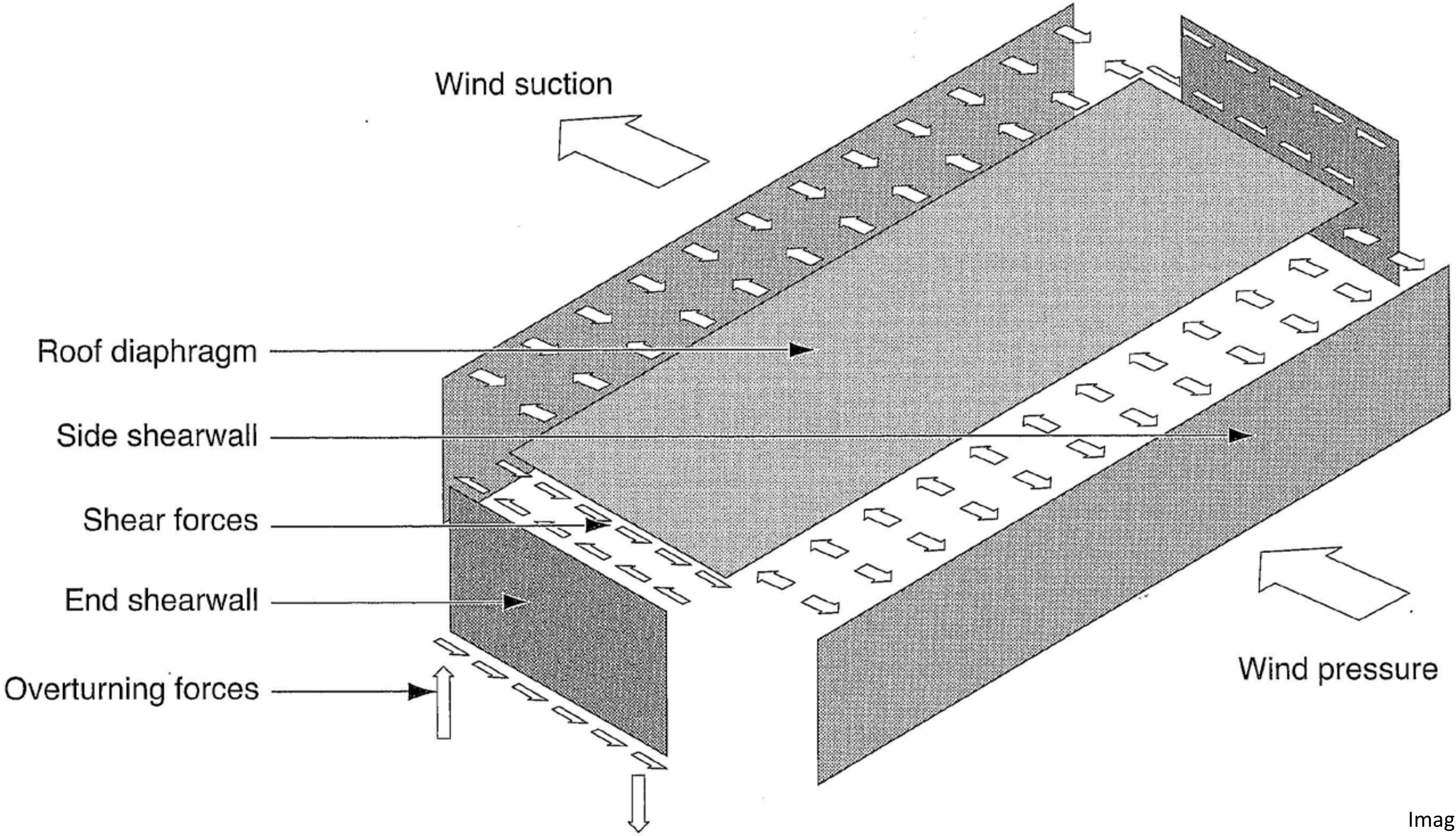


Image Courtesy of Canadian Wood Council

Distribute Lateral Loads on a Wood Building

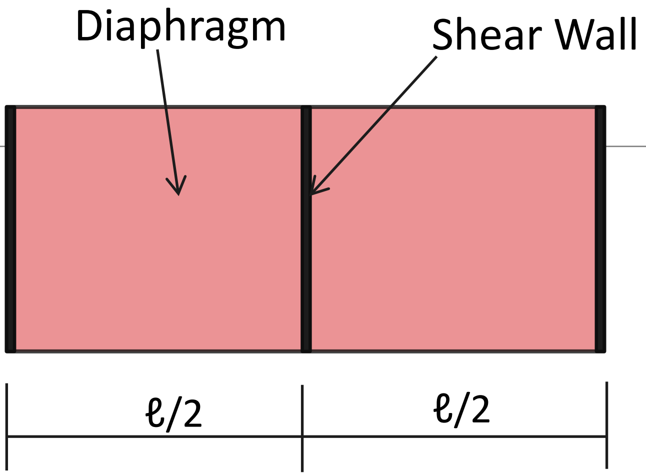
Two options for floor stiffness in our analysis:

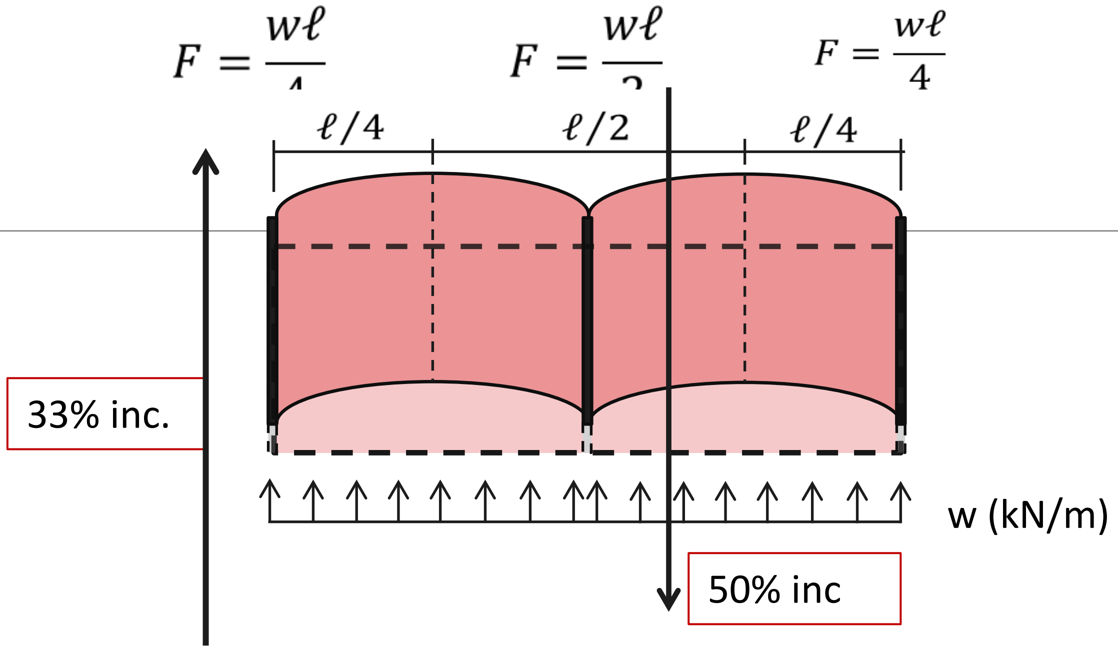
- **Flexible diaphragm** – deforms
- **Rigid diaphragm** – no deformation – keeps its shape
- **Semi-Rigid:** somewhere between Rigid and Flexible

APEGBC (3.5.2 (j)) **(Association of Professional Engineers Geoscientists British Columbia)**

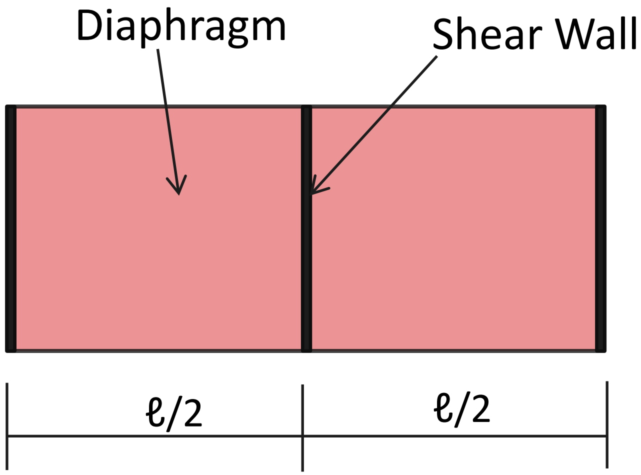
Recommends performing both a flexible and rigid analysis to determine maximum loads on each wall, if the force increases more than 15% due to the change, then design for envelope of forces

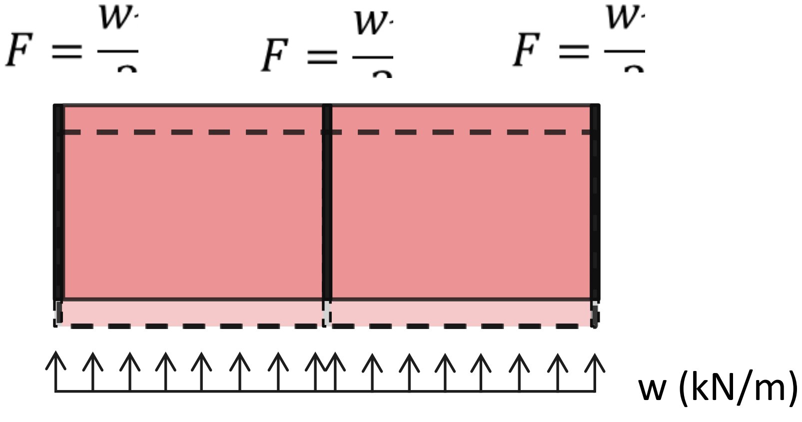
FLEXIBLE





RIGID





Resisting Lateral Loads

- Wood shear walls are stud walls with wood based panels (and gypsum), along with hold downs
- Loads resisted by Shear Walls:
  - Sheathing and nails resist shear load (not studs)
  - Hold downs and posts at the ends prevent tipping and overturning
  - Shear is transferred between floors by attaching walls through diaphragms
- Gypsum cannot be used to resist seismic loads in buildings over 4 stories!

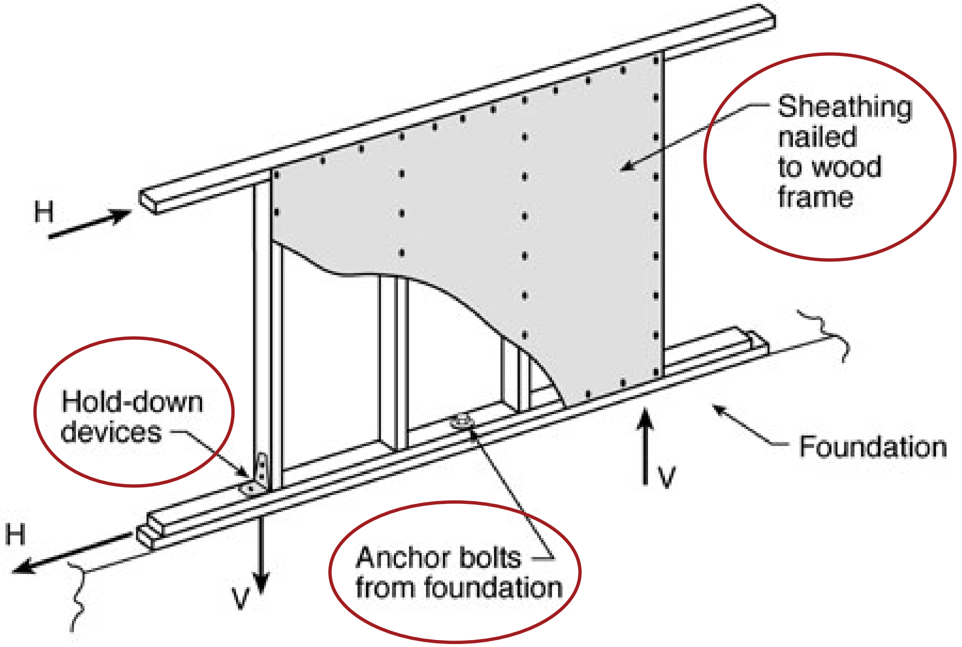
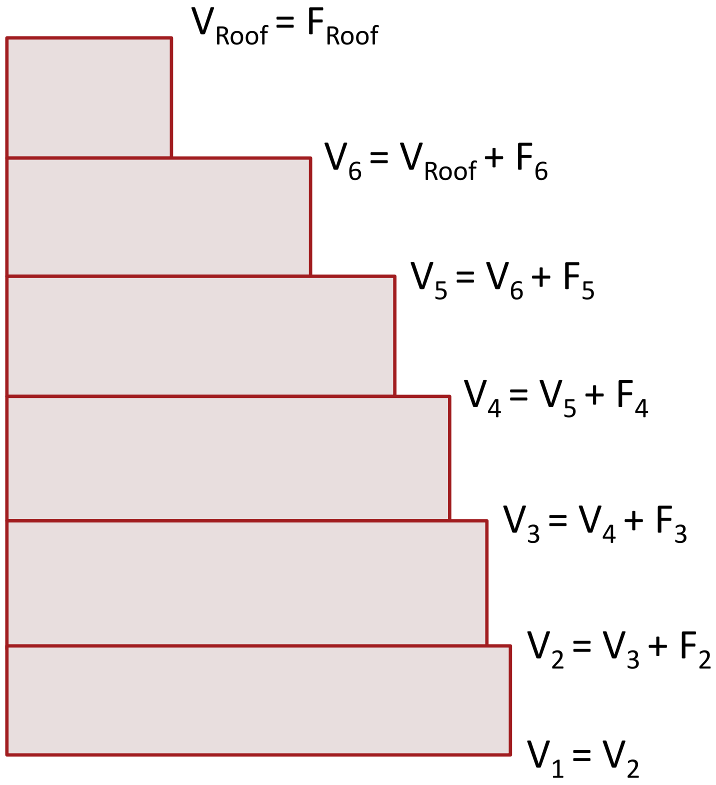


Image Courtesy of National Research Council Canada

Strength Checks - Shear



Shear Diagram

Check: Is Shear Capacity > Shear Force?

