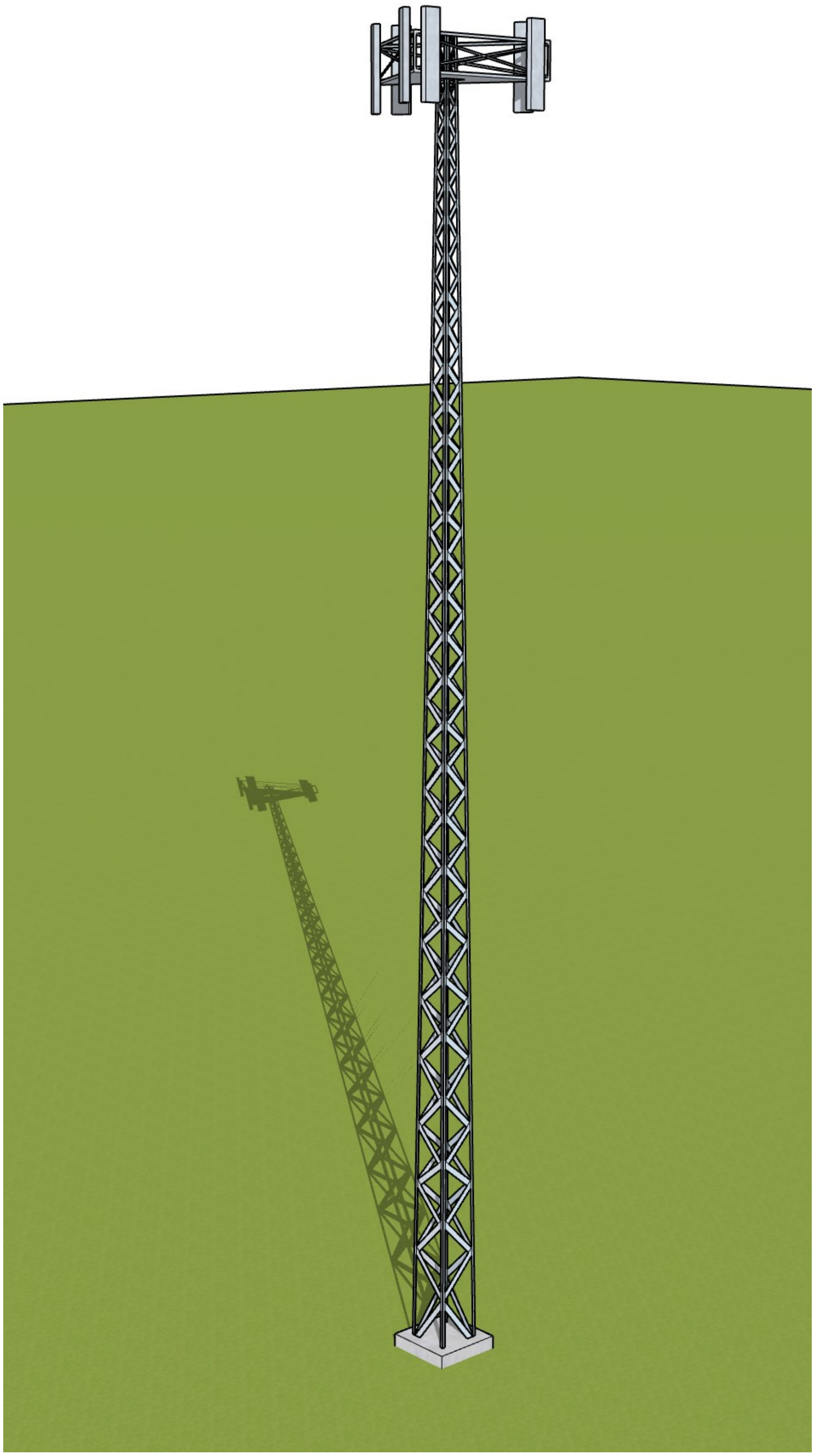
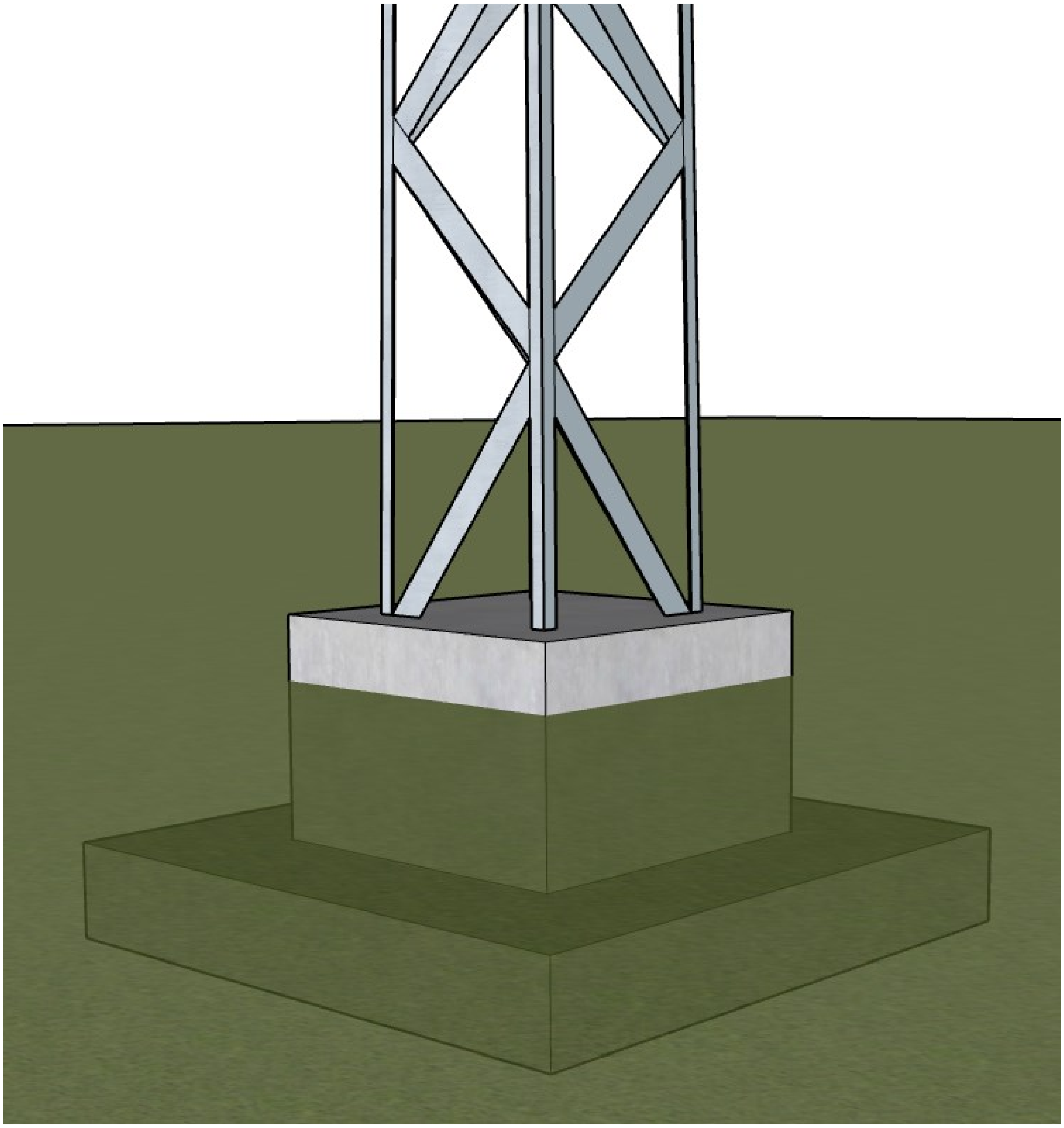
Telecommunication Tower Reinforced Concrete Foundation





Telecommunication Tower Reinforced Concrete Foundation

Telecom (Telecommunications) towers are a generic description of radio masts and towers built primarily to hold telecommunications antennas. As such antennas often have a large area and must be precisely pointed out, such towers have to be designed and built to limit wind induced movement. So very stable structure types like lower lattice towers and towers built of reinforced concrete are used in most cases, although also guyed masts are used for taller application. This case study focuses on the design of a telecom tower foundation using the engineering software program spMats. The tower under study is a 100 ft high and all members are hot-dip galvanized steel with single legged foundation. This tower can be used for several applications, such as microwave repeaters , wireless broadband, police and fire dispatch, and high wind coastal zones. All the information provided by the tower provider are shown in the following figure and design data section and will serve as input for detailed design. Because of good soil conditions at the site, a pier footing foundation is selected to resist applied gravity and wind loads as shown in the following figure.

