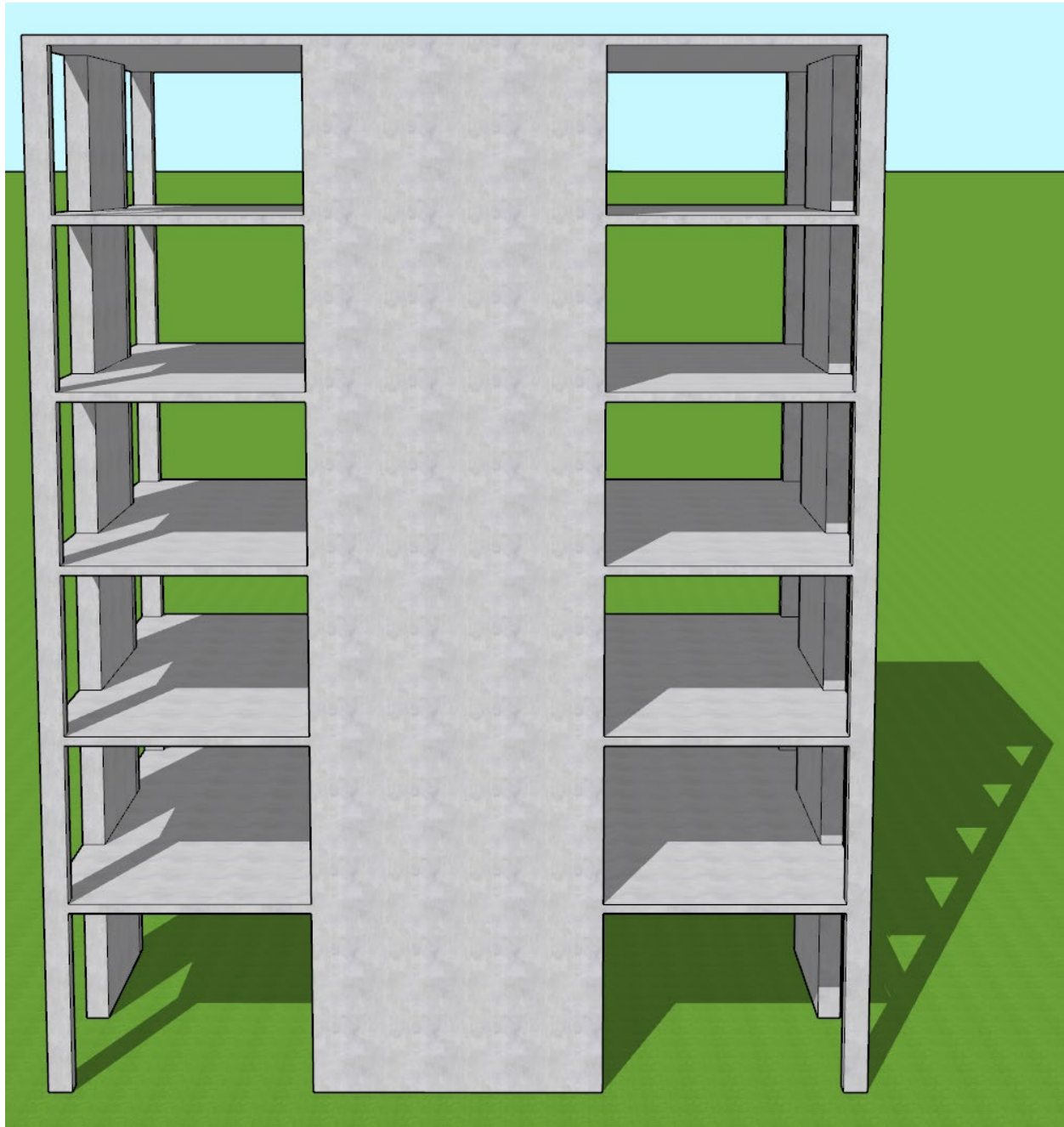
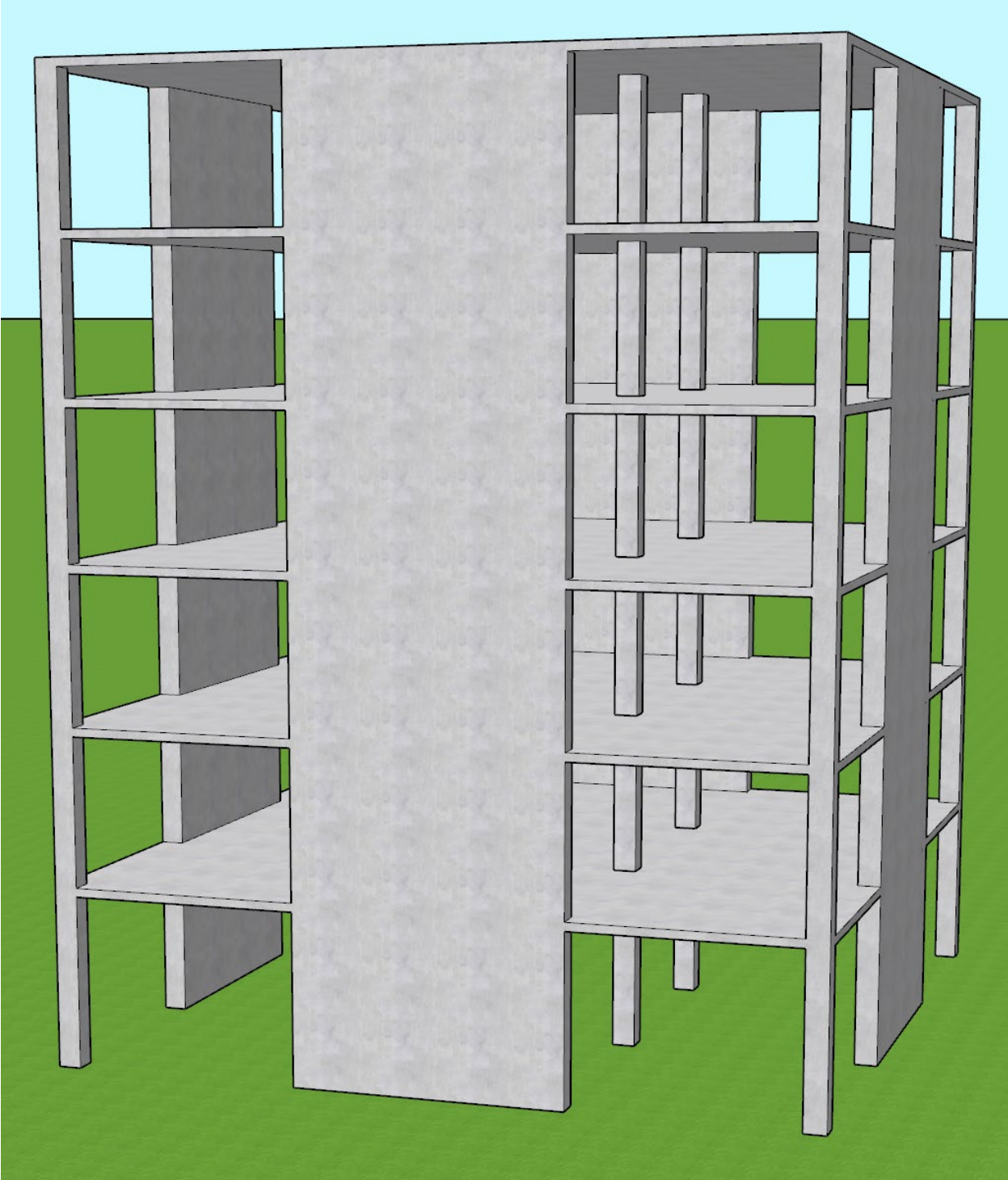


Reinforced Concrete Shear Wall Analysis and Design (CSA A23.3-14)





Reinforced Concrete Shear Wall Analysis and Design (CSA A23.3-14)

A structural reinforced concrete shear wall in a 6-story building provides lateral and gravity load resistance for the applied load as shown in the figure below (Detailed load calculations are discussed in [Section 2](#)). Shear wall section and assumed reinforcement is investigated after analysis to verify suitability for the applied loads based on CSA A23.3-14 provisions, then compared with numerical analysis results obtained from [spWall](#) engineering software program from [StructurePoint](#).

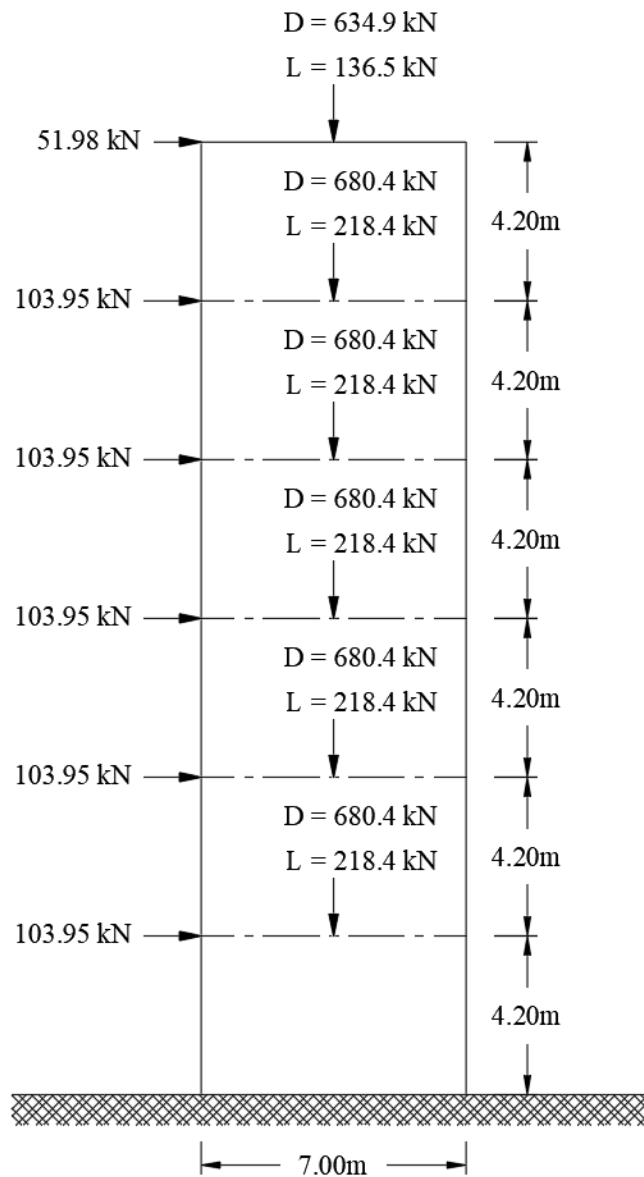


Figure 1 – Reinforced Concrete Shear Wall Geometry and Loading

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Code

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

References

- Reinforced Concrete Structures, 2nd Edition, 2018, Omar Chaallal, Presses de l’Université du Québec, Example 13.5
- [spWall Engineering Software Program Manual v10.00, STRUCTUREPOINT, 2022](#)
- “[Reinforced Concrete Shear Wall Analysis and Design \(ACI 318-14\)](#)” Design Example, STRUCTUREPOINT, 2018

Design Data

$f_c' = 40$ MPa normal weight concrete ($w_c = 24$ kN/m³)

$f_y = 400$ MPa

Wind Pressure = 1.5 kPa

Uniformly distributed loads on the roof:

$w_D = 5.5$ kPa

$w_L = 1.5$ kPa

Uniformly distributed loads on a typical floor:

$w_D = 6$ kPa

$w_L = 2.4$ kPa

Height between floors = 4.2 m.

Assumed wall thickness = 200 mm

Wall length = 7 m.

