spcolumn

Version 7.00

This Computer program (including software design, programming structure, graphics, manual, and on-line help) was created and published by STRUCTUREPOINT, formerly the Engineering Software Group of the Portland Cement Association (PCA), for engineering design and investigation of reinforced concrete sections subject to axial and flexural loads.

While STRUCTUREPOINT has taken every precaution to utilize the existing state-of-the-art and to assure the correctness of the analytical solution techniques used in this program, the responsibilities for modeling the structure, inputting data, applying engineering judgment to evaluate the output, and implementing engineering drawings remain with the structural engineer of record. Accordingly, STRUCTUREPOINT does and must disclaim any and all responsibility for defects or failures of structures in connection with which this program is used.

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spcolumn

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CHAPTER

1

INTRODUCTION

1.1   Introduction

spColumn is a software program for the design and investigation of reinforced concrete sections subject to axial and flexural loads. The section can be rectangular, round or irregular, with any reinforcement layout or pattern. Slenderness effects can be considered.

The program offers investigation of irregularly shaped, reinforced concrete column sections that may contain openings or boundary elements. Widely used for design of shear walls, bridge piers as well as typical framing elements in buildings, spColumn can investigate sections that are impossible to find on design charts or do by hand calculations. You can obtain the P-M interaction diagrams from both uniaxial and biaxial runs, as well as the M_x-M_y moment contour plots from biaxial runs for even the most irregular column and shear wall sections. Slenderness effects producing magnified moments may be included in the investigation.

1.2   Program Features

- Code support for ACI 318-19, ACI 318-14, ACI 318-11, ACI 318-08, ACI 318-05, ACI 318-02

- Code support for CSA A23.3-19, CSA A23.3-14, CSA A23.3-04, and CSA A23.3-94

- English and SI units

- Design and investigation run options

- Uniaxial or biaxial flexure combined with axial load

- Rectangular, circular, and irregular section geometry

- Non-slender and sway or nonsway slender columns

- Complete P-M and M_x-M_y interaction diagrams

- Customizable view of interaction diagrams

- Superposition of interaction diagram from a different run

- Factored, unfactored, axial, and control points loading

- Binary (COL) and text (CTI) input file formats

- Graphical input for irregular sections

- Imports geometry, reinforcement, and loads from text files

- Imports section shape and reinforcement from DXF files

- Exports section shape and reinforcement to DXF files

- spSection module for creating and modifying irregular sections

- spResults module for viewing and exporting input and output data

- spReporter module for generating , viewing, exporting and printing results

- Exports graphical reports (screen printouts) to EMF files

- Exports P-M diagrams, M_x-M_y diagrams, and 3D failure surface to TXT and CSV files

- GUI (Graphical User Interface) and batch mode (command prompt) runs

- Reports neutral axis location and maximum steel strain corresponding to section capacity

- Reports neutral axis location, net tensile steel strain, and strength reduction factors in text output

1.3   Program Capacity

- 10,000 reinforcing bars within a section.

- 10,000 exterior points that define the geometric outline of the cross section (spSection module).

- 10,000 interior points that define an opening in the cross section (spSection module).

- 10,000 factored load entries, each consisting of an axial load, a moment about the x-axis, and a moment about the y-axis.

- 50 service load entries, each consisting of dead, live, wind, earthquake, and snow axial loads, moments at column top about the x and y axes, and moments at column bottom about the x and y axes.

- 50 load combinations.

1.4   System Requirements

Any computer running Microsoft Windows Vista SP2, Windows 7, Windows 8, or Windows 10 operating system with 32 or 64 bit processing is sufficient to run the spColumn program. For instructions on how to troubleshoot system specific installation and licensing issues, please refer to support pages on StructurePoint website at www.StructurePoint.org.

1.5   Terms

The following terms are used throughout this manual. A brief explanation is given to help familiarize you with them.

Windows	refers to the Microsoft Windows environment as listed in System Requirements.
[ ]	indicates metric equivalent
Click on	means to position the cursor on top of a designated item or location and press and release the left-mouse button (unless instructed to use the right-mouse button).
Double-click on	means to position the cursor on top of a designated item or location and press and release the left-mouse button twice in quick succession.

1.6   Conventions

To help you locate and interpret information easily, the spColumn manual adheres to the following text format.

Italic	indicates a glossary item, or emphasizes a given word or phrase.
Bold	indicates the name of a menu or a menu item command such as File or Save.
`Mono-space`	indicates something you should enter with the keyboard. For example "c:*.txt".
KEY + KEY	indicates a key combination. The plus sign indicates that you should press and hold the first key while pressing the second key, then release both keys. For example, "ALT + F" indicates that you should press the "ALT" key and hold it while you press the "F" key. then release both keys.
SMALL CAPS	Indicates the name of an object such as a dialog box or a dialog box component. For example, the OPEN dialog box or the CANCEL or MODIFY buttons.

1.7   Installing, Purchasing and Licensing spColumn

To purchase StructurePoint software please visit StructurePoint.org/buy.asp

To download and install a trial version of StructurePoint software please visit StructurePoint.org/download-trial.asp

For setup, installation, and licensing please use the StructurePoint Setup & Licensing Guide

CHAPTER

2

METHOD OF SOLUTION

2.1   Definitions and Assumptions

1. The analysis of the reinforced concrete section performed by spColumn conforms to the provisions of the Strength Design Method[1] and Unified Design Provisions[2] and is based on the following assumptions.

    a) All conditions of strength satisfy the applicable conditions of equilibrium and strain compatibility[3]

    b) Strain in the concrete and in the reinforcement is directly proportional to the distance from the neutral axis[4]. In other words, plane sections normal to the axis of bending are assumed to remain plane after bending.

    c) The maximum usable (ultimate) strain at the extreme concrete compression fiber is assumed equal to 0.003 for ACI codes[5] and 0.0035 for CSA codes[6] unless otherwise specified by the user

    d) A uniform rectangular concrete stress block is used. For ACI code[7], the maximum uniform concrete compressive stress, f_c, is **0.85f_c'** by default and the block depth is $\beta_1 c$, where c is the distance from the extreme compression fiber to the neutral axis and β_1 is described in item 4 below. For CSA[8], f_c is taken as:

    $f_c = (0.85 - 0.0015f_c')f_c' \geq 0.68f_c'$, where f_c' is in MPa

    Both f_c and β_1 can be modified by the user.

    e) Concrete displaced by the reinforcement in compression is deducted from the compression block[9]

1. For CSA A23.3-19 (Ref. [18]) CSA A23.3-14 (Ref. [16]) CSA A23.3-04 (Ref. [8]) and CSA A23.3-94 (Ref.[9])
2. For ACI 318-19 (Ref. [1]), ACI 318-14 (Ref. [2]), ACI 318-11 (Ref. [3]), ACI 318-08 (Ref. [4]), ACI 318-05 (Ref. [5]) and ACI 318-02 (Ref. [6]); also see notes on ACI 318-08, 8.1.2 in Ref. [11] and notes on ACI 318-11, 8.1.2 in Ref. [15]
3. ACI 318-19, 4.5.1, 22.2.1.1, 13.2.6.4; ACI 318-14, 4.5.1, 22.2.1.1, 13.2.6.2; ACI 318-11, 10.2.1; ACI 318-08, 10.2.1; ACI 318-05, 10.2.1; ACI 318-02, 10.2.1; CSA A23.3-19, 10.1.1; CSA A23.3-14, 10.1.1; CSA A23.3-04, 10.1.1; CSA A23.3-94, 10.1.1
4. ACI 318-19, 22.1.2, 22.2.1.2; ACI 318-14, 22.1.2, 22.2.1.2; ACI 318-11, 10.2.2; ACI 318-08, 10.2.2; ACI 318-05, 10.2.2; ACI 318-02, 10.2.2; CSA A23.3-19, 10.1.2; CSA A23.3-14, 10.1.2; CSA A23.3-04, 10.1.2; CSA A23.3-94, 10.1.2
5. ACI 318-19, 22.2.2.1; ACI 318-14, 22.2.2.1; ACI 318-11, 10.2.3; ACI 318-08, 10.2.3; ACI 318-05, 10.2.3; ACI 318-02, 10.2.3
6. CSA A23.3-19, 10.1.3; CSA A23.3-14, 10.1.3; CSA A23.3-04, 10.1.3; CSA A23.3-94, 10.1.3
7. ACI 318-19, 22.2.2.3; ACI 318-14, 22.2.2.3; ACI 318-11, 10.2.6; ACI 318-08, 10.2.6, 10.2.7; ACI 318-05, 10.2.6, 10.2.7; ACI 318-02, 10.2.6, 10.2.6
8. CSA A23.3-19, 10.1.1; CSA A23.3-14, 10.1.1; CSA A23.3-04, 10.1.1; CSA A23.3-94, 10.1.1

f) For the reinforcing steel, the elastic-plastic stress-strain distribution is used[10]. Stress in the reinforcing steel below the yield strength, f_y, is directly proportional to the strain.

For strains greater than that corresponding to the yield strength, the reinforcement stress remains constant and equal to f_y. Reinforcing steel yield strength must be within customary ranges.

g) Tensile strength of concrete in axial and flexural calculations is neglected[11].

h) Reinforcement bars are located within section outline.

i) Irregular sections must be composed of a closed polygon without any intersecting sides.

j) Members with very large cross sectional area, multiple openings, and unusual geometry must be carefully evaluated in light of above assumption for solution stability and reliability of results.

2. The modulus of elasticity of concrete, E_c is computed as follows (unless otherwise specified by the user):

$$E_c = 57,000 \sqrt{f'_c} \text{ for the ACI code}^{12} \text{ where } f'_c \text{ and } E_c \text{ are in psi,}$$

$$E_c = 4,700 \sqrt{f'_c}, \text{ for the ACI code}^{13} \text{ where } f'_c \text{ and } E_c \text{ are in MPa.}$$

For the CSA standard[14], $E_c = 3,518 \sqrt{f'_c} + 7,355$, where f'_c and E_c are in MPa.

3. The modulus of elasticity of reinforcing steel[15], E_s, is taken as 29,000 ksi (200,000 MPa) unless otherwise specified by the user. The computed compression controlled strain limit cannot exceed 0.005 and is reset to 0.002 for user input f_y values in excess of 145 ksi.

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9. For consistency with Eq. 22.4.2.4 in ACI codes (Refs. [1], [2]) and for consistency with Eq. 10-1 and 10-2 in ACI codes (Refs. [3], [4], [5], [6]) and with Eq. 10-10 in CSA codes (Refs. [8], [9])

10. ACI 318-19, 20.2.2.1; ACI 318-14, 20.2.2.1; ACI 318-11, 10.2.4; ACI 318-08, 10.2.4; ACI 318-05, 10.2.4; ACI 318-02, 10.2.4; CSA A23.3-19, 8.5.3.2; CSA A23.3-14, 8.5.3.2; CSA A23.3-04, 8.5.3.2; CSA A23.3-94, 8.5.3.2

11. ACI 318-19, 22.2.2.2; ACI 318-14, 22.2.2.2; ACI 318-11, 10.2.5; ACI 318-08, 10.2.5; ACI 318-05, 10.2.5; ACI 318-02, 10.2.5; CSA A23.3-19, 10.1.5; CSA A23.3-14, 10.1.5; CSA A23.3-04, 10.1.5; CSA A23.3-94, 10.1.5

12. ACI 318-19, 19.2.2.1; ACI 318-14, 19.2.2.1; ACI 318-11, 8.5.1; ACI 318-08, 8.5.1; ACI 318-05, 8.5.1; ACI 318-02, 8.5.1

13. ACI 318M-19, 19.2.2.1; ACI 318M-14, 19.2.2.1; ACI 318M-11, 8.5.1; ACI 318M-08, 8.5.1; ACI 318M-05, 8.5.1; ACI 318M-02, 8.5.1

14. CSA A23.3-19, 8.6.2.2, Eq. 8.1, CSA A23.3-14, 8.6.2.2, Eq. 8.1, CSA A23.3-04, 8.6.2.2, Eq. 8.1 and CSA A23.3-94, 8.6.2.3, Eq. 8-6 (with $\gamma_c = 2400$ kg/m^3)

15. ACI 318-19, 20.2.2.2; ACI 318-14, 20.2.2.2; ACI 318-11, 8.5.2; ACI 318-08, 8.5.2; ACI 318-05, 8.5.2; ACI 318-02, 8.5.2; ACI 318M-05, 8.5.2; ACI 318M-02, 8.5.2; CSA A23.3-19, 8.5.4.1; CSA A23.3-14, 8.5.4.1; CSA A23.3-04, 8.5.4.1; CSA A23.3-94, 8.5.4.1
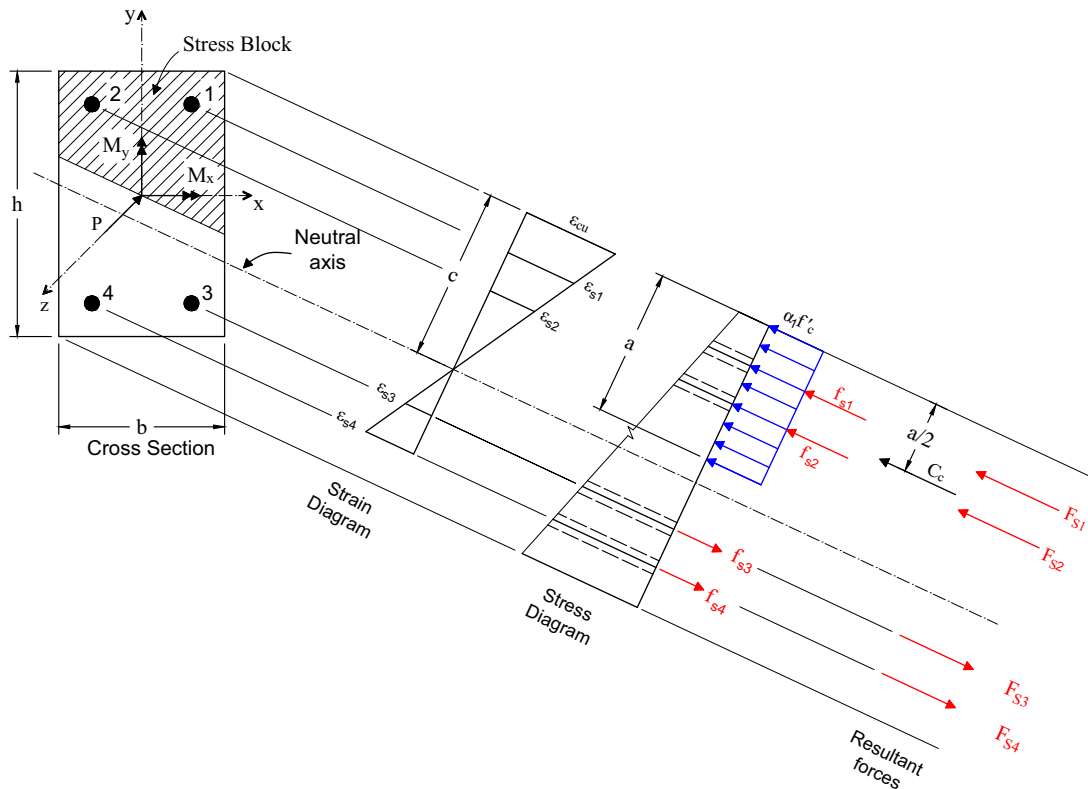
Figure 2-1 Analysis of Reinforced Section

4. The ratio of the concrete compression block depth to the distance between the extreme compression fiber and the neutral axis, $\boldsymbol{\beta_1}$, is computed as follows (unless otherwise specified by the user):

$$0.65 \le \beta_1 = 1.05 - 0.05f'_c \le 0.85, \text{ for the ACI code}[16] \text{ where } \boldsymbol{f'_c} \text{ is in ksi,}$$

$$0.65 \le \beta_1 = (149 - f'_c) / 140 \le 0.85, \text{ for the ACI code}[17] \text{ where } \boldsymbol{f'_c} \text{ is in MPa.}$$

For the CSA standard[18], $\beta_1 = 0.97 - 0.0025f'_c \ge 0.67$, where $\boldsymbol{f'_c}$ is in MPa.

5. Stress in the reinforcement is computed based on the strain at the centroid of each reinforcing bar.

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16. ACI 318-19, 22.2.2.4.3; ACI 318-14, 22.2.2.4.3; ACI 318-11, 10.2.7.3; ACI 318-08, 10.2.7.3; ACI 318-05, 10.2.7.3; ACI 318-02, 10.2.7.3

17. ACI 318M-19, 22.2.2.4.3; ACI 318M-14, 22.2.2.4.3; ACI 318M-11, 10.2.7.3; ACI 318M-08, 10.2.7.3; ACI 318M-05, 10.2.7.3; ACI 318M-02, 10.2.7.3

18. CSA A23.3-19, 10.1.7(c); CSA A23.3-14, 10.1.7(c); CSA A23.3-04, 10.1.7(c); CSA A23.3-94, 10.1.7(c)

6. All moments are referenced to the geometric centroid of the gross concrete section (neglecting the reinforcement).

7. For the ACI codes, the nominal (unreduced) capacity of the section is first computed. Then, the nominal capacity is reduced to the design capacity using the strength reduction factor, ϕ, the value of which is calculated based on the net tensile steel strain, ε_t, in the following way[19].

- For columns with spiral reinforcement per ACI 318-19

$$\phi = \begin{cases} 0.90 & \text{if } \varepsilon_t \geq \varepsilon_{ty} + 0.003 \text{ (tension controlled section)} \\ 0.75 + \dfrac{0.15\,(\varepsilon_t - \varepsilon_{ty})}{0.003} & \text{if } \varepsilon_{ty} < \varepsilon_t < \varepsilon_t + 0.003 \text{ (transition section)} \\ 0.75 & \text{if } \varepsilon_t \leq \varepsilon_{ty} \text{ (compression controlled section)} \end{cases}$$

Where $\varepsilon_{ty} = f_y / E_s$

- For columns with spiral reinforcement per ACI 318-14, ACI 318-11, and ACI 318-08

$$\phi = \begin{cases} 0.90 & \text{if } \varepsilon_t \geq 0.005 \text{ (tension controlled section)} \\ 0.75 + \dfrac{0.15\left(\varepsilon_t - f_y / E_s\right)}{0.005 - f_y / E_s} & \text{if } f_y / E_s < \varepsilon_t < 0.005 \text{ (transition section)} \\ 0.75 & \text{if } \varepsilon_t \leq f_y / E_s \text{ (compression controlled section)} \end{cases}$$

- For columns with spiral reinforcement per ACI 318-05 and ACI 318-02

$$\phi = \begin{cases} 0.90 & \text{if } \varepsilon_t \geq 0.005 \text{ (tension controlled section)} \\ 0.70 + \dfrac{0.20\left(\varepsilon_t - f_y / E_s\right)}{0.005 - f_y / E_s} & \text{if } f_y / E_s < \varepsilon_t < 0.005 \text{ (transition section)} \\ 0.70 & \text{if } \varepsilon_t \leq f_y / E_s \text{ (compression controlled section)} \end{cases}$$

- For other columns per ACI 318-19

$$\phi = \begin{cases} 0.90 & \text{if } \varepsilon_t \geq \varepsilon_{ty} + 0.003 \text{ (tension controlled section)} \\ 0.65 + \dfrac{0.15\,(\varepsilon_t - \varepsilon_{ty})}{0.003} & \text{if } \varepsilon_{ty} < \varepsilon_t < \varepsilon_t + 0.003 \text{ (transition section)} \\ 0.65 & \text{if } \varepsilon_t \leq \varepsilon_{ty} \text{ (compression controlled section)} \end{cases}$$

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19. ACI 318-19, 21.2; ACI 318-14, 21.2; ACI 318-11, 9.3.2, 10.3.3, 10.3.4; ACI 318-08, 9.3.2, 10.3.3, 10.3.4; ACI 318-05, 9.3.2, 10.3.3, 10.3.4; ACI 318-02, 9.3.2, 10.3.3, 10.3.4

Where $\varepsilon_{ty} = f_y / E_s$

- For other columns per ACI 318-14, ACI 318-11, ACI 318-08, ACI 318-05, and ACI 318-02

$$\phi = \begin{cases} 0.90 & \text{if } \varepsilon_t \geq 0.005 \text{ (tension controlled section)} \\ 0.65 + \dfrac{0.25\left(\varepsilon_t - f_y / E_s\right)}{0.005 - f_y / E_s} & \text{if } f_y / E_s < \varepsilon_t < 0.005 \text{ (transition section)} \\ 0.65 & \text{if } \varepsilon_t \leq f_y / E_s \text{ (compression controlled section)} \end{cases}$$

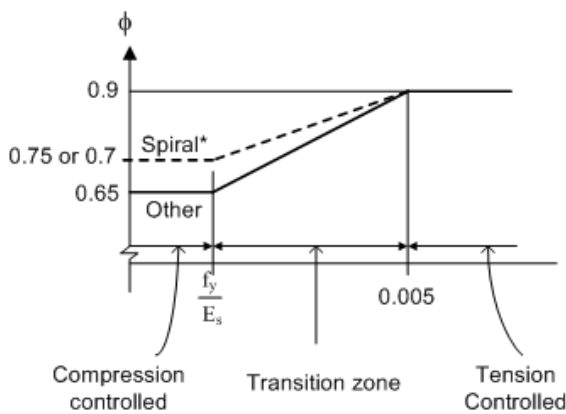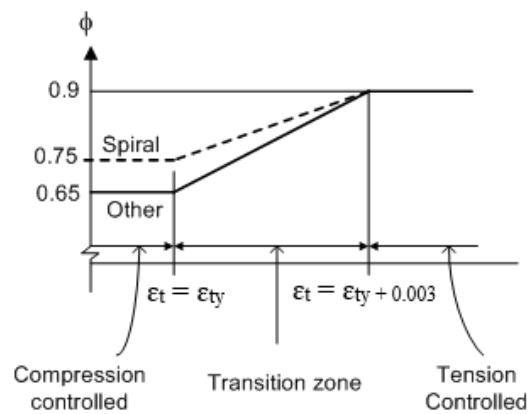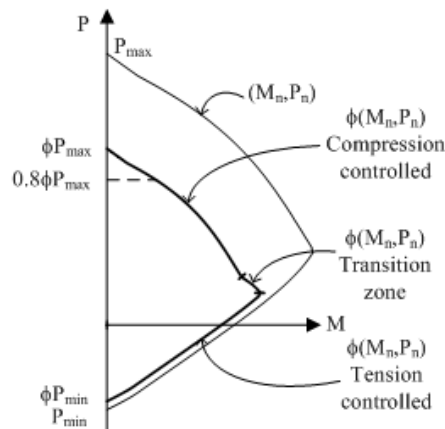Figure 2-2 Reduction factors for Flexural and Axial Capacity per ACI Code

Figure 2-2 illustrates variation of the strength reduction factor with net tensile strain in extreme tension steel and the impact of the strength reduction factor on the axial and flexural capacity

interaction diagram. It is worth noting that in the transition between compression controlled and tension controlled zones, the nominal axial capacity, P_n, decreases whereas the value of net tensile strain increases and so does the strength reduction factor, ϕ. Consequently, the resulting factored axial capacity (i.e. the product of nominal axial capacity and the strength reduction factor), ϕP_n, may either increase or decrease in the transition zone depending on the rates of axial force decrease and strength reduction increase for the section under consideration. Typically, the rate of axial capacity decrease dominates over the rate of strength reduction increase and thus the factored axial load capacity decreases as well.

For certain classes of sections (e.g. sections having a narrowing in the middle such as hollow core section, T-shaped, L-shaped, and I-shaped sections), however, the reverse may be true resulting in the factored axial load capacity increase in the transition zone between compression controlled and tension controlled zones. This unusual increase in axial load capacity is not illustrated by interaction diagrams produced by the program and is not considered for design and investigation of cross-sections. It will be flagged to inform the user, however, when the program is run using Control Points as the load type.

Where unsymmetrical members (e.g. C-shaped or U-shaped sections) are investigated under biaxial bending, the Mx-My contour diagram occasionally crosses the X or Y axes more than once. This presents an unusual situation where a load point may exist outside of the Mx-My contour while appearing within the P-Mx or P-My contour views. It is suggested the Mx-My contours be investigated carefully for each factored axial load level.

For the CSA standards, the program calculates the factored resistance directly using the factored compressive concrete strength[20], $\phi_c f'_c$, and the factored forces in reinforcement bars[21], $\phi_s S_i$. The material resistance factors are:

ϕ_c = 0.60 for CSA A23.3-94

    = 0.65 for CSA A23.3-04/14/19 (cast-in-place)

    = 0.70 for CSA A23.3-04/14/19 (precast)

ϕ_s = 0.85 for CSA A23.3-94/04/14/19

For all ACI and CSA A23.3-94/04 standards, the design axial capacity is capped[22] at 0.85 of the maximum axial capacity for sections with spiral reinforcement or at 0.80 for sections with tie reinforcement.

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20. CSA A23.3-19, 8.4.2, CSA A23.3-14, 8.4.2, 16.1.3; CSA A23.3-04, 8.4.2, 16.1.3; CSA A23.3-94, 8.4.2
21. CSA A23.3-19, 8.4.3; CSA A23.3-14, 8.4.3; CSA A23.3-04, 8.4.3; CSA A23.3-94, 8.4.3
22. ACI 318-19, 22.4.2.1; ACI 318-14, 22.4.2.1; ACI 318-11, 10.3.6; ACI 318-08, 10.3.6; ACI 318-05, 10.3.6; ACI 318-02, 10.3.6; CSA A23.3-14, 10.10.4; CSA A23.3-04, 10.10.4; CSA A23.3-94, 10.10.4

Additionally, for CSA A23.3-14 and CSA A23.3-19 the design axial capacity is capped[23] at 0.90 of the maximum axial capacity for sections with spiral reinforcement or at **(0.2+0.002*h*) ≤ 0.80** for sections with tie reinforcement where h is the wall thickness or the minimum column dimension.

Axial Load, P

$f_s=0$

$f_s=0.5f_y$

Balanced point
$\varepsilon_t = f_y/E_s$

Moment, M

Tension control
point $\varepsilon_t = 0.005$

Factored (Design) Interaction Diagram per ACI 318

Axial Load, P

$f_s=0$

$f_s=0.5f_y$

Balanced point
$\varepsilon_t = f_y/E_s$

Moment, M

Factored (Design) Interaction Diagram per CSA A23.3
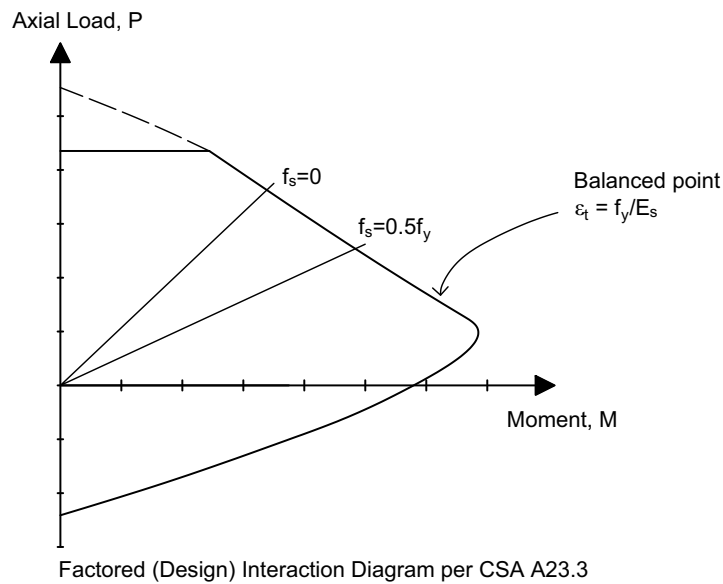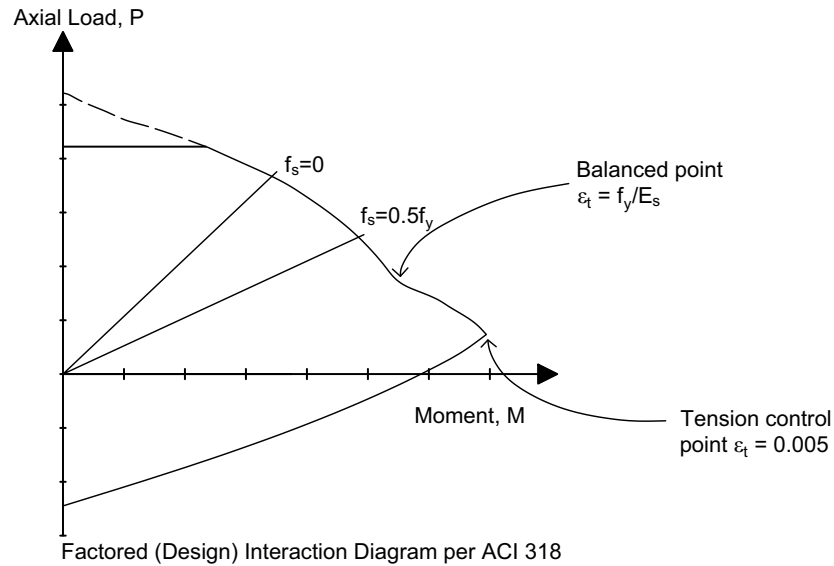
Figure 2-3 Shapes of P-M interaction diagram for ACI code and CSA standard

23. CSA A23.3-19, 10.10.4; CSA A23.3-14, 10.10.4

8. In the investigation mode the program will calculate capacity for any provided area of reinforcement. However, if the reinforcement area falls below the code-specified[24] minimum of 0.01 times the gross area, A_g, then two options, *Architectural* or *Structural*, are available.

   By default *Architectural* option is selected for which the capacity of the section is reduced. For the ACI codes, the reduction results from multiplying the maximum concrete stress, f'_c, by the ratio of reinforcement area to $\mathbf{0.01A_g}$. This produces the same effect as reducing the effective concrete area[25] to achieve ratio of reinforcement area to gross concrete area equal to 0.01. For the CSA standards[26], the factored axial and flexural resistances are multiplied by ratio $\mathbf{0.5\left(1 + \rho_t / 0.01\right)}$ for the 04 edition and $\rho_t / \mathbf{0.01}$ for the 94 edition.

   For *Structural* option, the section is treated "as is" without any reductions in capacity. This option is provided for informational purposes only, since per all codes supported by spColumn, capacity of compression members with reinforcement area less than $\mathbf{0.01A_g}$ has to be reduced and areas below $\mathbf{0.005A_g}$ are not allowed.

9. Under the Design option, the reinforcement ratio cannot be less than 1.0% if *Structural* column type is selected in design criteria and 0.5% in case of *Architectural* column type. For *Architectural* type, the capacity of the designed column is reduced as described above. Additionally, *User Defined* type is provided in the design criteria, which allows designs with reinforcement ratios not less than 0.1%. No reduction in capacity is applied for *User Defined* column type.

10. Maximum reinforcement ratio[27] for *Structural* and *Architectural* options in both Investigation and Design modes is 8%. For *User Defined* type in the Design mode the maximum reinforcement ratio is set to 20%.

11. Reinforcement design strength for standard materials is limited to the value permitted for design calculations[28] by ACI to 80 ksi and CSA to 500 MPa.

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24. ACI 318-19, 10.6.1.1; ACI 318-14, 10.6.1.1; ACI 318-11, 10.9.1; ACI 318-08, 10.9.1; ACI 318-05, 10.9.1; ACI 318-02, 10.9.1; CSA A23.3-19, 10.9.1; CSA A23.3-14, 10.9.1; CSA A23.3-04, 10.9.1; CSA A23.3-94, 10.9.1

25. ACI 318-19, 10.3.1.2; ACI 318-14, 10.3.1.2; ACI 318-11, 10.8.4; ACI 318-08, 10.8.4; ACI 318-05, 10.8.4; ACI 318-02, 10.8.4

26. CSA A23.3-19, 10.10.5; CSA A23.3-14, 10.10.5; CSA A23.3-04, 10.10.5; CSA A23.3-94, 10.10.5

27. ACI 318-19, 10.6.1.1; ACI 318-14, 10.6.1.1; ACI 318-11, 10.9.1; ACI 318-08, 10.9.1; ACI 318-05, 10.9.1; ACI 318-02, 10.9.1; CSA A23.3-19, 10.9.2; CSA A23.3-14, 10.9.2; CSA A23.3-04, 10.9.2; CSA A23.3-94, 10.9.2

28. ACI 318-19, Table 20.2.2.4a; ACI 318-14, Table 20.2.2.4a; CSA A23.3-19, 8.5.1; CSA A23.3-14, 8.5.1

2.2   Conventions

1. Positive axial forces are compressive and negative axial forces are tensile.

2. Looking in plan at the section with z-axis pointing outwards, the positive x-axis points to the right and the positive y-axis points up. For this section, vectors of positive bending moments have the same orientation as their corresponding axes x and y. Thus, a positive bending moment about the x-axis, M_x, produces tension at the top face of the section and compression at the bottom face. A positive bending moment about the y-axis, M_y, produces tension at the left face of the section and compression at the right face.
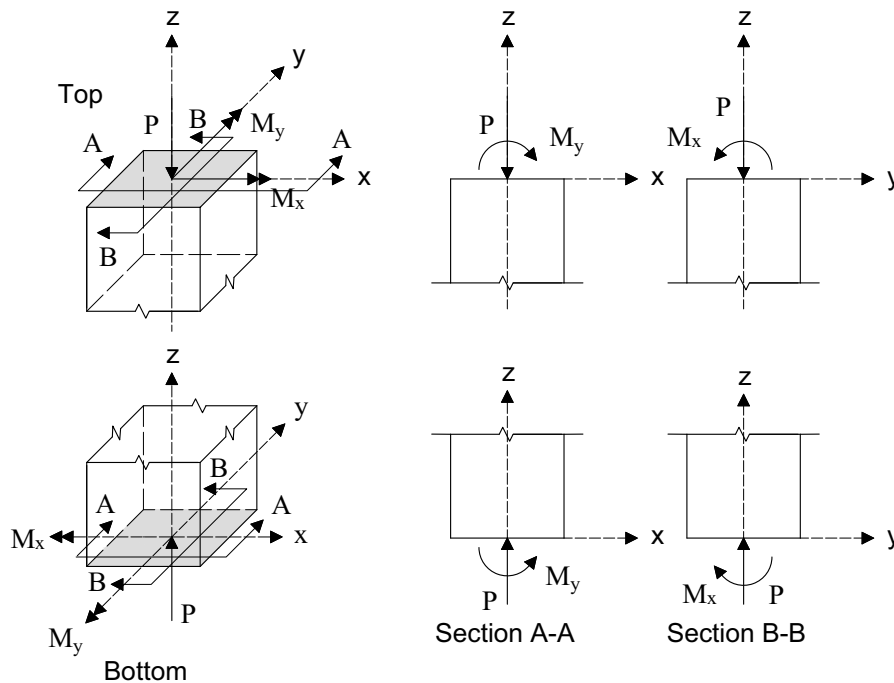
Figure 2-4 Positive axial force and bending moments (internal forces)

3. If service loads are input, moment loads at the upper (top) and lower (bottom) ends of the column are needed. Top and bottom moment loads of opposite signs produce single curvature bending. Top and bottom moment loads of the same sign produce double curvature bending.

   Positive moment loads at the upper end of the column coincide with positive bending moments. However, at the lower end, positive moment loads produce effects opposite to positive bending moments. Therefore, spColumn changes the sign of the service moment at the lower end to convert it from a moment load to a bending moment.

   Axial load is assumed to be constant so it is input only as for the upper end where positive axial load coincides with positive axial force.

4. If factored loads are input, they are considered to be applied at a section pointing upwards so that they have the same orientations as positive axial force and positive bending moments.
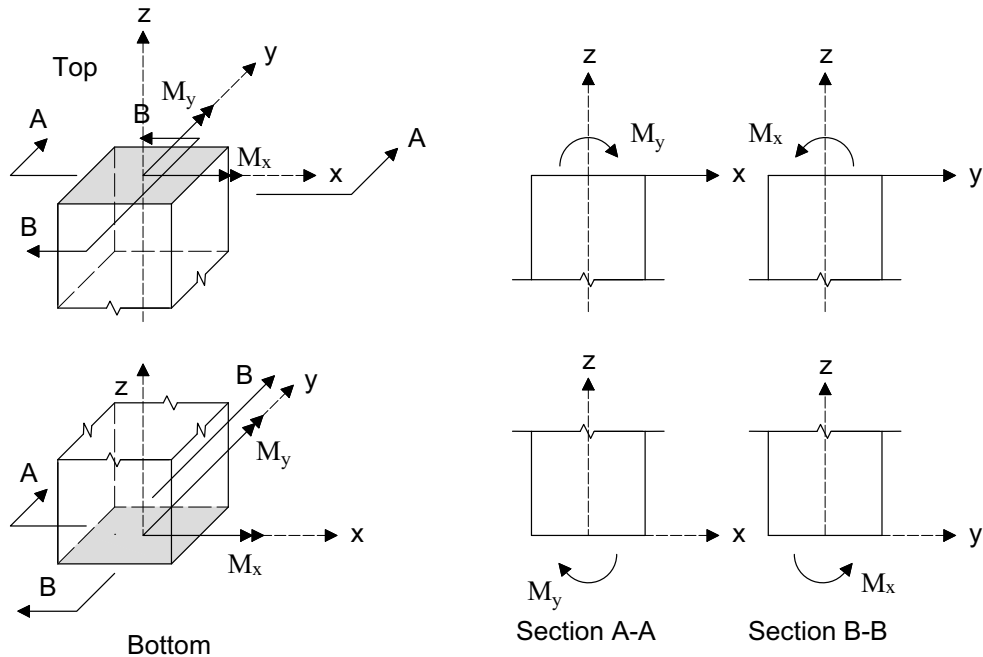
Figure 2-5 Positive moment loads (external forces)

5. The convention for the slenderness input of beam and column dimensions and their orientation is presented in Figure 2-6. Beams above the columns are shown. Same convention applies to beam below the column.
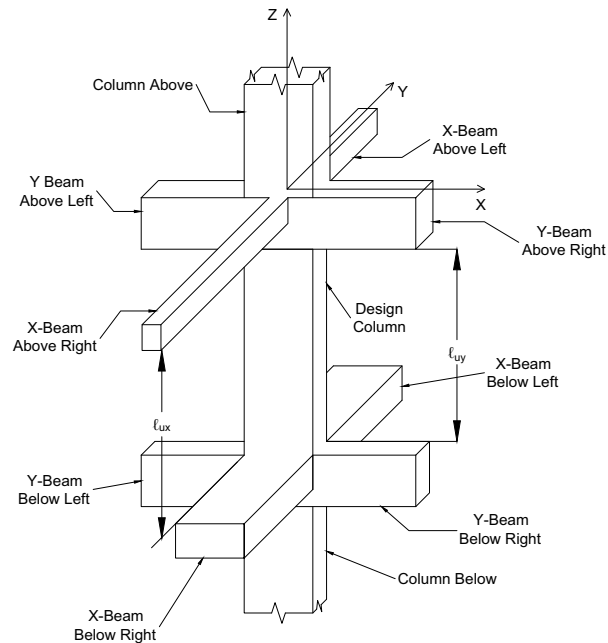
Figure 2-6 Slenderness Input Convention

2.3   Section Investigation Mode

2.3.1   Loading Options

The computations performed when investigating a section depend on the selected load mode:

a) Factored loads – for each load point, the capacity ratio is computed. For a biaxial run, the computed M_x and M_y moment capacities are at the same angle as that produced by the applied M_x and M_y moments. The program also reports the depth of neutral axis and maximum steel strain corresponding to the calculated capacity points. For the ACI code, the value of strength reduction factor is also reported.

spColumn allows defining up to 50 load combinations. The user has full control over the combinations. The program contains predefined (built into the program) default primary load combinations for the supported codes. These default combinations are created when starting a new project. The default load combinations of the Dead (D), Live (L), Wind (W), Earthquake (E) and Snow (S) loads considered by the program are shown below. For the ACI 318-19,14, 11, 08, 05, and 02 codes[29]:

---

29. ACI 318-19, 5.3; ACI 318-14, 5.3; ACI 318-11, 9.2; ACI 318-08, 9.2; ACI 318-05, 9.2; ACI 318-02, 9.2; (assuming W based on service-level wind load and E based on ultimate-level forces)

U1	=	1.4D
U2	=	1.2D + 1.6L + 0.5S
U3	=	1.2D +1.0L + 1.6S
U4	=	1.2D + 0.8W + 1.6S
U5	=	1.2D +1.0L + 1.6W + 0.5S
U6	=	0.9D + 1.6W
U7	=	1.2D − 0.8W + 1.6S
U8	=	1.2D +1.0L − 1.6W + 0.5S
U9	=	0.9D − 1.6W
U10	=	1.2D +1.0L +1.0E − 0.2S
U11	=	0.9D +1.0E
U12	=	1.2D +1.0L − 1.0E + 0.2S
U13	=	0.9D − 1.0E

For the CSA A23.3-94 code[30]:

U1	=	1.25D
U2	=	1.25D + 1.5L
U3	=	1.25D + 1.5L + 1.5S
U4	=	1.25D + 1.05L + 1.05W
U5	=	1.25D + 1.05L + 1.05W + 1.05S
U6	=	1.25D + 1.5W
U7	=	0.85D + 1.5W
U8	=	1.0D +1.0L + 1.0E
U9	=	1.0D +1.0L + 1.0E + 1.0S
U10	=	1.0D + 1.0E
U11	=	1.25D + 1.05L − 1.05W
U12	=	1.25D + 1.05L − 1.05W + 1.05S
U13	=	1.25D − 1.5W
U14	=	0.85D − 1.5W
U15	=	1.0D + 1.0L − 1.0E
U16	=	1.0D + 1.0L − 1.0E + 1.0S
U17	=	1.0D − 1.0E

---

30. CSA A23.3-94, 8.3.2 (conservatively assuming storage and assembly occupancies)

For the CSA A23.3-04 code[31]:

$U1 = 1.4D$

$U2 = 1.25D + 1.5L$

$U3 = 1.25D + 1.5L + 0.5S$

$U4 = 1.25D + 1.5L + 0.4W$

$U5 = 1.25D + 1.5L - 0.4W$

$U6 = 0.9D + 1.5L$

$U7 = 0.9D + 1.5L + 0.5S$

$U8 = 0.9D + 1.5L + 0.4W$

$U9 = 0.9D + 1.5L - 0.4W$

$U10 = 1.25D + 1.5S$

$U11 = 1.25D + 0.5L + 1.5S$

$U12 = 1.25D + 0.4W + 1.5S$

$U13 = 1.25D - 0.4W + 1.5S$

$U14 = 0.9D + 1.5S$

$U15 = 0.9D + 0.5L + 1.5S$

$U16 = 0.9D + 0.4W + 1.5S$

$U17 = 0.9D - 0.4W + 1.5S$

$U18 = 1.25D + 1.4W$

$U19 = 1.25D + 0.5L + 1.4W$

$U20 = 1.25D + 1.4W + 0.5S$

$U21 = 1.25D - 1.4W$

$U22 = 1.25D + 0.5L - 1.4W + 0.5S$

$U23 = 1.25D - 1.4W + 0.5S$

$U24 = 0.9D + 0.5L + 1.4W$

$U25 = 0.9D + 0.5L + 1.4W$

$U26 = 0.9D + 1.4W + 0.5S$

$U27 = 0.9D - 1.4W$

$U28 = 0.9D + 0.5L - 1.4W$

$U29 = 0.9D - 1.4W + 0.5S$

$U30 = 1.0D + 1.0E$

---

31. CSA A23.3-04, 8.3.2; CSA A23.3-04, Annex C, Table C1; NBCC 2005 [10], Table 4.1.3.2

U31 = 1.0D + 0.5L + 1.0E + 0.25S

U32 = 1.0D − 1.0E

U33 = 1.0D + 0.5L − 1.0E + 0.25S

For CSA A23.3-19 and CSA A23.3-14 codes[32]:

U1 = 1.4D

U2 = 1.25D + 1.5L

U3 = 1.25D + 1.5L + 1.0S

U4 = 1.25D + 1.5L + 0.4W

U5 = 1.25D + 1.5L − 0.4W

U6 = 0.9D + 1.5L

U7 = 0.9D + 1.5L + 1.0S

U8 = 0.9D + 1.5L + 0.4W

U9 = 0.9D + 1.5L − 0.4W

U10 = 1.25D + 1.5S

U11 = 1.25D + 1.0L + 1.5S

U12 = 1.25D + 0.4W + 1.5S

U13 = 1.25D − 0.4W + 1.5S

U14 = 0.9D + 1.5S

U15 = 0.9D + 1.0L + 1.5S

U16 = 0.9D + 0.4W + 1.5S

U17 = 0.9D − 0.4W + 1.5S

U18 = 1.25D + 1.4W

U19 = 1.25D + 0.5L + 1.4W

U20 = 1.25D + 1.4W + 0.5S

U21 = 1.25D − 1.4W

U22 = 1.25D + 0.5L − 1.4W

U23 = 1.25D − 1.4W + 0.5S

U24 = 0.9D + 1.4W

U25 = 0.9D + 0.5L + 1.4W

U26 = 0.9D + 1.4W + 0.5S

U27 = 0.9D − 1.4W

---

32. CSA A23.3-14/19 Annex C, Table C1; NBCC 2010 [10], Table 4.1.3.2A;

U28 = 0.9D + 0.5L − 1.4W

U29 = 0.9D − 1.4W + 0.5S

U30 = 1.0D + 1.0E

U31 = 1.0D + 0.5L + 1.0E + 0.25S

U32 = 1.0D − 1.0E

U33 = 1.0D + 0.5L − 1.0E + 0.25S

b) Service loads – the program calculates the factored loads using the input load combinations. If slenderness effects are to be checked and the column is found to be slender, the applied moments are magnified according to Procedures 2.5 and 2.6. For each calculated factored load, the same computations described in (a) above are performed.

c) Control points – for several key points on the interaction diagram, the program calculates axial load and moment capacity together with the neutral axis depth and maximum steel strain corresponding to the respective moment capacity. For ACI code, strength reduction factor is also reported. The following key points are used by the program: maximum compression, allowable compression, point where steel stress is zero, point where steel stress is **0.5f_y**, balanced point, pure flexure and maximum tension. For ACI code, an additional control point is introduced where maximum steel strain is equal to 0.005 (tension control limit).

d) Axial loads – for each input axial load, the program calculates the positive and negative moment capacities together with the corresponding neutral axis depths and maximum steel strains. For ACI code, strength reduction factors are also reported.

