Masonry Shear Walls
Ultimate Limit States: Flexure and Shear

Lecture Outline

1. Overview (10)
2. Design for Flexure and Axial Load
   a) Fully-Grouted Shear Walls (25)
   b) Partially-Grouted Shear Walls (25)
   c) Interaction Diagrams (10)
   d) Squat Shear Walls (15)
3. Design for Shear
   a) Fully- and Partially-Grouted Shear Walls (20)
   b) Squat Shear Walls (10)
4. Supplemental eLearning (5)
Overview

• Cantilever vs. Fixed-Fixed Ends
• Squat vs. Slender
• Reinforcement and Grouting
• Solid or Perforated
• Flanges or Boundary Elements

Fundamental to Masonry Shear Walls

• Similar to Reinforced Concrete
  • Fully-grouted wall
  • Lateral load shared by stiffness
  • Form core to building
  • Flanged and C-Shaped wall
  • Ductile behaviour
  • Seismic Force Resisting System
Fundamental to Masonry Shear Walls

- Different to Reinforced Concrete
  - Unreinforced and partially-grouted
  - Openings
  - Walls along peripheral of building
  - Wide-spaced reinforcement
  - Walled structure means more load sharing
  - Coupling difficult, not recognized SFRS

Ultimate Limit States

1. Moment
2. Axial Load
3. Diagonal Shear
4. Sliding Shear
10.2 Design requirements for axial load and bending

10.2.1 Plane sections assumption
Scans in reinforcement and masonry shall be assumed to be directly proportional to the distance from the neutral axis, except for deep flanged members as defined in Clause 10.2.8.

10.2.2 Maximum usable masonry strain
Maximum usable strain at the extreme masonry compression fibre shall be assumed to be equal to 0.003.

10.2.3 Reinforcement stress-strain relationships
The maximum stress in the reinforcement shall be calculated as $\sigma_p = f_y$ for reinforcing bars and $\sigma_p$ for tendons, times the force determined from strain compatibility based on a stress-strain curve representative of the steel.

For reinforcement with a specified yield strength of 400 MPa or less, the following assumptions may be used:
(a) for strains less than the yield strain, $\sigma_p/f_y$, the force in the reinforcement shall be taken as $\sigma_p = f_y$; and
(b) for strains greater than the yield strain, the force in the reinforcement shall be taken as $\sigma_p/f_y$.

10.2.4 Tensile strength of masonry
The tensile strength of masonry shall be neglected in the calculation of the factored bending resistance of reinforced walls and columns.

10.2.5 Masonry stress-strain relationship
The relationship between the masonry compressive stress and strain may be assumed to be parabolic, lognormal, or any other shape that results in prediction of strength in substantial agreement with results of comprehensive tests.

10.2.6 Equivalent rectangular masonry stress block
The requirements of Clause 10.2.5 may be satisfied by an equivalent rectangular masonry stress block defined by an assumed uniform masonry stress calculated at 0.85 $f_{cm}$ $a/2$ distributed over a compression zone located by the intersection and a straight line located parallel to the neutral axis at a distance $a/\beta$ from the fibre of maximum compressive stress.

where:

- $x$ = the factor used to account for the direction of compressive stress in a masonry member relative to the direction used for the determination of $f_{cm}$
- 0.5 for compressive forces applied normal to the head face and the gout is not horizontally continuous in the zone of compression
- 0.7 for compressive forces applied normal to the head face and the gout is horizontally continuous in the zone of compression
- 1.0 for compressive forces applied normal to the head face
- 0.8 for masonry stresses $f_{cm}$ up to and including 20 MPa
- 0.8 minus 0.1 for each 10 MPa of stress in excess of 20 MPa
- $a$ = the distance from the fibre of maximum compressive stress to the neutral axis measured in a direction perpendicular to that axis

Notes:
1. Gout is considered to be lengthwise continuous where the gout in the compression zone is not interrupted by webs.
2. Linear interpolation may be used to calculate $\beta$. 