Wall Tributary Area = $14 \text{ m} \times 6.5 \text{ m} = 91 \text{ m}^2$

Assumed vertical reinforcement: $A_{s, \text{vertical}} = 10\text{M @ } 300 \text{ mm (one curtain)}$

Assumed horizontal reinforcement: $A_{s, \text{horizontal}} = 10\text{M @ } 250 \text{ mm (one curtain)}$

1. Preliminary Member Sizing

$$t \geq \min \left\{ \begin{array}{l} \frac{l_w}{25} \\ \frac{h_u}{25} \\ 150 \text{ mm} \end{array} \right\} = \min \left\{ \begin{array}{l} \frac{7000}{25} \\ \frac{4200}{25} \\ 150 \end{array} \right\} = \left\{ \begin{array}{l} 280 \\ 168 \\ 150 \end{array} \right\} = 168 \text{ mm} \quad \text{CSA A23.3-14 (14.1.7.1)}$$

Choose $t = 200$ mm (first trial)

2. Load and Load Combination

For the factored Load

$$w_{u1} = 1.25 \times DL + 0.5 \times LL + 1.4 \times W \quad \text{CSA A23.3-14 (Annex C, Table C.1a)}$$

$$w_{u2} = 0.9 \times DL + 1.4 \times W \quad \text{CSA A23.3-14 (Annex C, Table C.1a)}$$

Dead Loads

Tributary area: $A_{tributary} = 14 \text{ m} \times 6.5 \text{ m} = 91 \text{ m}^2$ (Given)

On the roof and self-weight (per floor): $5.50 \times 91 + [0.2 \times 7.0 \times (4.2 - 0.2)] \times 24 = 634.90 \text{ kN}$

On a typical floor and self-weight (per floor): $6.00 \times 91 + [0.2 \times 7.0 \times (4.2 - 0.2)] \times 24 = 680.40 \text{ kN}$

Live Loads

On the roof: $1.5 \times 91 = 136.50 \text{ kN}$

On a typical floor: $2.4 \times 91 = 218.40 \text{ kN}$

Wind Loads (W)

$$\text{At the roof level: } W_{roof} = 1.5 \times \frac{4.2}{2} \times \frac{33}{2} = 51.98 \text{ kN}$$

$$\text{At a typical floor level: } W_{fp} = 1.5 \times 4.2 \times \frac{33}{2} = 103.95 \text{ kN}$$

3. Structural Analysis

For the combination: $(1.25 \times D + 0.5 \times L + 1.4 \times W)$

$$P_f = 1.25 \times (634.90 + 680.40 \times 5) + 0.5 \times (136.50 + 218.40 \times 5) = 5,660.38 \text{ kN}$$

$$V_f = 1.4 \times (51.98 + 103.95 \times 5) = 800.42 \text{ kN}$$

$$M_f = 1.4 \times [51.98 \times 4.2 \times 6 + 103.95 \times 4.2 \times (1 + 2 + 3 + 4 + 5)] = 11,002.07 \text{ kN-m}$$

For the combination: $(0.90 \times D + 1.4 \times W)$

$$P_f = 0.9 \times (634.90 + 680.40 \times 5) = 3,633.21 \text{ kN}$$

$$V_f = 1.4 \times (51.98 + 103.95 \times 5) = 800.42 \text{ kN}$$

$$M_f = 1.4 \times [51.98 \times 4.2 \times 6 + 103.95 \times 4.2 \times (1 + 2 + 3 + 4 + 5)] = 11,002.07 \text{ kN-m}$$

4. Shear Wall Design

Since the wall thickness is less than 210 mm, only one layer of reinforcement is therefore required.

CSA A23.3-14 (14.1.8.3)

The minimum horizontal reinforcement is $A_{h,min} = 0.002 \times A_g$

CSA A23.3-14 (14.1.8.6)

Use No. 10M bars.

$$s = \frac{100 \text{ mm}^2}{200 \text{ mm} \times 0.002} = 250 \text{ mm}$$

$$A_h \geq 0.06 \times \sqrt{f'_c} \times \frac{b_w \times s}{f_y} \quad \text{CSA A23.3-14 (Eq. 11.1)}$$

$$\frac{A_h}{s} = \frac{100}{250} = 0.4 \geq \frac{0.06 \times \sqrt{40} \times 200}{400} = 0.19$$

The effective shear depth, d_v , of a wall need not be taken as less than $0.8l_w$.

CSA A23.3-14 (21.5.9.2)

$$d_v = 0.8 \times l_w = 0.8 \times 7000 = 5600 \text{ mm}$$

The factored shear resistance shall be determined by

$$V_r = V_c + V_s + V_p = V_c$$

CSA A23.3-14 (Eq. 11.4)

However, V_r shall not exceed

$$V_{r,max} = 0.25 \times \phi_c \times f'_c \times b_w \times d_v \quad \text{CSA A23.3-14 (Eq. 11.5)}$$

$$V_{r,max} = \frac{0.25 \times 0.65 \times 40 \times 200 \times 5600}{1000} = 7280 \text{ kN} \geq V_f = 800.42 \text{ kN}$$

Shear strength provided by concrete

$$V_c = \phi_c \times \lambda \times \beta \times \sqrt{f'_c} \times b_w \times d_v \quad \text{CSA A23.3-14 (Eq. 11.6)}$$

$$\beta = 0.18 \quad \text{CSA A23.3-14 (11.3.6.3)}$$

$$\sqrt{f'_c} = \sqrt{40} = 6.33 < 8 \text{ MPa} \quad \text{CSA A23.3-14 (11.3.4)}$$

$$V_c = \frac{0.65 \times 1.0 \times 0.18 \times \sqrt{40} \times 200 \times 5600}{1000} = 828.77 \text{ kN}$$

$V_f = 800.42 \text{ kN} \leq V_r = V_c = 828.77 \text{ kN} \rightarrow$ No additional reinforcement required.

Use No. 10M @ 250 mm for horizontal reinforcement.

5. Flexural Design

Design the wall with the combination: $(1.25 \times D + 0.5 \times L + 1.4 \times W)$

For this wall, the moment at the base governs the design as shown in the previous Figure.

$$M_f = 11002.07 \text{ kN-m}$$

The minimum area of vertical reinforcement distributed between concentrated reinforcements (A_{IV}) at the wall ends is equal to:

$$A_{vertical} = 0.0015 \times A_g \quad \text{CSA A23.3-14 (14.1.8.5)}$$

Use No. 10M bars.

$$s = \frac{100 \text{ mm}^2}{200 \text{ mm} \times 0.0015} = 333.33 \text{ mm}$$

$$s_{provided} = 300 \text{ mm}$$

$$\text{Total number of vertical bars} = \frac{(7000 - 100)}{300} + 1 = 24$$

$$A_v = 24 \times 100 = 2400 \text{ mm}^2$$

$$\alpha = \frac{P_f}{\phi_c \times f'_c \times l_w \times t} = \frac{5660.37}{0.65 \times 40 \times 7000 \times 200} = 0.1555$$

$$\omega = \frac{\phi_s \times A_v \times f_y}{\phi_c \times f'_c \times l_w \times t} = \frac{0.85 \times 2400 \times 400}{0.65 \times 40 \times 7000 \times 200} = 0.0224$$

$$\alpha_1 = 0.85 - 0.0015 f'_c = 0.85 - 0.0015 \times 40 = 0.79 > 0.67 \quad \text{CSA A23.3-14 (Eq. 10.1)}$$

$$\beta_1 = 0.97 - 0.0025 f'_c = 0.97 - 0.0025 \times 40 = 0.87 > 0.67 \quad \text{CSA A23.3-14 (Eq. 10.2)}$$

$$\frac{c}{l_w} = \frac{\omega + \alpha}{2 \times \omega + \alpha_1 \times \beta_1} = \frac{0.0224 + 0.1555}{2 \times 0.0224 + 0.1555 \times 0.87} = 0.243$$

$$M_r = 0.5 \times \phi_s \times A_v \times f_y \times l_w \times \left(1 + \frac{P_f}{\phi_s \times A_v \times f_y} \right) \left(1 - \frac{c}{l_w} \right)$$

$$M_r = 0.5 \times 0.85 \times 2400 \times 400 \times 7000 \times \left(1 + \frac{5660.38}{0.85 \times 2400 \times 400} \right) (1 - 0.243)$$

$$M_r = 17158.74 \text{ kN-m} > M_f = 11002.07 \text{ kN-m}$$

Verification of the wall under the combination: $(0.90 \times D + 1.4 \times W)$

$$\alpha = \frac{P_f}{\phi_c \times f'_c \times l_w \times t} = \frac{3633.21}{0.65 \times 40 \times 7000 \times 200} = 0.0998$$

$$\omega = 0.0224, \alpha_1 = 0.79, \text{ and } \beta_1 = 0.87$$

$$\frac{c}{l_w} = \frac{\omega + \alpha}{2 \times \omega + \alpha_1 \times \beta_1} = \frac{0.0224 + 0.0998}{2 \times 0.0224 + 0.79 \times 0.87} = 0.167$$

$$M_r = 0.5 \times \phi_s \times A_{nv} \times f_y \times l_w \times \left(1 + \frac{P_f}{\phi_s \times A_{nv} \times f_y} \right) \left(1 - \frac{c}{l_w} \right)$$

$$M_r = 0.5 \times 0.85 \times 2400 \times 400 \times 7000 \times \left(1 + \frac{3633.21}{0.85 \times 2400 \times 400} \right) (1 - 0.167)$$

$$M_r = 12972.43 \text{ kN-m} > M_f = 11002.07 \text{ kN-m}$$

Use 2-15M at each end, due to concentrated wind generated load.

CSA A23.3-14 (14.1.8.8.1)

Therefore, a 10M bar is replaced by 2-15M as illustrated in the following Figure.

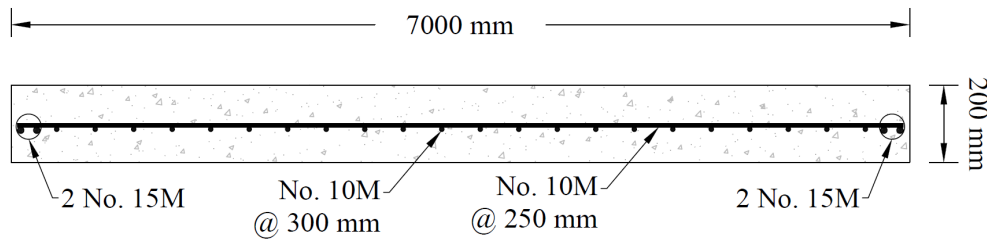


Figure 2 – Reinforcement Details

6. Shear Wall Analysis and Design – spWall Software

[spWall](#) is a program for the analysis and design of reinforced concrete shear walls, tilt-up walls, precast wall 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.

After the Finite Element Analysis (FEA) is completed 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 shear wall reinforcement. In stiffeners and boundary elements, [spWall](#) calculates the required shear and torsion steel reinforcement. Shear 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 the FEA results obtained from an [spWall](#) model created for the reinforced concrete shear wall in this example.

