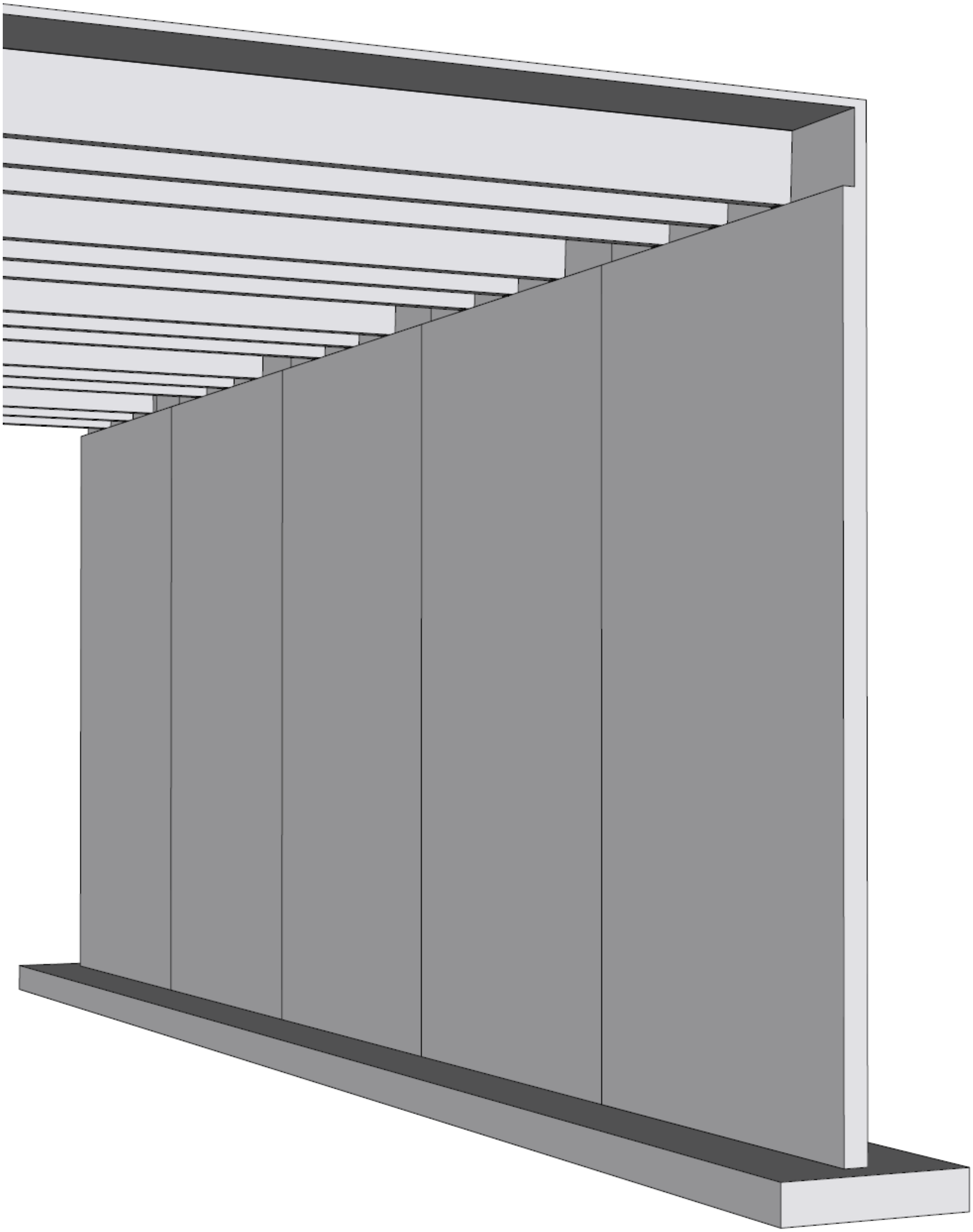
# Reinforced Concrete Tilt-Up Wall Panel Analysis and Design (ACI 551)



**Reinforced Concrete Tilt-Up Wall Panel Analysis and Design (ACI 551)**

Tilt-up is form of construction with increasing popularity owing to its flexibility and economics. Tilt-up concrete is essentially a precast concrete that is site cast instead of traditional factory cast concrete members. A structural reinforced concrete tilt-up wall panel in a single-story warehouse (big-box) building provides gravity and lateral load resistance for the following applied loads from three roof joists bearing in wall pockets in addition to the wind:

| | |
|---|---|
| Roof dead load | = 2.4 kip per joist |
| Roof live load | = 2.5 kip per joist |
| Wind load | = 27.2 psf |

The assumed tilt-up wall panel section and reinforcement are investigated after analysis to verify suitability for the applied loads then compared with numerical analysis results obtained from spWall engineering software program from StructurePoint.

