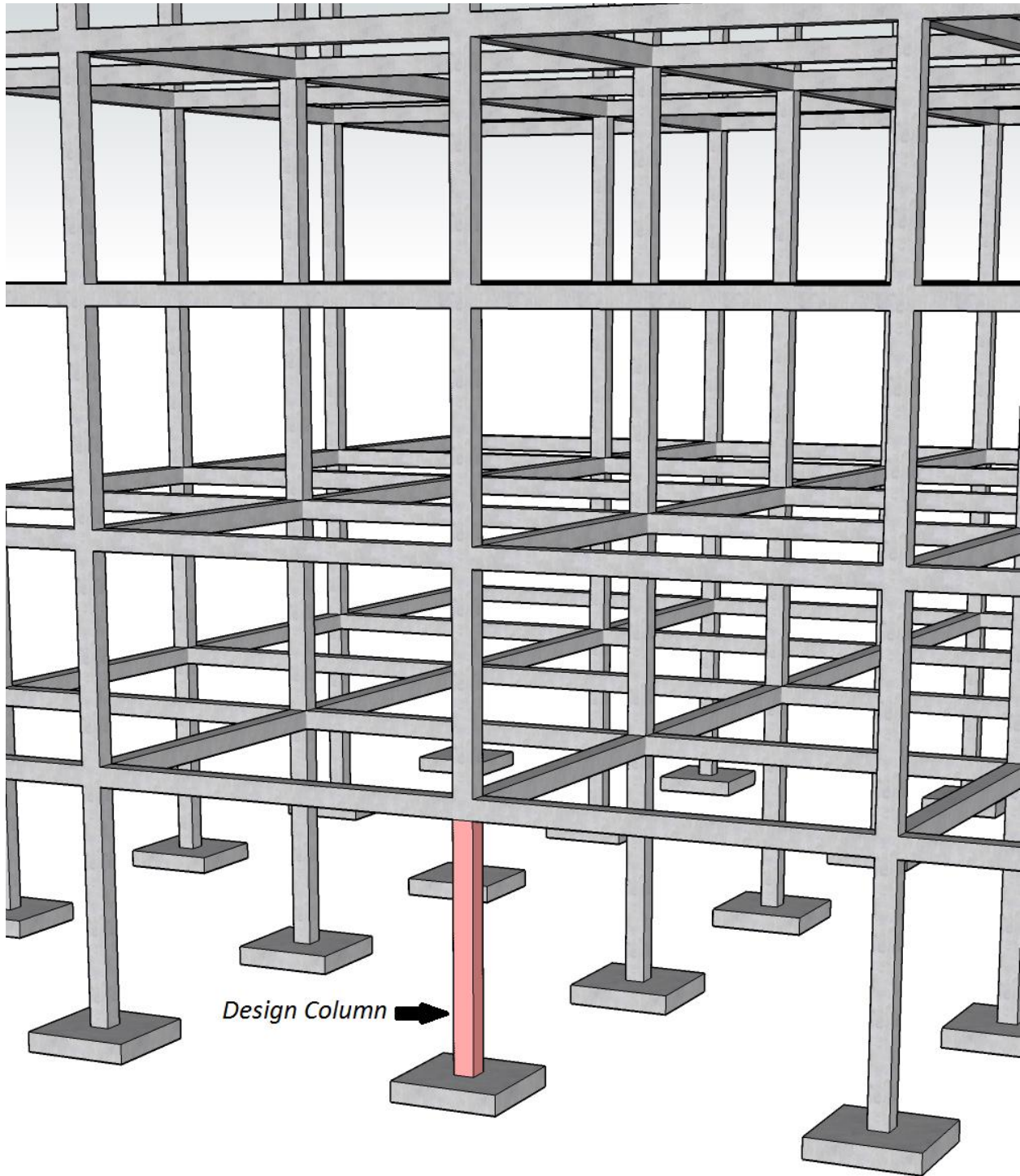**Slenderness Effects for Columns in Non-Sway Frame - Moment Magnification Method (ACI 318-19)**

Design Column →

**Slender Concrete Column Design in Non-Sway Frame Buildings**

Evaluate slenderness effects for columns in a non-sway multistory reinforced concrete frame by determining the adequacy of the square tied column shown below, which is an exterior first floor column. The design forces obtained from a first-order analysis are provided in the design data section below. The story height is 12 ft. it is assumed that the frame is braced sufficiently to prevent relative translation of its joints. Assume 40% of the factored axial load is sustained. Compare the calculated results with exact values from spColumn engineering software program from StructurePoint.
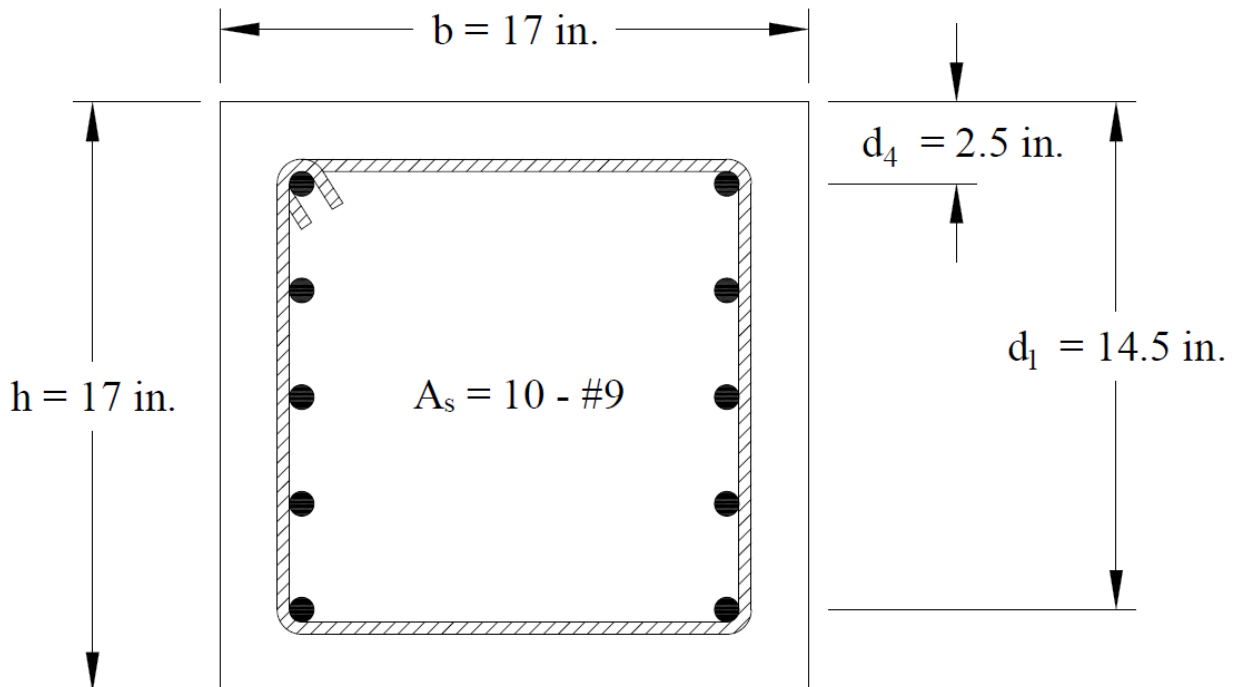


Figure 1 – Reinforced Concrete Column Cross-Section

# Contents

**Code**

Building Code Requirements for Structural Concrete (ACI 318-19) and Commentary (ACI 318R-19)

**Reference**

Reinforced Concrete Design, Eighth Edition, 2018, Wang C. et. al., Example 13.17.3.