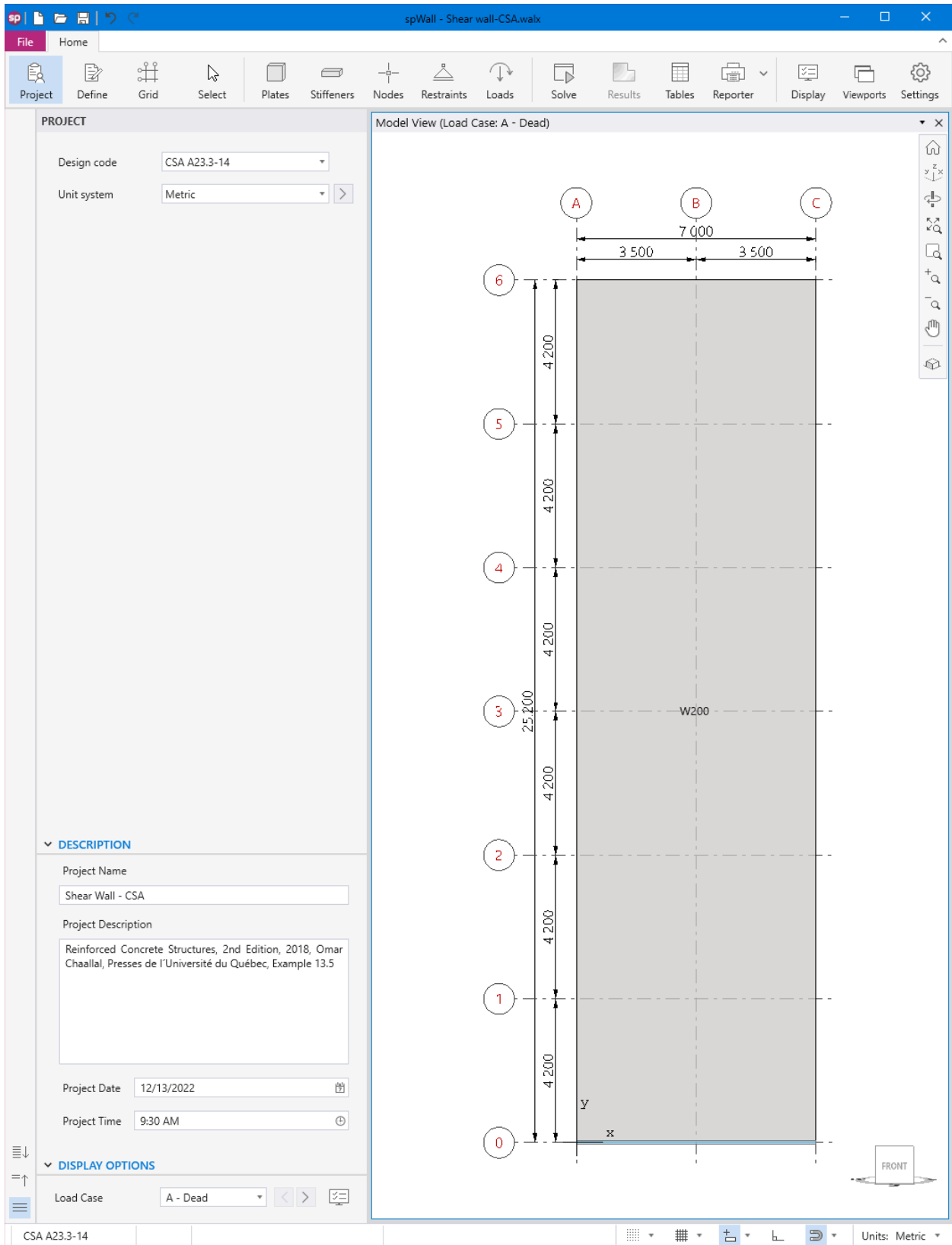


Figure 3 – spWall Interface

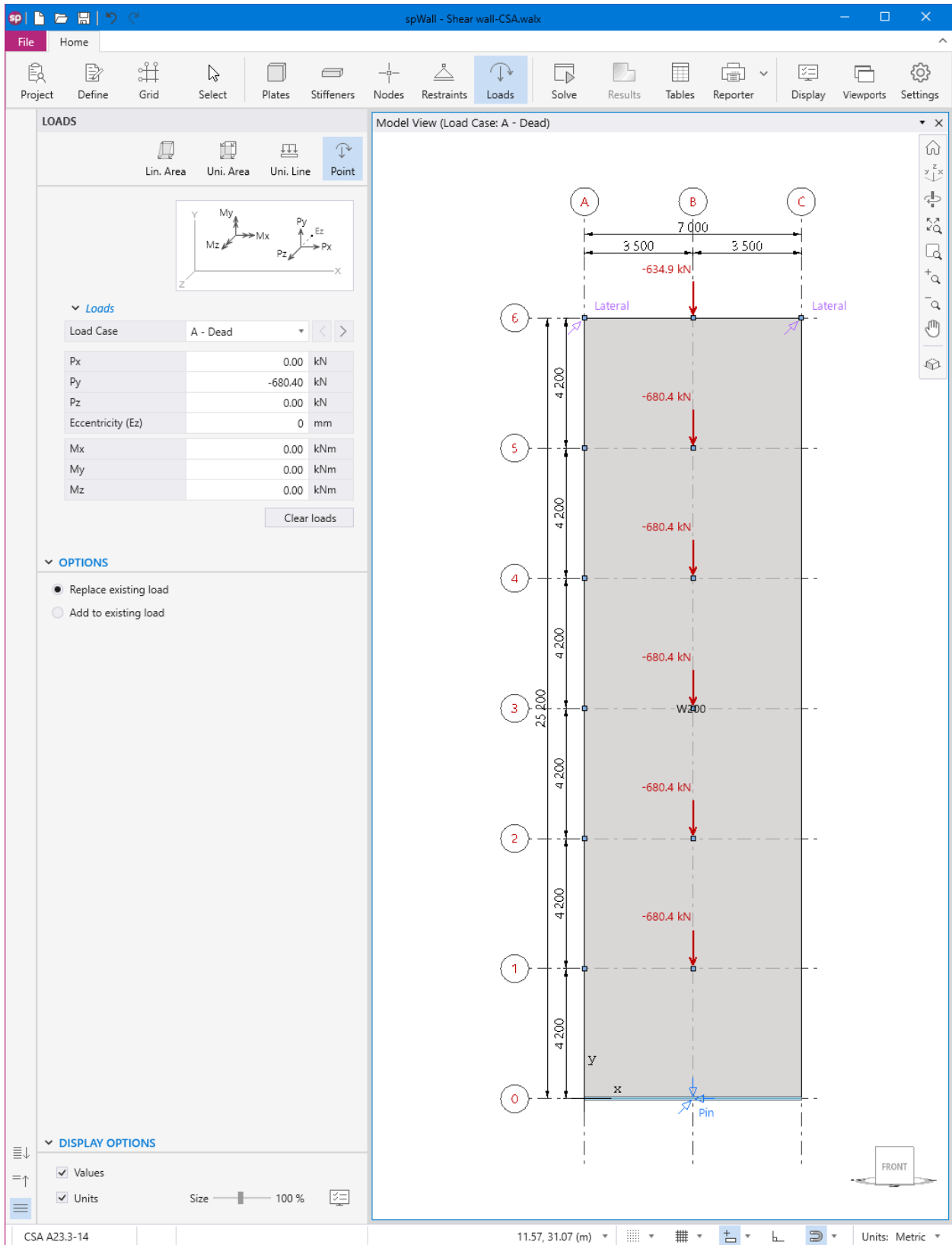


Figure 4 – Assigning Dead Loads for Shear Wall (spWall)

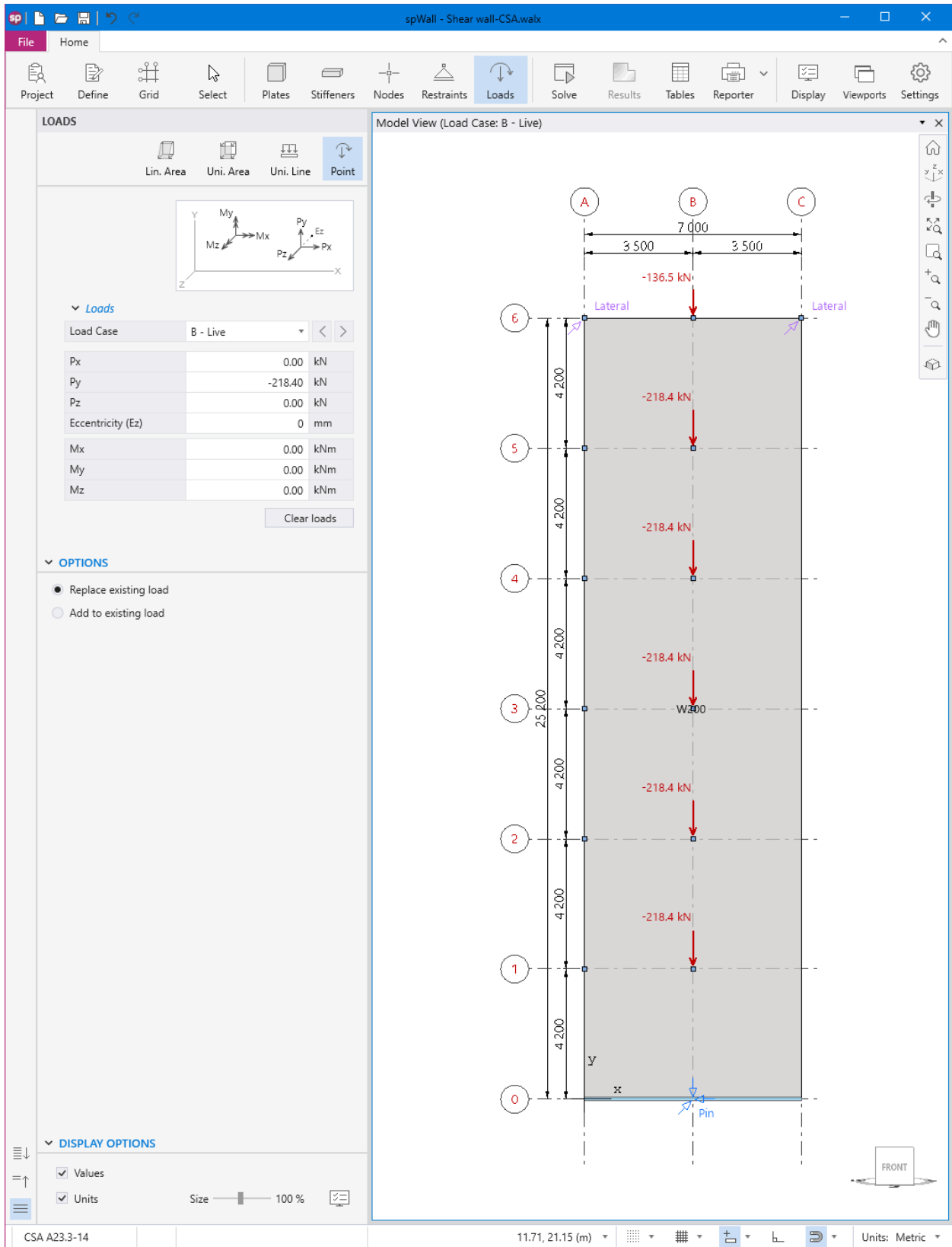


Figure 5 – Assigning Live Loads for Shear Wall (spWall)

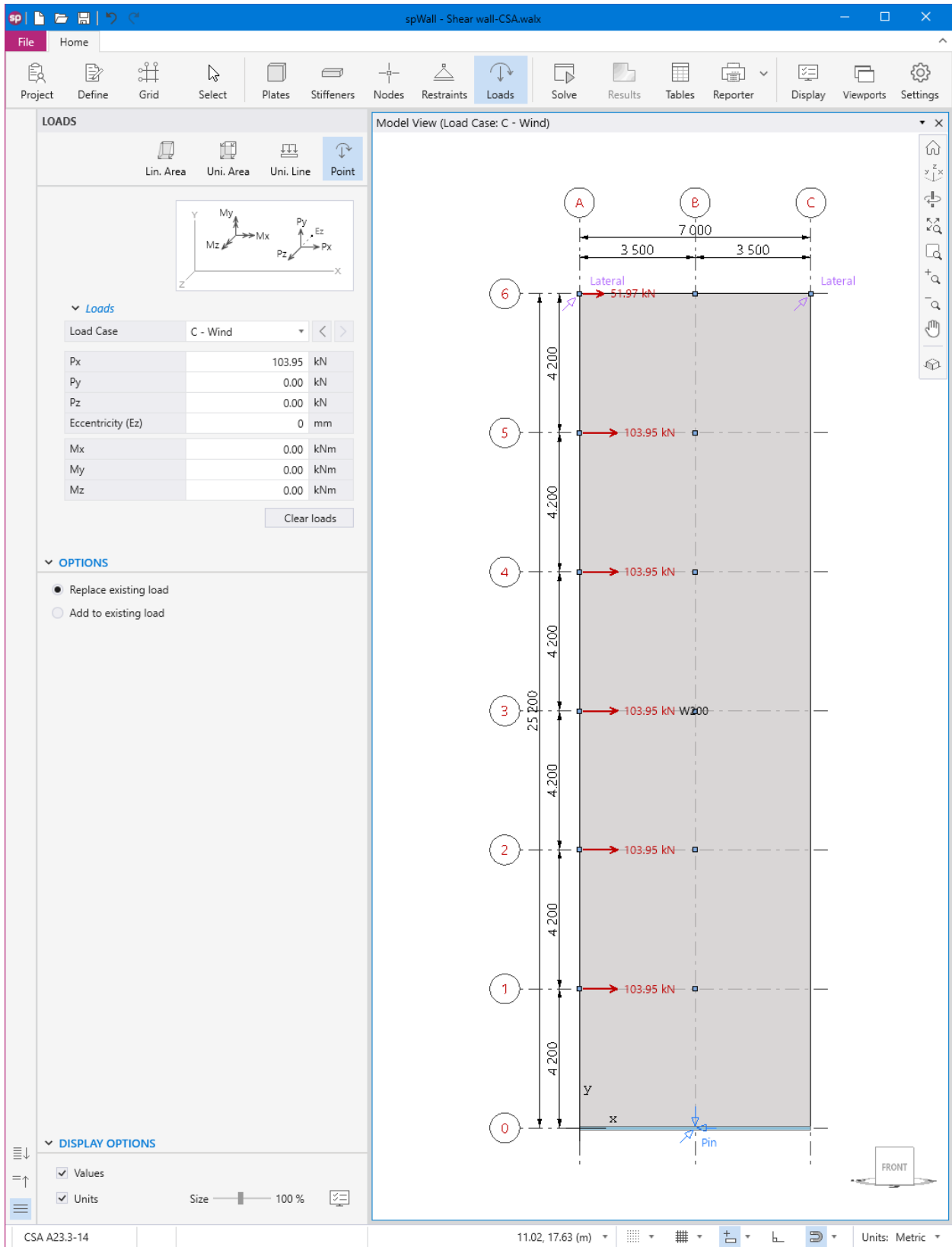


Figure 6 – Assigning Wind Loads for Shear Wall (spWall)

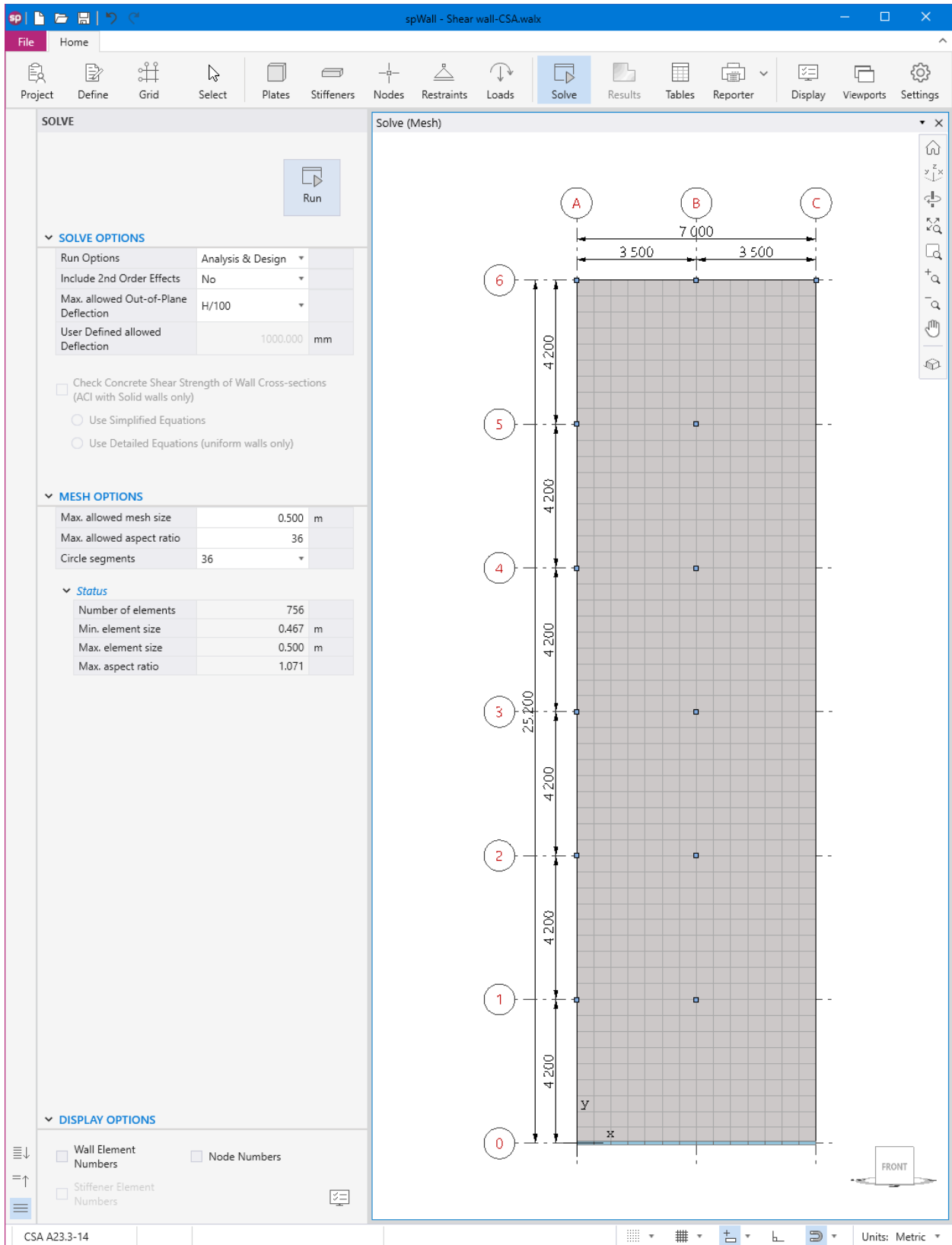


Figure 7 – Solve and Mesh Options (spWall)