Design Assumptions
**Masonry Shear Wall Loads**

- **Applied Axial Load**
  - 50 kN/m $D_L$
  - 50 kN/m $L_L$
  - 10 kN/m $S_L$

- **Applied Lateral Load**
  - 200 kN $E_L$
  - 6.0 m Long
  - 8.0 m Tall
  - 25 cm Units
  - 30 MPa Block, Type S Mortar, Fully-Grouted
  - 20 M Vertical Reinforcement @ 1.2 m

**Shear Wall Details**

<table>
<thead>
<tr>
<th>$d_1$</th>
<th>$d_2$</th>
<th>$d_3$</th>
<th>$d_4$</th>
<th>$d_5$</th>
<th>$d_6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,900 mm</td>
<td>4,700 mm</td>
<td>3,500 mm</td>
<td>2,500 mm</td>
<td>1,300 mm</td>
<td>100 mm</td>
</tr>
</tbody>
</table>
**Design Moment and Axial Load**

- Critical Cross-Section for Flexure at Base of Wall
- Triangular Moment Diagram

![Diagram showing Vf, Pf, Mf, and Pf = Pa + S_w]

1. **Design Moment + Axial Load**
   - **1.0 D_L + 1.0 E_L**
     - \( M_f = 1.0 \times (200 \text{ kN}) \times 8.0 \text{ m} = 1600 \text{ kN·m} \)
     - \( P_f = 1.0 \times (50 \text{ kN/m} \times 6.0 \text{ m} + 250 \text{ kN}) = 550 \text{ kN} \)
   - **2. 1.25 D_L + 1.5 L_L + 0.5 S_L**
     - \( M_f = 0 \)
     - \( P_f = 1.25 \times (550) + 1.5 \times (300) + 0.5 \times (60) = 1167.5 \text{ kN} \)
Assumptions for Bending and Axial Load

- Similar to Intermediate Reinforcement in Beams
- Compression Reinforcement not Typical
- Tension Reinforcement is not Required to Yield
- Possible Iterative Solution based on Neutral Axis Depth Assumption
Assumptions 1.0D_L + 1.0E_L

1. Strain Compatibility
   - Neutral Axis Depth
     • 1 bar under compression (ε_{s6})
     • 1 bar under tension but not yielding (ε_{s5})
     • All other Bars Yield

\[
\begin{align*}
\varepsilon_{s1} &= \frac{\varepsilon_{s2}}{d_1 - c} = \frac{\varepsilon_{s3}}{d_2 - c} = \frac{\varepsilon_{s4}}{d_3 - c} = \frac{\varepsilon_{s5}}{d_4 - c} = \frac{\varepsilon_{s6}}{d_5 - c} = \frac{\varepsilon_{mu}}{c - d_6} = \frac{\varepsilon_{mu}}{c}
\end{align*}
\]

2. Force Equilibrium

\[C - P_f = F_s1 + F_s2 + F_s3 + F_s4 + F_s5\]
Verify Assumptions

- $c = 798 \text{ mm}$
- Lies between $d_5$ and $d_6$
- $A_{s5}$ does not yield?

$$\varepsilon_{s5} = \frac{\varepsilon_{mu}(d_5 - c)}{c}$$

Moment Resistance
Maximum Factored Axial Load

1. \(1.0 \, D_L + 1.0 \, E_L\)
   - \(M_f = 1.0 \times (200 \, kN) \times 8.0 \, m = 1,600 \, kN \cdot m\)
   - \(P_f = 1.0 \times (50 \, kN/m \times 6.0 \, m + 250 \, kN) = 550 \, kN\)

2. \(1.25 \, D_L + 1.5 \, L_L + 0.5 \, S_L\)
   - \(M_f = 0\)
   - \(P_f = 1.25 \times (550) + 1.5 \times (300) + 0.5 \times (60) = 1,167.5 \, kN\)

10.4 Maximum factored axial load resistance

10.4.1
Except as permitted in Clause 10.4.2, the factored axial load resistance, \(P_f\), of compression members shall not be taken as greater than

\[P_{fact} = 0.80 \times 0.85 \times (A_c / A_s)\]

10.4.2
Where compression reinforcement is tied in accordance with the requirements of Clause 12.2, the factored axial load resistance, \(P_{fact}\), of compression members shall not be taken as greater than

\[P_{fact} = 0.80 \times 0.85 \times (A_c / A_s) \times (1 + \phi / A_s)\]

Review

- Similar approach as tall beams with intermediate reinforcement
  - Axial Load
- Symmetric wall and loads
  - Axial loads may not be concentric and cause a moment
  - "T" or "L" shaped walls have different strengths in either direction of loading
- Critical load cases
  - Axial load and over turning moment interaction
  - Highest moment may not govern, depends on axial load (interaction diagram)
- Shear walls as cantilevers
  - Typical for a triangular moment profile maximum at base
  - Self-weight maximum at base
- Reinforcement need not yield
  - Axial load carrying members need not meet the same criteria as beams (impractical)
Review: CSA S304 Clauses

4.2.2.2 Load combinations

The effect of factored loads for a building structural component shall be determined in accordance with the applicable interaction diagrams for the component. The component shall be considered loaded to the maximum factored load combination at the site in accordance with the applicable interaction diagrams for the component. The component shall be loaded to the maximum factored load combination at the site in accordance with the applicable interaction diagrams for the component.

