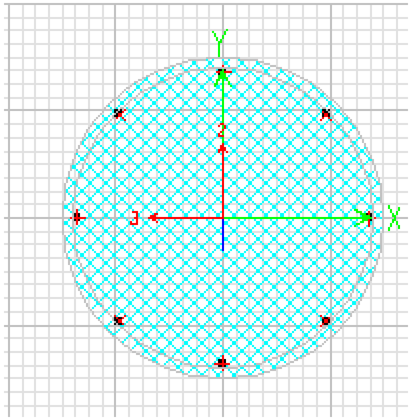
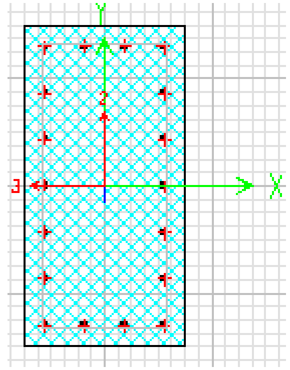
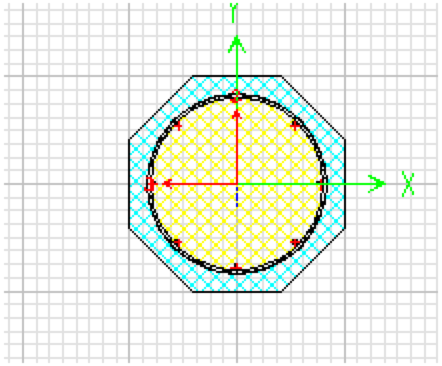
SAP2000 for Standalone Concrete Column and Beam Design

If you own any current version of SAP2000, you already have all the capabilities described in this document. If you don't want to tie up an expensive advanced of SAP2000 doing standalone column and beam design, you can purchase a basic level of SAP2000 for just $2,000 (not including multiple copy discount) with just $350/yr annual maintenance and support. In addition to rectangular and circular concrete columns, SAP2000 section designer (SD) can handle irregular shape columns, composite columns and offers special options for concrete octagon and hexagon sections. Right-click to modify dimensions and/or reinforcement within SD. Latest ACI 318 design code with older ACI codes available, and 11 international concrete design codes included.

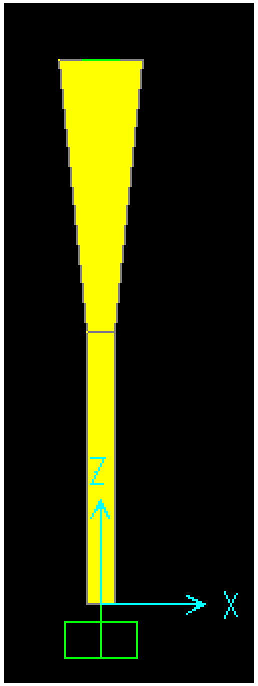


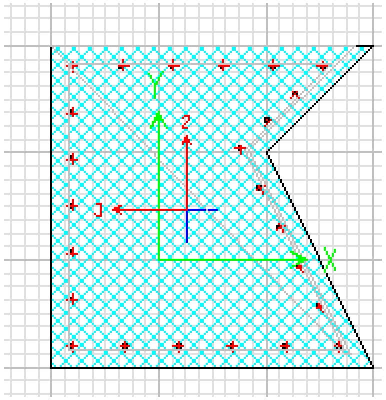


Octagon template

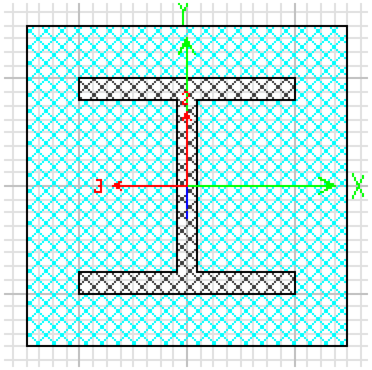


Tapered nonprismatic column with reinforcement designed at each station along the length