**Design Data**

Concrete $f_c' = 3000$ psi

Steel $f_y = 60000$ psi

Beams: h = 24 in., b = 14 in., l = 7 m

Columns: h = 17 in., b = 17 in. H = 12 ft

factored design forces obtained from first-order analysis from the reference:

| Table 1 - Column factored loads | | | |
|---|---|---|---|
| Load Case | Axial Load, kip | Bending Moment, kip.ft | |
| | | Top | Bottom |
| Factored Load | 1776[*] | 105 | 0 |
| [*] Assume 40% of the axial load is sustained | | | |

## 1. Slenderness Effects and Sway or Non-sway Frame Designation

Columns and stories in structures are considered as non-sway frames if the stability index for the story ($Q$) does not exceed 0.05.                                          ***ACI 318-19 (6.6.4.3)***

The reference assumed that the frame is a non-sway frame since Q value is less than 0.05.

## 2. Determine Slenderness Effects

The reference decided to be consistent with the more conservative procedure provided by **ACI 318-19 (6.6.4.4.3)** by taking k value equals to 1.0. However, the k value, in this example, is calculated based on the exact procedure for illustration purposes.

$$I_{column} = 0.7 \times \frac{c^4}{12} = 0.7 \times \frac{17^4}{12} = 4872 \text{ in.}^4 \qquad\qquad \textbf{\textit{ACI 318-19 (6.6.3.1.1(a))}}$$

$$I_{beam} = 0.35 \times \frac{b \times h^3}{12} = 0.35 \times \frac{14 \times 24^3}{12} = 5645 \text{ in.}^4 \qquad\qquad \textbf{\textit{ACI 318-19 (6.6.3.1.1(a))}}$$

$$E = 57,000 \times \sqrt{f_c^{'}} = 57,000 \times \sqrt{3000} = 3122 \text{ ksi} \qquad\qquad \textbf{\textit{ACI 318-19 (19.2.2.1.b)}}$$

For columns:

$$\frac{E \times I_{column}}{l_c} = \frac{3122 \times 4872}{12 \times 12} = 8.8 \times 10^3 \text{ kip.ft}$$

For beams framing into the columns:

$$\frac{E \times I_{beam}}{l_b} = \frac{3122 \times 5645}{30 \times 12} = 4.08 \times 10^3 \text{ kip.ft}$$

$$\Psi_A = \frac{\left(\sum \dfrac{EI}{l_c}\right)_{columns}}{\left(\sum \dfrac{EI}{l}\right)_{beams}} = \frac{2 \times 8.80 \times 10^3}{4.08 \times 10^3} = 4.32 \qquad\qquad \textbf{\textit{ACI 318-19 (Figure R6.2.5)}}$$

$\Psi_B = \infty$ (Column was assumed hinged at base)                     ***ACI 318-19 (Figure R6.2.5)***

Using Figure R6.2.5 from ACI 318-19 → $k = 0.959$ as shown in the figure below for the exterior columns with one beam framing into them in the directions of analysis.
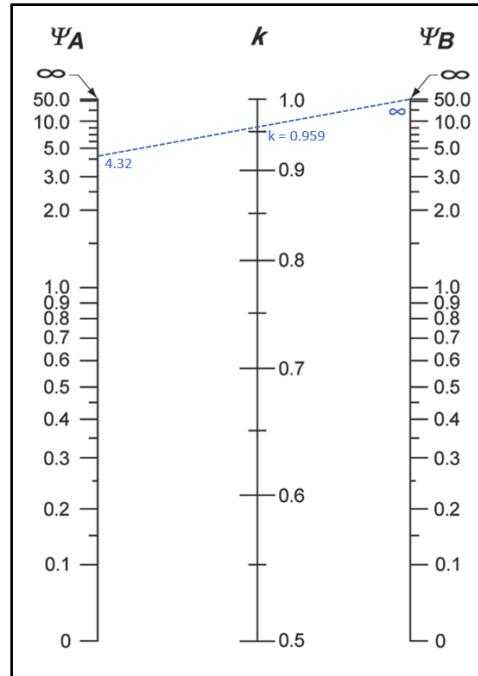
Figure 2 – Effective Length Factor (*k*) (Non-Sway Frame)

ACI 318-19 allows to neglect the slenderness in a non-sway frame if:

$$\frac{k \times l_u}{r} \le 34 + 12\left(\frac{M_1}{M_2}\right)$$

***ACI 318-19 (6.2.5b)***

Where:

$r = $ radius of gyration $= (a) \sqrt{\dfrac{I_g}{A_g}}$   *or*   (b) $0.3 \times c_1$

***ACI 318-19 (6.2.5.1)***

$$r = \sqrt{\frac{I_g}{A_g}} = \sqrt{\frac{c^2}{12}} = \sqrt{\frac{17^2}{12}} = 4.91 \text{ in.}$$

$$\frac{0.959 \times (12 \times 12 - 24)}{4.91} = 23.45 < 34 - 12\left(\frac{0}{105}\right) = 34 \qquad \therefore \text{ slenderness can be neglected.}$$

Even though it is not required to consider slenderness effects for this column, the moment magnification method will be shown for illustration.

