Reinforced Concrete Bearing Wall Design (CSA A23.3-14)
Reinforced Concrete Bearing Wall Design (CSA A23.3-14)

A structural reinforced concrete bearing wall in a single-story building provides gravity load resistance for the following applied loads:

- Roof uniform dead load $= 120 \text{ kN/m}$
- Roof uniform live load $= 150 \text{ kN/m}$

The assumed bearing wall section is investigated after analysis to verify suitability for the applied loads then compared with numerical analysis results obtained from spWall engineering software program from StructurePoint.

![Figure 1 – Reinforced Concrete Bearing Wall Geometry](image-url)

Figure 1 – Reinforced Concrete Bearing Wall Geometry
Contents

1. Simplified Equation Method........................................................................................................2

2. Wall Structural Analysis .................................................................................................................. 2
   2.1. Load and Load Combination .................................................................................................. 2
   2.2. Preliminary Member Sizing .................................................................................................. 2
   2.3. Calculation of axial resistance .............................................................................................. 3
   2.4. Minimum Horizontal Reinforcement .................................................................................. 3
   2.5. Minimum Vertical Reinforcement ......................................................................................... 4
   2.6. Check minimum standard requirements ............................................................................... 4

3. Reinforced Concrete Bearing Wall Analysis and Design – spWall Software ................................ 5

4. Design Results Comparison and Conclusions .............................................................................. 23
Code

Design of Concrete Structures (CSA A23.3-14) and Explanatory Notes on CSA Group standard A23.3-14 “Design of Concrete Structures”

Reference


• spWall Engineering Software Program Manual v10.00, STRUCTUREPOINT, 2022

Design Data

\( f_c' = 25 \text{ MPa normal weight concrete (} w_c = 24 \text{ kN/m}^3 \) \\
\( f_y = 400 \text{ MPa} \)

Wall height = 4.0 m.
Wall length = 8.0 m.
Used No. 10M bars for vertical and horizontal reinforcement (\( A_s = 100 \text{ mm}^2, d_b = 11.3 \text{ mm} \))
Clear cover = 40 mm

\( \text{CSA A23.3-14 (Table 17)} \)
1. **Simplified Equation Method**

Reinforced concrete bearing walls whether precast or cast in place can be analyzed using the provisions of Chapter 14 of the CSA A23.3-14. Bearing walls, are widely evaluated using the “Simplified Equation Method” in Section 14.2.2 having a simple expression. The applicable requirements of this procedure are summarized below:

- The wall has a solid rectangular constant cross-section over its height: **CSA A23.3-14 (14.2.2.2a)**
  The wall in this example has a solid rectangular constant cross-section over its height.

- The principal moment acts about the weak axis (axis parallel to the plane of the wall): **CSA A23.3-14 (14.2.2.2b)**
  This condition is not applicable for this wall (no moments are applied on the wall).

- The resultant of the factored axial (vertical) loads, including the effect of the principal moment, is located within the middle third of the total wall thickness: **CSA A23.3-14 (14.2.2.2c)**
  This condition is not applicable for this wall (no eccentricity – the factor axial load is applied at the center of the cross-section).

- The wall is supported against lateral displacements, at least along the top and bottom ends: **CSA A23.3-14 (14.2.2.2d)**
  The wall in this example is laterally supported at its top and bottom ends.

As a conclusion, the simplified equation method can be used for the wall discussed in this example.

2. **Wall Structural Analysis**

2.1. **Load and Load Combination**

For the factored Load

\[ w_u = 1.25 \times DL + 1.5 \times LL \]  

**CSA A23.3-14 (Annex C, Table C.1a)**

\[ w_u = 1.25 \times 120 + 1.5 \times 150 = 375 \text{ kN/m} \]

2.2. **Preliminary Member Sizing**

\[
\begin{align*}
t \geq & \min \left\{ \frac{t_u}{25}, \frac{h_u}{25} \right\} = \min \left\{ \frac{8000}{25}, \frac{4000}{25} \right\} = \left\{ \frac{320}{160} \right\} = 320 \text{ mm}
\end{align*}
\]