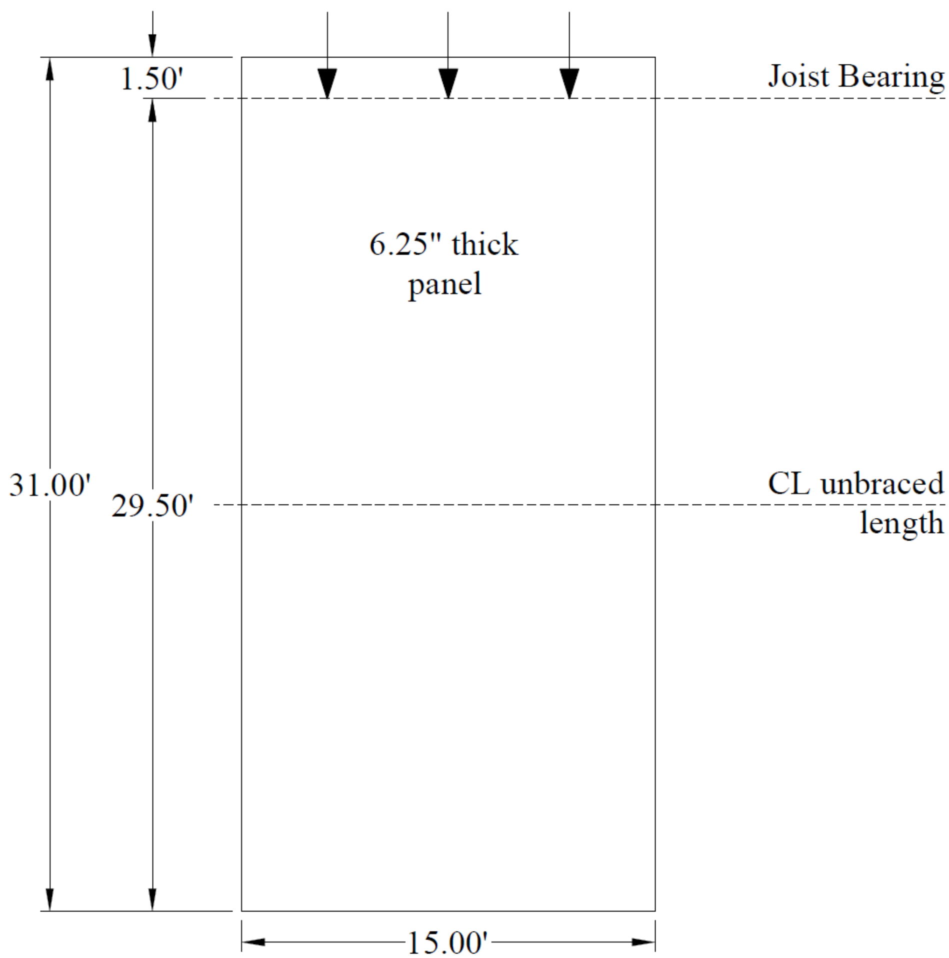



Figure 1 – Reinforced Concrete Tilt-Up Wall Panel Geometry

# Contents

**Code**

Building Code Requirements for Structural Concrete (ACI 318-11) and Commentary (ACI 318R-11)

**Reference**

Design Guide for Tilt-Up Concrete Panels, ACI 551.2R-15, 2015, Example B.1

spWall Engineering Software Program Manual v5.01, STRUCTUREPOINT, 2016

**Design Data**

$f_c'$ = 4,000 psi normal weight concrete ($w_c$ = 150 pcf)

$f_y$ = 60,000 psi

Wall length = $l_c$ = 31 ft – 1.5 ft = 29.5

Assumed wall thickness = 6.25 in.

Assumed eccentricity = $e_{cc}$ = 3 in.

Assumed vertical reinforcement: 16 #6 (single layer)

## 1. Minimum Vertical Reinforcement

$$\rho_l = \frac{A_{v,vertical}}{b \times h} = \frac{7.0}{(15\times12)\times6.25} = 0.0062$$ ***ACI 318-11 (2.1)***

$$\rho_{l,\min} = 0.0015$$ ***ACI 318-11 (14.3.2)***

$$\rho_l = 0.0062 \geq \rho_{l,\min} = 0.0015 \text{ (o.k)}$$

$$s_{l,\max} = \text{smallest of} \begin{Bmatrix} 3\times h \\ 18 \text{ in.} \end{Bmatrix} = \text{smallest of} \begin{Bmatrix} 3\times6.25 \\ 18 \text{ in.} \end{Bmatrix} = \text{smallest of} \begin{Bmatrix} 18.75 \text{ in.} \\ 18 \text{ in.} \end{Bmatrix} = 18 \text{ in.}$$ ***ACI 318-11 (7.6.5)***

$$s_{l,provided} = \frac{15\times12}{16} = 11.25 \text{ in.} \leq s_{l,\max} = 18 \text{ in. } (\textbf{o.k.})$$

## 2. Alternative Design Method ACI 318 Provisions

The design guide for tilt-up concrete panels ACI 551 states that tilt-up concrete walls can be analyzed using the provisions of Chapter 14 of the ACI 318-11. Most walls, and especially slender walls, are widely evaluated using the “Alternative design of slender walls” in Section 14.8. The same provisions are presented in ACI 318-14 but reorganized in different chapters and in slightly revised terminology. The method is applicable when the conditions summarized below are met:

- The cross section shall be constant over the height of the wall ***ACI 318-11 (14.8.2.2)***
- The wall can be designed as simply supported ***ACI 318-11 (14.8.2.1)***
- Maximum moments and deflections occurring at midspan ***ACI 318-11 (14.8.2.1)***
- The wall must be axially loaded ***ACI 318-11 (14.8.2.1)***
- The wall must be subjected to an out-of-plane uniform lateral load ***ACI 318-11 (14.8.2.1)***
- The wall shall be tension-controlled ***ACI 318-11 (14.8.2.3)***
- The reinforcement shall provide design strength greater than cracking strength ***ACI 318-11 (14.8.2.4)***

## 3. Tilt-Up Wall Structural Analysis

Using 14.8 provisions, calculate factored loads as follows for each of the considered load combinations:

### 3.1. Applied loads

$$\text{Wall self-weight} = \frac{6.25}{12}\times15\times\left(\frac{29.5}{2}+1.5\right)\times150\times\frac{1\text{ kip}}{1000\text{ lb}} = 19.0\text{ kip}$$

$$P_{DL} = 3\times2.4 = 7.2\text{ kip}$$

$$P_{LL} = 3\times2.5 = 7.5\text{ kip}$$

$$w = 27.2\text{ lb/ft}^2$$

## 3.2. Maximum wall forces

Calculate maximum factored wall forces in accordance with 14.8.3 including moment magnification due to second order (P-Δ) effects. Load combination U = 1.2 *D* x 1.6 $L_r$ x 0.5 *W* is considered in this example:

$$P_{ua} = 1.2 \times 7.2 + 1.6 \times 7.5 = 20.6 \text{ kip}$$

$$P_{um} = 20.6 + 1.2 \times 19.0 = 43.4 \text{ kip}$$

$$w_u = 0.5 \times 27.2 \times 15 \text{ ft} \times \frac{1 \text{ kip}}{1000 \text{ lb}} = 0.204 \text{ kip/ft}$$

$$M_u = \frac{M_{ua}}{1 - \dfrac{5 \times P_u \times l_c^2}{0.75 \times 48 \times E_c \times I_{cr}}}$$ ***ACI 318-11 (Eq. 14-6)***

$$M_{ua} = \frac{w_u \times l_c^2}{8} + \frac{P_{ua} \times e}{2} = \frac{0.204 \times (29.5)^2}{8} + \frac{20.6 \times 3}{2 \times 12} = 24.8 \text{ ft-kip}$$

Where $M_{ua}$ is the maximum factored moment at midheight of wall due to lateral and eccentric vertical loads, not including PΔ effects. ***ACI 318-11 (14.8.3)***

$$E_c = 57{,}000 \times \sqrt{f_c^{'}} = 57{,}000 \times \sqrt{4{,}000} = 3{,}605{,}000 \text{ psi}$$ ***ACI 318-11 (8.5.1)***

$$I_{cr} = n \times A_{se} \times (d - c)^2 + \frac{l_w \times c^3}{3}$$ ***ACI 318-11 (Eq. 14-7)***

$$n = \frac{E_s}{E_c} = \frac{29{,}000}{3{,}605} = 8.0 > 6.0 \ (\textbf{o.k.})$$ ***ACI 318-11 (14.8.3)***

Calculate the effective area of longitudinal reinforcement in a slender wall for obtaining an approximate cracked moment of inertia.

$$A_{se} = A_s + \frac{P_{um} \times h}{2 \times f_y \times d} = 7.0 + \frac{43.4 \times 6.25}{2 \times 60 \times (6.25/2)} = 7.72 \text{ in.}^2$$ ***ACI 318-11 (R14.8.3)***