4.2.2.3 Resistance factors

The resistance factors shall be determined by the following formulas:

Table 4

Specified compressive strength normal to the bed joint, \( f'_{bc} \)

<table>
<thead>
<tr>
<th>Specified compressive strength of unit (average net area)(^2), MPa</th>
<th>Type S mortar</th>
<th>Type N mortar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hollow</td>
<td>Solid or grooved</td>
<td>Hollow</td>
</tr>
<tr>
<td>40 or more</td>
<td>22</td>
<td>17</td>
</tr>
<tr>
<td>30</td>
<td>17.5</td>
<td>13.5</td>
</tr>
<tr>
<td>25</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>15</td>
<td>9.8</td>
<td>7.5</td>
</tr>
<tr>
<td>10</td>
<td>6.5</td>
<td>5</td>
</tr>
</tbody>
</table>

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10.2 Design requirements for axial load and bending

10.2.1 Plane sections assumption

Stress in reinforcement and masonry shall be assumed to be directly proportional to the distance from the neutral axis, except for deep flexural members as defined in Clause 10.2.8.

10.2.2 Maximum usable masonry strain

Maximum usable strain at the extreme masonry compression fibre shall be assumed to be equal to 0.003.

10.2.3 Reinforcement stress-strain relationships

The factored force in the reinforcement shall be calculated as \( f_y \) for reinforcing bars and \( f_y \) for tensile times the force determined from strain compatibility based on a stress-strain curve representative of the steel.

For reinforcement with a specified yield strength of 400 MPa or less, the following assumptions may be used:

(a) For strains less than the yield strain, \( f_y/3 \), the force in the reinforcement shall be taken as \( 0.7f_y \)

(b) For strains greater than the yield strain, the force in the reinforcement shall be taken as \( f_y \).

10.2.4 Tensile strength of masonry

The tensile strength of masonry shall be neglected in the calculation of the factored bending resistance of reinforced walls and columns.

10.2.5 Masonry stress-strain relationship

The relationship between the masonry compressive stress and strain may be assumed to be parabolic, trapezoidal, or any other shape that results in prediction of strength in substantial agreement with results of comprehensive tests.

Flexure & Axial Load: Partially-Grouted Shear Walls

(Pages 490 & 753)

Cl. 10 CSA S304
<table>
<thead>
<tr>
<th>Fully-Grouted Walls</th>
<th>Fire or Sound Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Resist Shear Forces</td>
</tr>
<tr>
<td></td>
<td>Meet Seismic Prescriptive Detailing</td>
</tr>
<tr>
<td></td>
<td>High Axial Load</td>
</tr>
<tr>
<td></td>
<td>Reinforcement Closely Spaced</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Partially-Grouted Walls</th>
<th>Lower Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reduced Self-Weight</td>
</tr>
<tr>
<td></td>
<td>Reduced Seismic Force</td>
</tr>
<tr>
<td></td>
<td>Conduits and Non-Structural</td>
</tr>
<tr>
<td></td>
<td>Moment Capacity</td>
</tr>
</tbody>
</table>
Partially-Grouted Shear Walls

Wall Properties

- Self-weight
- Effective Cross-sectional Area
- Masonry Strength

\[
A_{g.c.} \quad \text{Grouted Cell}
\]

\[
A_{u.g.c.} \quad \text{Ungrouted Face Shells}
\]
Assumptions 1.0DL + 1.0EL

1. Strain Compatibility
   • Axial Load is reduced to 449 kN
     • But also less area to resist
   • Neutral Axis Depth
     • 1 bar under compression ($\varepsilon_{s6}$)
     • 1 bar under tension but not yielding ($\varepsilon_{s5}$)
     • All other Bars Yield

2. Force Equilibrium

\[
P_f - \sum F_s = 0
\]

\[
C - P_f = F_{s1} + F_{s2} + F_{s3} + F_{s4} + F_{s5}
\]
Compression in Partially Grouted Masonry