**CSA A23.3-14 (14.1.7.1)**

Use \( t = 350 \text{ mm} \).
2.3. Calculation of axial resistance

The analysis is performed for a unit length (1,000 mm) of the wall.

\[ L = 1 \text{ m} = 1000 \text{ mm} \]

\[ A_g = L \times t = 1000 \times 350 = 350,000 \text{ mm}^2 \]

\[ \alpha_t = 0.85 - 0.0015 f_c = 0.85 - 0.0015 \times 25 = 0.81 > 0.67 \quad \text{CSA A23.3-14 (Eq. 10.1)} \]

\[ k = 0.8 \quad \text{(For walls restrained against rotation at one or both ends)} \quad \text{CSA A23.3-14 (14.2.2.3)} \]

\[ P_r = \frac{2}{3} \times \alpha_t \times \phi \times f_c \times A_g \times \left[ 1 - \left( \frac{k \times h_s}{32 \times t} \right)^2 \right] \quad \text{CSA A23.3-14 (Eq. 14.1)} \]

\[ P_r = \frac{2}{3} \times 0.81 \times 0.65 \times 25 \times 350,000 \times \left[ 1 - \left( \frac{0.8 \times 4,000}{32 \times 350} \right)^2 \right] / 1 \text{ m} = 2,821 \text{ kN/m} \]

\[ P_r = 2,821 \text{ kN/m} > P_f = 375 \text{ kN/m} \quad \text{O.K.} \]

2.4. Minimum Horizontal Reinforcement

Since the wall thickness is more than 210 mm, two layers of reinforcement is required.

\[ t = 350 \text{ mm} > 210 \text{ mm} \rightarrow 2 \text{ layers} \quad \text{CSA A23.3-14 (14.1.8.3)} \]

The minimum area for horizontal reinforcement is \( A_{h,\text{min}} = 0.002 \times A_g \).

\[ A_g = 350,000 \text{ mm}^2 \quad \text{(Calculated in Section 2.3)} \]

\[ A_{h,\text{min}} = 0.002 \times 350,000 = 700 \text{ mm}^2 \]

Use No. 10M bars \( (A_b = 100 \text{ mm}^2) \).

\[ s_h \leq A_b \times \frac{L}{A_h} = 100 \times \frac{1000}{700} \times 2 = 285.71 \text{ mm} \]

Use 10M @ 250 mm per layer for horizontal reinforcement.

\[ s_{\text{max}} = \min \left\{ \frac{3 \times t}{500} = \min \left\{ \frac{3 \times 350}{500} = \min \left\{ \frac{1050}{500} = 500 \text{ mm} \right. \right. \right. \]

\[ s_h = 250 \text{ mm} < s_{\text{max}} = 500 \text{ mm} \quad \text{O.K.} \]
2.5. Minimum Vertical Reinforcement

The minimum area for vertical reinforcement is $A_{v,\text{min}} = 0.0015 \times A_y$.  \( \text{CSA A23.3-14 (14.1.8.5)} \)

$$A_{v,\text{min}} = 0.0015 \times 350,000 = 525 \text{ mm}^2$$

Use No. 10M bars ($A_b = 100 \text{ mm}^2$).

$$s_v \leq A_y \times \frac{L}{A_y} = 100 \times \frac{1000}{525} \times 2 = 380.95 \text{ mm}$$

Use 10M @ 350 mm per layer for vertical reinforcement.

$$s_{\text{max}} = \min \left\{ \frac{3 \times t}{500}, \frac{3 \times 350}{500}, \frac{1050}{500} \right\} = 500 \text{ mm}$$  \( \text{CSA A23.3-14 (14.1.8.4)} \)

$$s_v = 350 \text{ mm} < s_{\text{max}} = 500 \text{ mm} \quad \text{o.k.}$$

2.6. Check minimum standard requirements

$$d_b \leq \frac{t}{10}$$  \( \text{CSA A23.3-14 (14.1.8.2)} \)