2.3.2   Interaction Diagram Options

The program also computes the interaction diagram (uniaxial runs) or the three-dimensional failure surface (biaxial runs) of the input section. The values of maximum compressive axial load capacity and maximum tensile load capacity are computed. These two values set the range within which the moment capacities are computed for a predetermined number of axial load values.

a) For uniaxial runs, positive and negative moment capacities about only the selected axis are computed. Moment capacities about the orthogonal axis are ignored. To compute the moment capacity at a certain level of axial load, the neutral axis angle is held constant, parallel to the selected axis. The neutral axis depth is adjusted to arrive at the desired axial load capacity. This is done for all the predetermined values of axial load.

b) For biaxial runs, the same predetermined values of axial load are utilized. For each level of axial load, the section is rotated in 10-degree increments from 0 degrees to 360 degrees and the M_x and M_y moment capacities are computed. Thus for each level of

axial load, an M_x-M_y contour is developed. Repeating this for the entire range of axial loads, the three-dimensional failure surface is computed. A three-dimensional visualization of the resulting entire nominal and factored failure surface is provided to support enhanced understanding of the section capacity.

Also for each point on the interaction diagram or on the three-dimensional failure surface, the program calculates the location of the neutral axis (expressed in terms of depth and angle of the neutral axis), maximum steel strain, and (for ACI codes only) the strength reduction factor. These results are reported for the maximum capacity of the section based on the ultimate limit states and not for the given loading input. The information can however be used to draw conclusions or make additional calculations for a given loading condition.

Figure showing interaction surface diagrams with axes P, M_x, M_y. Labels: "M_x - M_y slice at constant Load, P_1", "$\lambda = \arctan \dfrac{My}{Mx}$", "P-M slice at constant angle, λ", "P_1", "M_x", "M_y".

Below: diagram (a) with axes M_y, M_x, showing M_λ and angle λ. Diagram (b) with axes P, M(λ), labeled compression, tension.

(a) Moment slice at constant load P_1 (b) Half of P-M slice at constant angle λ
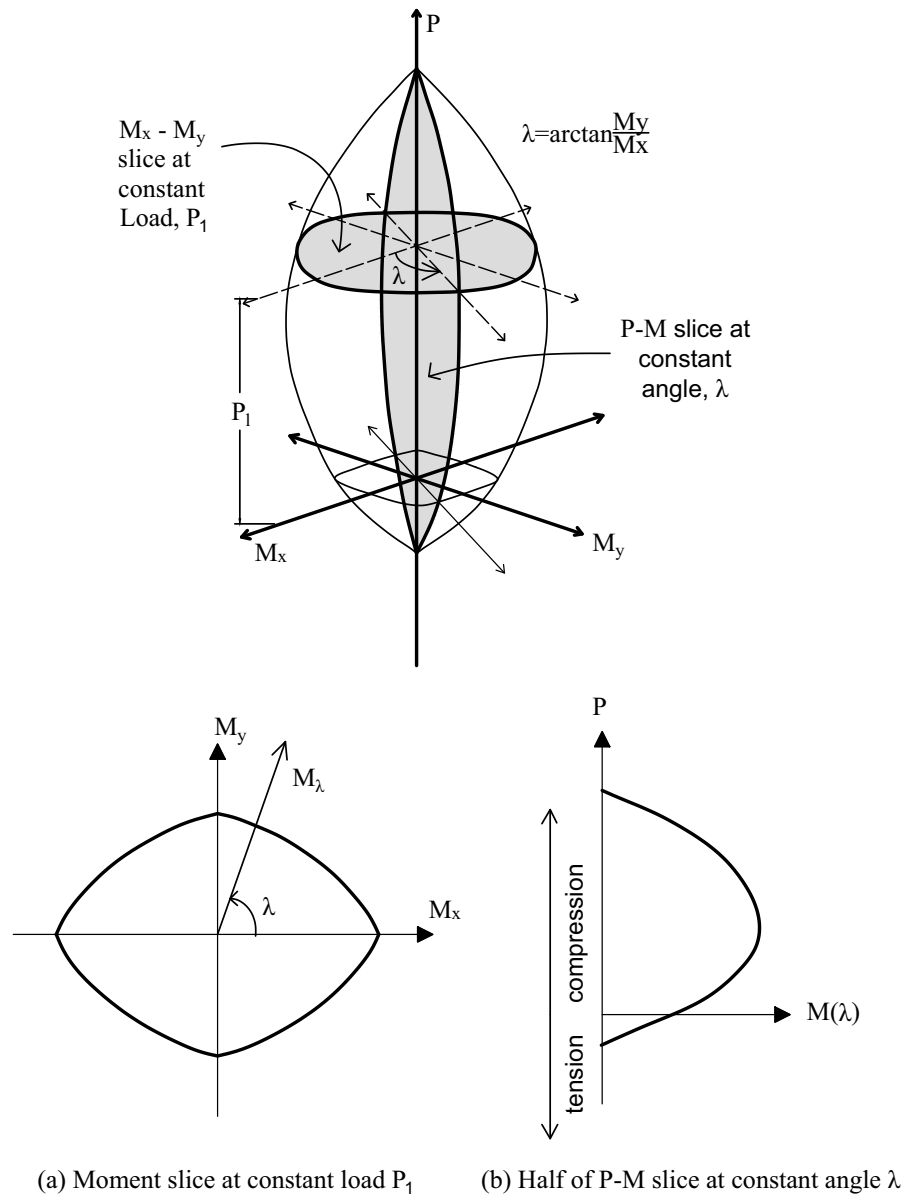
Figure 2-7 Interaction Surface for Combined Axial Load and Biaxial Bending

2.4   Section Design Mode

1. Based on the specified minimum, maximum and increment specified for the section and the reinforcing bars, the program selects the smallest section with the least amount of reinforcement for which the capacity exceeds the applied loads. If service loads are input, they are factored using the input load combinations. Depending on the design criteria the

user selects, the least amount of reinforcement the program searches for means either the smallest number of bars or the smallest steel area.

2. The program starts the design by trying the smallest section (minimum dimensions) and the least amount of reinforcing bars. The program verifies that the ratio of provided reinforcement is always within the specified minimum and maximum ratios. Furthermore, unless otherwise specified by the user[33], the bar spacing is always kept greater than or equal to the larger of 1.5 times the bar diameter or 1.5 in. [40 mm] for ACI[34] and 1.4 times the bar diameter or 1.2 in [30 mm] for CSA[35].

3. A section fails the design if, for any load point the capacity ratio exceeds 1.0 (unless otherwise specified in the Design Criteria dialog box).

4. Once a section passes the design, its capacity is computed and the calculations explained in Procedure 2.3 above are performed.

5. For members with large cross sectional area spColumn sometimes warns the user with the following message "Cannot achieve desired accuracy". This results when the program cannot meet the predefined convergence criteria and the corresponding point on the interaction diagram may be slightly off. The convergence criteria is more stringent than required in engineering practice, however, the shape of the interaction diagram should be verified to be relatively smooth and free of unexpected discontinuity.

2.5 Moment Magnification at Ends of Compression Member

This procedure accounts for moment magnification due to second-order effects at ends of columns in sway frames[36].

1. If properties of framing members are input, spColumn computes the effective length factor, k_s, for sway condition using the following equation[37]:

---

33. The user may select spacing greater than the default value to take into account tolerances for reinforcement placement (see ACI 117-06, Ref [7]) and other project specific considerations.
34. ACI 318-19, 25.2.3; ACI 318-14, 25.2.3; ACI 318-11, 7.6.3; ACI 318-08, 7.6.3; ACI 318-05, 7.6.3; ACI 318-02, 7.6.3
35. CSA A23.3-19, Annex A, 6.6.5.2; CSA A23.3-14, Annex A, 6.6.5.2; CSA A23.3-04, Annex A, 6.6.5.2; CSA A23.3-94, Annex A, A12.5.2
36. ACI 318-19, 6.6.4.6.1; ACI 318-14, 6.6.4.6.1; ACI 318-11, 10.10.7; ACI 318-08, 10.10.7; ACI 318-05, 10.13; ACI 318-02, 10.13; CSA A23.3-19, 10.16; CSA A23.3-14, 10.16; CSA A23.3-04, 10.16; CSA A23.3-94, 10.16
37. Exact formula derived in Ref. [14] pp. 851 for Jackson and Moreland alignment chart

$$\left[\frac{(\pi / k_s)^2 \psi_A \psi_B}{36} - 1 \right] \tan \frac{\pi}{k_s} - \left(\frac{\psi_A + \psi_B}{6} \right) \frac{\pi}{k_s} = 0$$

where ψ is the ratio of $\sum(EI/\ell_c)$ of columns to $\sum(EI/\ell)$ of beams in a plane at one end of the column, ψ_A and ψ_B are the values of ψ at the upper end and the lower end of the column. For a hinged end, ψ is very large. This happens in the case where $\sum(EI/\ell)$ of beams is very small (or zero) relative to the $\sum(EI/\ell_c)$ of columns at that end. In this case, the program outputs 999.9 for the value of ψ. The moment of inertia used in computing ψ is the gross moment of inertia multiplied by the cracked section coefficients[38] (specified in the Slenderness Factors dialog box).

2. For the ACI code[39], slenderness effects will be considered if $k\,\ell_u / r \geq 22.0$. For the CSA standards, all sway columns are designed for slenderness effects.

3. If the ratio $k\ell_u/r$ exceeds 100, slenderness effects cannot be accounted for using moment magnification procedure[40]. A more exact method must be used. In this case, the program issues a warning message and aborts design or investigation procedure except for calculations per ACI 318-19, ACI 318-14, ACI 318-11, and ACI 318-08 where limit of $k\,\ell_u / r < 100$ does not explicitly apply and the program continues calculations after showing the warning message.

4. Factored moments, $M_{ns,top}$ and $M_{ns,bot}$, due to dead, live, and snow loads assumed to cause no appreciable sidesway[41], are calculated at the top and bottom ends of the column.

5. Factored moments, $M_{s,top}$ and $M_{s,bot}$, due to lateral loads (wind and earthquake) assumed to cause appreciable sidesway[42], are calculated at the top and bottom ends of the column.

6. Flexural stiffness EI is calculated as[43]:

---

38. ACI 318-19, 6.6.3.1.1, 6.6.4.2, 6.7.1.3, 6.8.1.4; ACI 318-14, 6.6.3.1.1, 6.6.4.2, 6.7.1.3, 6.8.1.4; ACI 318-11, 10.10.4.1; ACI 318-08, 10.10.4.1; ACI 318-05, 10.11.1, 10.13.1; ACI 318-02, 10.11.1, 10.13.1; CCSA A23.3-14, 10.14.1.2, 10.16.1; CSA A23.3-19, 10.14.1.2, 10.16.1; CSA A23.3-04, 10.14.1.2, 10.16.1; CSA A23.3-94, 10.14.1, 10.16.1

39. ACI 318-19, 6.2.5; ACI 318-14, 6.2.5; ACI 318-11, 10.10.1; ACI 318-08, 10.10.1; ACI 318-05, 10.13.2; ACI 318-02, 10.13.2

40. ACI 318-05, 10.11.5; ACI 318-02, 10.11.5; CSA A23.3-19, 10.13.2; CSA A23.3-14, 10.13.2; CSA A23.3-04, 10.13.2; CSA A23.3-94, 10.13.2

41. ACI 318-19, 2.1; ACI 318-14, 2.1; ACI 318-11, 2.1; ACI 318-08, 2.1; ACI 318-05, 2.1; ACI 318-02, 10.0; CSA A23.3-19, 3.2; CSA A23.3-14, 3.2; CSA A23.3-04, 2.3; CSA A23.3-94, 10.0

42. ACI 318-14, 2.1; ACI 318-11, 2.1; ACI 318-08, 2.1; ACI 318-05, 2.1; ACI 318-02, 10.0; CSA A23.3-04, 2.3; CSA A23.3-94, 10.0

43. ACI 318-19, 6.6.4.4.4, Eq. 6.6.4.4.4b; ACI 318-14, 6.6.4.4.4, Eq. 6.6.4.4.4b; ACI 318-11, 10.10.6 Eq. 10-14; ACI 318-08, 10.10.6 Eq. 10-14; ACI 318-05, 10.12.3 Eq. 10-11; ACI 318-02, 10.12.3. Eq. 10-10; CSA A23.3-14/19, 10.16.3.2, 10.15.3 Eq. 10-19; CSA A23.3-04, 10.16.3.2, 10.15.3 Eq. 10-18; CSA A23.3-94, 10.16.3.2, 10.15.3.1 Eq. 10-18

$$EI = \frac{0.2E_cI_g + E_sI_{se}}{1 + \beta_{ds}}$$

where E_c is the modulus of elasticity of concrete, E_s is the modulus elasticity of steel, I_g is the gross moment of inertia of the concrete section, I_{se} is the moment of inertia of reinforcement. Assuming that shear due to lateral loads is not sustained in most frames[44], the β_{ds} is taken as zero (with the exception of strength and stability of the structure as a whole under factored gravity loads described in Step 11).

7. The critical buckling load, P_c, is computed as[45].

$$P_c = \frac{\pi^2 EI}{(k\,l_u)^2}$$

8. The sway moment magnification factor, δ_s, is computed as[46]:

$$\delta_s = \frac{1.0}{1 - \frac{\Sigma P_u}{\phi_k \Sigma P_c}} \geq 1.0$$

where the stiffness reduction factor, ϕ_K, is equal to 0.75.

ΣP_u is taken as the factored axial load for the load combination under consideration times the ratio $\Sigma P_u/P_u$, i.e.[47] $\Sigma P_u = P_u\,(\Sigma P_u/P_u)$.

ΣP_c is taken as the critical buckling load for the load combination under consideration times the ratio $\Sigma P_c/P_c$, i.e. $\Sigma P_c = P_c\,(\Sigma P_c/P_c)$.

ϕ_K and the ratios $\Sigma P_u/P_u$ and $\Sigma P_c/P_c$ may be modified using the Slenderness Factors input box.

9. The magnified moments at the top and bottom ends of the compression member are computed as[48]:

---

44. ACI 318-19, R6.6.4.6.2(b); ACI 318-14, R6.6.4.6.2(b); ACI 318-11, R10.10.7.4; ACI 318-08, R10.10.7.4; ACI 318-05, R10.13.4.1, R10.13.4.3; ACI 318-02, R10.13.4.1, R10.13.4.3; Ref. [10] pp 586 (first paragraph from the bottom)
45. ACI 318-19, 6.6.4.4.2, Eq. 6.6.4.4.2; ACI 318-14, 6.6.4.4.2, Eq. 6.6.4.4.2; ACI 318-11, 10.10.6 Eq. 10-13; ACI 318-08, 10.10.6 Eq. 10-13; ACI 318-05, 10.12.3 Eq. 10-10; ACI 318-02, 10.12.3 Eq. 10-10; CSA A23.3-19, 10.16.3.2, 10.15.3.1 Eq. 10-18; CSA A23.3-14, 10.16.3.2, 10.15.3.1 Eq. 10-18; CSA A23.3-04, 10.16.3.2, 10.15.3.1 Eq. 10-17; CSA A23.3-94, 10.16.3.2, 10.15.3 Eq. 10-17
46. ACI 318-19, 6.6.4.6.2, Eq. 6.6.4.6.2b; ACI 318-14, 6.6.4.6.2, Eq. 6.6.4.6.2b; ACI 318-11, 10.10.7.4 Eq. 10-21; ACI 318-08, 10.10.7.4 Eq. 10-21; ACI 318-05, 10.13.4.3 Eq. 10-18; ACI 318-02, 10.13.4.3 Eq. 10-18; CSA A23.3-19, 10.16.3.2 Eq. 10-24; CSA A23.3-14, 10.16.3.2 Eq. 10-24; CSA A23.3-04, 10.16.3.2 Eq. 10-23; CSA A23.3-94, 10.16.3.2 Eq. 10-23
47. To minimize required input, the program uses one value of ratio $\Sigma P_u / P_u$ for all load combinations. However, the ratio can vary depending on the combination under consideration. In this case, it will be conservative to use the highest value of the ratio.

$$M_{top} = M_{ns,top} + \delta_s M_{s,top}$$

$$M_{bot} = M_{ns,bot} + \delta_s M_{s,bot}$$

10. The smaller and the larger factored end moments are then determined based on absolute values of magnified top and bottom end moments

$$M_1 = \begin{cases} M_{bot} & if \ |M_{top}| \geq |M_{bot}|, \\ M_{top} & if \ |M_{top}| < |M_{bot}|, \end{cases}$$

$$M_2 = \begin{cases} M_{top} & if \ |M_{top}| \geq |M_{bot}|, \\ M_{bot} & if \ |M_{top}| < |M_{bot}|. \end{cases}$$

While design codes define moment M_2 as always positive and the sign of moment M_1 depending on single or double curvature bending[49], spColumn retains actual signs of moments M_1 and M_2. This revision ensures proper comparison against negative and positive moment capacities of unsymmetrical sections (see Figure 2-8).

11. Strength and stability of the structure as a whole under factored gravity loads[50] is ensured by checking that the value of the moment magnification factor, δ_s. is positive and does not exceed 2.5.

The program performs this check for all load combinations that include only gravity loads with the exception of the ACI 318-19/14/11/08 codes for which the check is not performed and CSA A23.3-94 where the check is performed only for the load combination of 1.25 dead load plus 1.5 live load plus (1.5 snow or 0.0 snow), if this combination is present (default). The β_d factor for the load combination under consideration is equal to the maximum sustained factored axial load to the maximum factored axial load.

48. ACI 318-19, 6.6.4.6.1; ACI 318-14, 6.6.4.6.1; ACI 318-11, 10.10.7; ACI 318-08, 10.10.7; ACI 318-05, 10.13.3; ACI 318-02, 10.13.3; CSA A23.3-19, 10.16.2; CSA A23.3-14, 10.16.2; CSA A23.3-04, 10.16.2; CSA A23.3-94, 10.16.2
49. ACI 318-14, 2.1; ACI 318-11, 2.1; ACI 318-08, 2.1; ACI 318-05, 2.1; ACI 318-02, 10.0; CSA A23.3-19, 3.2;CSA A23.3-14, 3.2; CSA A23.3-04, 2.3; CSA A23.3-94, 10.0
50. ACI 318-05, 10.13.6; ACI 318-02, 10.13.6; CSA A23.3-19, 10.16.5; CSA A23.3-14, 10.16.5; CSA A23.3-04, 10.16.5; CSA A23.3-94, 10.16.5

2.6 Moment Magnification along Length of Compression Member

This procedure accounts for moment magnification due to second-order effect along the length of compression members that are part of either nonsway[51] or sway frames[52]. In nonsway frames, moment magnification along length is neglected by the program if the condition in Step 3 is satisfied.

In sway frames designed per ACI 318-02/05 and CSA A23.3-94/04/14/19, the magnification along the length is neglected if[53]:

$$\frac{\ell_u}{r} \leq \frac{35}{\sqrt{\dfrac{P_u}{f'_c A_g}}}$$

By rearranging and introducing $k' = \sqrt{P_u / (f'_c A_g)}$, this condition can be succinctly expressed as $k' \ell_u / r \leq 35$. For columns designed per ACI 318-19, ACI 318-14, ACI 318-11, and ACI 318-08 codes, moment magnification along length is to be considered for all slender compression members, i.e. columns in either nonsway or sway frames regardless of the $k' \ell_u / r$ ratio. Since various published examples of columns designed per ACI 318-19, ACI 318-14, ACI 318-11, and ACI 318-08 do not combine moment magnification at ends and along length of columns in sway frames[54], spColumn optionally allows not considering moment magnification along the length of a column in a sway frame based on engineering judgment of the user.

When moment magnification along the length of a compression member is considered, the following procedure is followed:

1. The effective length factor, **k**, is either entered by the user or calculated by the program. The value of **k** must be between 0.5 and 1.0 for moment magnification along length and the recommended[55] value is 1.0. Smaller values can be used if justified by analysis. If

51. ACI 318-19, 6.6.4.4.2, 6.6.4.5.1, 6.6.4.5.2; ACI 318-14, 6.6.4.4.2, 6.6.4.5.1, 6.6.4.5.2; ACI 318-11, 10.10.6; ACI 318-08, 10.10.6; ACI 318-05, 10.12; ACI 318-02, 10.12; CSA A23.3-19, 10.15; CSA A23.3-14, 10.15; CSA A23.3-04, 10.15; CSA A23.3-94, 10.15

52. ACI 318-19, 6.6.1.1; ACI 318-14, 6.6.1.1; ACI 318-11, 10.10.2.2; ACI 318-08, 10.10.2.2; ACI 318-05, 10.13.5; ACI 318-02, 10.13.5; CSA A23.3-19, 10.16.4; CSA A23.3-14, 10.16.4; CSA A23.3-04, 10.16.4; CSA A23.3-94, 10.16.4

53. ACI 318-05, Eq. 10-19; ACI 318-02, Eq. 10-19; CSA A23.3-04, Eq. 10-26; CSA A23.3-04, Eq. 10-25; CSA A23.3-94, Eq. 10-25

54. See Example 11.2 in Ref. [11], Example 12.4 in Ref. [13], and Example 12.3 in Ref. [12]

properties of framing members are input, spColumn computes the effective length factor, k, for nonsway condition from the following equation[56]:

$$\frac{\psi_A \psi_B}{4}\left(\frac{\pi^2}{k^2}\right) + \left(\frac{\psi_A + \psi_B}{2}\right)\left(1 - \frac{\pi/k}{\tan(\pi/k)}\right) + \frac{2}{\pi/k}\tan\frac{\pi}{2k} = 1$$

Where ψ is the ratio of $\sum(EI/\ell_c)$ of columns to $\sum(EI/\ell)$ of beams in a plane at one end of the column, ψA and ψB are the values of ψ at the upper end and the lower end of the column, respectively. Moments of inertia used in computing ψ factors are gross moments of inertia multiplied by the cracked section coefficients[57] (specified in the Slenderness Factors dialog box).

2. Moments at column ends, M_1 and M_2, are calculated, where M_1 is the moment with the smaller absolute value and M_2 is the moment with the larger absolute value. For columns in nonsway frames, the end moments will be equal to the factored applied first order moment. For columns in sway frames, the end moments will be the moments M_1 and M_2 calculated in the procedure for moment magnification at ends of compression member. While design codes define moment M_2 as always positive and the sign of moment M_1 depending on single or double curvature bending[58], spColumn retains actual signs of moments M_1 and M_2 to ensure proper comparison of resulting magnified moments against negative and positive moment capacities of unsymmetrical sections (see Figure 2-8). This revised interpretation does not affect results of the moment magnification along length procedure because the procedure relies on the M_1/M_2 ratio. spColumn follows the code definition which assumes the ratio to be positive if the member is bent in single curvature and negative if bent in double curvature. If both moments are equal to zero, the program conservatively assumes the ratio of M_1/M_2=**1.0**.

3. Second-order effects along length for columns in nonsway frames can be ignored if:

$$\frac{k\,\ell_u}{r} \le 34 - 12\frac{M_1}{M_2} \le 40 \text{ for ACI codes}[59],$$

---

55. ACI 318-19, 6.6.4.4.3, R6.6.4.4.3; ACI 318-14, 6.6.4.4.3, R6.6.4.4.3; ACI 318-11, 10.10.6.3, R10.10.6.3; ACI 318-08, 10.10.6.3, R10.10.6.3; ACI 318-05, 10.12.1; ACI 318-02, 10.12.1; CSA A23.3-19, 10.15.1; CSA A23.3-14, 10.15.1; CSA A23.3-04, 10.15.1; CSA A23.3-94, 10.15.1

56. Exact formula derived in Ref. [14] pp. 848 for Jackson and Moreland alignment chart

57. ACI 318-19, 6.6.3.1.1, 6.6.4.2, 6.7.1.3, 6.8.1.4; ACI 318-14, 6.6.3.1.1, 6.6.4.2, 6.7.1.3, 6.8.1.4; ACI 318-11, 10.10.4.1; ACI 318-08, 10.10.4.1; ACI 318-05, 10.11.1, 10.12.1; ACI 318-02, 10.11.1, 10.12.1; CSA A23.3-19, 10.14.1.2, CSA A23.3-14, 10.14.1.2, 10.15.1; CSA A23.3-04, 10.14.1.2, 10.15.1; CSA A23.3-94, 10.14.1, 10.15.1

58. ACI 318-14, 2.1; ACI 318-11, 2.1; ACI 318-08, 2.1; ACI 318-05, 2.1; ACI 318-02, 10.0; CSA A23.3-19, 3.2; CSA A23.3-14, 3.2;CSA A23.3-04, 2.3; CSA A23.3-94, 10.0

59. ACI 318-19, 6.2.5.1; ACI 318-14, 6.2.5; ACI 318-11, 10.10.1; ACI 318-08, 10.10.1; ACI 318-05, 10.12.2; ACI 318-02, 10.12.2

and

$$\frac{k\,\ell_u}{r} \le \frac{25 - 10(M_1 / M_2)}{\sqrt{P_f / \left(f'_c A_g\right)}}, \text{ for the CSA standards}[60],$$

where ℓ_u is the unsupported column length, $r = \sqrt{I_g / A}$ is the radius of gyration, and the ratio M_1/M_2 is always taken as greater than or equal to –0.5. (For CSA A23.3-19, if M_2 is less than $M_{2,min}$ the M_1/M_2 ratio shall be taken as equal to 1.0)

4. If the ratio $k\,\ell_u/r$ exceeds 100, slenderness effects cannot be accounted for using moment magnification procedure[61]. A more exact method must be used. In this case, the program issues a warning message and aborts design or investigation procedure except for calculations per ACI 318-19, ACI 318-14, ACI 318-11, and ACI 318-08 where limit of $k\,\ell_u/r < 100$ does not explicitly apply and the program continues calculations after showing the warning message.

5. The factor C_m is computed as[62]:

$$C_m = 0.6 + 0.4\frac{M_1}{M_2}$$

and for codes other than ACI 318-19, ACI 318-14, ACI 318-11, and ACI 318-08, C_m is taken as not less than 0.4.

If $M_1=M_2=0$, the program assumes C_m to be equal to 1.0[63]. This is consistent with the assumption made above (in Step 2).

For CSA A23.3-19, if $M_{2,min}$ exceeds M_2, C_m shall be taken as equal to 1.0[64].

60. CSA A23.3-19, 10.15.2; CSA A23.3-14, 10.15.2; CSA A23.3-04, 10.15.2; CSA A23.3-94, 10.15.2
61. ACI 318-05, 10.11.5; ACI 318-02, 10.11.5; CSA A23.3-14, 10.13.2; CSA A23.3-04, 10.13.2; CSA A23.3-94, 10.13.2
62. ACI 318-19, 6.6.4.5.3; ACI 318-14, 6.6.4.5.3; ACI 318-11, 10.10.6.4; ACI 318-08, 10.10.6.4; ACI 318-05, 10.12.3.1; ACI 318-02, 10.12.3.1; CSA A23.3-19, 10.15.3.2; CSA A23.3-14, 10.15.3.2; CSA A23.3-04, 10.15.3.2; CSA A23.3-94, 10.15.3.1
63. ACI 318-19, 6.6.4.5.4; ACI 318-14, 6.6.4.5.4; ACI 318-11, 10.10.6.5; ACI 318-08, 10.10.6.5; ACI 318-05, 10.12.3.2; ACI 318-02, 10.12.3.2
64. CSA A23.3-19, 10.15.3.1

6. The sustained load factor β_{dns} (β_d for ACI 318-05/02 and CSA A23.3-14/04/94) is computed as the ratio of maximum factored axial sustained load to the maximum factored axial load for the load combination under consideration for compression members either in nonsway[65] or sway[66] frames. The value of β_{dns} is not taken greater than 1.0.

7. Flexural stiffness EI is computed as[67]:

$$EI = \frac{0.2E_c I_g + E_s I_{se}}{1 + \beta_{dns}}$$

where E_c is the modulus of elasticity of concrete, E_s is the modulus of elasticity of steel, I_g is the gross moment of inertia of the concrete section, and I_{se} is the moment of inertia of reinforcement.

8. The critical buckling load, P_c is computed as[68]:

$$P_c = \frac{\pi^2 EI}{(k\ell_u)^2}$$

9. The magnification factor for moment along length, δ, is computed as[69]:

$$\delta = \frac{C_m}{1 - \frac{P_u}{\phi_K P_c}} \geq 1.0$$

where the stiffness reduction factor, ϕ_k, is equal to 0.75 (may be modified using the Slenderness Factors input box) and P_u is the factored axial load for the load combination under consideration.

65. ACI 318-14, 6.6.4.4.4; ACI 318-14, 6.6.4.4.4; ACI 318-11, 10.10.6.2; ACI 318-08, 10.10.6.2; ACI 318-05, 10.11.1; ACI 318-02, 10.0; CSA A23.3-19, 3.2; CSA A23.3-14, 3.2; CSA A23.3-04, 2.3; CSA A23.3-94, 10.0

66. ACI 318-19, 6.6.1.1; ACI 318-14, 6.6.1.1; ACI 318-11, 10.10.2.2, 10.10.6.2; ACI 318-08, 10.10.2.2, 10.10.6.2; ACI 318-05, 10.13.5; ACI 318-02, 10.13.5; CSA A23.3-19, 10.14.1.3(a), 10.16.4; CSA A23.3-14, 10.14.1.3(a), 10.16.4; CSA A23.3-04, 10.14.1.3(a), 10.16.4; CSA A23.3-94, β_d definition (a) in 10.0, 10.16.4

67. ACI 318-19, 6.6.4.4.4 Eq. 6.6.4.4.4(b); ACI 318-14, 6.6.4.4.4 Eq. 6.6.4.4.4(b); ACI 318-11, 10.10.6.1 Eq. 10-14; ACI 318-08, 10.10.6.1 Eq. 10-14; ACI 318-05, 10.12.3 Eq. 10-11; ACI 318-02, 10.12.3. Eq. 10-10; CSA A23.3-19, 10.15.3 Eq. 10-19; CSA A23.3-14, 10.15.3.2 Eq. 10-19; CSA A23.3-04, 10.15.3.1 Eq. 10-18; CSA A23.3-94, 10.15.3.1 Eq. 10-18

68. ACI 318-19, 6.6.4.4.2, Eq. 6.6.4.4.2; ACI 318-14, 6.6.4.4.2, Eq. 6.6.4.4.2; ACI 318-11, 10.10.6 Eq. 10-13; ACI 318-08, 10.10.6 Eq. 10-13; ACI 318-05, 10.12.3 Eq. 10-10; ACI 318-02, 10.12.3 Eq. 10-10; CSA A23.3-19, 10.15.3.1 Eq. 10-18; CSA A23.3-14, 10.15.3.1 Eq. 10-18; CSA A23.3-04, 10.15.3.1 Eq. 10-17; CSA A23.3-94, 10.15.3 Eq. 10-17

69. ACI 318-19, 6.6.4.5.2 Eq. 6.6.4.5.2; ACI 318-14, 6.6.4.5.2 Eq. 6.6.4.5.2; ACI 318-11, 10.10.6 Eq. 10-12; ACI 318-08, 10.10.6 Eq. 10-12; ACI 318-05, 10.12.3 Eq. 10.9; ACI 318-02, 10.12.3 Eq. 10.9; CSA A23.3-19, 10.15.3.1 Eq. 10-17; CSA A23.3-14, 10.15.3.1 Eq. 10-17; CSA A23.3-04, 10.15.3.1 Eq. 10-16; CSA A23.3-94, 10.15.3 Eq. 10-16

10. The moment due to minimum eccentricity, e_{min} is computed as[70]:

$M_{min} = P_u e_{min}$, where

$e_{min} = 0.6 + 0.03h$, with h in inches,

$e_{min} = 15 + 0.03h$, with h in mm,

and h is the section dimension (diameter for circular sections) in the direction being considered.

11. The factored magnified moment along the length of a compression member, M_c, is the larger[71] of δM_2 and δM_{min}. The program also calculates moment M_c based on the smaller end moment, M_1, to account for scenario when M_1 and M_2 are of different sign (double curvature bending). For an unsymmetrical section, the smaller moment, M_1, may govern the design when the moment capacity on the negative side of the interaction diagram is smaller than the moment capacity on the positive side (see Figure 2-8).

70. ACI 318-19, 6.6.4.5.4; ACI 318-14, 6.6.4.5.4; ACI 318-11, 10.10.6.5; ACI 318-08, 10.10.6.5; ACI 318-05, 10.12.3.2; ACI 318M-05, 10.12.3.2; ACI 318-02, 10.12.3.2; ACI 318M-02 10.12.3.2; CSA A23.3-19, 10.15.3.1; CSA A23.3-14, 10.15.3.1; CSA A23.3-04, 10.15.3.1; CSA A23.3-94, 10.15.3.
71. ACI 318-19, 6.6.4.5.4; ACI 318-14, 6.6.4.5.4; ACI 318-11, 10.10.6.5; ACI 318-08, 10.10.6.5; ACI 318-05, 10.12.3.2; ACI 318-02, 10.12.3.2; CSA A23.3-19, 10.15.3.1; CSA A23.3-14, 10.15.3.1; CSA A23.3-04, 10.15.3.1; CSA A23.3-94, 10.15.3
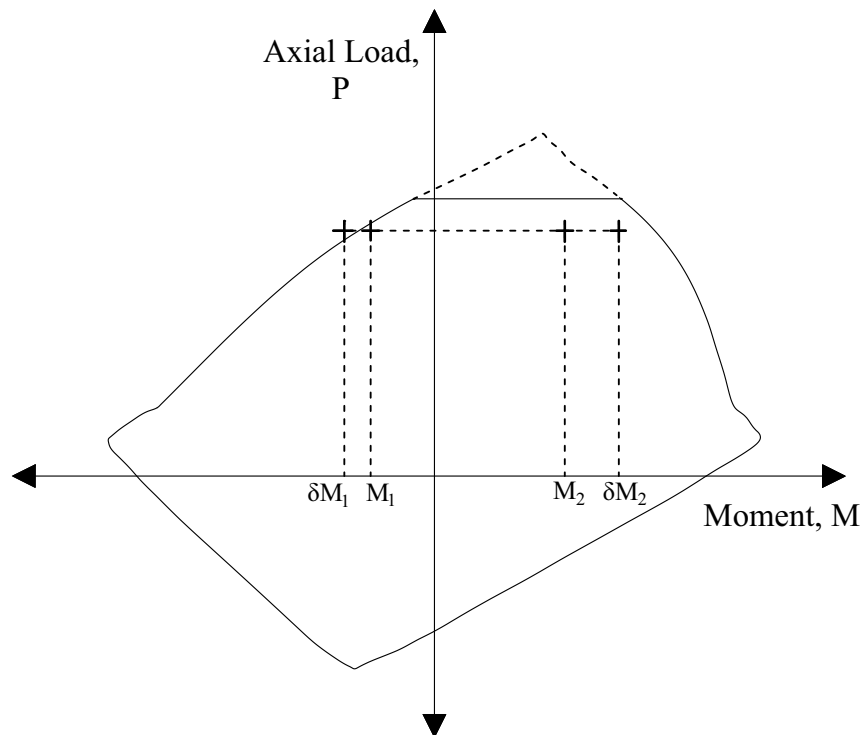
Figure 2-8 Case of unsymmetrical section bent in double curvature (M_1 and M_2 of different sign) with the smaller end moment, M_1, governing the design

2.7   Moments Magnification Ratio

For calculations in accordance with ACI 318-19/14/11/08, the value of total magnified moment including second-order effects (combined magnification at ends and along length of compression member) cannot exceed 1.4 times the corresponding moment due to first order effects[72]. Columns with second-order moment to first-order moment ratios exceeding 1.4 do not meet requirements of ACI 318-19/14/11/08.

The ratio of second-order moment, M_{2nd}, to first-order moment M_{1st} is calculated for both values (i =1, 2) of magnified moment along length, M_{c_i}, i.e. based on M_1 and M_2:

---

72. ACI 318-19, 6.2.5.3; ACI 318-14, 6.2.6; ACI 318-11, 10.10.2.1; ACI 318-08, 10.10.2.1

$$\frac{M_{2nd_i}}{M_{1st_i}} = \begin{cases} \dfrac{M_{c_i}}{M_{u_i}} & if \ \left|M_{u_i}\right| \geq \left|M_{min}\right| \\[3mm] \dfrac{M_{c_i}}{M_{min}} & if \ \left|M_{u_i}\right| < \left|M_{min}\right| \end{cases}$$

Cutoff value of M_{min} is applied to M_{u_i} in order to avoid unduly large ratios in cases where M_{u_i} moments are smaller than M_{min}.

If only magnification at ends is considered (i.e. when user chooses to bypass provision 10.10.2.2 of ACI 318-11/08 and provision 6.6.4.6.4 of ACI 318-19/14 and ignores second order effects along the length of a compression member in a sway frame), the ratio of second-order moment, M_{2nd}, to first-order moment, M_{1st}, is calculated at both ends (i =1, 2) as:

$$\frac{M_{2nd_i}}{M_{1st_i}} = \frac{M_i}{M_{u_i}} = \frac{M_{ins} + \delta_s M_{is}}{M_{ins} + M_{is}}$$

where M_i are the magnified end moments M_1 and M_2, and M_{u_i} are the corresponding factored applied moment composed of the part that causes no appreciable sidesway, M_{ins}, and the part that causes appreciable sidesway, M_{is}. If both M_{2nd_i} and M_{1st_i} moments are equal to zero, the program will report the ratio equal to 1.0. If only M_{1st_i} moment is equal to zero, the program will report the ratio as a large value.

2.8   Section Capacity

The program computes capacity ratio for all load points. For a load point, capacity ratio is always computed at the same angles as that produced by the applied M_x and M_y moments of that load point.
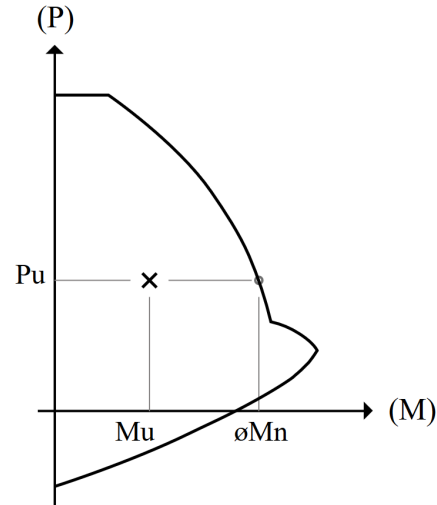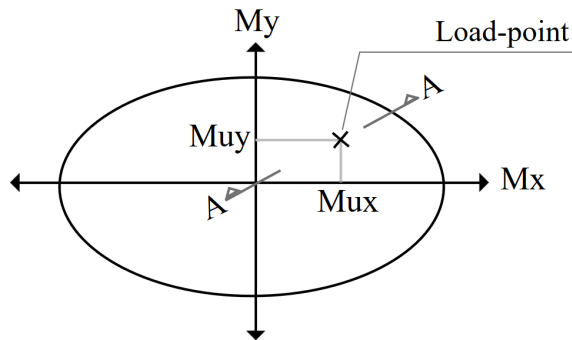
Section A-A (P-M Diagram)

The user can select one of the two available methods i.e. Moment-capacity or Critical-capacity, for calculation of capacity ratio. In both methods:

Capacity ratio < 1   : internal load-point (is safe)

Capacity ratio = 1   : load point on diagram

Capacity ratio > 1   : external load point

Moment capacity

$$CapacityRatio = \frac{M_u}{\Phi M_n}$$

Sometimes the value of ΦMn cannot be obtained. In such cases the program reports a Capacity ratio of "< 1" for load points inside the failure surface and a Capacity ratio of "> 1" for load points outside the failure surface.

