Design of Multi-Storey Shear Walls

3:15 PM – 4:30 PM

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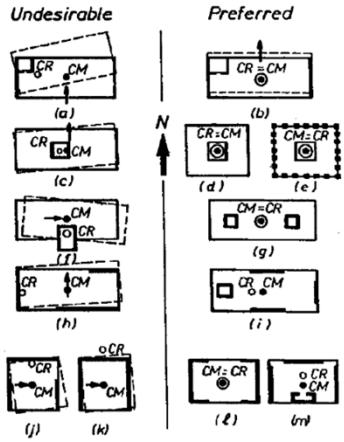
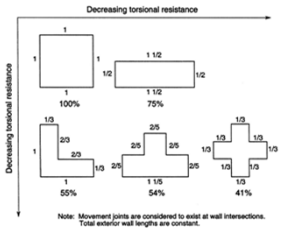
Lecture Outline

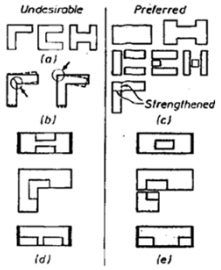
1. Multi-storey Building Lateral Load Distribution
   a) Wall Layout (10)
   b) Equivalent Static Force Procedure (10)
   c) Distribution of Loads to Shear walls (5)
2. Non-Structural Walls (10)
3. Ductile Shear Walls (R_d = 3.0) and Boundary Elements (40)

Design of Multi-Storey Masonry Structures

(Pages 467-469, 697-745)



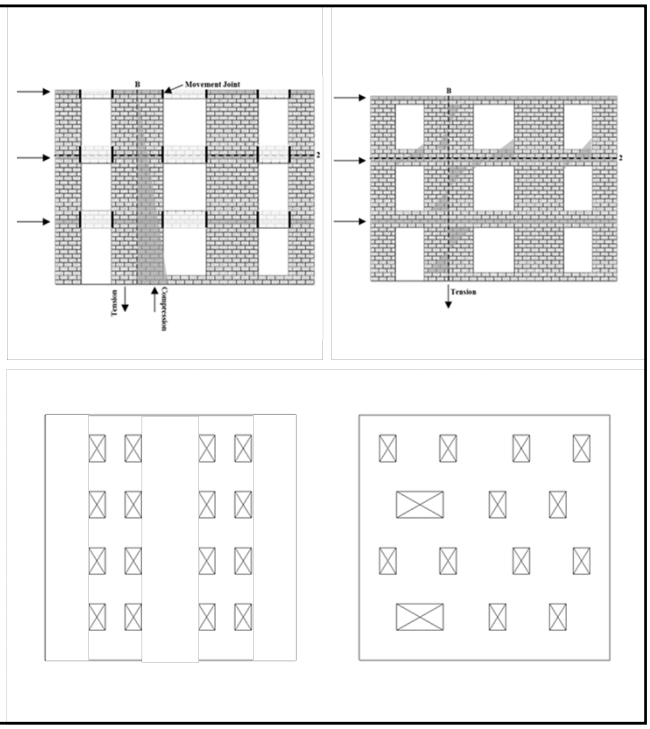




Building Plan

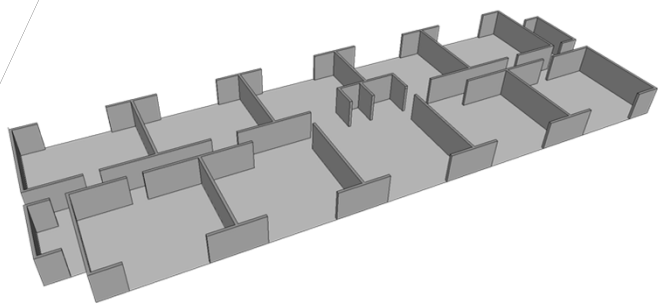
Elevations

- Vertical alignment of openings
  - Movement joints create defined shear walls
  - Otherwise frame action
- Irregular opening spacing
  - Complex analysis