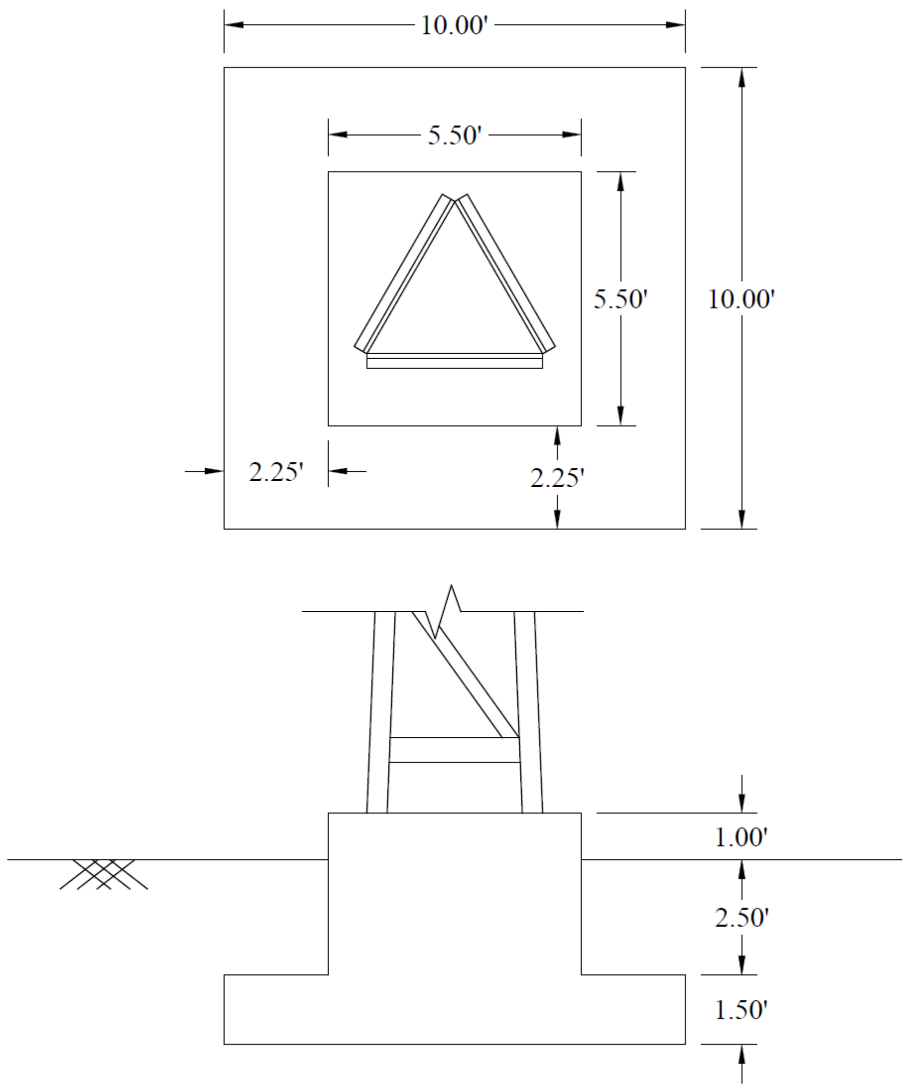


Figure 1 – Telecom Tower Foundation Layout Plan

Code

Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (ACI 318R-14)

Reference

spMats Engineering Software Program Manual v8.50, StucturePoint LLC., 2016

Design Data

Concrete Pier

Size = 5.5 ft x 5.5 ft

Height = 3.5 ft

Weight = 15.88 kips

Concrete Footing

f_c' = 3,000 psi

f_y = 60,000 psi

Thickness = 18 in.

Clear Cover = 3 in.

Superimposed Soil Weight = 337.5 psf over the foundation cross-section

Foundation Loads

P_{DL} = 3.0 kips

P_{LL} = 1.0 kips-ft

$M_{x,wind}$ = 150 kips-ft (Reversible)

$M_{y,wind}$ = Not provided

Supporting Soil

Type = Sandy soil

Subgrade Modulus = 100 kcf

Allowable Pressure = 2.0 ksf

Contents

1. Foundation Analysis and Design – spMats Software

spMats uses the Finite Element Method for the structural modeling, analysis and design of reinforced concrete slab systems or mat foundations subject to static loading conditions.

The slab, mat, or footing is idealized as a mesh of rectangular elements interconnected at the corner nodes. The same mesh applies to the underlying soil with the soil stiffness concentrated at the nodes. Slabs of irregular geometry can be idealized to conform to geometry with rectangular boundaries. Even though slab and soil properties can vary between elements, they are assumed uniform within each element. Piles are modeled as springs connected to the nodes of the finite element model. Unlike for springs, however, punching shear check is performed around piles.

For illustration and purposes, the following figures provide a sample of the input modules and results obtained from an spMats model created for the telecom tower reinforced concrete footing in this example.