How to increase shear Capacity in a Wood Shear Wall?

A) Sheathing:

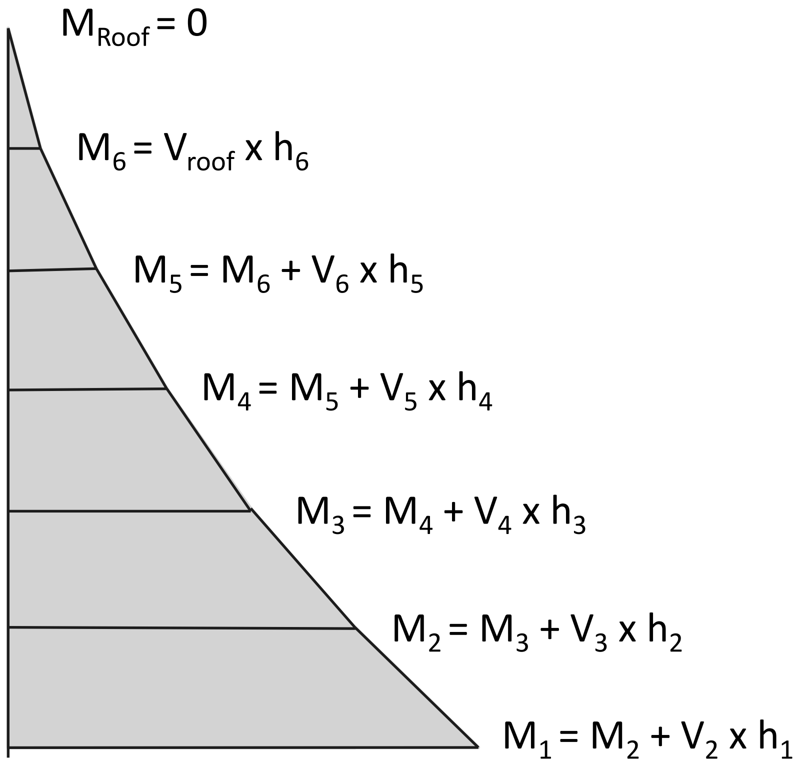
- Thickness
- Material (OSB, plywood)
- Add to both faces of wall

B) Change nail spacing

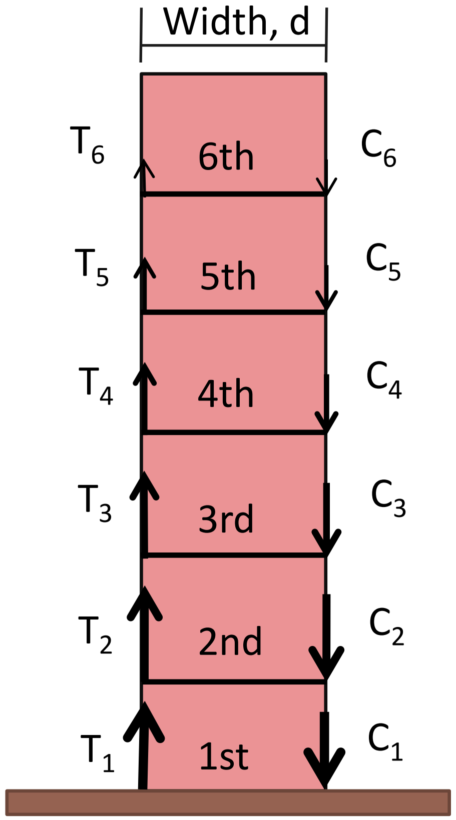
C) Increase nail size or diameter

A lot of design combinations, 100+

Strength Checks - Moment



Moment Diagram



Tension/Compression

$$T_i = C_i = \frac{M_i}{d}$$

-Built-up wood posts at each end used to resist compressive force

-Hold down at each end used to resist tension force

Hold Downs

Traditional Hold Down

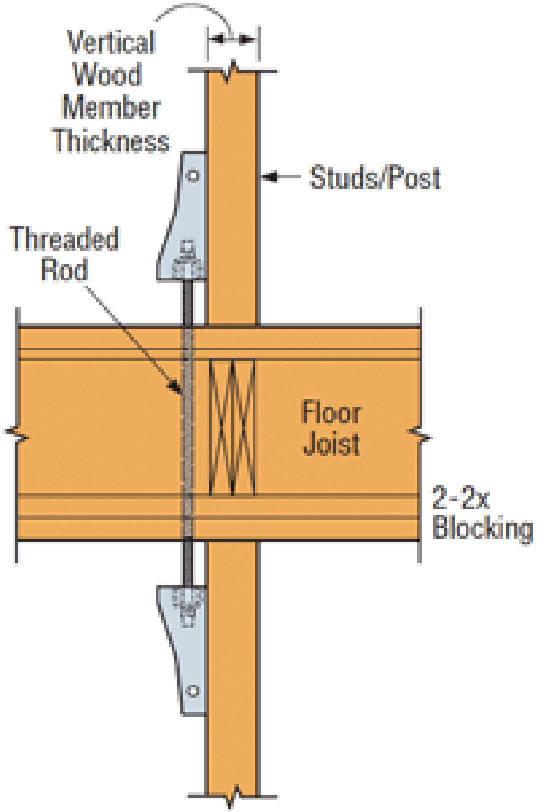


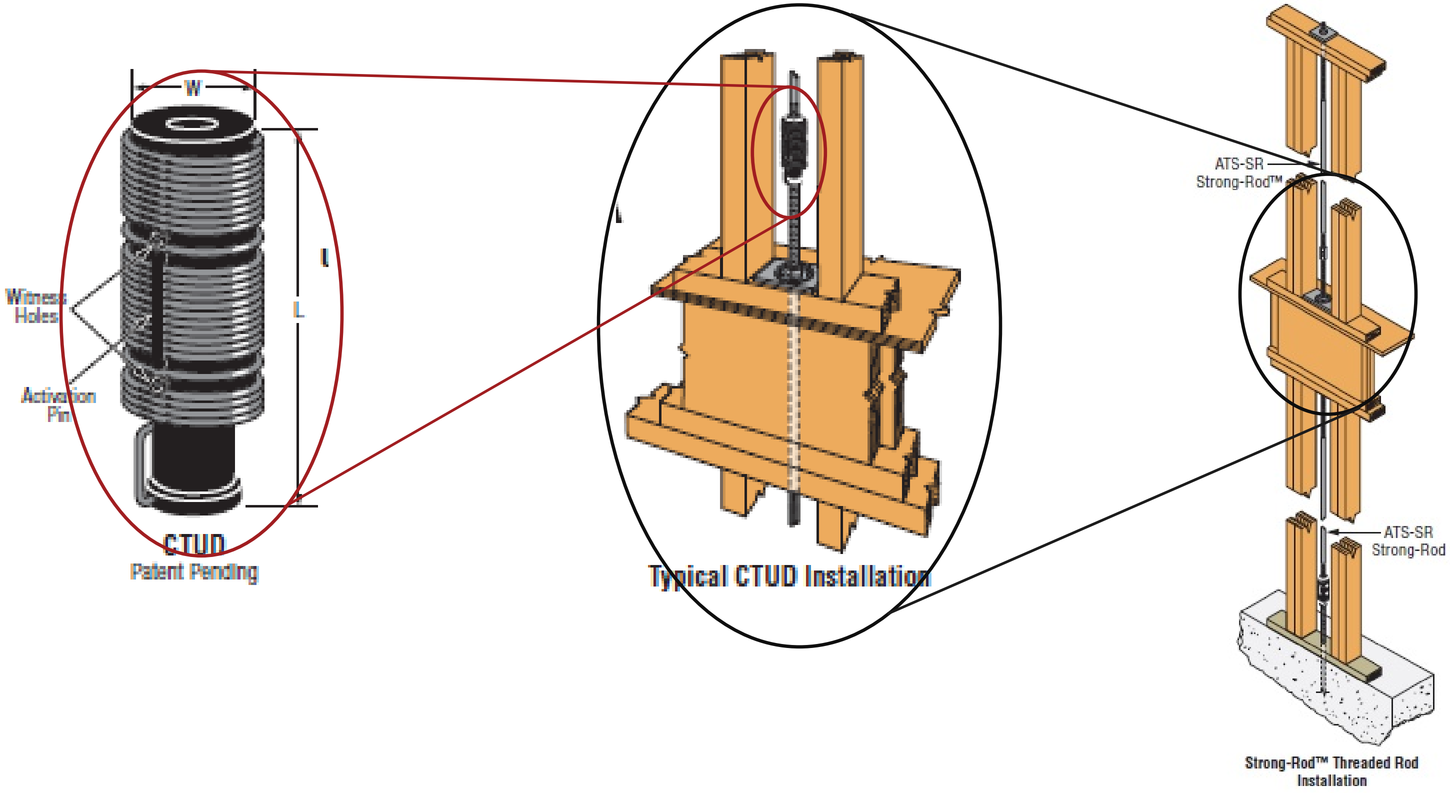
Image Courtesy of Simpson Strong Tie

Hold Downs

Threaded Rod
Tie-down System

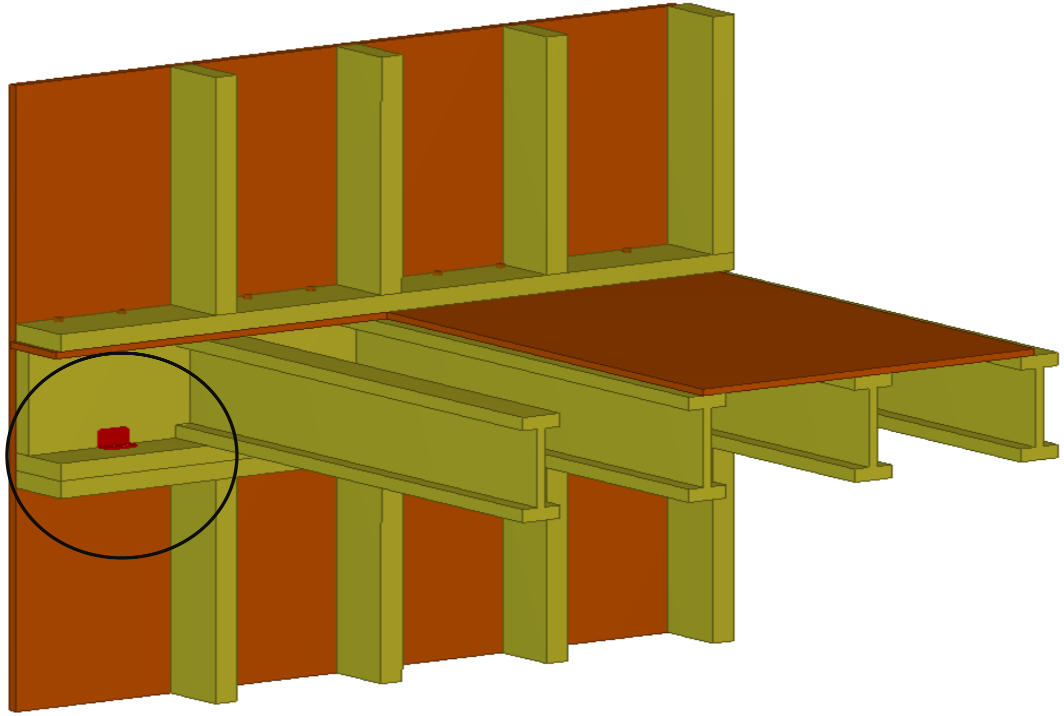
-Less anchorage deflection

-Takeup device allows structure to shrink while keeping the rod in tension.