- Equivalent stress block
- Different $f'_{m}$ for grouted and ungrouted

Verify Assumptions

- $c = 1,223$ mm
- Lies between $d_5$ and $d_6$
- $A_{s5}$ does not yield
- $\beta_1c = 978$ mm
- Ends in ungrouted cell
Moment Resistance

Maximum Factored Axial Load

- Axial Load Case
- $1.25 D_L + 1.5 L_L + 0.5 S_L$
  - $M_f = 0$
  - $P_f = 1.25 (449) + 1.5 (300) + 0.5 (60) = 1,041 \text{kN}$

\[\begin{align*}
A_{g.c.} &= 288,000 \text{ mm}^2 \\
A_{ug.c.} &= 370,560 \text{ mm}^2 \\
A_e &= 658,560 \text{ mm}^2
\end{align*}\]
• Equivalent material
  • Strength and geometry reflect partial grouting effects
  • Makes iterative solutions simpler
  • Table 4, Note 3

Assumptions
1.0D_L + 1.0E_L

2. Force Equilibrium

C - P_f = F_{s1} + F_{s2} + F_{s3} + F_{s4} + F_{s5}
Review

- Reduced grout to reduce self-weight
  - Smaller axial load reduces neutral axis depth
  - Less area to carry axial loads will increase
- Lower seismic weight of structure
  - Lateral loads proportional to material dead loads
- Discrete and Smearred methods
  - Grouted cells and face shells treated as distinct
  - Equivalent smeared area
- Iterative solutions and assumption check
  - Discrete method can prove to be complex
  - Check where compression block lies

Review: CSA S304 Clauses
10.3 Effective cross-sectional area
The effective cross-sectional area, $A_{e}$, to be used in the design of masonry walls and columns shall include:
the mortar bedded area and the area of voids filled with grout. It shall take into account crazed joints, voids, chases, and spalls in the section. No reduction in area is required for:
(a) voids that do not exceed 25% of the area of normal brick units, and
(b) concave beveling of mortar joints to a depth not exceeding 3 mm.

Table 4
Specified compressive strength normal to the bed joint, $f'_{cm}$
for concrete block masonry, MPa

<table>
<thead>
<tr>
<th>Class</th>
<th>$f'_{cm}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>25.0</td>
</tr>
<tr>
<td>II</td>
<td>22.0</td>
</tr>
<tr>
<td>III</td>
<td>19.0</td>
</tr>
</tbody>
</table>

Note: For partially grouted walls, a weighted value of $f'_{cm}$ may be used to account for the percent of the wall length that is grouted. Alternatively, the grouted and ungrouted parts of the wall may be treated separately, provided that compatibility of deformations is included.
Design Moment-Axial Load Interaction Diagram

- Not typically derived by hand
- Computer Program Generated
  - MASS
- Illustrates governing load case

Interaction Diagrams

Axial Load Dominated
Over-Reinforced
Transition
Under-Reinforced Wall
Pure Flexure
Critical Load Case

- Consider Moment-Axial Load Resistance Envelope
  - Interaction Diagram
- Governing Load Cases?

Flexure & Axial Load: Squat Shear Walls
Squat Shear Walls

Effective Depth

\[ d_{eff} = \sum \frac{F_s d_i}{F_s l} \]
Equivalent Moments

\[ C \Sigma F_{si} \]

\[ C \]

\[ F_{s1} \]
\[ F_{s2} \]
\[ F_{s3} \]
\[ F_{s4} \]
\[ F_{s5} \]
\[ \Sigma F_{si} \]

Squat Shear Walls

- Reduced Moment Arm
- Effective Depth
  - \( = 0.67t_w \times 0.7h_w \)
  - Cl. 10.2.8

\[ d_{eff} = \sum \frac{F_{si}d_i}{F_{si}} \leq \min(0.67\ell_w, 0.7hw) \]
Review

- When wall height is less than wall length the wall is considered squat
  - Clause 10.2.8 may apply
  - In multi-storey shear walls wall height is measured as the total wall height, not the inter-storey height
- Force equilibrium and strain compatibility still applies with prescriptive reduction
  - Solve for internal forces and neutral axis depth as we have previously
- Effective depth of reinforcement
  - May be determined for all tension reinforcement
  - Weighted average depth based on the depth and force carried in individual bars
- Reduced effective depth
  - When the wall is short enough the effective depth of the reinforcement may be reduced by Cl. 10.2.8
  - Worst-case effective depth governs and Cl. 10.2.8 should not improve resistance of a cross-section