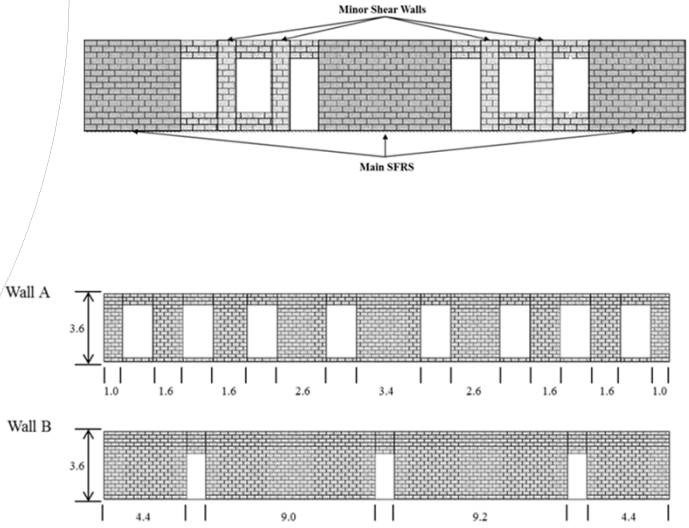
Flanged Walls

- Increase curvature ductility, moment
  - Cl. 10.6.2 Flange Widths
  - Act along both axes of loads
- Built integrally
  - Units bonded
- Anchored



Minor Shear Walls

- NBCC Permits structural framing elements not a part of SFRS
  - CSA S304-14 has explicitly mentioned this as well due to prevalence in masonry buildings
- Flexible Diaphragm
  - Consider walls within shearline
- Rigid Diaphragm
  - Consider all walls within structure



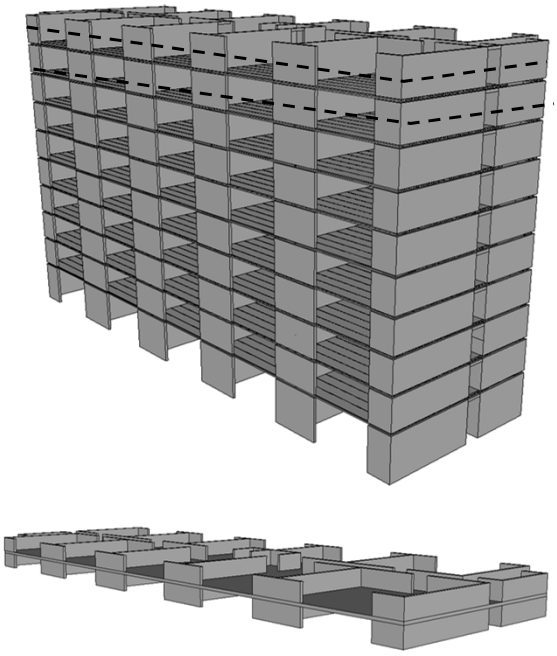
Equivalent Static Force Procedure

- Structure to meet any of the following
  - Seismic Hazard Index < 0.35
  - Regular Structures < 60m, T < 2.0s
  - Irregular Structure < 20m, T < 0.5s

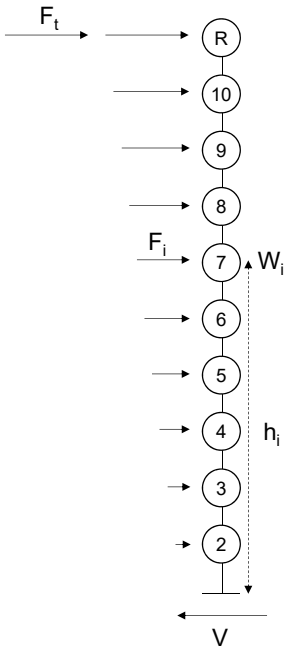
$$T = 0.05(h_n)^{3/4} < 2.0$$

Seismic Weight

- DL + 0.25SL
- Floors and Walls tend to dominate
  - Assign weight at discrete points
  - ½ wall height above and below



Seismic Forces



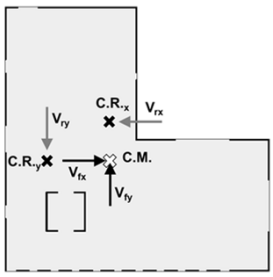
$$F_i = (V - F_t)\frac{W_i h_i}{\sum W_i h_i}$$

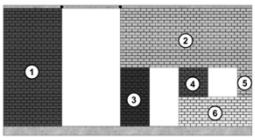
$$V_i = F_t + \sum_i^R F_i$$

$$M_i = F_t(h_R - hi) + \sum_{i+1}^R F_i\,(h_R - hi)$$

Distribution of Forces to Shear Walls

- Multiple stories can be treated the same as a single storey
  - Wall layout constant
  - t, E, etc. constant
- Be aware of assumptions being used
  - Elastic response
  - May warrant more detailed analysis