Critical capacity

Critical capacity ratio calculation is based on the closest distance (d) of a load-point from the interaction diagram. But because the horizontal axis (M) & vertical axis (P) of P-M diagrams have different units and scales, spColumn uses a normalized diagram for the calculation of closest distance (d).

The normalized diagram is created by:

Dividing all "P" components of diagram-points and load-points by P_{max}

Dividing all "M" components of diagram-points and load-points by M_{max}

P-M Diagram Normalized P-M Diagram
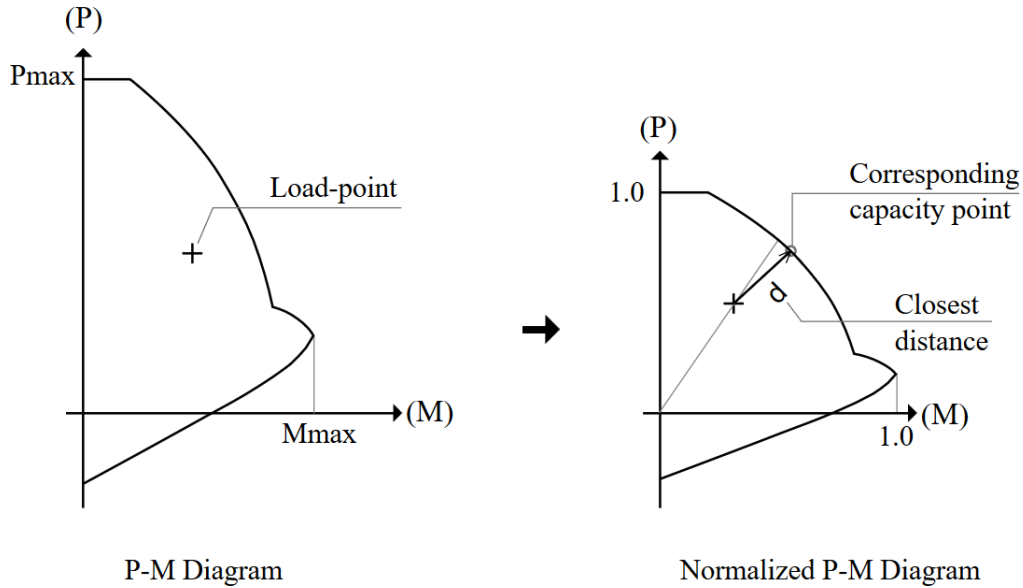
And the Critical capacity ratio of a load-point is:

Capacity ratio = 1 - d   : internal load-point (is safe)

Capacity ratio = 1   : load point on diagram

Capacity ratio = 1 + d   : external load point

The closest distance (d) can alternatively be calculated by finding the corresponding capacity point $(\Phi Pn, \Phi Mn)$ on the diagram which minimizes the following equation:

$$d = \sqrt{\left(\frac{\Phi P_n - P_u}{P_{max}}\right)^2 + \left(\frac{\Phi M_n - M_u}{M_{max}}\right)^2}$$

2.9   References

[1] Building Code Requirements for Structural Concrete (ACI 318-19) and Commentary (ACI 318R-19), American Concrete Institute, 2019
[2] Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (ACI 318R-14), American Concrete Institute, 2014
[3] Building Code Requirements for Structural Concrete (ACI 318-11) and Commentary (ACI 318R-11), American Concrete Institute, 2011
[4] Building Code Requirements for Structural Concrete (ACI 318-08) and Commentary (ACI 318R-08), American Concrete Institute, 2008
[5] Building Code Requirements for Structural Concrete (ACI 318-05) and Commentary (ACI 318R-05), American Concrete Institute, 2005

[6] Building Code Requirements for Structural Concrete (ACI 318-02) and Commentary (ACI 318R-02), American Concrete Institute, 2002

[7] Specification for Tolerances for Concrete and Materials and Commentary, An ACI Standard (ACI 117-06), American Concrete Institute, 2006

[8] A23.3-04, Design of Concrete Structures, Canadian Standards Association, 2004

[9] A23.3-94, Design of Concrete Structures, Canadian Standards Association, 1994 (Reaffirmed 2000)

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[12] Wight J.K. and MacGregor J.G., Reinforced Concrete, Mechanics and Design, Fifth Edition, Pearson Prentice Hall, 2009

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[17] National Building Code of Canada 2010, Volume 1, Canadian Commission on Buildings and Fire Codes, National Research Council of Canada, 2010

[18] A23.3-14, Design of Concrete Structures, Canadian Standards Association, 2019

CHAPTER

3

spColumn INTERFACE

3.1 spColumn Interface

The **spColumn Interface** will appear after the program is started as shown below. The **spColumn Interface** consists of a **Control Menu**, **Title Bar**, **Menu Bar**, **Toolbar**, **Information Bar**, **Graphics Bar**, and a **Status Bar**. The program name and current data file name is shown in the **Title Bar**. All the menu commands can be accessed from the **Menu Bar** and some frequently used commands also can be accessed from the buttons in the **Toolbar**. The **Status Bar** shows the current state of the program.
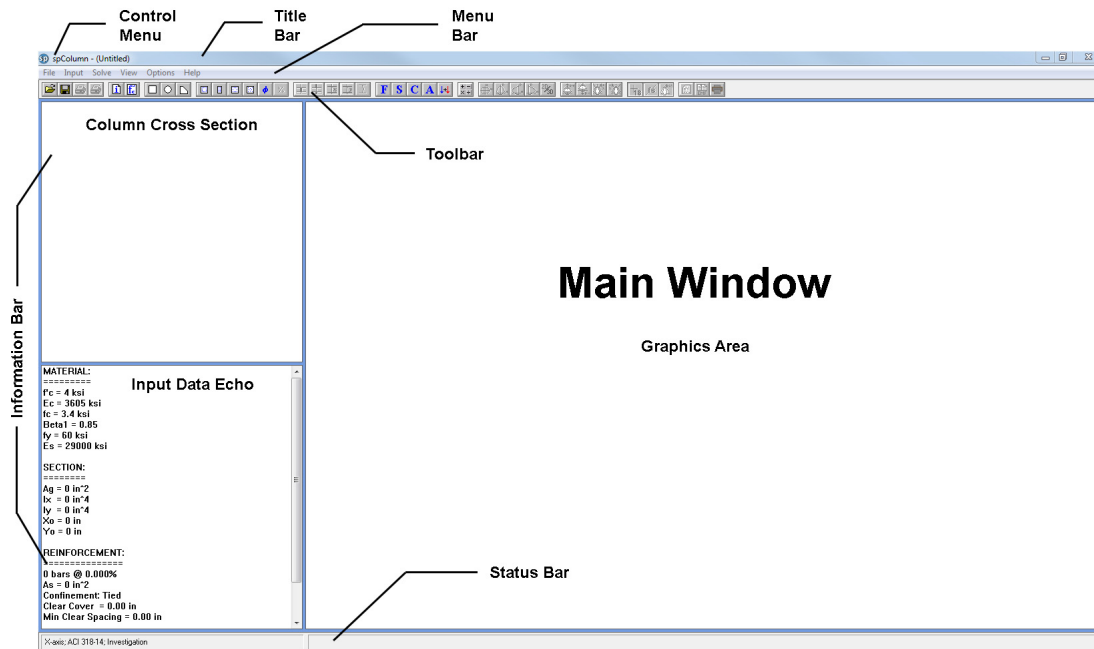
Figure 3-1 Main Window

Control Menu

The **Control** menu is located in the upper-left corner of the window and includes commands for sizing, moving, enlarging, restoring, and closing the window, as well as switching to other applications. To access the **Control** menu using the mouse, click the left mouse button on the box; using the keyboard, press ALT+ SPACEBAR.

Title Bar

The **Title Bar** displays the name of the application (spColumn in this case), along with the name of the current data file in use. If the data has not been saved into a file, the word Untitled is displayed in the **Title Bar**.

Menu Bar

The **Menu Bar** is located directly beneath the **Title Bar**. It lists the available menus. There is a total of 6 distinct drop-down menus accessible from the **Menu Bar**. The majority of commands appearing in the drop-down menus are also accessible via the program's **Main Window** area.

Toolbar

The **Toolbar** is located directly below the **Menu** bar. It contains a collection of buttons (or icons) that provide a shortcut to accessing the menu commands. The **Toolbar** buttons can only be accessed using the mouse.

Information Bar

The **Information** bar is located on the left side of the spColumn window. The top part displays the column cross section. The bottom part is a list of selected input data echo.

Graphics Area

The **Graphics Area** covers most of the window. This is where the interaction diagram is shown.

Status Bar

The **Status Bar** is located directly beneath the program's **Main Window** area. It displays important information such as units, design code, cursor position, and helpful messages.

3.2   File Menu

The **File** menu gives access to file operations, printing operations and to exiting the spColumn program.

New (CTRL+N)

Clears any input data and returns the data to the default values so that a new data file may be input.

Open (CTRL+O)

Opens an existing data file.

Save (CTRL+S)

Saves the changes you have made to the current input file under that same filename.
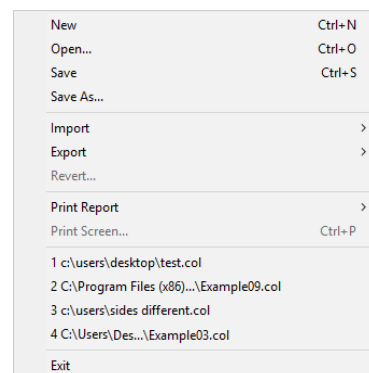
Save As

Enables you to name or rename a data file.

Import

Reads geometry, reinforcement or loads data from an ASCII (TXT) file, or imports section geometry and reinforcement from a DXF file.

Export

Exports interaction diagram and 3D failure surface to Comma-Separated Values (CSV) files (readable by most spreadsheet programs) or Tab-Delimited Text (TXT) files. Exports a column section to Drawing Exchange Format (DXF) file (readable by most CAD programs). Exports graphical report (screen printout) to Enhanced Metafile Format (EMF) file (readable by most graphics and word processing programs).

Revert

Discards any changes to the data file and returns to the most recently saved version of the data file. This option will only be available if the data file has been previously saved and there have been modifications done on the data file since. Do not save the data file immediately prior to reverting otherwise this command will have no effect.

Print Report

Provides the option to print **Default** report or **Customize** the report before printing.

Print Screen (CTRL+P)

Prints the graphical image displayed in the **Graphics/Input Area** of the **Main Window**. Displays Print dialog box and prints the results similarly as they appear on the screen.

Recent Data File List

Provides quick access to up to four recently open data files.

Exit

Ends the spColumn program. If you have made any changes to your data and have not saved them, spColumn will prompt you whether you want to save or abandon any changes you have made before you exit.

3.3 Input Menu

The **Input Menu** includes commands used to input the data needed to define a problem. The **Input Menu** contains the following commands: **General Information**, **Material Properties**, **Section**, **Reinforcement**, **Slenderness**, **Loads**, and **Flip/Rotate Section**.
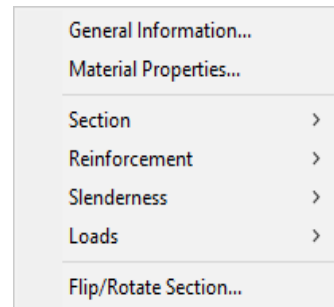
General Information

The **General Information** command allows you to enter the project, column and engineer names. It also allows the selection of units, run options, run axis and slenderness consideration.

Material Properties

The **Material Properties** command enables you to input material properties for concrete and reinforcing steel.

Section

Rectangular: Input the dimensions of a rectangular section.

Circular: Input the diameter of a circular section.

Irregular: Initiates spSection module to define an irregularly shaped section. *Available under investigation option only*. See Chapter 6 for spSection module.

Reinforcement

All Sides Equal: Input a reinforcement pattern in which all the bars are of one size, and the number of bars is the same on all four sides of a rectangular layout or are equally spaced for a circular layout. Number of bars should be enter as multiple of four (4). *Available for rectangular and circular sections.*

Equal Spacing: Input a reinforcement pattern in which all bars are of one size and are uniformly spaced on all four sides of a rectangular layout. Number of bars should be entered as multiple of four (4). *Available for rectangular sections only.*

Sides Different: Input a reinforcement pattern in which each one of the four sides of a rectangular section has a certain number of bars and a certain bar size. *Available for rectangular sections only.*

Irregular Pattern: Input a reinforcement pattern in such a way that bars of any size can be placed anywhere within the column section.

Confinement: Input confinement-related data such as the capacity reduction factors and the size of ties associated with the longitudinal bar size.

Design Criteria: Input parameters that govern the design of the section such as column type, minimum and maximum reinforcement ratio, bar selection criterion, minimum clear spacing, and allowable capacity (ratio).

Slenderness

Design Column: Input data needed for slenderness related to the column being considered.

Column Above/Below: Input data needed for slenderness related to the columns above and below the design column.

X-Beams: Input data needed for slenderness related to beams perpendicular to the x-axis framing into the design column at top and bottom joints.

Y-Beams: Input data needed for slenderness related to beams perpendicular to the y-axis framing into the design column at top and bottom joints.

Factors: Slenderness factors related to stiffness reduction factor and cracked-section coefficients. Code defaults are selected by default. However, user-defined selection is also available.

Loads

Factored: Input factored axial loads and moments. *This option is available for non-slender columns only.*

Service: Input service-level (dead, live, wind, earthquake, and snow) axial loads and moments about the active axis. Moments are input at the top and at the bottom of the column. *This option is available for both slender and non-slender columns.*

Control Points: If chosen, the program will compute key points on the interaction diagram. In addition, the splice regions are shown on the interaction diagram. *This option is available for non-slender columns under the investigation option only. Also the splice lines are only shown for uniaxial runs.*

Axial Loads: Input a group of axial loads with an initial value, a final value, and an increment. *This option is available for uniaxial non-slender columns under the investigation option only.*

Load Combinations: Input the load factors and combinations used to combine the service loads.

Flip/Rotate Section

Flip an unsymmetrical section about an axis or rotate an irregular section (created in spSection).

3.4   Solve Menu

The **Solve Menu** contains the command to execute the design or investigation calculations along with options that control inclusion of nominal capacity calculations, tracing through the design process, and creating the classic results file. The **Solve Menu** contains the following commands: **Execute**, **Include Nominal Diagram**, **Design Trace**, and **Results File**.

Execute	F5
Include Nominal Diagram	
Design Trace	
Classic Results File	
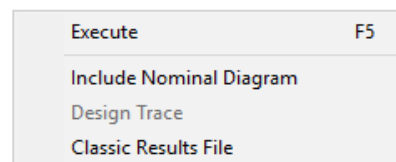
Execute (F5)

Executes the Solver.

Include Nominal Diagram

Toggles INCLUDE NOMINAL DIAGRAM option on and off.

Design Trace

Toggles DESIGN TRACE option on and off.

Classic Results File

Toggles CLASSIC RESULTS FILE option on and off.

3.5   View Menu

The **View** menu commands can be used to customize the
display screen to suit your viewing needs and enable you
to view the result diagrams. The **View** menu contains the
following commands: **Results, Reporter, Redraw,
Copy Diagram to Clipboard, Information Bar, Tool
Bar, Status Bar, Grid, Mx-My Diagram, P-M
Diagram - Full, P-M Diagram - M Positive, P-M
Diagram - M Negative, 2D/3D Viewer, Next Load,
Previous Load, Next Angle, Previous Angle, Show
Load Point Labels, Show Splice Lines, Show Normal
Diagram, Superimpose...**

Results		F6
Reporter		F7
Redraw		
Copy Diagram to Clipboard		Ctrl+C
✓	Information Bar	
✓	Tool Bar	
✓	Status Bar	
	Grid	
✓	Mx-My Diagram	
	P-M Diagram - Full	
	P-M Diagram - M positive	
	P-M Diagram - M negative	
	2D/3D Viewer	
	Next Load	Ctrl+Arrow Up
	Previous Load	Ctrl+Arrow Down
	Next Angle	Ctrl+Arrow Right
	Previous Angle	Ctrl+Arrow Left
✓	Show Load Point Labels	
	Show Splice Lines	
✓	Show Nominal Diagram	
	Superimpose...	

Results (F6)

Executes the spResults module to view the input and
output data after a successful run has been performed.

Reporter (F7)

Executes the spReporter module to generate and print reports after a successful run has been
performed.

Redraw

Redraws the displayed diagrams or contours.

Copy Diagram to Clipboard (CTRL+C)

Copies the displayed diagram or contour to clipboard so that in can be pasted in other
applications.

Information Bar

Shows or hides the **Information Bar**.

Tool Bar

Shows or hides the **Tool Bar**.

Status Bar

Toggles the **Status Bar** at the bottom of the screen on or off.

Grid

Shows or hides the **Grid**.

Mx-My Diagram

View a contour of the failure surface sliced at a constant axial load.

P-M Diagram - Full

View an interaction diagram sliced at a constant (M_x, M_y) angle drawn for both positive and negative moments.

P-M Diagram - M positive

View an interaction diagram sliced at a constant (M_x, M_y) angle drawn for the positive moments only.

P-M Diagram - M negative

View an interaction diagram sliced at a constant (M_x, M_y) angle drawn for the negative moments only.

2D/3D Viewer

View and analyze 2D interaction diagrams and contours along with 3D failure surfaces in a multi viewport environment.

Next Load (Ctrl + Arrow Up)

View an M_x-M_y interaction diagram for the factored load next to the one displayed currently on the interaction diagram.

Previous Load (Ctrl + Arrow Up)

View an M_x-M_y interaction diagram for the factored load previous to the one displayed currently on the interaction diagram.

Next Angle

View a P-M interaction diagram for the (M_x, M_y) angle next to the one currently displayed on the interaction diagram.

Previous Angle

View a P-M interaction diagram for the (M_x, M_y) angle previous to the one currently displayed on the interaction diagram.

Show Load Point Labels

Show/Hide Load Point labels of loads input.

Show Splice Lines

Show the P-M splice lines corresponding to $f_s = 0$ and $f_s = 0.5f_y$.

Show Nominal Diagram
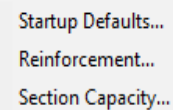
Show nominal (unfactored) capacity interaction diagram in addition to the design (factored) capacity interaction diagram. Available only when **Include Nominal Diagram** option is selected in the **Solve** menu.

Superimpose

Superimpose an interaction diagram from a previously saved run over the current interaction diagram.

3.6   Options Menu

The **Options** menu allows you to change the startup options of the spColumn program to suit your needs. The **Options** menu contains the following commands: **Startup Defaults** and **Reinforcement.**

| Startup Defaults... |
| Reinforcement... |
| Section Capacity... |

Startup Defaults

The **Startup Defaults** command allows you to change the default system of units, design code, reinforcement database, and the data directory which is where the program looks for data when it is executed.

Reinforcement

View or Edit reinforcing bar set.

Section Capacity

The **Section Capacity** command allows you to change the method by which the adequacy of the system to the set of applied loads is checked.

3.7   Help Menu

The **Help** menu includes commands that enable you to obtain online help for the program and show the copyright and registration information about your software.

spColumn Info

Opens information page for the current version of spColumn being used in the default browser. Internet connection is required.

Submit a Question

Opens "Submit a Question" page where you can ask questions on
Technical, Licensing, Sales, Pricing or other topics via e-mail. Internet connection is required.

Manual

Opens spColumn Manual in the default browser. Internet connection is required.

Help

Uses the default browser to open spColumn Help. It provides access to all available help topics. Click on any topic and a help screen will appear with information about that item. Internet connection is required.

Tutorial Videos

Uses the default browser to open a page containing spColumn tutorial videos. Internet connection is required.

Design Examples
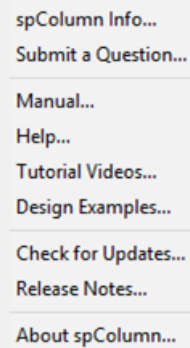
Uses the default browser to open a page containing design examples for StructurePoint software. Internet connection is required.

Check for Updates

Checks if a newer version of spColumn is available. Internet connection is required.

Release Notes

Uses default browser to open a page containing release notes for the version of spColumn being used. Internet connection is required.

About spColumn

Shows the version number of the program, the licensing information, and the copyright information. In the case of a trial license, the expiration date is given as well as the locking code which is needed to obtain a standalone license.

CHAPTER

4

OPERATING spColumn

4.1   Introduction

In this chapter, the sections follow the order in which commands and options appear beginning with those found under the **File** menu and ending with those under the **Help** menu.

Many of the commands and options that appear under these menus are also accessible by other methods. Consequently, these other methods are also explained.

4.2   Creating New File

When spColumn is loaded, the program is ready to begin receiving input for a new project. Until you save the file, the data will not have a filename associated with it, and the title bar will display the word *Untitled* as illustrated here:
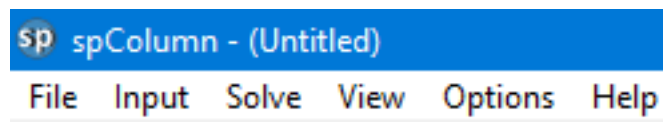
- From the **File** menu, choose **New**. This clears the screen in preparation for a new project or data entry file and returns the program to its default settings.

- If existing data on an open project has been changed prior to executing the **New** command, the program will display the following message box inquiring whether you wish to save the data on the open project or data file before creating a new file:
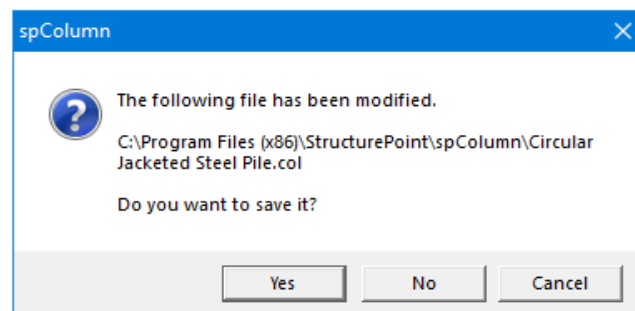
4.3   Opening File

spColumn allows you to open data files that were saved at an earlier time including files from previous versions of spColumn as well as pcaColumn. Note that the extension name of a

pcaColumn and spColumn file is .COL. spColumn also opens files with the spColumn Text Input, .CTI, extension.

- From the **File** menu, choose **Open** and a dialog box will appear.

- All files with the COL extension contained in the current drive and directory are displayed in the FILE NAME list box. To view files with the .CTI[72] extension use the file type drop-down menu to choose the .CTI extension.

- To open a file that exists in another drive or directory, select the drive or directory you want from the LOOK IN drop-down list.

- From the FILE NAME list box, select the file to be opened, or simply type its name in the text box.

- Choose the OK button.

- Alternatively, an input file can be opened by spColumn if the file is drag-and-dropped onto the program window or if the file pathname is provided as a command line parameter when invoking spColumn from the command prompt.
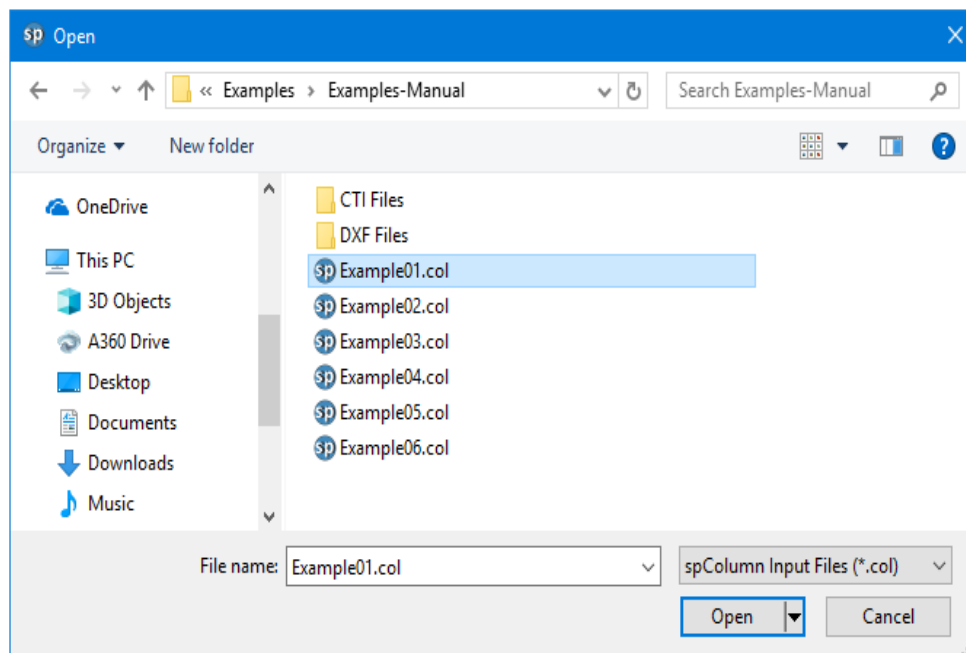
4.4   Saving File

spColumn files are saved in a binary format with .COL or .CTI extensions.

72.*For more information see "spColumn Text Input (CTI) file format" on page 183.*

4.4.1   Save the data with the same file name

- At any time while editing a data file that has previously been saved under a file name, choose **File** and **Save** to save the changes under the same file name, overwriting the old file. From the File menu, select the Save command before giving the data file a name displays the Save As dialog box.

4.4.2   Change format or rename the file

- From the **File** menu, select **Save As**, and a dialog box will appear.

- All files with .COL extensions contained in the current drive and directory are displayed in the FILE NAME list box.

- To save the file to a drive or directory other than the default, select a different drive or directory drive from the SAVE IN drop-down list.

- Use FILE TYPE list box to select either spColumn Input File, .COL, or spColumn Text Input File, .CTI.

- In the FILE NAME text box, type a new file name. If no file extension is specified, an extension will be appended to the specified file name based on the selected file type.

- Choose the OK button.
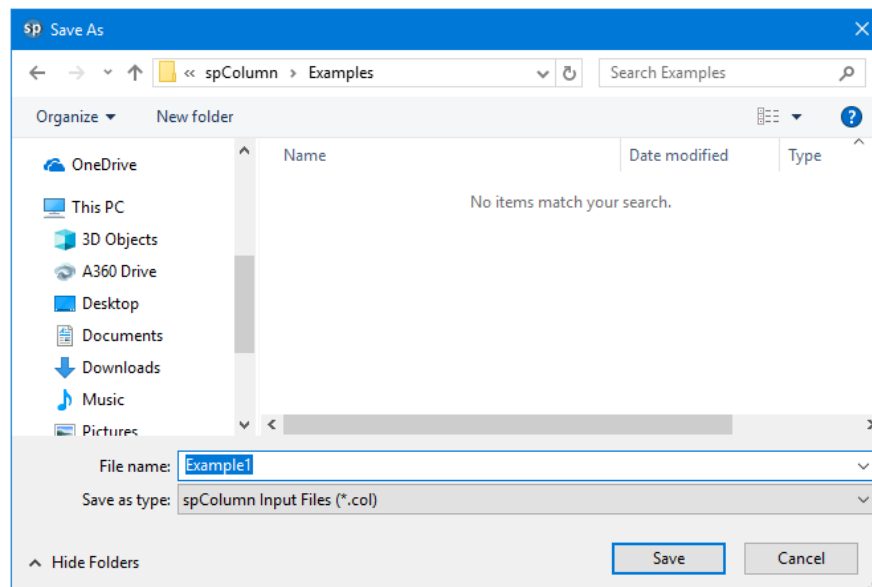
4.5 Most Recently Used Files (MRU)
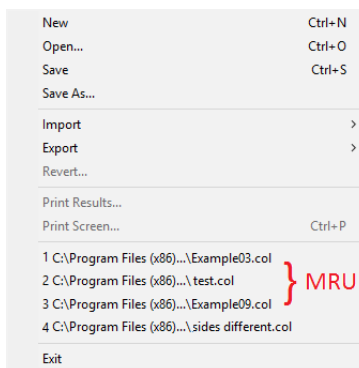
The Most Recently Used Files (MRU) list shows the four data files that were opened most recently. Selecting a data file from this list makes it easier and faster to open the file. The list is empty when the program is executed for the first time.

4.6 Importing

4.6.1 Importing Data

Geometry, reinforcement or load data may be imported from a text file. The import file must be saved in pure ASCII (text) format.[73]

- Select **File | Import | Import Data…** or press CTRL + I keyboard shortcut to display IMPORT DATA dialog box.

- Select the type of data you want to import: SERVICE LOADS, FACTORED LOADS, REINFORCEMENT OR GEOMETRY.

- Choose the OK button. The Open Import file box is displayed.

- All files with the TXT extension contained in the current drive and directory are displayed in the FILE NAME list box.

- To open a file that exists in another drive or directory, select the drive or directory you want from the LOOK IN drop-down list.

- From the File Name list box, select the file to be opened, or simply type its name in the text box.

- Choose the OPEN button.
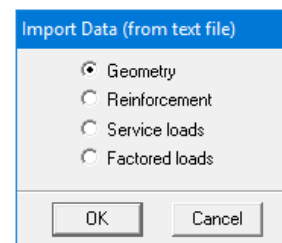
73.*For more information see "spColumn Text Input (CTI) file format" on page 183.*

4.6.2   Importing DXF Files

- Select **File | Import | Import DXF…**. to display Open Import file box.

- All files with the DXF extension contained in the current drive and directory are displayed in the FILE NAME list box.

- To open a file that exists in another drive or directory, select the drive or directory you want from the LOOK IN drop-down list.

- From the File Name list box, select the file to be opened, or simply type its name in the text box.

- Choose the OPEN button.

- The basic IMPORT MODEL FROM DXF FILE dialog box is displayed.
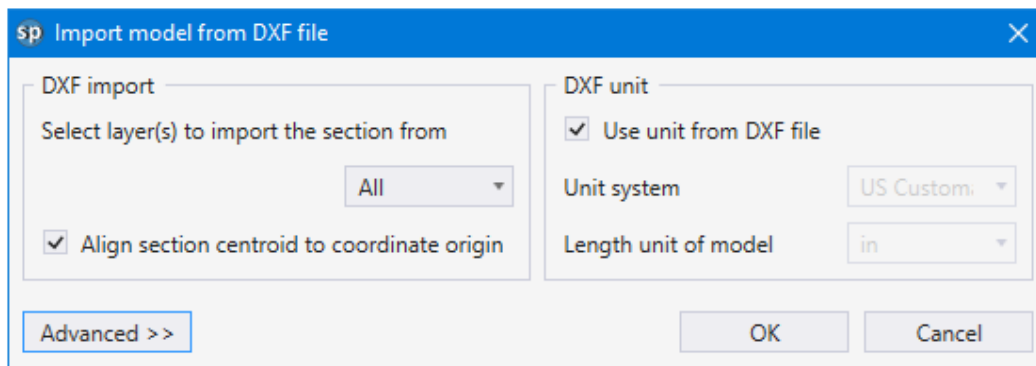
- Press OK button.

The advanced IMPORT MODEL FROM DXF FILE dialog box can be displayed by clicking Advanced >> button in the basic view and is shown below.
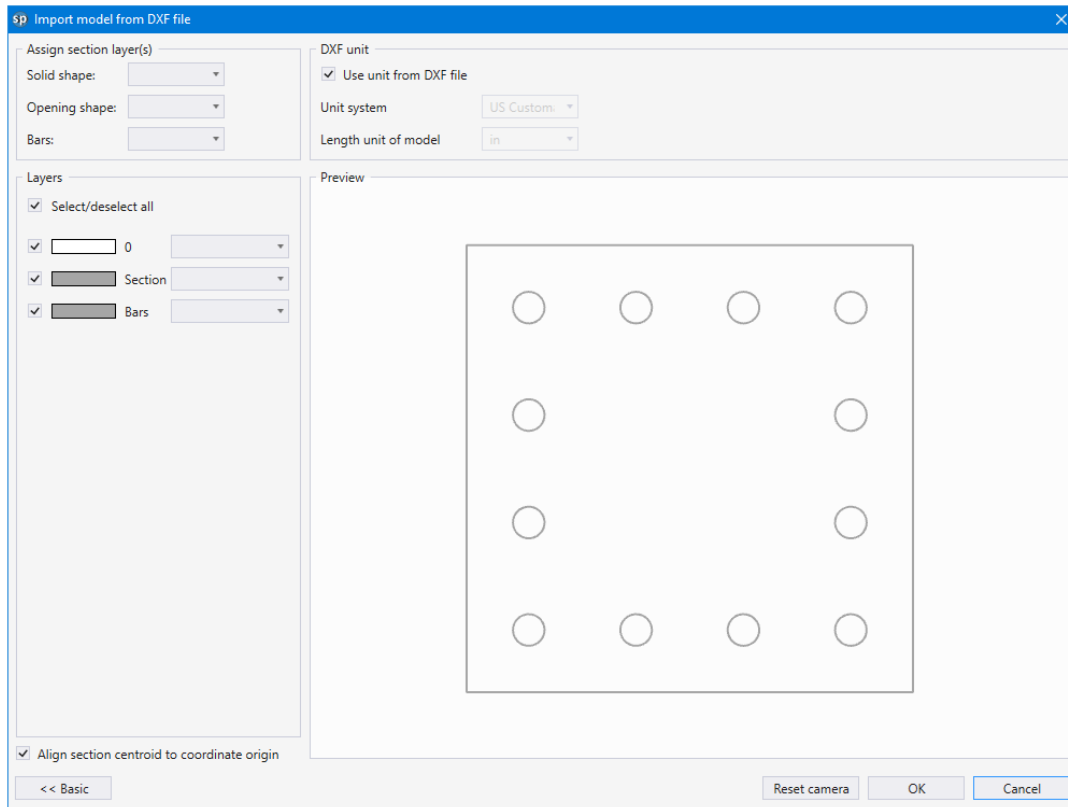
If the DXF file (or selected layer) contains a closed polyline entity (either LWPOLYLINE or POLYLINE) it will be interpreted as the section outline. If multiple closed polylines are present then the first two will be automatically recognized as the outline and the opening and the rest will be ignored.

Reinforcing bars are derived from DXF circle entities (CIRCLE). If no closed polylines are present then the first circle entity will be interpreted as a circular shape of the column and the rest will be interpreted as reinforcing bars.

Dimensions of imported entities will be automatically converted to current project units based on DXF header variable $INSUNITS if the "Use unit from DXF file" option is checked otherwise the DXF file will be assigned the user defined length units and unit system which will then be converted to the current project units.

4.7   Exporting

Once a successful run has been performed you may export results data of the following:
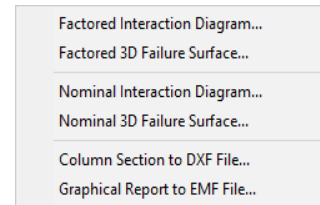
1. Points from the interaction diagram or 3D failure surface to a Comma-Separated Values (CSV) file or to a Tab Delimited Text file (TXT). These files can be read by most spreadsheet and mathematical programs where data produced by spColumn can be further analyzed and processed as needed by the user. Coordinates of the points (P, M_x, M_y) are saved together with corresponding location of the neutral axis (depth and angle), maximum steel strain, and (for ACI code) strength reduction factor.

2. The column section can be exported to a file in Drawing Exchange Format (DXF) format that is readable by most CAD programs.

3. A graphical report can be exported to a file in Enhanced Metafile Format (EMF) that is readable by most graphics and word processing programs. The file will include column section, column information, and the interaction diagram currently displayed on the screen presented the same way as in the printout created by the default printer using the **File | Print Screen** command. The following steps are used to export various output data:

- Select **File | Export | Factored Interaction Diagram** to export P-M or M_x-M_y diagram currently displayed on the screen.

- Select **File | Export | Factored 3D Failure Surface** to export 3D failure surface (biaxial runs only).

- Select **File | Export | Nominal Interaction Diagram** to export nominal (unfactored) P-M or M_x-M_y diagram corresponding to the one currently displayed on the screen.

- Select **File | Export | Nominal 3D Failure Surface** to export nominal (unfactored) 3D failure surface (biaxial runs only).

- Select **File | Export | Column Section to DXF File** to export column section to DXF file

- Select **File | Export | Graphical Report to EMF File** to export graphical report to EMF file.

- For interaction diagrams and 3D failure surface, use FILE TYPE list box to select either Comma-Separated Values (CSV) file or Tab Delimited Text file (TXT). For sections, only DXF format is available and for graphical reports, only EMF format is available.

- In the FILE NAME text box, type the file name. If no file extension is specified, an extension will be appended to the specified file name based on the selected file type.

- Choose the SAVE button.
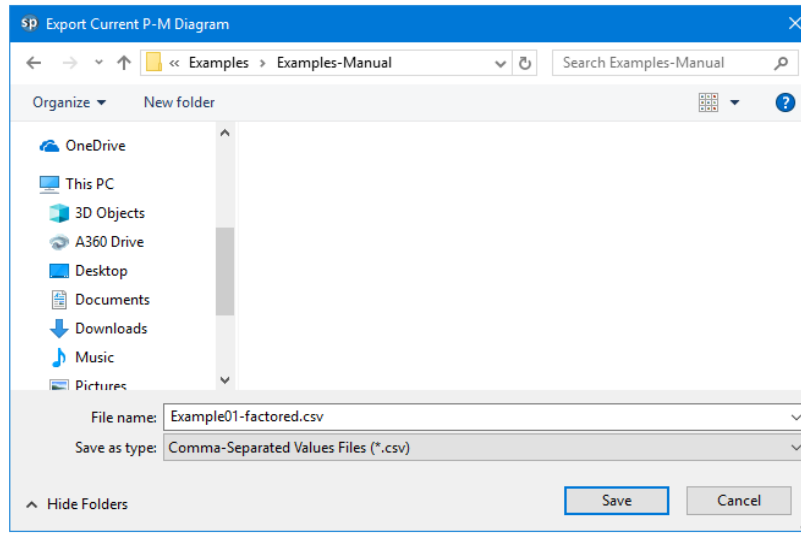
4.8 Revert

Discards any changes to the data and returns to the last version of saved data. This option will only be available if the file has been modified since the last file save.

4.9 Printing

Once a successful run has been performed you may print the diagram displayed on the screen using **File | Print Screen** command. You may print the report using **File | Print Report | Default Report**. If you select **File | Print Report | Customized Report** you will be taken to the spReporter module.

4.9.1 Print Screen

- Select **File | Print Screen**. A dialog box appears.

- Select the printer to send the diagram displayed on the screen to.

- Use Print dialog controls to set up the printer options.

- Choose the OK button to start the printing or choose the CANCEL to terminate the print job.
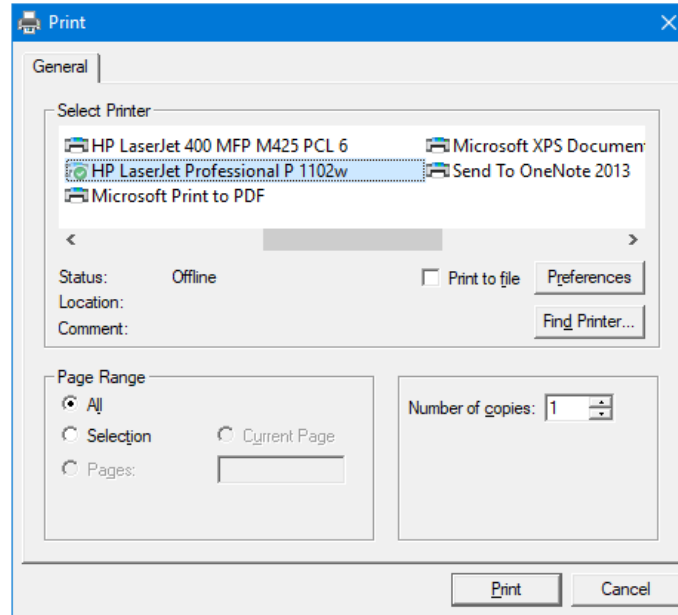
4.9.2   Print Report
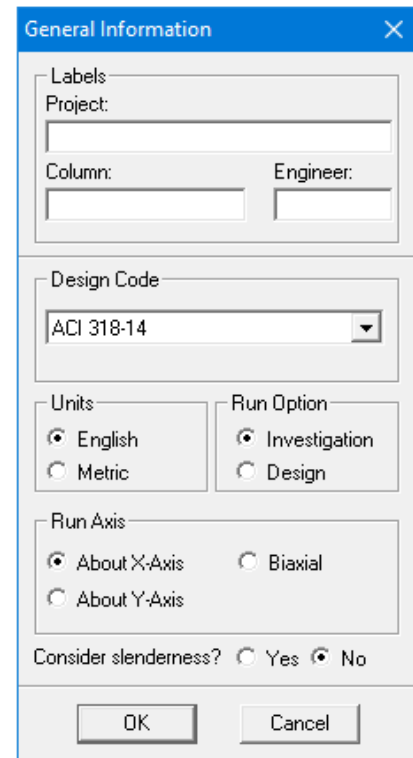
- Select **File | Print Report | Default Report.** A dialog box appears.

- Select the printer to send the report to.

- Use the PROERTIES button to access and modify the printer options if required.

- choose the OK button to start printing or CANCEL to terminate the print job.
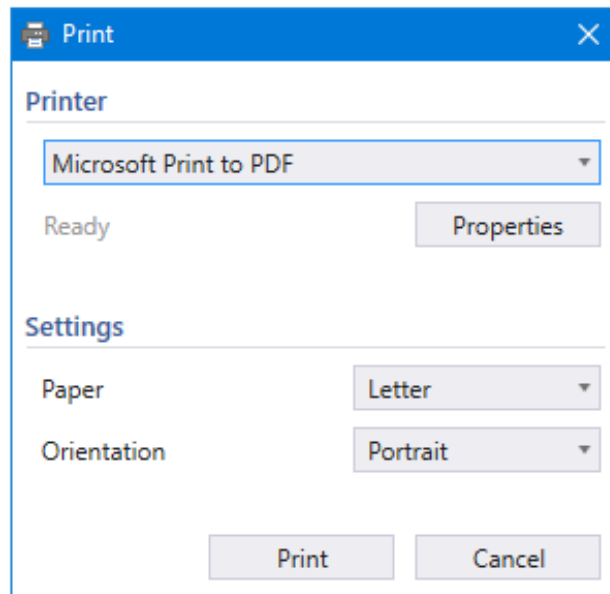
4.10   General Information

The General Information command allows you to define or change options that will affect the rest of the input.