### 3. Moment Magnification – Non-Sway Frame

$$M_{c2} = \delta M_2$$                    *ACI 318-19 (6.6.4.5.1)*

Where:

$$\delta = \text{magnification factor} = \frac{C_m}{1 - \dfrac{P_u}{0.75P_c}} \geq 1.0$$                    *ACI 318-19 (6.6.4.5.2)*

$$P_c = \frac{\pi^2 (EI)_{eff}}{(kl_u)^2}$$                    *ACI 318-19 (6.6.4.4.2)*

Where:

$$(EI)_{eff} = \begin{cases} \text{(a)} & \dfrac{0.4E_c I_g}{1 + \beta_{dns}} \\[3mm] \text{(b)} & \dfrac{0.2E_c I_g + E_s I_{se}}{1 + \beta_{dns}} \\[3mm] \text{(c)} & \dfrac{E_c I}{1 + \beta_{dns}} \end{cases}$$                    *ACI 318-19 (6.6.4.4.4)*

There are three options for calculating the effective flexural stiffness of slender concrete columns $(EI)_{eff}$. The second equation provides accurate representation of the reinforcement in the section and will be used in this example and is also used by the solver in spColumn. Further comparison of the available options is provided in "Effective Flexural Stiffness for Critical Buckling Load of Concrete Columns" technical note.

### 3.1. Calculation of Critical Load (P_c)

$$I_{column} = \frac{c^4}{12} = \frac{17^4}{12} = 6960 \text{ in.}^4$$                    *ACI 318-19 (Table 6.6.3.1.1(a))*

$$E_c = 57,000 \times \sqrt{f_c'} = 57,000 \times \sqrt{3000} = 3122 \text{ ksi}$$                    *ACI 318-19 (19.2.2.1.a)*

$\beta_{dns}$ is the ratio of maximum factored sustained axial load to maximum factored axial load associated with the same load combination.                    *ACI 318-19 (6.6.4.4.4)*

In this example, it is assumed that 40% of the factored axial load is sustained.

$$\beta_{dns} = \frac{P_{u,sustained}}{P_u} = \frac{0.4 \times P_u}{P_u} = 0.40 < 1.00 \quad \rightarrow \quad \therefore \beta_{dns} = 0.40$$

With 10-#9 reinforcement equally distributed on two sides and 17 in. x 17 in. column section → $I_{se} = 360$ in.$^4$.

$$(EI)_{eff} = \frac{0.2E_c I_g + E_s I_{se}}{1 + \beta_{dns}}$$                    *ACI 318-19 (6.6.4.4.4(b))*

$$(EI)_{eff} = \frac{0.2 \times 3122 \times 6960 + 29,000 \times 360}{1+0.4} = 10.56 \times 10^6 \text{ kip-in.}^2$$

$$P_c = \frac{\pi^2 \times 10.56 \times 10^6}{\left(0.959 \times (12-2) \times 12\right)^2} = 7871 \text{ kip}$$

### 3.2. Calculation of Magnified Moment ($M_c$)

$$C_m = 0.6 + 0.4 \frac{M_1}{M_2} \qquad\qquad\qquad \textit{\textbf{ACI 318-19 (6.6.4.5.3a)}}$$

$$C_m = 0.6 + 0.4 \left(\frac{0}{105}\right) = 0.6$$

$$\delta = \frac{C_m}{1 - \dfrac{P_u}{0.75 P_c}} \geq 1.0 \qquad\qquad\qquad \textit{\textbf{ACI 318-19 (6.6.4.5.2)}}$$

$$\delta = \frac{0.6}{1 - \dfrac{525}{0.75 \times 7871}} = 0.66 < 1.00 \rightarrow \delta = 1.00$$

$$M_{min} = P_u (0.6 + 0.03h) \qquad\qquad\qquad \textit{\textbf{ACI 318-19 (6.6.4.5.4)}}$$

Where $P_u = 525$ kip, and $h$ = the section dimension in the direction being considered = 17 in.

$$M_{min} = 525 \left(\frac{0.6 + 0.03 \times 17}{12}\right) = 48.56 \text{ kip.ft}$$

$$M_2 = 105 \text{ kip.ft} > M_{2,min} = 48.56 \text{ kip.ft} \rightarrow M_2 = 105 \text{ kip.ft} \qquad \textit{\textbf{ACI 318-19 (6.6.4.5.4)}}$$

$$M_{c2} = \delta M_2 \qquad\qquad\qquad \textit{\textbf{ACI 318-19 (6.6.4.5.1)}}$$

$$M_{c2} = 1.00 \times 105 = 105 \text{ kip.ft}$$

## 4. Column Design

Based on the factored axial loads and magnified moments considering slenderness effects, the capacity of the assumed column section (17 in. × 17 in. with 10 – #9 bars distributed on two sides) will be checked and confirmed to finalize the design. A column interaction diagram will be generated using strain compatibility analysis, the detailed procedure to develop column interaction diagram can be found in "Interaction Diagram - Tied Reinforced Concrete Column" example.
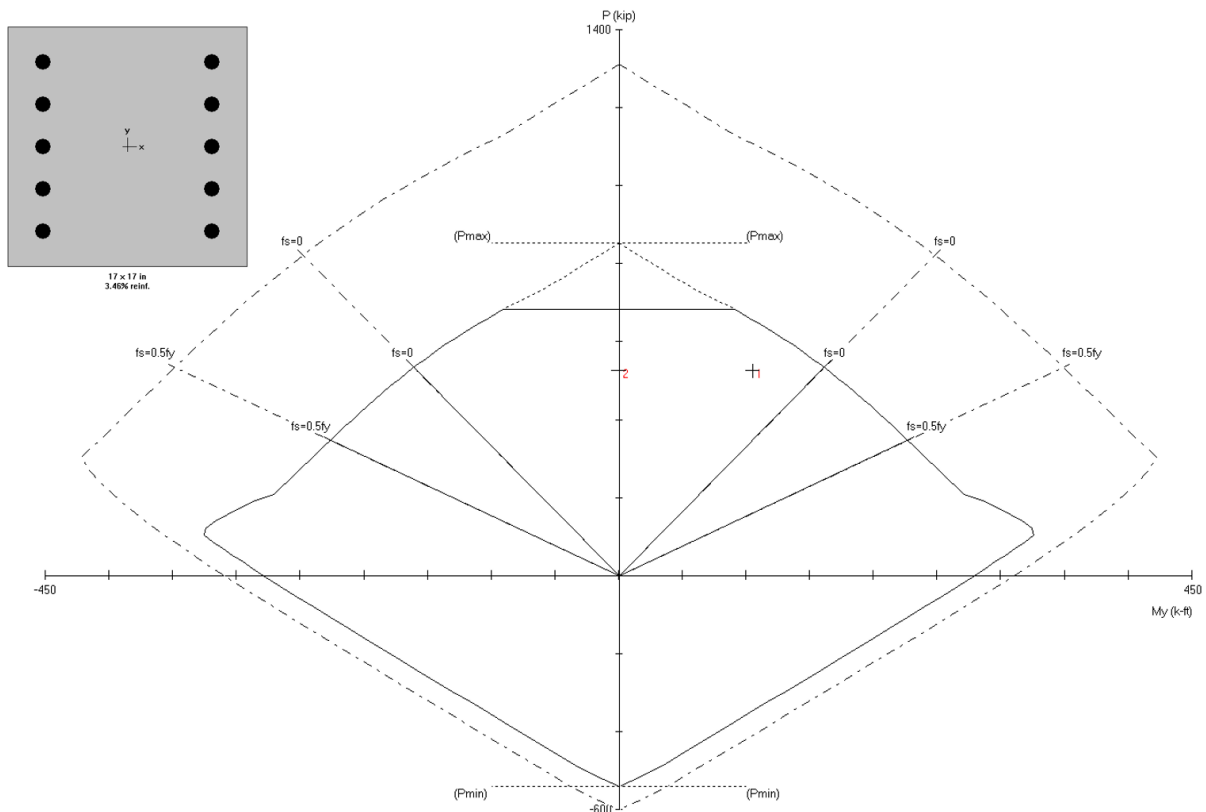