The following calculation are performed with the effective area of steel in lieu of the actual area of steel.

$$a = \frac{A_{se} \times f_y}{0.85 \times f_c^{'} \times b} = \frac{7.72 \times 60}{0.85 \times 4 \times (15 \times 12)} = 0.757 \text{ in.}$$

$$c = \frac{a}{\beta_1} = \frac{0.757}{0.85} = 0.891 \text{ in.}$$

$$\frac{c}{d} = \frac{0.891}{3.13} = 0.285 < 0.375 \therefore \text{ tension-controlled}$$ ***ACI 318-11 (R9.3.2.2)***

$\phi = 0.9$ **ACI 318-11 (9.3.2)**

$$I_{cr} = 8.0 \times 7.72 \times (3.13 - 0.891)^2 + \frac{(15 \times 12) \times 0.891^3}{3} = 353 \text{ in.}^4$$ **ACI 318-11 (Eq. 14-7)**

$$M_u = \frac{M_{ua}}{1 - \dfrac{P_{um}}{0.75 \times K_b}}$$ **ACI 318-11 (Eq. 14-6)**

$$K_b = \frac{48 \times E_c \times I_{cr}}{5 \times l_c^2} = \frac{48 \times 3605 \times 353}{5 \times (29.5 \times 12)^2} = 97.4 \text{ kip}$$

$$M_u = \frac{24.8}{1 - \dfrac{43.4}{0.75 \times 97.4}} = 61.2 \text{ ft-kip}$$

3.3. Tension-controlled verification **ACI 318-11 (14.8.2.3)**

$$P_n = \frac{P_{um}}{\phi} = \frac{43.4}{0.9} = 48.2 \text{ kips}$$

$$a = \frac{A_{se,w} \times f_y}{0.85 \times f_c' \times l_w} = \frac{\dfrac{P_n \times h}{2 \times d} + A_s \times f_y}{0.85 \times f_c' \times l_w} = \frac{\dfrac{48.2 \times 6.25}{2 \times 3.13} + 7.0 \times 60}{0.85 \times 4 \times 15 \times 12} = 0.765 \text{ in.}$$

$$c = \frac{a}{\beta_1} = \frac{0.765}{0.85} = 0.900 \text{ in.}$$

$$\varepsilon_t = \left(\frac{0.003}{c}\right) \times d_t - 0.003 = \left(\frac{0.003}{0.900}\right) \times 3.13 - 0.003 = 0.0074 > 0.0050$$

Therefore, section is tension controlled **ACI 318-11 (10.3.4)**

## 4. Tilt-Up Wall Cracking Moment Capacity ($M_{cr}$)

Determine $f_r$ = Modulus of rapture of concrete and $I_g$ = Moment of inertia of the gross uncracked concrete section to calculate $M_{cr}$

$$f_r = 7.5\lambda\sqrt{f_c'} = 7.5 \times 1.0 \times \sqrt{4,000} = 474.3 \text{ psi}$$ **ACI 318-11 (Eq. 9-10)**

$$I_g = \frac{l_w h^3}{12} = \frac{(15 \times 12) \times 6.25^3}{12} = 3662 \text{ in.}^4$$

$$y_t = \frac{h}{2} = \frac{6.25}{2} = 3.13 \text{ in.}$$

$$M_{cr} = \frac{f_r I_g}{y_t} = \frac{474.3 \times 3662}{3.13} \times \frac{1}{1000} \times \frac{1}{12} = 46.3 \text{ ft-kip}$$ **ACI 318-11 (Eq. 9-9)**

## 5. Tilt-Up Wall Flexural Moment Capacity (ϕMn)

For load combination #1:

$$M_n = A_{se} \times f_y \times \left(d - \frac{a}{2}\right) = 7.72 \times 60 \times \left(3.13 - \frac{0.757}{2}\right) = 1277.78 \text{ in.-kip} = 106.5 \text{ ft-kip}$$

It was shown previously that the section is tension controlled → ϕ = 0.9

$$\phi M_n = \phi \times M_n = 0.9 \times 106.48 = 95.5 \text{ ft-kip} > M_u = 61.2 \text{ ft-kip } (\textbf{o.k.})$$ ***ACI 318-11 (14.8.3)***

$$\phi M_n = 95.5 \text{ ft-kip} > M_{cr} = 46.3 \text{ ft-kip } (\textbf{o.k.})$$ ***ACI 318-11 (14.8.2.4)***

$$\Delta_u = \frac{M_u}{0.75 \times K_b} = \frac{61.2 \times 12}{0.75 \times 97.4} = 10.0 \text{ in.}$$ ***ACI 318-11 (Eq. 14-5)***

## 6. Tilt-Up Wall Vertical Stress Check

$$\frac{P_{um}}{A_g} = \frac{43.4 \times 1000}{6.25 \times (15 \times 12)} = 38.6 \text{ psi} < 0.06 \times f_c^{'} = 0.06 \times 4{,}000 = 240 \text{ psi } (\textbf{o.k.})$$ ***ACI 318-11 (14.8.2.6)***

## 7. Tilt-Up Wall Shear Stress Check

In-plane shear is not evaluated since in-plane shear forces are not applied in this example. Out-of-plane shear due to lateral load should be checked against the shear capacity of the wall. By inspection of the maximum shear forces f, it can be determined that the maximum shear force is under 10 kip width. The wall has a shear capacity approximately 140 kip width and no detailed calculations are required by engineering judgement. (See figure 8 for detailed shear force diagram)

## 8. Tilt-Up Wall Mid-Height Deflection (Δs)

The maximum out-of-plane deflection ($\Delta_s$) due to service lateral and eccentric vertical loads, including PΔ effects, shall not exceed $l_c$/150. Where $\Delta_s$ is calculated as follows: ***ACI 318-11 (14.8.4)***

$$\Delta_s = \begin{cases} \frac{2}{3}\Delta_{cr} + \dfrac{M_a - \frac{2}{3}M_{cr}}{M_n - \frac{2}{3}M_{cr}} \times \left(\Delta_n - \frac{2}{3}\Delta_{cr}\right) & \text{When} \quad M_a > \frac{2}{3}M_{cr} \\ \left(\dfrac{M_a}{M_{cr}}\right)\Delta_{cr} & \text{When} \quad M_a < \frac{2}{3}M_{cr} \end{cases}$$ ***ACI 318-11 (14.8.4)***

Where $M_a$ is the maximum moment at mid-height of wall due to service lateral and eccentric vertical loads including PΔ effects.