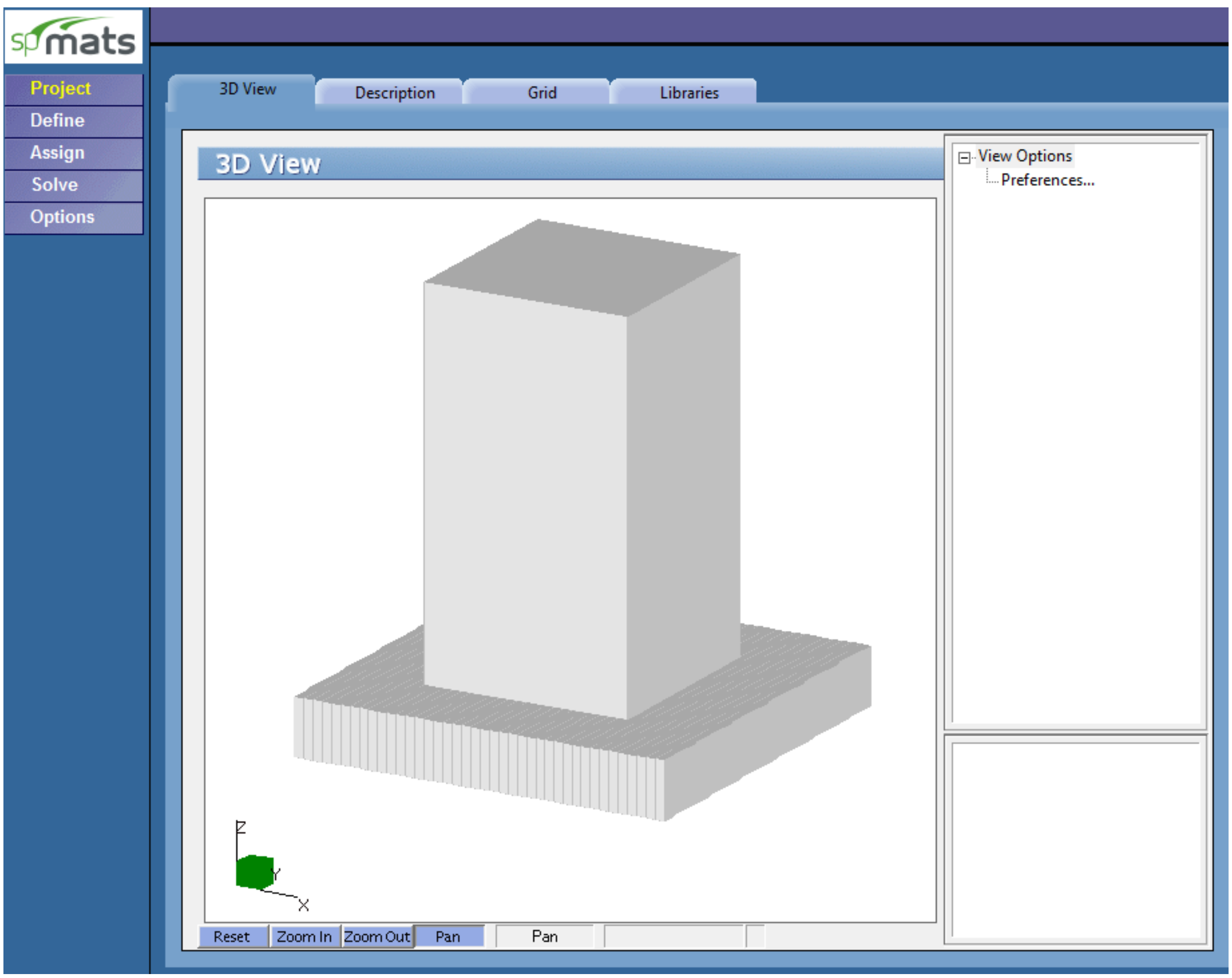


Figure 2 – Telecom Tower Foundation Model 3D View

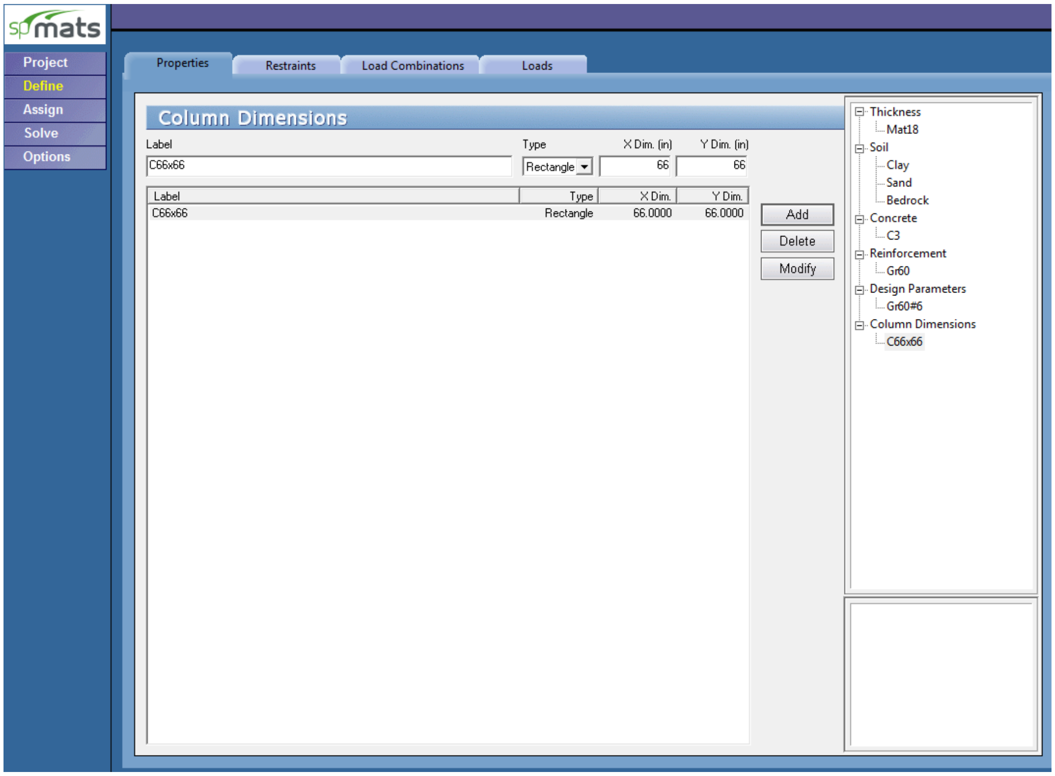


Figure 3 –Defining Concrete Pier

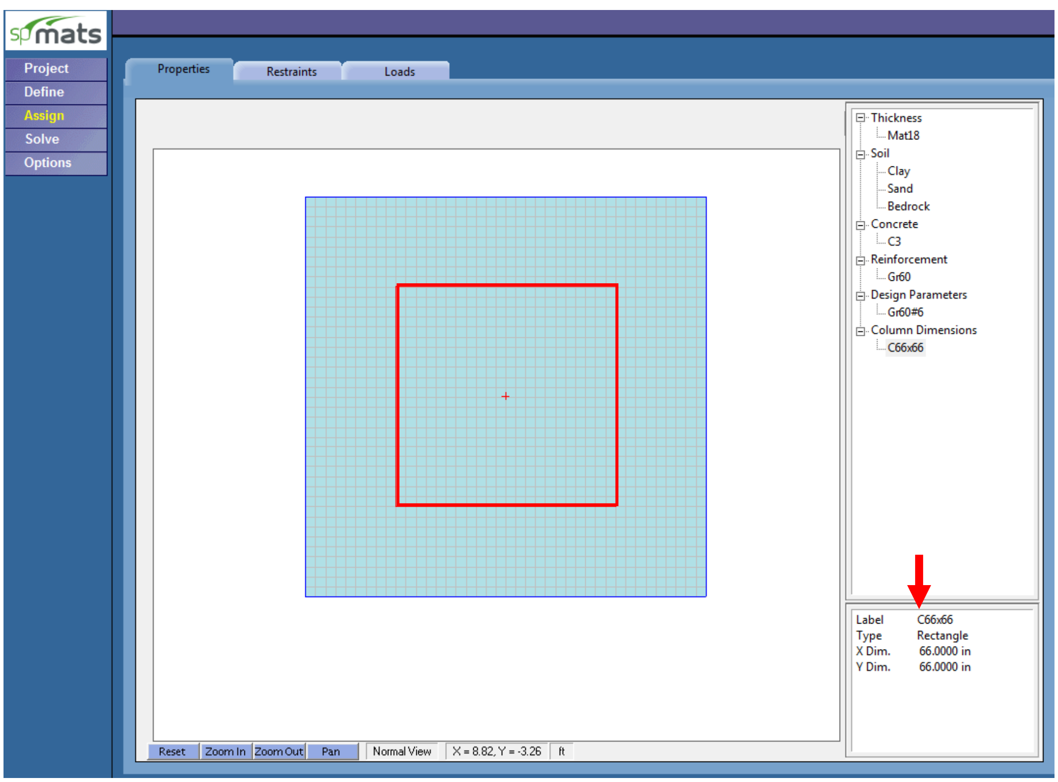


Figure 4 – Assigning Concrete Pier

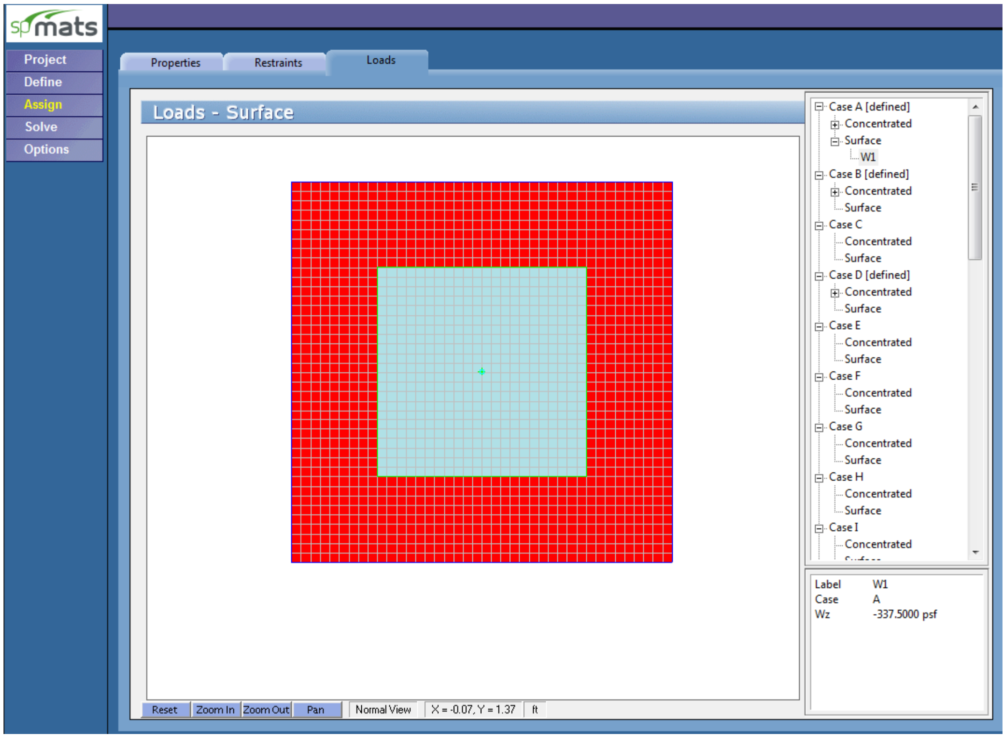


Figure 5 – Assigning Loads

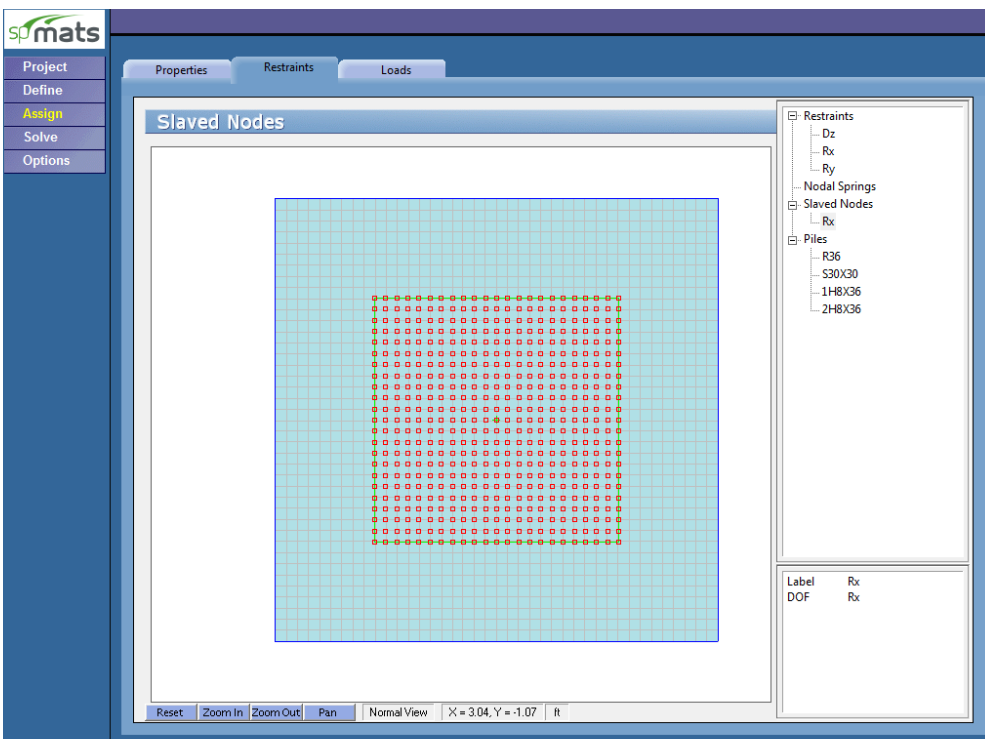


Figure 6 – Assigning Slave Nodes

Slave nodes are assigned to restrain the rotation about the axis where the moment is applied for the nodes under the concrete pier to simulate the stiffness of the pier above the foundation and to prevent any stress concentrations due to applying the axial load and moments as point loads.