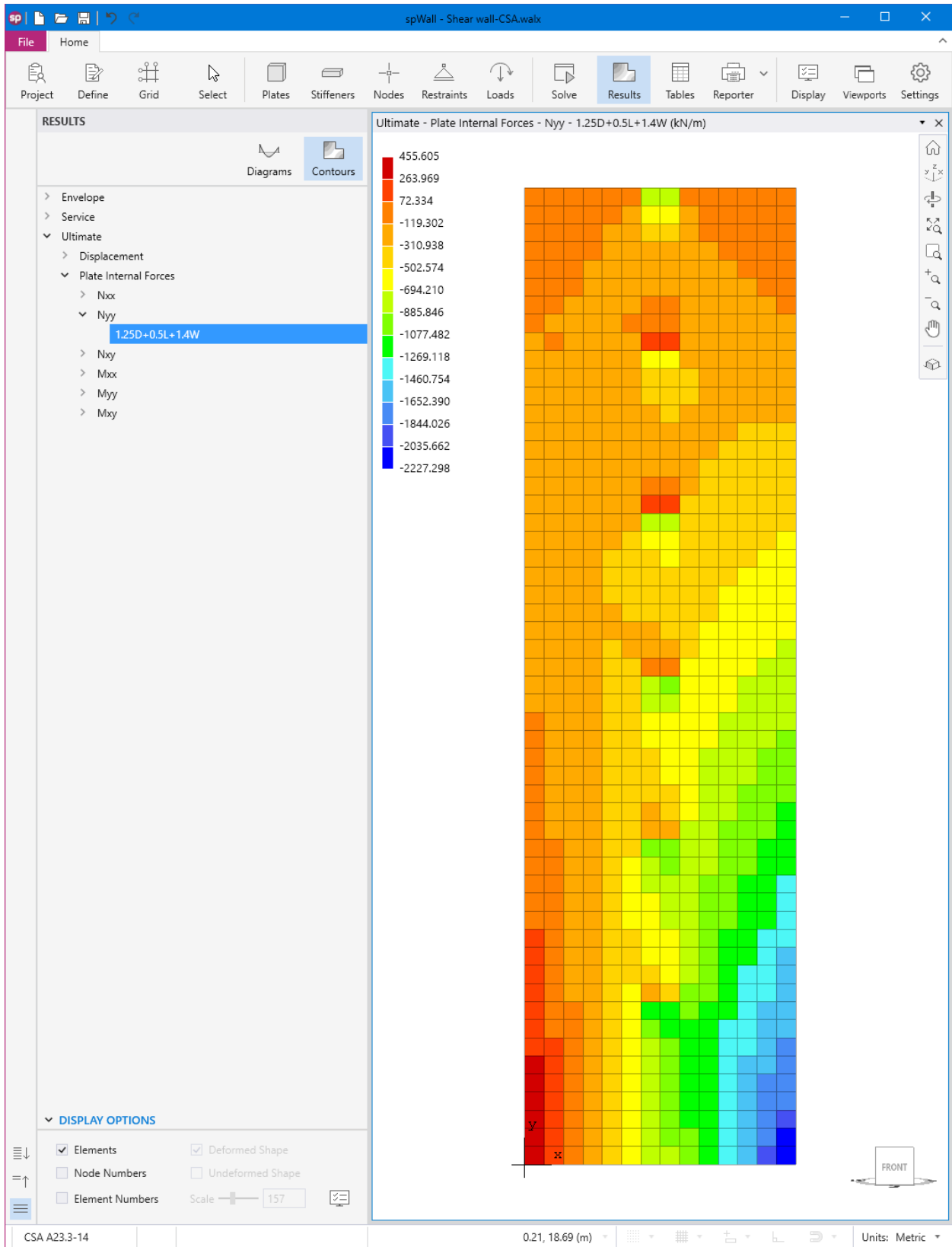


Figure 8 – Factored Axial Forces Contour Normal to Shear Wall Cross-Section (spWall)

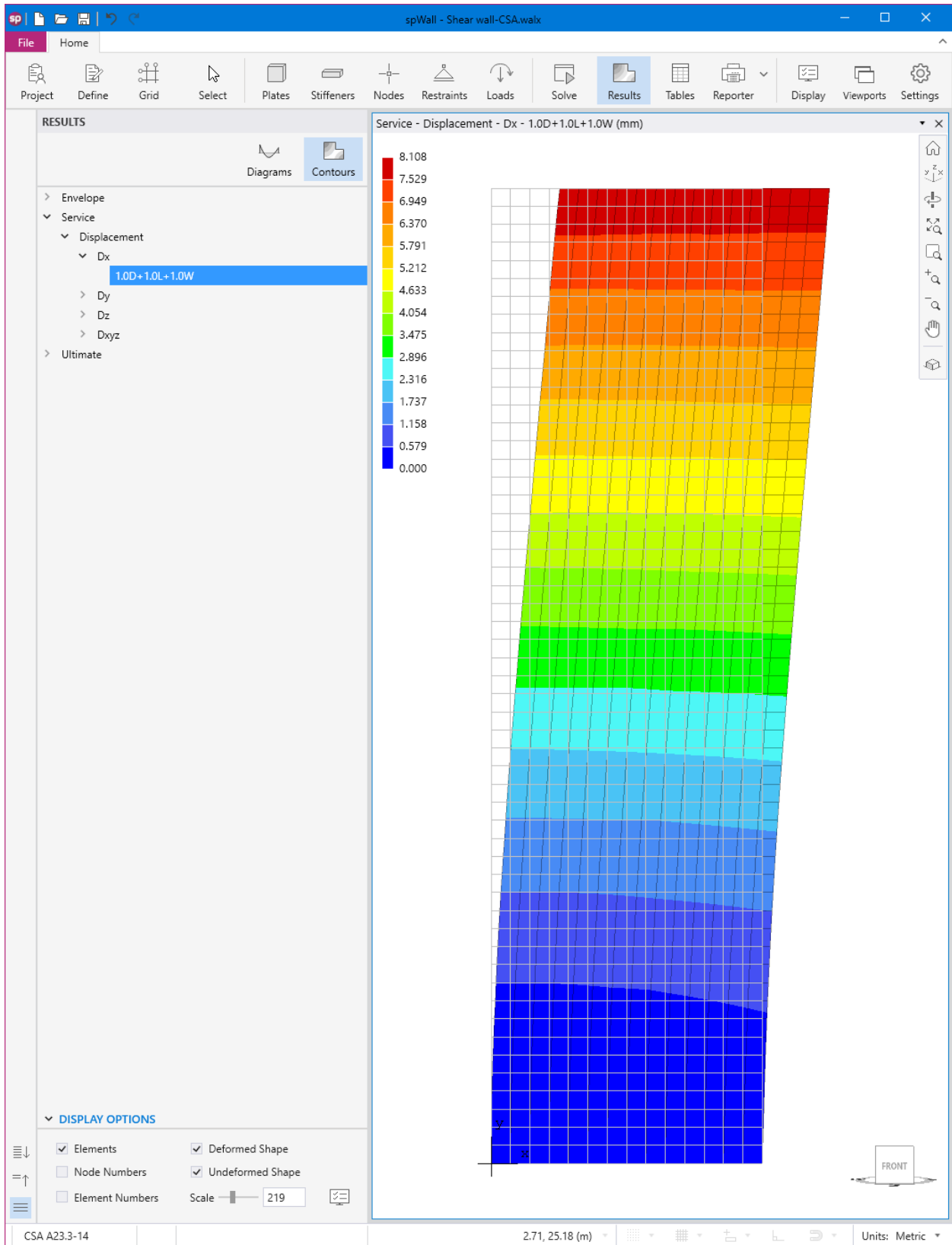


Figure 9 – Shear Wall Lateral Displacement Contour (spWall)

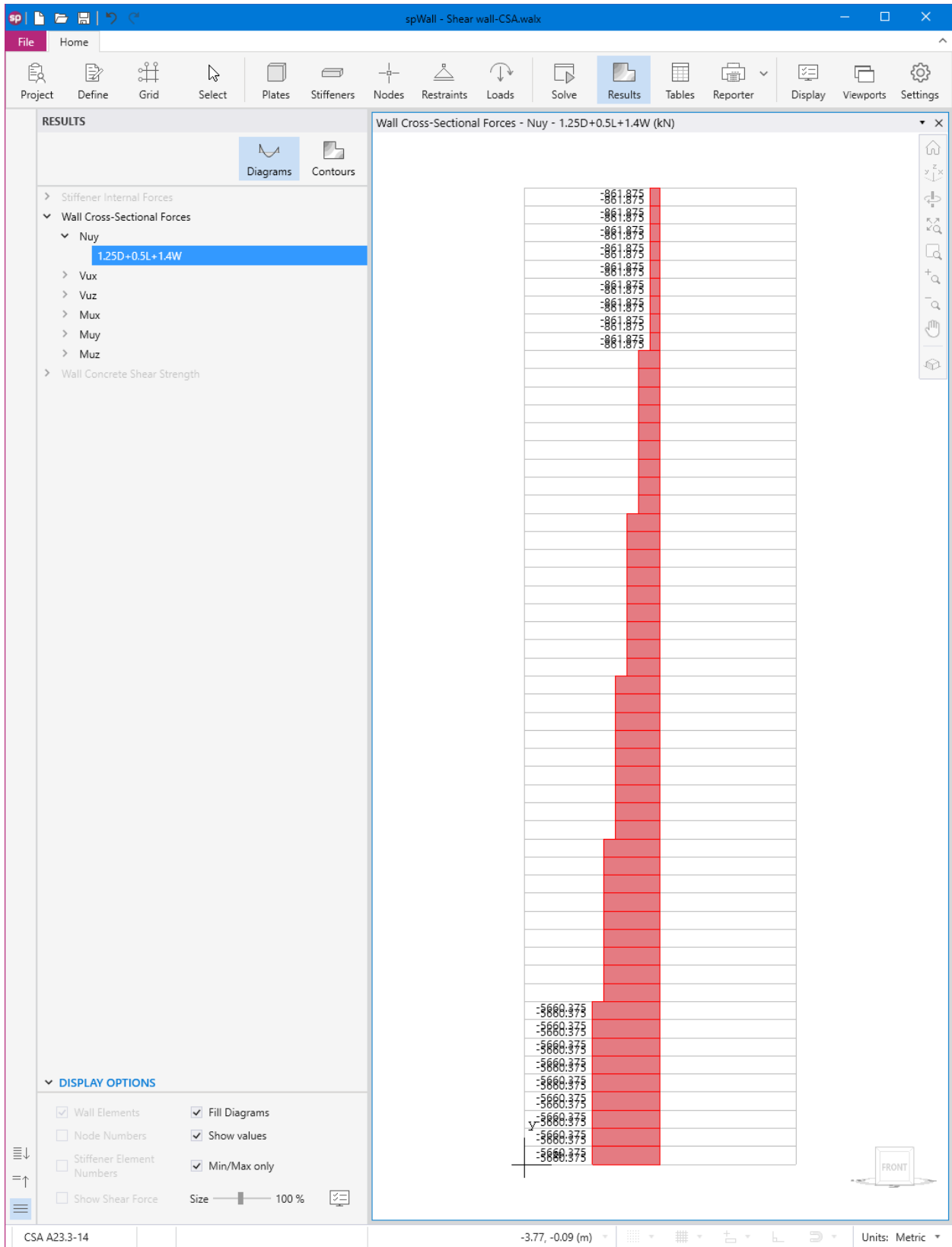


Figure 10 – Shear Wall Axial Load Diagram (spWall)