$$M_a = M_{sa} + P_s \Delta_s$$

$$M_{sa} = \frac{w_s \times l_c^2}{8} + \frac{P_a \times e}{2} = \frac{\left(0.7 \times \frac{27.2}{1.6} \times 15\right) \times (29.5)^2}{8 \times 1000} + \frac{(7.2) \times 3/12}{2} = 20.3 \text{ ft-kip}$$

$$P_s = P_{DL} + \text{wall self-weight} = 7.2 + 19 = 26.2 \text{ kip}$$

$$M_{cr} = \frac{f_r I_g}{y_t} = 46.3 \text{ ft-kip (as calculated perviously)}$$ ***ACI 318-11 (Eq. 9-9)***

$$\Delta_{cr} = \frac{5}{48} \times \frac{M_{cr} \times l_c^2}{E_c \times I_g} = \frac{5}{48} \times \frac{46.3 \times 12 \times (29.5 \times 12)^2}{3,605 \times 3662} = 0.55 \text{ in.}$$ ***ACI 318-11 (Eq. 14-10)***

$\Delta_s$ will be calculated by trial and error method since $\Delta_s$ is a function of $M_a$ and $M_a$ is a function of $\Delta_s$.

$$\text{Assume } M_{sa} < \frac{2}{3} M_{cr}$$

$$\text{Assume } \Delta_s = \left(\frac{M_{sa}}{M_{cr}}\right) \Delta_{cr} = \left(\frac{20.30}{46.30}\right) \times 0.55 = 0.24 \text{ in.}$$

$$M_a = M_{sa} + P_s \Delta_s = 20.3 \times 12 + 26.2 \times 0.24 = 249.9 \text{ in.-kip} = 20.8 \text{ ft-kip}$$

$$\Delta_s = \left(\frac{M_a}{M_{cr}}\right) \Delta_{cr} = \frac{20.8}{46.3} \times 0.55 = 0.25 \text{ in.}$$ ***ACI 318-11 (Eq. 14-9)***

No further iterations are required

$$M_a = 20.8 \text{ ft-kip} < \frac{2}{3} M_{cr} = \frac{2}{3} \times 46.3 = 30.9 \text{ ft-kip} \quad (\textbf{o.k.})$$

$$\Delta_s = 0.25 \text{ in.} < \frac{l_c}{150} = \frac{29.5 \times 12}{150} = 2.36 \text{ in.} \quad (\textbf{o.k.})$$

The wall is adequate with 16 #6 vertical reinforcement and 6.25 in. thickness.

## 9. Tilt-Up Wall Panel Analysis and Design – spWall Software

spWall is a program for the analysis and design of reinforced concrete shear walls, tilt-up 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 (ACI 318-11 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 wall in this example.

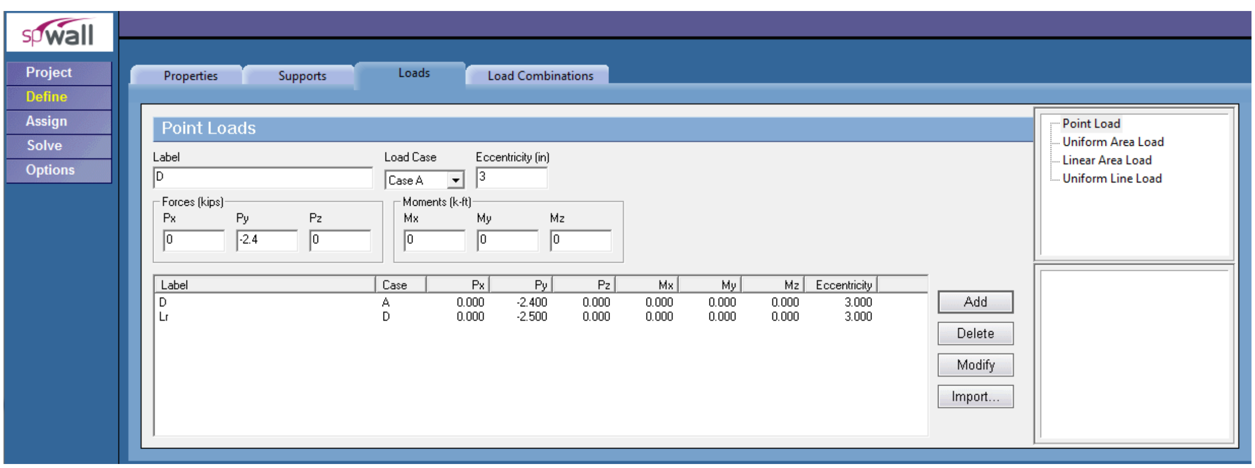



Figure 2 –Defining Loads for Tilt-Up Wall Panel (spWall)