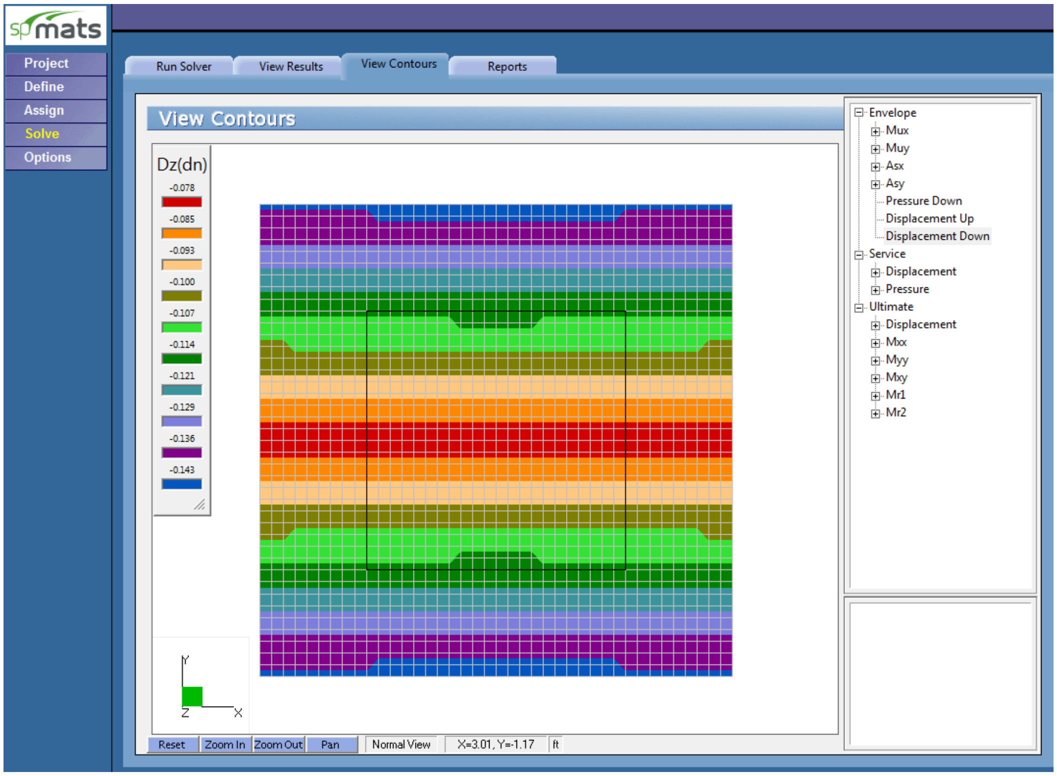


Figure 7 – Vertical (Down) Displacement Contour

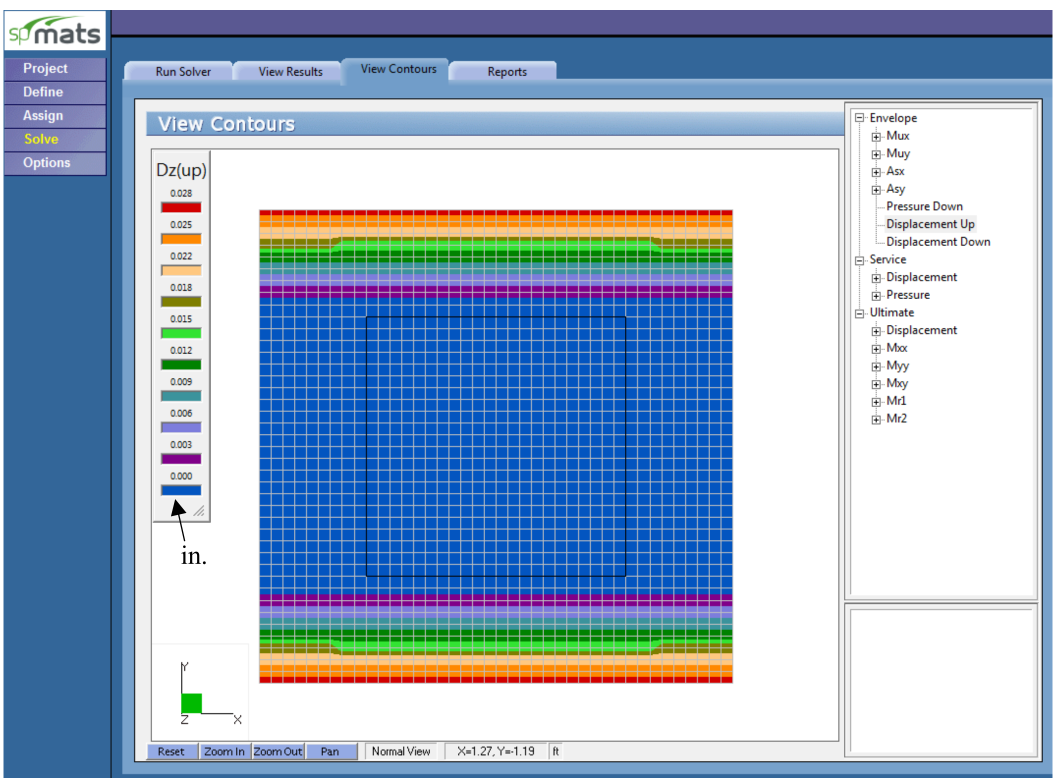


Figure 8 – Vertical (Up) Displacement Contour

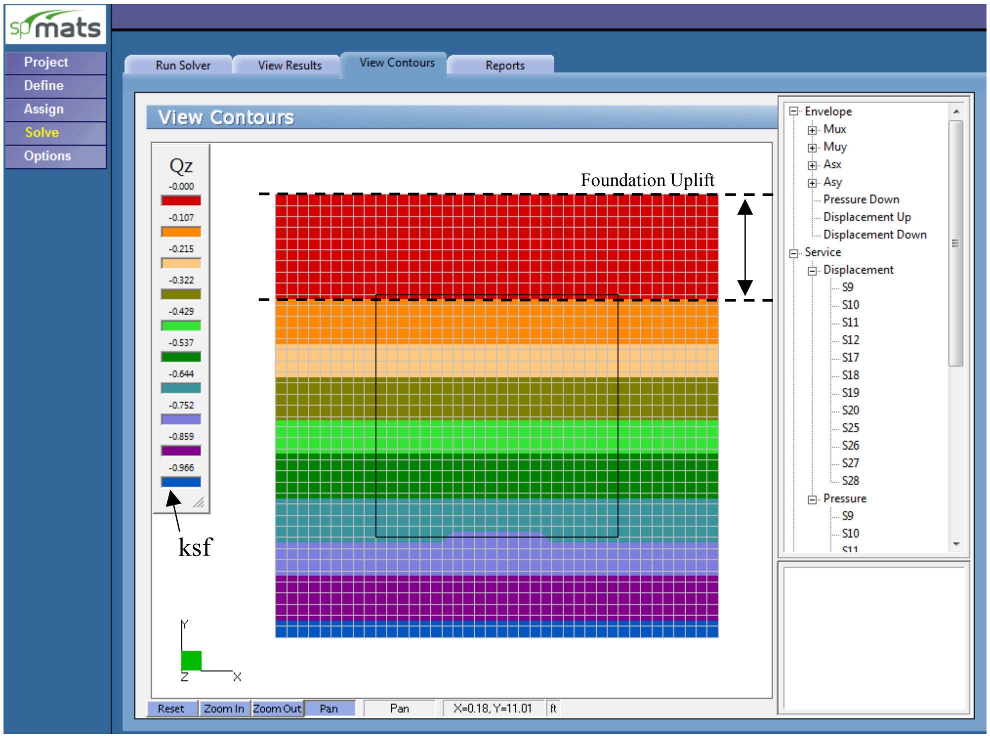


Figure 9 – Foundation Uplift

In some load cases foundation uplift might occur due to overturning moments. spMats can control the amount of allowable uplift (as percentage of the cross-sectional area of the foundation) that can occur.