Figure 3 – Column Interaction Diagram

## 5. Column Design - spColumn Software

spColumn program performs the analysis of the reinforced concrete section conforming to the provisions of the Strength Design Method and Unified Design Provisions with all conditions of strength satisfying the applicable conditions of equilibrium and strain compatibility and includes slenderness effects using moment magnification method for sway and nonsway frames. For this column section, we ran in design mode with control points using the ACI 318-19. The graphical and text results are provided below for both input and output of the spColumn model.

spColumn - Slenderness_Non-Sway_ACI.col

File  Input  Solve  View  Options  Help

**General Information**

Labels
Project:
Pincheira Example 13.17.3
Column: Exterior
Engineer: SP

Design Code
ACI 318-19

Units: ● English  ○ Metric
Run Option: ● Investigation  ○ Design

Run Axis: ○ About X-Axis  ● About Y-Axis  ○ Biaxial

Consider slenderness? ● Yes  ○ No

**Material Properties**

Concrete
Strength, f'c: 3 ksi
☑ Standard
Elasticity, Ec: 3122.02 ksi
Max stress, fc: 2.55 ksi
Beta(1): 0.85
Ultimate strain: 0.003

Reinforcing Steel
Strength, fy: 60 ksi
☑ Standard
Elasticity, Es: 29000 ksi
Compression-controlled strain limit,
Eps_yt: 0.00206897

**Sides Different**

| | Top | Bottom | Left | Right |
|---|---|---|---|---|
| No. of bars: | 2 | 2 | 3 | 3 |
| Bar size: | #9 | #9 | #9 | #9 |
| Clear cover: | 1.936 | 1.936 | 1.936 | 1.936 in |

Cover to: ○ Transverse bars  ● Longitudinal bars

**Rectangular Section**
Width (along X): 17 in
Depth (along Y): 17 in

17 x 17 in
3.46% reinf.

MATERIAL:
=========
f'c = 3 ksi
Ec = 3122.02 ksi
fc = 2.55 ksi
Beta1 = 0.85
fy = 60 ksi
Es = 29000 ksi

SECTION:
========
Ag = 289 in^2
Ix = 6960.08 in^4
Iy = 6960.08 in^4
Xo = 0 in
Yo = 0 in

REINFORCEMENT:
==============
10 #9 bars @ 3.460%
As = 10 in^2
Confinement: Tied
Clear Cover = 1.94 in
Min Clear Spacing = 1.87 in

SLENDERNESS:
============
kx(nonsway) = N/A
kx(sway) = N/A
ky(nonsway) = 0.958678
ky(sway) = N/A

**Design Column**

X-Axis
Clear height: 10 ft
○ Nonsway frame
○ Sway frame
Sway criteria
(Sum Pc)/(Pc): 1
(Sum Pu)/(Pu): 1
☑ 2'nd order effects along length
Effective length factors
○ Compute 'k' factors
● Input 'k' factors:
k(ns): 1  k(s): 0
Copy to Y-Axis

Y-Axis
Clear height: 10 ft
● Nonsway frame
○ Sway frame
Sway criteria
(Sum Pc)/(Pc): 1
(Sum Pu)/(Pu): 1
☑ 2'nd order effects along length
Effective length factors
● Compute 'k' factors
○ Input 'k' factors:
k(ns): 0.9602  k(s): 3.2912
Copy to X-Axis

**Slenderness Factors**
● Code defaults  ○ User-defined
Stiffness reduction factor: 0.75
Cracked-section coefficients
Beams (cIb): 0.35
Columns (cIc): 0.7

**Service Loads**

| | Axial Load (kip) | X-Moments (k-ft) @ Top | @ Bot | Y-Moments (k-ft) @ Top | @ Bot | Sustained Load (%) |
|---|---|---|---|---|---|---|
| Dead: | 525 | 105 | 0 | 105 | 0 | 40 |
| Live: | 0 | 0 | 0 | 0 | 0 | 0 |
| Wind: | 0 | 0 | 0 | 0 | 0 | 0 |
| EQ: | 0 | 0 | 0 | 0 | 0 | 0 |
| Snow: | 0 | 0 | 0 | 0 | 0 | 0 |

No. (P, Mxt, Mxb, Myt, Myb) for each case
1  D ( 525, 105, 0, 105, 0 ) L ( 0, 0, 0, 0, 0 ) W ( 0, 0, 0, 0, 0 ) E ( 0, 0, 0, 0, 0 ) S ( 0, 0, 0, 0, 0 )