Review: CSA S304 Clauses
10.2.8 Low-aspect-ratios (squat) shear walls
Masonry shear walls having height-to-length ratios \( h_w/L_w < 1.0 \) shall be designed as deep sections having a reduced moment arm between the compression zone and the tensile reinforcement. For these members, the effective depth, \( d_e \), may be taken as \( 0.67c_f \) of the section depth, but not greater than 0.7\( h_w \).
Shear Reinforcement

- Horizontal Bond Beams
- Bed Joint Reinforcement
- Dowels

Diagonal Shear Resistance

- $V_m$
  - Shear Strength of Masonry, MPa
- $P_d$
  - Axial Load
- $d_v$
  - Effective Shear Depth
- $\gamma_g$
  - Factor to Account for Partial Grouting
- $A_v$
  - Area of Shear Reinforcement at Spacing $s$
10.10.1.1 General

The factored shear resistance, $V_s$, shall be taken as

$$V_s = \phi_s \left( V_{aw} + 0.23 \frac{d_2}{f} \frac{F_a}{0.060 + \frac{d_2}{f}} \right)$$

but not greater than

$$0.4 \phi_s \sqrt{\phi_s A_s f}$$

where

- $\phi_s$ = shear strength attributed to the masonry and given in Clause 10.10.1.4, MPa
- $d_2$ = effective depth, which need not be taken less than $0.8 t_f$, for walls with flexure reinforcement distributed along the length, mm
- $F_a$ = axial compressive load on the section under consideration, based on 0.9 times dead load plus any axial load arising from bending in coupling beams, kN

$\gamma_f$ = factor to account for partially grouted or ungrouted walls that are constructed of hollow or semi-solid units.

- 1 for fully grouted masonry, fully solid concrete block masonry, or solid brick masonry; otherwise $= A_s/A_s$, but not greater than 0.3

where

- $A_s$ = gross cross-sectional area, mm$^2$

**Ultimate Shear Capacity**

- $t_w = 3.6$ m
- $h_w = 3.8$ m
- 290 mm Units
  - 20 MPa
  - Type S Mortar
  - $t_f = 41.4$ mm
- $A_{s,vertical}$
  - 25M @ 1.2m
- $A_{s, horizontal}$
  - 2x10M @ 1.2m
  - 2x4.76 mm @ 400 mm
**Critical Load Case**

- $E_L = 280 \text{ kN}$
- $D_L = 300 \text{ kN}$
- $S.W. = 59.0 \text{ kN}$

- $V_i = 280 \text{ kN}$
- $P_D = 300 \text{ kN}$
- $P_i = 359.0 \text{ kN}$

**Ultimate Shear Capacity**

\[
V_r = V_m + V_s = \phi_m (v_m b_w d_v + 0.25 P_d) \gamma_g + \left( \frac{0.6 \phi_s A_v f_y \gamma_g}{s} \right)
\]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value (CSA S304-04 Reference if Applicable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi_m$</td>
<td>0.6 (Cl. 4.3.2.1)</td>
</tr>
<tr>
<td>$v_m$</td>
<td>Cl. 10.10.1.4</td>
</tr>
<tr>
<td>$b_w$</td>
<td>290 mm ($V_g$ accounts for partial grouting)</td>
</tr>
<tr>
<td>$d_v$</td>
<td>0.8$L_v = 2,880 \text{ mm}$</td>
</tr>
<tr>
<td>$P_d$</td>
<td>0.9$D_o = 323.1 \text{ kN}$</td>
</tr>
<tr>
<td>$\gamma_g$</td>
<td>$A_v/A_g$</td>
</tr>
<tr>
<td>$\phi_s$</td>
<td>0.85 (Cl. 4.3.2.2)</td>
</tr>
<tr>
<td>$A_v$</td>
<td>200 mm$^2$</td>
</tr>
<tr>
<td>$f_y$</td>
<td>400 MPa</td>
</tr>
<tr>
<td>$s$</td>
<td>1,200 mm</td>
</tr>
</tbody>
</table>

| 
| 35.6 mm$^2$ |
| 
| 400 mm |
Weighted Masonry Properties

- Partially-grouted masonry
  - $f_m'$ taken as weighted
  - $\gamma_g = A_e/A_g$
- Face shells and Grouted Cells