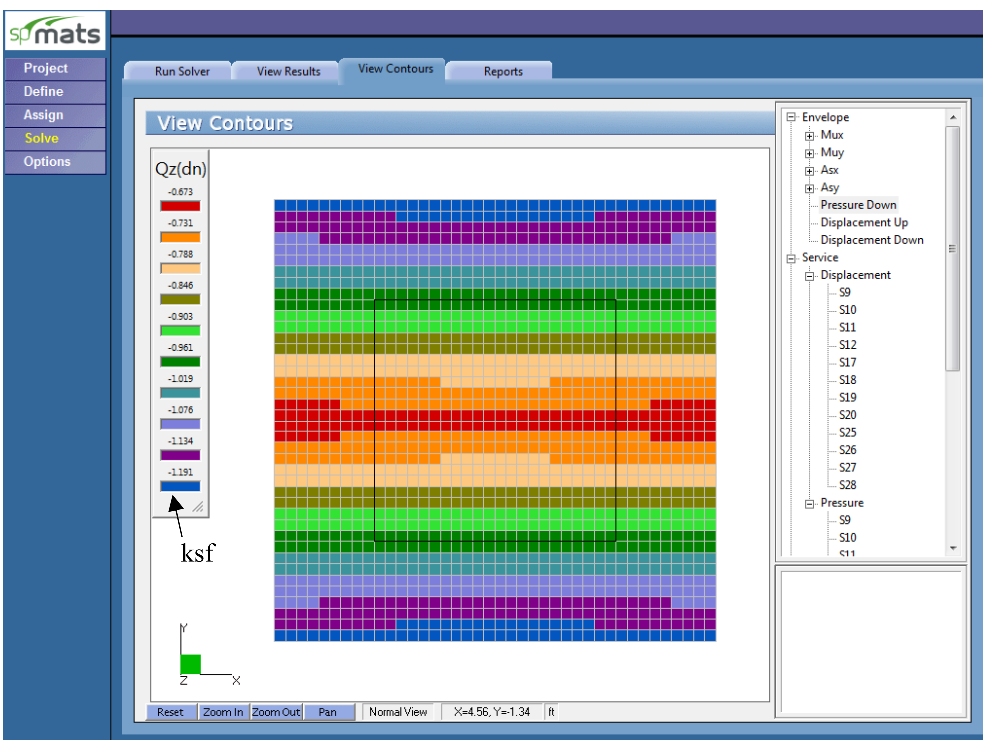


Figure 10 – Soil Pressure Contour

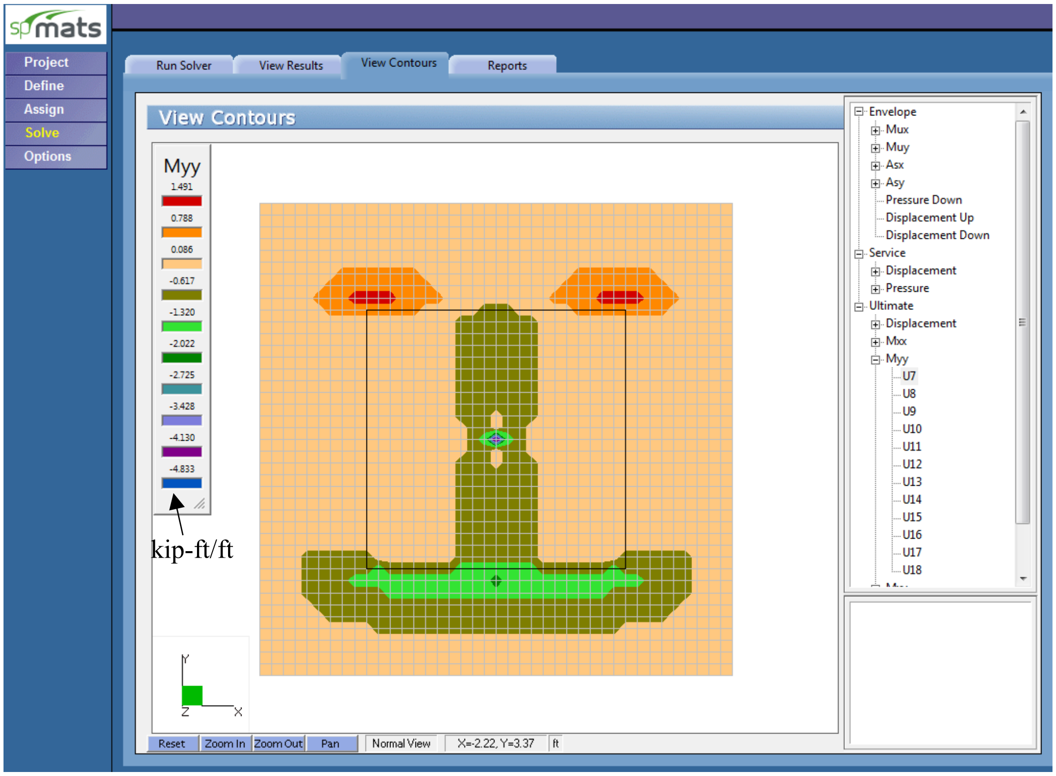


Figure 11 – Moment Contour along Y-Axis

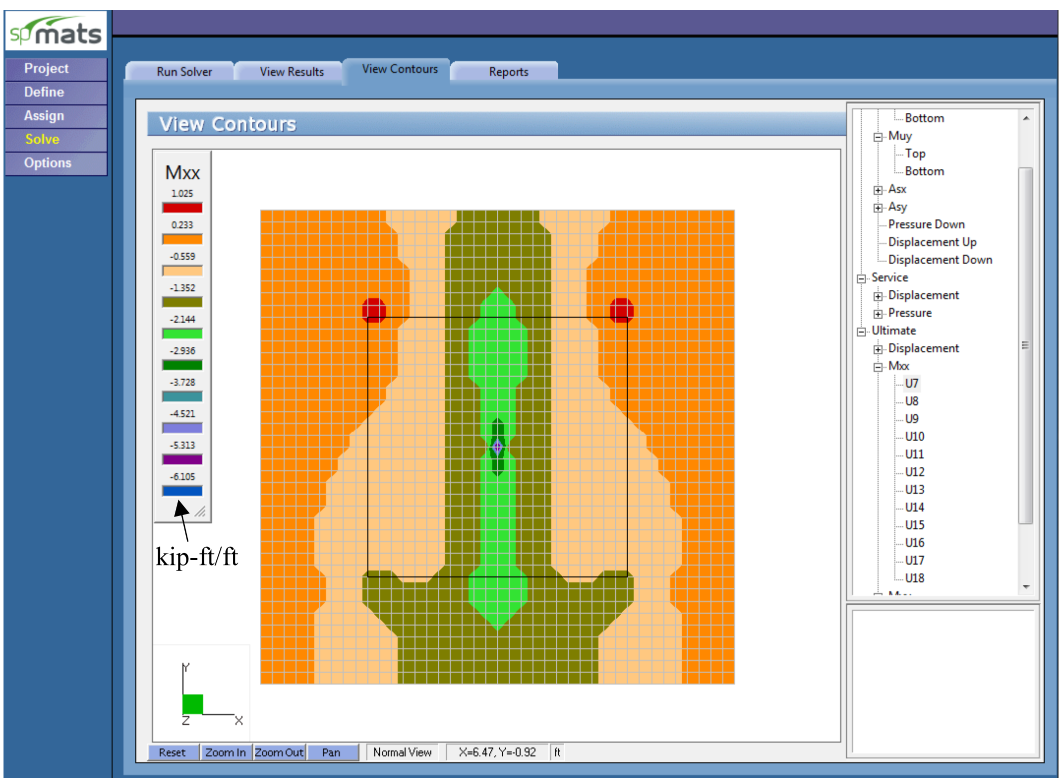


Figure 12 – Moment Contour along X-Axis

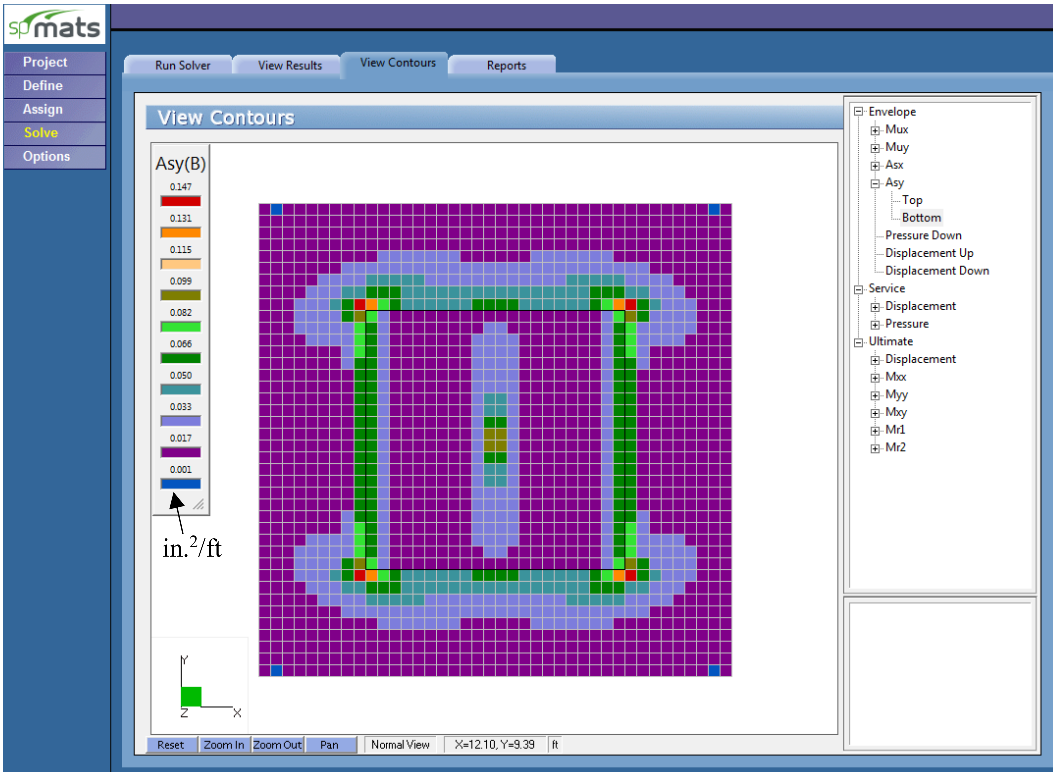


Figure 13 – Required Reinforcement Contour along Y Direction without Defining $A_{s,min}$

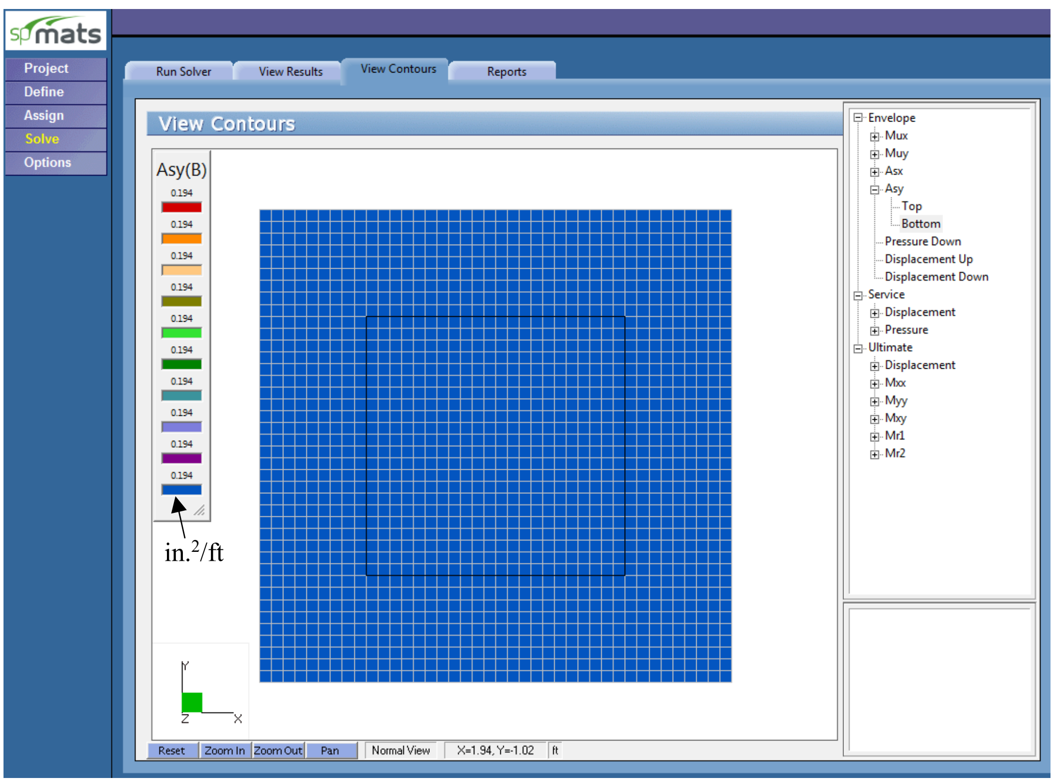


Figure 14 – Required Reinforcement Contour along Y Direction with $A_{s,min}$ Defined