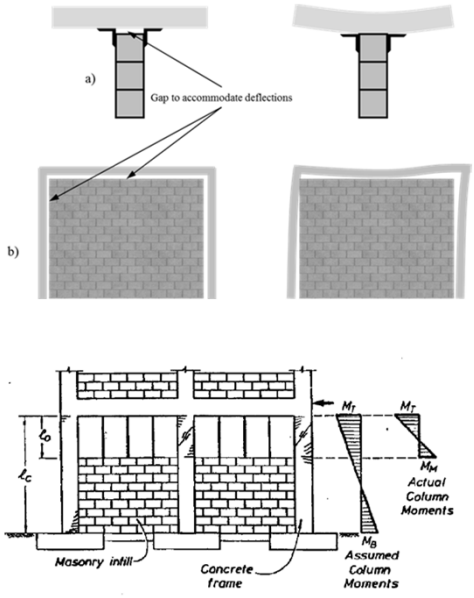




Non-Structural Walls

Partition Walls

- Non-loadbearing
  - Defined by axial loads
  - May still resist out-of-plane loads
- Internal wind pressures
- Seismic “Non-Structural Components”

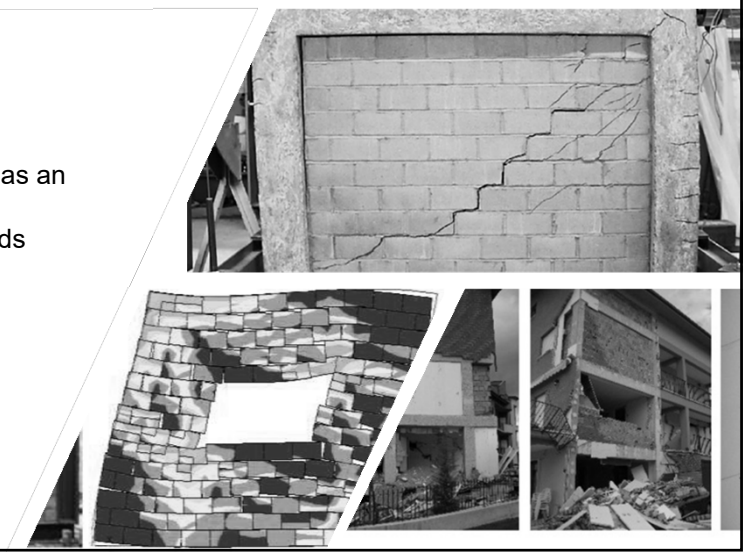


Structural Isolation

- Unintended infill wall behaviour
  - Shear critical
- Loads transferred via floor diaphragm
  - Sufficient gap required

Infill Walls

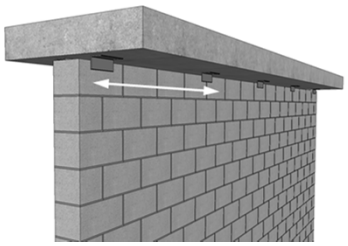
- Chapter 10 in textbook
  - Beyond scope of course
  - Not a recognized SFRS
- Danger arises when partitions acts as an **unintentional** infill wall
  - Transfer of axial and lateral loads
  - Braced frame behaviour



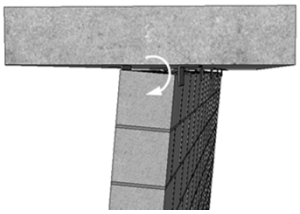
In-Plane vs. Out-of-Plane

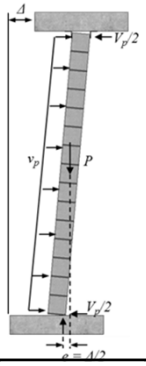
- Relative stiffness out-of-plane very low
- Support can be provided with minimal impact on strucutre