$$d_{b,\text{max}} = \frac{350}{10} = 35 \text{ mm}$$

For No. 10M bars ($d_b = 11.3 \text{ mm}$)

$$d_b = 11.3 \text{ mm} < d_{b,\text{max}} = 35 \text{ mm} \quad \text{o.k.}$$

Use 2-15M at each end of the wall, due to the concentrated vertical load.  \( \text{CSA A23.3-14 (14.1.8.8.1)} \)
3. Reinforced Concrete Bearing Wall Analysis and Design – spWall Software

spWall is a program for the analysis and design of reinforced concrete shear walls, tilt-up walls, cast-in-place walls, precast walls, and Insulate Concrete Form (ICF) walls. It uses a graphical interface that enables the user to easily generate complex wall models. Graphical user interface is provided for:

- Wall geometry (including any number of openings and stiffeners)
- Material properties including cracking coefficients
- Wall loads (point, line, and area),
- Support conditions (including translational and rotational spring supports)

spWall uses the Finite Element Method for the structural modeling, analysis, and design of slender and non-slender reinforced concrete walls subject to static loading conditions. The wall is idealized as a mesh of rectangular plate elements and straight-line stiffener elements. Walls of irregular geometry are idealized to conform to geometry with rectangular boundaries. Plate and stiffener properties can vary from one element to another but are assumed by the program to be uniform within each element.

Six degrees of freedom exist at each node: three translations and three rotations relating to the three Cartesian axes. An external load can exist in the direction of each of the degrees of freedom. Sufficient number of nodal degrees of freedom should be restrained in order to achieve stability of the model. The program assembles the global stiffness matrix and load vectors for the finite element model. Then, it solves the equilibrium equations to obtain deflections and rotations at each node. Finally, the program calculates the internal forces and internal moments in each element. At the user’s option, the program can perform second order analysis. In this case, the program takes into account the effect of in-plane forces on the out-of-plane deflection with any number of openings and stiffeners.

In spWall, the required flexural reinforcement is computed based on the selected design standard (CSA A23.3-14 is used in this example), and the user can specify one or two layers of wall reinforcement. In stiffeners and boundary elements, spWall calculates the required shear and torsion steel reinforcement. Wall concrete strength (in-plane and out-of-plane) is calculated for the applied loads and compared with the code permissible shear capacity.

For illustration and comparison purposes, the following figures provide a sample of the input modules and results obtained from an spWall model created for the reinforced concrete bearing wall in this example.
Figure 2 – spWall Interface
Figure 3 – Assigning Dead Loads for Bearing Wall (spWall)
Figure 4 – Assigning Live Loads for Bearing Wall (spWall)
Figure 5 – Solve and Mesh Options (spWall)
Figure 6 – Factored Axial Forces Contour Normal to Reinforced Concrete Bearing Wall Cross-Section (spWall)
Figure 7 – Reinforced Concrete Bearing Wall Vertical Displacement Contour (In-Plane) (spWall)
Figure 8 – Reinforced Concrete Bearing Wall Axial Load Diagram (spWall)
Contents

1. Project .................................................................................................................. 3
  1.1. General Information .................................................................................... 3
  1.2. Solver Options ............................................................................................. 3

2. Definitions ............................................................................................................. 3
  2.1. Grid Lines ..................................................................................................... 3
    2.1.1. Vertical .................................................................................................. 3
    2.1.2. Horizontal ............................................................................................. 3
  2.2. Objects .......................................................................................................... 3
    2.2.1. Plates .................................................................................................... 3

2.3. Properties ......................................................................................................... 3
  2.3.1. Concrete .................................................................................................. 3
  2.3.2. Reinforcement ......................................................................................... 3
  2.3.3. Plate Cracking Coefficients .................................................................... 4
  2.3.4. Plate Design Criteria ............................................................................. 4

2.4. Restraints .......................................................................................................... 4
  2.4.1. Supports ................................................................................................. 4

2.5. Load Case/Combo ............................................................................................ 4
  2.5.1. Load Cases ............................................................................................. 4
  2.5.2. Load Combinations ................................................................................ 4