2. Two-way (Punching) Shear Check - Pier

```
B6 - Punching Shear Around Columns (Ultimate Load Combinations):
================================================================
Units --> Applied Shear Force Vu (kips), Applied Moments Mux, Muy (k-ft)
          Factored Shear Stress vu (psi), Factored Shear Resistance Phi*vc (psi)
          Concrete Strength f'c (psi), distances X_Offset, Y_Offset (ft)
          Average depth (in), Dimensions Bx, By (ft)
          Area (in^2), Jxx, Jyy, Jxy (in^4)

Geometry of Resisting Area
--------------------------
      _________Column_________ Average  ___Dimensions____  _____Centroid____
 Node      Label      Location  Depth      Bx       By     X_Offset Y_Offset
----- -------------- -------- -------- -------- --------  -------- --------
  841 C66x66          Inner      14.63     6.72     6.72     -0.00    -0.00

Properties of Resisting Area
----------------------------
 Node  Column Label      Area          Jxx          Jyy          Jxy
----- -------------- ---------- ------------ ------------ ------------
  841 C66x66            4716.56   5151950.50   5151950.50         0.00

Ultimate Load Combination: U14
------------------------------

  Factored Applied Forces:
  ------------------------
   Node  Column Label       Vu             Mux        Gamma_X         Muy        Gamma_Y
  ----- -------------- ---------- ---------------- ------- --------------- -------
    841 C66x66             -23.66            -60.0   0.400             0.0   0.400

  Factored Stress and Capacity:
  -----------------------------
                                                            _Critical Point__
   Node  Column Label       vu           f'c       Phi*vc   X_Offset Y_Offset Status
  ----- -------------- ------------ ---------- ----------  -------- -------- ------
    841 C66x66             -10.65     3000.00     156.67     -3.36     3.36   Safe


B7 - Punching Shear Around Piles (Ultimate Load Combinations):
==============================================================
    * No piles assigned
```

Figure 15 – Two-Way Shear Results around the Column

3. Soil Reactions

```
B3 - REACTIONS:
===============
Units --> Force (kip), Moment (kip-ft)
Service Load Combination: S9
   Sum of all forces and moments with respect to center of gravity (X, Y) = (5.00, 5.00) ft

   Sum of Reactions       Fz           Mx           My
   ---------------- ------------ ------------ ------------
   Soil                 64.921      -90.000       -0.000
   Springs                   -            -            -
   Piles                     -            -            -
   Restraints                -            -            -
   Slaved Nodes          0.000       -0.000        0.000
   ---------------- ------------ ------------ ------------
   Total Reactions      64.921      -90.000       -0.000
   Total Loads         -64.921       90.000       -0.000
```

Figure 16 – Soil Service Pressure Reactions

```
B3 - REACTIONS:
===============
Units --> Force (kip), Moment (kip-ft)
Ultimate Load Combination: U7
   Sum of all forces and moments with respect to center of gravity (X, Y) = (5.00, 5.00) ft

   Sum of Reactions       Fz           Mx           My
   ---------------- ------------ ------------ ------------
   Soil                 77.905      -75.000       -0.000
   Springs                   -            -            -
   Piles                     -            -            -
   Restraints                -            -            -
   Slaved Nodes          0.000       -0.000        0.000
   ---------------- ------------ ------------ ------------
   Total Reactions      77.905      -75.000       -0.000
   Total Loads         -77.905       75.000       -0.000
```

Figure 17 – Soil Ultimate Pressure Reactions

Note: Positive and negative reaction values indicate compression and tension forces on soil, respectively.

Note: Positive and negative reaction values indicate compression and tension forces in piles, respectively.

4. Foundation Model Statistics

Since spMats is utilizing finite element analysis to model and design the foundation. It is useful to track the number of elements and nodes used in the model to optimize the model results (accuracy) and running time (processing stage). spMats provides model statistics to keep tracking the mesh sizing as a function of the number of nodes and elements.

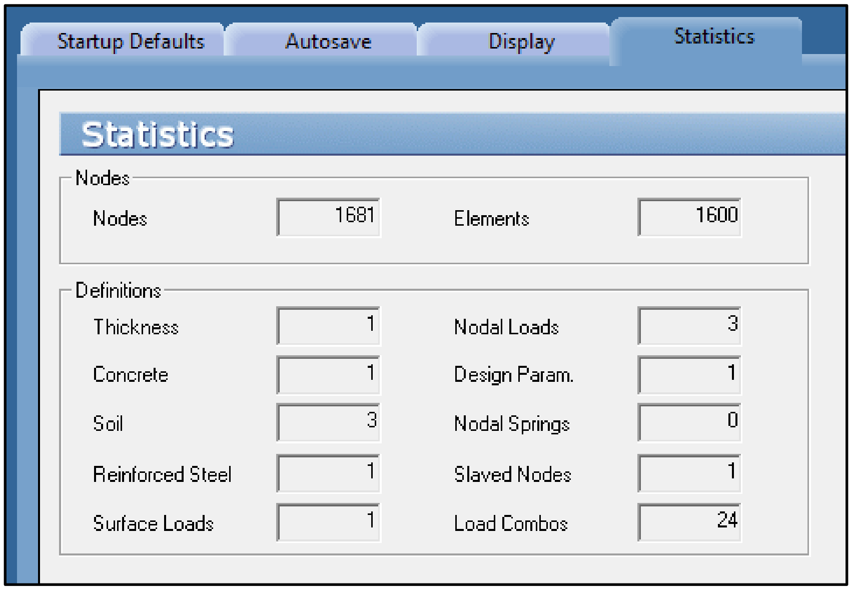


Figure 18 – Model Statistics

5. Column and Pile Design - spColumn

spMats provides the options to export column and pile information from the foundation model to spColumn. Input (CTI) files are generated by spMats to include the section, materials, and the loads from the foundation model required by spColumn for strength design and investigation of piles and columns. Once the foundation model is completed and successfully executed, the following steps illustrate the design of a sample pile and column.