- Select **Input | General Information**. A dialog box appears.

- Enter the PROJECT, COLUMN, and ENGINEER labels.

- Select the units of measure, ENGLISH or METRIC.

- Select the axis about which the column capacity is to be computed: ABOUT X-AXIS, ABOUT Y-AXIS, or BIAXIAL.

- Select a design code to conform to: ACI 318-19, ACI 318-14, ACI 318-11, ACI 318-08, ACI 318-05, ACI 318-02, CSA A23.3-14, CSA A23.3-04 or CSA A23.3-94.

- Choose a run option: INVESTIGATION or DESIGN.

- Specify whether slenderness effects are to be considered or not by checking either YES or NO under the CONSIDER SLENDERNESS? option.

- Choose the OK button.

4.11   Material Properties

- Select **Input | Material Properties**. A dialog box appears.

- Enter the concrete compressive strength, f'$_c$ under STRENGTH, f'c. The modulus of elasticity, E$_c$, under ELASTICITY, Ec; the constant stress intensity, f$_c$ at the maximum usable strain used to calculate the force on concrete, under MAX STRESS, fc; the factor used to determine the depth of the stress block, under BETA(1); and the maximum usable strain at the extreme concrete compression fiber, at the ULTIMATE STRAIN are automatically computed and displayed. Modify any of the values if different than computed.

- For the reinforcing steel, enter the yield strength, f$_y$ under STRENGTH, fy. The modulus of elasticity, E$_s$ under the ELASTICITY, Es, as well as Compression-controlled strain limit,

Eps_yt are automatically computed and displayed. Modify any of the values if different than computed.

- Choose the OK button to accept standard or modified values based on user's judgment.

4.12　Section / Rectangular

4.12.1　Input for the Investigation Option:

- Select **Input | Section | Rectangular**. A dialog box appears.

- Enter the width and depth of the rectangular section using WIDTH (ALONG X) and DEPTH (ALONG Y) respectively. Note that width is measured along the x-axis and depth is measured along the y-axis.

- Choose the OK button

4.12.2　Input for the Design Option:

- Select **Input | Section | Rectangular**. A dialog box appears.

- Enter the starting and ending values for each dimension (width and depth) along with an increment for each dimension under START, END and INCREMENT columns along WIDTH (ALONG X) and DEPTH (ALONG Y). Note that the starting and ending values may be the same (in which case the increment must be zero).

- Choose the OK button.

4.13   Section/Circular

4.13.1   Input for the Investigation Option:

- Select **Input | Section | Circular**. A dialog box appears.

- Enter the diameter of the column section.

- Choose the OK button.
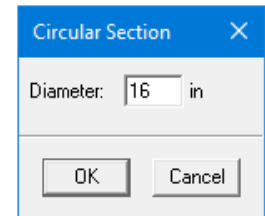
4.13.2   Input for the Design Option:

- Select **Input | Section | Circular**. A dialog box appears.

- Enter the starting and ending values of the diameter along with an increment. Note that the starting and ending values may be the same (in which case the increment must be zero).

- Choose the OK button.
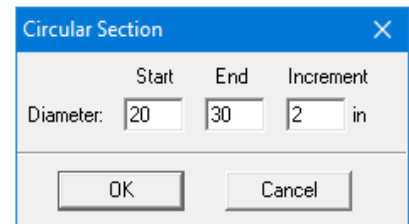
4.14   Reinforcement/All Sides Equal

The **Input | Reinforcement | All Sides Equal** command allows you to enter the total number of bars in the column section. The program attempts to place equal number of bars on each side of a rectangular layout then equally space them on each side. For a circular layout, the program attempts to equally space the bar.

4.14.1   Input for the Investigation Option:

- Select **Input | Reinforcement | All Sides** Equal. A dialog box appears.

- Enter the total number of bars in the section NO. OF BARS (*Must be at least 4 and a multiple of 4*).

- Select the bar size.

- Enter the clear cover and specify whether it is to the transverse bars (ties) or to the longitudinal bars.
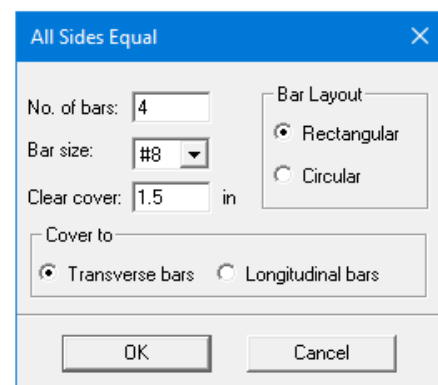
- Select a bar layout, CIRCULAR or RECTANGULAR. The default is CIRCULAR for a circular section and RECTANGULAR for a rectangular section.

- Choose the OK button

4.14.2   Input for the Design Option

- Select **Input | Reinforcement | All Sides Equal**. A dialog box appears.

- Enter the minimum and maximum total number of bars in the section (*must be at least 4 and a multiple of 4 for a rectangular layout*).

- Select the minimum and maximum bar sizes along with the clear cover.

- Enter the clear cover and specify whether it is to the transverse bars (ties) or to the longitudinal bars.

- Select a bar layout, Circular or Rectangular. The default is CIRCULAR for a circular section and RECTANGULAR for a rectangular section.

- Choose the OK button.

4.15   Reinforcement/Equal Spacing

The **Input | Reinforcement | Equal Spacing** command allows you to enter the total number of bars in the column section. The program attempts to place the bars equally spaced on all four sides of a rectangular layout. This command is only applicable for rectangular sections.

4.15.1   Input for the Investigation Option:

- Select **Input | Reinforcement | Equal Spacing**. A dialog box appears.

- Enter the total number of bars in the section NO. OF BARS. (*Must be at least 4 and a multiple of 4*).

- Select the bar size.

- Enter the clear cover and specify whether it is to the transverse bars (ties) or to the longitudinal bars.

- Choose the OK button.

4.15.2 Input for the Design Option:

- Select **Input | Reinforcement | Equal Spacing**. A dialog box appears.

- Enter the minimum and maximum total number of bars in the section under MINIMUM and MAXIMUM corresponding to NO. OF BARS. (*must be at least 4 and a multiple of 4*).

- Select the minimum and maximum bar sizes.

- Enter the clear cover and specify whether it is to the transverse (ties) or to the longitudinal bars.

- Choose the OK button.
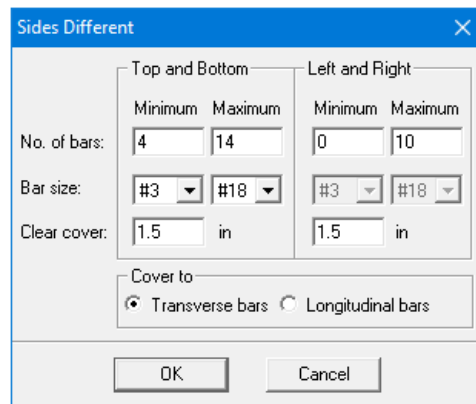
4.16 Reinforcement/Sides Different

4.16.1 Input for the Investigation Option:

- Select **Input | Reinforcement | Sides Different**. A dialog box appears.

- Enter the number of bars to be placed on each of the top, bottom (*on the top and bottom, number of bars needs to be at least 2*), left and right sides (*on the left and right, the number of bars may be any number*) of the rectangular section. *Note that corner bars are associated with the top and bottom sides.*

- Select the bar size and enter the clear cover for each of the top, bottom, left and right sides of the section.

- Specify whether the clear cover entered is to the transverse (ties) or to the longitudinal bars.

- Choose the OK button.

4.16.2   Input for the Design Option:

• Select **Input | Reinforcement | Sides Different**. A dialog box appears.

• In the Top and Bottom Group

  – Enter the minimum and maximum **total** number of bars to be placed on the top and bottom sides.

  – The number of bars must be greater than 4 and a multiple of 2. Corner bars are associated with the top and bottom sides.

  – Select the minimum and maximum bar size and enter the clear cover.

• In the Left and Right Group

  – Enter the minimum and maximum **total** number of bars to be placed on the Left and Right sides. The minimum and maximum number of bars can be set to zero (0) or must be multiple of 2.

  – The minimum and maximum bar size entries are inactivated, therefore, follows the entries for Top and Bottom Group.

  – Enter the clear cover.

• Specify whether the clear cover entered is to the transverse (ties) or to the longitudinal bars.

• Choose the OK button.

4.17   Reinforcement/Irregular Pattern

The **Input | Reinforcement | Irregular Pattern** command allows you to specify any number of bars (up to 10,000) to be placed anywhere within the column section. Each bar may have any cross-sectional area. *This command is available with the Investigation option only.*

- Select **Input | Reinforcement | Irregular Pattern**. If the section is irregular, The spSection window, where the section reinforcement may be graphically input, is displayed. Otherwise, a dialog box appears.

- Enter the bar area, along with its x- and y-coordinates.

- Choose the INSERT button. The data are added to the list box.

- Repeat the steps above for each entry.

- To edit an entry, select it from the list box, modify its values in the text boxes, and choose the MODIFY button. To change the area for several bars at once, select those bars from the list box, enter the new area in the AREA text box, and choose MODIFY.

- To delete a bar entry, select it from the list box and choose the DELETE button.

- Choose the OK button.
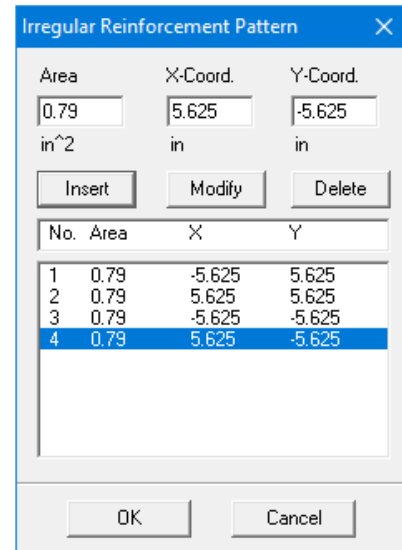
4.18   Reinforcement/Confinement

- Select **Input | Reinforcement | Confinement**. A dialog box appears.

- Select the type of bar confinement: TIED (default), SPIRAL, or Other. The capacity reduction factors change depending on the selection.

- To modify the capacity reduction factors, choose OTHER for confinement type.

For the ACI code:

Phi(a) is the reduction factor for allowable compression,

Phi(b) is the strength reduction factor for tension controlled failure,

Phi(c) is the reduction factor for compression controlled failure.

For the CSA code:

Phi(a) is the reduction factor for allowable compression,
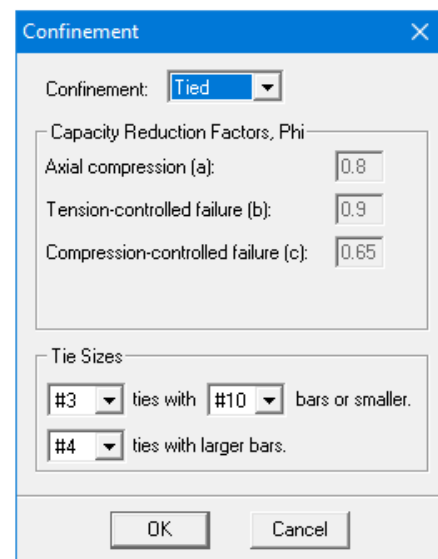
Phi(s) is the material resistance factor for steel,

Phi(c) is the material resistance factor for concrete.
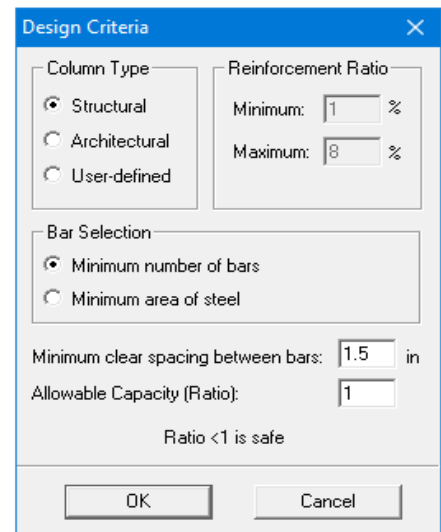
- Specify the tie size associated with the particular longitudinal bar sizes. The code requirements are used as defaults.

- Choose the OK button.

Note that if confinement is selected as TIED or SPIRAL then the program will automatically adjust the factors when the user changes the design code. However, if OTHER confinement is selected, the factors will not be adjusted.

For CSA A23.3-14, the reduction factor for allowable compression is variable (shown as VAR) and for irregular sections the wall thickness or minimum column dimension must also be specified.

4.19   Reinforcement / Design Criteria

- Select **Input | Reinforcement | Design Criteria**. A dialog box appears. *This command is available with the Design option only*.

- Specify whether the column is to be considered STRUCTURAL (default), ARCHITECTURAL, or OTHER. Notice that the minimum and maximum reinforcement ratios change depending on the selection.

- Choose whether bar selection is to be based on MINIMUM NUMBER OF BARS (default) or on MINIMUM AREA OF STEEL.

- To modify the limiting reinforcement ratios, choose OTHER. Enter the minimum and maximum reinforcement ratios in the corresponding text boxes.

- Enter the minimum clear bar spacing and the allowable capacity (ratio).

- Choose the OK button.

4.20   Slenderness / Factors

- Select **Input | Slenderness | Factors**. A dialog box appears. *Note: this command is available for slender columns only.*

- The default values, per the design code, for the stiffness reduction factor (used to compute the moment magnification factors) and the cracked section coefficients for beams and columns are displayed. To modify these values, select the USER-DEFINED option and enter your values.

- Choose the OK button.
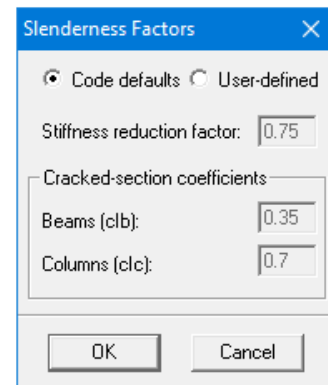
4.21   Slenderness / Design Column
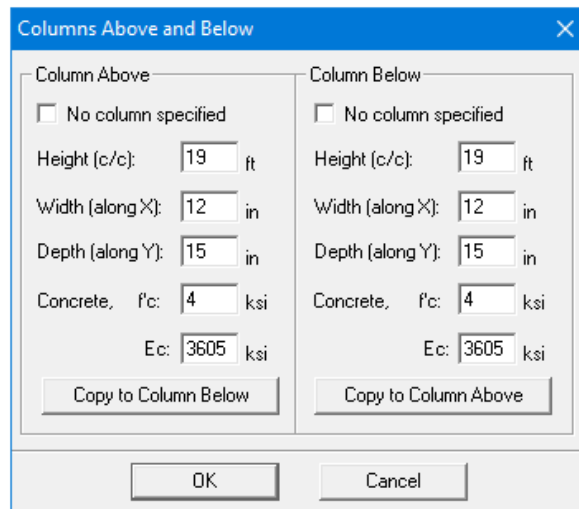
- Select **Input | Slenderness | Design Column**. A dialog box appears. The x-axis or y-axis data groups may be disabled depending on the active run axis. *Note: this command is available for slender columns only.*

- Enter the clear column height in the corresponding text box.

- Specify whether the column is braced against sidesway or not by selecting or clearing the NONSWAY FRAME option.

- For a sway column, enter the ratio of the sum of the critical load of all story columns to the critical load of the column under consideration, (SUM PC)/PC. Also, enter the ratio of the sum of the factored axial load of all story columns to the factored axial load of the column under consideration, (SUM PU)/ PU. Check 2$^{\text{ND}}$ ORDER EFFECTS ALONG LENGTH option to consider 2$^{\text{nd}}$ order effects along length. *Note: this option is available for ACI 318-19, ACI 318-14, ACI 318-11, and ACI 318-08 codes only. For more information see "Moment Magnification along Length of Compression Member" on page 34.*

- In the EFFECTIVE LENGTH FACTORS group, specify whether the k factor(s) are to be user-input or computed by the program, by selecting the corresponding option.
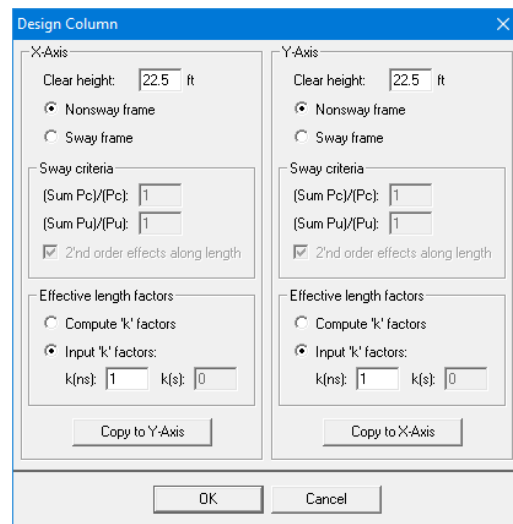
- If you chose INPUT K FACTORS, enter the effective length factors for nonsway and sway conditions, k(ns) and k(s), respectively.

- Repeat the steps above for each active axis.

- Choose the OK button.

4.22   Slenderness / Columns Above and Below

- Select **Input | Slenderness | Columns Above/Below**. A dialog box appears. *Note: this command is available for slender columns only for which the* COMPUTE K FACTORS *option is selected in the* DESIGN COLUMN *dialog box.*
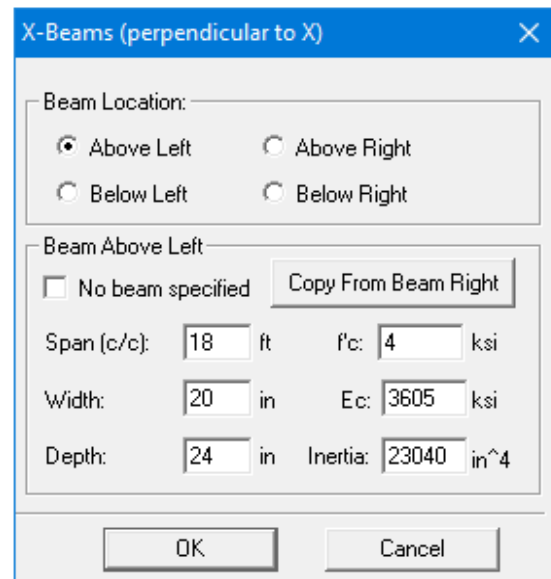
- In the COLUMN ABOVE group, specify whether or not a column above the design column exists, by selecting or clearing the NO COLUMN SPECIFIED OPTION.

- If a column above exists; enter the center-to-center height, the width (along the x-axis), the depth (along the y-axis), the concrete compressive strength, and the concrete modulus of elasticity of the column above in the corresponding text boxes. For circular sections, enter zero for the DEPTH and input the section diameter in the WIDTH box. If zero is entered for both Width and Depth, the dimensions of the design column will be automatically used.

- Repeat the same for the column below or, if the column above and the column below are the same, choose the COPY TO COLUMN BELOW button.

- Choose the OK button.

4.23   Slenderness / X-Beams

- Select **Input | Slenderness | X-Beams**. A dialog box appears. Beams defined using this command span perpendicular to the x-axis. *Note: this command is available for slender columns only for which the* COMPUTE K FACTORS *option is selected in the* DESIGN COLUMN *dialog box and the* RUN AXIS *is* BIAXIAL *or uniaxial* ABOUT X-AXIS.

- From the BEAM LOCATION group, choose the appropriate option. The data group below updates depending on the selection.

- For the selected beam, specify whether or not a beam exists, by selecting or clearing the NO BEAM SPECIFIED OPTION.

- If a beam exists; enter the center-to-center span length, width, depth, concrete compressive strength, concrete modulus of elasticity, and moment of inertia (if different than computed) of the beam.

- Repeat the steps above for the beams ABOVE RIGHT, BELOW LEFT, and BELOW RIGHT.

- Choose the OK button.

4.24   Slenderness / Y-Beams

- Select **Input | Slenderness | Y-Beams**. A dialog box appears. Beams defined using this command span perpendicular to the y-axis. *Note: this command is available for slender columns only for which the* COMPUTE K FACTORS *option is selected in the* DESIGN COLUMN *dialog box and the* RUN AXIS *is* BIAXIAL *or uniaxial* ABOUT Y-AXIS.

- From the BEAM LOCATION group, choose the appropriate option. The data group below updates depending on the selection.

- For the selected beam, specify whether or not a beam exists, by selecting or clearing the NO BEAM SPECIFIED OPTION.

- If a beam exists; enter the center-to-center span length, width, depth, concrete compressive strength, concrete modulus of elasticity, and moment of inertia (if different than computed) of the beam.

- Repeat the steps above for the beams ABOVE RIGHT, BELOW LEFT, and BELOW RIGHT.

- Choose the OK button.

4.25   Loads / Factored

When designing or investigating a non-slender column, factored loads consisting of applied axial loads and moments about the active axis may be input. This command is not available for slender columns.

- Select **Input | Loads | Factored**. A dialog box appears.

- Enter the factored axial load in the LOAD text box.

- Based on the active axis, enter the factored moment about the x-axis, X-MOMENT, the factored moment about the y-axis, Y-MOMENT, or both.

- Choose the INSERT button. The data are added to the list box.

- Repeat the steps above for each factored load entry.

- To edit an entry, select it from the list box, modify its values in the text boxes, and choose the MODIFY button.

- To delete an entry, select it from the list box and choose the DELETE button.

- Choose the OK button.

4.26   Loads / Service

When designing or investigating a non-slender or slender column, service level loads consisting of dead, live, lateral (wind and earthquake), and snow axial loads and moments at both column ends about the active axis may be input. These loads are then factored and combined based on the load combinations.

- Select **Input | Loads | Service**. A dialog box appears.

- For each of the load cases: Dead, Live, Wind, Earthquake (EQ), and Snow, enter the axial load and the applicable moment (about x or y) at the column top and bottom.

- Enter the percentage of the sustained part of the load in each load case (by default only Dead Load is assumed to be 100% sustained). These percentages will be used to arrive at sustained axial load ratio β_{dns} to calculate moment magnification factor along length of the column[74].

- Choose the INSERT button. The data are added to the list box.

- Repeat the steps above for each entry.

---

74. For moment magnification at ends of a column in a sway frame, the value of β_{ds} is assumed to be zero and is not affected by sustained load factors (*For more information see "Moment Magnification at Ends of Compression Member" on page 30.*)

- To edit an entry, select it from the list box, modify its values in the text boxes, and choose the MODIFY button.

- To delete an entry, choose it from the list box and choose the DELETE button.

- Choose the OK button.
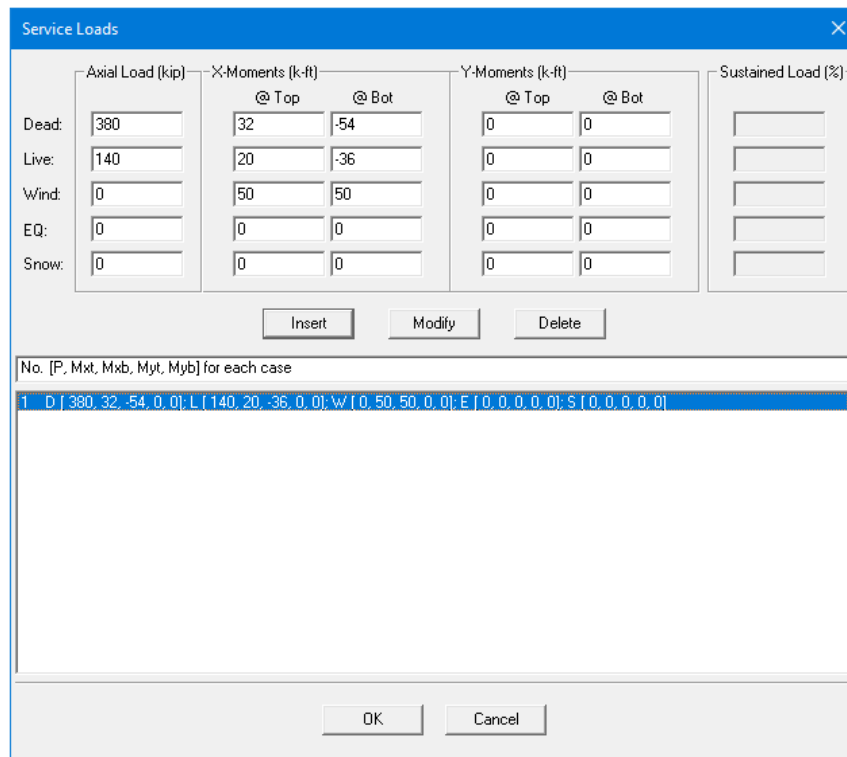
4.27   Loads / Control Points

A non-slender column may be investigated without inputting any loads. The capacity of the section is computed along with other section capacity parameters. *This command is not available for slender columns or under the Design option.*

- Select **Input | Loads | Control Points**.

  In the output file, key points (e.g. balanced point and pure bending) on the interaction diagram are listed. For each point, the axial load and bending moment capacities, along with the corresponding neutral axis depth, distance from extreme compression fiber to centroid of extreme layer of longitudinal tension steel, net tensile strain in extreme layer of longitudinal tension steel at nominal strength, and strength reduction factor (ACI only) are listed. For a biaxial run, these points are listed for bending about positive and negative X and Y axes.

For ACI code, the program flags the unusual increase in axial load capacity in transition zone between the balanced point and the tension control point.

For uniaxial runs, the bar splice requirements for columns[75] are indicated on the interaction diagram.

4.28   Loads / Axial Loads

When investigating a non-slender column (uniaxial runs only), grouped factored applied axial loads may be input. The corresponding moment capacity for each load is computed and output. *This command is not available under the* DESIGN *option, for biaxial runs, or if the column is slender.*

- Select **Input | Loads | Axial Loads**. A dialog box appears.

- To input a range of axial loads, enter the initial, final and increment values in the corresponding text boxes. To input a discrete (single) axial load, enter its value in the INITIAL text box, and enter zero in the FINAL and INCREMENT text boxes.

- Choose the INSERT button. The data are added to the list box.

- Repeat the steps above for each axial load entry you may have.

- To edit an entry, select it from the list box, modify its values in the text boxes, and choose the MODIFY button.

- To delete an entry, choose it from the list box and choose the DELETE button.

- Choose the OK button

---

75. ACI 318-14, Fig. R10.7.5.2; ACI 318-11, Fig. R12.17; ACI 318-08, Fig. R12.17; ACI 318-05, Fig. R12.17; ACI 318-02, Fig. R12.17; CSA A23.3-14, 12.17.3; CSA A23.3-04, 12.17.3; CSA A23.3-94, 12.17.3

4.29 Loads / Load Combinations

spColumn allows you to specify up to 50 load combinations. The service load input under the load cases (dead, live, wind, earthquake, and snow) are combined based on these combinations. A minimum of one combination must be input.

- Select **Input | Loads | Load Combinations**. A dialog box appears. For a new file, the default combinations per the selected code are shown in the list box.

- To add a new combination, enter the load factors or multipliers for each load case, DEAD, LIVE, WIND, Earthquake (EQ), and SNOW.

- Choose the INSERT button. The data are added to the list box.

- Repeat the steps above for each load combination. Up to fifty combinations may be defined.

- To edit an entry, select it from the list box, modify its values in the text boxes, and choose the MODIFY button.

- To delete an entry, choose it from the list box and choose the DELETE button.

- Choose OK when done.

4.30 Flipping / Rotating the Section

This command is available for Irregular sections and for sections with Sides Different or Irregular reinforcement.

- Select **Input | Flip/Rotate Section**. A dialog box appears.

- Select one of the options: FLIP SECTION ABOUT X-AXIS, FLIP SECTION ABOUT Y-AXIS, or ROTATE SECTION. The last option is available for irregular sections only.

- If ROTATE SECTION is selected, enter the angle of rotation (clockwise is positive).

- Choose the OK button.
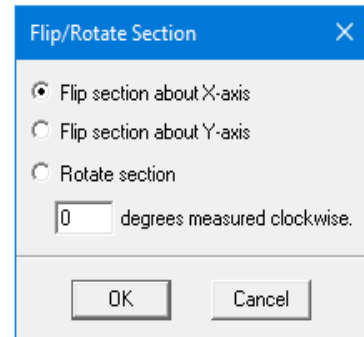
4.31 Executing a Run

4.31.1 From the program

- Select **Solve | Classic Results File**. This is an option that may be turned ON or OFF by choosing it again. With this option ON, an output file will be created while the program is solving. The output file is a text file that contains an echo of the input along with slenderness calculation output, load combinations, and the critical points on the interaction diagram.

- Select **Solve | Include Nominal Diagram**. This is an option that may be turned ON or OFF by choosing it again. With this option ON, calculations of nominal (unfactored) capacity interaction diagram will also be included in the calculations so that the nominal diagram can be viewed and exported in addition to the design (factored) capacity diagram.

- Select **Solve | Design Trace** (*design option only*). This is an option that may by turned ON or OFF be choosing it again. With this option ON, if designing a column section, the program will pause at each cross section and reinforcement layout it tries, and display the cross section with its bars in the Information bar.

- Select **Solve | Execute**. If more data are needed to solve the problem, an error box appears and you will be prompted for the required data. If all the needed data are input, the solver portion of spColumn will start executing. The Solving box appears with a progress indicator. Click Cancel to terminate the solution process. After a successful run, the interaction diagram or the contour plot is displayed in the Graphics area of the window.
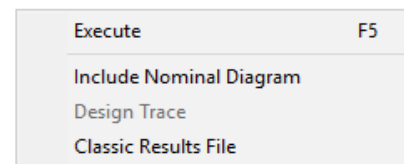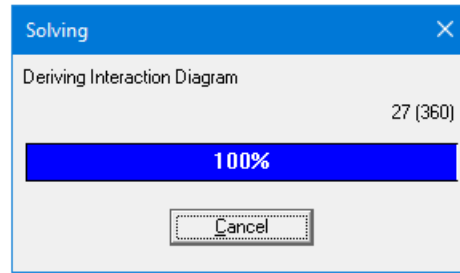
4.31.2   From the command prompt

spColumn run can also be executed in batch mode from the command line prompt. Input data file, output data file, and run options can be passed to the program via parameters. For instance typing `spColumn /i:Examples\Example01.col` will run spColumn and solve the column defined in input file Example01.col.
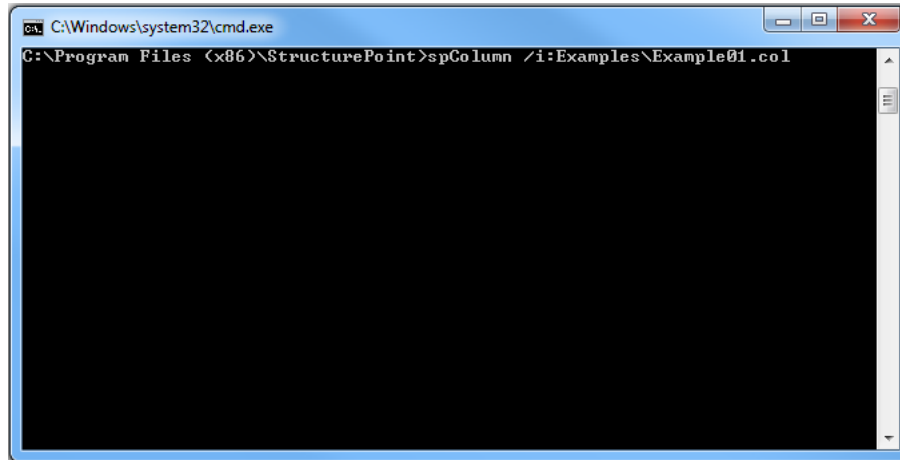
Multiple cross-sections can be designed and analyzed by executing spColumn with multiple input files using batch (BAT) files (see Examples.bat in the spColumn program folder). Combined with Column Text Input files (CTI), this feature can be used for automation spColumn runs for projects involving large numbers of cross-sections.

Help on how to use command line parameters can be obtained by typing `spColumn /?` at the command prompt.

```
spColumn Command Line Help                                          ×

       spColumn [/i:input_file] [/o:output_file] [/arch|/stru] [/wind|/eq] [/iad] [/csv|/txt] [/nom] [/dxf]
       [/emf[:eachp|:eachm|:each|:pall|:mall:all]] [/cti] [/rdoc|/rpdf|/rtxt|rcsv|/rxls] [/help|/?]

       Parameters:
       /i:        Input data file name
       /o:        Output data file name

       /arch      If reinforcement ratio is below 1%, consider column as architectural
       /stru      If reinforcement ratio is below 1%, consider column as structural
       /wind      If input file version prior to 3.50 is detected, consider lateral loads as wind loads
       /eq        If input file version prior to 3.50 is detected, consider lateral loads as earthquake
                  loads

       /iad       Export interaction diagram to IAD file that can be superimposed in spColumn
       /csv       Export interaction diagram to Comma-Separated Values file that can be
                  imported into spreadsheet program
       /txt       Export interaction diagram to Tab-Delimited Text file that can be imported into
                  spreadsheet program
       /nom       Include nominal interaction diagram in export

       /dxf       Export column section to DXF file that can be imported into CAD program
       /emf       Export graphical reports to EMF files that can be imported into graphics
                  and word processing software
                  For uniaxial runs, single P-M diagram is exported. For biaxial, one P-M
                  and one Mx-My diagrams are exported.

                  :eachm   P-M diagrams separately for each factored load point
                  :eachp   Mx-My diagrams separately for each factored load point
                  :each    P-M and Mx-My diagrams separately for each factored load point
                  :mall    P-M diagrams for all sorted and grouped angles of factored resultant moment
                  :pall    Mx-My diagrams for all sorted and grouped levels of factored axial load
                  :all     P-M and Mx-My diagrams for all sorted and grouped resultant
                           moments and axial loads

       /rdoc      Export report in Word format
       /rpdf      Export report in PDF format
       /rtxt      Export report in TEXT format
       /rcsv      Export report in CSV format
       /rxls      Export report in Excel format

       /cti       Export input data to spColumn Text Input file
       /help      Show this help
       /?         Show this help

       Examples:
       spColumn /i:input.col
       spColumn /i:input.col /o:output.out /iad /dxf /csv
       spColumn /i:C:\proj\input.col /o:D:\proj\output.out /emf
       spColumn /i:input.col /o:output.out /iad /emf:all /wind /arch

                                                                  [    OK    ]
```

4.32   Viewing Results

Once a successful run has been performed, you may view the results file.

- Select **View | Results**. spColumn executes the spResults module. Alternatively you can also access spResults by pressing the F6 key.

- Use the explorer, options in the toolbar or the "PAGEUP" and "PAGEDOWN" buttons to navigate through the data tables.

- You can click the CLOSE button in the top right corner to exit spResults window.

4.33   Changing Startup Defaults

You can change some default settings that spColumn uses when it is started or when the **File | New** command is executed.

- Select **Options | Startup Defaults**. A dialog box appears.

- Enter the full path of the directory to which spColumn defaults when opening a data file.

- Select the system of units, design code, reinforcement, and section capacity calculation method to be used as defaults whenever a new file is started.

- Enter the number of lines per page to be used in formatting the classic results file.

- Choose the SAVE button to save these options in the registry.

4.34 Changing Reinforcement Bar Set

- Select **Options | Reinforcement**. A dialog box appears

4.34.1 Select a different set

- From the BAR SET drop-down list, select the set to be used.

- Choose the OK button.

4.34.2 Create or modify a user-defined set

- From the BAR SET drop-down list, select USER-DEFINED. The ADD, DELETE and MODIFY buttons are enabled.

- To edit an entry, select it from the list box, modify its values, and choose the MODIFY button.

- To delete an entry, select it from the list box and choose the DELETE button.

- To add an entry, enter the bar size, diameter, area and unit weight in the corresponding text box, and choose the ADD button. The data are added to the list box.

- A user-defined set may be saved to disk for use in other files. To do so, choose the SAVE button after inputting the bars. The bar set is saved to the file specified by the user. To retrieve a saved set, choose the READ button.

- Choose the OK button.

4.35 Changing Section Capacity Calculation Method

You can change the method that spColumn uses to calculate section capacity.
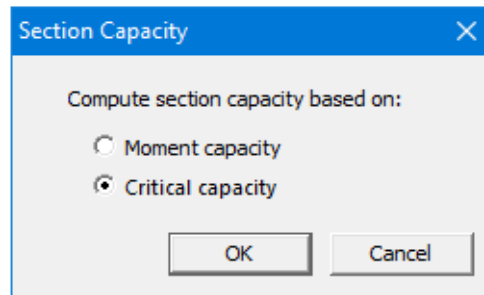
- Select **Options | Section Capacity**. A dialog box appears.

- Choose between Moment capacity or Critical capacity for calculating section capacity.

- Choose the OK button.

4.36   Superimposing Diagrams

After executing a run and selecting the **File | Save** command, the program saves the diagram data in a separate file that has the same file name as the input file, with an IAD extension. If calculations of nominal interaction diagram are included, the program stores also the nominal diagram data in an additional IAD file named as the input file name suffixed with "-nominal.iad".

The IAD interaction diagram file may be later read by the program and two diagrams (of different files) may be superimposed for the purpose of comparison. Note that the RUN AXIS (uniaxial or biaxial) of the two files must be the same.

- Select **View | Superimpose** option. The open dialog box appears.

- All files with the IAD extension contained in the current drive and directory are displayed in the FILE NAME list box. To open a file that exists in another drive or directory, select a different drive or directory drive from the LOOK IN drop-down list.

- From the FILE NAME list box, select the file to be opened, or simply type its name in the text box.

- Choose the OK button. If the data is successfully read, the diagram from the IAD file (shown dotted) is superimposed over the currently displayed diagram.

- To clear the superimposed diagram, uncheck the **View | Superimpose** option.

4.37 Viewing 2D Diagrams

By default, the program displays diagrams based on the design (factored) section capacity. Display of diagrams based on the nominal (unfactored) strength is controlled by the **View | Show Nominal Diagram** option which is available when calculations of nominal diagram are activated using the **Solve | Include Nominal Diagram** option.

For a uniaxial run, the program computes and displays the P-M interaction diagram. For a biaxial run, the program computes the three-dimensional failure surface (P, M_x, M_y). The failure surface can be viewed in one of two ways:

    a) P-M interaction diagram (vertical slice at an angle measured from M_x)

    b) M_x-M_y contour curve (horizontal slice at a constant axial load).

Whenever the mouse cursor moves over the Graph area, the axial load, moment, and eccentricity are displayed in the Status bar.

4.37.1 Viewing P-M Interaction Diagram

- Select **View | P-M Diagram - Full**. A dialog box appears.

- You may also select **View | P-M Diagram – M positive** or **View | P-M Diagram – M negative** to view the interaction diagram only for positive or negative moments.

- Specify whether you want to enter an angle or the values of the moments that produce a view angle by selecting either the ANGLE or MOMENTS option, respectively.

- If the ANGLE option was selected, select an angle from the list, use the scroll bar to pick an angle, or simply enter the value in the text box.

- If the MOMENTS option was selected, enter the values of M_x and M_y which define the view angle. The value of that view angle is computed and shown in the ANGLE text box.

- To display all load points and their numbers check the LIST POINT NUMBERS option. To display unique angle values only, leave the option unchecked.

- Choose the OK button.
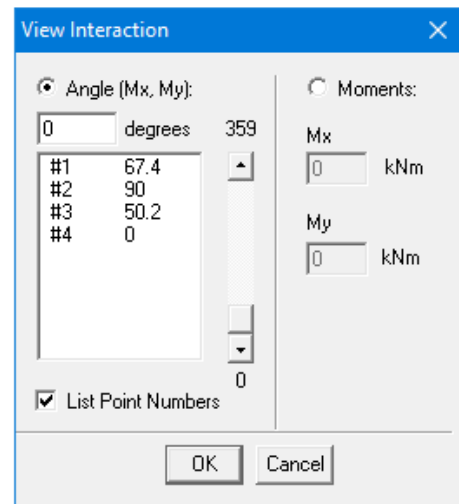
- You may browse through the angles by using **View | Next angle** and **View | Previous angle** respectively.

4.37.2   Viewing M$_x$-M$_y$ Contours

- Select **View | Mx-My Diagram**. A dialog box appears.

- Select an axial load from the list, use the scroll bar to pick a load, or simply enter the value in the text box.

- To display all load points and their numbers check the LIST POINT NUMBERS option. To display unique axial load values only, leave the option unchecked.

- Choose the OK button.

- You may browse through the loads by using **View | Next Load** and **View | Previous Load** respectively.
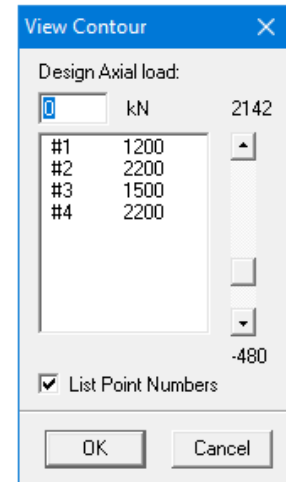
CHAPTER

5

EXAMPLES

5.1   Example 1 - Capacity of a Square Column

5.1.1   Problem Formulation

For a column section[76] which is 16" x 16" and reinforced with 4-#8 bars, calculate the load moment capacities for the following load conditions:

Case 1: Bar stress near tension face of member equal to zero, ($f_s = 0$).

Case 2: Bar stress near tension face of member equal to $0.5f_y$, ($f_s = 0.5f_y$).

Case 3: At limit for compression controlled sections. ($\varepsilon_s = \varepsilon_{ty}$)

Case 4: At limit for tension controlled sections. ($\varepsilon_s = \varepsilon_{ty} + 0.003$)

Given a concrete of 4 ksi and reinforcing steel of 60 ksi.

5.1.2   Preparing Input

- From the **File** menu, choose **New**. Any input data is cleared and the default values are restored.

- From the **Input** menu, choose **General Information**.

  - Input the PROJECT header.

  - Select ENGLISH units and ACI 318-19 code.

  - Select About X-axis for run axis, Investigation for run option and No for Consider slenderness?

  - Choose OK.

---

[76]. Based on Example 6.4, pp 6-33 from Notes on ACI 318-11 Building Requirements for Structural Concrete with Design Applications, Edited by Mahmoud E. Kamara and Lawrence C. Novak, Twelfth Edition, 2013, Portland Cement Association.

5.1.3   Assigning Properties

- From the **Input** menu, choose **Material Properties**.