10.10.1.4 Masonry shear strength

Shear strength contributed by masonry, $V_m$, shall be as given by

$$V_m = 0.16 \left( 2 - \frac{M_s}{V_i h_i} \right) \gamma_m$$

where

- $M_s$ is a value that shall not be more than 1 or less than 0.25 for the concurrent factored moment, $M_s$, and factored shear, $V_i$, at the section under consideration

Masonry Shear Strength

$$M_i = V_i x h_i$$
Fully-Grouted Shear Wall

- S.W. = 86.5 kN
- $\gamma_g = 1.0$
- $f'_m = 10\text{MPa}$

In-Plane Sliding Shear
10.10.4 Factored sliding shear resistance

Notes:
(1) Shear reinforcement is not taken into account in the calculation of the sliding shear resistance, the provisions of Clause 7.10.4 may be used.
(2) Dowels may be used at the base of the masonry to resist sliding shear. When flushings reduce the friction that resists sliding shear, the frictional coefficients, \( \mu \), would be based on the particular flushing material.

10.10.4.1 Factored in-plane sliding shear resistance

The factored in-plane sliding shear resistance, \( V_s \), shall be taken as

\[
V_s = \gamma_g P_b
\]

where

\( \mu = \begin{cases} 
1.0 & \text{for a masonry-to-masonry or masonry-to-reinforced concrete sliding plane} \\
0.7 & \text{for a masonry-to-smooth concrete or bare steel sliding plane} 
\end{cases} \)

\( P_b = \) compressive force in the masonry acting normal to the sliding plane, normally taken as \( P_{ct} \) plus the factored tensile force at yield of the vertical reinforcement and 90% of the factored vertical component of the compressive forces resulting from the diagonal strut action found in infill walls, \( N \)

---

In-Plane Sliding Shear

---

Review

- Partially-Grouted Walls must consider \( \gamma_g \) reduction factor
  - Fully-grouted \( \gamma_g = 1.0 \)
  - Use actual block width, \( b_w \), and \( \gamma_g \) will account for partially grouted effects

- Shear reinforcement may not be required
  - If needed, may consist of bed joint wire reinforcement or bond beam reinforcement or a combination of the two
  - Fully-grouting the wall will have a dramatic effect on shear strength compared with the effect on moment

- Seismic Detailing and Minimum Spacings
  - To be covered in next lecture and through eLearning
  - Often governs spacing requirements over strength design
Diagonal Shear and Sliding: Squat Shear Walls
CI. 10 CSA S304

Squat Shear Wall

- $f_u = 8.0 \text{ MPa}$
- $h_w = 3.8 \text{ m}$
- 290 mm Units
  - 20 MPa
  - Type S Mortar
  - $t_f = 41.4 \text{ mm}$
- $A_{s, \text{vertical}}$
  - 25M @ 1.2m
- $A_{s, \text{horizontal}}$
  - 2x10M @1.2m
  - 2x4.76 mm @ 200 mm

$V_f = 800 \text{ kN}$
$P_{DL} = 1,200 \text{ kN}$
$P_f = 1,329 \text{ kN}$
$P_{DL} = 1,200 \text{ kN}$
Squat Wall Shear Resistance

- Means of assuring load is distributed along length
- New effective properties
  - \( f_m' = 11.6 \text{ MPa} \)
  - \( \gamma_g = 0.43 \)
  - \( d_s = 6,400 \text{ mm} \)
  - \( v_m = 0.766 \text{ MPa} \)

Factored Shear Strength

- \( V_r = 893.9 \text{ kN} > V_f \)
- \( V_{r \text{max}} = 976.8 \text{ kN} \)
- 50% increase over non-squat

10.10.1.3 Low-aspect-ratio (squat) shear walls

The upper limit on the factored shear resistance of low-aspect-ratio walls \((h_w / l_s < 3)\) is greater than that given in Clause 10.10.1.1; however, care shall be taken to ensure that the shear input to the wall is distributed along the entire length of the wall and will not lead to failure of a portion of the wall. If such care is taken, then the maximum factored shear resistance may be increased to

\[
0.4 \times \sqrt{\frac{1}{\gamma_g} \frac{l_s}{d_s} \left[2 - \frac{h_w}{l_s}\right]}
\]

where
- \( h_w \) = wall length, mm
- \( l_s \) = total wall height, mm
- \( h_w / l_s \) = a value that shall not be less than 0.5 nor more than 1
Supplemental eLearning

Masonry Shear Walls

Unreinforced Masonry, Floor Connections and Intersecting Walls

Overview of Changes from 2004 to 2014 CSA S304 for Ductile Shear Wall Design