3. Assignments .......................................................................................................... 4
  3.1. Plates ............................................................................................................ 4
  3.2. Stiffeners ...................................................................................................... 4
  3.3. Uniform Line Loads .................................................................................... 5

4. Results .................................................................................................................. 5
  4.1. Envelope ....................................................................................................... 5
    4.1.1. Plate Flexure Reinforcement ................................................................. 5
  4.2. Ultimate ........................................................................................................ 5
    4.2.1. Plate Internal Forces ............................................................................ 5
    4.2.1.1. 1.25DL+1.50LL .............................................................................. 5

5. Screenshots .......................................................................................................... 6
  5.1. Extrude 3D view ........................................................................................... 6
  5.2. Plates & Stiffeners ID .................................................................................. 7
  5.3. Restraints ..................................................................................................... 8

6. Loads - Case A - Dead ...................................................................................... 9

7. Loads - Case B - Live ...................................................................................... 10
1. Project
   1.1. General Information

<table>
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<th>Bearing Wall-CSA wax</th>
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<td>Project</td>
<td>Bearing Wall Design - CSA A23.3-14</td>
</tr>
<tr>
<td>Code</td>
<td>CSA A23.3-14</td>
</tr>
<tr>
<td>Units</td>
<td>Metric</td>
</tr>
<tr>
<td>Date</td>
<td>12/19/2022</td>
</tr>
<tr>
<td>Time</td>
<td>12:30 PM</td>
</tr>
</tbody>
</table>

1.2. Solver Options

- Include 2nd order effects: No
- Check out-of-plane service deflections: Yes
- Maximum permissible out-of-plane deflections: 40,000 mm
- Check concrete shear strength of wall crosssection: No

2. Definitions

2.1. Grid Lines

2.1.1. Vertical

<table>
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<tr>
<th>Label</th>
<th>Coordinate-X (m)</th>
<th>Spacing (m)</th>
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</thead>
<tbody>
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</tr>
<tr>
<td>B</td>
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2.1.2. Horizontal

<table>
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<tr>
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<th>Coordinate-Y (m)</th>
<th>Spacing (m)</th>
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<td>1</td>
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2.2. Objects

2.2.1. Plates

<table>
<thead>
<tr>
<th>Label</th>
<th>Thickness (mm)</th>
<th>Concrete</th>
<th>Reinforcement</th>
<th>Design Criteria</th>
<th>Cracking Coeff.</th>
<th>Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>W350</td>
<td>350</td>
<td>C25</td>
<td>Gr60</td>
<td>2C#4</td>
<td>PCG1</td>
<td>Yes</td>
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</tbody>
</table>

2.3. Properties

2.3.1. Concrete

<table>
<thead>
<tr>
<th>Label</th>
<th>$f_c$ (MPa)</th>
<th>$W_d$ (kg/m³)</th>
<th>$E_c$ (MPa)</th>
<th>$v$</th>
<th>Precast</th>
<th>Used</th>
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</thead>
<tbody>
<tr>
<td>C25</td>
<td>25.000</td>
<td>2400.0</td>
<td>24942.6</td>
<td>0.20</td>
<td>No</td>
<td>Yes</td>
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</tbody>
</table>

2.3.2. Reinforcement

<table>
<thead>
<tr>
<th>Label</th>
<th>$f_y$ (MPa)</th>
<th>$E_s$ (MPa)</th>
<th>Used</th>
<th>Label</th>
<th>$f_y$ (MPa)</th>
<th>$E_s$ (MPa)</th>
<th>Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gr60</td>
<td>400.000</td>
<td>200000.0</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>
### 2.3.3. Plate Cracking Coefficients

<table>
<thead>
<tr>
<th>Label</th>
<th>Service Combinations</th>
<th>Ultimate Combinations</th>
<th>Used</th>
</tr>
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<tr>
<td></td>
<td>In-plane</td>
<td>Out-of-plane</td>
<td>In-plane</td>
</tr>
<tr>
<td>PCC1</td>
<td>1</td>
<td>0.7</td>
<td>1</td>
</tr>
</tbody>
</table>