    - Accept the default properties as they match those in the problem statement

    - Choose OK.
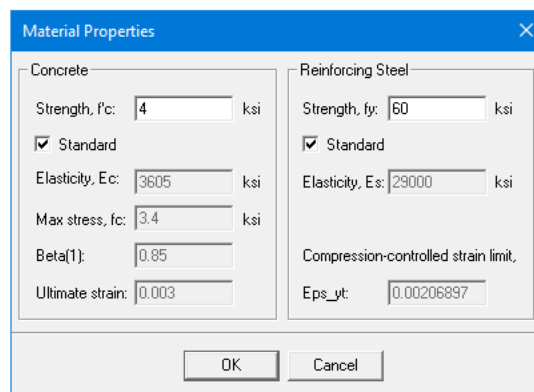
- From the **Input** menu, choose **Section | Rectangular**.

    - For the section WIDTH (ALONG X), input 16

    - For the section DEPTH (ALONG Y), input 16.

    - Choose OK.

- From the **Input** menu, choose **Reinforcement | All Sides Equal**

    - Input 4-#8 bars under NO. OF BARS.

    - Input 1.5 in for the CLEAR COVER and select TRANSVERSE BARS under COVER TO.

    - Choose OK.

- From the **Input** menu, choose **Loads | Control Points**.
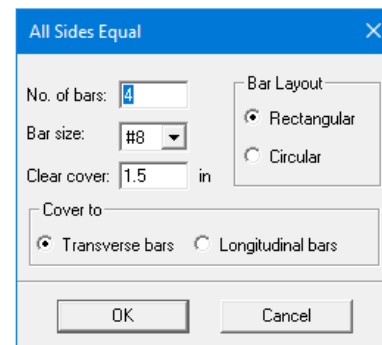
5.1.4   Solving

- From the **Solve** menu, choose **Execute**.

    - The P-M_X contour is displayed in the Graphics area.

5.1.5   Viewing and Printing Results

- From the **View** menu, choose **Results**.

    - Use the explorer in the spResults module or the **Previous Table** and **Next Table** buttons in the toolbar to navigate through the tables.

    - Use the close button at the top right corner of the spResults windows to quit the spResults module and get back to spColumn.

- From the **File** menu, choose **Print Report | Default Report**.

    - Select the printer to send the default report to.

    - Choose PRINT.

- From the **File** menu, choose **Print Screen**.

    - Select the printer to send the graphical results to.

    - Choose PRINT

![spColumn logo]
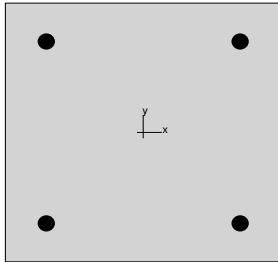
16 x 16 in

General Information

Project	spColumn ... Example 1
Column	PCANotes 6.4
Engineer	SP
Code	ACI 318-19
BarSet	ASTM A615
Units	English
RunOption	Investigation
RunAxis	X - axis
Slenderness	Not Considered
ColumnType	Structural
CapacityMethod	Moment capacity

Materials

f'_c	4 ksi
E_c	3605 ksi
f_y	60 ksi
E_s	29000 ksi

Section

Type	Rectangular
Width	16 in
Depth	16 in
A_g	256 in^2
I_x	5461.33 in^4
I_y	5461.33 in^4

Reinforcement

Pattern	All sides equal
Barlayout	Rectangular
Coverto	Transverse bars
Clearcover	1.5 in
Bars	4 #8
Confinementtype	Tied
Totalsteelarea, A_s	3.16 in^2
Rho	1.23 %
Min.clearspacing	10.25 in
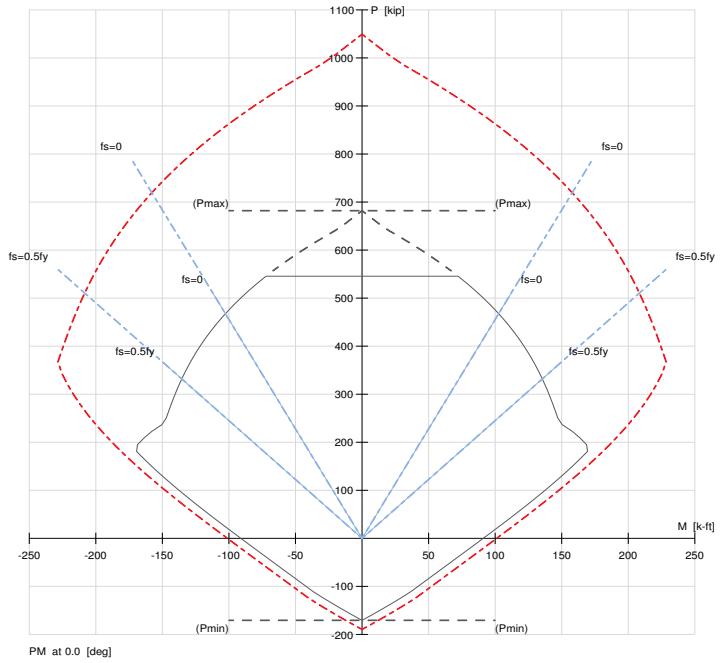
PM at 0.0 [deg]

1. General Information

File Name	C:\Program Files (x86)\Structure...\Example01.col
Project	spColumn Manual Example 1
Column	PCANotes 6.4
Engineer	SP
Code	ACI 318-19
Bar Set	ASTM A615
Units	English
Run Option	Investigation
Run Axis	X - axis
Slenderness	Not Considered
Column Type	Structural
Capacity Method	Moment capacity

2. Material Properties

2.1. Concrete

Type	Standard
f'_c	4 ksi
E_c	3605 ksi
f_c	3.4 ksi
ε_u	0.003 in/in
β_1	0.85

2.2. Steel

Type	Standard
f_y	60 ksi
E_s	29000 ksi
ε_{yt}	0.00206897 in/in

3. Section

3.1. Shape and Properties

Type	Rectangular
Width	16 in
Depth	16 in
A_g	256 in^2
I_x	5461.33 in^4
I_y	5461.33 in^4
r_x	4.6188 in
r_y	4.6188 in
X_o	0 in
Y_o	0 in

3.2. Section Figure

Rectangular 16 x 16 in   1.23% reinf.

Figure 1: Column section

4. Reinforcement

4.1. Bar Set: ASTM A615

Bar	Diameter	Area	Bar	Diameter	Area	Bar	Diameter	Area
	in	in^2		in	in^2		in	in^2
#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 ϕ, (b)	0.9
Compression controlled ϕ, (c)	0.65

4.3. Arrangement

Pattern	All sides equal
Bar layout	Rectangular
Cover to	Transverse bars
Clear cover	1.5 in
Bars	4 #8
Total steel area, A$_s$	3.16 in^2
Rho	1.23 %

Minimum clear spacing	10.25 in

5. Control Points

About	Point	P	X-Moment	Y-Moment	NA Depth	d_t Depth	ε_t	ϕ
		kip	k-ft	k-ft	in	in		
X	@ Max compression	682.0	0.00	0.00	43.90	13.63	-0.00207	0.65000
X	@ Allowable comp.	545.6	72.20	0.00	15.81	13.63	-0.00041	0.65000
X	@ f_s = 0.0	467.6	102.64	0.00	13.63	13.63	0.00000	0.65000
X	@ f_s = 0.5 f_y	331.8	135.43	0.00	10.13	13.63	0.00103	0.65000
X	@ Balanced point	238.9	148.49	0.00	8.06	13.63	0.00207	0.65000
X	@ Tension control	186.4	171.25	0.00	5.07	13.63	0.00507	0.90000
X	@ Pure bending	0.0	91.03	0.00	2.24	13.63	0.01528	0.90000
X	@ Max tension	-170.6	0.00	0.00	0.00	13.63	9.99999	0.90000
-X	@ Max compression	682.0	0.00	0.00	43.90	13.63	-0.00207	0.65000
-X	@ Allowable comp.	545.6	-72.20	0.00	15.81	13.63	-0.00041	0.65000
-X	@ f_s = 0.0	467.6	-102.64	0.00	13.63	13.63	0.00000	0.65000
-X	@ f_s = 0.5 f_y	331.8	-135.43	0.00	10.13	13.63	0.00103	0.65000
-X	@ Balanced point	238.9	-148.49	0.00	8.06	13.63	0.00207	0.65000
-X	@ Tension control	186.4	-171.25	0.00	5.07	13.63	0.00507	0.90000
-X	@ Pure bending	0.0	-91.03	0.00	2.24	13.63	0.01528	0.90000
-X	@ Max tension	-170.6	0.00	0.00	0.00	13.63	9.99999	0.90000

5.2   Example 2 - Investigation of a Slender Column - Nonsway Frame

5.2.1   Problem Formulation

Determine the adequacy of a 14" x 20" column[77] with 6-#11 bars in a nonsway frame with a clear height of 22'6". Use k=1.0.

The concrete used is 4.5 ksi and the reinforcing steel is 50 ksi.
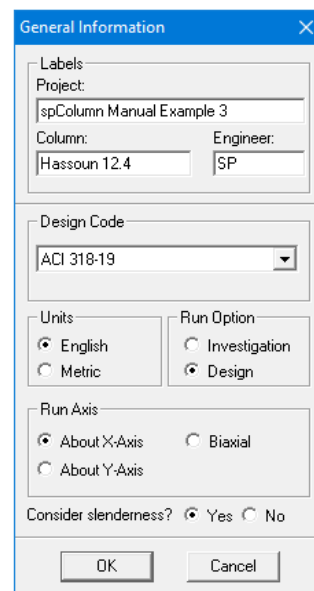
The factored load values for the column under consideration are as follows:

|	
P (kip)	115 kips
Top M_{uy} (kip-ft)	279 k-ft
Bottom M_{uy} (kip-ft)	-279 ft-kips

5.2.2   Preparing Input

From the **File** menu, choose **New**. Any input data is cleared and the default values are restored.

- From the **Input** menu, choose **General Information**.

    - Input the PROJECT header.

    - Select ENGLISH units and ACI 318-19 code.

    - Select Biaxial for run axis, Investigation for run option and Yes for Consider Slenderness?
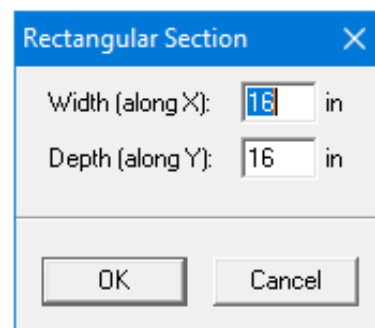
    - Choose OK.

---

77. Based on Example 15.8.5 from Reinforced Concrete Design by Chu-Kia Wang, Charles G. Salmon, and Jose A. Pincheira, Seventh Edition, 2007, John Wiley and Sons, Inc.

5.2.3   Assigning Properties

- From the **Input** menu, choose **Material Properties**.

  - Input 4.5 for the CONCRETE STRENGTH. Change the REINFORCING STEEL STRENGTH to 50. Other properties are computed and will be accepted.
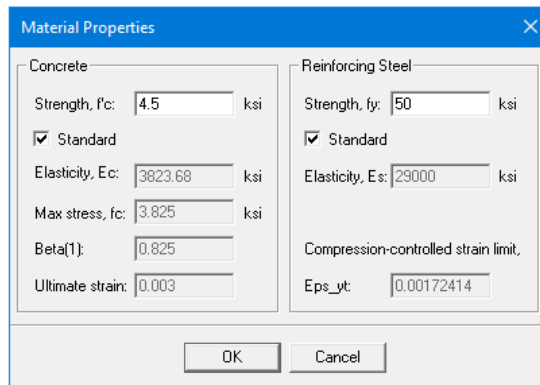
  - Choose Ok.

- From the **Input** menu, choose **Section | Rectangular**.

  - Input 20 and 14 for the section width (along X) and depth (along Y).
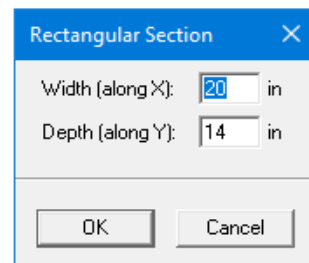
  - Choose OK.

- From the **Input** menu, choose **Reinforcement | Sides Different**.

  - Input 2-#11 bars for TOP and BOTTOM and 1-#11 for LEFT and RIGHT. Input 1.5 in for the cover and select LONGITUDINAL BARS.
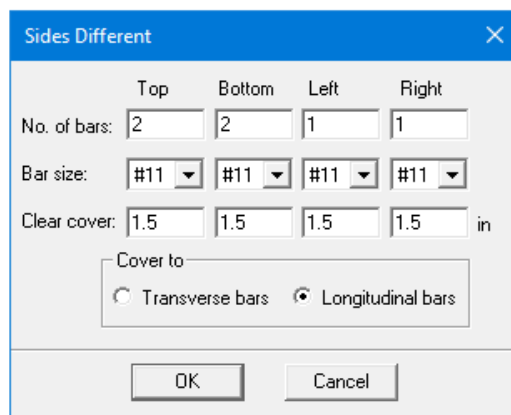
  - Choose OK.

- From the **Input** menu, choose **Slenderness | Design Column**.

  - Input 22.5 for the column CLEAR HEIGHT.

  - Check NONSWAY FRAME and select INPUT 'k' FACTORS. Input 1 for k.

  - Press COPY TO Y-AXIS.

  - Choose OK.
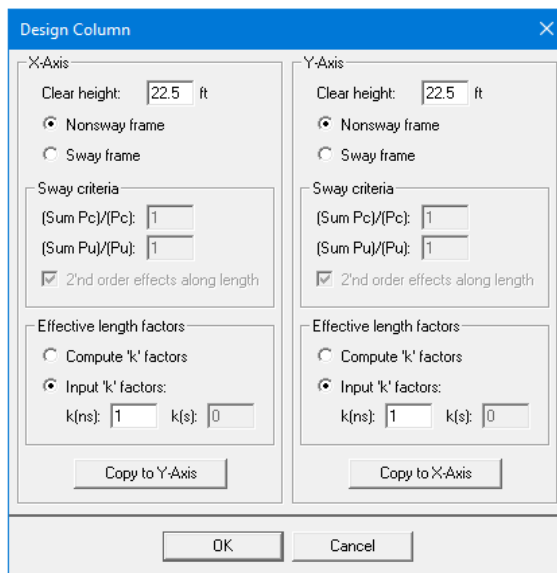
- From the **Input** menu, choose **Loads | Service**.

    - Under LIVE, input `71.875` for the AXIAL LOAD, `0` for the X-MOMENTS @TOP, `0` for the X-MOMENTS @BOT, `174.375` for the Y-MOMENTS @TOP and `-174.375` for the Y-MOMENTS @BOTTOM, respectively.

    - In column SUSTAINED LOAD keep default setting for dead load equal 100%.

    - Choose INSERT to add the entry to the list box.
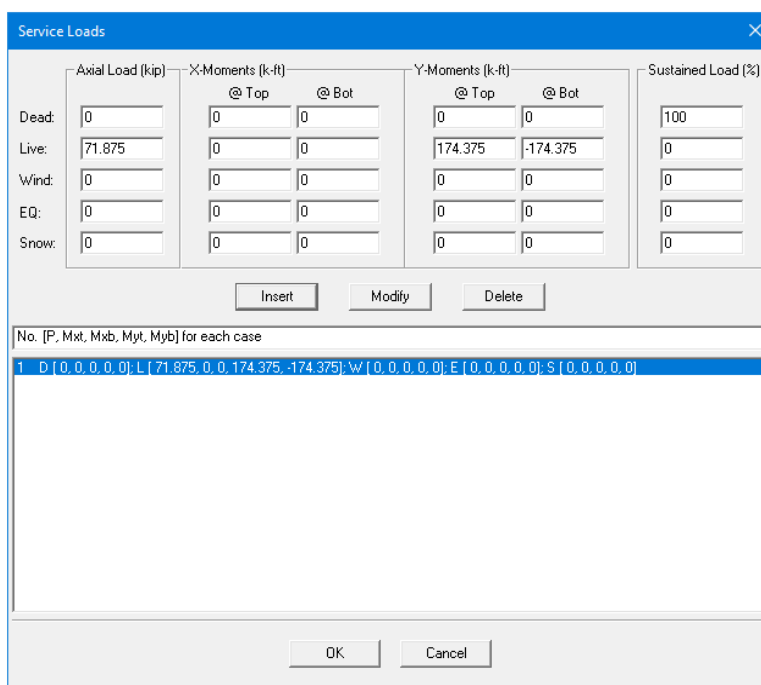
    - Choose OK.

- From the **Input** menu, choose **Loads | Load Combinations**.

  - If the list displays thirteen combinations, choose only the second load combination U2 and delete all the others by selecting them and using DELETE. Choose OK.
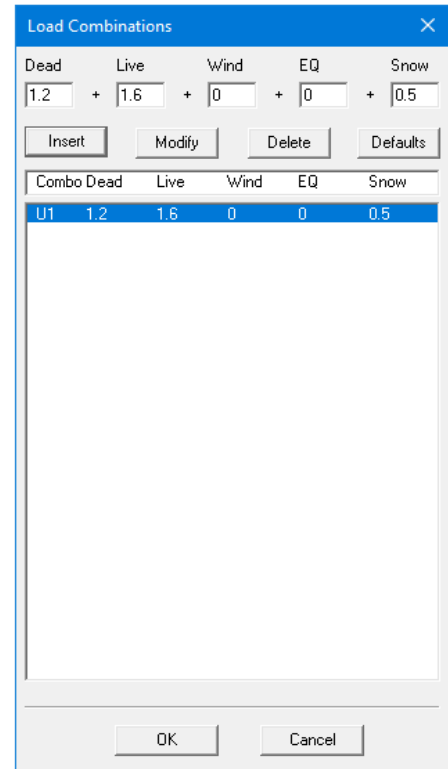
5.2.4　Solving

- From the **Solve** menu, choose **Execute**.

  - The solver of the program is started and, upon completion, displays the interaction diagram of the section with the load point plotted within the diagram.

5.2.5　Viewing and Printing Results

- From the **View** menu, choose **Results**.

  - Use the explorer in the spResults module or the **Previous Table** and **Next Table** buttons in the toolbar to navigate through the tables.

  - Use the close button at the top right corner of the spResults windows to quit the spResults module and get back to spColumn.

- From the **File** menu, choose **Print Report | Default Report**.

  - Select the printer to send the default report to.

  - Choose PRINT.

- From the **File** menu, choose **Print Screen**.

  - Select the printer to send the graphical results to.

  - Choose PRINT.

STRUCTUREPOINT - spColumn v7.00
Licensed to: StructurePoint. License ID: 00000-0000000-4-25EF2-228DB
C:\Program Files (x86)\StructurePoint\spColumn\Examples\Examples-Manual\Example02.col

Page | 1
9/13/2019
8:32 AM

20 x 14 in

General Information

Project	spColumn ... Example 2
Column	Wang 15.18.5
Engineer	SP
Code	ACI 318-19
BarSet	ASTM A615
Units	English
RunOption	Investigation
RunAxis	Biaxial
Slenderness	Considered
ColumnType	Structural
CapacityMethod	Moment capacity

Materials

f'_c	4.5	ksi
E_c	3823.68	ksi
f_y	50	ksi
E_s	29000	ksi

Section

Type	Rectangular	
Width	20	in
Depth	14	in
A_g	280	in^2
I_x	4573.33	in^4
I_y	9333.33	in^4

Reinforcement

Pattern	Sides different
Barlayout	Rectangular
Coverto	Longitudal bars
Clearcover	---
Bars	---
Confinementtype	Tied
Totalsteelarea, A_s	9.36 in^2
Rho	3.34 %
Min.clearspacing	3.39 in

PM at 88.0 [deg]

No.	LoadCombo			P_u kip	M_{ux} k-ft	M_{uy} k-ft	ϕP_n kip	ϕM_{nx} k-ft	ϕM_{ny} k-ft	Capacity Ratio
1	1	U1	Top	115.0	11.5	293.0	115.00	13.83	353.32	0.83
2	1	U1	Bot	115.0	11.5	293.0	115.00	13.83	353.32	0.83

Max. Capacity Ratio: 0.83

20 x 14 in

General Information

Project	spColumn ... Example 2
Column	Wang 15.18.5
Engineer	SP
Code	ACI 318-19
BarSet	ASTM A615
Units	English
RunOption	Investigation
RunAxis	Biaxial
Slenderness	Considered
ColumnType	Structural
CapacityMethod	Moment capacity

Materials

f'_c	4.5 ksi
E_c	3823.68 ksi
f_y	50 ksi
E_s	29000 ksi

Section

Type	Rectangular
Width	20 in
Depth	14 in
A_g	280 in²
I_x	4573.33 in⁴
I_y	9333.33 in⁴

Reinforcement

Pattern	Sides different
Barlayout	Rectangular
Coverto	Longitudal bars
Clearcover	---
Bars	---
Confinementtype	Tied
Totalsteelarea,A_s	9.36 in²
Rho	3.34 %
Min.clearspacing	3.39 in

MM at P=115.0 [kip]

No.		LoadCombo		P_u kip	M_{ux} k-ft	M_{uy} k-ft	ϕP_n kip	ϕM_{nx} k-ft	ϕM_{ny} k-ft	Capacity Ratio
1	1	U1	Top	115.0	11.5	293.0	115.00	13.83	353.32	0.83
2	1	U1	Bot	115.0	11.5	293.0	115.00	13.83	353.32	0.83

Max. Capacity Ratio: 0.83

1. General Information

File Name	C:\Program Files (x86)\Structure...\Example02.col
Project	spColumn Manual Example 2
Column	Wang 15.18.5
Engineer	SP
Code	ACI 318-19
Bar Set	ASTM A615
Units	English
Run Option	Investigation
Run Axis	Biaxial
Slenderness	Considered
Column Type	Structural
Capacity Method	Moment capacity

2. Material Properties

2.1. Concrete

Type	Standard
f'_c	4.5 ksi
E_c	3823.68 ksi
f_c	3.825 ksi
ε_u	0.003 in/in
β_1	0.825

2.2. Steel

Type	Standard
f_y	50 ksi
E_s	29000 ksi
ε_{yt}	0.00172414 in/in

3. Section

3.1. Shape and Properties

Type	Rectangular
Width	20 in
Depth	14 in
A_g	280 in^2
I_x	4573.33 in^4
I_y	9333.33 in^4
r_x	4.04145 in
r_y	5.7735 in
X_o	0 in
Y_o	0 in

3.2. Section Figure

Rectangular 20 x 14 in   3.34% 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 #11 bars or less	#3 ties
For larger bars	#4 ties
Capacity Reduction Factors	
Axial compression, (a)	0.8
Tension controlled ϕ, (b)	0.9
Compression controlled ϕ, (c)	0.65

4.3. Arrangement

Pattern	Sides different
Bar layout	Rectangular
Cover to	Longitudal bars
Clear cover	---
Bars	---
Total steel area, A_s	9.36 in²
Rho	3.34 %

Minimum clear spacing	3.39 in

4.4. Bars Provided

		Bars	Clear cover
			in
Top	2	#11	1.5
Bottom	2	#11	1.5
Left	1	#11	1.5
Right	1	#11	1.5

5. Loading

5.1. Load Combinations

Combination	Dead	Live	Wind	EQ	Snow
U1	1.200	1.600	0.000	0.000	0.500

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	0.00	0.00	0.00	0.00	0.00
1	Live	71.88	0.00	0.00	174.38	-174.38
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	100
Live	0
Wind	0
EQ	0
Snow	0

6. Slenderness

6.1. Sway Criteria

X-Axis	Non-sway column
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	X	22.5	20	14	4573.33	4.5	3823.68
Design	Y	22.5	20	14	9333.33	4.5	3823.68
Above	X	(no column specified...)					
Above	Y	(no column specified...)					
Below	X	(no column specified...)					
Below	Y	(no column specified...)					

6.3. X - Beams

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

6.4. Y - Beams

Beam	Length	Width	Depth	I	f'c	Ec
	ft	in	in	in⁴	ksi	ksi
Above Left	(no beam specified...)					
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, ϕ_K	0.75
Cracked section coefficients, cl(beams)	0.35
Cracked section coefficients, cl(columns)	0.7
$0.2 \, E_c \, I_g + E_s \, I_{se}$ (X-axis)	7.66e+006 kip-in²
$0.2 \, E_c \, I_g + E_s \, I_{se}$ (Y-axis)	2.36e+007 kip-in²
Minimum eccentricity, $e_{x \, min}$	1.02 in
Minimum eccentricity, $e_{y \, min}$	1.20 in

7.2. Effective Length Factors

Axis	Ψ_{top}	Ψ_{bottom}	k (Nonsway)	k (Sway)	kl_u/r
X	0.000	0.000	1.000	(N/A)	66.81
Y	0.000	0.000	1.000	(N/A)	46.77

7.3. Magnification Factors: X - axis

Load Combo			At Ends					Along Length				
		$\sum P_u$	P_c	$\sum P_c$	β_{ds}	δ_s	P_u	$k'l_u/r$	P_c	β_{dns}	C_m	δ
		kip	kip	kip			kip		kip			
1	U1	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	115.00	(N/A)	1036.79	0.000	1.000	1.174

7.4. Magnification Factors: Y - axis

Load Combo			At Ends					Along Length				
		$\sum P_u$	P_c	$\sum P_c$	β_{ds}	δ_s	P_u	$k'l_u/r$	P_c	β_{dns}	C_m	δ
		kip	kip	kip			kip		kip			
1	U1	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	115.00	(N/A)	3199.27	0.000	1.000	1.050

8. Factored Moments

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

8.1. X - axis

Load Combo			1st Order				2nd Order			Ratio
			M_{ns}	M_s	M_u	M_{min}		M_i	M_c	2nd/1st
			k-ft	k-ft	k-ft	k-ft		k-ft	k-ft	
1	U1	Top	0.00	(N/A)	0.00	9.78	$M_1=$	0.00	11.47	1.174
1	U1	Bot	0.00	(N/A)	0.00	9.78	$M_2=$	0.00	11.47	1.174

8.2. Y - axis

Load Combo			1st Order				2nd Order			Ratio
			M_{ns}	M_s	M_u	M_{min}		M_i	M_c	2nd/1st
			k-ft	k-ft	k-ft	k-ft		k-ft	k-ft	
1	U1	Top	279.00	(N/A)	279.00	11.50	$M_1=$	279.00	293.04	1.050
1	U1	Bot	279.00	(N/A)	279.00	11.50	$M_2=$	279.00	293.04	1.050

9. Factored Loads and Moments with Corresponding Capacity Ratios

NOTE: Calculations are based on "Moment 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_{ux}	M_{uy}	ϕP_n	ϕM_{nx}	ϕM_{ny}	NA Depth	ε_t	ϕ	Ratio
				kip	k-ft	k-ft	kip	k-ft	k-ft	in			
1	1	U1	Top	115.00	11.47	293.04	115.00	13.83	353.32	5.19	0.00810	0.900	0.83
2	1	U1	Bot	115.00	11.47	293.04	115.00	13.83	353.32	5.19	0.00810	0.900	0.83

5.3　Example 3 - Design of a Slender Column - Sway Frame

5.3.1　Problem Formulation

Design a square column[78] with a clear height of 16 ft. The column is sway and subjected to dead, live and wind loads as shown below.

	Dead	Live	Wind
P (kip)	380	140	0
Top M_x (kip-ft)	32	20	50
Bottom M_x (kip-ft)	54	36	50

The column is to be checked for the following load combinations:

U1 = 1.2 D + 1.6 L
U2 = 1.2 D + 0.5 L + 1.6 W

The calculations in the reference are done based on the load combination U2.

In practice, the ratio $\Sigma P_c / P_c$ would have to be calculated before the problem can be attempted, using a trial value of $\Sigma P_c / P_c$. Here, the value of $\Sigma P_c / P_c$ used is 28.67 based on the reference value of P_c. There are 14 interior columns, 18 exterior columns and 4 corner columns. Therefore, the value of $\Sigma P_u / P_u = 14 + 18 * 2/ 3 + 4 * 1/3 = 27.33$ irrespective of the load combination being used.

5.3.2　Preparing Input

- From the **File** menu, choose **New**. Any input data is cleared and the default values are restored.

- From the **Input** menu, choose **General Information**

    - Input the PROJECT header.

---

78. Based on Example 12.4, pp 409, from Structural Concrete: Theory and Design by M. Nadim Hassoun and Akthem Al-Manaseer, Fourth Edition, 2008, John Wiley and Sons, Inc.

- Select English units and ACI 318-19 code.

- Select About X-Axis for run axis, Design for run option and Yes for Consider slenderness?

- Choose OK.

5.3.3   Assigning Properties

• From the **Input** menu, pick **Material Properties**.

   - Input 5 for the concrete strength. Other properties are computed and will be accepted.

   - Input 80 for the reinforcing steel strength (High strength reinforcing bar). Other properties are computed and will be accepted.
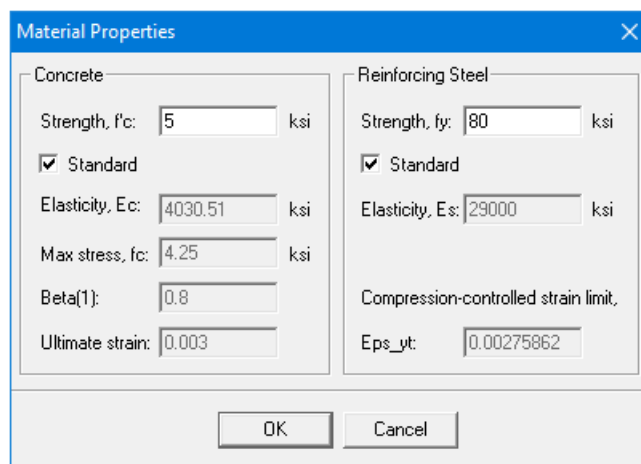
   - Choose OK.

• From the **Input** menu, pick **Section | Rectangular**.

   - Input 18 and 18 for the WIDTH (ALONG X) and DEPTH (ALONG Y) under both START and END options.

   - Choose OK.
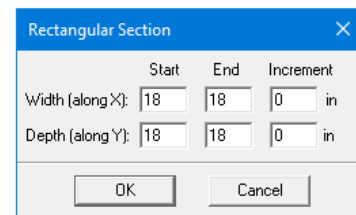
- From the **Input** menu, choose **Reinforcement | All Sides Equal**

  - Input `4-#10` bars for Minimum, and `40-#10` bars for Maximum and `1.5` in for the cover, and select Transverse bars and RECTANGULAR Bar Layout.

  - Choose OK.
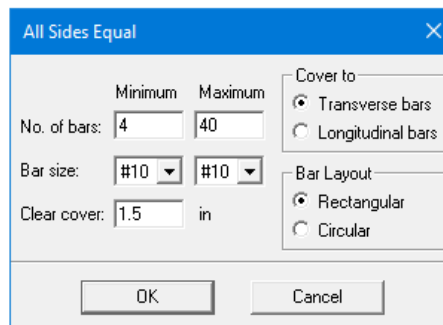
- From the **Input** menu, choose **Slenderness | Design Column.**

  - Input `16` for the column Clear Height.

  - Check Sway frame

  - Under Sway criteria, input `28.67` and `27.33` for the $\Sigma Pc/Pc$ and $\Sigma Pu/Pu$, respectively.

  - Leave 2ND order effect along length option checked (default)

  - Select Compute 'k' factors.

  - Choose OK.
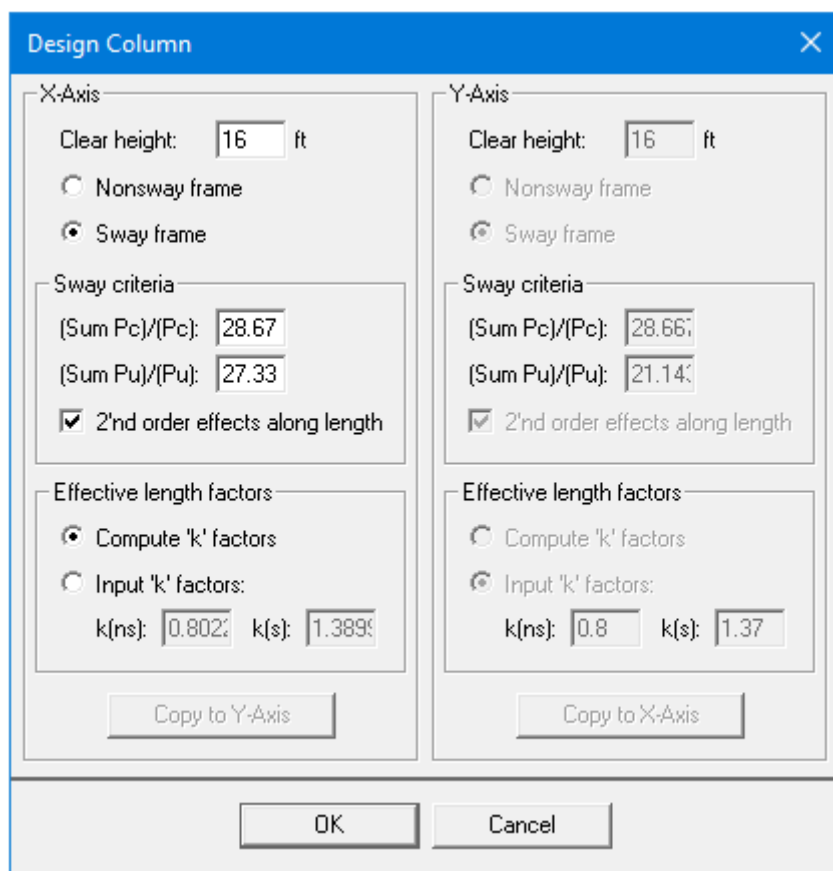
- From the **Input** menu, choose
  Slenderness | Columns Above/Below.

  - Clear the NO COLUMN SPECIFIED option.

  - Input 11 for the column height (center-to-center) under HEIGHT (C/C) and leave the other data as is.

  - Choose Copy to Column Below.

  - Choose OK.
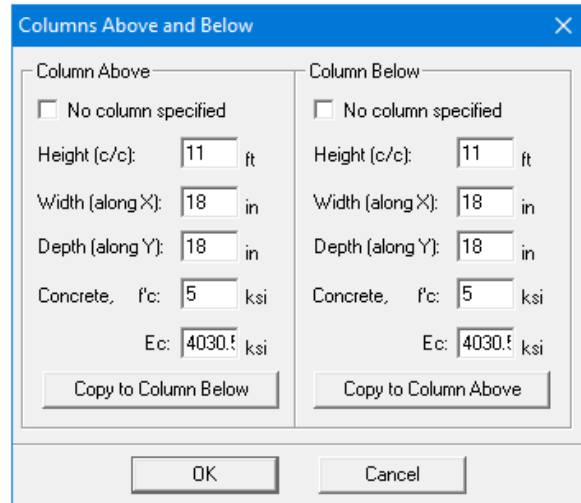
- From the **Input** menu, choose
  Slenderness | X-Beams.

  - Choose ABOVE LEFT.

  - Clear the NO BEAM SPECIFIED option.

  - Input 20 for the span (center-to-center) under SPAN(C/C).

  - Input 0.00 and 0.00 for the WIDTH and DEPTH, respectively.

  - Input 21436.6 for the moment of inertia under INERTIA.

  - Leave the other data as it is.

  - Choose ABOVE RIGHT and click on COPY FROM BEAM LEFT.

  - Choose BELOW LEFT and click on COPY FROM BEAM ABOVE.

  - Choose BELOW RIGHT and click on COPY FROM BEAM ABOVE.

  - Choose OK.
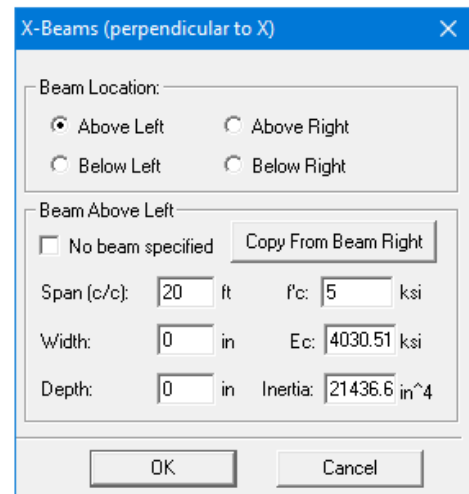
- From the **Input** menu, choose **Loads | Service**.

  - Under DEAD, input 380, 32 and -54 for the AXIAL LOAD, X-MOMENTS @ TOP and X-MOMENTS @ BOT respectively.

  - Under LIVE, input 140, 20 and -36 for the AXIAL LOAD, X-MOMENTS @ TOP and X-MOMENTS @ BOT, respectively.

  - Under WIND, input 0, 50 and -50 for the AXIAL LOAD, X-MOMENTS @ TOP and X-MOMENTS @ BOT, respectively.

- Under SUSTAINED LOAD keep the default settings of 100% for dead and 0% for all other load cases.

- Choose INSERT to add the entry to the list box.

- Choose OK.

- From the **Input** menu, choose **Loads | Load Combinations**.

  - Select all load combinations by clicking on U1 and dragging to U13. Then choose DELETE.

  - Enter `1.2` for Dead, `1.6` for Live, and `0.5` for Snow then choose INSERT.

  - Enter `1.2` for Dead, `0.5` for Live, `1.6` for Wind, and `0.5`for Snow then choose INSERT.

  - Choose OK.
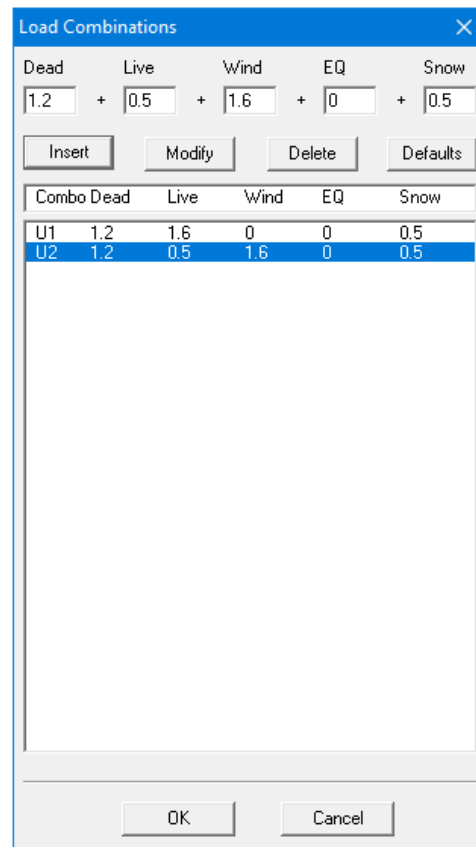
5.3.4   Solving

- From the **Solve** menu, choose **Execute**.

  - The solver of the program is started and, upon completion, displays the interaction diagram of the section with the load points plotted within the diagram.

5.3.5   Viewing and Printing Results

- From the **View** menu, choose **Results**.

  - Use the explorer in the spResults module or the **Previous Table** and **Next Table** buttons in the toolbar to navigate through the tables.

  - Use the close button at the top right corner of the spResults windows to quit the spResults module and get back to spColumn.

- From the **File** menu, choose **Print Report | Default Report**.

  - Select the printer to send the default report to.

  - Choose PRINT.

- From the **File** menu, choose **Print Screen**.

  - Select the printer to send the graphical results to.

  - Choose PRINT.

18 x 18 in
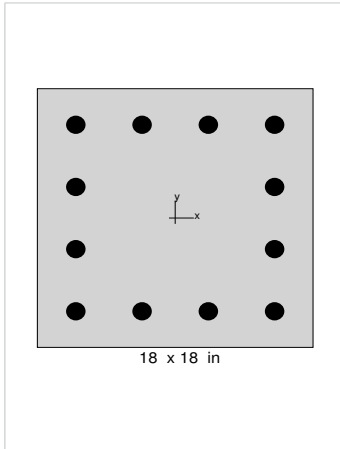
General Information

Project	spColumn ... Example 3
Column	Hassoun 12.4
Engineer	SP
Code	ACI 318-19
BarSet	ASTM A615
Units	English
RunOption	Design
RunAxis	X - axis
Slenderness	Considered
ColumnType	Structural
CapacityMethod	Moment capacity

Materials

f'_c	5	ksi
E_c	4030.51	ksi
f_y	80	ksi
E_s	29000	ksi

Section

Type	Rectangular	
Width	18	in
Depth	18	in
A_g	324	in^2
I_x	8748	in^4
I_y	8748	in^4

Reinforcement

Pattern	All sides equal
Barlayout	Rectangular
Coverto	Transverse bars
Clearcover	1.5 in
Bars	12 #10
Confinementtype	Tied
Totalsteelarea, A_s	15.24 in^2
Rho	4.70 %
Min.clearspacing	3.06 in
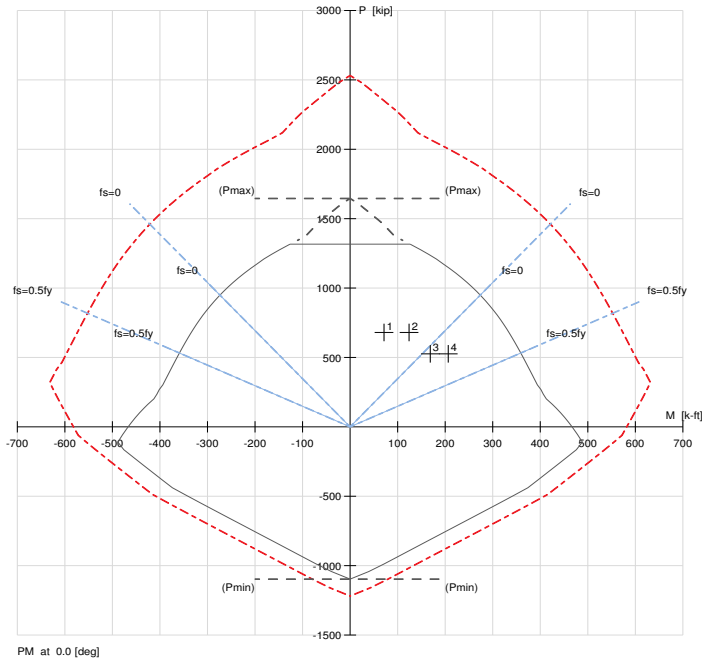
PM at 0.0 [deg]

No.	LoadCombo			P_u kip	M_{ux} k-ft	ϕP_n kip	ϕM_{nx} k-ft	Capacity Ratio
4	1	U2	Bot	526.0	206.5	526.00	359.97	0.57
3	1	U2	Top	526.0	168.7	526.00	359.97	0.47
2	1	U1	Bot	680.0	124.0	680.00	334.13	0.37
1	1	U1	Top	680.0	71.3	680.00	334.13	0.21

Max.CapacityRatio:0.57

1. General Information

File Name	X:\exchange\Houshiar\spColumn\Re...\Example03.cti
Project	spColumn Manual Example 3
Column	Hassoun 12.4
Engineer	SP
Code	ACI 318-19
Bar Set	ASTM A615
Units	English
Run Option	Design
Run Axis	X - axis
Slenderness	Considered
Column Type	Structural
Capacity Method	Moment capacity

2. Material Properties

2.1. Concrete

Type	Standard
f'_c	5 ksi
E_c	4030.51 ksi
f_c	4.25 ksi
ε_u	0.003 in/in
β_1	0.8

2.2. Steel

Type	Standard
f_y	80 ksi
E_s	29000 ksi
ε_{yt}	0.00275862 in/in

3. Section

3.1. Shape and Properties

Type	Rectangular
Width	18 in
Depth	18 in
A_g	324 in^2
I_x	8748 in^4
I_y	8748 in^4
r_x	5.19615 in
r_y	5.19615 in
X_o	0 in
Y_o	0 in

STRUCTUREPOINT - spColumn v7.00
Licensed to: StructurePoint. License ID: 00000-0000000-4-25EF2-228DB
X:\exchange\Houshiar\spColumn\Release\spColumn v7.00\Final_Documents\6- Release\Fi...\Example03.cti

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3.2. Section Figure

Rectangular 18 x 18 in   4.70% reinf.