In-Plane
Free Movement



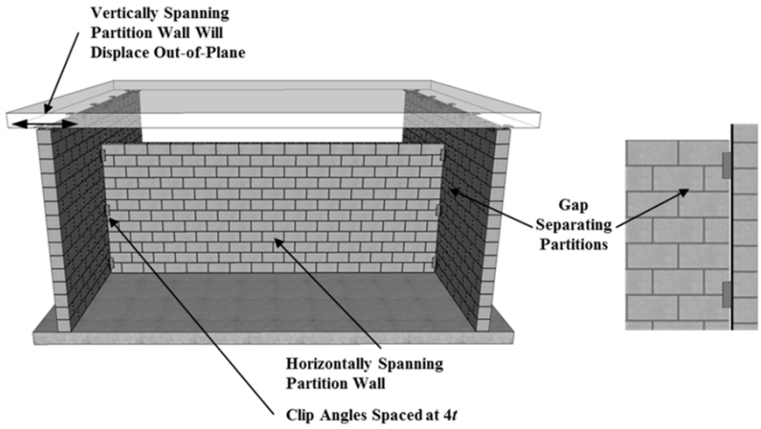
Out-of-Plane
Simple Support Created





Horizontally Spanning Walls

- May not be feasible to support along top
  - Walls can be supported along vertical edges
  - Horizontal bending
  - χ-factor



Ductile Shear Walls and Boundary Elements

(Cl. 16 CSA S304-2014)

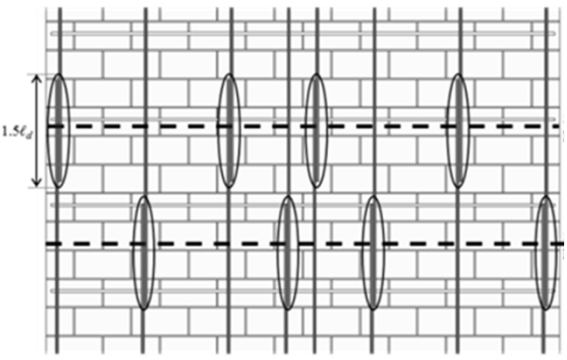
Limitations to Multi-Storey Masonry

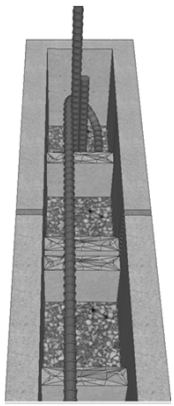
- High axial loads
  - Reduce ductility
  - Increase seismic effects
- Low unit strength
- Difficult to provide compression reinforcement

Ductile Shear Walls

- New SFRS Category in 2014 CSA S304
- Rd = 3.0
- Tighter restrictions over moderately ductile walls

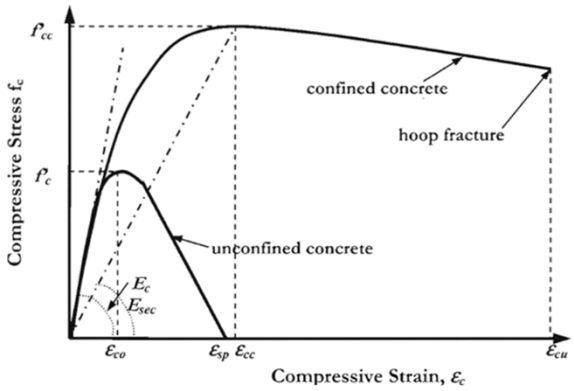
Section of Shear Wall containing Plastic Hinge		Moderately Ductile Shear Walls	Ductile Shear Walls
Default Value		20	12
Wall Containing Boundary Element	Boundary Element	20	12
	Rest of Wall	30	16
Rectangular Cross-Section		If $c < (4b_w$ or $0.3\ell_w) = 30$	If $c < (4b_w$ or $0.3\ell_w) = 16$
Flanged Cross-Section (Flange Width > h/5, Flange thickness > 190mm)		If $c < 3b_w = 30$	If $c < 3b_w = 30$





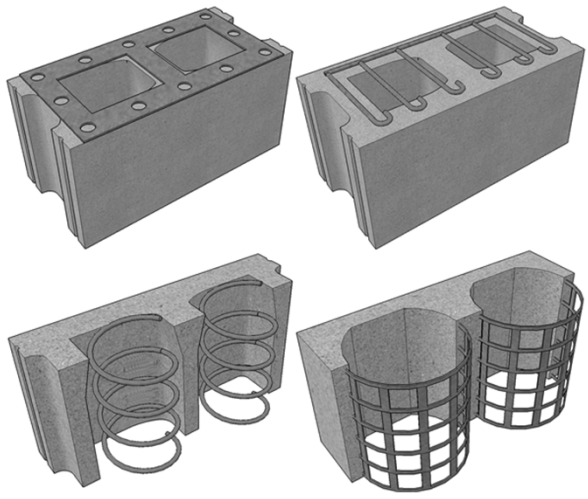
Increasing Compressive Strain in Masonry