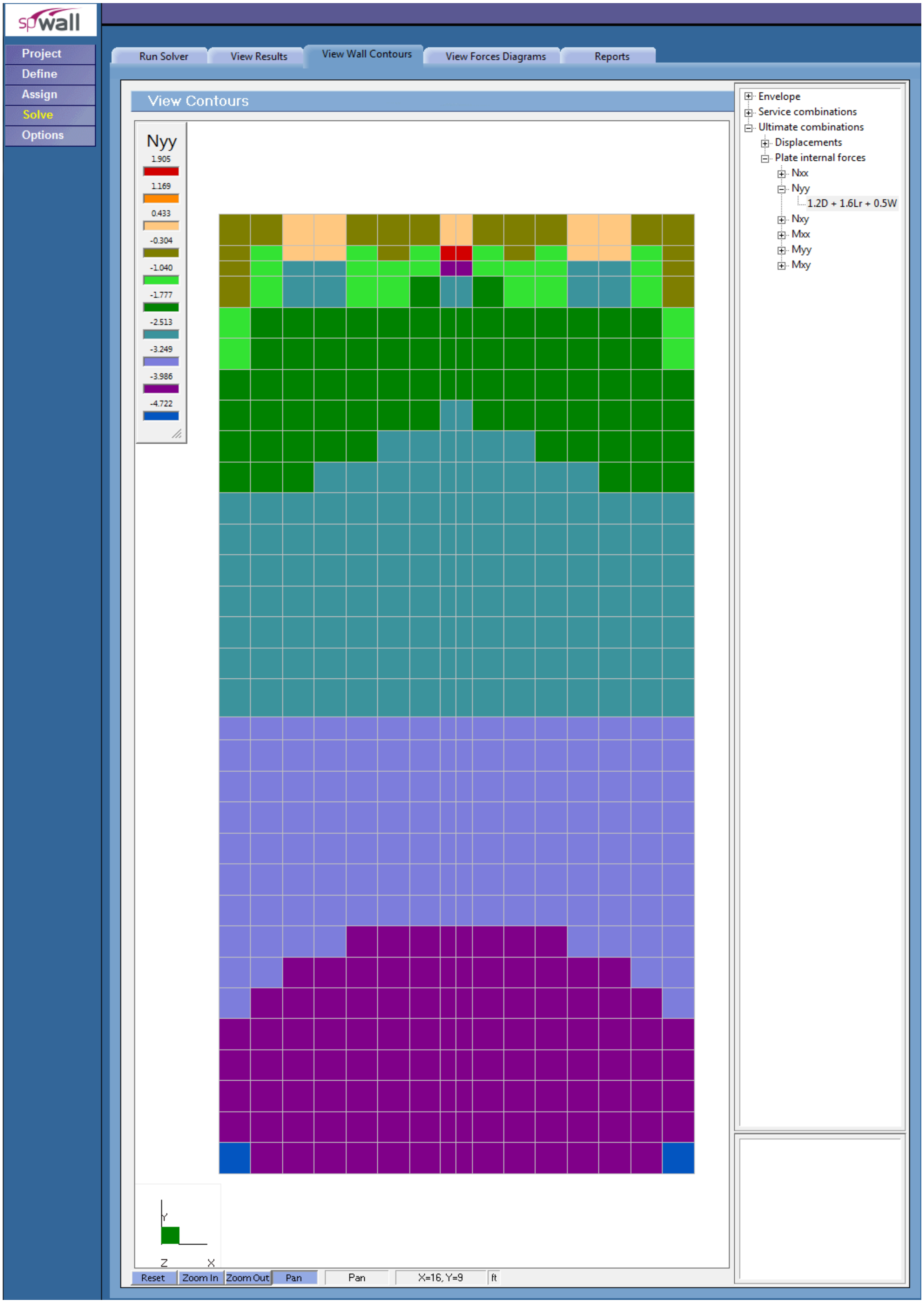


Figure 3 –Factored Axial Forces Contour Normal to Tilt-Up Wall Panel Cross-Section (spWall)

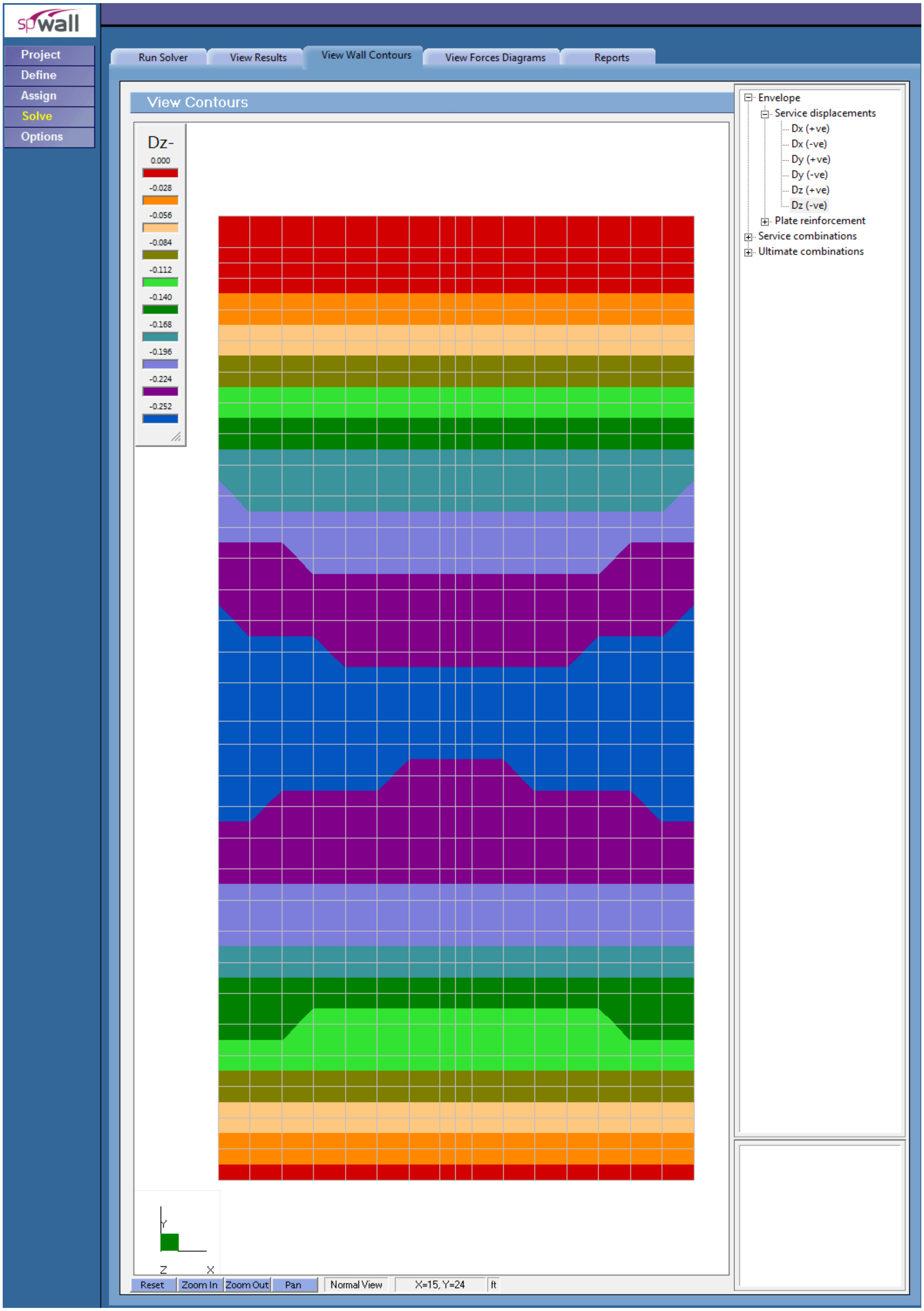



Figure 4 – Tilt-Up Wall Panel Lateral Displacement Contour (Out-of-Plane) (spWall)