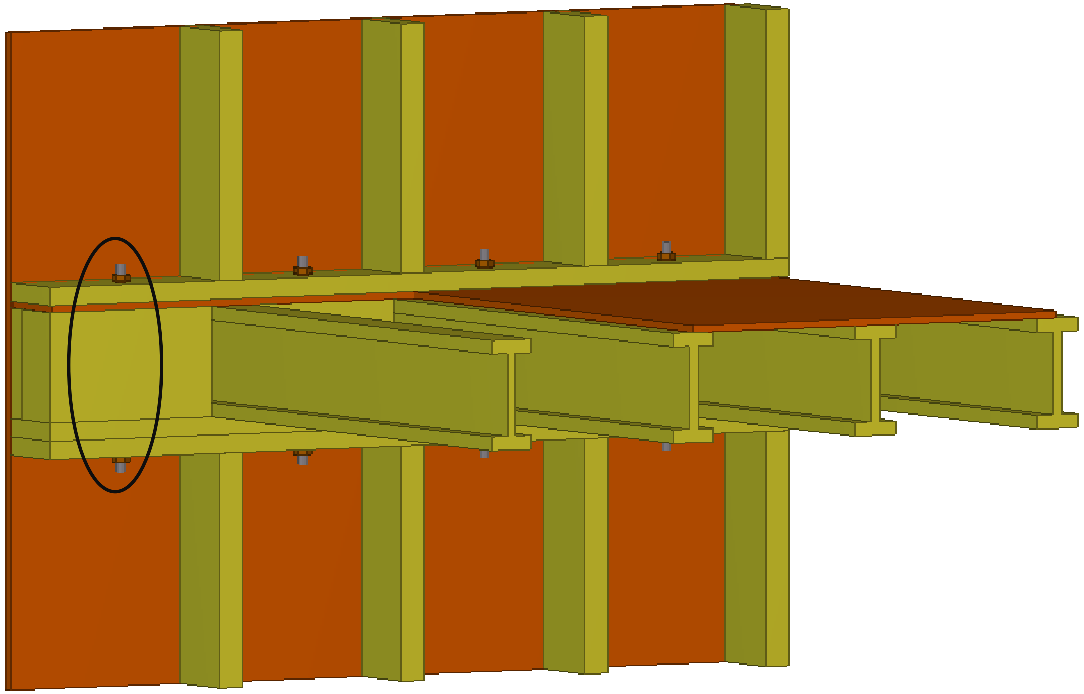


Images Courtesy of Simpson Strong Tie

Shear Transfer Between Wood Floors



Shear transfer through the ledger with screws and clips



Direct shear transfer with through bolts and blocking

Deflection Checks

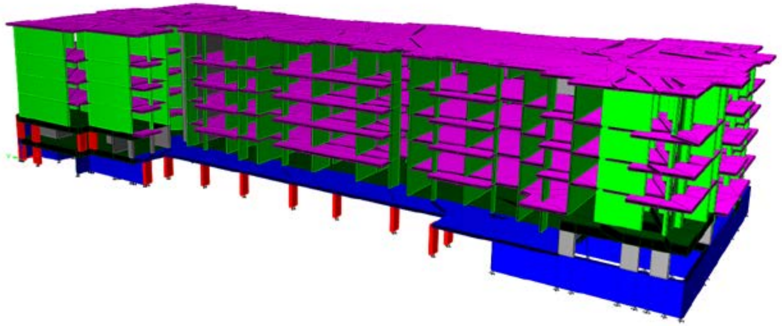
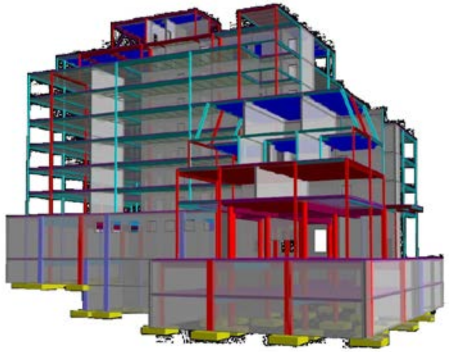
Deflection is a result of four components:

1. Bending of the shear wall
2. Shearing of the shear wall
3. Slip of the nails in the sheathing
4. Slip/elongation of the hold down anchorage

$$\Delta_i^{storey} = \overbrace{\Delta_{b,i}^{storey}}^{1} + \overbrace{\Delta_{s,i}^{storey}}^{2} + \overbrace{\Delta_{n,i}^{storey}}^{3} + \overbrace{\Delta_{a,i}^{storey}}^{4}$$

Midrise Building Structural Design

Can we design a six storey wood building using a commercial software **design** package?

Concrete	Steel	Wood
ETABS	RAM	???
		

The Problem: The Current 1-D Design Approach

- Design was by hand, wood design charts and simple spreadsheets to struggle through design, the confidence level on the design was low

- Large amounts of information to keep track of for each wall at each storey:
  - Geometry
  - Different Wall types and combinations
  - Lateral Loads (Load Cases and Combinations)
  - Resulting Forces and Deflections

- Very time consuming to reanalyze for any architectural changes that may arise during design.

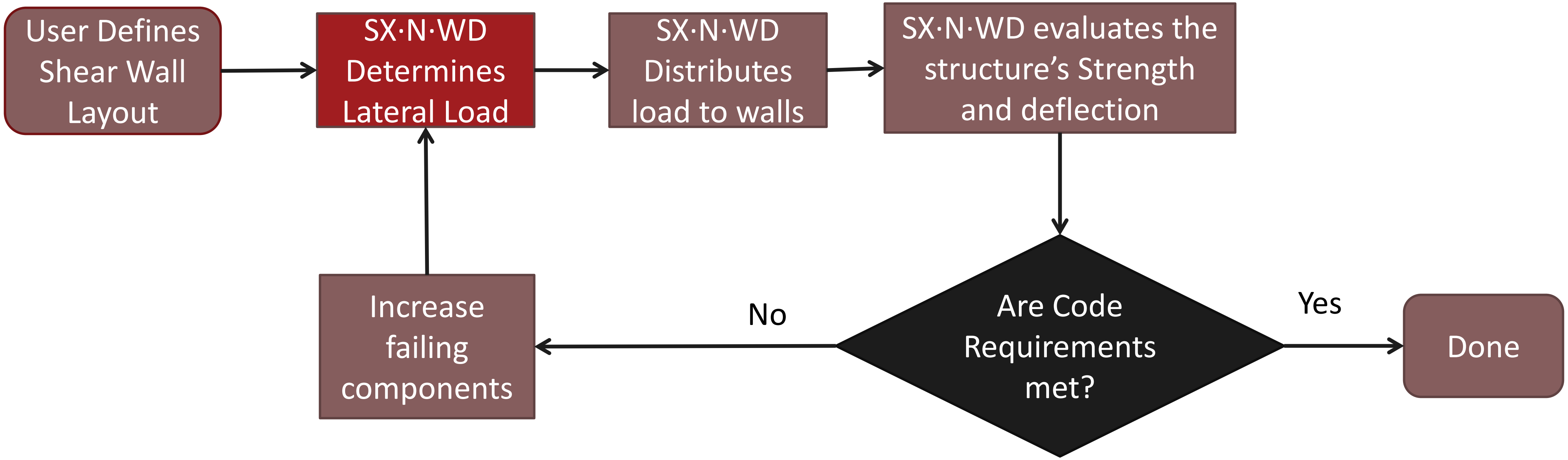
- Design is not optimized, does not take into account the **cost of wall assemblies or hold-downs**

SBM’s : SX·N·WD Lateral Design Software

- **SX·N·WD**: The Structural design of Wood buildings under lateral loads
- The program allows for modelling of the lateral loads and shear walls of the entire building, quasi- ***3D design software, taking the entire building into account***
- Easier to accommodate architectural changes during the design
- Optimization of structure becomes feasible (material/labor cost vs. performance)
- Accounts for Non-wood elements in addition to wood shear walls – concrete and masonry shear walls
- Analysis of structure for both flexible and rigid diaphragms
- Takes into account all CSA 086-14 and OBC 2012 code changes + APEG BC Best Practices Guidelines

Operation of Program

What does SX·N·WD do?



User Defines Shear Wall Layout

SX·N·WD Determines Lateral Load

SX·N·WD Distributes load to walls

SX·N·WD evaluates the structure’s Strength and deflection

Are Code Requirements met?

Yes

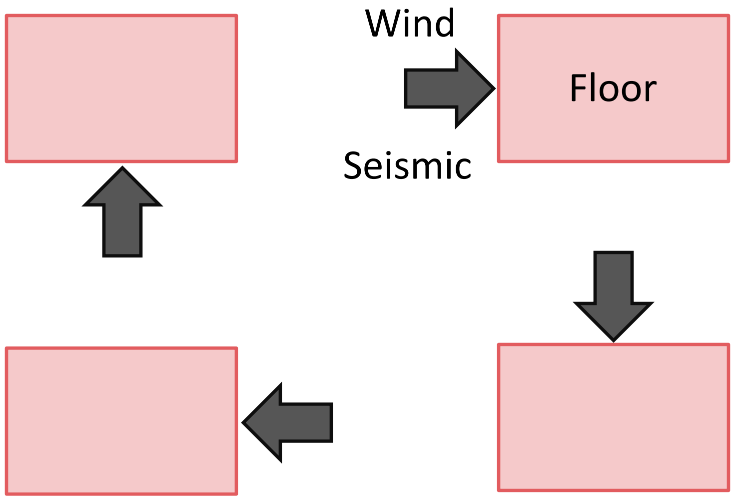
Done

No

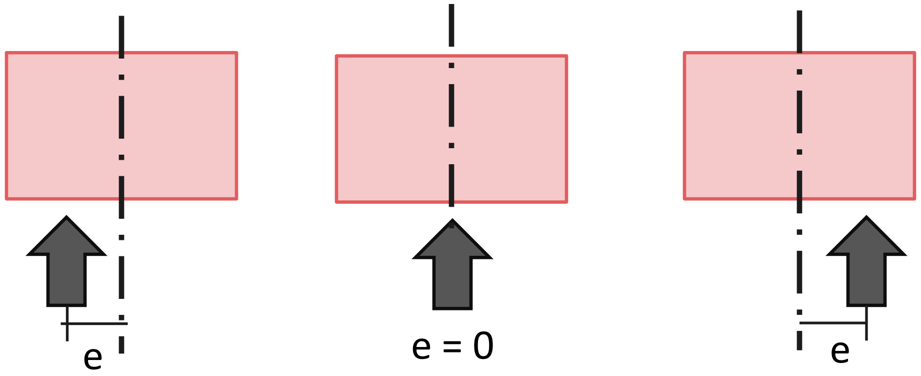
Increase failing components

Loads and Load Cases

Loads can come from different sources (wind, seismic), directions, and can be balanced or unbalanced



Eccentricities, e

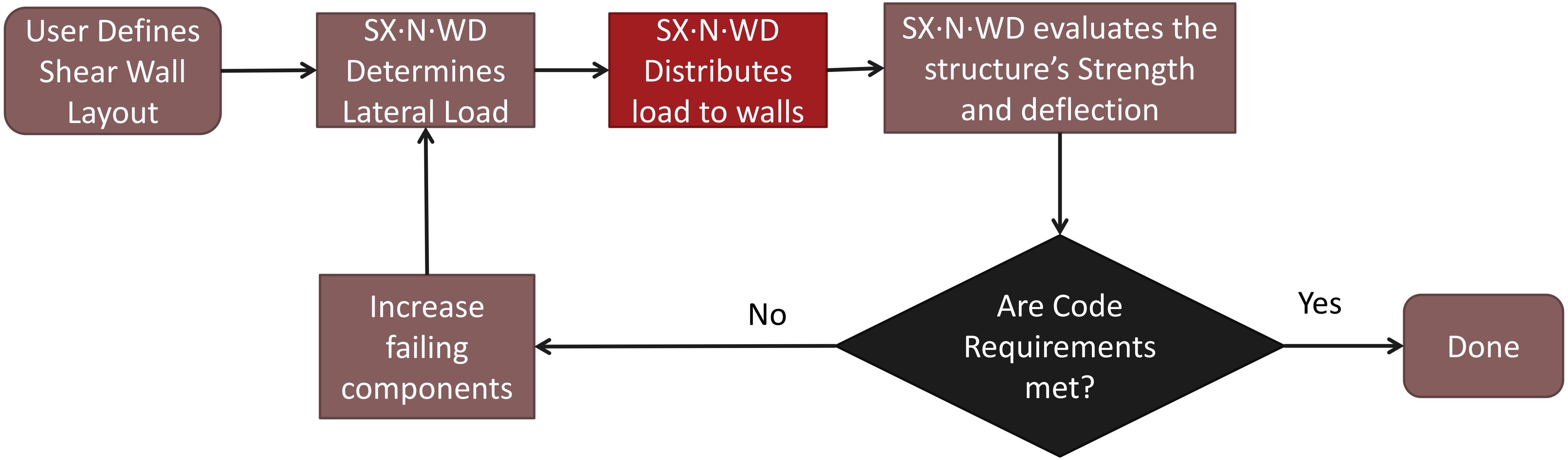


2 sources x 4 directions x 3 eccentricities = 24 load cases

100’s of Load Combination

Operation of Program

<u>What does SX·N·WD do?</u>



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Yes

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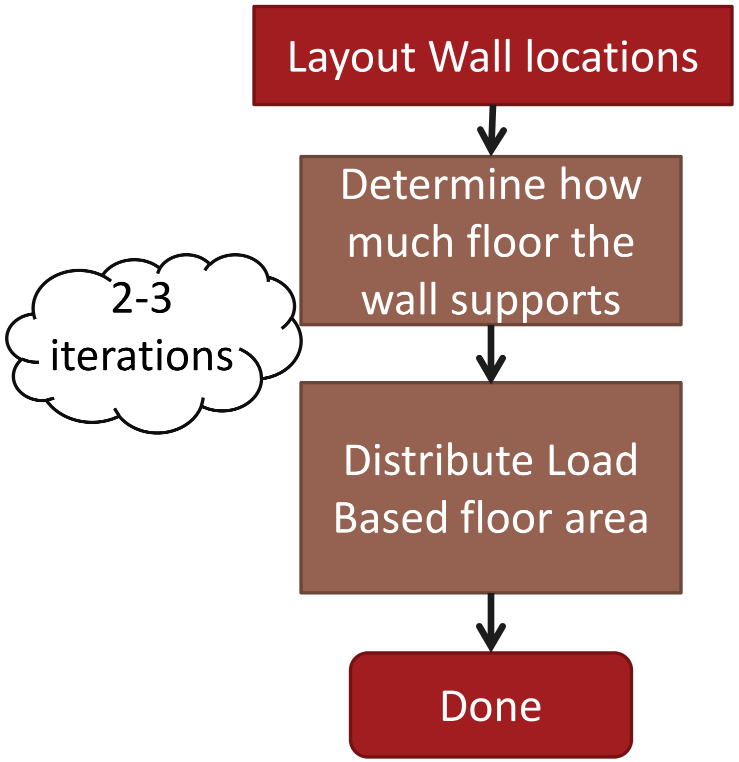
No