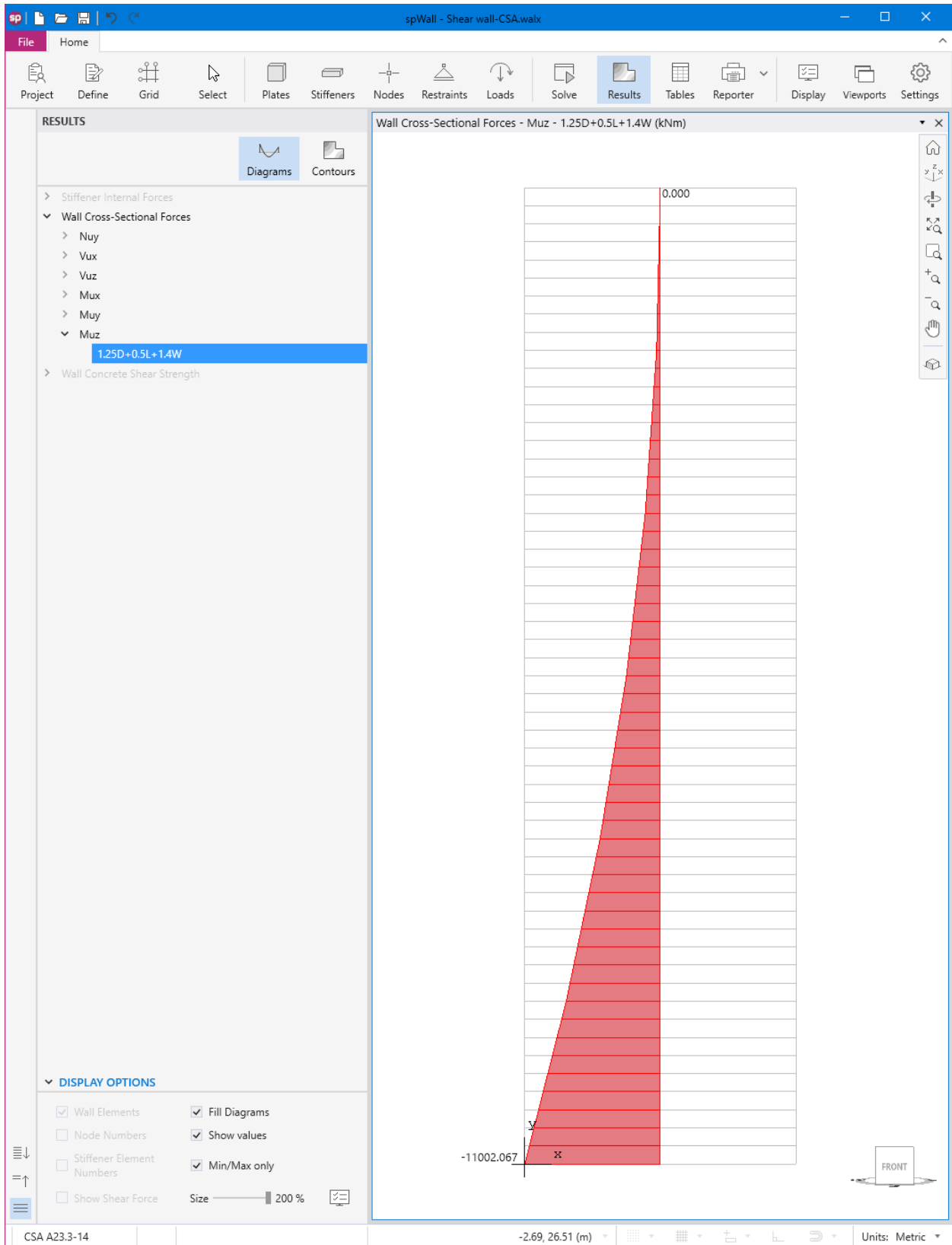


Figure 12 – Shear Wall Moment Diagram (spWall)



spWall v10.00 (TM)
A Computer Program for Analysis and Design of Reinforced Concrete, Precast, and Tilt-up Walls
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1. Project

1.1. General Information

File Name	Shear wall-CSA.walx
Project	Shear Wall - CSA
Code	CSA A23.3-14
Units	Metric
Date	12/13/2022
Time	9:30 AM

1.2. Solver Options

Include 2nd order effects	No
Check out-of-plane service deflections	Yes
Maximum permissible out-of-plane deflections	252.000 mm
Check concrete shear strength of wall crosssection	No

2. Definitions

2.1. Grid Lines

2.1.1. Vertical

Label	Coordinate-X m	Spacing m
A	0.000	0.000
B	3.500	3.500
C	7.000	3.500

2.1.2. Horizontal

Label	Coordinate-Y m	Spacing m
0	0.000	0.000
1	4.200	4.200
2	8.400	4.200
3	12.600	4.200
4	16.800	4.200
5	21.000	4.200
6	25.200	4.200

2.2. Objects

2.2.1. Plates

Label	Thickness mm	Concrete	Reinforcement	Design Criteria	Cracking Coeff.	Used
W200	200	C40	Gr400	W10_C_N10M	PCC1	Yes

2.3. Properties

2.3.1. Concrete

Label	f'_c MPa	W_c kg/m ³	E_c MPa	ν -	Precast	Used
C40	40.000	2400.0	29601.7	0.20	No	Yes

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2.3.2. Reinforcement

Label	f _y MPa	E _s MPa	Used	Label	f _y MPa	E _s MPa	Used
Gr400	400.000	210000.0	Yes				

2.3.3. Plate Cracking Coefficients

Label	Service Combinations		Ultimate Combinations		Used
	In-plane	Out-of-plane	In-plane	Out-of-plane	
PCC1	1	0.7	1	0.35	Yes

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

Label	Curtains	Flags	Reinforcement Ratio				Reinforcement Location				Used
			Rmin (Hor) %	Rmax (Hor) %	Rmin (Ver) %	Rmax (Ver) %	Back H. (BH) mm	Back V. (BV) mm	Front H. (FH) mm	Front V. (FV) mm	
W10_C_N10M	1		0.20	8.00	0.15	8.00	111	100	---	---	Yes

2.4. Restraints

2.4.1. Supports

Label	Translations			Rotations			Used
	Dx	Dy	Dz	Rx	Ry	Rz	
Pin	Fixed	Fixed	Fixed	Free	Free	Free	Yes
Lateral	Free	Free	Fixed	Free	Free	Free	Yes

2.5. Load Case/Combo.

2.5.1. Load Cases

NOTE: Self weight is not included under Case A.

Case	Type	Case Label	Load Defined?
A	Dead	Dead	Yes
B	Live	Live	Yes
C	Wind	Wind	Yes

2.5.2. Load Combinations

Combo./Case	A	B	C	D	E	F	G	H	I	Combo Type
Type	Dead	Live	Wind							
Combo./Label	Dead	Live	Wind							
1.0D+1.0L...	1.000	1.000	1.000	-	-	-	-	-	-	Ser.
1.25D+0.5...	1.250	0.500	1.400	-	-	-	-	-	-	Ult.

3. Assignments

3.1. Nodes

ID	X Coord. m	Y Coord. m	Rigid Support	Spring Support
N1	0.000	4.200		
N2	3.500	4.200		
N3	0.000	8.400		
N4	3.500	8.400		

ID	X Coord. m	Y Coord. m	Rigid Support	Spring Support
N5	0.000	12.600		
N6	3.500	12.600		
N7	0.000	16.800		
N8	3.500	16.800		
N9	0.000	21.000		
N10	3.500	21.000		
N11	0.000	25.200	Lateral	
N12	3.500	25.200		
N13	7.000	25.200	Lateral	

3.2. Plates

ID	Label	Shape	Top Left/Center X m	Top Left/Center Y m	Width (B) m	Height (H)/Dia. (D) m
P1	W200	Polygonal	3.500	12.600	7.000	25.200

3.3. Stiffeners

ID	Label	Direction	Start X m	End X m	Start Y m	End Y m	Length m	Rigid Support
S1	- Null -	Horizontal	0.000	7.000	0.000	0.000	7.000	Pin

3.4. Point Loads

Nodes ID	Load Case	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm	Ecc. mm
N1	C	103.95	0.00	0.00	0.00	0.00	0.00	0
N2	A	0.00	-680.40	0.00	0.00	0.00	0.00	0
	B	0.00	-218.40	0.00	0.00	0.00	0.00	0
N3	C	103.95	0.00	0.00	0.00	0.00	0.00	0
N4	A	0.00	-680.40	0.00	0.00	0.00	0.00	0
	B	0.00	-218.40	0.00	0.00	0.00	0.00	0
N5	C	103.95	0.00	0.00	0.00	0.00	0.00	0
N6	A	0.00	-680.40	0.00	0.00	0.00	0.00	0
	B	0.00	-218.40	0.00	0.00	0.00	0.00	0
N7	C	103.95	0.00	0.00	0.00	0.00	0.00	0
N8	A	0.00	-680.40	0.00	0.00	0.00	0.00	0
	B	0.00	-218.40	0.00	0.00	0.00	0.00	0
N9	C	103.95	0.00	0.00	0.00	0.00	0.00	0
N10	A	0.00	-680.40	0.00	0.00	0.00	0.00	0
	B	0.00	-218.40	0.00	0.00	0.00	0.00	0
N11	C	51.97	0.00	0.00	0.00	0.00	0.00	0
N12	A	0.00	-634.90	0.00	0.00	0.00	0.00	0
	B	0.00	-136.50	0.00	0.00	0.00	0.00	0

4. Results

4.1. Envelope

4.1.1. Plate Flexure Reinforcement

Coordinate System: Global

Element	Curtains	Direction	Mf (x/y) kNm/m	Nf (x/y) Ld Comb. kN/m	As (x/y) mm ² /m	Rho %	Tie
1	1	Horizontal	0.00	150.62 1.25D+0.5L+1...	501	0.25	
		Vertical	0.00	485.03 1.25D+0.5L+1...	1441	0.72	

Elements along the wall base

$$\sum A_{s,i} = 5812 \text{ mm}^2/\text{m}$$

$$\text{Element width} = 0.5 \text{ m}$$

$$\sum A_{s,i} = 5812 \text{ mm}^2/\text{m} \times 0.5 \text{ m} = 2906 \text{ mm}^2$$

→ Elements along the wall base

Element	Curtains	Direction	Mf (x/y) kNm/m	Nf (x/y) Ld Comb. kN/m	As (x/y) mm ² /m	Rho	Tie
2	1	Horizontal	0.00	68.16 1.25D+0.5L+1...	400	0.20	
		Vertical	0.00	259.56 1.25D+0.5L+1...	771	0.39	
3	1	Horizontal	0.00	41.04 1.25D+0.5L+1...	400	0.20	
		Vertical	0.00	40.50 1.25D+0.5L+1...	300	0.15	
4	1	Horizontal	0.00	-75.32 1.25D+0.5L+1...	400	0.20	
		Vertical	0.00	-237.83 1.25D+0.5L+1...	300	0.15	
5	1	Horizontal	0.00	-118.08 1.25D+0.5L+1...	400	0.20	
		Vertical	0.00	-432.87 1.25D+0.5L+1...	300	0.15	
6	1	Horizontal	0.00	-164.11 1.25D+0.5L+1...	400	0.20	
		Vertical	0.00	-622.63 1.25D+0.5L+1...	300	0.15	
7	1	Horizontal	0.00	-212.41 1.25D+0.5L+1...	400	0.20	
		Vertical	0.00	-807.97 1.25D+0.5L+1...	300	0.15	
8	1	Horizontal	0.00	-262.38 1.25D+0.5L+1...	400	0.20	
		Vertical	0.00	-989.93 1.25D+0.5L+1...	300	0.15	
9	1	Horizontal	0.00	-313.37 1.25D+0.5L+1...	400	0.20	
		Vertical	0.00	-1170.99 1.25D+0.5L+1...	300	0.15	
10	1	Horizontal	0.00	-365.33 1.25D+0.5L+1...	400	0.20	
		Vertical	0.00	-1356.28 1.25D+0.5L+1...	300	0.15	
11	1	Horizontal	0.00	-418.54 1.25D+0.5L+1...	400	0.20	
		Vertical	0.00	-1555.67 1.25D+0.5L+1...	300	0.15	
12	1	Horizontal	0.00	-479.32 1.25D+0.5L+1...	400	0.20	
		Vertical	0.00	-1782.06 1.25D+0.5L+1...	300	0.15	
13	1	Horizontal	0.00	-524.40 1.25D+0.5L+1...	400	0.20	
		Vertical	0.00	-2100.92 1.25D+0.5L+1...	300	0.15	
14	1	Horizontal	0.00	-784.88 1.25D+0.5L+1...	400	0.20	
		Vertical	0.00	-2433.60 1.25D+0.5L+1...	300	0.15	

4.2. Ultimate

4.2.1. Wall Cross-Sectional Forces

4.2.1.1. 1.25D+0.5L+1.4W

Coordinate System: Global
(+) Horizontal cross-section above Y-coordinate
(-) Horizontal cross-section below Y-coordinate