- Readily Accomplished in reinforced concrete
- Lateral ties around at least 4 vertical bars
- Area of Concentrated Reinforcement



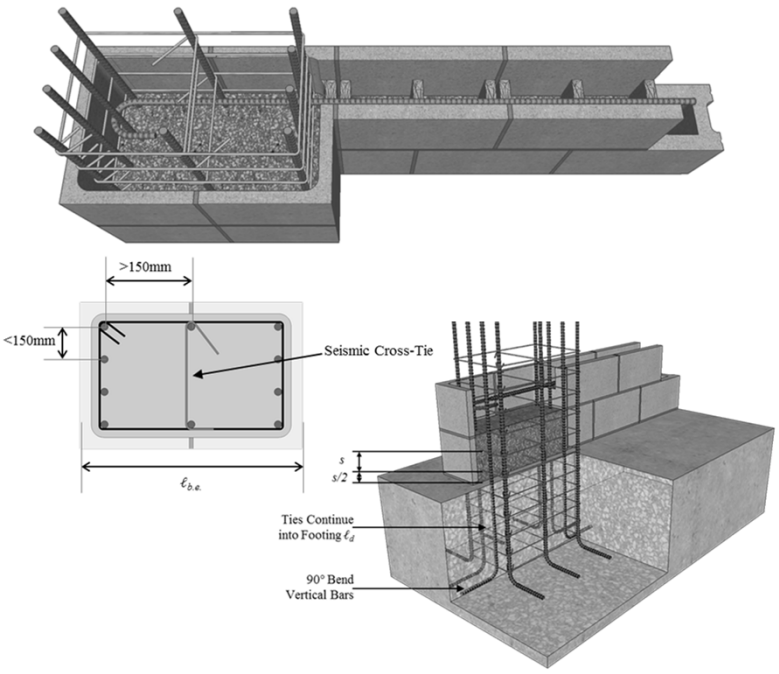
Increasing Compressive Strain in Masonry

- Difficult to accomplish using concrete practices
  - Limited space in conventional units
- Alternative means to improve unit confinement
  - Not necessarily beneficial to compression steel
  - Proprietary units
  - Limited application (US, NZ)



Masonry Boundary Elements

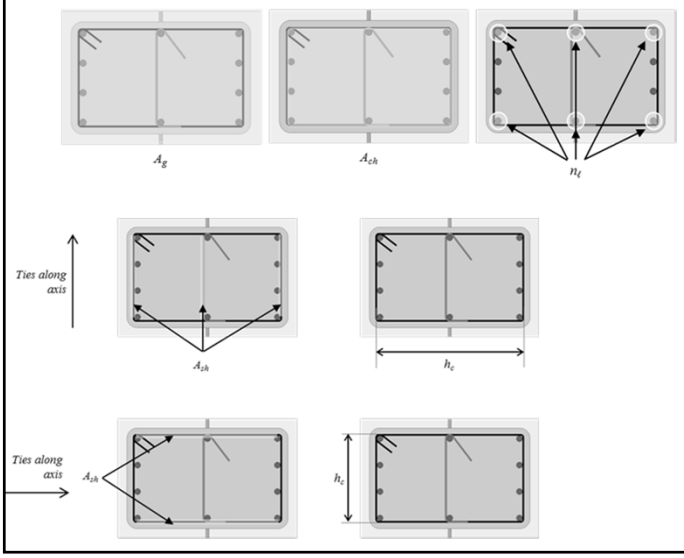
- Prescriptive design requirements given in CSA S304-2014
  - Mimics 'area of concreted reinforcement' in CSA A23.3
  - Non-proprietary
- Increase compressive strain in masonry
- Provides compression reinforcement



Construction of Boundary Elements

- "Boundary Element" Units
  - Thinner face shell than pilaster units
  - Notched edged for grout and reinforcement continuity
- Cage embedded in footing
- Stack pattern
  - Inspection and clean out

Detailing Requirements



$$A_{sh} \geq 0.2 k_n k_{p1} \frac{A_g}{A_{ch}} \frac{f'_m}{f_{yh}} sh_c$$

$$k_n = \frac{n_\ell}{(n_\ell - 2)}$$

$$k_{p1} = 1 + 30\varepsilon_{mu}$$

$$\varepsilon_{mu} \leq 0.008$$