Figure 1: Column section

4. Reinforcement

4.1. Bar Set: ASTM A615

Bar	Diameter	Area	Bar	Diameter	Area	Bar	Diameter	Area
	in	in^2		in	in^2		in	in^2
#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 ϕ, (b)	0.9
Compression controlled ϕ, (c)	0.65

4.3. Arrangement

Pattern	All sides equal
Bar layout	Rectangular
Cover to	Transverse bars
Clear cover	1.5 in
Bars	12 #10
Total steel area, A_s	15.24 in^2
Rho	4.70 %

STRUCTUREPOINT - spColumn v7.00
Licensed to: StructurePoint. License ID: 00000-0000000-4-25EF2-228DB
X:\exchange\Houshiar\spColumn\Release\spColumn v7.00\Final_Documents\6- Release\Fi...\Example03.cti

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9/12/2019
11:01 AM

Minimum clear spacing	3.06 in

5. Loading

5.1. Load Combinations

Combination	Dead	Live	Wind	EQ	Snow
U1	1.200	1.600	0.000	0.000	0.500
U2	1.200	0.500	1.600	0.000	0.500

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	380.00	32.00	-54.00	0.00	0.00
1	Live	140.00	20.00	-36.00	0.00	0.00
1	Wind	0.00	50.00	-50.00	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	100
Live	0
Wind	0
EQ	0
Snow	0

6. Moment Magnification

6.1. General Parameters

Factors	Code defaults
Stiffness reduction factor, ϕ_K	0.75
Cracked section coefficients, cI(beams)	0.35
Cracked section coefficients, cI(columns)	0.7
$0.2 E_c I_g + E_s I_{se}$ (X-axis)	2.02e+007 kip-in²
Minimum eccentricity, $e_{x\,min}$	1.14 in

6.2. Effective Length Factors

Axis	Ψ_{top}	Ψ_{bottom}	k (Nonsway)	k (Sway)	kl_u/r
X	1.252	1.252	0.802	1.390	51.36

6.3. Magnification Factors: X - axis

Load Combo	At Ends					Along Length				
	$\sum P_u$	P_c	$\sum P_c$	β_{ds}	δ_s	P_u	$k'l_u/r$	P_c	β_{dns}	C_m	δ
	kip	kip	kip			kip		kip			
1 U1	18584.40	2792.45	80059.52	0.000	1.448	680.00	(N/A)	5018.30	0.671	0.830	1.013
1 U2	14375.58	2792.45	80059.52	0.000	1.315	526.00	(N/A)	4490.56	0.867	0.927	1.098

7. Factored Moments

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

7.1. X - axis

Load Combo		1st Order				2nd Order		Ratio
		M_{ns}	M_s	M_u	M_{min}	M_i	M_c	2nd/1st
		k-ft	k-ft	k-ft	k-ft	k-ft	k-ft	
1 U1	Top	70.40	0.00	70.40	64.60 $M_1=$	70.40	71.32	1.013

Load			1st Order				2nd Order		Ratio
Combo			M_{ns}	M_s	M_u	M_{min}	M_i	M_c	2nd/1st
			k-ft	k-ft	k-ft	k-ft		k-ft	k-ft	
1	U1	Bot	122.40	0.00	122.40	64.60	M_2=	122.40	124.00	1.013
1	U2	Top	48.40	80.00	128.40	49.97	M_1=	153.58	168.69	1.314
1	U2	Bot	82.80	80.00	162.80	49.97	M_2=	187.98	206.47	1.268

8. Factored Loads and Moments with Corresponding Capacity Ratios

NOTE: Calculations are based on "Moment Capacity" Method.
Allowable Capacity (Ratio) <= 1.00
Each loading combination includes the following cases:
Top - At column top
Bot - At column bottom

No.	Load			Demand		Capacity		Parameters at Capacity			Capacity
	Combo			P_u	M_{ux}	ϕP_n	ϕM_{nx}	NA Depth	ε_t	ϕ	Ratio
				kip	k-ft	kip	k-ft	in			
1	1	U1	Top	680.00	71.32	680.00	334.13	12.09	0.00084	0.650	0.21
2	1	U1	Bot	680.00	124.00	680.00	334.13	12.09	0.00084	0.650	0.37
3	1	U2	Top	526.00	168.69	526.00	359.97	10.56	0.00140	0.650	0.47
4	1	U2	Bot	526.00	206.47	526.00	359.97	10.56	0.00140	0.650	0.57

5.4 Example 4 - Investigation of Concrete Shear Wall Capacity

5.4.1 Problem Formulation

Investigate the axial load and moment capacity of a shear wall[79] for a given location of the neutral axis. Use 4-ksi concrete and 60-ksi reinforcing steel.
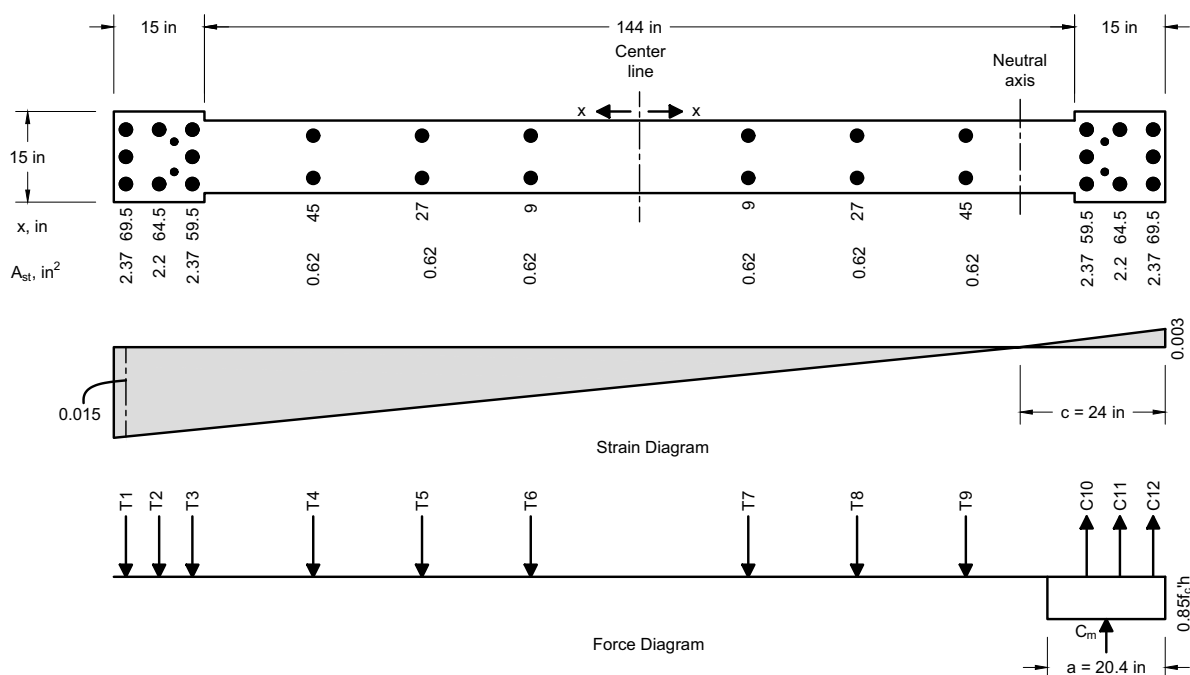
spColumn provides a comprehensive model editor for irregular shapes. For this example, however, a specific tool provided with spColumn will be used for frequently needed shapes.

- From the **Start** Menu, go to **All Programs | StructurePoint | spColumn** and run **Design Assistant**[80].

- Design Assistant uses macros to export data to text files. If a macro warning is displayed when opening Design Assistant, make sure macros are enabled in order for the exporting function to work properly.

---

79. Based on Example 4-4, pp 333, from Seismic and Wind Forces Structural Design Examples by Alan Williams, Third Edition, 2007, International Code Council.

80. Design Assistant is a Microsoft Excel spreadsheet that can be used to facilitate creation of spColumn text import files for a variety of sections including dumbbell shaped and C-shaped shear walls.

- Choose **Example 4** Tab in the spreadsheet.

- **Input** the data shown below:

  - Under OVERALL SECTION WIDTH IN X, input 15.

  - Under OVERALL SECTION HEIGHT IN Y, input 144.

  - Under WEB WIDTH, input 12.

  - Under WEB HEIGHT, input 114.

  - Under NUMBER OF BOUNDARY BARS IN X, input 3.

  - Under NUMBER OF BOUNDARY BARS IN Y, input 3.

  - Under NUMBER OF WEB BARS PER LAYER, input 8.

  - Under WEB BAR SPACING, input 18.

  - Under COVER, input 2.5.

  - Under REINFORCEMENT AREA PER BOUNDARY BAR, input 0.79.

  - Under REINFORCEMENT AREA PER WEB BAR, input 0.31.

Input field	Value
Overall Section Width in X:	15
Overall Section Height in Y:	144
Web Width	12
Web Height	114
Number of Boundary Bars in X	3
Number of Boundary Bars in Y	3
Number of Web Bars per Layer	8
Web Bar Spacing	18
Cover	2.5
Reinforcement Area per Boundary Bar:	0.79
Reinforcement Area per Web Bar:	0.31

Geometry

X	Y
-7.500	72.000
7.500	72.000
7.500	57.000
6.000	57.000
6.000	-57.000
7.500	-57.000
7.500	-72.000
-7.500	-72.000
-7.500	-57.000
-6.000	-57.000
-6.000	57.000
-7.500	57.000
-7.500	72.000

Reinforcement

Boundary	X	Y	Web	X	Y
1	5.000	69.500	1	3.500	63.000
2	5.000	59.500	2	3.500	45.000
3	0.000	69.500	3	3.500	27.000
4	0.000	59.500	4	3.500	9.000
5	-5.000	69.500	5	3.500	-9.000
6	-5.000	59.500	6	3.500	-27.000
7	5.000	64.500	7	3.500	-45.000
8	-5.000	64.500	8	3.500	-63.000
9	5.000	-69.500	9	-3.500	63.000
10	5.000	-59.500	10	-3.500	45.000
11	0.000	-69.500	11	-3.500	27.000
12	0.000	-59.500	12	-3.500	9.000
13	-5.000	-69.500	13	-3.500	-9.000
14	-5.000	-59.500	14	-3.500	-27.000
15	5.000	-64.500	15	-3.500	-45.000
16	-5.000	-64.500	16	-3.500	-63.000

- Press **Export Geometry** Button and **Save Geometry File** box appears. Save the file as `Example4-Geo.txt`
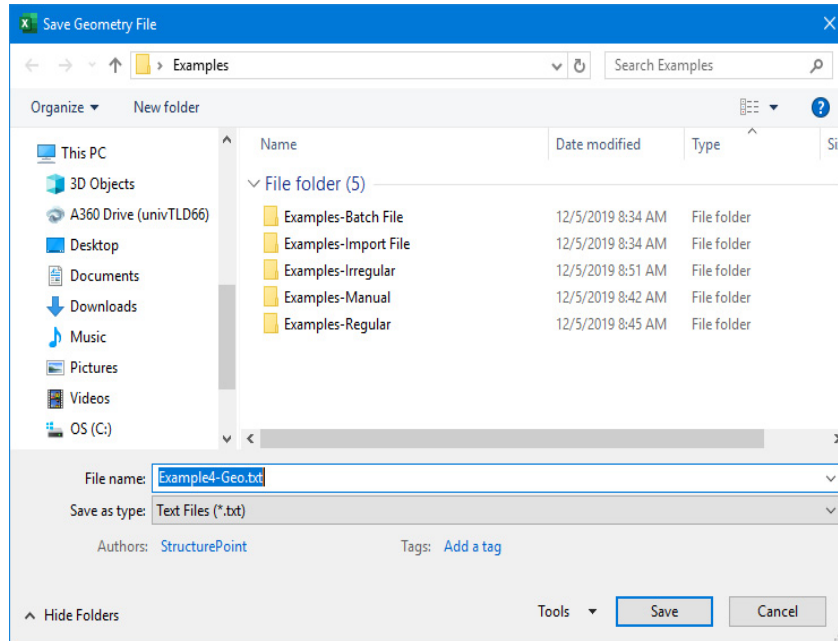
- Press **Export Reinforcement** button and **Save Reinforcement File** dialog box appears. Save the file as `Example4-Reinf.txt`
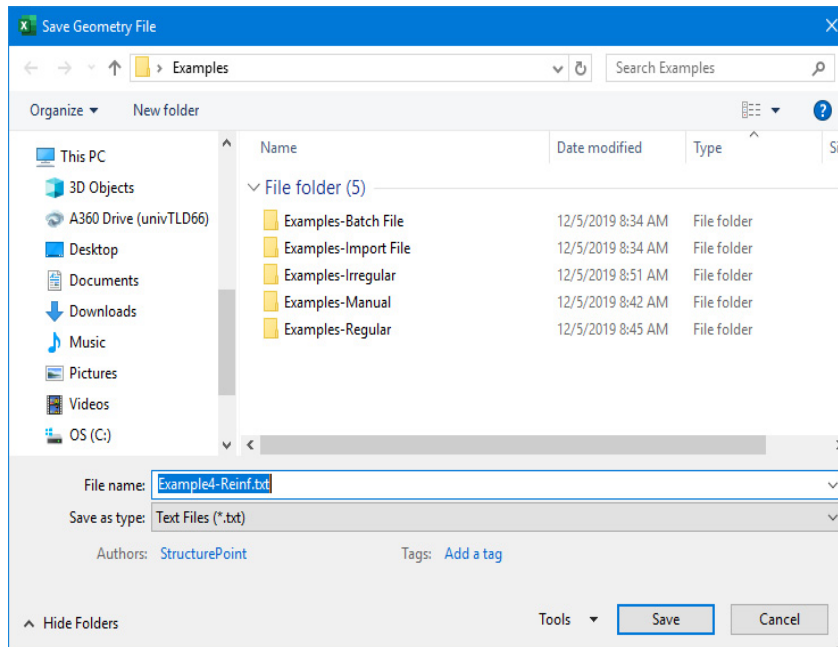
- Save and close the Design Assistant spreadsheet.

- From the **Start** Menu, go to **All Programs | StructurePoint | spColumn** and run **spColumn**

- From the **File** menu, choose **New**. Any input data is cleared and the default values are restored.

- From the **File** menu, choose **Import | Import Data.** Import Data (from text file) dialog box appears. Make sure that **Geometry** radio button is checked, choose OK
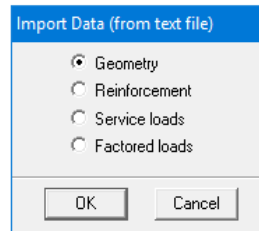
- **Open Import File** box appears. Select `Example4-Geo.txt` file and choose **Open**. The shear wall geometry appears on the spColumn screen.
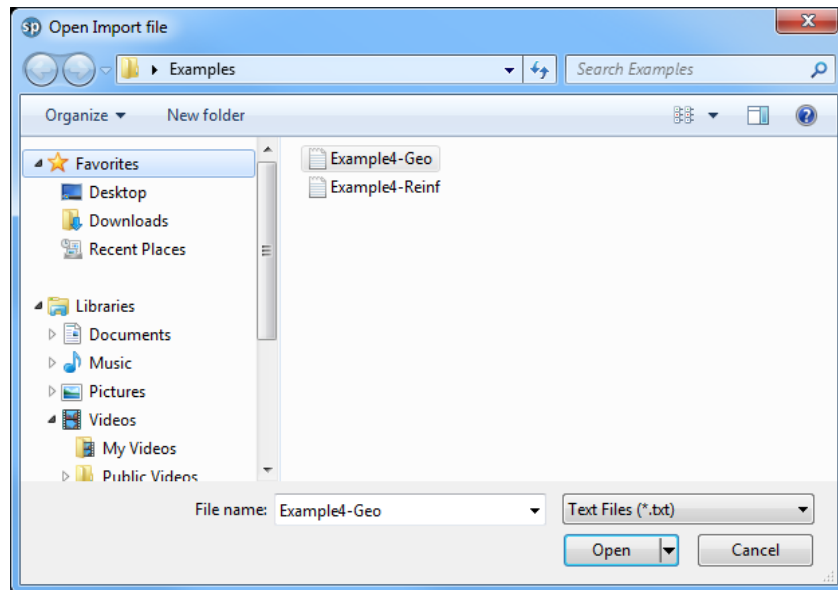
- From the **File** menu, choose **Import | Import Data.** Import Data (from text file) box appears. Press **Reinforcement** radio button, then Choose OK
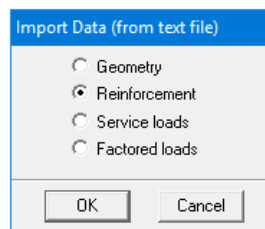
- **Open Import File** box appears. Select `Example4-Reinf.txt` file and choose **Open**. The shear wall reinforcement appears on the spColumn screen as well.
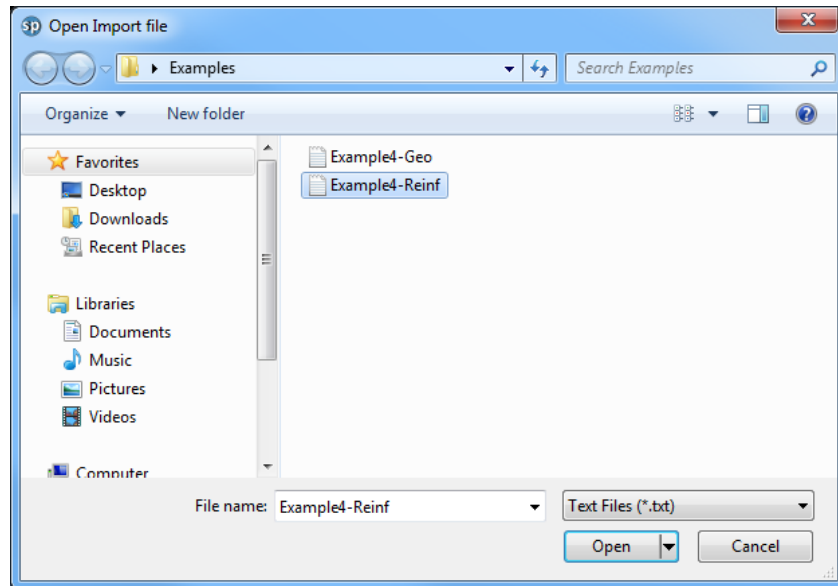
- From the **Input** menu, choose **General Information** Tab. Input Project Information and leave all other options in their default settings of ACI 318-19 design code. Choose OK
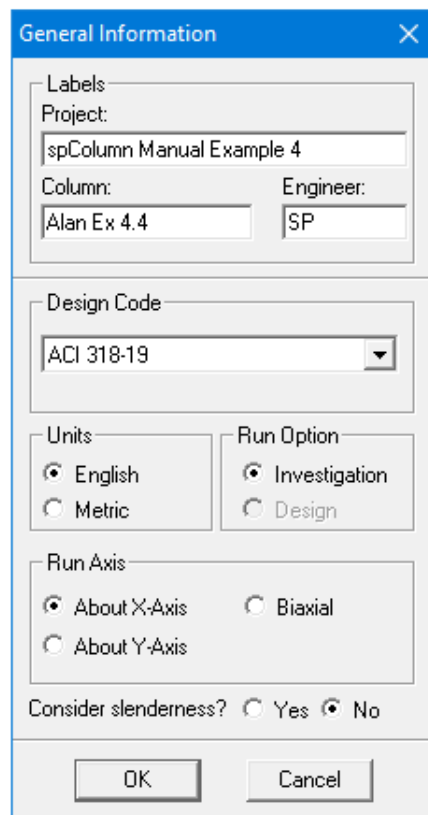
5.4.2　　Assigning Properties

- From the Input menu, choose the **Material Properties** tab. VERIFY CONCRETE STRENGTH, fc', and REINFORCING STEEL STRENGTH, fy, values are entered as 4 ksi, and 60 ksi respectively. Leave all other options in their default settings. Choose OK
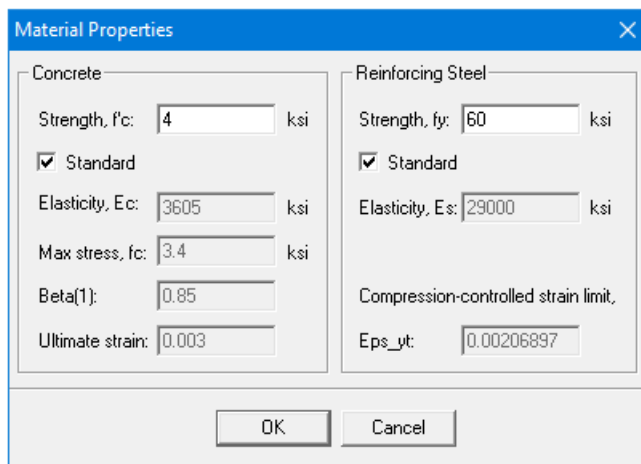
- From the **Input** menu, choose **Reinforcement | Confinement** Tab.

  - From the CONFINEMENT drop-down menu choose OTHER.

  - Input AXIAL COMPRESSION (a) as 0.85.

  - Input COMPRESSION CONTROLLED FAILURE (c) as 0.7.

  - Leave all other options in their default settings. Choose OK
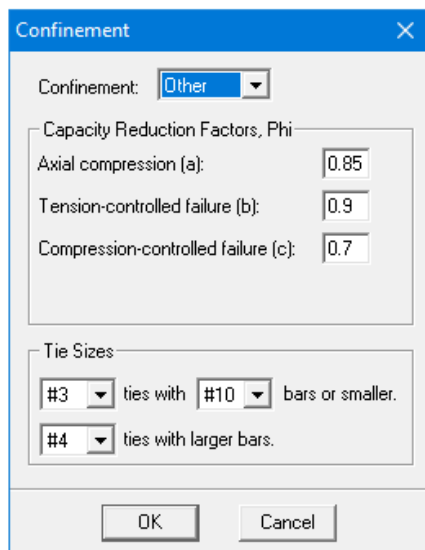
- From the Input menu, choose **Loads | Axial Loads** Tab

  - Input `649.5` for the Initial Load. The initial axial load was selected through trial and error procedure in order to match neutral axis depth of 24 in. given in the example.

  - Choose Insert. Then, choose OK

Axial Loads dialog:

Initial load	Final load	Increment
649.5	0	0
(kip)	(kip)	(kip)

Insert | Modify | Delete

No.	Initial	Final	Inc
1	649.5	0	0

OK | Cancel
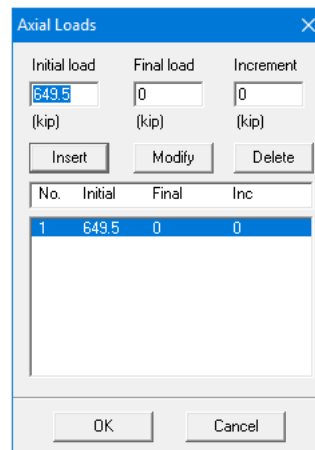
5.4.3   Solving

- From the **Solve** menu, choose **Execute**.

  - Click No when the warning message is displayed saying "Reinforcement ratio is less than 1%. Consider column as architectural (i.e. fc is reduced by reinforcement ratio?)".

  - The solver of the program is started and, upon completion, displays the interaction diagram of the section.

5.4.4   Viewing and Printing Results

- From the **View** menu, choose **Results**.

  - Use the explorer in the spResults module or the **Previous Table** and **Next Table** buttons in the toolbar to navigate through the tables.

  - Use the close button at the top right corner of the spResults windows to quit the spResults module and get back to spColumn.

- From the **File** menu, choose **Print Report | Default Report**.

  - Select the printer to send the default report to.

  - Choose PRINT.

15 x 144 in
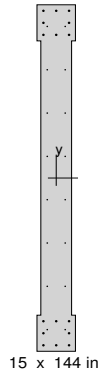
General Information

Project	spColumn ... Example 4
Column	Alan Ex 4.4
Engineer	SP
Code	ACI 318-19
BarSet	ASTM A615
Units	English
RunOption	Investigation
RunAxis	X - axis
Slenderness	Not Considered
ColumnType	Structural
CapacityMethod	Moment capacity

Materials

f'_c	4	ksi
E_c	3605	ksi
f_y	60	ksi
E_s	29000	ksi

Section

Type	Irregular	
A_g	1818	in^2
I_x	3.36209e+006	in^4
I_y	24853.5	in^4

Reinforcement

Pattern	Irregular	
Barlayout	---	
Coverto	---	
Clearcover	---	
Bars	---	
Confinementtype	Other	
Totalsteelarea,A_s	17.60	in^2
Rho	0.97	%
Min.clearspacing	1.31	in
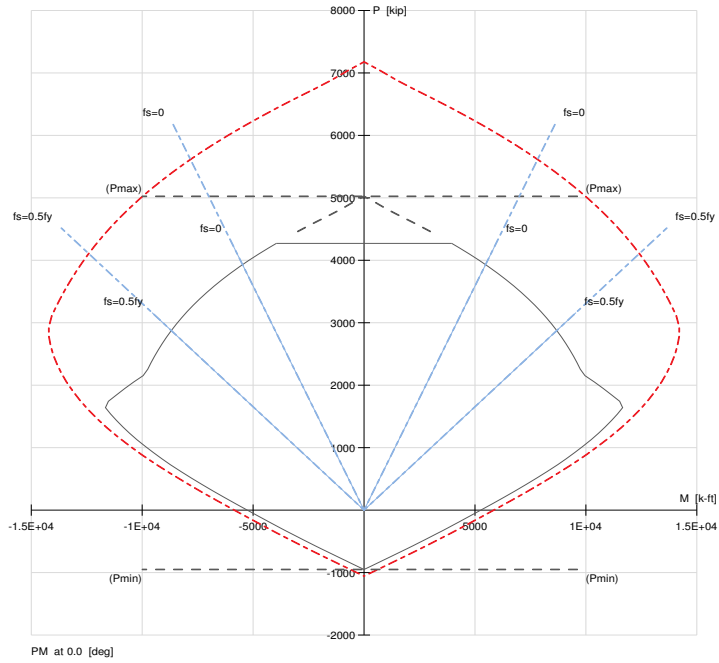
PM at 0.0 [deg]

1. General Information

File Name	C:\Program Files (x86)\Structure...\Example04.col
Project	spColumn Manual Example 4
Column	Alan Ex 4.4
Engineer	SP
Code	ACI 318-19
Bar Set	ASTM A615
Units	English
Run Option	Investigation
Run Axis	X - axis
Slenderness	Not Considered
Column Type	Structural
Capacity Method	Moment capacity

2. Material Properties

2.1. Concrete

Type	Standard
f'_c	4 ksi
E_c	3605 ksi
f_c	3.4 ksi
ε_u	0.003 in/in
β_1	0.85

2.2. Steel

Type	Standard
f_y	60 ksi
E_s	29000 ksi
ε_{yt}	0.00206897 in/in

3. Section

3.1. Shape and Properties

Type	Irregular
A_g	1818 in^2
I_x	3.36209e+006 in^4
I_y	24853.5 in^4
r_x	43.0039 in
r_y	3.6974 in
X_o	0 in
Y_o	0 in
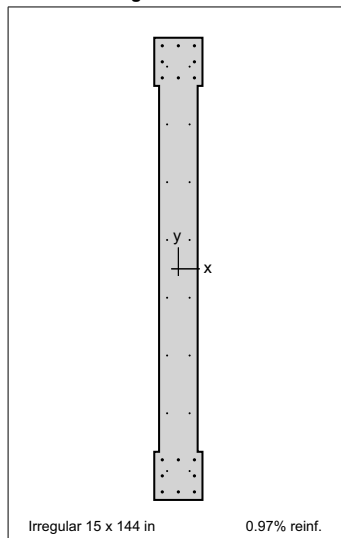
3.2. Section Figure

Figure 1: Column section

3.3. Exterior Points

Points	X	Y	Points	X	Y	Points	X	Y
	in	in		in	in		in	in
1	-7.5	72.0	2	7.5	72.0	3	7.5	57.0
4	6.0	57.0	5	6.0	-57.0	6	7.5	-57.0
7	7.5	-72.0	8	-7.5	-72.0	9	-7.5	-57.0
10	-6.0	-57.0	11	-6.0	57.0	12	-7.5	57.0

4. Reinforcement

4.1. Bar Set: ASTM A615

Bar	Diameter	Area	Bar	Diameter	Area	Bar	Diameter	Area
	in	in^2		in	in^2		in	in^2
#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	Other
For #10 bars or less	#3 ties
For larger bars	#4 ties
Capacity Reduction Factors	
Axial compression, (a)	0.85
Tension controlled ϕ, (b)	0.9
Compression controlled ϕ, (c)	0.7

4.3. Arrangement

Pattern	Irregular

Bar layout	---
Cover to	---
Clear cover	---
Bars	---
Total steel area, A_s	17.60 in²
Rho	0.97 %
Minimum clear spacing	1.31 in

(Note: Rho < 1.0%)

4.4. Bars Provided

Area	X	Y	Area	X	Y	Area	X	Y
in²	in	in	in²	in	in	in²	in	in
0.79	5.0	69.5	0.79	5.0	59.5	0.79	0.0	69.5
0.79	0.0	59.5	0.79	-5.0	69.5	0.79	-5.0	59.5
0.79	5.0	64.5	0.79	-5.0	64.5	0.79	5.0	-69.5
0.79	5.0	-59.5	0.79	0.0	-69.5	0.79	0.0	-59.5
0.79	-5.0	-69.5	0.79	-5.0	-59.5	0.79	5.0	-64.5
0.79	-5.0	-64.5	0.31	3.5	63.0	0.31	3.5	45.0
0.31	3.5	27.0	0.31	3.5	9.0	0.31	3.5	-9.0
0.31	3.5	-27.0	0.31	3.5	-45.0	0.31	3.5	-63.0
0.31	-3.5	63.0	0.31	-3.5	45.0	0.31	-3.5	27.0
0.31	-3.5	9.0	0.31	-3.5	-9.0	0.31	-3.5	-27.0
0.31	-3.5	-45.0	0.31	-3.5	-63.0			

5. Axial Loads and Corresponding Moments Capacities

No	ϕP_n	ϕM_{nx}	NA Depth	d_t Depth	ε_t	ϕ
	kip	k-ft	in	in		
1	649.5	8395.14	23.998	141.500	0.01469	0.900
2	649.5	-8395.14	23.998	141.500	0.01469	0.900

5.5   Example 5 - Capacity of an Irregular Section

5.5.1   Problem Formulation

Compute horizontal moment capacity M_x of the unsymmetrical beam cross section[81] shown below. Use 3-ksi concrete and 60-ksi reinforcing steel.
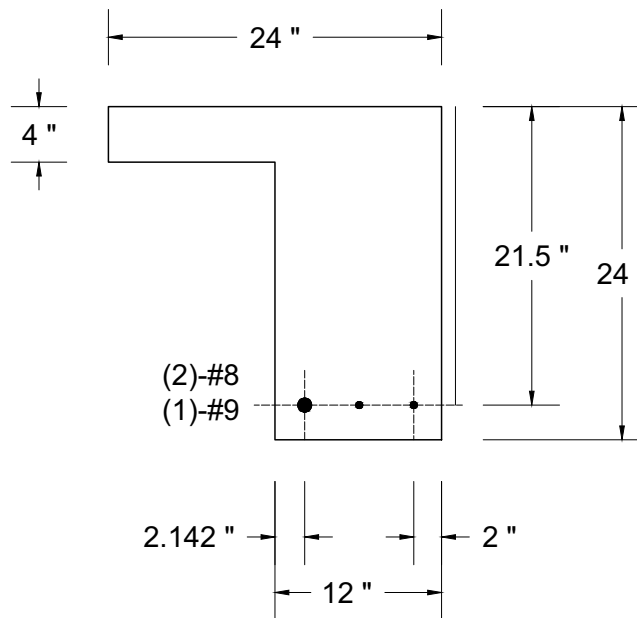
Note: when instructed to move to a location (15, 25), move the cursor until the cells in the Status bar show "x=15" and "y=25".

From the **File** menu, choose **New**. Any input data is cleared and the default values are restored.

---

81. Based on Example 4.7, pp 161 from Reinforced Concrete: Mechanics and Design by James G. Wight and James K. MacGregor, Fifth Edition, 2009, Pearson Prentice Hall, Pearson Education Inc.

5.5.2   Preparing Input

- From the **Input** menu, choose **General Information**.

  - Select English units and ACI 318-19 code.

  - Select Biaxial for run axis, Investigation for run option and No for consider slenderness.
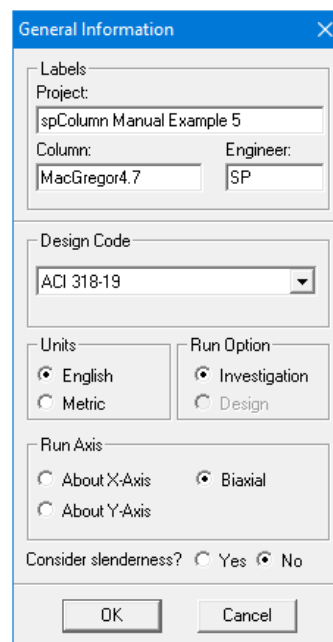
  - Choose Ok.

5.5.3   Assigning Properties

- From the **Input** menu, choose **Material Properties**.

  - Under Concrete, input 3 for the strength. Other properties are computed and will be accepted.
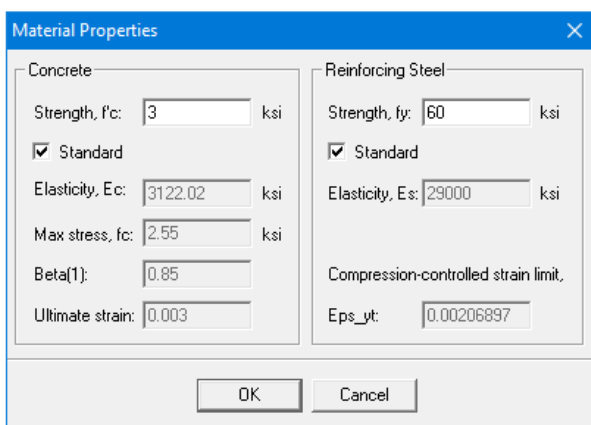
  - Choose Ok.

- From the **Input** menu, choose **Section | Irregular**. When spSection module is loaded its window occupies the desktop. Open the Drawing Area box by selecting the arrow under

  the **Grid On/Off** button .

  - Under Limits, input 0 and 24 for the minimum X and maximum X, respectively.

  - Under limits, input -20 and 4 for the minimum Y and maximum Y, respectively.

  - Under Grid, input 4 and 4 for X and Y grid step, respectively.

  - Choose Ok.

- Click Polygon icon under Draw Menu. The default shape type is Solid.

- In the drawing area, move the cursor to the location (0, 0) and click the left mouse button. A node is inserted.

- Move to (12, 0) and click the left mouse button.

- Move to (12, -20) and click the left mouse button.

- Move to (24, -20) and click the left mouse button.

- Move to (24, 4) and click the left mouse button.

- Move to (0, 4) and click the left mouse button.

- Move to (0, 0) and click the left mouse button.

• Select Single icon under Reinforcement Menu.

- Under Options Menu on the left, select #9 from the drop-down list for BAR SIZE. Under Commands Menu, enter `14.142` for X-COORD and `-17.5` for Y-COORD. Choose OK.

- Under Options Menu on the left, select #8 from the drop-down list for BAR SIZE. Under Commands Menu, enter `18.0` for X-COORD and `-17.5` for Y-COORD. Choose OK.

- Under Options Menu on the left, select #8 from the drop-down list for BAR SIZE. Under Commands Menu, enter `22.0` for X-COORD and `-17.5` for Y-COORD. Choose OK.
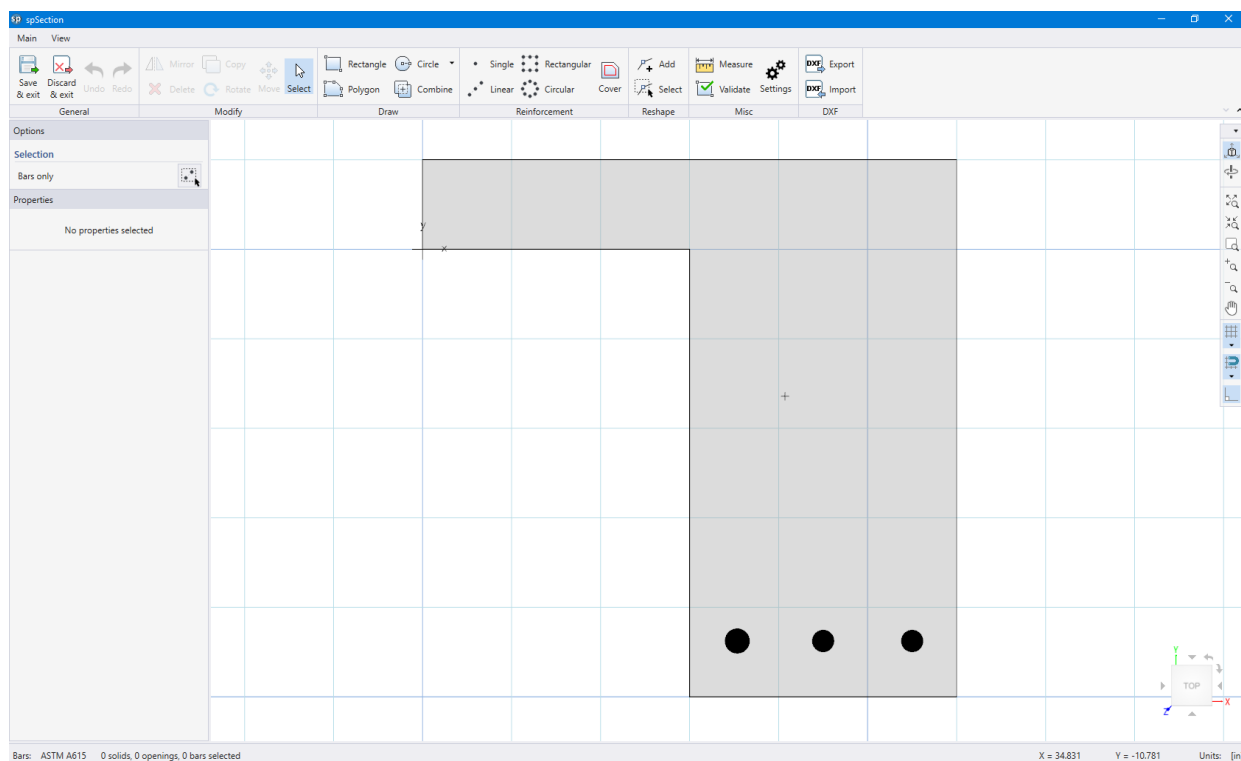
- From the **General** Menu, choose **Save and Exit**. You are returned to spColumn and the section is shown in the Information bar.

- From the **Input** menu, choose **Input** | **Loads | Factored**

  - Enter LOAD as 0 (zero), X-MOMENT as −225 k-ft and Y-MOMENT as 0. Choose INSERT.

  - Choose OK.
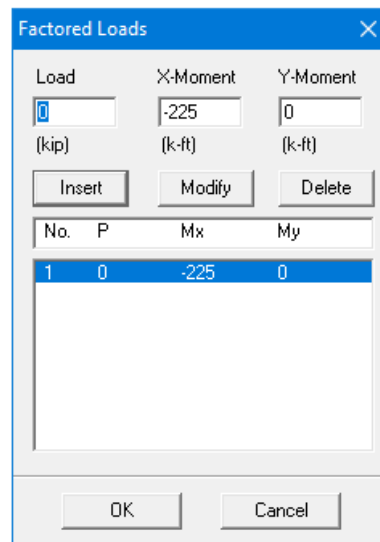
5.5.4 Solving

- From the **Solve** menu, choose **Execute**.

  - A message is displayed saying "Reinforcement ratio is less than 1% Consider column as architectural (i.e. fc is reduced by reinforcement ratio?)". Click NO for this option.

  - The solver of the program is started and, upon completion, displays the interaction diagram of the section.

5.5.5 Viewing and Printing Results

- From the **View** menu, choose **Results**.

  - Use the explorer in the spResults module or the **Previous Table** and **Next Table** buttons in the toolbar to navigate through the tables.

  - Use the close button at the top right corner of the spResults windows to quit the spResults module and get back to spColumn.

- From the **File** menu, choose **Print Report | Default Report**.

  - Select the printer to send the default report to.

  - Choose PRINT.

- From the **File** menu, choose **Print Screen**.

  - Select the printer to send the graphical results to.

  - Choose PRINT

  - Change the interaction diagram to show the P-M diagram at 180° using the ⬛ icon.