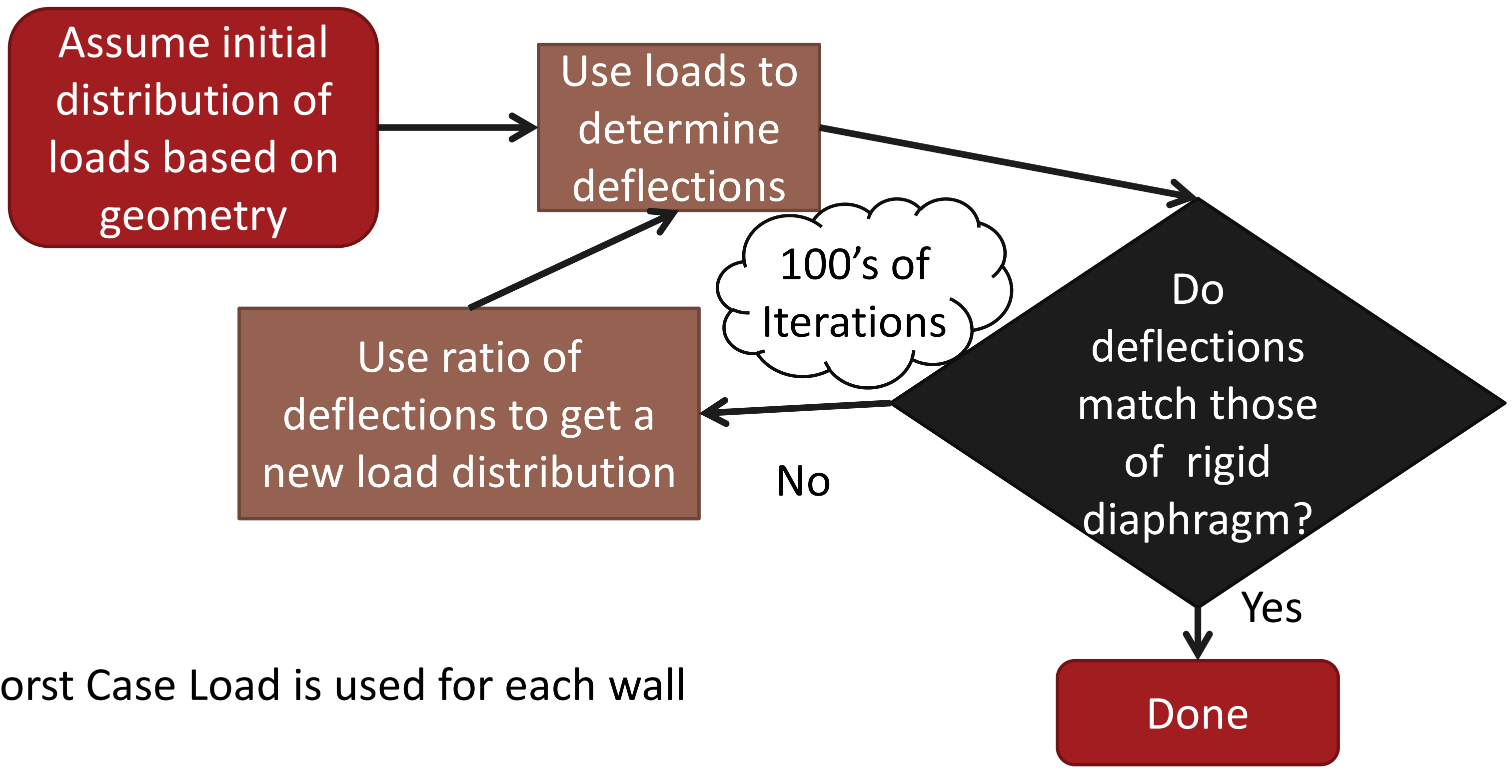
Increase failing components

Flexible and Rigid in SX·N·WD

<u>Flexible Diaphragm Distribution</u>



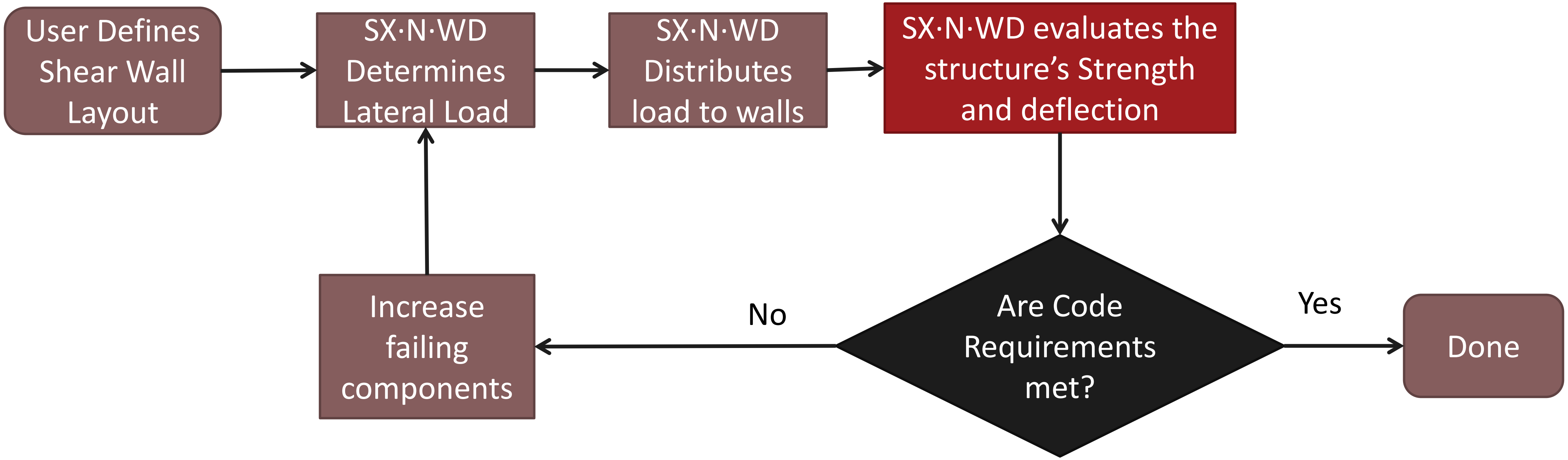
<u>Rigid Diaphragm Distribution</u>



Worst Case Load is used for each wall

Operation of Program

What does SX·N·WD do?



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Yes

Done

No

Increase failing components

Strength Evaluation

Shear:

- Shear is less than shear capacity ($V_f < V_r$) for wall panels
- Seismic shear increased by factor of 1.2 is less than capacity ($1.2V_f < V_r$) for interstorey connections and hold downs (in high seismic zones)

Moment: Used to compute tension and compression in chords $T_f = C_f = M_f/d$

Tension: Tension less than capacity ($T_f < T_r$) for hold down rods and components

Compression: Compression less than axial capacity ($C_f < C_r$) for end wall posts

Misc: Plate crushing, post crushing, bearing failures etc.

Deflection Evaluation

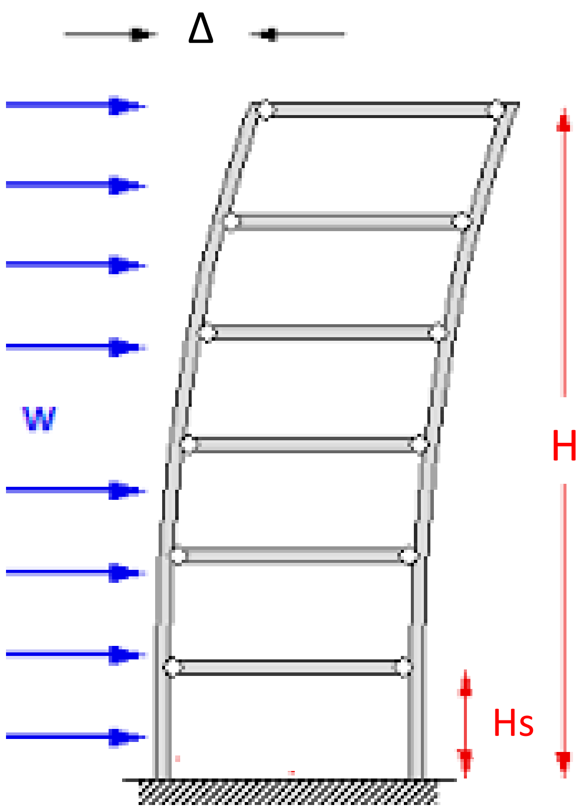
Wind Deflection Limits

- Total Building Deflection: H/400
  - 50mm (2”) for a 20m (65ft) building
- Interstorey Drift: Hs/500
  - 6mm (¼”) for a 3m (10ft) storey

Seismic Deflection Limits

Interstorey Drift

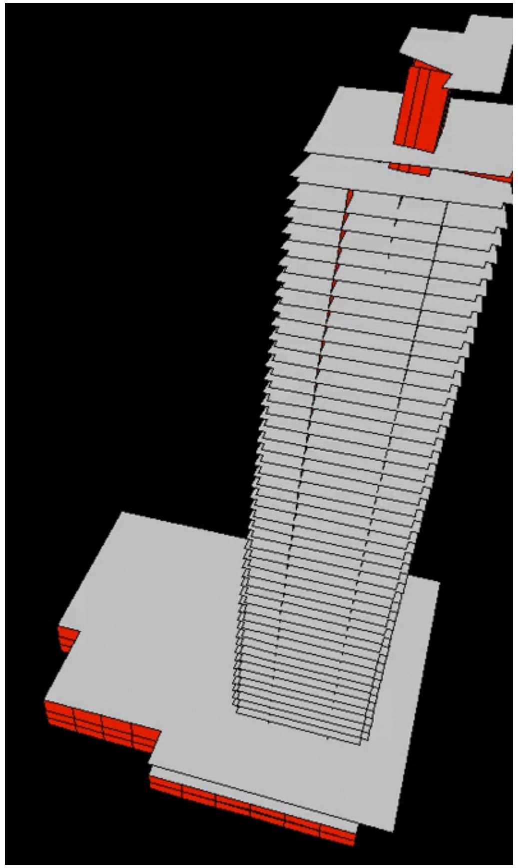
- Hs/100 for Post Disaster Buildings
- Hs/50 for High Importance Buildings
- Hs/40 for All other Buildings
  - 75mm (3”) for a 3m (10ft) storey



Additional Checks – Natural Frequency

- Wind loading in OBC based on assumption that natural frequency, f_n, is greater than 1 Hz
- Determination of Natural Frequency is based on deflection.
- If frequency is less than 1 Hz, the structure needs to be stiffened or designed for additional dynamic wind loading

$$f_n = \frac{1}{2\pi}\sqrt{\frac{\sum_{i=1}^{N} F_i \frac{x_i}{x_N}}{x_N \sum_{i=1}^{N} M_i \left(\frac{x_i}{x_N}\right)^2}}$$

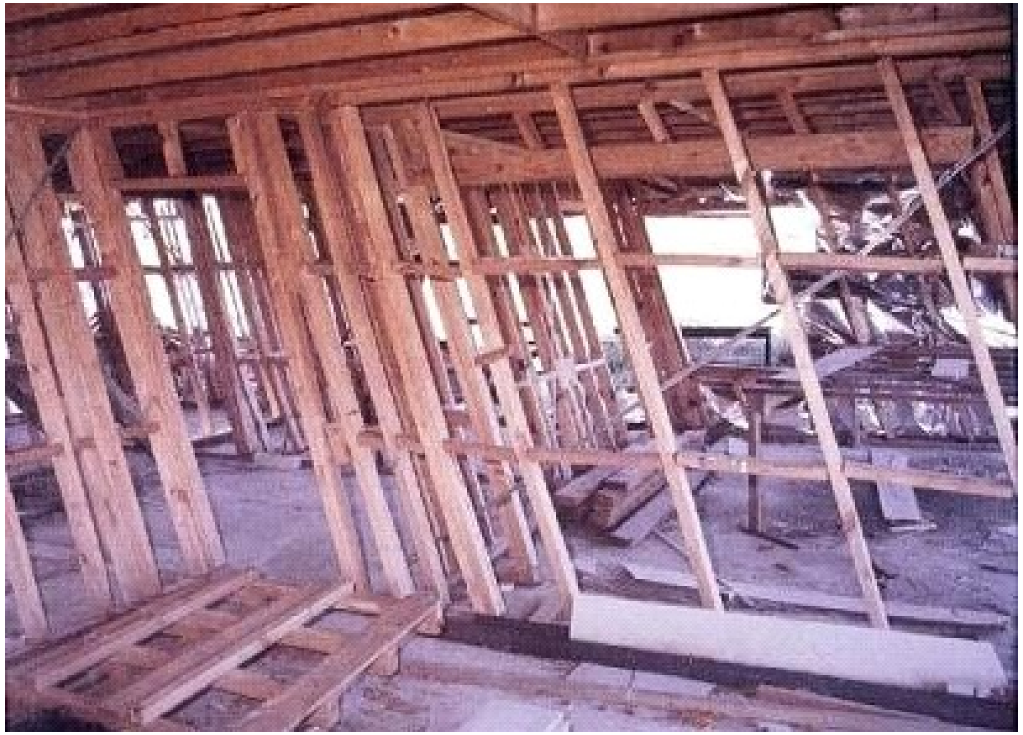


Courtesy University of Toronto, Civil Engineering Department

Additional Checks – Seismic Interstorey Drift

- If seismic interstorey drift exceeds 1% of storey height:
- Gypsum cannot be used to resist lateral loads
- Gypsum cannot be used to brace studs
  - Additional blocking may be required

Note: Gypsum cannot be used to resist seismic loads in wood buildings greater than 4 stories