No.	Wall Crosssection		In-Plane Forces			Out-Of-Plane Forces		
	Y coordinate m	X-Centroid m	Vux kN	Nuy kN	Muz kNm	Vuz kN	Mux kNm	Muy kNm
1-	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.00
1+	0.000	3.500	800.41	-5660.38	-11002.07	0.00	0.00	0.00
2-	0.467	3.500	800.41	-5660.38	-10628.54	0.00	0.00	0.00
2+	0.467	3.500	800.41	-5660.38	-10628.54	0.00	0.00	0.00
3-	0.933	3.500	800.41	-5660.38	-10255.01	0.00	0.00	0.00
3+	0.933	3.500	800.41	-5660.38	-10255.01	0.00	0.00	0.00
4-	1.400	3.500	800.41	-5660.38	-9881.49	0.00	0.00	0.00
4+	1.400	3.500	800.41	-5660.38	-9881.49	0.00	0.00	0.00
5-	1.867	3.500	800.41	-5660.38	-9507.96	0.00	0.00	0.00
5+	1.867	3.500	800.41	-5660.38	-9507.96	0.00	0.00	0.00
6-	2.333	3.500	800.41	-5660.38	-9134.43	0.00	0.00	0.00
6+	2.333	3.500	800.41	-5660.38	-9134.43	0.00	0.00	0.00
7-	2.800	3.500	800.41	-5660.38	-8760.91	0.00	0.00	0.00
7+	2.800	3.500	800.41	-5660.38	-8760.91	0.00	0.00	0.00
8-	3.267	3.500	800.41	-5660.38	-8387.38	0.00	0.00	0.00
8+	3.267	3.500	800.41	-5660.38	-8387.38	0.00	0.00	0.00
9-	3.733	3.500	800.41	-5660.38	-8013.85	0.00	0.00	0.00

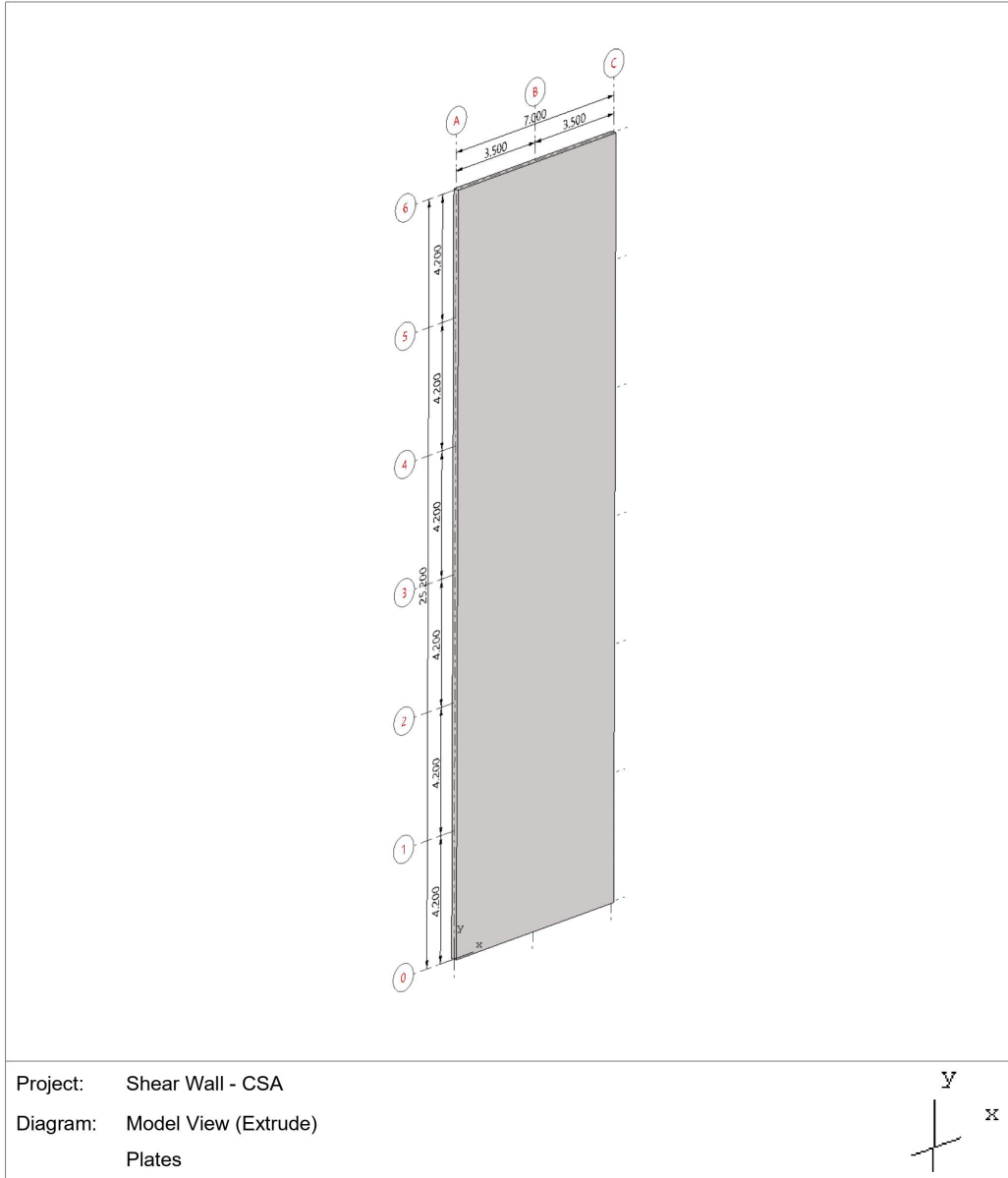
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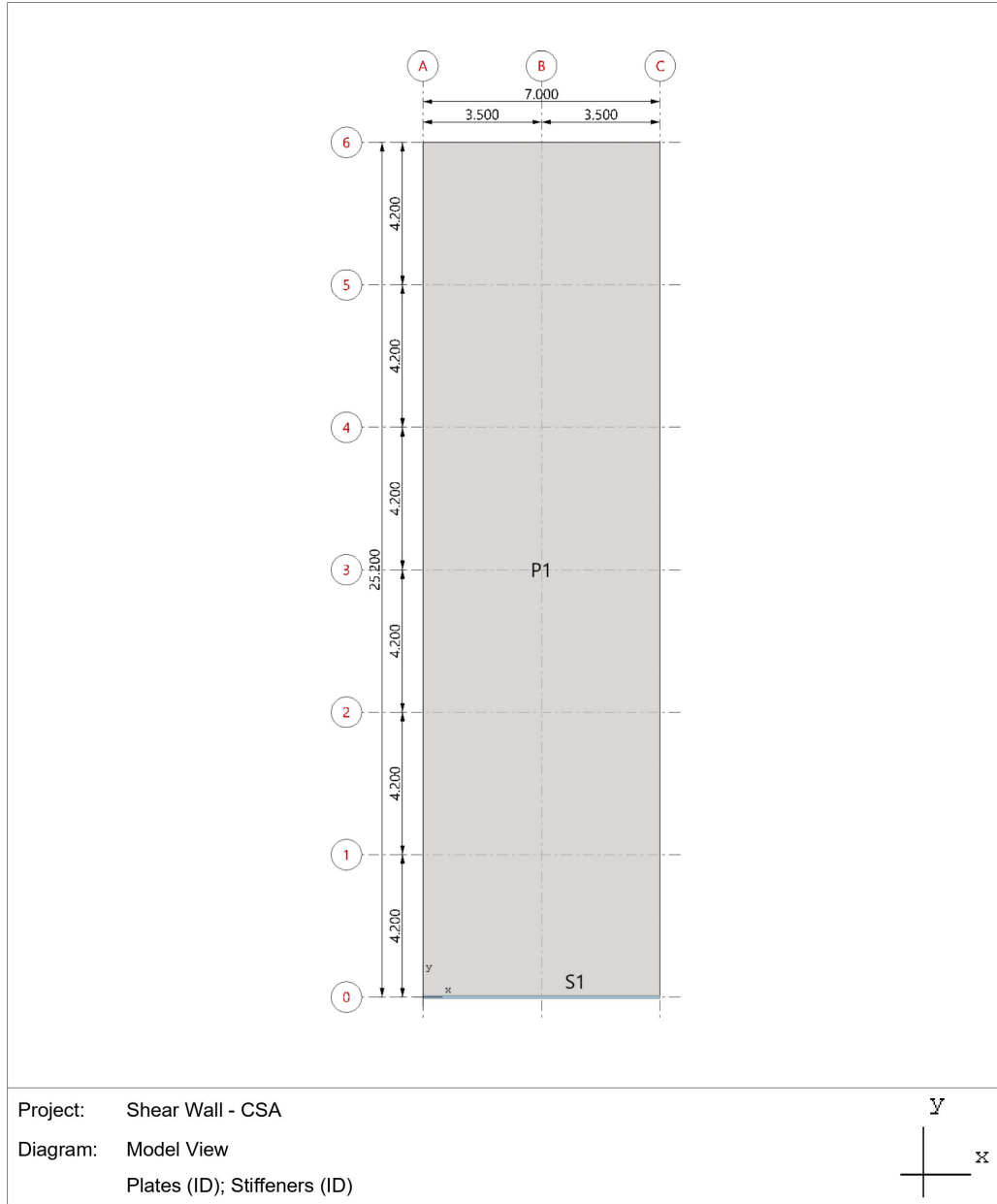
No.	Wall Crossection		In-Plane Forces			Out-Of-Plane Forces		
	Y coordinate m	X-Centroid m	Vux kN	Nuy kN	Muz kNm	Vuz kN	Mux kNm	Muy kNm
9+	3.733	3.500	800.41	-5660.38	-8013.85	0.00	0.00	0.00
10-	4.200	3.500	800.41	-5660.38	-7640.32	0.00	0.00	0.00
10+	4.200	3.500	654.88	-4700.68	-7640.32	0.00	0.00	0.00
11-	4.667	3.500	654.88	-4700.68	-7334.71	0.00	0.00	0.00
11+	4.667	3.500	654.88	-4700.68	-7334.71	0.00	0.00	0.00
12-	5.133	3.500	654.88	-4700.68	-7029.10	0.00	0.00	0.00
12+	5.133	3.500	654.88	-4700.68	-7029.10	0.00	0.00	0.00
13-	5.600	3.500	654.88	-4700.68	-6723.49	0.00	0.00	0.00
13+	5.600	3.500	654.88	-4700.68	-6723.49	0.00	0.00	0.00
14-	6.067	3.500	654.88	-4700.68	-6417.87	0.00	0.00	0.00
14+	6.067	3.500	654.88	-4700.68	-6417.87	0.00	0.00	0.00
15-	6.533	3.500	654.88	-4700.68	-6112.26	0.00	0.00	0.00
15+	6.533	3.500	654.88	-4700.68	-6112.26	0.00	0.00	0.00
16-	7.000	3.500	654.88	-4700.68	-5806.65	0.00	0.00	0.00
16+	7.000	3.500	654.88	-4700.68	-5806.65	0.00	0.00	0.00
17-	7.467	3.500	654.88	-4700.68	-5501.03	0.00	0.00	0.00
17+	7.467	3.500	654.88	-4700.68	-5501.03	0.00	0.00	0.00
18-	7.933	3.500	654.88	-4700.68	-5195.42	0.00	0.00	0.00
18+	7.933	3.500	654.88	-4700.68	-5195.42	0.00	0.00	0.00
19-	8.400	3.500	654.88	-4700.68	-4889.81	0.00	0.00	0.00
19+	8.400	3.500	509.35	-3740.98	-4889.81	0.00	0.00	0.00
20-	8.867	3.500	509.35	-3740.98	-4652.11	0.00	0.00	0.00
20+	8.867	3.500	509.35	-3740.98	-4652.11	0.00	0.00	0.00
21-	9.333	3.500	509.35	-3740.98	-4414.41	0.00	0.00	0.00
21+	9.333	3.500	509.35	-3740.98	-4414.41	0.00	0.00	0.00
22-	9.800	3.500	509.35	-3740.98	-4176.71	0.00	0.00	0.00
22+	9.800	3.500	509.35	-3740.98	-4176.71	0.00	0.00	0.00
23-	10.267	3.500	509.35	-3740.98	-3939.01	0.00	0.00	0.00
23+	10.267	3.500	509.35	-3740.98	-3939.01	0.00	0.00	0.00
24-	10.733	3.500	509.35	-3740.98	-3701.31	0.00	0.00	0.00
24+	10.733	3.500	509.35	-3740.98	-3701.31	0.00	0.00	0.00
25-	11.200	3.500	509.35	-3740.98	-3463.61	0.00	0.00	0.00
25+	11.200	3.500	509.35	-3740.98	-3463.61	0.00	0.00	0.00
26-	11.667	3.500	509.35	-3740.98	-3225.91	0.00	0.00	0.00
26+	11.667	3.500	509.35	-3740.98	-3225.91	0.00	0.00	0.00
27-	12.133	3.500	509.35	-3740.98	-2988.22	0.00	0.00	0.00
27+	12.133	3.500	509.35	-3740.98	-2988.22	0.00	0.00	0.00
28-	12.600	3.500	509.35	-3740.98	-2750.52	0.00	0.00	0.00
28+	12.600	3.500	363.82	-2781.28	-2750.52	0.00	0.00	0.00
29-	13.067	3.500	363.82	-2781.28	-2580.73	0.00	0.00	0.00
29+	13.067	3.500	363.82	-2781.28	-2580.73	0.00	0.00	0.00
30-	13.533	3.500	363.82	-2781.28	-2410.95	0.00	0.00	0.00
30+	13.533	3.500	363.82	-2781.28	-2410.95	0.00	0.00	0.00
31-	14.000	3.500	363.82	-2781.28	-2241.16	0.00	0.00	0.00
31+	14.000	3.500	363.82	-2781.28	-2241.16	0.00	0.00	0.00
32-	14.467	3.500	363.82	-2781.28	-2071.38	0.00	0.00	0.00
32+	14.467	3.500	363.82	-2781.28	-2071.38	0.00	0.00	0.00
33-	14.933	3.500	363.82	-2781.28	-1901.59	0.00	0.00	0.00
33+	14.933	3.500	363.82	-2781.28	-1901.59	0.00	0.00	0.00
34-	15.400	3.500	363.82	-2781.28	-1731.81	0.00	0.00	0.00
34+	15.400	3.500	363.82	-2781.28	-1731.81	0.00	0.00	0.00
35-	15.867	3.500	363.82	-2781.28	-1562.02	0.00	0.00	0.00
35+	15.867	3.500	363.82	-2781.28	-1562.02	0.00	0.00	0.00
36-	16.333	3.500	363.82	-2781.28	-1392.24	0.00	0.00	0.00