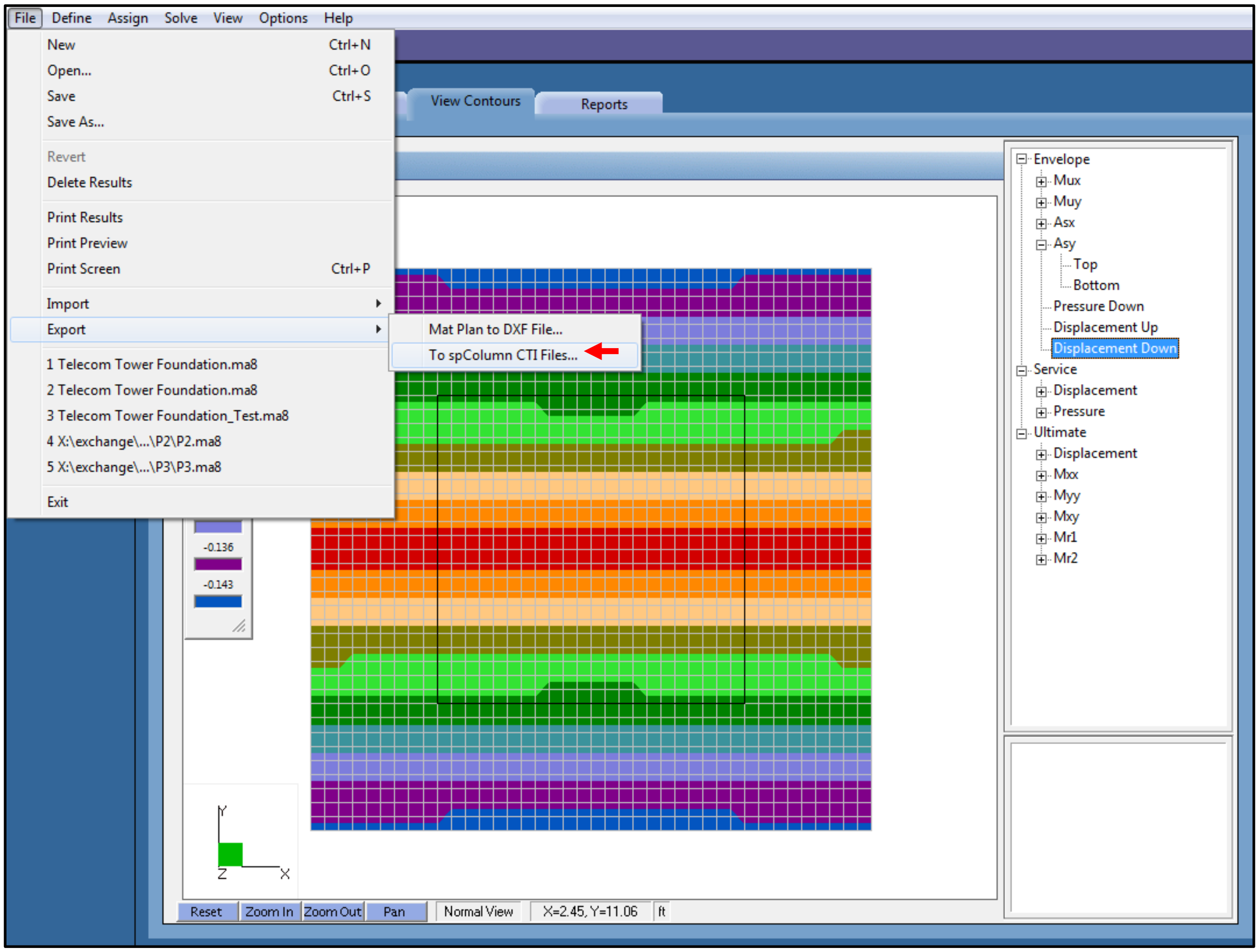


Figure 19 – Exporting CTI Files

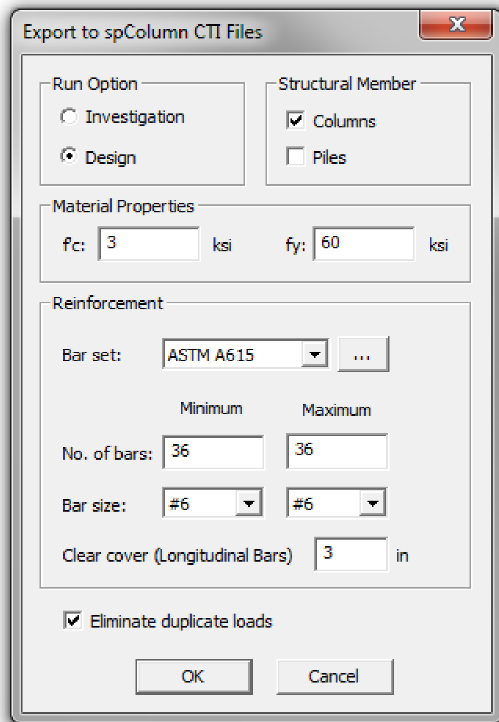
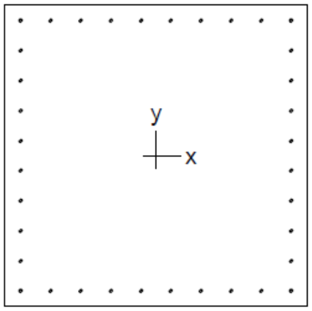


Figure 20 – Exporting CTI Files Dialog Box

After exporting spColumn input files, the pile and column design/investigation can proceed/modified to meet project specifications and criteria. In the following the column design results are shown as an example.



66 x 66 in

Code: ACI 318-14

Units: English

Run axis: About X-axis

Run option: Investigation

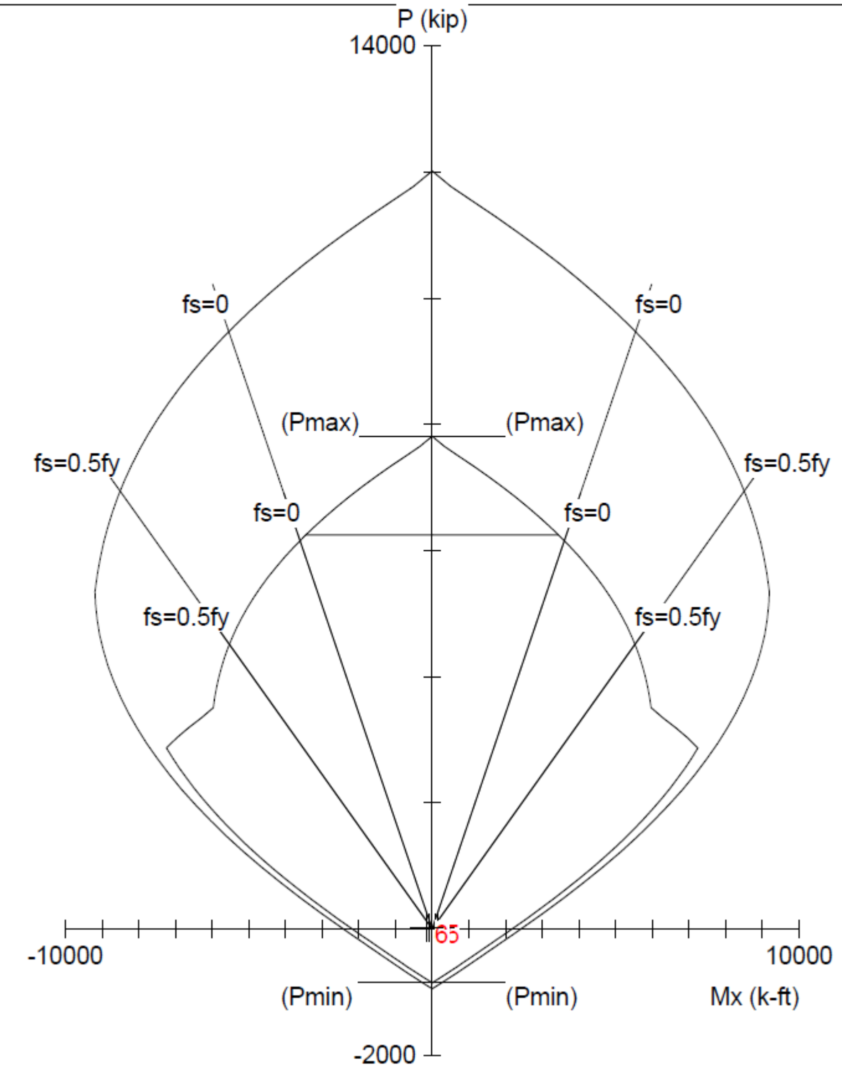
Slenderness: Not considered

Column type: Structural

Bars: ASTM A615

Date: 02/26/19

Time: 09:36:58



STRUCTUREPOINT - spColumn v6.50 (TM). Licensed to: StructurePoint.

File:

Project: Telecom Tower Foundation.ma8

Column: C-841		Engineer: -	
f'c = 3 ksi	fy = 60 ksi	Ag = 4356 in^2	36 #6 bars
Ec = 3122 ksi	Es = 29000 ksi	As = 15.84 in^2	rho = 0.36%
fc = 2.55 ksi	e_yt = 0.00206897 in/in	Xo = 0.00 in	Ix = 1.58123e+006 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 1.58123e+006 in^4
Beta1 = 0.85		Min clear spacing = 5.83 in	Clear cover = 3.00 in
Confinement: Tied			
phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65			