Y-axis; ACI 318-14; Investigation

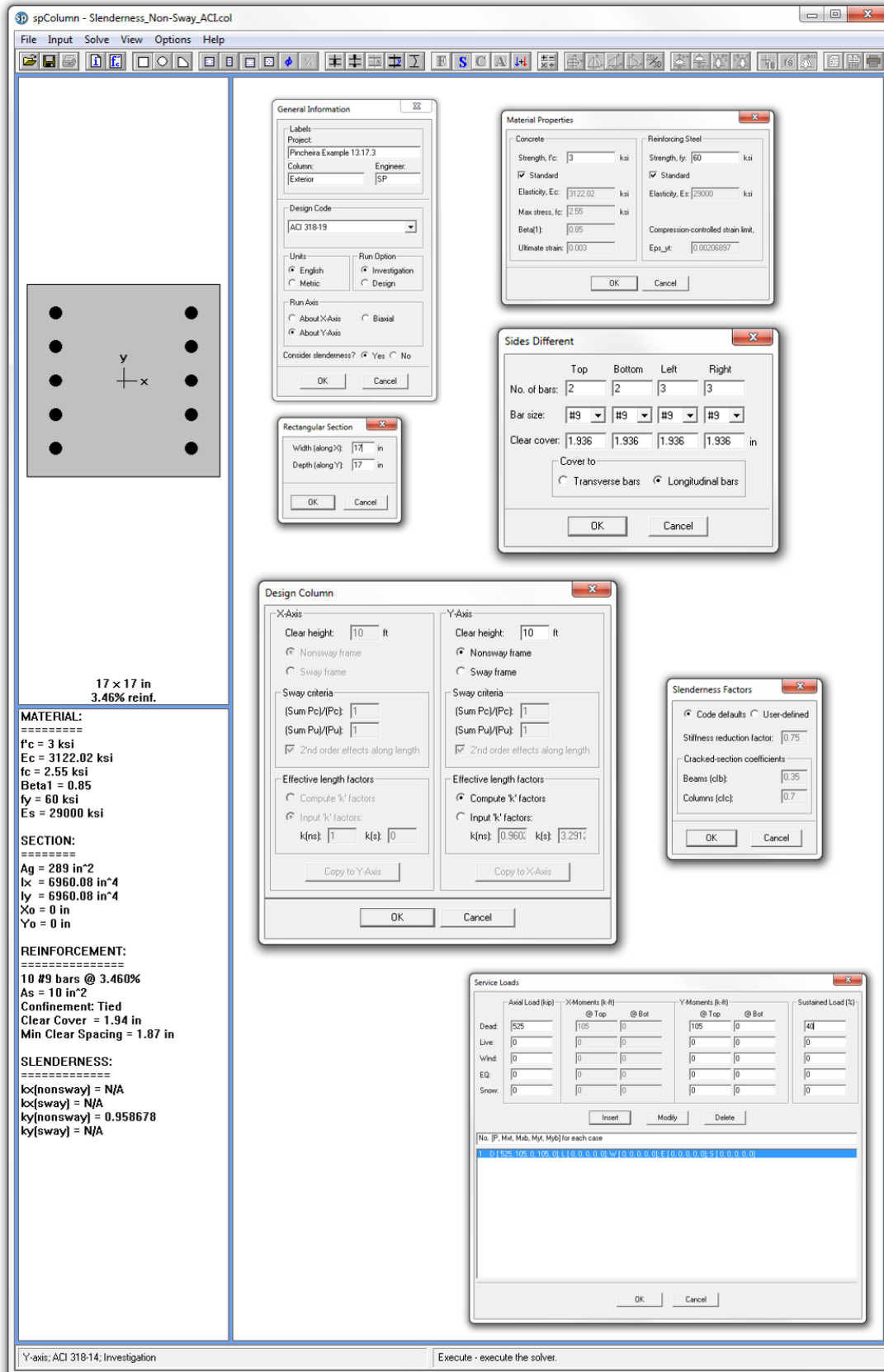Execute - execute the solver.
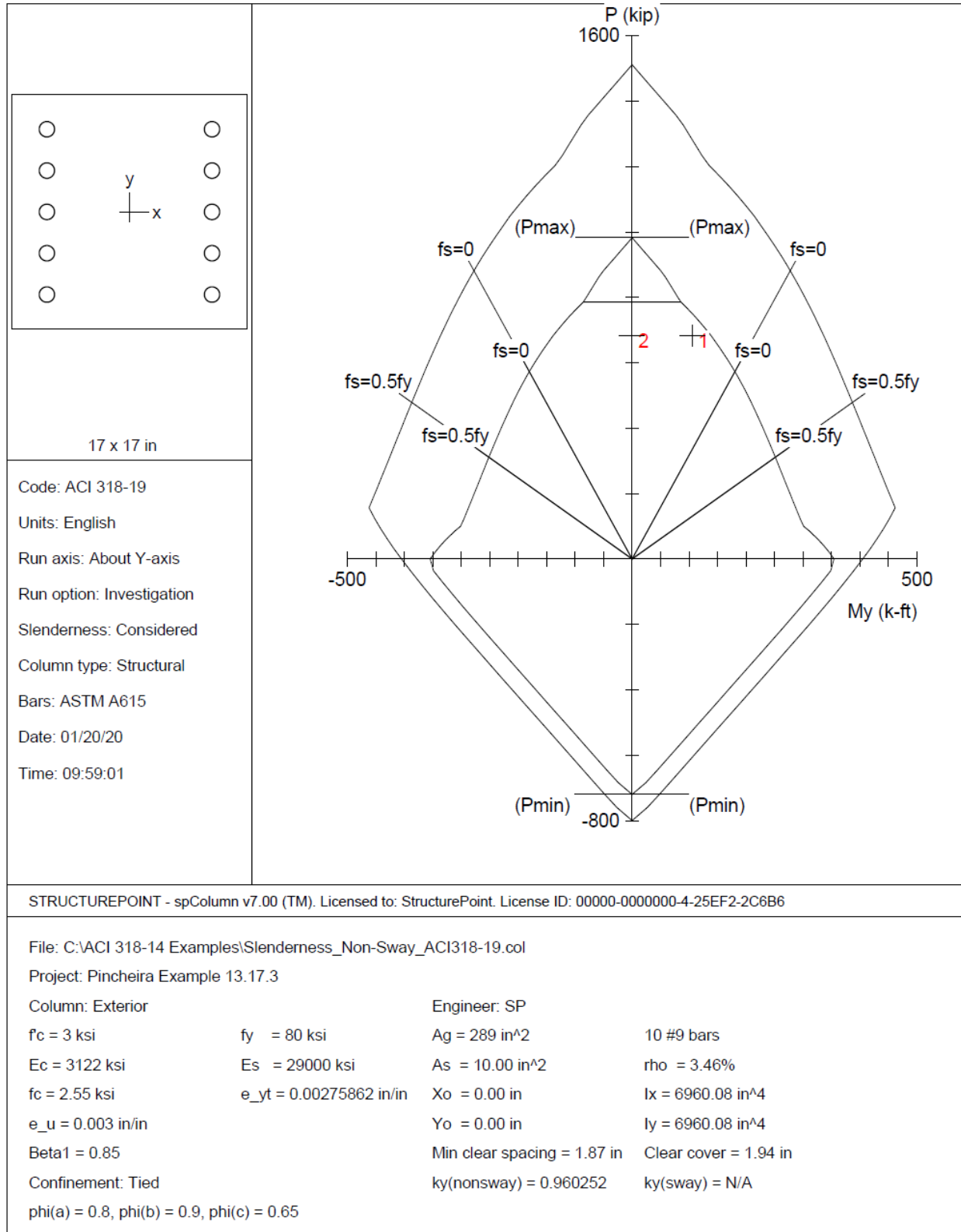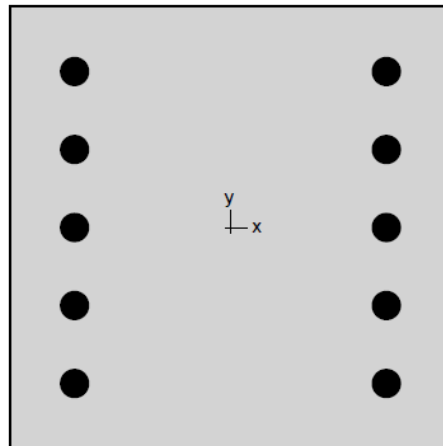
Figure 4 – spColumn Model Input Wizard Windows