### 2.3.4. Plate Design Criteria

NOTE: Bar centroid location measured from Z-ve face for Back Curtain and Z+ve face for Front Curtain

<table>
<thead>
<tr>
<th>Label</th>
<th>Curtains</th>
<th>Flags</th>
<th>Reinforcement Ratio</th>
<th>Reinforcement Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rmin (Hor) %</td>
<td>Rmax (Hor) %</td>
</tr>
<tr>
<td>2C#4</td>
<td>2</td>
<td></td>
<td>0.20</td>
<td>8.00</td>
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### 2.4. Restraints

#### 2.4.1. Supports

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<tr>
<th>Label</th>
<th>Translations</th>
<th>Rotations</th>
<th>Used</th>
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<tbody>
<tr>
<td></td>
<td>Dx</td>
<td>Dy</td>
<td>Dz</td>
</tr>
<tr>
<td></td>
<td>Fixed</td>
<td>Fixed</td>
<td>Fixed</td>
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</table>

### 2.5. Load Case/Combo.

#### 2.5.1. Load Cases

NOTE: Self weight is not included under Case A.

<table>
<thead>
<tr>
<th>Case</th>
<th>Type</th>
<th>Case Label</th>
<th>Load Defined?</th>
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<tbody>
<tr>
<td>A</td>
<td>Dead</td>
<td>Dead</td>
<td>Yes</td>
</tr>
<tr>
<td>B</td>
<td>Live</td>
<td>Live</td>
<td>Yes</td>
</tr>
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#### 2.5.2. Load Combinations

<table>
<thead>
<tr>
<th>Combo/Case</th>
<th>Type</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>Dead</td>
</tr>
<tr>
<td>B</td>
<td>Live</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Combo/Label</th>
<th>Dead</th>
<th>Live</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00DL+1.0</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>1.25DL+1...</td>
<td>1.250</td>
<td>1.500</td>
</tr>
</tbody>
</table>

Ser. Ult.

### 3. Assignments

#### 3.1. Plates

<table>
<thead>
<tr>
<th>ID</th>
<th>Label</th>
<th>Shape</th>
<th>Top Left/Center X</th>
<th>Top Left/Center Y</th>
<th>Width (B)</th>
<th>Height (H)/Dia. (D)</th>
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<tbody>
<tr>
<td>P1</td>
<td>W350</td>
<td>Polygon</td>
<td>0.500</td>
<td>2.000</td>
<td>1.000</td>
<td>4.000</td>
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#### 3.2. Stiffeners

<table>
<thead>
<tr>
<th>ID</th>
<th>Label</th>
<th>Direction</th>
<th>Start X</th>
<th>End X</th>
<th>Start Y</th>
<th>End Y</th>
<th>Length</th>
<th>Rigid Support</th>
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<tbody>
<tr>
<td>S1</td>
<td>- Null</td>
<td>Horizontal</td>
<td>0.000</td>
<td>1.000</td>
<td>0.000</td>
<td>0.000</td>
<td>1.000</td>
<td>Pin</td>
</tr>
<tr>
<td>S2</td>
<td>- Null</td>
<td>Horizontal</td>
<td>0.000</td>
<td>1.000</td>
<td>4.000</td>
<td>4.000</td>
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3.3. Uniform Line Loads

<table>
<thead>
<tr>
<th>Stiffener ID</th>
<th>Load Case</th>
<th>Wx</th>
<th>Wy</th>
<th>Wz</th>
<th>Ecc.</th>
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<tr>
<td>S2 A</td>
<td>0.00</td>
<td>-120.00</td>
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<td>0</td>
<td></td>
</tr>
<tr>
<td>S2 B</td>
<td>0.00</td>
<td>-150.00</td>
<td>0.00</td>
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4. Results