No.	Wall Crossection		In-Plane Forces			Out-Of-Plane Forces		
	Y coordinate m	X-Centroid m	Vux kN	Nuy kN	Muz kNm	Vuz kN	Mux kNm	Muy kNm
36+	16.333	3.500	363.82	-2781.28	-1392.24	0.00	0.00	0.00
37-	16.800	3.500	363.82	-2781.28	-1222.45	0.00	0.00	0.00
37+	16.800	3.500	218.29	-1821.58	-1222.45	0.00	0.00	0.00
38-	17.267	3.500	218.29	-1821.58	-1120.58	0.00	0.00	0.00
38+	17.267	3.500	218.29	-1821.58	-1120.58	0.00	0.00	0.00
39-	17.733	3.500	218.29	-1821.58	-1018.71	0.00	0.00	0.00
39+	17.733	3.500	218.29	-1821.58	-1018.71	0.00	0.00	0.00
40-	18.200	3.500	218.29	-1821.58	-916.84	0.00	0.00	0.00
40+	18.200	3.500	218.29	-1821.58	-916.84	0.00	0.00	0.00
41-	18.667	3.500	218.29	-1821.58	-814.97	0.00	0.00	0.00
41+	18.667	3.500	218.29	-1821.58	-814.97	0.00	0.00	0.00
42-	19.133	3.500	218.29	-1821.58	-713.10	0.00	0.00	0.00
42+	19.133	3.500	218.29	-1821.58	-713.10	0.00	0.00	0.00
43-	19.600	3.500	218.29	-1821.58	-611.23	0.00	0.00	0.00
43+	19.600	3.500	218.29	-1821.58	-611.23	0.00	0.00	0.00
44-	20.067	3.500	218.29	-1821.58	-509.35	0.00	0.00	0.00
44+	20.067	3.500	218.29	-1821.58	-509.35	0.00	0.00	0.00
45-	20.533	3.500	218.29	-1821.58	-407.48	0.00	0.00	0.00
45+	20.533	3.500	218.29	-1821.58	-407.48	0.00	0.00	0.00
46-	21.000	3.500	218.29	-1821.58	-305.61	0.00	0.00	0.00
46+	21.000	3.500	72.76	-861.88	-305.61	0.00	0.00	0.00
47-	21.467	3.500	72.76	-861.88	-271.66	0.00	0.00	0.00
47+	21.467	3.500	72.76	-861.88	-271.66	0.00	0.00	0.00
48-	21.933	3.500	72.76	-861.88	-237.70	0.00	0.00	0.00
48+	21.933	3.500	72.76	-861.88	-237.70	0.00	0.00	0.00
49-	22.400	3.500	72.76	-861.88	-203.74	0.00	0.00	0.00
49+	22.400	3.500	72.76	-861.88	-203.74	0.00	0.00	0.00
50-	22.867	3.500	72.76	-861.88	-169.79	0.00	0.00	0.00
50+	22.867	3.500	72.76	-861.88	-169.79	0.00	0.00	0.00
51-	23.333	3.500	72.76	-861.88	-135.83	0.00	0.00	0.00
51+	23.333	3.500	72.76	-861.88	-135.83	0.00	0.00	0.00
52-	23.800	3.500	72.76	-861.88	-101.87	0.00	0.00	0.00
52+	23.800	3.500	72.76	-861.88	-101.87	0.00	0.00	0.00
53-	24.267	3.500	72.76	-861.88	-67.91	0.00	0.00	0.00
53+	24.267	3.500	72.76	-861.88	-67.91	0.00	0.00	0.00
54-	24.733	3.500	72.76	-861.88	-33.96	0.00	0.00	0.00
54+	24.733	3.500	72.76	-861.88	-33.96	0.00	0.00	0.00
55-	25.200	3.500	72.76	-861.88	0.00	0.00	0.00	0.00
55+	25.200	0.000	0.00	0.00	0.00	0.00	0.00	0.00