Figure 5 – Column Section Interaction Diagram about Y-Axis (spColumn)

spColumn v7.00
Computer program for the Strength Design of Reinforced Concrete Sections
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## 1. General Information

| | |
|---|---|
| File Name | C:\ACI 318-...\Slenderness_Non-Sway_ACI318-19.col |
| Project | Pincheira Example 13.17.3 |
| Column | Exterior |
| Engineer | SP |
| Code | ACI 318-19 |
| Bar Set | ASTM A615 |
| Units | English |
| Run Option | Investigation |
| Run Axis | Y - axis |
| Slenderness | Considered |
| Column Type | Structural |
| Capacity Method | Critical capacity |

## 2. Material Properties
### 2.1. Concrete

| Type | Standard | |
|---|---|---|
| $f'_c$ | 3 | ksi |
| $E_c$ | 3122.02 | ksi |
| $f_c$ | 2.55 | ksi |
| $\varepsilon_u$ | 0.003 | in/in |
| $\beta_1$ | 0.85 | |

### 2.2. Steel

| Type | Standard | |
|---|---|---|
| $f_y$ | 80 | ksi |
| $E_s$ | 29000 | ksi |
| $\varepsilon_{yt}$ | 0.00275862 | in/in |

## 3. Section
### 3.1. Shape and Properties

| Type | Rectangular | |
|---|---|---|
| Width | 17 | in |
| Depth | 17 | in |
| $A_g$ | 289 | in² |
| $I_x$ | 6960.08 | in⁴ |
| $I_y$ | 6960.08 | in⁴ |
| $r_x$ | 4.90748 | in |
| $r_y$ | 4.90748 | in |
| $X_o$ | 0 | in |
| $Y_o$ | 0 | in |

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### 3.2. Section Figure



Rectangular 17 x 17 in                    3.46% reinf.
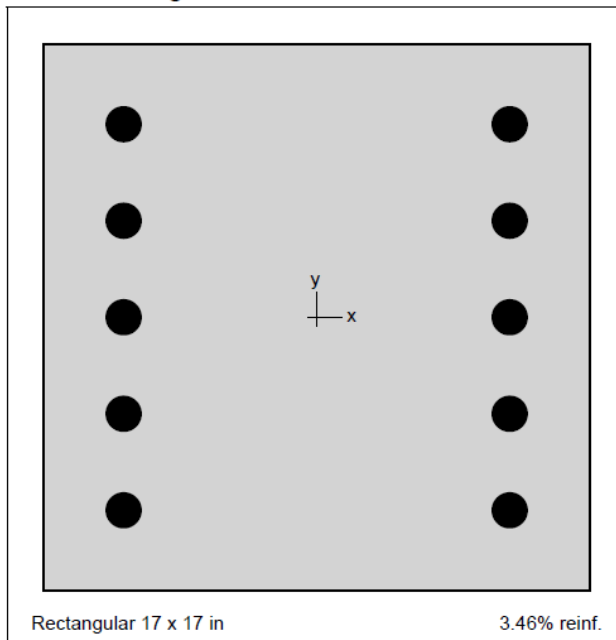
**Figure 1: Column section**

## 4. Reinforcement
### 4.1. Bar Set: ASTM A615

| Bar | Diameter | Area | Bar | Diameter | Area | Bar | Diameter | Area |
|-----|----------|------|-----|----------|------|-----|----------|------|
| | in | in² | | in | in² | | in | in² |
| #3 | 0.38 | 0.11 | #4 | 0.50 | 0.20 | #5 | 0.63 | 0.31 |
| #6 | 0.75 | 0.44 | #7 | 0.88 | 0.60 | #8 | 1.00 | 0.79 |
| #9 | 1.13 | 1.00 | #10 | 1.27 | 1.27 | #11 | 1.41 | 1.56 |
| #14 | 1.69 | 2.25 | #18 | 2.26 | 4.00 | | | |

### 4.2. Confinement and Factors

| Confinement type | Tied |
|------------------|------|
| For #10 bars or less | #3 ties |
| For larger bars | #4 ties |
| | |
| **Capacity Reduction Factors** | |
| Axial compression, (a) | 0.8 |
| Tension controlled $\phi$, (b) | 0.9 |
| Compression controlled $\phi$, (c) | 0.65 |

### 4.3. Arrangement

| Pattern | Sides different |
|---------|-----------------|
| Bar layout | Rectangular |
| Cover to | Longitudal bars |
| Clear cover | --- |
| Bars | --- |

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| | | |
|---|---|---|
| Total steel area, $A_s$ | 10.00 in$^2$ | |
| Rho | 3.46 % | |
| Minimum clear spacing | 1.87 in | |

## 4.4. Bars Provided

| | | Bars | Clear cover |
|---|---|---|---|
| | | | in |
| Top | 2 | #9 | 1.936 |
| Bottom | 2 | #9 | 1.936 |
| Left | 3 | #9 | 1.936 |
| Right | 3 | #9 | 1.936 |

# 5. Loading

## 5.1. Load Combinations

| Combination | Dead | Live | Wind | EQ | Snow |
|---|---|---|---|---|---|
| U1 | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 |

## 5.2. Service Loads

| No. | Load Case | Axial Load | Mx @ Top | Mx @ Bottom | My @ Top | My @ Bottom |
|---|---|---|---|---|---|---|
| | | kip | k-ft | k-ft | k-ft | k-ft |
| 1 | Dead | 682.50 | 105.00 | 0.00 | 105.00 | 0.00 |
| 1 | Live | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1 | Wind | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1 | EQ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1 | Snow | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

## 5.3. Sustained Load Factors

| Load Case | Factor |
|---|---|
| | % |
| Dead | 40 |
| Live | 0 |
| Wind | 0 |
| EQ | 0 |
| Snow | 0 |

# 6. Slenderness

## 6.1. Sway Criteria

| Y-Axis | Non-sway column |
|---|---|

## 6.2. Columns

| Column | Axis | Height | Width | Depth | I | $f'_c$ | $E_c$ |
|---|---|---|---|---|---|---|---|
| | | ft | in | in | in$^4$ | ksi | ksi |
| Design | Y | 10 | 17 | 17 | 6960.08 | 3 | 3122.02 |
| Above | Y | 12 | 17 | 17 | 6960.08 | 3 | 3122.02 |
| Below | Y | (no column specified...) | | | | | |