4.1. Envelope

4.1.1. Plate Flexure Reinforcement

Coordinate System: Global

<table>
<thead>
<tr>
<th>Element</th>
<th>Curtains</th>
<th>Direction</th>
<th>Mf (x/y) kN/m</th>
<th>Nf (x/y) Ld Comb. kN/m</th>
<th>As (x/y) mm²/m</th>
<th>Rho %</th>
<th>Tie</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>Horizontal</td>
<td>0.00</td>
<td>-99.85 1.25DL+1.50L...</td>
<td>700</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Vertical</td>
<td>0.00</td>
<td>-393.81 1.25DL+1.50L...</td>
<td>525</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>Horizontal</td>
<td>0.00</td>
<td>-59.16 1.25DL+1.50L...</td>
<td>700</td>
<td>0.20</td>
<td></td>
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<tr>
<td>4</td>
<td>2</td>
<td>Vertical</td>
<td>0.00</td>
<td>-381.99 1.25DL+1.50L...</td>
<td>525</td>
<td>0.15</td>
<td></td>
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4.2. Ultimate

4.2.1. Plate Internal Forces

4.2.1.1. 1.25DL+1.50LL

Coordinate System: Global

<table>
<thead>
<tr>
<th>Element</th>
<th>Nxx kN/m</th>
<th>Nyy kN/m</th>
<th>Nxy kN/m</th>
<th>Mxx kN/m/m</th>
<th>Myy kN/m/m</th>
<th>Mxy kN/m/m</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>-83.96</td>
<td>-377.92</td>
<td>15.89</td>
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<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>-49.25</td>
<td>-372.08</td>
<td>-9.91</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>3</td>
<td>-49.25</td>
<td>-372.08</td>
<td>-9.91</td>
<td>0.00</td>
<td>0.00</td>
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<td>-377.92</td>
<td>15.89</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

N_{yy,avg} = 375 kN

A_{v,avg} = 525 mm²

A_{h,avg} = 700 mm²
5. Screenshots
5.1. Extrude 3D view

Project: Bearing Wall Design - CSA A23.3-1...
Diagram: Model View (Extrude)
          Plates
5.2. Plates & Stiffeners ID

Project:  Bearing Wall Design - CSA A23.3-1...
Diagram:  Model View
          Plates (ID); Stiffeners (ID)
5.3. Restraints

Project: Bearing Wall Design - CSA A23.3-1...
Diagram: Model View
Plates; Stiffeners; Restraints (Label)
5.4. Loads - Case A - Dead

| Project   | Bearing Wall Design - CSA A23.3-1...
| Diagram   | Model View (Load Case: A - Dead)  
|           | Plates; Stiffeners |
5.5. Loads - Case B - Live

Project: Bearing Wall Design - CSA A23.3-1...
Diagram: Model View (Load Case: B - Live)
Plates; Stiffeners
4. Design Results Comparison and Conclusions

Table 1 – Comparison of Precast Wall Panel Analysis and Design Results

<table>
<thead>
<tr>
<th>Solution</th>
<th>$P_t$ (kN)</th>
<th>$A_{s,vertical}$ (mm$^2$)</th>
<th>$A_{s,horizontal}$ (mm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand</td>
<td>375</td>
<td>525</td>
<td>700</td>
</tr>
<tr>
<td>Reference</td>
<td>375</td>
<td>525</td>
<td>700</td>
</tr>
<tr>
<td><strong>spWall</strong></td>
<td>375</td>
<td>525</td>
<td>700</td>
</tr>
</tbody>
</table>

The results of all the hand calculations and the reference used illustrated above are in precise agreement with the automated exact results obtained from the **spWall** program.
For investigation purposes, the spWall model was revised to apply a line load equals to the axial resistance of the concrete wall ($P_f = P_r = 2,821 \text{ kN/m}$). It was noticed that the minimum reinforcement still governs.

Figure 9 – Reinforced Concrete Bearing Wall Axial Load Diagram ($P_f = P_r = 2821 \text{ kN/m}$) (spWall)
Figure 10 – Reinforced Concrete Bearing Wall Required Vertical Reinforcement ($P_f = P_r = 2821$ kN/m) (spWall)
If required, the spColumn program can be used to analyze a model of this concrete wall to arrive at the complete interaction diagram including the maximum allowable compression capacity of this section.