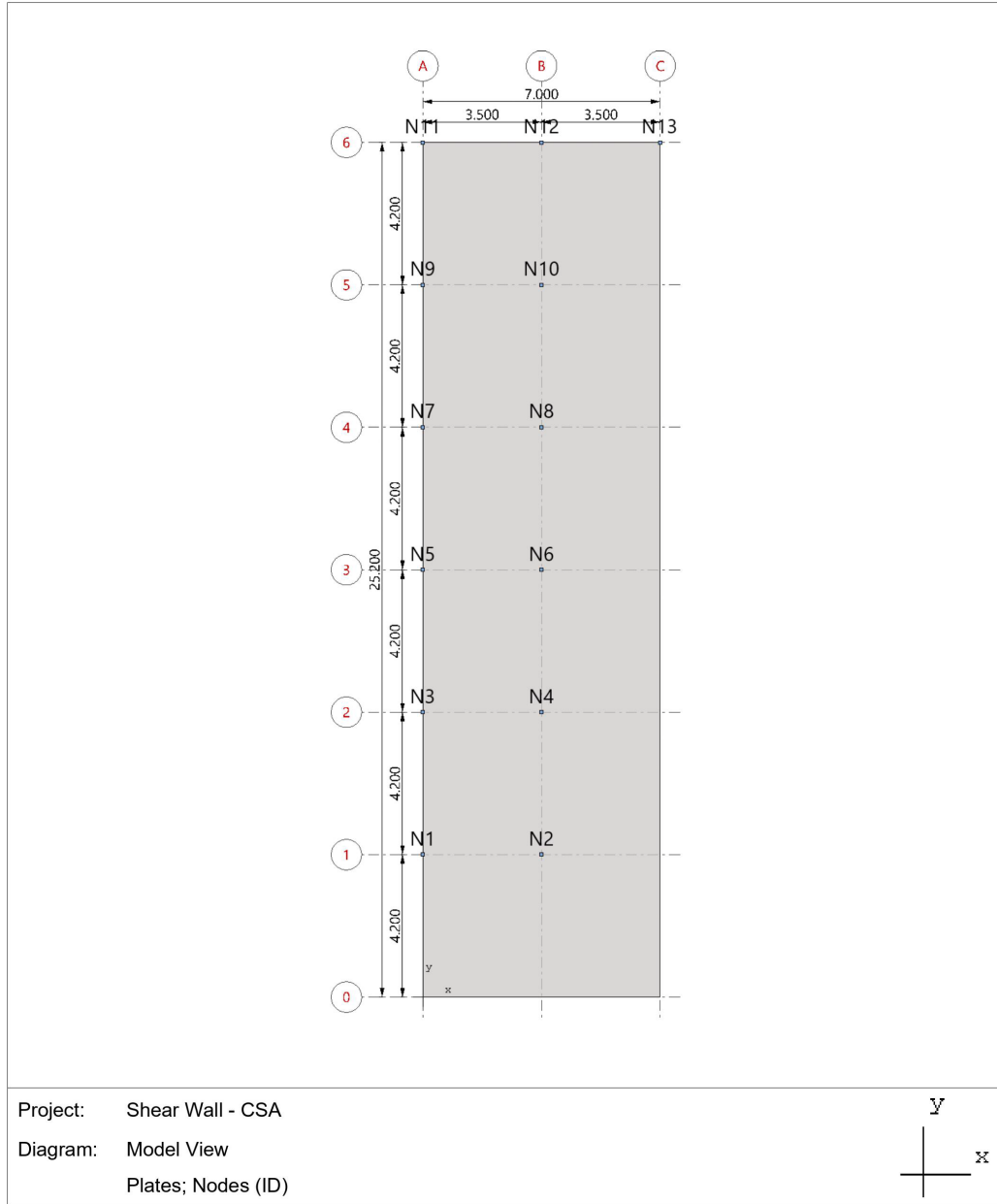
5. Screenshots
5.1. Extrude 3D view



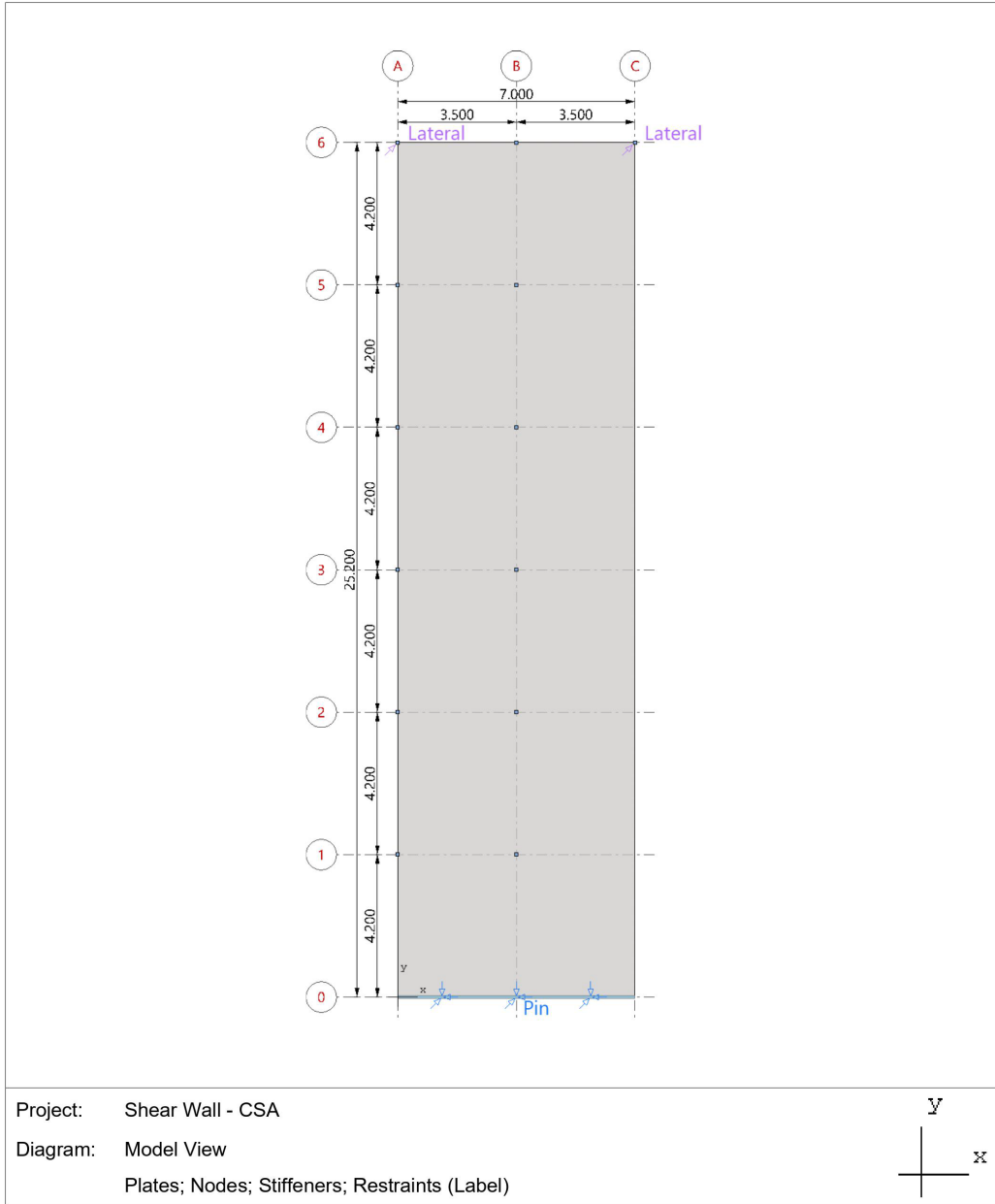
5.2. Plates & Stiffeners ID



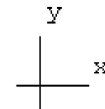
5.3. Nodes ID



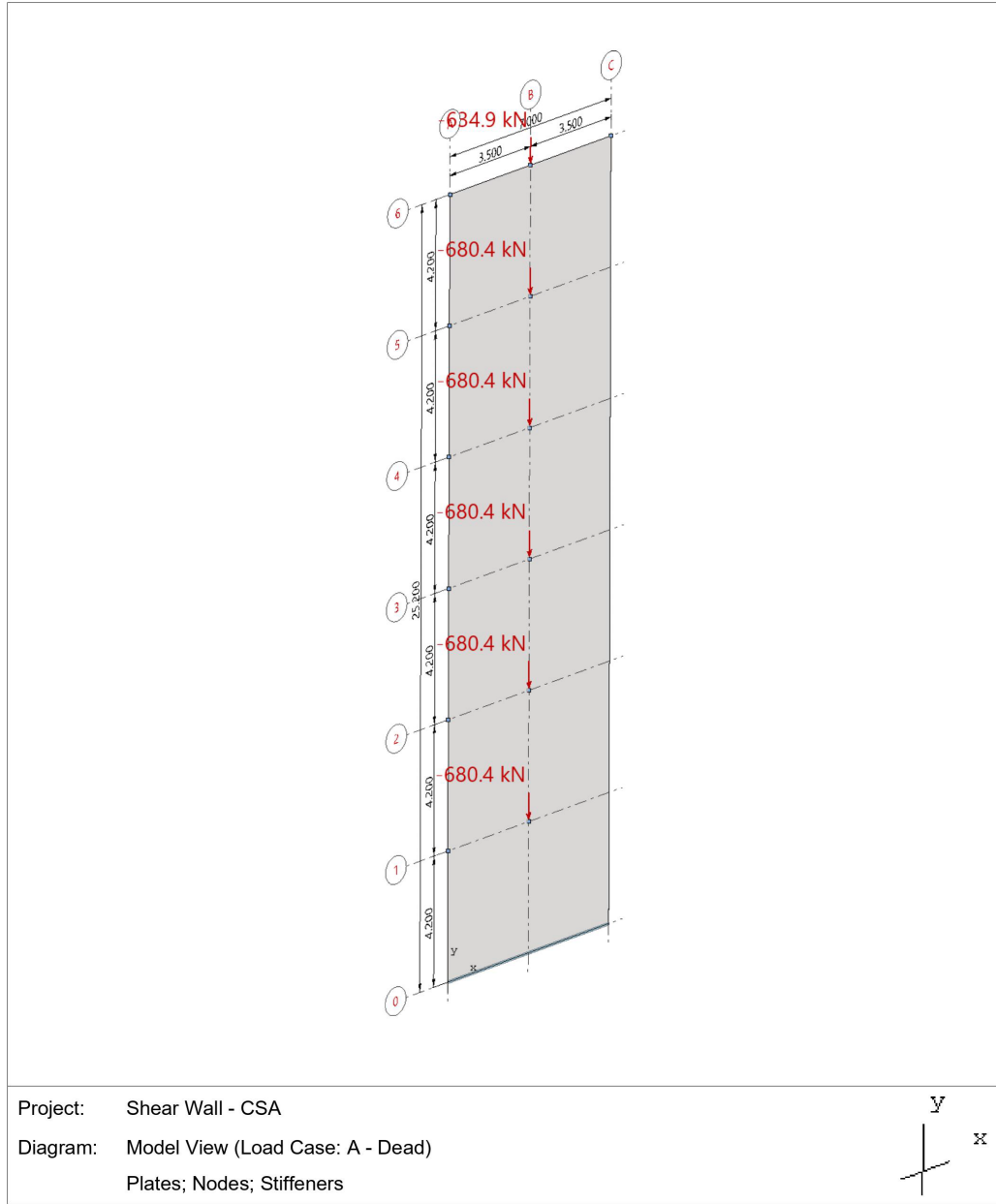
5.4. Restraints



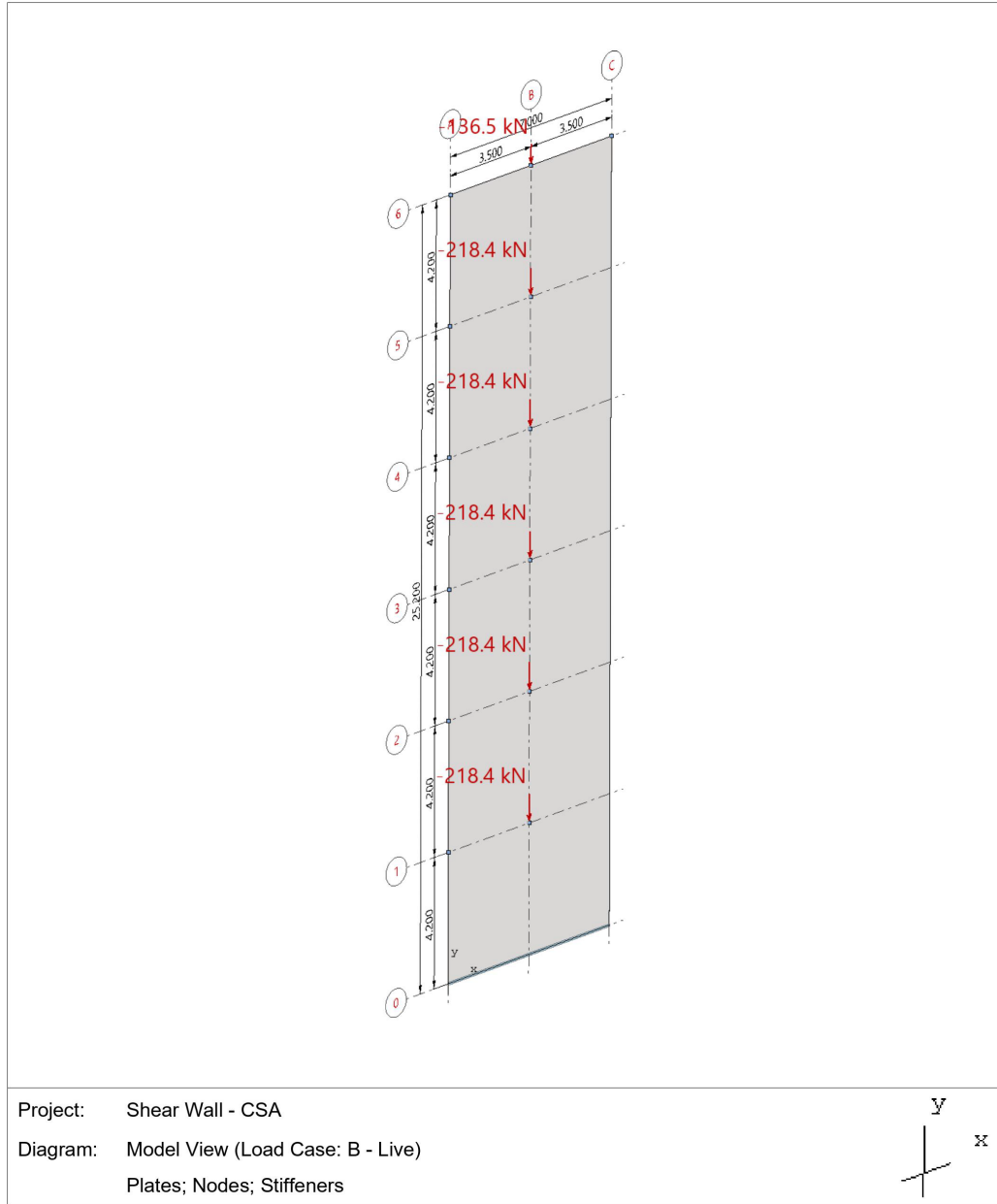
Project: Shear Wall - CSA
Diagram: Model View
Plates; Nodes; Stiffeners; Restraints (Label)



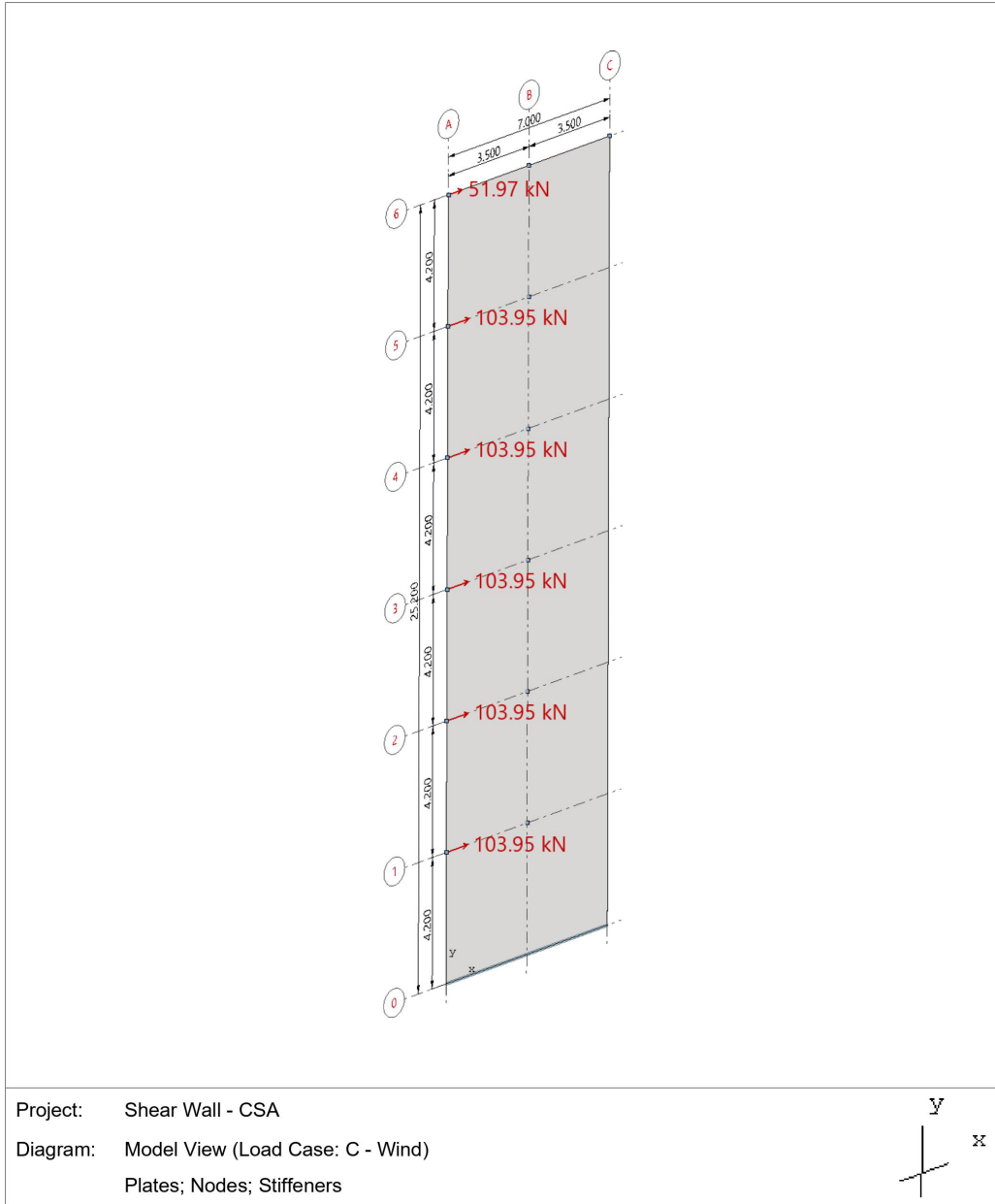
5.5. Loads - Case A - Dead



5.6. Loads - Case B - Live



5.7. Loads - Case C - Wind



7. Design Results Comparison and Conclusions

Solution	Wall Cross-Sectional Forces			$A_{s, \text{vertical}}$ (mm ²)	
	M_f (kN-m)	N_f (kN)	V_f (kN)	$A_{s, \text{required}}$	$A_{s, \text{provided}}$
Hand	11,002	5,660	800	---	3,000
Reference	11,000	5,660	800	---	3,000
spWall	11,002	5,660	800	2,906	3,000*

* Area of steel provided was selected based on the $A_{s, \text{required}}$ reported in [spWall](#).

The results of all the hand calculations and the reference used illustrated above are in very good agreement with the automated results obtained from the [spWall](#) FEA. It is worth noting that the minimum area of steel is governed by the minimum reinforcement ratio stipulated by the code. The same can be seen in [spWall](#) output for elements 3 through 14.

8. Conclusions & Observations

Engineers can evaluate several options when arriving at the reinforcing bar arrangement from an FEA model. The following conclusions and observations can be used to better understand designing and investigating shear walls using [spWall](#):

1. In finite element analysis, selecting mesh size has a crucial impact on the results accuracy (as an example the amount and distribution of reinforcement). The mesh size should be optimized in a way that changing the element size has slight effect on the results obtained. However, the optimum element size is dependent on multiple parameters in the model which makes it difficult to find a generalized procedure to select the optimum size. [Multiple studies](#) conducted by StructurePoint showed that the element length should not be greater than 10% of the total wall length and a coarser mesh should be used with caution and engineering judgement.
2. [spWall](#) calculates the required area of steel for each element along the section. This area of steel is selected in a way that it should be enough to satisfy the strength requirements under a specific sets of extreme design forces. This approach will lead to placing most of the reinforcement at wall section ends, as was shown in this example, leading to the highest possible flexural capacity that can be achieved for the section with the same amount of steel. In practice, having a uniform distribution of reinforcement along the wall section is more common and the flexural capacity of the concrete wall is usually calculated based on it.
3. Concrete Shear walls can be analyzed and designed using simplified structural analysis approaches as the one used in this example. However, as the level of complexity of the wall increases, analyzing and designing shear walls using hand solution become more challenging and less effective. Computer software utilizing FEA (e.g. [spWall](#)) is an efficient solution to analyze and design concrete shear walls regardless of the level of complexity. [spWall](#) selects the minimum required area of steel with the optimum reinforcement distribution for the wall section in which the highest bending capacity of the wall section is achieved. [spColumn](#) software can be also utilized to obtain the wall interaction diagram to help better understand the behavior of the section selected. More information about this topic can be found in [the Appendix of “Reinforced Concrete Shear Wall Analysis and Design \(ACI 318-14\)” design example](#).