Type 4 and 5 Irregularities

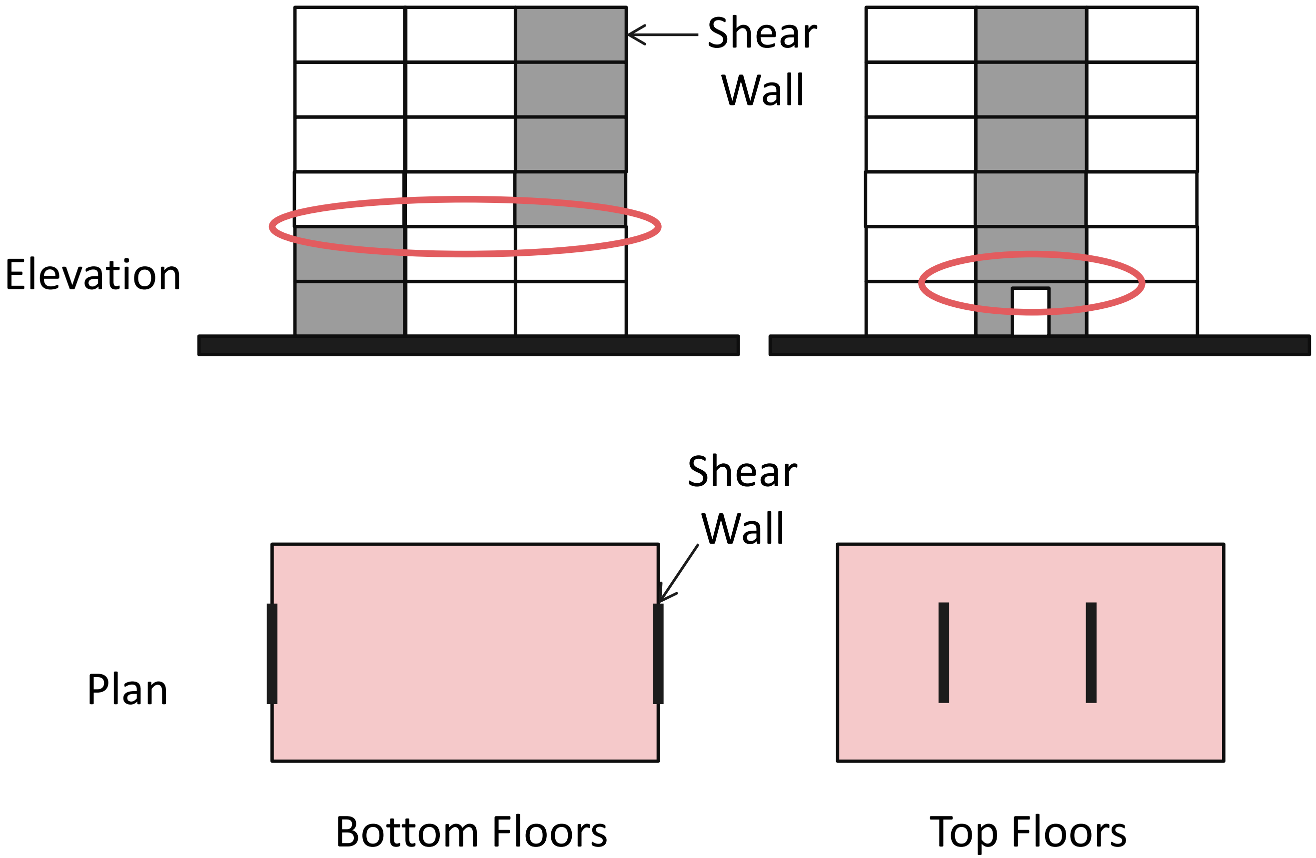
Type 4 Irregularities

- In plane offset
- Reduction in lateral stiffness on stories below

Not allowed in High Seismic Zones!

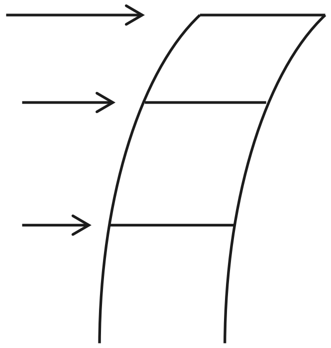
Type 5 Irregularities

- Discontinuity of lateral force path



Over Capacity Ratio Check

Seismic Load distribution in OBC based on assumed response of structure



Assumed Structural Response

Unacceptable Structural Responses

$$Over\ capacity\ coefficient = c = \frac{Shear\ Capacity}{Shear\ Force}$$

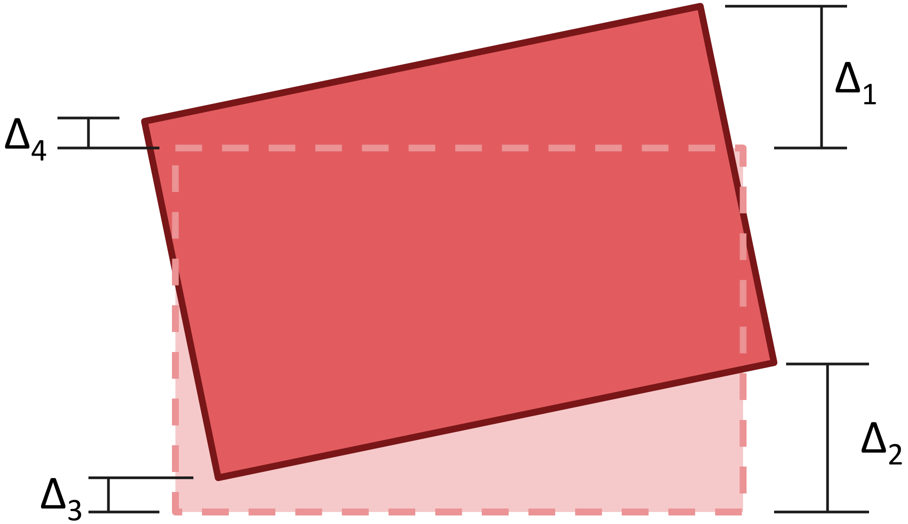
$$Over\ capacity\ ratio = OCR = \frac{c_2}{c_1}$$

$$0.9 \leq OCR \leq 1.2$$

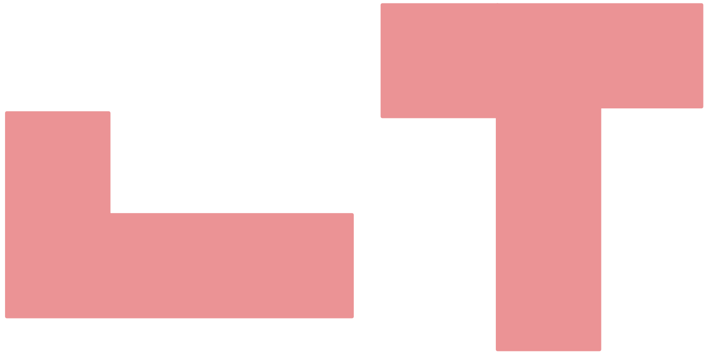
Torsional Sensitivity (High Seismic Zones)

What is a torsionally sensitive building? B > 1.7

$$B = \frac{\Delta_{max}}{\Delta_{avg}}$$



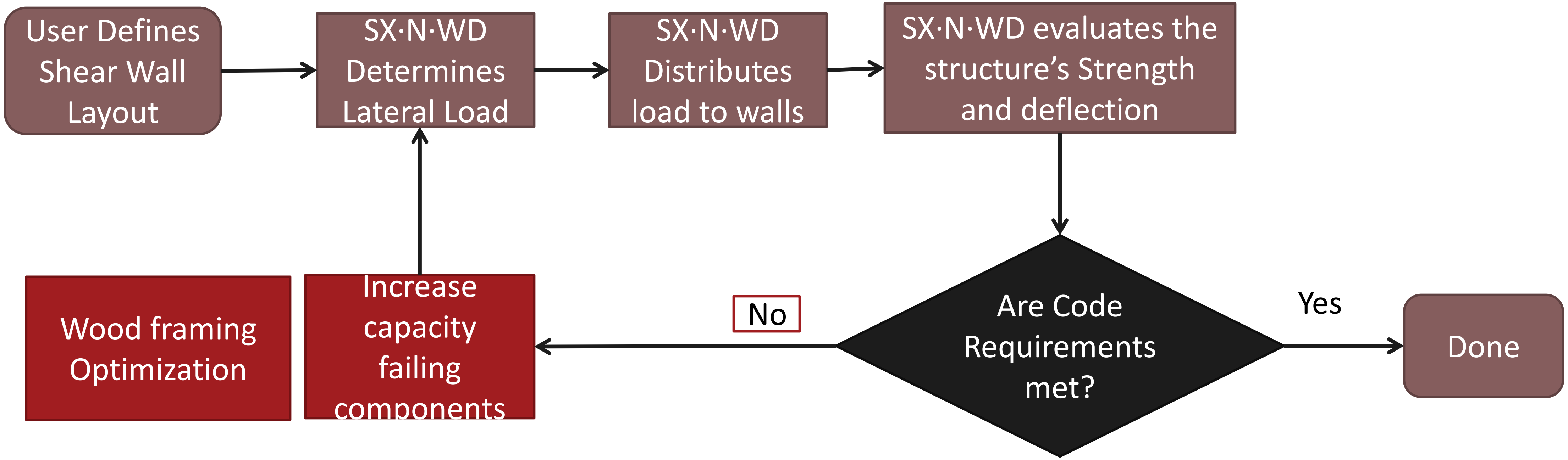
Torsionally Sensitive floor plate shapes (plan):



For torsionally sensitive buildings, in high seismic zones, the static force procedure cannot be used – dynamic analysis required

Operation of Program

<u>What does SX·N·WD do?</u>



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Are Code Requirements met?

Yes

Done

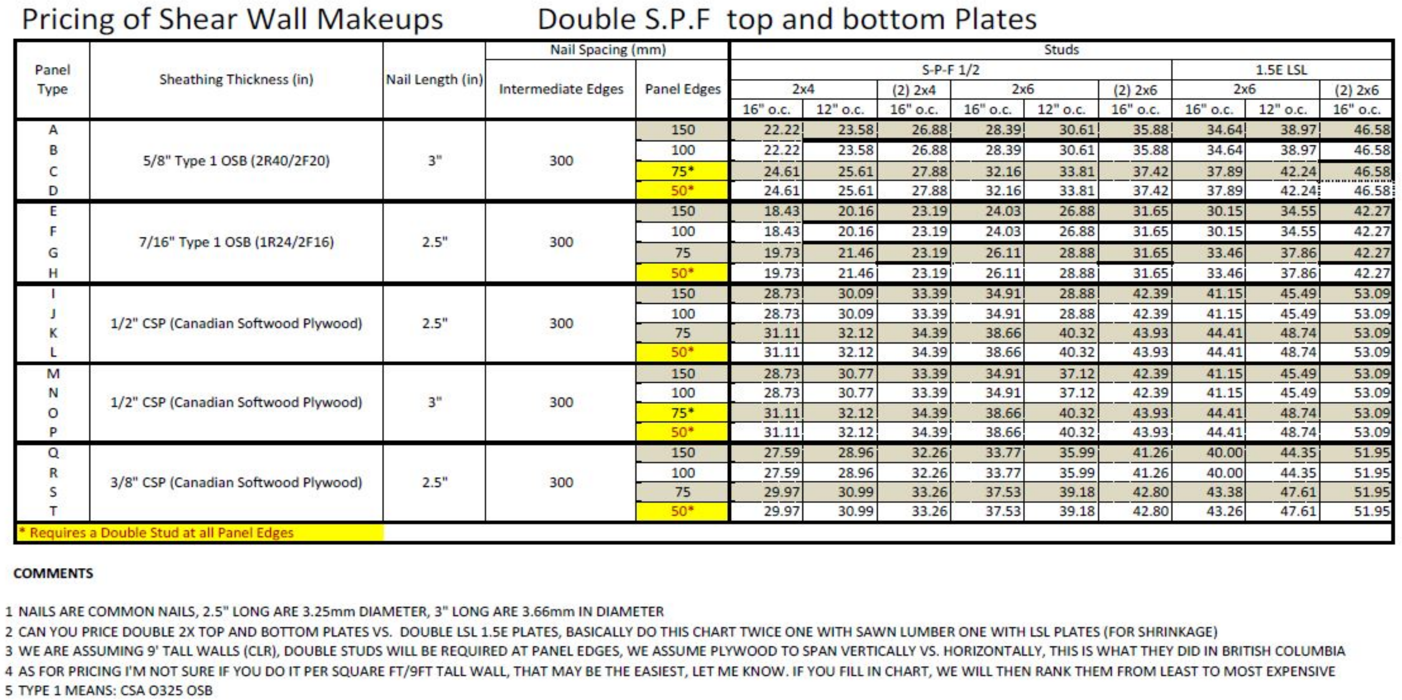
No

Increase capacity failing components

Wood framing Optimization

Wood Framing: Optimization with SX·N·WD

- *Ranking of 180 different wood shear wall assemblies by cost, including labour and materials*: stud size and spacing, sheathing type and thickness, nail size, length and spacing and hold-down anchors



Pricing of Shear Wall Makeups Double S.P.F top and bottom Plates

Panel Type	Sheathing Thickness (in)	Nail Length (in)	Nail Spacing (mm)		Studs								
					S-P-F 1/2						1.5E LSL		
			Intermediate Edges	Panel Edges	2x4		(2) 2x4	2x6		(2) 2x6	2x6		(2) 2x6
					16" o.c.	12" o.c.	16" o.c.	16" o.c.	12" o.c.	16" o.c.	16" o.c.	12" o.c.	16" o.c.
A	5/8" Type 1 OSB (2R40/2F20)	3"	300	150	22.22	23.58	26.88	28.39	30.61	35.88	34.64	38.97	46.58
B				100	22.22	23.58	26.88	28.39	30.61	35.88	34.64	38.97	46.58
C				75*	24.61	25.61	27.88	32.16	33.81	37.42	37.89	42.24	46.58
D				50*	24.61	25.61	27.88	32.16	33.81	37.42	37.89	42.24	46.58
E	7/16" Type 1 OSB (1R24/2F16)	2.5"	300	150	18.43	20.16	23.19	24.03	26.88	31.65	30.15	34.55	42.27
F				100	18.43	20.16	23.19	24.03	26.88	31.65	30.15	34.55	42.27
G				75	19.73	21.46	23.19	26.11	28.88	31.65	33.46	37.86	42.27
H				50*	19.73	21.46	23.19	26.11	28.88	31.65	33.46	37.86	42.27
I	1/2" CSP (Canadian Softwood Plywood)	2.5"	300	150	28.73	30.09	33.39	34.91	28.88	42.39	41.15	45.49	53.09
J				100	28.73	30.09	33.39	34.91	28.88	42.39	41.15	45.49	53.09
K				75	31.11	32.12	34.39	38.66	40.32	43.93	44.41	48.74	53.09
L				50*	31.11	32.12	34.39	38.66	40.32	43.93	44.41	48.74	53.09
M	1/2" CSP (Canadian Softwood Plywood)	3"	300	150	28.73	30.77	33.39	34.91	37.12	42.39	41.15	45.49	53.09
N				100	28.73	30.77	33.39	34.91	37.12	42.39	41.15	45.49	53.09
O				75*	31.11	32.12	34.39	38.66	40.32	43.93	44.41	48.74	53.09
P				50*	31.11	32.12	34.39	38.66	40.32	43.93	44.41	48.74	53.09
Q	3/8" CSP (Canadian Softwood Plywood)	2.5"	300	150	27.59	28.96	32.26	33.77	35.99	41.26	40.00	44.35	51.95
R				100	27.59	28.96	32.26	33.77	35.99	41.26	40.00	44.35	51.95
S				75	29.97	30.99	33.26	37.53	39.18	42.80	43.38	47.61	51.95
T				50*	29.97	30.99	33.26	37.53	39.18	42.80	43.26	47.61	51.95