24 x 24 in

General Information

Project	spColumn ... Example 5
Column	MacGregor4.7
Engineer	SP
Code	ACI 318-19
BarSet	ASTM A615
Units	English
RunOption	Investigation
RunAxis	Biaxial
Slenderness	Not Considered
ColumnType	Structural
CapacityMethod	Moment capacity

Materials

f'_c	3	ksi
E_c	3122.02	ksi
f_y	60	ksi
E_s	29000	ksi

Section

Type	Irregular	
A_g	336	in²
I_x	18002.3	in⁴
I_y	9956.56	in⁴

Reinforcement

Pattern	Irregular	
Barlayout	---	
Coverto	---	
Clearcover	---	
Bars	---	
Confinementtype	Tied	
Totalsteelarea,A_s	2.58	in²
Rho	0.77	%
Min.clearspacing	2.79	in

PM at 180.0 [deg]

No.	P_u	M_{ux}	M_{uy}	ϕP_n	ϕM_{nx}	ϕM_{ny}	Capacity
	kip	k-ft	k-ft	kip	k-ft	k-ft	Ratio
1	0.0	-225.0	0.0	0.00	-224.43	0.00	1.00

Max. Capacity Ratio: 1.00
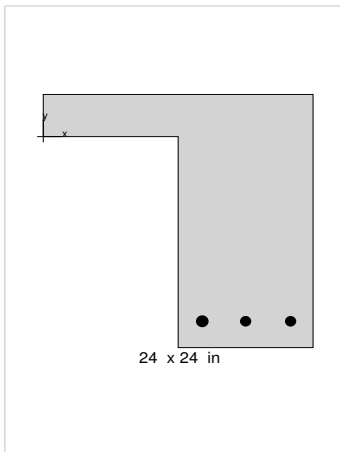
STRUCTUREPOINT - spColumn v7.00
Licensed to: StructurePoint. License ID: 00000-0000000-4-25EF2-228DB
C:\Program Files (x86)\StructurePoint\spColumn\Examples\Examples-Manual\Example05.col

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8:23 AM

24 x 24 in

General Information

Project	spColumn ... Example 5
Column	MacGregor4.7
Engineer	SP
Code	ACI 318-19
BarSet	ASTM A615
Units	English
RunOption	Investigation
RunAxis	Biaxial
Slenderness	Not Considered
ColumnType	Architectural
CapacityMethod	Moment capacity

Materials

f'_c	3 ksi
E_c	3122.02 ksi
f_y	60 ksi
E_s	29000 ksi

Section

Type	Irregular
A_g	336 in^2
I_x	18002.3 in^4
I_y	9956.56 in^4

Reinforcement

Pattern	Irregular
Barlayout	---
Coverto	---
Clearcover	---
Bars	---
Confinementtype	Tied
Totalsteelarea, A_s	2.58 in^2
Rho	0.77 %
Min.clearspacing	2.79 in

MM at P=0.0 [kip]

No.	P_u kip	M_{ux} k-ft	M_{uy} k-ft	ϕP_n kip	ϕM_{nx} k-ft	ϕM_{ny} k-ft	Capacity Ratio
1	0.0	-225.0	0.0	0.00	-208.63	0.00	1.08

Max. Capacity Ratio: 1.08

STRUCTUREPOINT - spColumn v7.00
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C:\Program Files (x86)\StructurePoint\spColumn\Examples\Examples-Manual\Example05.col

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1. General Information

File Name	C:\Program Files (x86)\Structure...\Example05.col
Project	spColumn Manual Example 5
Column	MacGregor4.7
Engineer	SP
Code	ACI 318-19
Bar Set	ASTM A615
Units	English
Run Option	Investigation
Run Axis	Biaxial
Slenderness	Not Considered
Column Type	Structural
Capacity Method	Moment capacity

2. Material Properties

2.1. Concrete

Type	Standard
f'_c	3 ksi
E_c	3122.02 ksi
f_c	2.55 ksi
ε_u	0.003 in/in
β_1	0.85

2.2. Steel

Type	Standard
f_y	60 ksi
E_s	29000 ksi
ε_{yt}	0.00206897 in/in

3. Section

3.1. Shape and Properties

Type	Irregular
A_g	336 in^2
I_x	18002.3 in^4
I_y	9956.56 in^4
r_x	7.31972 in
r_y	5.44359 in
X_o	16.2857 in
Y_o	-6.57143 in

3.2. Section Figure

Irregular 24 x 24 in   0.77% reinf.
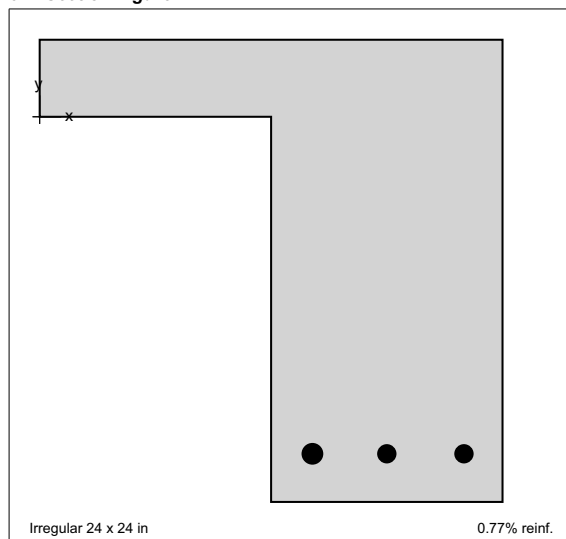
Figure 1: Column section

3.3. Exterior Points

Points	X	Y	Points	X	Y	Points	X	Y
	in	in		in	in		in	in
1	0.0	0.0	2	12.0	0.0	3	12.0	-20.0
4	24.0	-20.0	5	24.0	4.0	6	0.0	4.0

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 φ, (b)	0.9
Compression controlled φ, (c)	0.65

4.3. Arrangement

Pattern	Irregular
Bar layout	---
Cover to	---

Clear cover	---
Bars	---
Total steel area, A_s	2.58 in^2
Rho	0.77 %
Minimum clear spacing	2.79 in

(Note: Rho < 1.0%)

4.4. Bars Provided

Area	X	Y	Area	X	Y	Area	X	Y
in^2	in	in	in^2	in	in	in^2	in	in
1.00	14.1	-17.5	0.79	18.0	-17.5	0.79	22.0	-17.5

5. Factored Loads and Moments with Corresponding Capacity Ratios

NOTE: Calculations are based on "Moment Capacity" Method.

No.	Demand			Capacity			Parameters at Capacity			Capacity
	P_u	M_{ux}	M_{uy}	ϕP_n	ϕM_{nx}	ϕM_{ny}	NA Depth	ε_t	ϕ	Ratio
	kip	k-ft	k-ft	kip	k-ft	k-ft	in			
1	0.00	-225.00	0.00	0.00	-224.43	0.00	7.21	0.00685	0.900	1.00 #

Section capacity exceeded. Revise design!

5.6 Example 6 - Investigation of a Rectangle Short Column

5.6.1 Problem Formulation

Determine the adequacy of a 200 mm x 350 mm column[82] with 6-15M bars. Note that since the least column dimension is less than 300mm, the maximum section axial design capacity is capped in CSA A23.3-14 as required by clause 10.10.4.

The concrete used is 30 MPa and the reinforcing steel is 400 MPa.

The factored load values for the column under consideration are as follows:

P (kN)	500 kN
M_{ux} (kN-m)	37.5 kN-m

From the **File** menu, choose **New**. Any input data is cleared and the default values are restored.

5.6.2 Preparing Input
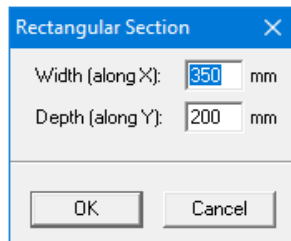
- From the **Input** menu, choose **General Information**.
    - Input the PROJECT header.
    - Select METRIC units and CSA A23.3-19 code.
    - Select About X-Axis for run axis, Investigation for run option and No for Consider Slenderness?
    - Choose OK.

5.6.3 Assigning Properties
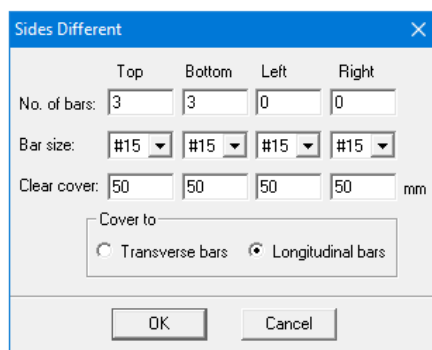
- From the **Input** menu, choose **Material Properties**.

---

82. Based on STRUCTUREPOINT Hand Verification Example based on CSA A23.3-14 Concrete Design Handbook

- Input 30 for the CONCRETE STRENGTH, and 400 for the REINFORCING STEEL STRENGTH. Other properties are computed and will be accepted.

- Choose OK.

• From the **Input** menu, choose **Section | Rectangular**.

- Input 350 and 200 for the section width (along X) and depth (along Y).

- Choose OK.

• From the **Options** menu, choose **Reinforcement**.

- For Bar Set, choose CSA G30.18 from the drop down list.

- Choose OK.

• From the **Input** menu, choose **Reinforcement | Sides Different**

- Input 3-#15 bars for TOP and BOTTOM and 0-#15 for LEFT and RIGHT. Input 50 in for the cover and select LONGITUDINAL BARS.

- Choose OK.

• From the **Input** menu, choose **Loads | Factored**.

- Input 500 for the AXIAL LOAD, 37.5 for the X-MOMENTS.

- Choose INSERT to add the entry to the list box.

- Choose OK.

5.6.4 Solving

- From the **Solve** menu, choose **Execute**.

    - The solver of the program is started and, upon completion, displays the interaction diagram of the section with the load point plotted within the diagram.

5.6.5 Viewing and Printing Results

- From the **View** menu, choose **Results**.

    - Use the explorer in the spResults module or the **Previous Table** and **Next Table** buttons in the toolbar to navigate through the tables.

    - Use the close button at the top right corner of the spResults windows to quit the spResults module and get back to spColumn.

- From the **File** menu, choose **Print Report | Default Report**.

    - Select the printer to send the default report to.

    - Choose PRINT.

- From the **File** menu, choose **Print Screen**.

    - Select the printer to send the graphical results to.

    - Choose PRINT.
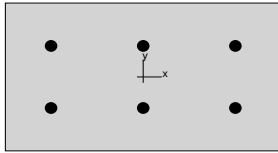
350 x 200 mm

General Information

Project	spColumn ... Example 6
Column	Rect-200x350
Engineer	SP
Code	CSA A23.3-19
BarSet	CSA G30.18
Units	Metric
RunOption	Investigation
RunAxis	X - axis
Slenderness	Not Considered
ColumnType	Structural
CapacityMethod	Moment capacity

Materials

f'_c	30	MPa
E_c	26621.1	MPa
f_y	400	MPa
E_s	200000	MPa

Section

Type	Rectangular	
Width	350	mm
Depth	200	mm
A_g	70000	mm^2
I_x	2.33333e+008	mm^4
I_y	7.14583e+008	mm^4

Reinforcement

Pattern	Sides different	
Barlayout	Rectangular	
Coverto	Longitudal bars	
Clearcover	---	
Bars	---	
Confinementtype	Tied	
Totalsteelarea,A_s	1200	mm^2
Rho	1.71	%
Min.clearspacing	68	mm
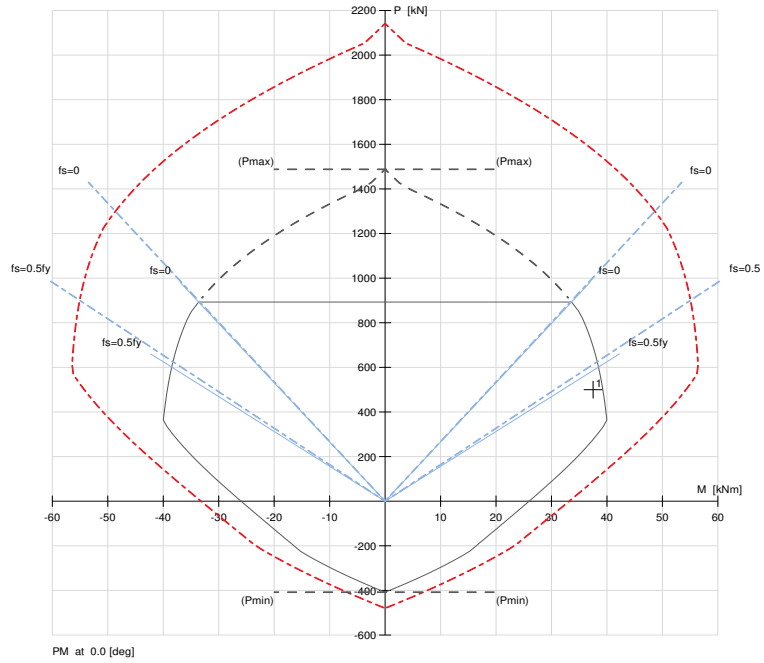
PM at 0.0 [deg]

No.	P_f kN	M_{fx} kNm	P_r kN	M_{rx} kNm	Capacity Ratio
1	500.0	37.5	500.00	39.25	0.96

Max.CapacityRatio:0.96

STRUCTUREPOINT - spColumn v7.00
Licensed to: StructurePoint. License ID: 00000-0000000-4-25EF2-228DB
X:\exchange\Houshiar\spColumn\Release\spColumn v7.00\Prog_EXE\12-05-19_Obfuscated\...\Example06.col

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12/5/2019
10:33 AM

1. General Information

File Name	X:\exchange\Houshiar\spColumn\Re...\Example06.col
Project	spColumn Manual Example 6
Column	Rect-200x350
Engineer	SP
Code	CSA A23.3-19
Bar Set	CSA G30.18
Units	Metric
Run Option	Investigation
Run Axis	X - axis
Slenderness	Not Considered
Column Type	Structural
Capacity Method	Moment capacity

2. Material Properties
2.1. Concrete

Type	Standard
f'_c	30 MPa
E_c	26621.1 MPa
f_c	24.15 MPa
ε_u	0.0035 mm/mm
β_1	0.895

2.2. Steel

Type	Standard
f_y	400 MPa
E_s	200000 MPa
ε_{yt}	0.002 mm/mm

3. Section
3.1. Shape and Properties

Type	Rectangular
Width	350 mm
Depth	200 mm
A_g	70000 mm^2
I_x	2.33333e+008 mm^4
I_y	7.14583e+008 mm^4
r_x	57.735 mm
r_y	101.036 mm
X_o	0 mm
Y_o	0 mm

3.2. Section Figure

Rectangular 350 x 200 mm   1.71% reinf.
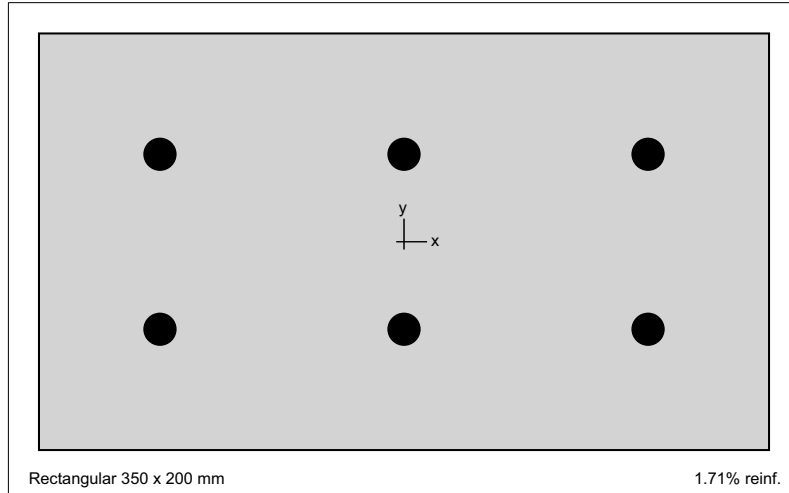
Figure 1: Column section

4. Reinforcement

4.1. Bar Set: CSA G30.18

Bar	Diameter	Area	Bar	Diameter	Area	Bar	Diameter	Area
	mm	mm²		mm	mm²		mm	mm²
#10	11.30	100.00	#15	16.00	200.00	#20	19.50	300.00
#25	25.20	500.00	#30	29.90	700.00	#35	35.70	1000.00
#45	43.70	1500.00	#55	56.40	2500.00			

4.2. Confinement and Factors

Confinement type	Tied
For #55 bars or less	#10 ties
For larger bars	#10 ties
Material Resistance Factors	
Axial compression, (a)	0.6
Steel (ϕ_s)	0.85
Concrete (ϕ_c)	0.65
Minimum dimension, h	200 mm

4.3. Arrangement

Pattern	Sides different
Bar layout	Rectangular
Cover to	Longitudal bars
Clear cover	---
Bars	---
Total steel area, A_s	1200 mm²
Rho	1.71 %
Minimum clear spacing	68 mm

4.4. Bars Provided

		Bars	Clear cover
			mm
Top	3	#15	50
Bottom	3	#15	50
Left	0	#15	50
Right	0	#15	50

5. Factored Loads and Moments with Corresponding Capacity Ratios

NOTE: Calculations are based on "Moment Capacity" Method.

No.	Demand		Capacity		Parameters at Capacity		Capacity
	P_f	M_{fx}	P_r	M_{rx}	NA Depth	ε_t	Ratio
	kN	kNm	kN	kNm	mm		
1	500.00	37.50	500.00	39.25	101	0.00140	0.96

CHAPTER

6

spSection MODULE

6.1   Introduction

spSection is an add-on module to the spColumn program. It enables the user to investigate irregularly shaped reinforced concrete sections subject to a combination of loadings. spSection considers a polygonal section reinforced with bars located at any location. The section may contain one opening.

spSection is accessed from within spColumn. Once spColumn is started, you can activate spSection by selecting the **Section | Irregular** command from the **Input** menu. This starts spSection, locks the spColumn window and maximizes the spSection window. The section geometry may then be defined by drawing it on the screen or by inputting the coordinates of the polygon nodes. Once the section definition is complete, return to spColumn by selecting **Save and Exit** from the **Main** menu or the Toolbar. The following is a list of the spSection window components.
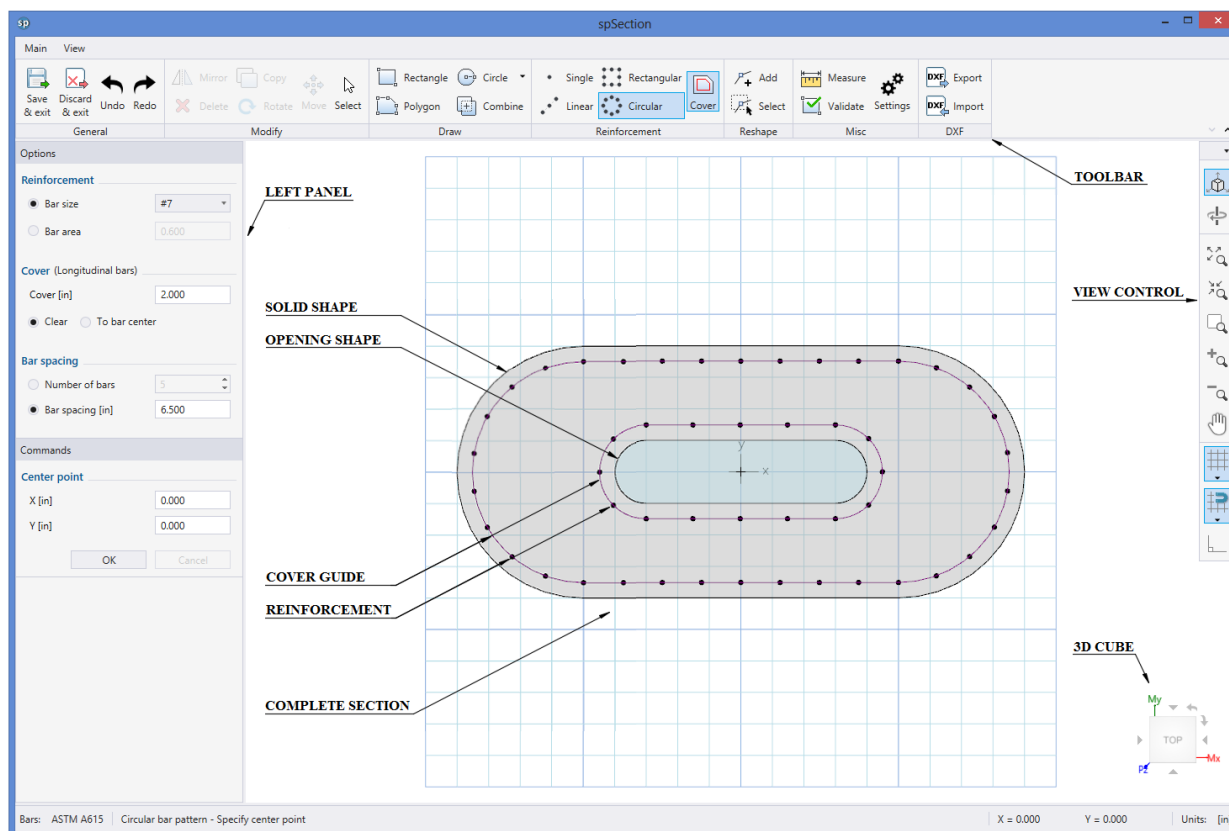
6.2   Main Menu

Import

Imports the DXF File.

Export

Exports to the DXF File.

Errors

Lists the errors in the spSection model.

Validate

Checks if the section is valid for analysis by spColumn.

Save and Exit

Saves changes and exits.

Exit without Saving

Discards changes and exits.

6.3   View Menu

Toolbar

Provides five options to determine the location and size of the toolbar.

Settings

Provides the user with options to modify general and color settings.

In General Settings, user controls are provided for display, at exit choices, and precision options.

Display:

- Coordinate system sign: Provides a cross-hair indicating the X and Y axes.
- Object Centroid: Provides a cross-hair at the object centroid.
- Grid labels: Show or hide grid labels
- Flying text: Displays the parameters related to the operation in flying text box while performing that operation.

At Exit:

- Combine all shapes: When checked, it combines all shapes at exit.
- Align model centroid to coordinate system origin: When checked, it aligns model centroid to the coordinate system centroid at exit.

Precision:

- General: Shows on 0 to 3 trailing decimal places when entering dimensions at the left panel textboxes.
- Flying text: Shows on 0 to 3 trailing decimal places when displaying flying text.

In Colors Settings:

- Shapes: Color options for solid, selected solids, openings, and selected openings.
- Reinforcement: Color options for bar, selected bar, and overlapped bar.
- Misc: Color options for main grid lines, other grid lines, and screen background.
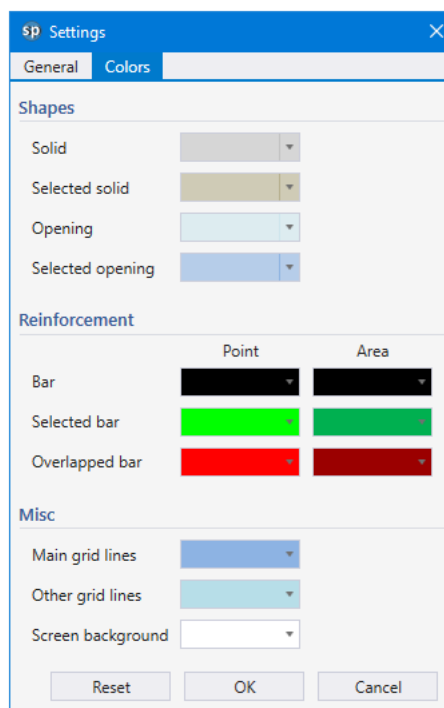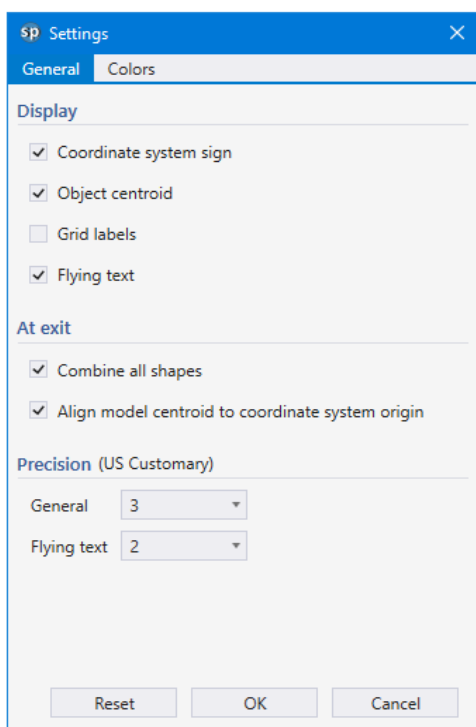
View Controls

Shows or hides the view controls. Arrows in the upper right corner provide controls for the location or the tool and extent of functions. The icons show in blue when active. View controls provide the following operator functions:

- Show and hide 3D rotation cube.

- Rotate section in 3D (shift + middle mouse button)

- Zoom to workspace

- Zoom to model

- Zoom to window

- Zoom in (mouse wheel)

- Zoom out (mouse wheel)

- Pan (middle mouse button)

- Grid On/Off: Shows or hides the grids. The arrow at the bottom of the icon opens Drawing Area dialog box which enables the user to edit the limits of drawing area and grid steps in X, and Y directions.

- Snap On/Off: Activates or deactivates the snap feature, the arrow at the bottom of the icon opens Snap dialog box. Snap options are: Grid, shapes, cover, reinforcements, intersections, and coordinate system origin.
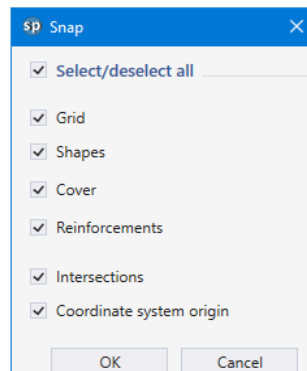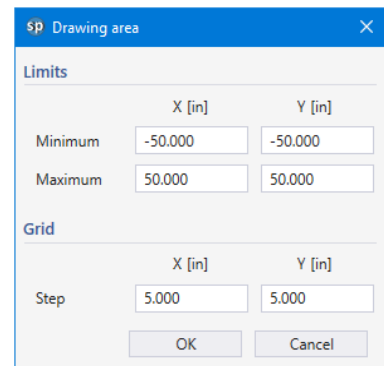
- Ortho mode On/Off: Restrict cursor movement to horizontal and vertical direction when creating or modifying sections.

Status Bar

Shows or hides the status bar. Status bar is located at the bottom of the screen and displays the bars set, active command and its instruction, the coordinates of the cursor, and the units.

6.4   Toolbar - General

Save and Exit

   Saves changes and exits.

Exit without Saving

   Discards changes and exits.

Undo

   Undo last operation (Ctrl + Z).

Redo

   Redo last operation (Ctrl + Y).

6.5   Toolbar - Modify

Mirror

   Mirrors selected items about line or point.

Delete

   Deletes selected items.

Copy

   Copies selected items to new location.

Rotate

   Rotates selected items from a base point by a specified angle.

Move

   Moves selected items to new location.

Select

   Selects items to perform operations.

6.6   Toolbar - Draw

Rectangle

Creates rectangular shapes of solid or opening by clicking the start and end points. Alternately, the shape can be created by typing precise start point coordinates and dimensions at the left panel when Draw | Rectangle icon is active.

Polygon

Creates polygon shapes by specifying its vertices in the drawing area until the closed polygon shape is obtained or by typing precise point coordinates and then pressing close button at the left panel when Draw | Polygon icon is active.

Circle

Creates circular shapes in one of the three methods namely;

- Circle | Draw circle by radius: Create circular shape by specifying center point and radius.
- Circle 2 points | Draw circle by diameter: Create circular shape by specifying its diameter.
- Circle 3 points | Draw circle by tangent points: Create circular shape by specifying three tangent points.

Combine

Combines all shapes or just selected shapes.

6.7   Toolbar - Reinforcement

Single – Add single reinforcement bar

Creates a single reinforcement bar at a point. When the reinforcement single icon is active, single bar can be created by clicking at any point on the screen. Alternatively, single reinforcement bar can also be created by entering precise coordinates at the left panel.

Linear – Add bars in linear pattern

Creates a linear bar pattern based on the specified bar number or bar spacing. When the reinforcement linear icon is active, linear bar pattern can be created by specifying start and next points on the screen. Alternatively, linear bar pattern can also be created by entering precise coordinates of the start point and next points at the left panel.

Rectangular – Add bars in rectangular pattern

Creates a rectangular bar pattern based on the specified number of bars in the X and Y directions respectively. When the reinforcement rectangular icon is active, rectangular bar pattern can be created by specifying start and end points of the diagonal on the screen. Alternatively, rectangular bar pattern can also be created by entering precise coordinates of the start point and the translation vector of the diagonal for the rectangle, at the left panel.

Circular – Add bars in circular pattern

Creates a circular bar pattern based on the specified bar number or bar spacing. When the reinforcement circular icon is active, circular bar pattern can be created by specifying the center point of the circle and the end point of its radius on the screen. Alternatively, circular bar pattern can also be created by entering precise coordinates of the center point, the radius and its angle with x-axis, at the left panel.

Cover

Shows and hides the bar cover guide. The cover type i.e. clear or to bar center and the required value can be specified while using each of the above mentioned commands for reinforcement.

6.8   Toolbar - Reshape

Add – Add nodes

Creates additional nodes on shape edges.

Select – Select nodes

Selects nodes to move or delete.

6.9   Toolbar - Misc

Measure

Measures distance between two points.

Validate

Checks if the section is valid for analysis by spColumn.

Settings

Modifies settings for view, display, combine, precision, and colors. Refer to View Menu for more information on settings.

6.10   Toolbar - DXF

Export DXF
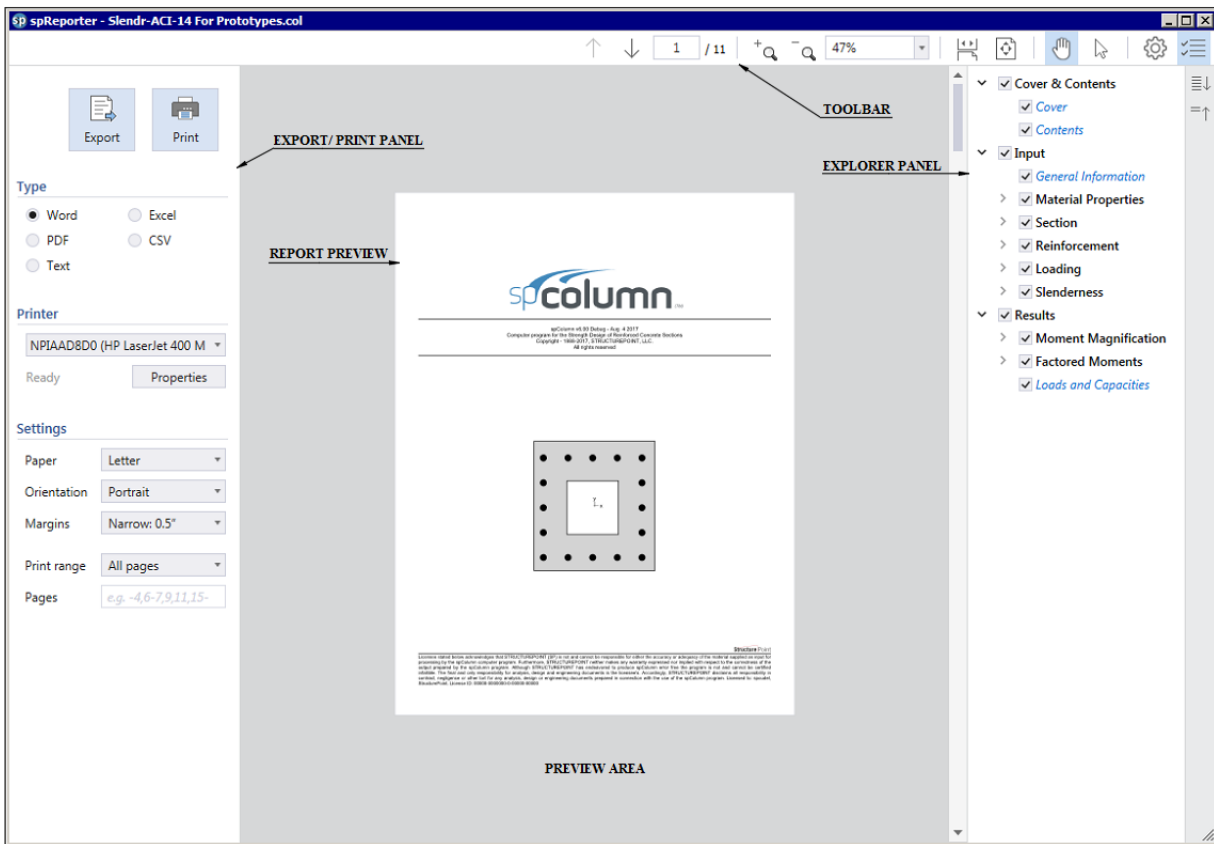
Exports the model to DXF file.

Import DXF

Imports a model from DXF file.

CHAPTER

7

spReporter MODULE

7.1   Introduction

spReporter is a module of the spColumn program. It enables the user to view, customize, print and export reports in different formats.

spReporter is accessed from within spColumn. Once a successful run has been performed, you can open spReporter by selecting the Reporter command from the View menu. Alternatively, spReporter can also be accessed by pressing the F7 key or by clicking on the spReporter button in the program toolbar. Immediately after opening spReporter, you can export and/or print the default report by pressing Export/Print button. Various options to customize the report before printing and/or exporting it are also provided. Once the work in spReporter is complete click the close button in the top right corner to exit the spReporter window.

7.2   Toolbar

Previous page

   Displays the previous page of the report.

Next page

   Displays the next page of the report.

Page number box

   Displays the page with the page number entered in the box.

Zoom in

   Zooms in on the report (Ctrl + Mouse wheel up).

Zoom out

   Zooms out on the report (Ctrl + Mouse wheel down).

Zoom box

   Zooms on the report preview to the extent typed in the box or selected from the dropdown
   list.

Fit to window width and enable scrolling

   Fits the width of report to the preview space width and enables scrolling.

Fit one full page to window

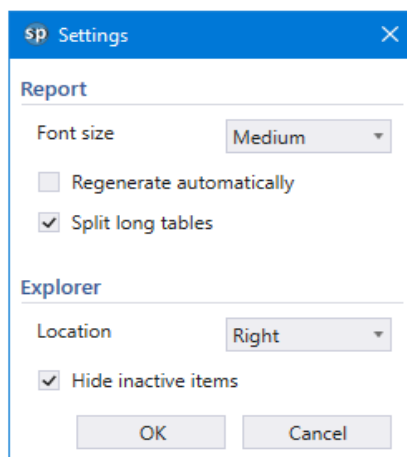   Fits one full page in the preview space.

Pan

   When toggled on and if the report is bigger than preview window, enables panning the
   report.

Text selection

   When toggled on enables selecting text in the report.

Settings

   Modifies settings for report and explorer panel.

– **Report Settings**

Regenerate automatically: Enables automatic regeneration of report when content selection is modified by the user.

Split long tables: Displays table headings in all pages when tables are split along several pages.

– **Explorer Settings**

Location: Displays explorer panel on the left or right side of screen depending on selection.

Hide inactive items:: Hides unused tables from the explorer view.

Explorer

Shows or hides the explorer panel.

7.3　Export / Print Panel

Export

Exports the report in the selected format.

Print

Prints the report in the selected format when the option is available.

Type

Provides 5 format options to print and/or export the reports

- **Word**: Produces a Microsoft Word file with .docx extension.

- **PDF**: Produces an Adobe Acrobat file with .pdf extension.

- **Text**: Produces a Text file with .txt extension.

- **Excel**: Produces a Microsoft Excel file with .xlsx extension.

- **CSV**: Produces a Comma Separated file with .csv extension.

Printer

Provides the option to select available printers and change printer properties.

Settings

Provides the options to modify print settings.

- **Paper**: Provides the options to select from available paper sizes.

- **Orientation**: Provides the options to select between landscape or portrait paper orientation.

- **Margins**: Provides the options to use narrow, normal, wide or custom margins to the report.
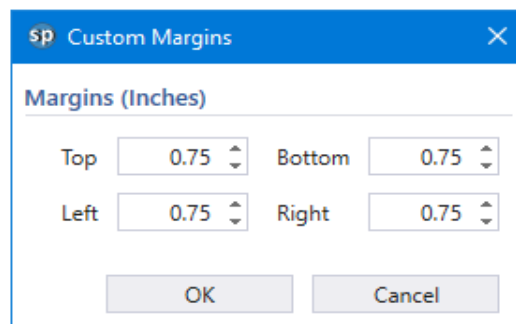
- **Print range**: Provides the options to select the pages to print and/or export.

7.4   Explorer panel

The explorer panel consists of all the available report items classified into sections and arranged hierarchically. Each item listed in the explorer panel is preceded by a checkbox. The user can check/uncheck the checkbox to include or exclude from the report, the items or sections.

Expand all

Expands item list.

Collapse all

Collapses item list.

CHAPTER

8

spResults MODULE
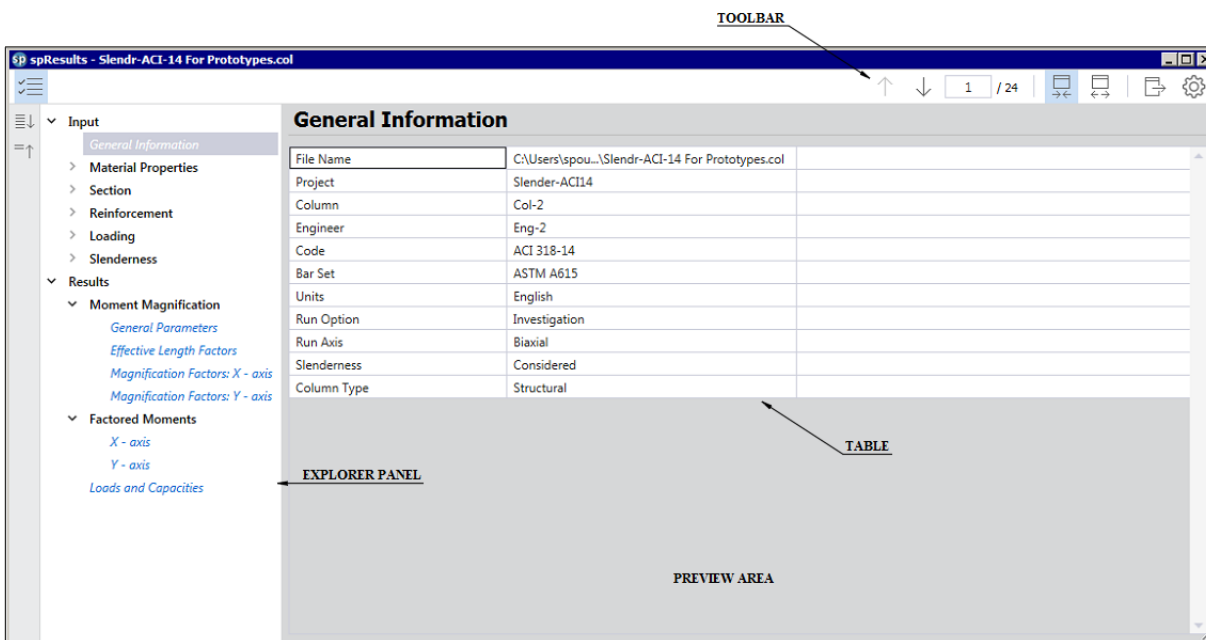
8.1 Introduction

spResults is a module of the spColumn program. It enables the user to view program input and output in tables and export them in different formats.

spResults is accessed from within spColumn. Once a model has been successfully executed, you can open spResults by selecting the Results command from the View menu. Alternatively, spResults can also be accessed by pressing the F6 key or by clicking on the spResults button in the program toolbar. Once the work in spResults is complete click the close button in the top right corner to exit spResults window.

8.2 Toolbar

Previous table

Displays the previous table.

Next table

Displays the next table.

Table number box

Displays the table with the table number entered in the box.

Auto fit column width to view area

When toggled on always fits the width of table to the preview space width.

Maintain maximum column width

Switches all table columns to their default maximum width.

Export current table

Exports the table being viewed in the selected format.

Settings

Modifies settings for tables and explorer panel.
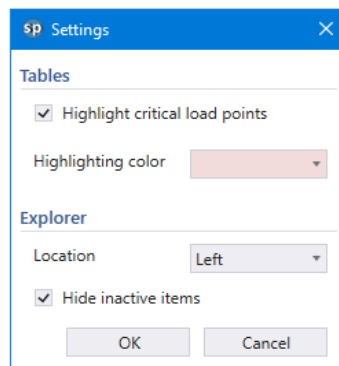
– **Tables settings**

Highlight critical items: Enables highlighting of critical items in the "Loads and Capacities" table.

Highlighting color: Provides color options for highlighting critical items.

– **Explorer settings**

Location: Displays explorer panel on the left or right side of screen depending on selection

Hide inactive items: Hides unused tables from the explorer view.

Explorer

Shows or hides the explorer panel.

8.3 Explorer panel

The explorer panel consists of all the available items of the result classified into sections and arranged hierarchically. Any item in the explorer panel can be clicked on to display the corresponding table in the preview space.

Expand all

Expands item list.

Collapse all

Collapses item list.

sp2D3DView Module

9.1 Introduction

sp2D3DView is a 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.

sp2D3DView is accessed from within spColumn. Once a successful run has been performed, you can open sp2D3DView by selecting the **2D/3D Viewer** command from the **View** menu. Alternatively, sp2D3DView can also be accessed by clicking the 2D/3D Viewer button in the program toolbar.
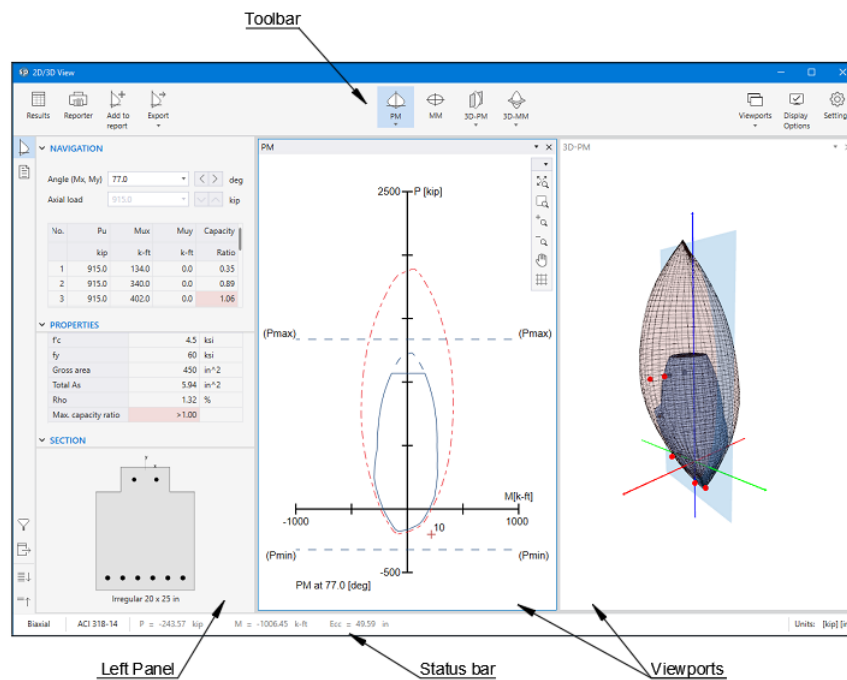
9.2 Toolbar

Results

Executes the spResults module to view the input and output data.