## 6.3. Y - Beams

| Beam | Length | Width | Depth | I | $f'_c$ | $E_c$ |
|---|---|---|---|---|---|---|
| | ft | in | in | in$^4$ | ksi | ksi |
| Above Left | 30 | 14 | 24 | 16128 | 3 | 3122.02 |

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| Beam | Length | Width | Depth | I | f'$_c$ | E$_c$ |
|---|---|---|---|---|---|---|
| | ft | in | in | in$^4$ | ksi | ksi |
| Above Right | (no beam specified...) | | | | | |
| Below Left | (no beam specified...) | | | | | |
| Below Right | (no beam specified...) | | | | | |

# 7. Moment Magnification

## 7.1. General Parameters

| Factors | Code defaults |
|---|---|
| Stiffness reduction factor, $\phi_K$ | 0.75 |
| Cracked section coefficients, cI(beams) | 0.35 |
| Cracked section coefficients, cI(columns) | 0.7 |
| | |
| $0.2\,E_c\,I_g + E_s\,I_{se}$ (Y-axis) | 1.48e+007 kip-in$^2$ |
| Minimum eccentricity, $e_{y\,min}$ | 1.11 in |

## 7.2. Effective Length Factors

| Axis | $\Psi_{top}$ | $\Psi_{bottom}$ | k (Nonsway) | k (Sway) | $kl_u/r$ |
|---|---|---|---|---|---|
| Y | 4.512 | 999.000 | 0.960 | (N/A) | 23.48 |

## 7.3. Magnification Factors: Y - axis

* Slenderness need not be considered.

| Load Combo | | At Ends | | | | | Along Length | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\Sigma P_u$ | $P_c$ | $\Sigma P_c$ | $\beta_{ds}$ | $\delta_s$ | $P_u$ | $k'l_u/r$ | $P_c$ | $\beta_{dns}$ | $C_m$ | $\delta$ |
| | | kip | kip | kip | | | kip | | kip | | | |
| 1 | U1 | (N/A) | (N/A) | (N/A) | (N/A) | (N/A) | 682.50 | (N/A) | 7850.31 | 0.400 | (N/A) | (N/A) * |

# 8. Factored Moments

NOTE: Each loading combination includes the following cases:
Top - At column top
Bot - At column bottom

## 8.1. Y - axis

| Load Combo | | | 1$^{st}$ Order | | | 2$^{nd}$ Order | | | | Ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $M_{ns}$ | $M_s$ | $M_u$ | $M_{min}$ | | $M_i$ | $M_c$ | 2$^{nd}$/1$^{st}$ |
| | | | k-ft | k-ft | k-ft | k-ft | | k-ft | k-ft | |
| 1 | U1 | Top | 105.00 | (N/A) | 105.00 | (N/A) | $M_2=$ | (N/A) | (N/A) | (N/A) |
| 1 | U1 | Bot | 0.00 | (N/A) | 0.00 | (N/A) | $M_1=$ | (N/A) | (N/A) | (N/A) |

# 9. Factored Loads and Moments with Corresponding Capacity Ratios

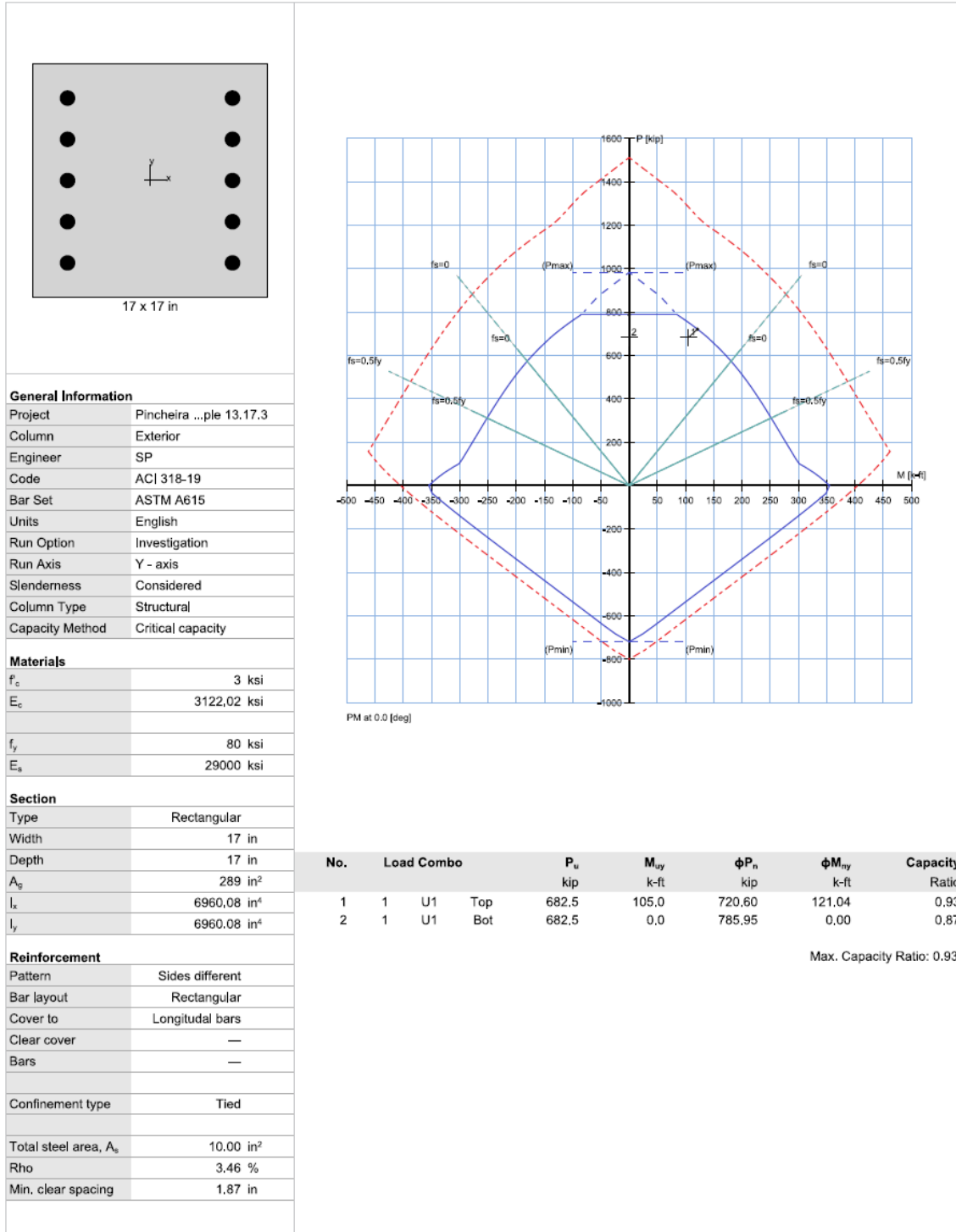NOTE: Calculations are based on "Critical Capacity" Method.
Each loading combination includes the following cases:
Top - At column top
Bot - At column bottom