* Requires a Double Stud at all Panel Edges

COMMENTS

1 NAILS ARE COMMON NAILS, 2.5" LONG ARE 3.25mm DIAMETER, 3" LONG ARE 3.66mm IN DIAMETER
2 CAN YOU PRICE DOUBLE 2X TOP AND BOTTOM PLATES VS. DOUBLE LSL 1.5E PLATES, BASICALLY DO THIS CHART TWICE ONE WITH SAWN LUMBER ONE WITH LSL PLATES (FOR SHRINKAGE)
3 WE ARE ASSUMING 9' TALL WALLS (CLR), DOUBLE STUDS WILL BE REQUIRED AT PANEL EDGES, WE ASSUME PLYWOOD TO SPAN VERTICALLY VS. HORIZONTALLY, THIS IS WHAT THEY DID IN BRITISH COLUMBIA
4 AS FOR PRICING I'M NOT SURE IF YOU DO IT PER SQUARE FT/9FT TALL WALL, THAT MAY BE THE EASIEST, LET ME KNOW. IF YOU FILL IN CHART, WE WILL THEN RANK THEM FROM LEAST TO MOST EXPENSIVE
5 TYPE 1 MEANS: CSA O325 OSB

What cost more?????????

1/2” PLWD , 2-2x4 @ 16, 2.5” lg nails, nailing @ 150mm panel edge, 300mm interior

$33.39 plf

Or

7/16” OSB, 2x6@12, 2.5”lg nails, nailing @ 150mm panel edge, 300mm interior

$26.88 plf

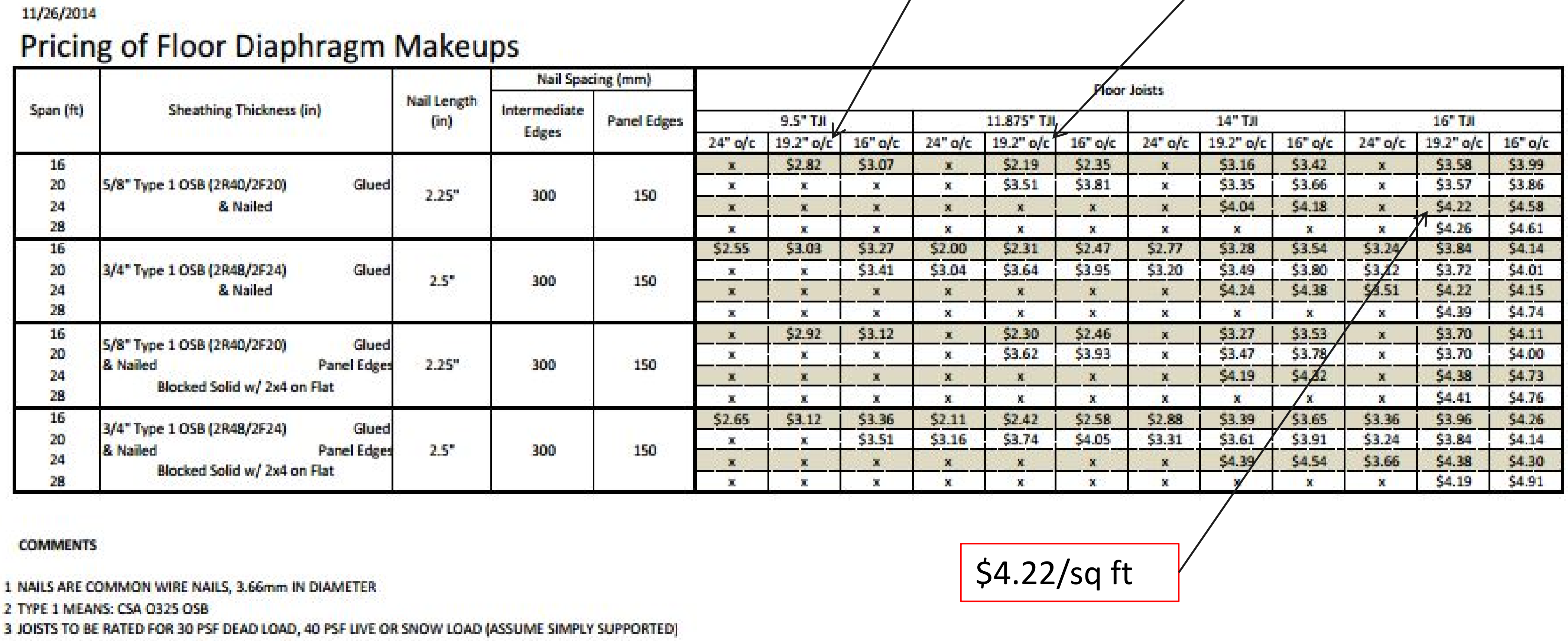
Or

3/8” PLWD, 2x4@16, 2.5”lg nails, nailing @ 150mm panel edge, 300mm interior

$27.59 plf

$2.82/sq ft

$2.19/sq ft



11/26/2014

Pricing of Floor Diaphragm Makeups

Span (ft)	Sheathing Thickness (in)	Nail Length (in)	Nail Spacing (mm)		Floor Joists											
			Intermediate Edges	Panel Edges	9.5" TJI			11.875" TJI			14" TJI			16" TJI		
					24" o/c	19.2" o/c	16" o/c	24" o/c	19.2" o/c	16" o/c	24" o/c	19.2" o/c	16" o/c	24" o/c	19.2" o/c	16" o/c
16	5/8" Type 1 OSB (2R40/2F20) Glued & Nailed	2.25"	300	150	x	$2.82	$3.07	x	$2.19	$2.35	x	$3.16	$3.42	x	$3.58	$3.99
20					x	x	x	x	$3.51	$3.81	x	$3.35	$3.66	x	$3.57	$3.86
24					x	x	x	x	x	x	x	$4.04	$4.18	x	$4.22	$4.58
28					x	x	x	x	x	x	x	x	x	x	$4.26	$4.61
16	3/4" Type 1 OSB (2R48/2F24) Glued & Nailed	2.5"	300	150	$2.55	$3.03	$3.27	$2.00	$2.31	$2.47	$2.77	$3.28	$3.54	$3.24	$3.84	$4.14
20					x	x	$3.41	$3.04	$3.64	$3.95	$3.20	$3.49	$3.80	$3.12	$3.72	$4.01
24					x	x	x	x	x	x	x	$4.24	$4.38	$3.51	$4.22	$4.15
28					x	x	x	x	x	x	x	x	x	x	$4.39	$4.74
16	5/8" Type 1 OSB (2R40/2F20) Glued & Nailed Panel Edges Blocked Solid w/ 2x4 on Flat	2.25"	300	150	x	$2.92	$3.12	x	$2.30	$2.46	x	$3.27	$3.53	x	$3.70	$4.11
20					x	x	x	x	$3.62	$3.93	x	$3.47	$3.78	x	$3.70	$4.00
24					x	x	x	x	x	x	x	$4.19	$4.32	x	$4.38	$4.73
28					x	x	x	x	x	x	x	x	x	x	$4.41	$4.76
16	3/4" Type 1 OSB (2R48/2F24) Glued & Nailed Panel Edges Blocked Solid w/ 2x4 on Flat	2.5"	300	150	$2.65	$3.12	$3.36	$2.11	$2.42	$2.58	$2.88	$3.39	$3.65	$3.36	$3.96	$4.26
20					x	x	$3.51	$3.16	$3.74	$4.05	$3.31	$3.61	$3.91	$3.24	$3.84	$4.14
24					x	x	x	x	x	x	x	$4.39	$4.54	$3.66	$4.38	$4.30
28					x	x	x	x	x	x	x	x	x	x	$4.19	$4.91

COMMENTS

1 NAILS ARE COMMON WIRE NAILS, 3.66mm IN DIAMETER
2 TYPE 1 MEANS: CSA O325 OSB
3 JOISTS TO BE RATED FOR 30 PSF DEAD LOAD, 40 PSF LIVE OR SNOW LOAD (ASSUME SIMPLY SUPPORTED)

$4.22/sq ft

Optimization with SX·N·WD

- Ranking of wall assemblies based on labour and material costs, 1 to 180, for **each individual project**
- Initially set the structure to the cheapest assembly, Ranked Wall: 1,2…..
- Run analysis – each time a shear component fails, move to the next cheapest option
- Repeat until all components meet code requirements, CSA O86/OBC 2012
- Different wall configurations can be considered and compared, user can check all wall designs and 'optimize' even further
- *End of design process, the least expensive code compliant system is achieved*

What’s next for SX·N·WD?

- National Research Grant, working with Western University to create a Finite Element Design software program for midrise wood framed buildings,
- Two year long project with grants from both federal/provincial level
- Field testing and laboratory testing to confirm FEM model
- **Will allow for static and dynamic seismic design, proper modeling of the floor diaphragm (semi-rigid), taking into account non-linear behavior of shear wall panels and floor diaphragm**
- **The program will allow for more accurate designs and we feel more cost effective structures, advancing the wood industry into the future**

QUESTIONS

sbm
STRIK
BALDINELLI
MONIZ
CIVIL • STRUCTURAL ENGINEERS

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6 STOREY WOOD CASE STUDIES & COST ANALYSIS

Outline

- CASE STUDIES
- COST BREAKDOWN AND ANALYSIS
- EFFICIENCIES

Case Study 1

REMY – RICHMOND, BC

REMY Apartments

First 6 storey wood building constructed in BC under the 2009 code revision

6 stories of wood platform framing over 1 storey of concrete

Main floor mercantile with residential above

Rear half of main floor was also framed of concrete to accommodate additional on-site parking

CREDIT: Stephanie Tracey, Photography West, Kelowna, BC

Source - The Canadian Wood Council; Mid-rise Construction in British Columbia: A Case Study Based on the Remy Project in Richmond, BC

REMY Apartments

As the first 6 storey wood building in BC, guidelines were established at the onset of the project to mitigate costs:

- Exterior walls were aligned, with no severe steps or architectural projections
- Interior shearwalls were aligned full-height
- Units were laid out to ensure shear-walls fell between parking stalls at the main floor and below
- Balconies were contained within building; no cantilevers
- A single, panelized material was used on the building façade

CREDIT: Patrick Cotter, ZGF Cotter Architects

REMY Apartments

The Result:

The building was originally designed out of concrete and steel, but was shelved in 2008 due to the economic recession

With the changes to the BC Building Code in 2009, the building was out of Light Wood Framing

Developer realized a *construction* cost savings of 12% ($4.8 Million) compared to the original building design

CREDIT: CPA Development Consultants

Case Study 2

BTY GROUP

BTY Group Case Study

BTY Group conducted a cost comparison between three 6-storey residential buildings in Vancouver, BC (2011)

Considerations:

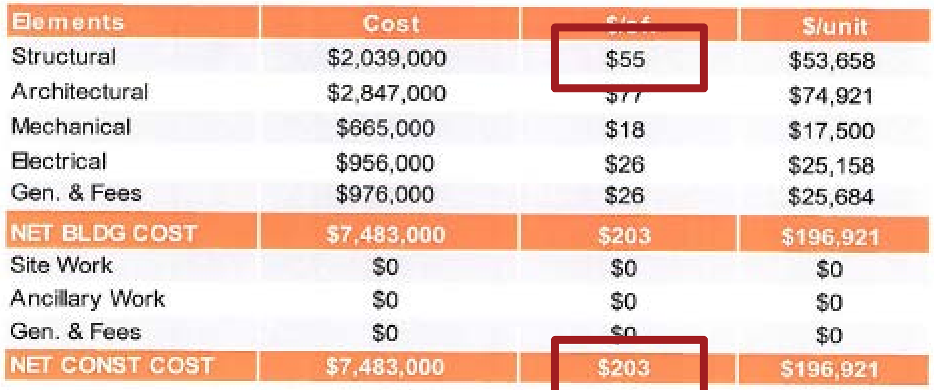
- One level below grade parking
- Concrete suspended slab at grade and at 2nd floor
- Commercial space at main floor
- Five floors of residential units above, 38 units total
- Total Area = ± 37,000 sq ft (not including parking)

Building was designed using a Concrete Frame, Light Steel Frame, and Lightweight Wood Framing

BTY Group Case Study

Case 1 – Concrete Structure:

Standard foundations, architectural concrete, aluminum window-wall and windows



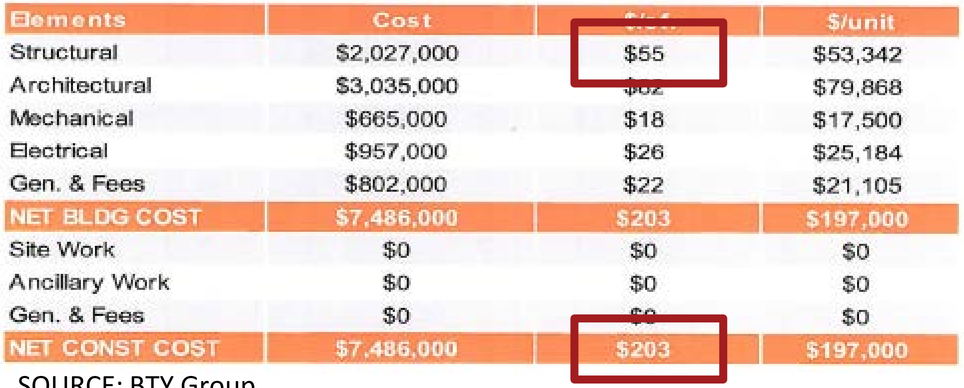
Elements	Cost	$/sf	$/unit
Structural	$2,039,000	$55	$53,658
Architectural	$2,847,000	$77	$74,921
Mechanical	$665,000	$18	$17,500
Electrical	$956,000	$26	$25,158
Gen. & Fees	$976,000	$26	$25,684
NET BLDG COST	$7,483,000	$203	$196,921
Site Work	$0	$0	$0
Ancillary Work	$0	$0	$0
Gen. & Fees	$0	$0	$0
NET CONST COST	$7,483,000	$203	$196,921

SOURCE: BTY Group

BTY Group Case Study

Case 2 – Lightweight Steel Structure:

Standard foundations, structural steel frame, interior concrete shearwalls, metal deck, concrete topping, masonry veneer on steel studs backup, Type X drywall drop ceiling



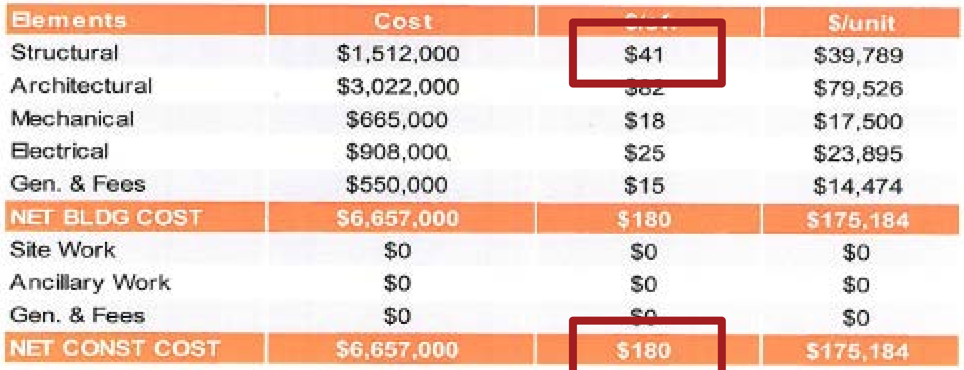
Elements	Cost	$/sf	$/unit
Structural	$2,027,000	$55	$53,342
Architectural	$3,035,000	$82	$79,868
Mechanical	$665,000	$18	$17,500
Electrical	$957,000	$26	$25,184
Gen. & Fees	$802,000	$22	$21,105
NET BLDG COST	$7,486,000	$203	$197,000
Site Work	$0	$0	$0
Ancillary Work	$0	$0	$0
Gen. & Fees	$0	$0	$0
NET CONST COST	$7,486,000	$203	$197,000

SOURCE: BTY Group

BTY Group Case Study

Case 3 – Wood Structure:

Standard foundations, wood frame structure with masonry walls to stair and elevation shafts, hardie plank rainscreen on wood studs, Type X drywall ceiling

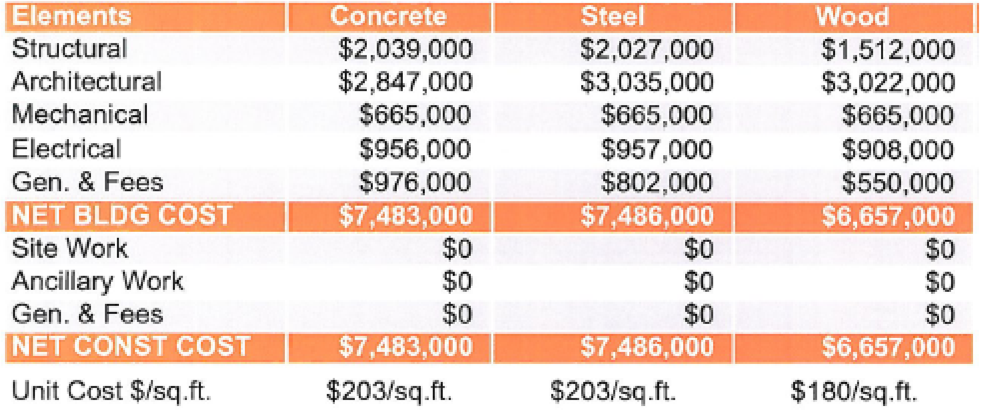


Elements	Cost	$/sf	$/unit
Structural	$1,512,000	$41	$39,789
Architectural	$3,022,000	$82	$79,526
Mechanical	$665,000	$18	$17,500
Electrical	$908,000	$25	$23,895
Gen. & Fees	$550,000	$15	$14,474
NET BLDG COST	$6,657,000	$180	$175,184
Site Work	$0	$0	$0
Ancillary Work	$0	$0	$0
Gen. & Fees	$0	$0	$0
NET CONST COST	$6,657,000	$180	$175,184

SOURCE: BTY Group

BTY Group Case Study

Comparison:



Elements	Concrete	Steel	Wood
Structural	$2,039,000	$2,027,000	$1,512,000
Architectural	$2,847,000	$3,035,000	$3,022,000
Mechanical	$665,000	$665,000	$665,000
Electrical	$956,000	$957,000	$908,000
Gen. & Fees	$976,000	$802,000	$550,000
NET BLDG COST	$7,483,000	$7,486,000	$6,657,000
Site Work	$0	$0	$0
Ancillary Work	$0	$0	$0
Gen. & Fees	$0	$0	$0
NET CONST COST	$7,483,000	$7,486,000	$6,657,000
Unit Cost $/sq.ft.	$203/sq.ft.	$203/sq.ft.	$180/sq.ft.

SOURCE: BTY Group

25% savings on building Structural

6% increase on Architectural (fire assemblies)

44% savings on Gen. & Fees (faster schedule)

Overall savings of 11% when compared to a similar concrete or steel building

(Similar to REMY – 12%)

Case Study 3

WOODWORKS!

WoodWORKS! Case Study

RHC Design/Build

Costing analysis based on two recent projects

- Cold Formed Steel
- Light Wood Frame

Buildings of 4 and 6 storeys were considered

A savings of $20 / sq ft was determined between the two materials in each case

Estimates also indicated the structure could be erected in about 70% of the time, reducing carrying costs of the project as well

woodWORKS!
Project of the Canadian Wood Council

wood solutions
in mid-rise construction

Report by | Jeff Walker
Walker Consulting Group

Case Study 4

SBM CASE STUDY

SBM Case Study

SBM conducted an in-house case study to quantify the cost implications of extending light wood framing to 6 storeys

The study was based on a recent SBM project for the Tricar Group, which consisted of a 4-storey residential wood building in London, ON

Two additional storeys were added to the reference building to determine the increased demand on the wood framing and concrete foundations

Buildings were modeled using SX·N·WD Ver 1.3

Results were provided to TRS Components for material take-offs and pricing

Reference Building

4 Storey Wood Framing

- 2x6 Walls, Double Plates Top and Bottom
- 14” Deep Pre-Eng Floors Joists Spanning max. 24’-0”
- 1.25” lightweight concrete topping
- Joist span parallel to main corridor
- 2x8 floor joists at corridor

2 Storey Structural Steel-Framed Breezeway

Conventional Frost Wall Foundations with Slab on Grade

Total GFA: 52,302 sq ft

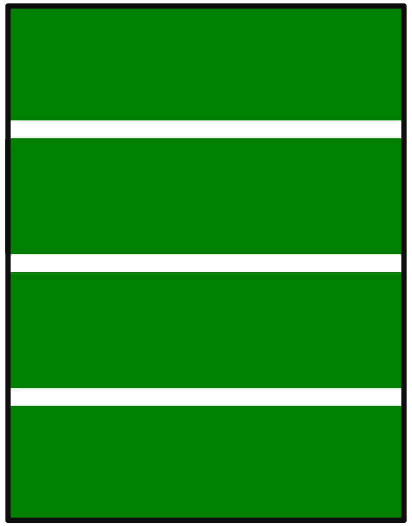
Location: London, Ontario

Soil Type: Site Class C

Soil Capacity: Serviceability Limit States = 3000 psf
Ultimate Limit States = 4000 psf

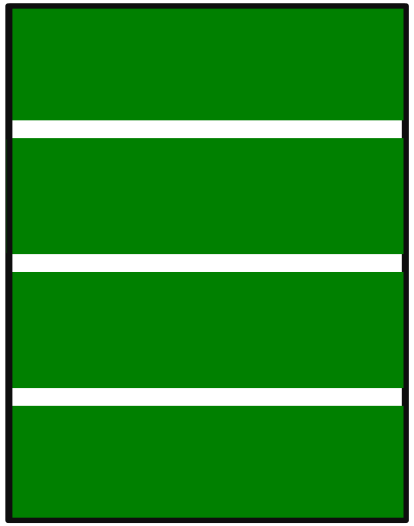
89 RIDOUT STREET: NORTHEAST PERSPECTIVE
STANTEC 140014009 | 2014-02-04

Analysis



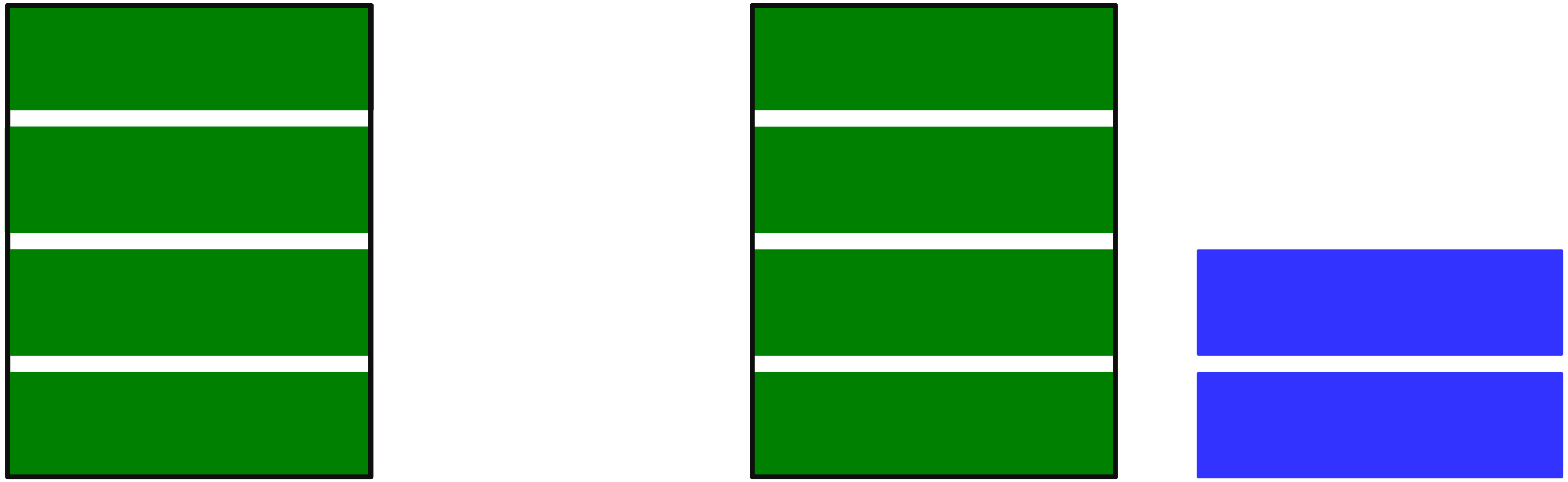
4 Storeys Wood

Analysis



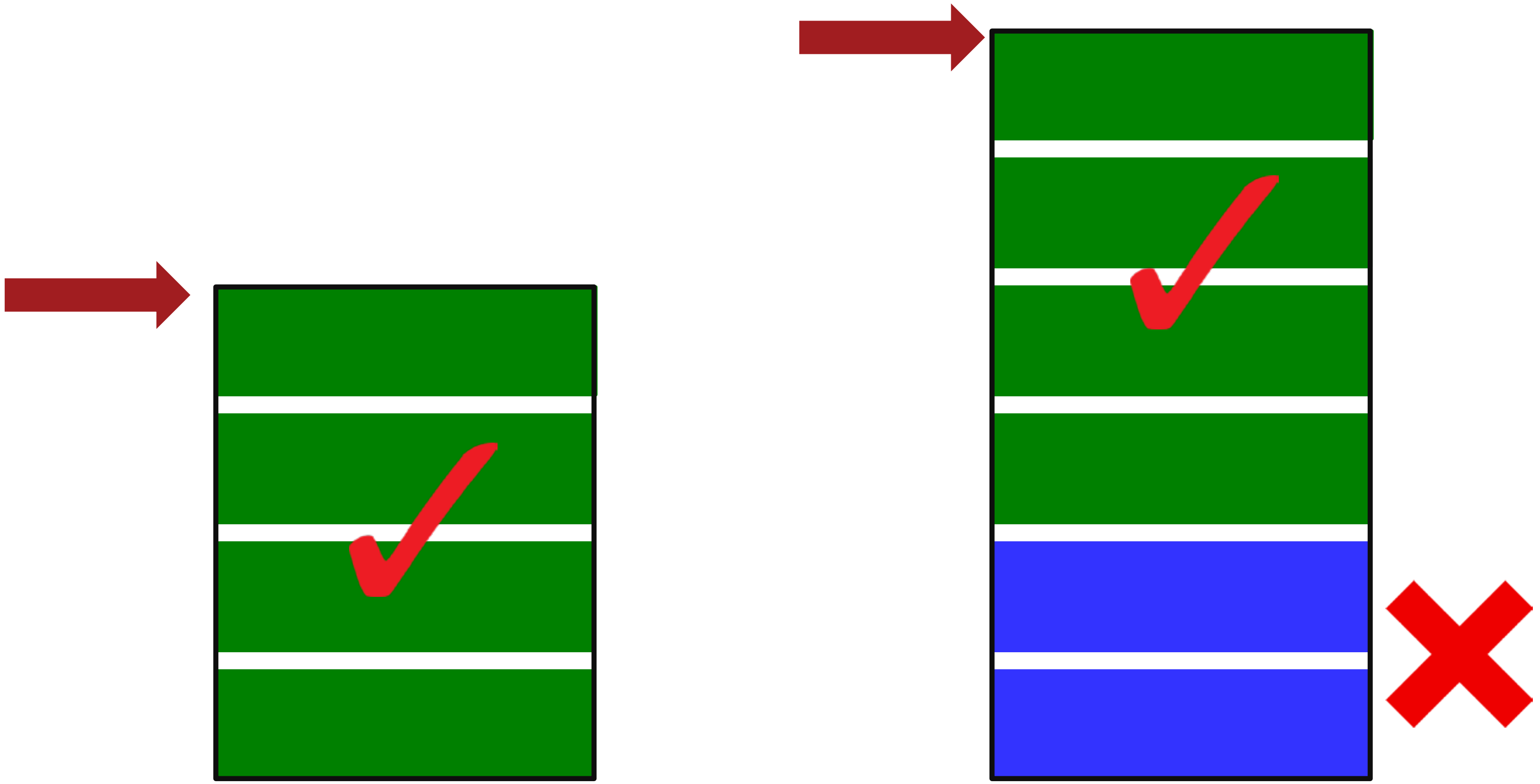
4 Storeys Wood

Analysis



4 Storeys Wood

Analysis



4 Storeys Wood

6 Storeys Wood

Failed in:

- Gravity
- Lateral Resistance
- Deflection

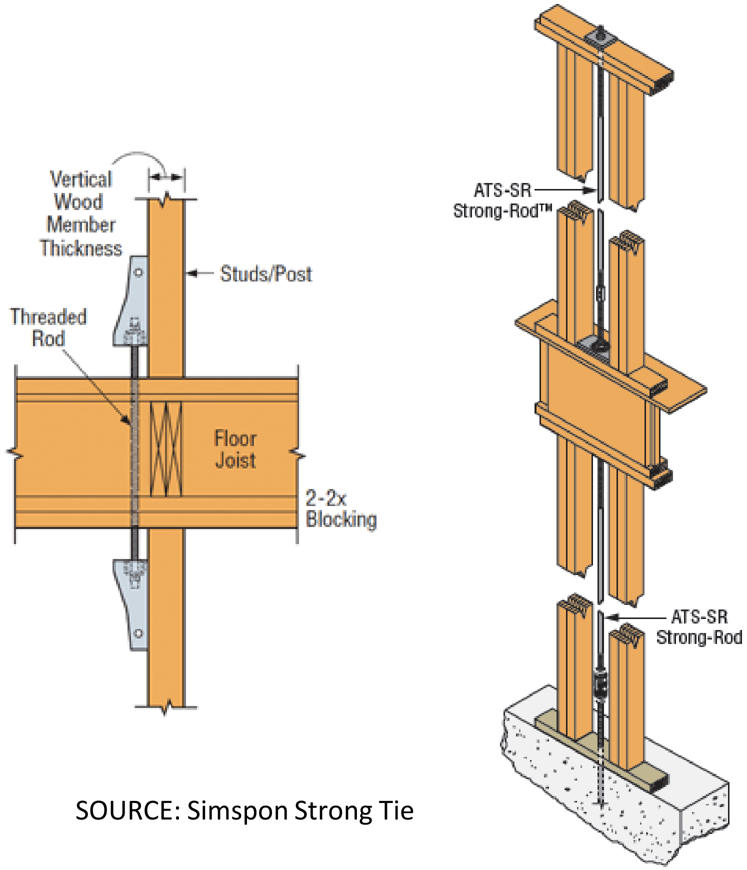
Solutions

Due to the light weight of the building, Wind governed the lateral design (typically Seismic for Concrete)

The traditional hold-down system used in the Reference Building was too flexible for the increased loads, allowing the building to Drift beyond acceptable limits

Full-height Anchor Tiedown Systems (ATS) were introduced to restrain the building against overturning

The shrinkage compensating devices also helped to reduce slippage in the system, further controlling the overall drift of the building



SOURCE: Simspon Strong Tie

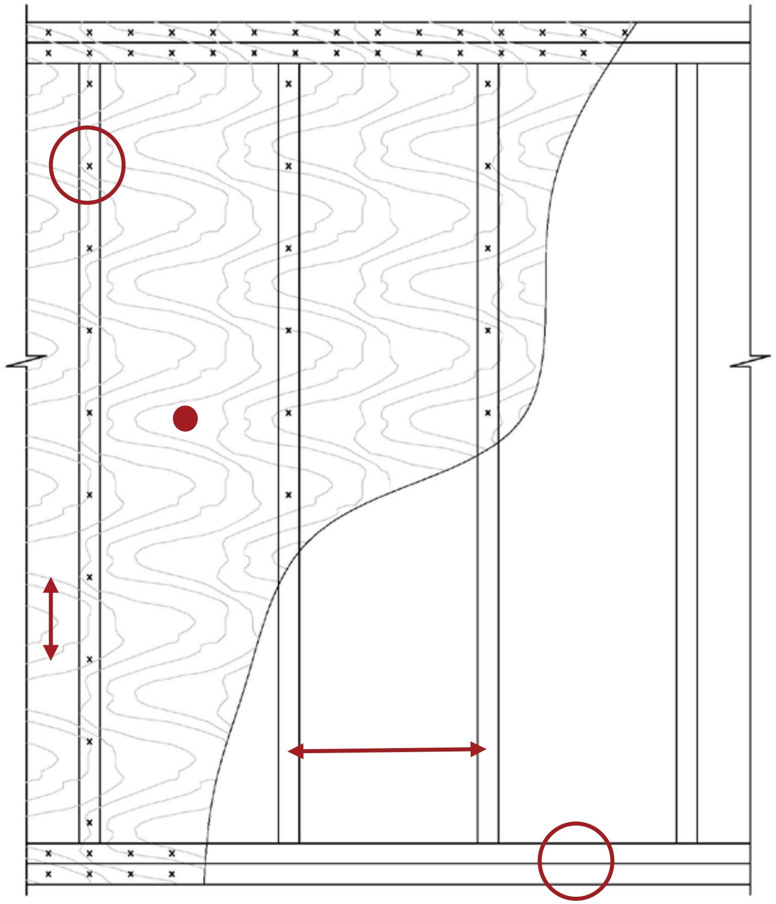
Solutions

Additional shearwalls were added to increase the strength and stiffness of the building

The capacities of the walls were also increased by:

- Increasing the panel thickness
- Increasing the nail size and penetration
- Reducing the nail spacing
- Reducing the stud spacing

Marginal increases were also made at the floor to floor connections to transfer the higher loads from the diaphragm to the walls below

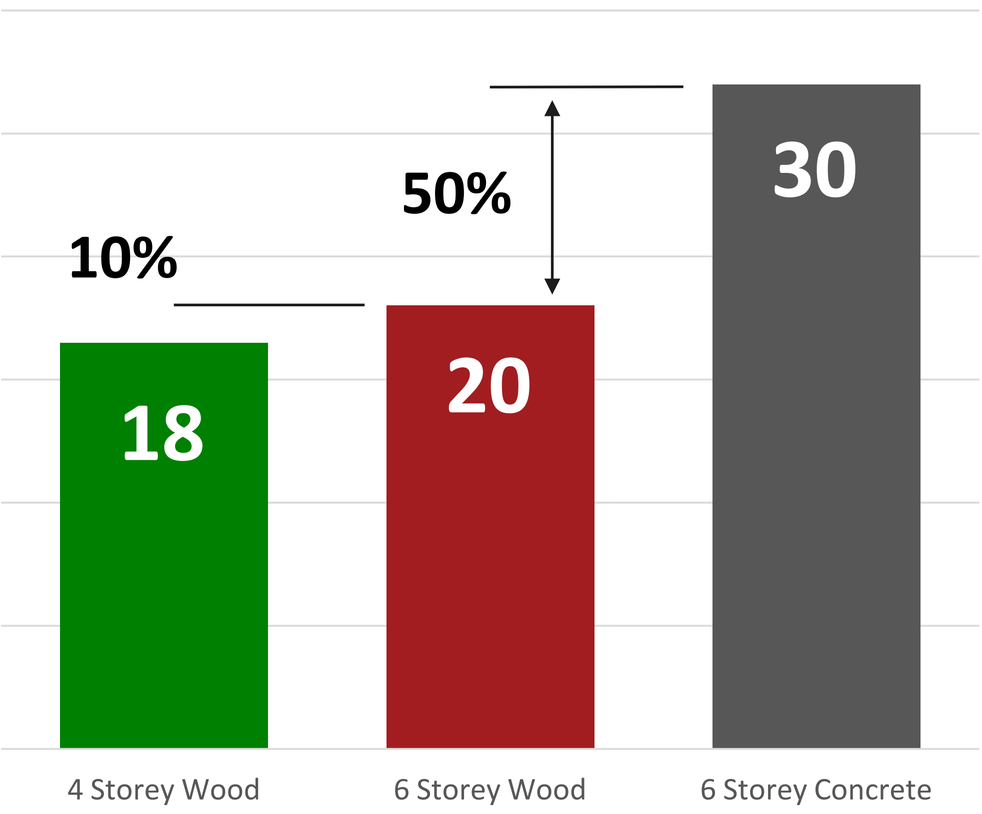


Results – Above Grade Framing

Based on the Reference Building and other past SBM projects, 4 Storey wood framing is typically in the order $16-17/sq ft

The 6 Storey wood Case Study yielded an increase of ± 10% in framing costs over that of the 4 storey, resulting in an average cost of $20/sq ft

Past projects and common industry estimates typically suggest an average cost of $30/sq ft for 6 Storey concrete framing, approximately 50% more than for 6 Storey wood

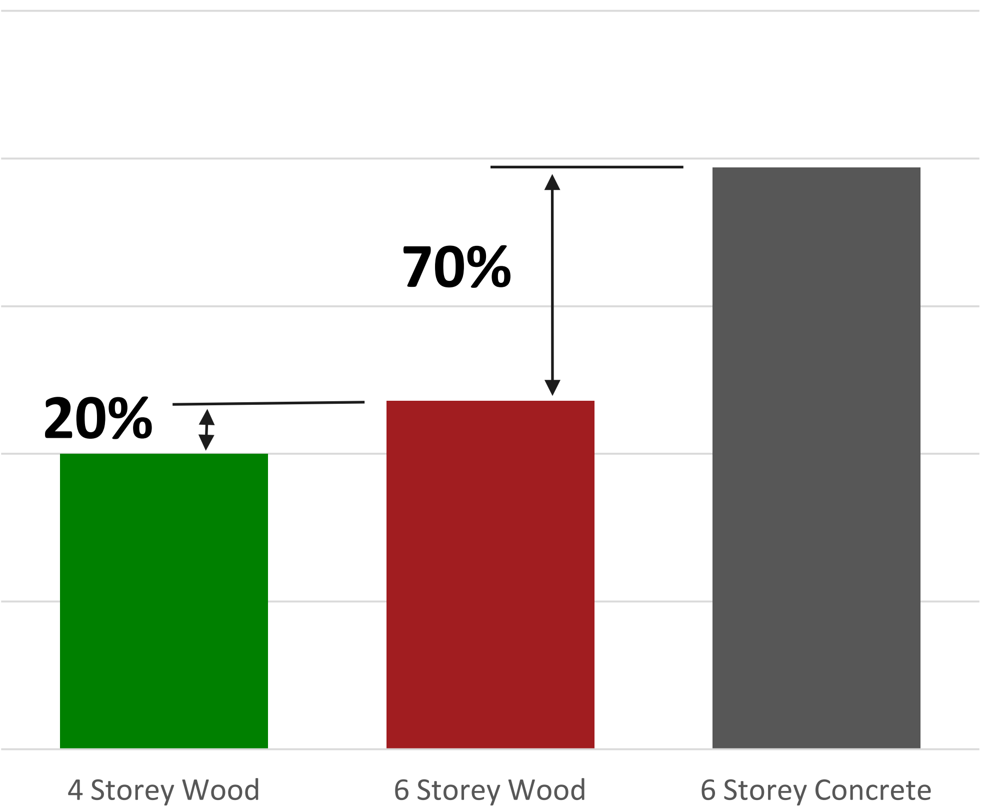


Results - Foundations

SBM also used the Reference Building to model a sample 6 Storey concrete building. The relative foundation volumes were then compared between the three building types

The additional loads on the 6 Storey wood building yielded a 20% increase in foundation volume compared to that of the 4 Storey, despite a 50% increase in floor area

The 6 Storey concrete building added 4x more mass, which also increased the loads to be resisted in a seismic event. This contributed to a 70% increase in foundation **volume** compared to that of the 6 storey wood structure



Affordable Housing: London

- 6 Stories, Slab on grade
- 57,000 sq. ft. Building Area
- 58 units, mix of bachelor/1 bedrooms
- Masonry Shafts
- Wood framed walls and Floors
- Helical Piers and Grade Beams for Foundations
- Floor and Walls to be panelized offsite
- 11.875” joists with 2x6 walls (single wall)
- Supply and Install price: $16/ per sq. ft.

7 Storey Hotel w/ below grade parking

Poor Soil to depths of 12-15 ft

1 Storey Buildings on West side