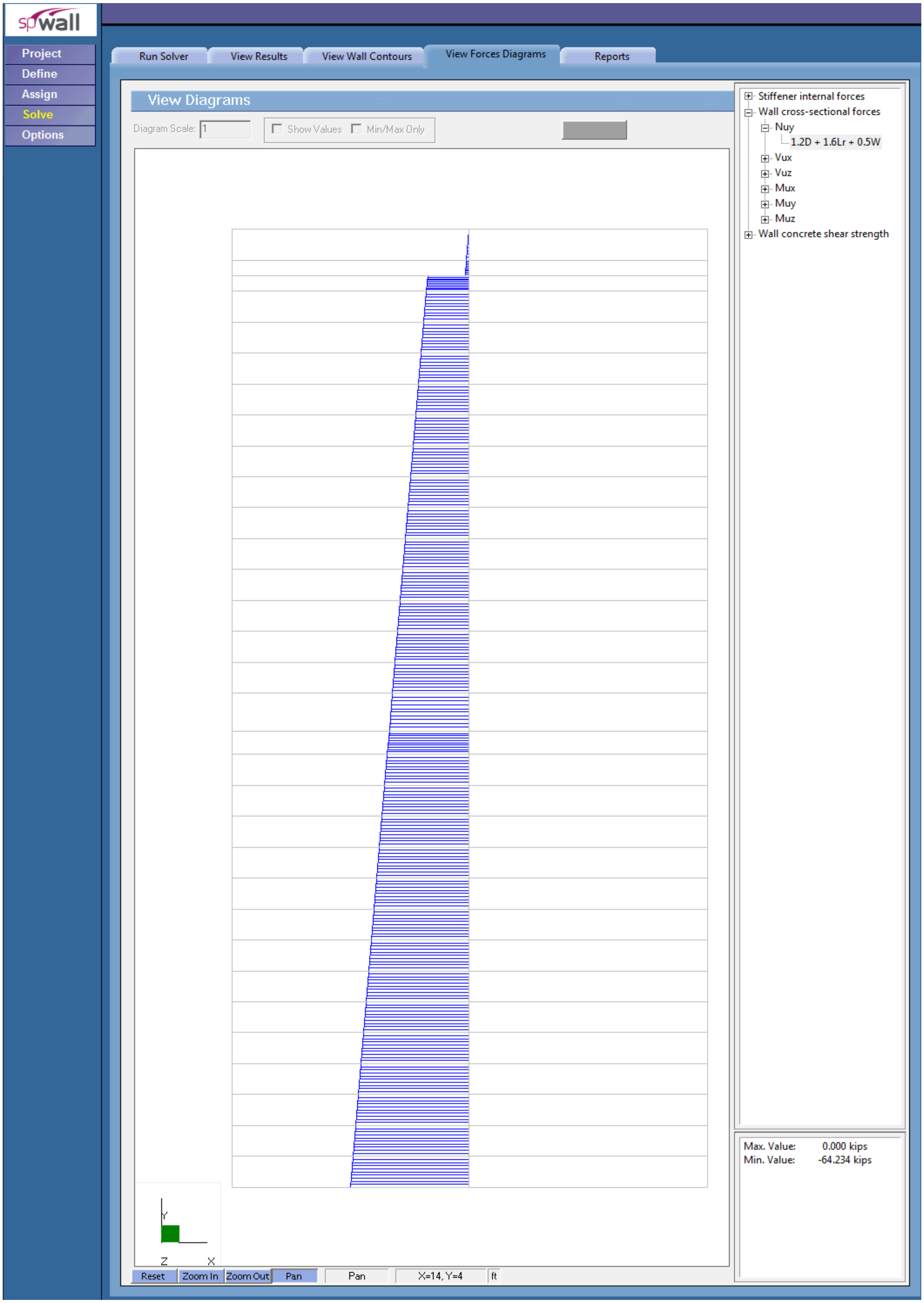



Figure 5 – Tilt-Up Wall Panel Axial Load Diagram (spWall)

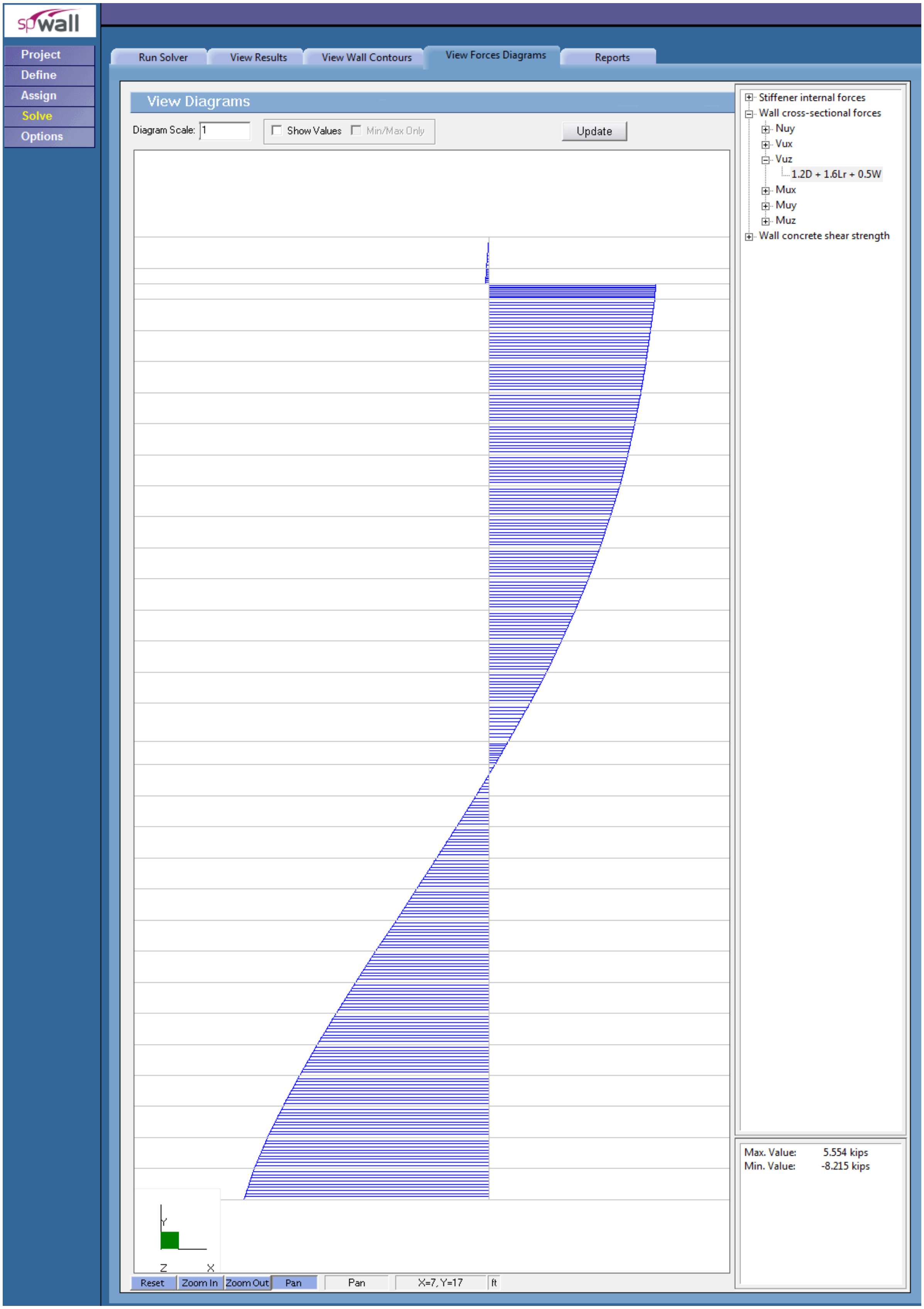



Figure 6 – Out-of-plane Shear Diagram (spWall)