| No. | Load Combo | | | Demand | | Capacity | | Parameters at Capacity | | | Capacity Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $P_u$ | $M_{uy}$ | $\phi P_n$ | $\phi M_{ny}$ | NA Depth | $\varepsilon_t$ | $\phi$ | |
| | | | | kip | k-ft | kip | k-ft | in | | | |
| 1 | 1 | U1 | Top | 682.50 | 105.00 | 720.60 | 121.04 | 18.20 | -0.00061 | 0.650 | 0.93 |
| 2 | 1 | U1 | Bot | 682.50 | 0.00 | 785.95 | 0.00 | 19.95 | -0.00082 | 0.650 | 0.87 |

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# 10. Diagrams
## 10.1. PM at θ=0 [deg]



### General Information

| | |
|---|---|
| Project | Pincheira ...ple 13.17.3 |
| Column | Exterior |
| Engineer | SP |
| Code | ACI 318-19 |
| Bar Set | ASTM A615 |
| Units | English |
| Run Option | Investigation |
| Run Axis | Y - axis |
| Slenderness | Considered |
| Column Type | Structural |
| Capacity Method | Critical capacity |

### Materials

| | |
|---|---|
| $f'_c$ | 3 ksi |
| $E_c$ | 3122,02 ksi |
| $f_y$ | 80 ksi |
| $E_s$ | 29000 ksi |

### Section

| | |
|---|---|
| Type | Rectangular |
| Width | 17 in |
| Depth | 17 in |
| $A_g$ | 289 in² |
| $I_x$ | 6960,08 in⁴ |
| $I_y$ | 6960,08 in⁴ |

### Reinforcement

| | |
|---|---|
| Pattern | Sides different |
| Bar layout | Rectangular |
| Cover to | Longitudal bars |
| Clear cover | — |
| Bars | — |
| Confinement type | Tied |
| Total steel area, $A_s$ | 10.00 in² |
| Rho | 3.46 % |
| Min. clear spacing | 1,87 in |

| No. | Load Combo | | | $P_u$ kip | $M_{uy}$ k-ft | $\phi P_n$ kip | $\phi M_{ny}$ k-ft | Capacity Ratio |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | U1 | Top | 682,5 | 105,0 | 720,60 | 121,04 | 0,93 |
| 2 | 1 | U1 | Bot | 682,5 | 0,0 | 785,95 | 0,00 | 0,87 |

Max. Capacity Ratio: 0.93

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**6. Summary and Comparison of Design Results**

Analysis and design results from the hand calculations above are compared with the exact values obtained from spColumn model.

| | k | $(EI)_{eff}$, kip.in.$^2$ | $P_c$, kip | $P_u$, kip | $\delta_{ns}$ | $M_c$, kip.ft |
|---|---|---|---|---|---|---|
| | | Table 2 – Parameters for moment magnification of column in non-sway frame | | | | |
| Hand | 0.959 | $10.56\times10^6$ | 7871 | 525 | 0.66 | 105 |
| spColumn | 0.960 | $10.57\times10^6$ | 7850 | 525 | N/A | 105 |

All the results of the hand calculations illustrated above are in precise agreement with the automated exact results obtained from the spColumn program. $\delta_{ns}$ in the methods of solution shown above need not be calculated since the slenderness effects need not be considered. The hand solution shows this value for illustration purposes.

**7. Conclusions & Observations**

7.1. General Observations

The analysis of the reinforced concrete section performed by spColumn conforms to the provisions of the Strength Design Method and Unified Design Provisions with all conditions of strength satisfying the applicable conditions of equilibrium and strain compatibility and includes slenderness effects using moment magnification method for sway and nonsway frames.

ACI 318 provides multiple options for calculating values of r and $(EI)_{eff}$ leading to variability in the determination of the adequacy of a column section. Engineers must exercise judgment in selecting suitable options to match their design condition. The spColumn program utilizes the exact methods whenever possible and allows user to override the calculated values with direct input based on their engineering judgment wherever it is permissible.

## 7.2. Design Column Boundary Conditions in Slenderness Calculations

When the slenderness effects for a non-sway frame column is considered in creating a model using spColumn, the effective length factor can be computed by defining the properties of the columns and beams connected to the top and bottom of the design column. The following notes are helpful when using spColumn to calculate the k value for some of the special boundary conditions cases:

1.  To model pin supports at the top and bottom of the design column:



2.  To model fix supports at the top and bottom of the design column:

3. To model pin support at the top and fix support at the bottom of the design column:



**Columns Above and Below**

**Column Above**
- ☑ No column specified
- Height (c/c): 12 ft
- Width (along X): 17 in
- Depth (along Y): 17 in
- Concrete, f'c: 3 ksi
- Ec: 3122.( ksi
- Copy to Column Below

**Column Below**
- ☑ No column specified
- Height (c/c): 12 ft
- Width (along X): 17 in
- Depth (along Y): 17 in
- Concrete, f'c: 3 ksi
- Ec: 3122.( ksi
- Copy to Column Above

OK    Cancel

"No column specified" for column above and column below

**Y-Beams (perpendicular to Y)**

**Beam Location:**
- ○ Above Left    ○ Above Right
- ● Below Left    ○ Below Right

**Beam Below Left**
- ☐ No beam specified    Copy From Beam Above
- Span (c/c): 30 ft    f'c: 3 ksi
- Width: 14 in    Ec: 3122.02 ksi
- Depth: 24 in    Inertia: 1e+011 in^4
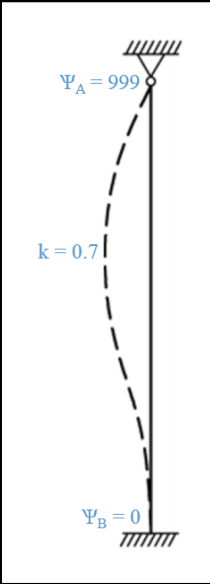
OK    Cancel

Define a high moment of inertia value for one of the beams at the location of the fix support.
"No beam specified" for beams at the location of the pin support.

$\Psi_A = 999$

$k = 0.7$

$\Psi_B = 0$