Reporter

Executes the spReporter module to generate and print reports.

Add to Report

Adds the active 2D diagram to the report.

Export

> **Graphical Report to EMF File:** Exports the active 2D diagram as a graphical report to and EMF file.

> **Copy Diagram to Clipboard:** Copies the active 2D diagram to the clipboard to be basted elsewhere.

> **Factored Diagram to CSV File:** Exports the Active factored 2D diagram or the active factored 3D surface to a CSV file.

> **Nominal Diagram to CSV File:** Exports the active nominal 2D diagram or the active nominal 3D surface to a CSV file when the nominal diagram display is toggled on.

PM

> **PM:** Displays an interaction diagram sliced at a constant $\left(M_x, M_y\right)$ angle drawn for both positive and negative moments.

> **+PM:** Displays an interaction diagram sliced at a constant $\left(M_x, M_y\right)$ angle drawn for the negative moments only.

> **-PM:** Displays an interaction digram sliced at a constant $\left(M_x, M_y\right)$ angle drawn for the negative moments only.

MM

Displays a contour of the failure surface sliced at a constant axial load.

3D-PM

Displays a 3D visualization of the failure surface with a vertical plane (biaxial runs only).

> **Show Plane:** Toggles the display of vertical plane on and off.

> **Cut:** Cuts the failure surface at the location of the vertical plane or restores it.

> **Swap:** Swaps the visible part of the 3D-PM surface when it is cut.

3D-MM

Displays a 3D visualization of the failure surface with a horizontal plane (biaxial runs only).

> **Show Plane:** Toggles the display of horizontal plane on and off.

> **Cut:** Cuts the failure surface at the location of the horizontal plane or restores it.

Swap: Swaps the visible part of the 3D-MM surface when it is cut.

The commands **PM**, **MM**, **3D-PM** and **3D-MM** and their sub commands are also available in the right click menu of the viewports.
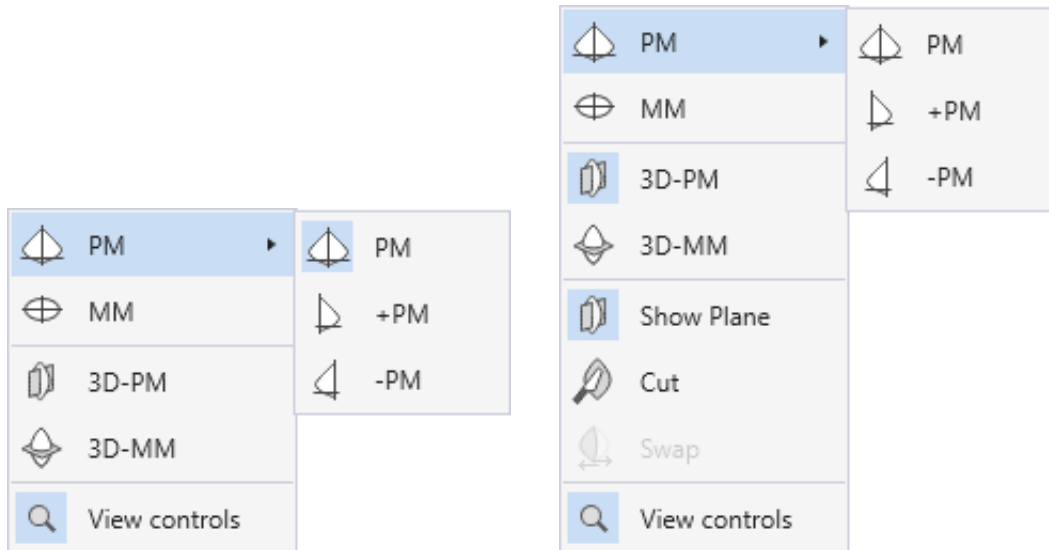
For viewport displaying 2D diagrams For viewport displaying 3D surfaces

Viewports (biaxial runs only)

2D/3D – PM: Displays two vertical viewports; PM and 3D-PM.

2D/3D – MM: Displays two vertical viewports; MM and 3D-MM.

2D/3D – PM/MM: Displays four equal viewports; MM and 3D-MM at the top and PM and 3D-PM at the bottom.

New Window: Creates a new floating viewport with the contents of the existing active viewport.

Display Options

Provides the user with an option to toggle the display of different items in both 2D diagrams and 3D surfaces.
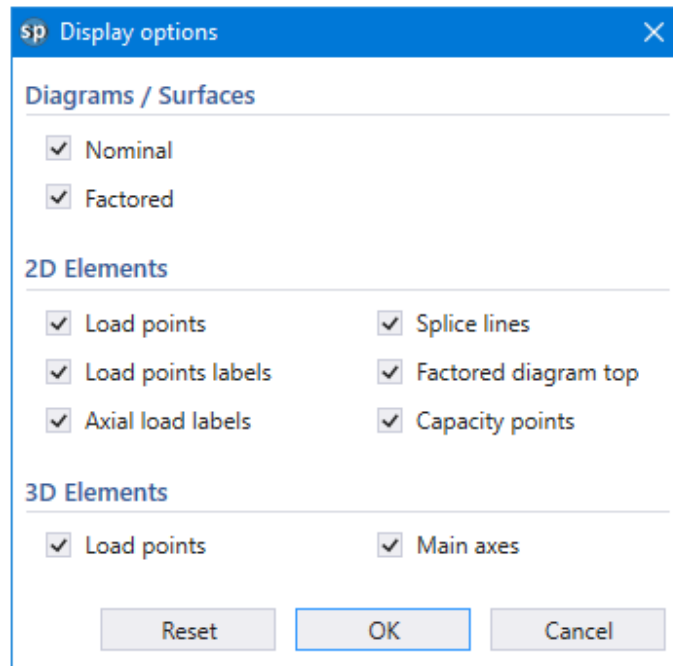
Diagrams / Surfaces

Nominal - Shows or hides nominal (unfactored) interaction diagram, contour or 3D surface. Available only when **Include Nominal Diagram** option is selected in the Solve menu.

Factored - Shows or hides factored capacity interaction diagram, contour or 3D surface.

2D Elements

Load Points - Shows or hides load points in 2D contours and interaction diagrams.

Load Point Labels - Shows or hides load point labels in 2D contours and interaction diagrams.

Axial Load Labels - Shows or hides axial load labels 2D interaction diagrams.

Splice Lines - Shows or hides splice lines in 2D interaction diagrams (uniaxial runs only).

Factored Diagram Top - Shows or hides the top part of factored diagram in 2D interaction diagrams.

3D Elements

Load Points - Shows or hides load points in 2D contours and interaction diagrams.

Main Axes - Shows or hides M_x, M_y and P_z axes in the 3D diagram.

9.3 Settings
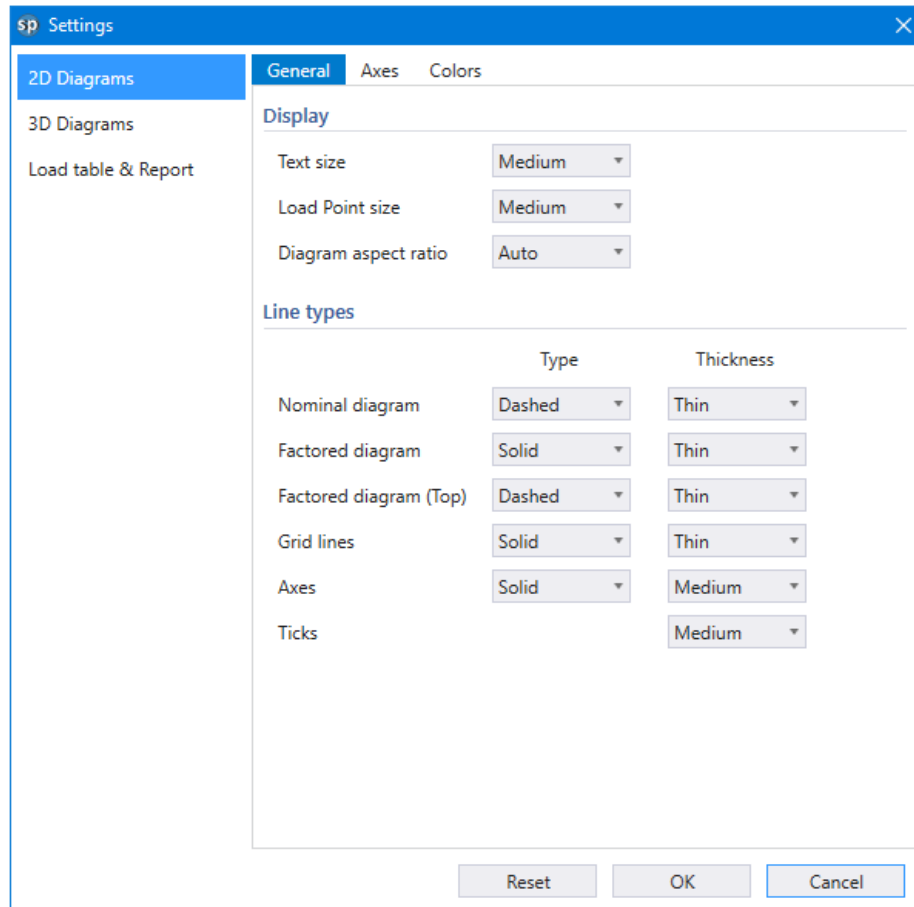
Provides the user with options to modify various settings for 2D diagrams, 3D diagrams and Load Table & Report.

9.3.1 2D Diagram

Provides users with the options to modify general, axes and color settings for 2D diagrams.

General

Display

Text size - Small, medium and large size options for text in 2D diagrams.

Load Point size - Small, medium and large size options for load points in 2D diagrams.

Diagram aspect ratio - 1:1 or Auto diagram aspect ratios for 2D diagrams

Line types

This section allows the user to choose the line types and line thicknesses for nominal diagram, factored diagram, factored diagram (top), grid lines, axes and ticks.

Axes

Axis value - Provides the option to show labels for all ticks on axes or only for ticks representing maximum values in axes.

Uniform "axis values" for M-M diagrams - When checked, all MM diagrams have the same maximum value in each axis making comparison between different contours easier.

Uniform "axis values" for P-M diagrams - When checked, all PM diagrams have the same maximum value in each axis making comparison between different interaction diagrams easier.

Colors

Diagrams

Color options for factored diagram, nominal diagram and splice lines

Load points

Color options for load points inside the diagram, load points outside the diagram, selected load points and load points with cursor hovering over them.

Misc

Color options for grid lines, axes and screen backgrounds.

9.3.2   3D Diagram

Provides users with the options to modify general and color settings for 3D diagrams.

General

Display

Coordinate system - Show/Hide coordinate system for 3D surfaces.

Planes

Mx-My plane - Show/Hide Mx-My plane for 3D surfaces.

P-My plane - Show/Hide P-My plane for 3D surfaces.

P-Mx plane - Show/Hide P-Mx plane for 3D surfaces.

Camera

Provides the options to switch between perspective and isometric camera types.

Colors

Factored surface

Color, opacity and line size options for factored surface

Nominal surface

Color, opacity and line size options for nominal surface

Load points

Color and size options for load points inside the diagram, load points outside the diagram, selected load points and load points with cursor hovering over them.

Main axes planes

Color and opacity options for M_x-M_y, P-M_x and P-M_y planes

Axes

Color and opacity options for X, Y and Z axes

Cutter plane

Color and opacity options for cutter plane

9.3.3   Load table & Report

General

Load table

Highlight critical load points - When checked, critical load points in the load point list of Navigation section of left panel are highlighted.

Highlighting color - Color options for highlighting of critical load points in the load point list of Navigation section of left panel.

Automatically include in report

PM Diagrams - Provides options to automatically include all PM diagrams in the report or include PM diagrams based on load point capacity ratios, and angles at which the PM diagrams are generated.

MM Diagrams - Provides options to automatically include all MM diagrams in the report or include MM diagrams based on load point capacity ratios, and axial loads at which the MM diagram are generated.

View Controls

Arrow in the upper right corner provides control for the location of the tool.

Commands listed in view controls vary depending on if the viewport is displaying 2D diagrams or 3D surfaces. The icons show in blue when active.

In viewports showing 2D Diagrams

View controls for a 2D diagram viewport provide the following operator functions:

- Zoom to workspace
- Zoom to window
- Zoom in (mouse wheel)
- Zoom out (mouse wheel)
- Pan (Middle mouse button)
- Grid On/Off: Shows or hides the grids.

In viewports containing 3D Surfaces

View controls for a 3D diagram viewport provide the following operator functions:

- Show/Hide 3D rotation cube

- Rotate section in 3D (shift + middle mouse button)

- Free guide plane control: Enable free movement of horizontal and vertical planes.

- Zoom to window

- Zoom in (mouse wheel)

- Zoom out (mouse wheel)

- Pan (Middle mouse button)

9.3.4   Left Panel
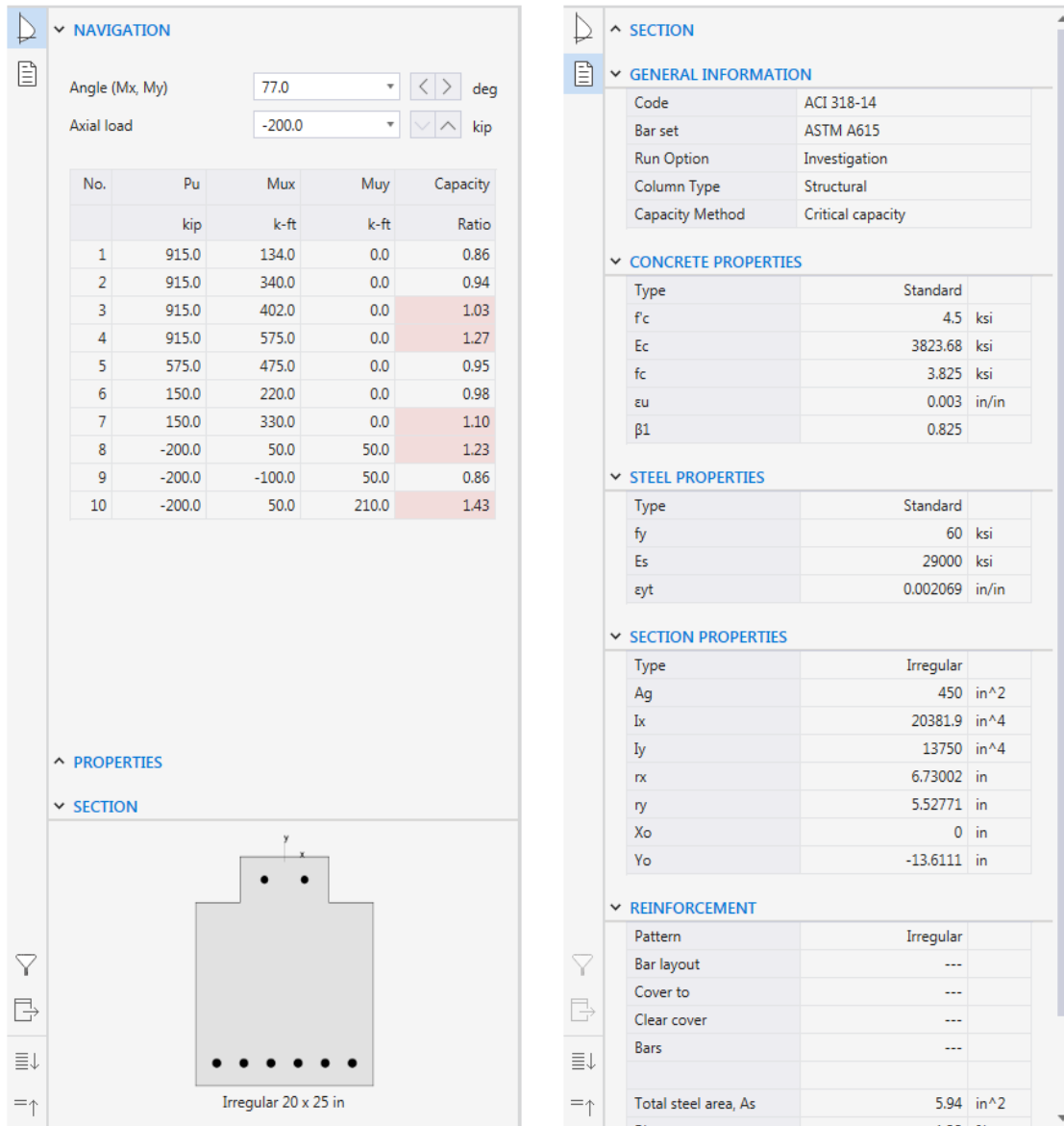
Image A. Navigate Tab Properties Tab

Navigate Tab

- Navigation: Consists of tools that enable navigating the 2D diagrams and 3D surfaces; angle control box Axial load control box and the load points list.

- Properties: List out the crucial section and design properties.

- Section: Displays the section being analyzed.

- Filter Options: Filters the load points in the load points list and the diagrams based on load point location, capacity ratio and presence in diagram.
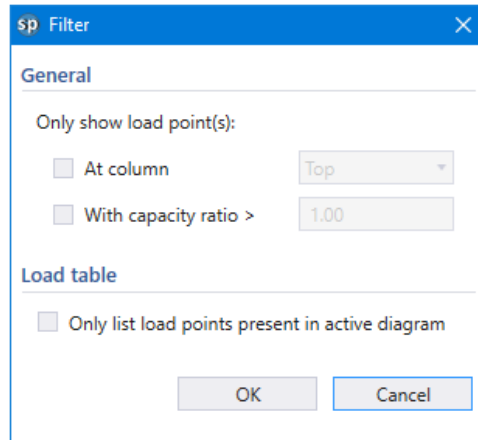
Properties Tab

Lists out the General, Concrete, Steel, Section, Reinforcement and Slenderness properties of the section being analyzed along with a diagram of the section being analyzed.

9.3.5   Viewing and Navigating 2D and 3D Diagrams

The 2D diagram and 3D surfaces can be navigated using the Navigation section of the left panel.

Viewing and navigating P-M interaction diagrams (biaxial runs only)

P-M interaction diagrams can be navigated using the **Angle**$\left(\mathbf{M_x, M_y}\right)$ option. This controls the direction of the vertical plane in the 3D surface, which indicates the location of the P-M interaction diagram.

- To view the desire P-M diagram enter the angle value or select and angle from the drop-down list.

- You can browse through the angles by using ![< >] buttons adjacent to the box containing the angle values.

Viewing and navigating M_x, M_y *contours (biaxial runs only)*

M_x, M_y contours can be navigated using the **Axial load** option. This controls the elevation of the horizontal plane in the 3D surface, which indicates the location of the M_x, M_y contour.

- To view the desired M_x, M_y contour enter the axial load value or select and axial load from the drop-down list.

- You can browse through the axial loads by using ![⌄ ⌃] buttons adjacent to the box containing the axial load values.

Viewing load points

To investigate a particular load point

- Click on the desired load point in the load point list immediately below the **Angle** and **Axial load** options. This creates P-M interaction diagram and M_x, M_y contours at the required location and also highlights the selected load point for easy observation.

- Alternatively, you can also directly click on a load point in the diagram and view its associated angle, axial load and load point details in the navigation section.

CHAPTER

A

APPENDIX

A.1 Import File Formats

Geometry, reinforcement or load data may be imported from a text file. The import file must be saved in pure ASCII (text) format. Data fields on each line should be separated by spaces or TABs. Comments or blank lines should not be placed within the import file.

A.1.1 Service Loads Data:

```
No_Of_Load_Points
P1_D M1x_DT M1x_DB M1y_DB M1y_DB
P1_L M1x_LT M1x_LB M1y_LT M1y_LB
P1_W M1x_WT M1x_WB M1y_WT M1y_WB
P1_EQ M1x_EQT M1x_EQB M1y_EQT M1y_EQB
P1_S M1x_ST M1x_SB M1y_ST M1y_SB
...
Pn_D Mnx_DT Mnx_DB Mny_DB Mny_DB
Pn_L Mnx_LT Mnx_LB Mny_LT Mny_LB
Pn_W Mnx_WT Mnx_WB Mny_WT Mny_WB
Pn_EQ Mnx_EQT Mnx_EQB Mny_EQT Mny_EQB
Pn_S Mnx_ST Mnx_SB Mny_ST Mny_SB
```

Each service load point has five lines of data (one line for each load case, i.e. Dead, Live, Wind, Earthquake, and Snow). Each data line has five values. For a service load point i, `Pi_D`, `Mix_DT`, `Mix_DB`, `Miy_DT`, and `Miy_DB` are the axial load, M_x at top, M_x at bottom, M_y at top and M_y at bottom, respectively. The notation `D`, `L`, `W`, `EQ`, and `S` designate the Dead, Live, Wind, Earthquake, and Snow load cases, respectively.

A.1.2 Factored Loads Data:

```
No_Of_Load_Points
P1 M1x M1y
P2 M2x M2y
...
Pn Mnx Mny
```

For a factored load point `i`, `Pi` is the factored axial load, `Mix` is the factored moment about x and `Miy` is the factored moment about y.

A.1.3 Reinforcement Data:

```
No_Of_Bars
A1 X1 Y1
...
An Xn Yn
```

For a bar `i`, `Ai` is the bar area, `Xi` is its x-coordinate, and `Yi` is its y-coordinate.

A.1.4 Geometry Data:

```
No_Of_Section_Nodes
Xs1 Ys1
Xs2 Ys2
...
Xsn Ysn
No_Of_Opening_Nodes
Xo1 Yo1
Xo2 Yo2
...
Xon Yon
```

For a section node `si`, `Xsi` is the x-coordinate of the node and `Ysi` is its y-coordinate.

For an opening node `oi`, `Xoi` is the x-coordinate of the node and `Yoi` is its y-coordinate.

If the section does not contain an opening, you must have a zero for the value of `No_Of_Opening_Nodes`.

A.2 spColumn Text Input (CTI) file format

spColumn is able to read and save its input data into two file formats, COL file or CTI file. CTI files are plain text files that can be edited by any text editing software.

Caution must be used when editing a CTI file because some values may be interrelated. If one of these values is changed, then other interrelated values should be changed accordingly. While this is done automatically when a model is edited in the spColumn user graphic user interface (GUI), one must update all the related values in a CTI file manually in order to obtain correct results. For example, if units are changed from English to Metric in GUI, all the related input values are updated automatically. If this is done by editing a CTI file, however, not only the unit flag but also all the related input values must be updated manually.

The best way to create a CTI file is by using the spColumn GUI and selecting CTI file type in the Save As menu command. Then, any necessary modifications to the CTI file can be applied with any text editor. However, it is recommended that users always verify modified CTI files by loading them in the spColumn GUI to ensure that the modifications are correct before running manually revised CTI files in batch mode.

The CTI file is organized by sections. Each section contains a title in square brackets, followed by values required by the section. The CTI file contains the following sections.

```
[spColumn Version]
[Project]
[Column ID]
[Engineer]
[Investigation Run Flag]
[Design Run Flag]
[Slenderness Flag]
[User Options]
[Irregular Options]
[Ties]
[Investigation Reinforcement]
[Design Reinforcement]
[Investigation Section Dimensions]
[Design Section Dimensions]
[Material Properties]
[Reduction Factors]
[Design Criteria]
[External Points]
```

```
[Internal Points]
[Reinforcement Bars]
[Factored Loads]
[Slenderness: Column]
[Slenderness: Column Above And Below]
[Slenderness: Beams]
[EI]
[SldOptFact]
[Phi_Delta]
[Cracked I]
[Service Loads]
[Load Combinations]
[BarGroupType]
[User Defined Bars]
[Sustained Load Factors]
```

Each section of a CTI file and allowable values of each parameter are described in details below. Corresponding GUI commands are presented in parenthesis.

```
#spColumn Text Input (CTI) File
```

The number sign, #, at the beginning of a line of text indicates that the line of text is a comment. The # sign must be located at the beginning of a line. Comments may be added anywhere necessary in a CTI file to make the file more readable. If a comment appears in multiple lines, each line must be started with a # sign

```
[spColumn Version]
```

Reserved. Do not edit.

```
[Project]
```

There is one line of text in this section.

Project name (menu Input | General Information…)

```
[Column ID]
```

There is one line of text in this section.

Column ID (menu Input | General Information…)

`[Engineer]`

There is one line of text in this section.

Engineer name (Menu Input | General Information…)

`[Investigation Run Flag]`

Reserved. Do not edit.

`[Design Run Flag]`

Reserved. Do not edit.

`[Slenderness Flag]`

Reserved. Do not edit.

`[User Options]`

There are 27 values separated by commas in one line in this section. These values are described below in the order they appear from left to right.

1. 0-Investigation Mode; 1-Design Mode; (Run Option on menu Input | General Information…)

2. 0-English Unit; 1-Metric Units; (Units on menu Input | General Information…)

3. 0-ACI 318-02; 1- CSA A23.3-94; 2-ACI 318-05; 3-CSA A23.3-04; 4-ACI 318-08; 5-ACI 318-11; 6-ACI 318-14; 7-CSA A23.3-14; 8-ACI 318-19; 9-CSA A23.3-19 (Design Code on menu Input | General Information…)

4. 0-X Axis Run; 1-Y Axis Run; 2-Biaxial Run; (Run Axis on menu Input | General Information…)

5. Reserved. Do not edit.

6. 0-Slenderness is not considered; 1-Slenderness in considered; (Consider slenderness? on menu Input | General Information…)

7. 0-Design for minimum number of bars; 1-Design for minimum area of reinforcement; (Bar selection on menu Input | Reinforcement | Design Criteria…)

8. Reserved. Do not edit.

9. 0-Rectangular Column Section; 1-Circular Column Section; 2-Irregular Column Section; (menu Input | Section)

10. 0-Rectangular reinforcing bar layout; 1-Circular reinforcing bar layout; (Bar Layout on menu Input | Reinforcement | All Sides Equal)

11. 0-Structural Column Section; 1-Architectural Column Section; 2-User Defined Column Section; (Column Type on menu Input | Reinforcement | Design Criteria…)

12. 0-Tied Confinement; 1-Spiral Confinement; 2-Other Confinement; (Confinement drop-down list on menu Input | Reinforcement | Confinement…)

13. Load type for investigation mode: (menu Input | Loads) 0-Factored; 1-Service; 2-Control Points; 3-Axial Loads

14. Load type for design mode: (menu Input | Loads)

    0-Factored; 1-Service; 2-Control Points; 3-Axial Loads

15. Reinforcement layout for investigation mode: (menu Input | Reinforcement)

    0-All Side Equal; 1-Equal Spacing; 2-Sides Different; 3-Irregular Pattern

16. Reinforcement layout for design mode: (menu Input | Reinforcement)

    0-All Side Equal; 1-Equal Spacing; 2-Sides Different; 3-Irregular Pattern

17. Reserved. Do not edit for regular bars. No of bars for irregular bars.

18. Number of factored loads (menu Input | Loads | Factored…)

19. Number of service loads (menu Input | Loads | Service…)

20. Number of points on exterior column section

21. Number of points on interior section opening

22. Reserved. Do not edit.

23. Reserved. Do not edit.

24. Cover type for investigation mode: (menu Input | Reinforcement)

    0-To transverse bar; 1-To longitudinal bar

25. Cover type for design mode: (menu Input | Reinforcement)

    0-To transverse bar; 1-To longitudinal bar

26. Number of load combinations; (menu Input | Load | Load Combinations…)

27. 0-Moment capacity method; 1-Nearest point method; (menu Options | Section capacity…)

[Irregular Options]

There are 13 values separated by commas in one line in this section. These values are described below in the order they appear from left to right. (menu Input | Section | Irregular | Section Editor menu Main | Drawing Area)

1. Reserved. Do not edit.
2. Reserved. Do not edit.
3. Reserved. Do not edit.
4. Reserved. Do not edit.
5. Area of reinforcing bar that is to be added through irregular section editor
6. Maximum X value of drawing area of irregular section editor
7. Maximum Y value of drawing area of irregular section editor
8. Minimum X value of drawing area of irregular section editor
9. Minimum Y value of drawing area of irregular section editor
10. Grid step in X of irregular section editor
11. Grid step in Y of irregular section editor
12. Grid snap step in X of irregular section editor
13. Grid snap step in Y of irregular section editor

[Ties]

There are 3 values separated by commas in one line in this section. These values are described below in the order they appear from left to right. (Menu Input | Reinforcement | Confinement…)

1. Index (0 based) of tie bars for longitudinal bars smaller that the one specified in the 3rd item in this section in the drop-down list
2. Index (0 based) of tie bars for longitudinal bars bigger that the one specified in the 3rd item in this section in the drop-down list
3. Index (0 based) of longitudinal bar in the drop-down list

[Investigation Reinforcement]

This section applies to investigation mode only. There are 12 values separated by commas in one line in this section. These values are described below in the order they appear from left to right.

If Side Different (Menu Input | Reinforcement | Side Different…) is selected:

1. Number of top bars

2. Number of bottom bars

3. Number of left bars

4. Number of right bars

5. Index (0 based) of top bars (Top Bar Size drop-download list)

6. Index (0 based) of bottom bars (Bottom Bar Size drop-download list)

7. Index (0 based) of left bars (Left Bar Size drop-download list)

8. Index (0 based) of right bars (Right Bar Size drop-download list)

9. Clear cover to top bars

10. Clear cover to bottom bars

11. Clear cover to left bars

12. Clear cover to right bars

If All Sides Equal (Menu Input | Reinforcement | All Sides Equal…) or Equal Spacing (Menu Input | Reinforcement | Equal Spacing…) is selected:

1. Number of bars (No. of Bars text box)

2. Reserved. Do not edit.

3. Reserved. Do not edit.

4. Reserved. Do not edit.

5. Index (0 based) of bar (Bar Size drop-down list)

6. Reserved. Do not edit.

7. Reserved. Do not edit.

8. Reserved. Do not edit.

9. Clear cover to bar (Clear Cover text box)

10. Reserved. Do not edit.

11. Reserved. Do not edit.

12. Reserved. Do not edit.

If Irregular Pattern (Menu Input | Reinforcement | Irregular Pattern…) is selected:

Reserved. Do not edit.

`[Design Reinforcement]`

This section applies to design mode only. There are 12 values separated by commas in one line in this section. These values are described below in the order they appear from left to right.

If Side Different (Menu Input | Reinforcement | Side Different…) is selected:

1. Minimum number of top and bottom bars
2. Maximum number of top and bottom bars
3. Minimum number of left and right bars
4. Maximum number of left and right bars
5. Index (0 based) of minimum size for top and bottom bars
6. Index (0 based) of maximum size for top and bottom bars
7. Index (0 based) of minimum size for left and right bars
8. Index (0 based) of maximum size for left and right bars
9. Clear cover to top and bottom bars
10. Reserved. Do not edit.
11. Clear cover to left and right bars
12. Reserved. Do not edit.

If All Sides Equal (Menu Input | Reinforcement | All Sides Equal…) or Equal Spacing (Menu Input | Reinforcement | Equal Spacing…) is selected:

1. Minimum number of bars
2. Maximum number of bars
3. Reserved. Do not edit.
4. Reserved. Do not edit.
5. Index (0 based) of minimum size of bars
6. Index (0 based) of maximum size of bars
7. Reserved. Do not edit.
8. Reserved. Do not edit.
9. Clear cover
10. Reserved. Do not edit.
11. Reserved. Do not edit.
12. Reserved. Do not edit.

[Investigation Section Dimensions]

This section applies to investigation mode only. There are 2 values separated by commas in one line in this section. These values are described below in the order they appear from left to right.

If rectangular section (Menu Input | Section | Rectangular…) is selected:

1. Section width (along X)
2. Section depth (along Y)

If circular section (Menu Input | Section | Circular…) is selected:

1. Section diameter
2. Reserved. Do not edit.

If irregular section (Menu Input | Section | Irregular) is selected:

1. Reserved. Do not edit.
2. Reserved. Do not edit.

[Design Section Dimensions]

This section applies to design mode only. There are 6 values separated by commas in one line in this section. These values are described below in the order they appear from left to right.

If rectangular section (Menu Input | Section | Rectangular…) is selected:

1. Section width (along X) Start
2. Section depth (along Y) Start
3. Section width (along X) End
4. Section depth (along Y) End
5. Section width (along X) Increment
6. Section depth (along Y) Increment

If circular section (Menu Input | Section | Circular…) is selected:

1. Diameter start
2. Reserved. Do not change.
3. Diameter end
4. Reserved. Do not change.
5. Diameter increment
6. Reserved. Do not change.

[Material Properties]

There are 11 values separated by commas in one line in this section. These values are described below in the order they appear from left to right. (Menu Input | Material Properties…)

1. Concrete strength, f'c

2. Concrete modulus of elasticity, Ec

3. Concrete maximum stress, fc

4. Beta(1) for concrete stress block

5. Concrete ultimate strain

6. Steel yield strength, fy

7. Steel modulus of elasticity, Es

8. Precast material for concrete. Only applicable for CSA A23.3-14 and CSA A23.3-04.

    0-Non-precast; 1-Precast

9. Standard material for concrete

    0-Non-standard; 1-Standard

10. Standard material for reinforcing steel

    0-Non-standard; 1-Standard

11. Compression-controlled strain limit

[Reduction Factors]

There are 5 values separated by commas in one line in this section. These values are described below in the order they appear from left to right. (Menu Input | Reinforcement | Confinement…)

1. Phi(a) for axial compression

2. Phi(b) for tension-controlled failure

3. Phi(c) for compression-controlled failure

4. Reserved. Do not edit

5. Minimum dimension of tied irregular sections for CSA-A23.3-14; 0-for all other cases

[Design Criteria]

There are 4 values separated by commas in one line in this section. These values are described below in the order they appear from left to right. (Menu Input | Reinforcement | Design Criteria…)

1. Minimum reinforcement ratio

2. Maximum reinforcement ratio

3. Minimum clear spacing between bars

4. Allowable Capacity (Ratio)

[External Points]

This section applies to irregular section in investigation mode only. The first line contains the number of points on exterior section perimeter. Each of the following lines contains 2 values: X and Y coordinates (separated by comma) of a point.

```
Number of Points, n
Point_1_X, Point_1_Y
Point_2_X, Point_2_Y
...
Point_n_X, Point_n_Y
```

[Internal Points]

This section applies to irregular section in investigation mode only. The first line contains the number of points on an interior opening perimeter. Each of the following lines contains 2 values: X and Y coordinates (separated by comma) of a point. If no opening exists, then the first line must be 0.

```
Number of Points, n
Point_1_X, Point_1_Y
Point_2_X, Point_2_Y
...
Point_n_X, Point_n_Y
```

[Reinforcement Bars]

This section applies to irregular section in investigation mode only. The first line contains the number of reinforcing bars. Each of the following lines contains 3 values: area, X and Y coordinates (separated by comma) of a bar.

```
Number of bars, n
Bar_1_area, Bar_1_X, Bar_1_Y
Bar_2_area, Bar_2_X, Bar_2_Y
...
```

```
Bar_n_area, Bar_n_X, Bar_n_Y
```

```
[Factored Loads]
```

The first line contains the number of factored loads defined. Each of the following lines contains 3 values: axial load, X-moment, and Y-moment separated by commas. (Menu Input | Loads | Factored Loads…)

```
Number of Factored Loads, n
Load_1, X-Moment_1, Y-Moment_1
Load_2, X-Moment_2, Y-Moment_2
...
Load_n, X-Moment_n, Y-Moment_n
```

```
[Slenderness: Column]
```

This section contains 2 lines describing slenderness parameters for column being designed. The first line is for X-axis parameters, and the second line is for Y-axis parameters.

There are 8 values[1] separated by commas in each line. These values are described below in the order they appear from left to right. (Menu Input | Slenderness | Design Column…)

1. Column clear height
2. k(nonsway)
3. k(sway)
4. 0-Sway frame; 1-Nonsway frame
5. 0-Compute 'k' factors; 1-Input k factors
6. $(\Sigma P_c)/P_c$
7. $(\Sigma P_u)/P_u$
8. 0-Do not ignore moment magnification along column length in sway frames; 1-Ignore moment magnification along column length in sway frames. Use for ACI 318-11 and ACI 318-08 only. For all other codes the value must be 0.

```
[Slenderness: Column Above And Below]
```

---

1. Value No 8 introduced in spColumn v4.60.

This section contains 2 lines describing slenderness parameters for column above and column below. The first line is for column above, and the second line is for column below. (Menu Input | Slenderness | Columns Above/Below…)

There are 6 values separated by commas in line 1 for column above. These values are described below in the order they appear from left to right.

1. 0-Column specified; 1-No column specified
2. Column Height
3. Column width (along X)
4. Column depth (along Y)
5. Concrete compressive strength, f'c
6. Concrete modulus of elasticity, Ec

There are 6 values separated by commas in line 2 for column below. These values are described below in the order they appear from left to right.

1. 0-Column specified; 1-No column specified
2. Column Height
3. Column width (along X)
4. Column depth (along Y)
5. Concrete compressive strength, f'c
6. Concrete modulus of elasticity, Ec


```
[Slenderness: Beams]
```

This section contains 8 lines. Each line describes a beam.

Line 1: X-Beam (perpendicular to X), Above Left

Line 2: X-Beam (perpendicular to X), Above Right

Line 3: X-Beam (perpendicular to X), Below Left

Line 4: X-Beam (perpendicular to X), Below Right

Line 5: Y-Beam (perpendicular to Y), Above Left

Line 6: Y-Beam (perpendicular to Y), Above Right

Line 7: Y-Beam (perpendicular to Y), Below Left

Line 8: Y-Beam (perpendicular to Y), Below Right

There are 7 values separated by commas for each beam in each line. (Menu Input | Slenderness | X-Beams…, Input | Slenderness | Y-Beams…) These values are described below in the order they appear from left to right.

1. 0-beam specified; 1-no beam specified
2. Beam span length (c/c)
3. Beam width
4. Beam depth
5. Beam section moment of inertia
6. Concrete compressive strength, f'c
7. Concrete modulus of elasticity, Ec

[EI]

Reserved. Do not edit.

[SldOptFact]

There is 1 value in this section for slenderness factors. (Code Default and User Defined radio buttons on menu Input | Slenderness | factors…)

0-Code default; 1-User defined

[Phi_Delta]

There is 1 value in this section for slenderness factors. (Menu Input | Slenderness | factors…)

Stiffness reduction factor

[Cracked I]

There are 2 values separated by commas in one line in this section. These values are described below in the order they appear from left to right. (Menu Input | Slenderness | factors...)

1. Beam cracked section coefficient
2. Column cracked section coefficient

[Service Loads]

This section describes defined service loads. (Menu Input | Loads | Service…) The first line contains the number of service loads. Each of the following lines contains values for one service load.

There are 25 values for each service load in one Line separated by commas. These values are described below in the order they appear from left to right.

1. Dead Axial Load
2. Dead X-moment at top
3. Dead X-moment at bottom
4. Dead Y-moment at top
5. Dead Y-moment at bottom
6. Live Axial Load
7. Live X-moment at top
8. Live X-moment at bottom
9. Live Y-moment at top
10. Live Y-moment at bottom
11. Wind Axial Load
12. Wind X-moment at top
13. Wind X-moment at bottom
14. Wind Y-moment at top
15. Wind Y-moment at bottom
16. EQ. Axial Load
17. EQ. X-moment at top
18. EQ. X-moment at bottom
19. EQ. Y-moment at top
20. EQ. Y-moment at bottom
21. Snow Axial Load
22. Snow X-moment at top
23. Snow X-moment at bottom
24. Snow Y-moment at top
25. Snow Y-moment at bottom

[Load Combinations]

This section describes defined load combinations. (Menu Input | Loads | Load Combinations…)
The first line contains the number of load combinations. Each of the following lines contains load
factors for one load combination.

```
Number of load combinations, n
Dead_1, Live_1, Wind_1, E.Q._1, Snow_1
Dead_2, Live_2, Wind_2, E.Q._2, Snow_2
...
Dead_n, Live_n, Wind_n, E.Q._n, Snow_n
```

[BarGroupType]

There is 1 value in this section. (Bar Set drop-down list on menu Options | Reinforcement…)

0-User defined

1-ASTM615

2-CSA G30.18

3-prEN 10080

4-ASTM615M

[User Defined Bars]

This section contains user-defined reinforcing bars. (Menu Options | Reinforcement…) The first
line contains the number of defined bars. Each of the following lines contains values for one bar
separated by commas.

```
Number of user-defined bars, n
Bar_1_size, Bar_1_diameter, Bar_1_area, Bar_1_weight
Bar_2_size, Bar_2_diameter, Bar_2_area, Bar_2_weight
...
Bar_n_size, Bar_n_diameter, Bar_n_area, Bar_n_weight
```

[Sustained Load Factors]

There are 5 values separated by commas in one line in this section. Each value respectively
represents percentage of Dead, Live, Wind, EQ, and Snow load case that is considered sustained
(Menu Input | Loads | Service…).

A.3 Conversion Factors - English to SI

To convert from	To	Multiply by
in.	m (1000 mm)	0.025400
ft	m	0.304800
lb	N (0.001 kN)	4.448222
kip (1000 lbs)	kN	4.448222
plf (lb/ft)	N/m	14.593904
psi (lb/in.^{2})	kPa	6.894757
ksi (kips/in.^{2})	MPa	6.894757
psf (lb/ft^2)	N/m^2 (Pa)	47.88026
pcf (lb/ft^3)	kg/m^3	16.018460
ft-kips	kN · m	1.355818

A.4   Conversion Factors - SI to English

To convert from	To	Multiply by
m (1000 mm)	in	39.37008
m	ft	3.28084
N (0.001 kN)	lb	0.224809
kN	kip (1000 lbs)	0.224809
kN/m	plf (lb/ft)	68.52601
MPa	psi (lb/in^2)	145.0377
MPa	ksi (kips/in^2)	0.145038
kN/m^2 (kPa)	psf (lb/ft^2)	20.88555
kg/m^3	pcf (lb/ft^3)	0.062428
kN $\cdot$ m	ft-kips	0.737562

A.5   Material Strength Value Limits

ACI	Standard Material		Non-Standard Material	
	Min.	Max.	Min.	Max.
f'c	2 ksi	12 ksi	2 ksi	20 ksi
fy	10 ksi	80 ksi	10 ksi	270 ksi

CSA	Standard Material		Non-Standard Material	
	Min.	Max.	Min.	Max.
f'c	10 MPa	80 MPa	10 MPa	150 MPa
fy	100 MPa	500 MPa	100 MPa	1860 MPa

A.6   Contact Information

Web Site: http://www.StructurePoint.org

E-mail: info@StructurePoint.org

support@StructurePoint.org

StructurePoint, LLC.
5420 Old Orchard Road
Skokie, IL 60077
USA

Phone: +1- 847- 966- 4357
Fax: +1- 847- 966- 1542