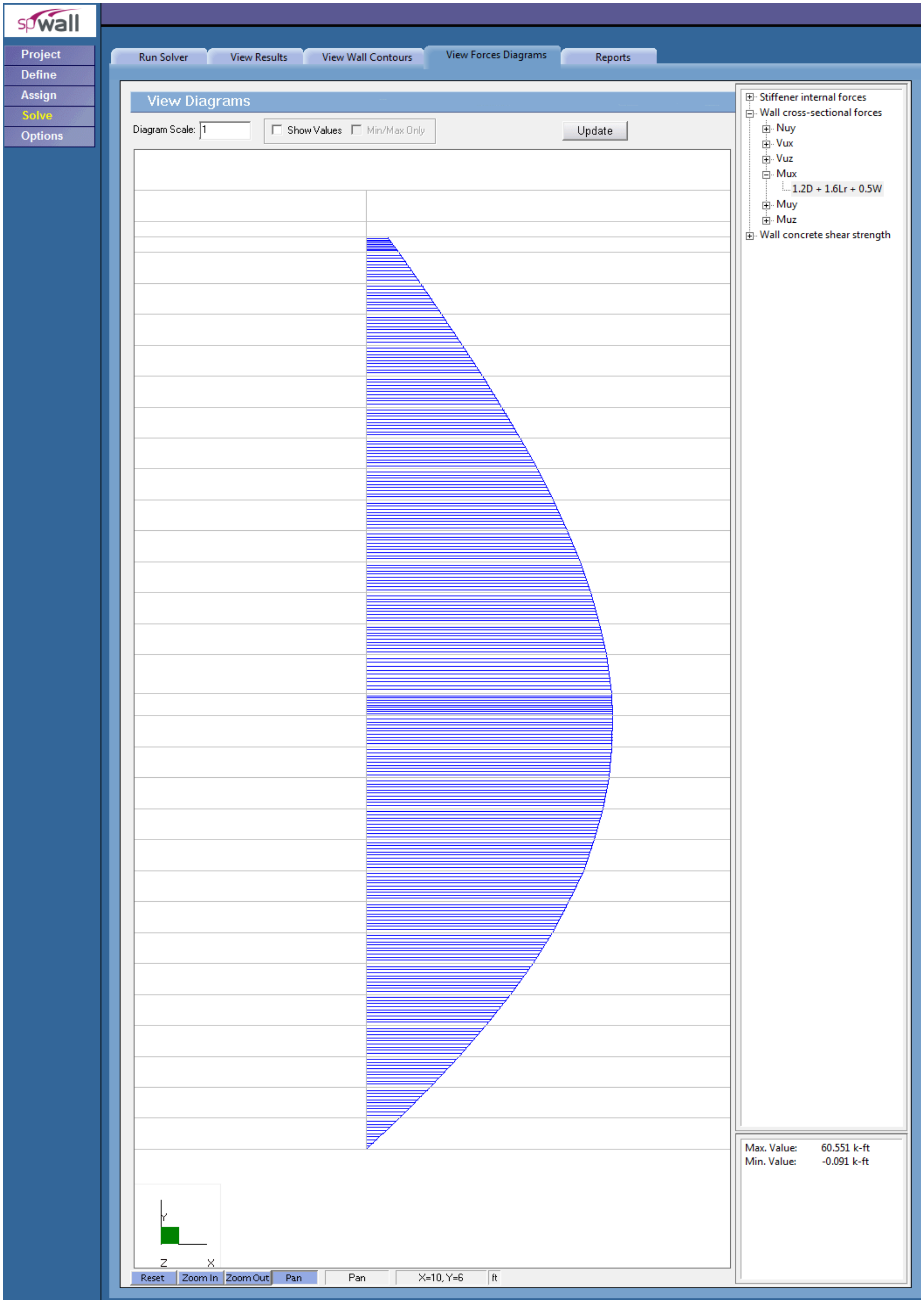



Figure 7 – Tilt-Up Wall Moment Diagram (spWall)

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Ultimate combinations | Wall cross-sectional forces | 1.2D + 1.6Lr + 0.5W
=========================================================================

  Coordinate System:  Global
  ==================

  Units:
  ======
  Y-coordinate, X-centroid: ft
  Force (Vux, Nuy, Vuz): kips, Moment (Mux, Muy, Muz): k-ft

  Notes:
  ======
  (-) Horizontal cross-section below Y-coordinate
  (+) Horizontal cross-section above Y-coordinate
```

| Wall Cross-section | | | In-plane Forces | | | Out-of-plane Forces | | |
|---|---|---|---|---|---|---|---|---|
| No. | Y-coordinate | X-centroid | Vux | Nuy | Muz | Vuz | Mux | Muy |
| 16- | 14.750 | 7.500 | -1.1990e-013 | -4.3492e+001 | 6.6365e-012 | 6.4425e-001 | 6.0237e+001 | 7.0391e-012 |
| 16+ | 14.750 | 7.500 | -2.0723e-014 | -4.3492e+001 | 1.3335e-012 | 6.4425e-001 | 6.0234e+001 | -3.9646e-011 |

Figure 8 – Tilt-Up Wall Panel Cross-Sectional Forces (spWall)

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Service combinations | Displacements | 1.2D + 1.6Lr + 0.5W
==========================================================

  Coordinate System:  Global
  ==================

  Units:
  ======
  Displacement (Dx, Dy, Dz): in
```

| Node | Dx | Dy | Dz |
|---|---|---|---|
| 239 | -1.23e-004 | -1.44e-003 | -2.52e-001 |
| 240 | -1.07e-004 | -1.45e-003 | -2.49e-001 |
| 241 | -9.11e-005 | -1.45e-003 | -2.46e-001 |
| 242 | -7.49e-005 | -1.46e-003 | -2.45e-001 |
| 243 | -5.85e-005 | -1.46e-003 | -2.43e-001 |
| 244 | -4.19e-005 | -1.46e-003 | -2.42e-001 |
| 245 | -2.52e-005 | -1.46e-003 | -2.41e-001 |
| 246 | -8.42e-006 | -1.46e-003 | -2.41e-001 |
| 247 | -8.37e-017 | -1.46e-003 | -2.41e-001 |
| 248 | 8.42e-006 | -1.46e-003 | -2.41e-001 |
| 249 | 2.52e-005 | -1.46e-003 | -2.41e-001 |
| 250 | 4.19e-005 | -1.46e-003 | -2.42e-001 |
| 251 | 5.85e-005 | -1.46e-003 | -2.43e-001 |
| 252 | 7.49e-005 | -1.46e-003 | -2.45e-001 |
| 253 | 9.11e-005 | -1.45e-003 | -2.46e-001 |
| 254 | 1.07e-004 | -1.45e-003 | -2.49e-001 |
| 255 | 1.23e-004 | -1.44e-003 | -2.52e-001 |

$D_{z,avg}$ = 0.245 in.