Figure 21 – Column Interaction Diagram with Factored Load

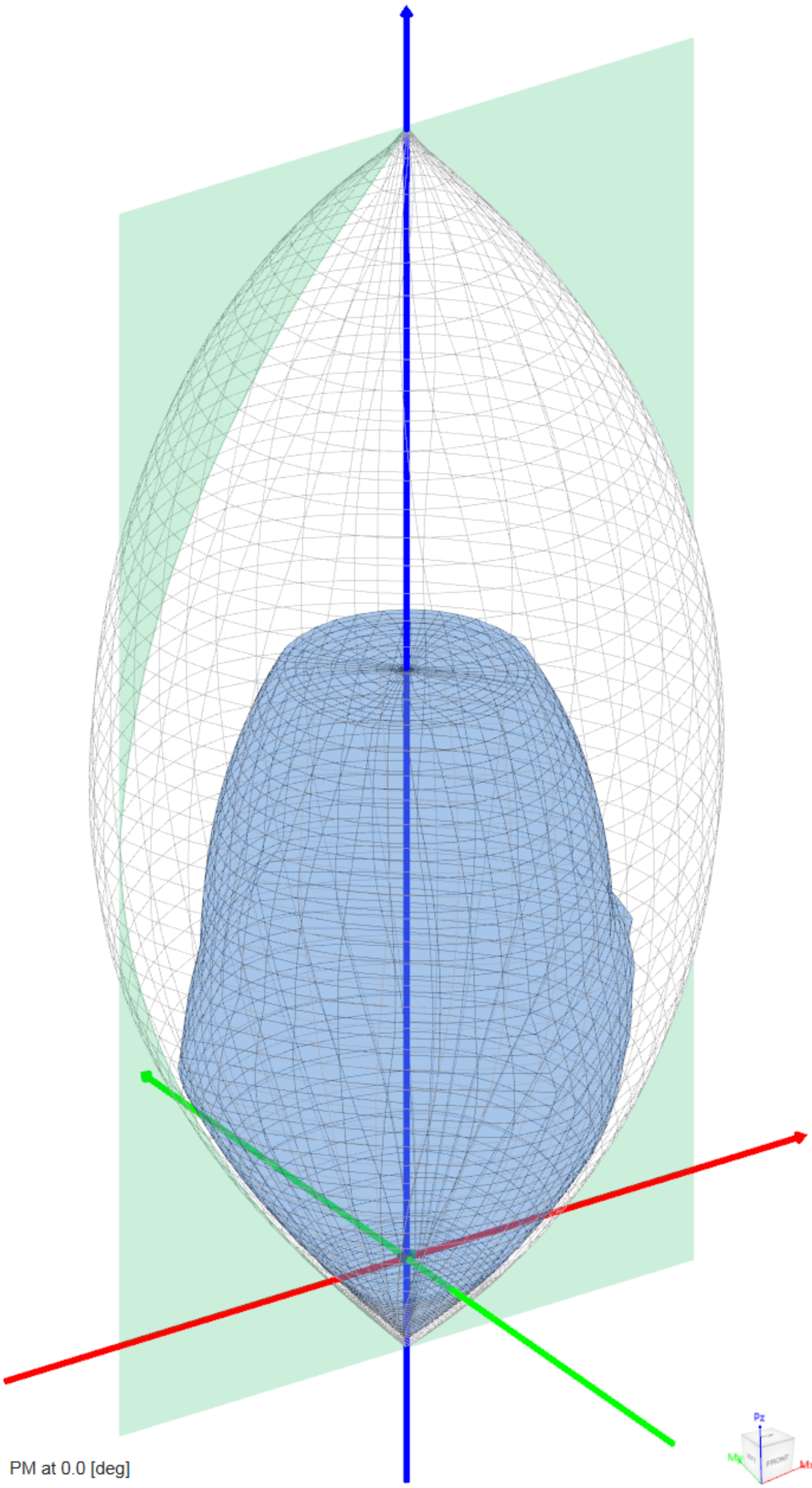


Figure 22 – Column 3D Failure Surfaces

6. 2D/3D Viewer

2D/3D Viewer is an advanced module of the spColumn program. It enables the user to view and analyze 2D interaction diagrams and contours along with 3D failure surfaces in a multi viewport environment.

2D/3D Viewer is accessed from within spColumn. Once a successful run has been performed, you can open 2D/3D Viewer by selecting the **2D/3D Viewer** command from the **View** menu. Alternatively, 2D/3D Viewer can also be accessed by clicking the 2D/3D Viewer button in the program toolbar.

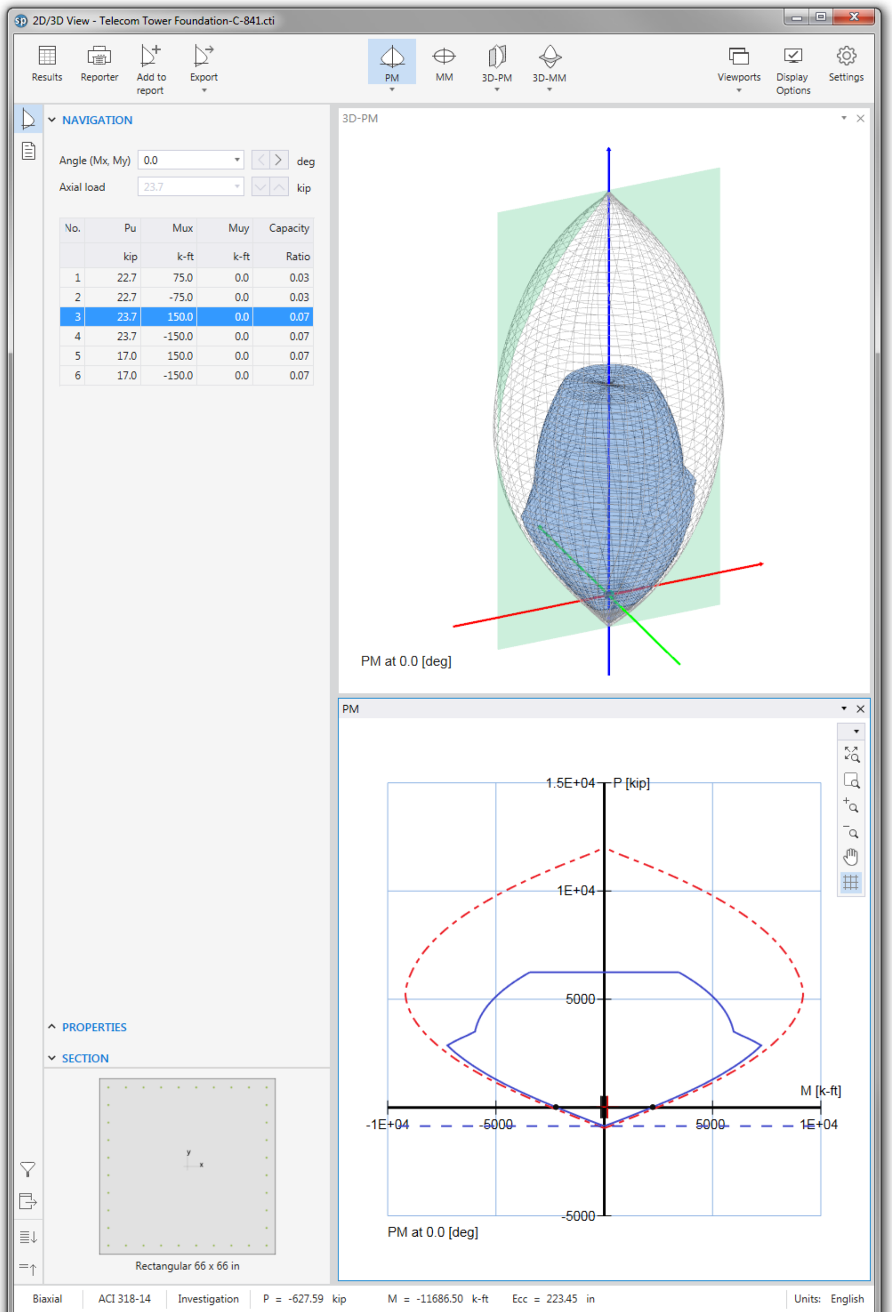


Figure 23 – 2D/3D View for Column

7. Pile Section Optimization

To further optimize pile design, it was agreed with the builder that 28#6 reinforcement cage can be used for this pier. The following figure illustrate the reduced axial strength capacity is adequate to resist the maximum pier loading.

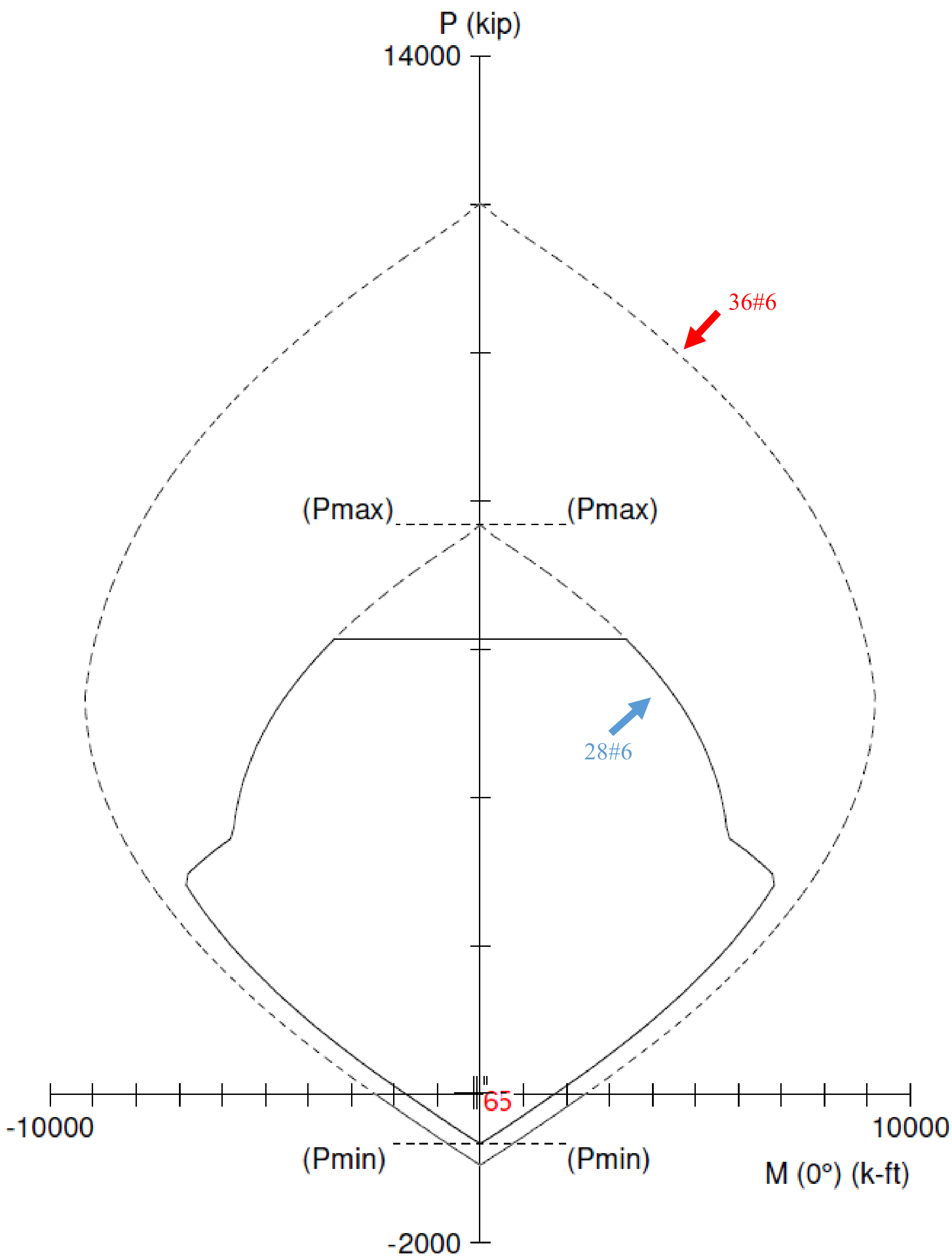


Figure 24 – Superimpose Feature