Figure 9 – Tilt-Up Wall Panel Displacement at Critical Section (Service Combinations) (spWall)

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Ultimate combinations | Displacements | 1.2D + 1.6Lr + 0.5W
===========================================================

  Coordinate System:  Global
  ==================

  Units:
  ======
  Displacement (Dx, Dy, Dz): in

   Node     Dx          Dy          Dz
  ----- ----------- ---------- ----------
    239 -2.03e-004 -2.23e-003 -1.00e+001
    240 -1.76e-004 -2.23e-003 -9.93e+000
    241 -1.50e-004 -2.24e-003 -9.83e+000
    242 -1.23e-004 -2.24e-003 -9.76e+000
    243 -9.64e-005 -2.24e-003 -9.70e+000
    244 -6.91e-005 -2.24e-003 -9.66e+000
    245 -4.16e-005 -2.25e-003 -9.63e+000
    246 -1.39e-005 -2.25e-003 -9.62e+000
    247 -1.38e-016 -2.25e-003 -9.62e+000
    248  1.39e-005 -2.25e-003 -9.62e+000
    249  4.16e-005 -2.25e-003 -9.63e+000
    250  6.91e-005 -2.24e-003 -9.66e+000
    251  9.64e-005 -2.24e-003 -9.70e+000
    252  1.23e-004 -2.24e-003 -9.76e+000
    253  1.50e-004 -2.24e-003 -9.83e+000
    254  1.76e-004 -2.23e-003 -9.93e+000
    255  2.03e-004 -2.23e-003 -1.00e+001
```

$D_{z,avg}$ = 9.76 in.

Figure 10 – Tilt-Up Wall Panel Displacement at Critical Section (Ultimate Combinations) (spWall)

## 10. Design Results Comparison and Conclusions

| Table 1 – Comparison of Tilt-Up Wall Panel Analysis and Design Results | | | | |
|---|---|---|---|---|
| Solution | $M_u$ (kip-ft) | $N_u$ (kips) | $D_{z,service}$ (in.) | $D_{z,ultimate}$ (in.) |
| Hand | 61.2 | 43.4 | 0.247 | 10.00 |
| Reference | 61.2 | 43.4 | 0.247 | 10.00 |
| spWall | 60.6 | 43.5 | 0.245 | 9.76 |

The results of all the hand calculations and the reference used illustrated above are in agreement with the automated exact results obtained from the spWall program.

In column and wall analysis, section properties shall be determined by taking into account the influence of axial loads, the presence of cracked regions along the length of the member, and the effect of load duration (creep effects). ACI 318 permits the use of moment of inertia values of 0.70 $I_g$ for uncracked walls and 0.35$I_g$ for cracked walls.

***ACI 318-11 (10.10.4.1)***

In spWall program, these effects are accounted for where the user can input reduced moment of inertia using "cracking coefficient" values for plate and stiffener elements to effectively reduce stiffness. Cracking coefficients for out-of-plane (bending and torsion) and in-plane (axial and shear) stiffness can be entered for plate elements. Because the values of the cracking coefficients can have a large effect on the analysis and design results, the user must take care in selecting values that best represent the state of cracking at the particular loading stage. Cracking coefficients are greater than 0 and less than 1.

At ultimate loads, a wall is normally in a highly cracked state. The user could enter a value of out-of-plane cracking coefficient for plates of $I_{cracked}/I_{gross}$ based on estimated values of $A_s$. after the analysis and design, if the computed value of $A_s$ greatly differs from the estimated value of $A_s$, the analysis should be performed again with new values for the cracking coefficients. To account for variations in material properties and workmanship, a factor of 0.75 can be used to reduce the calculated bending stiffness of the concrete section in accordance with ACI 318-11, Chapters 10 and 14. ACI 551 states, this bending stiffness reduction factor should be incorporated by all other design methods to comply with the requirements of ACI 318.

At service loads, a wall may or may not be in a highly cracked state. For service load deflection analysis, a wall panel should be modeled with an out-of-plane cracking coefficient of ($I_{effective}/I_{gross}$).

Based on the previous discussion, the ratio between $I_{cr}$ and $I_g$ including a reduction factor of 0.75 is used as the cracking coefficient for the out-of-plane case for ultimate load combinations. In this example, $I_{cr}$ and $I_g$ were found to be equal to 353 in.$^4$ and 3,662 in.$^4$. Thus, the out-of-plane cracking coefficient for ultimate load combinations can be found as follows:

$$\alpha = \text{ cracking coefficient} = \frac{0.75 \times I_{cr}}{I_g} = \frac{0.75 \times 353}{3,662} = 0.072$$

For the service load combinations, $M_a$ equals 20.8 ft-kip which is less than $M_{cr}$ = 46.3 ft-kip indicating the section is uncracked (I effective = I gross) and the cracking coefficient can be set to 1.

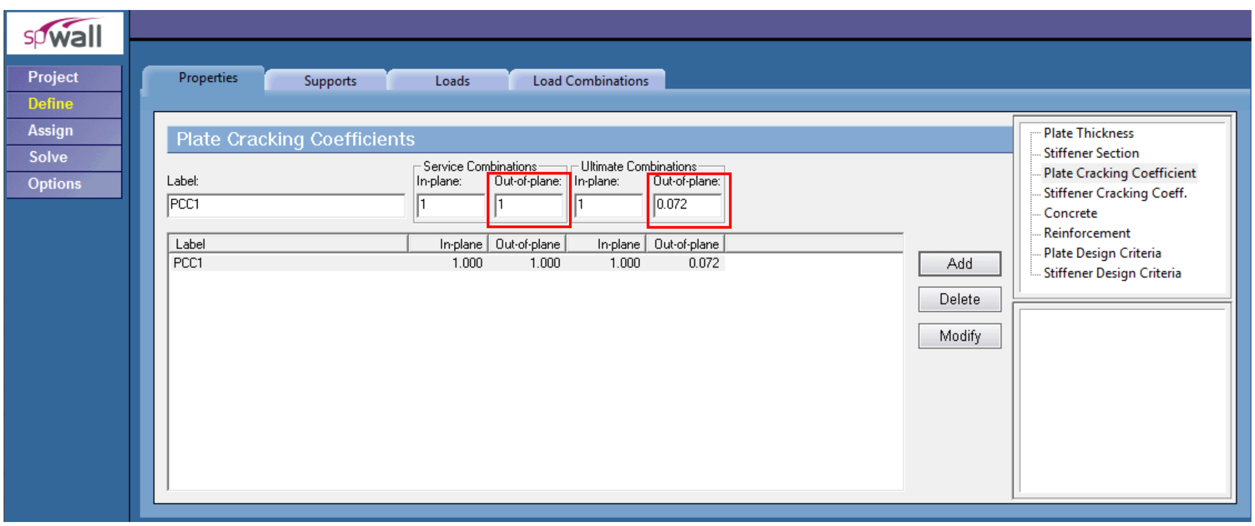


Figure 11 – Defining Cracking Coefficient (spWall)