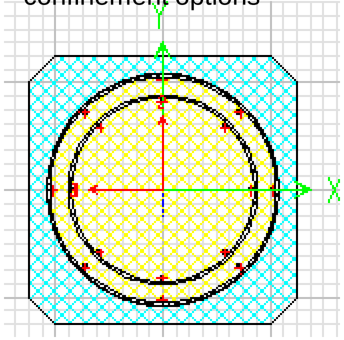




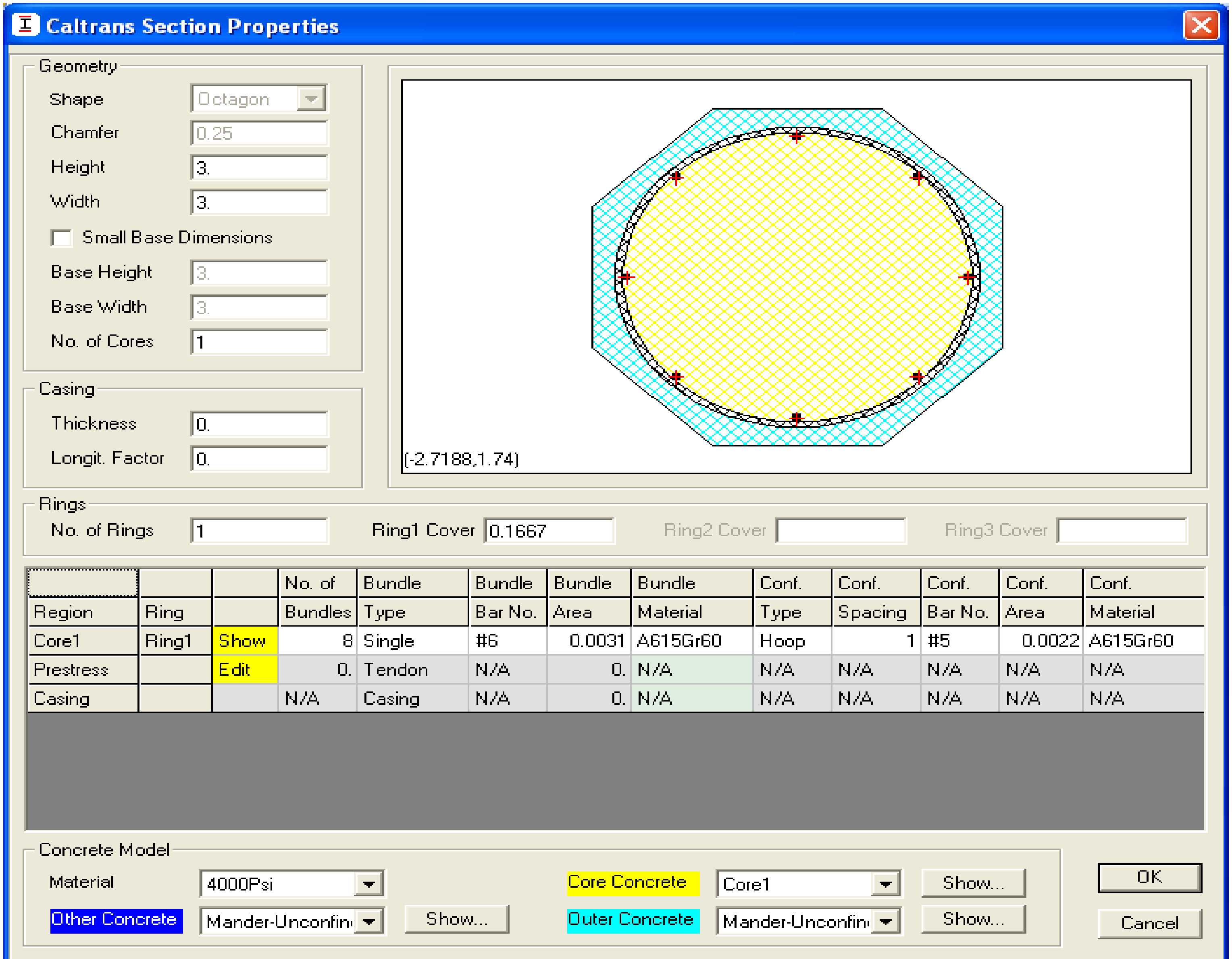
Composite concrete rectangular section with steel shape



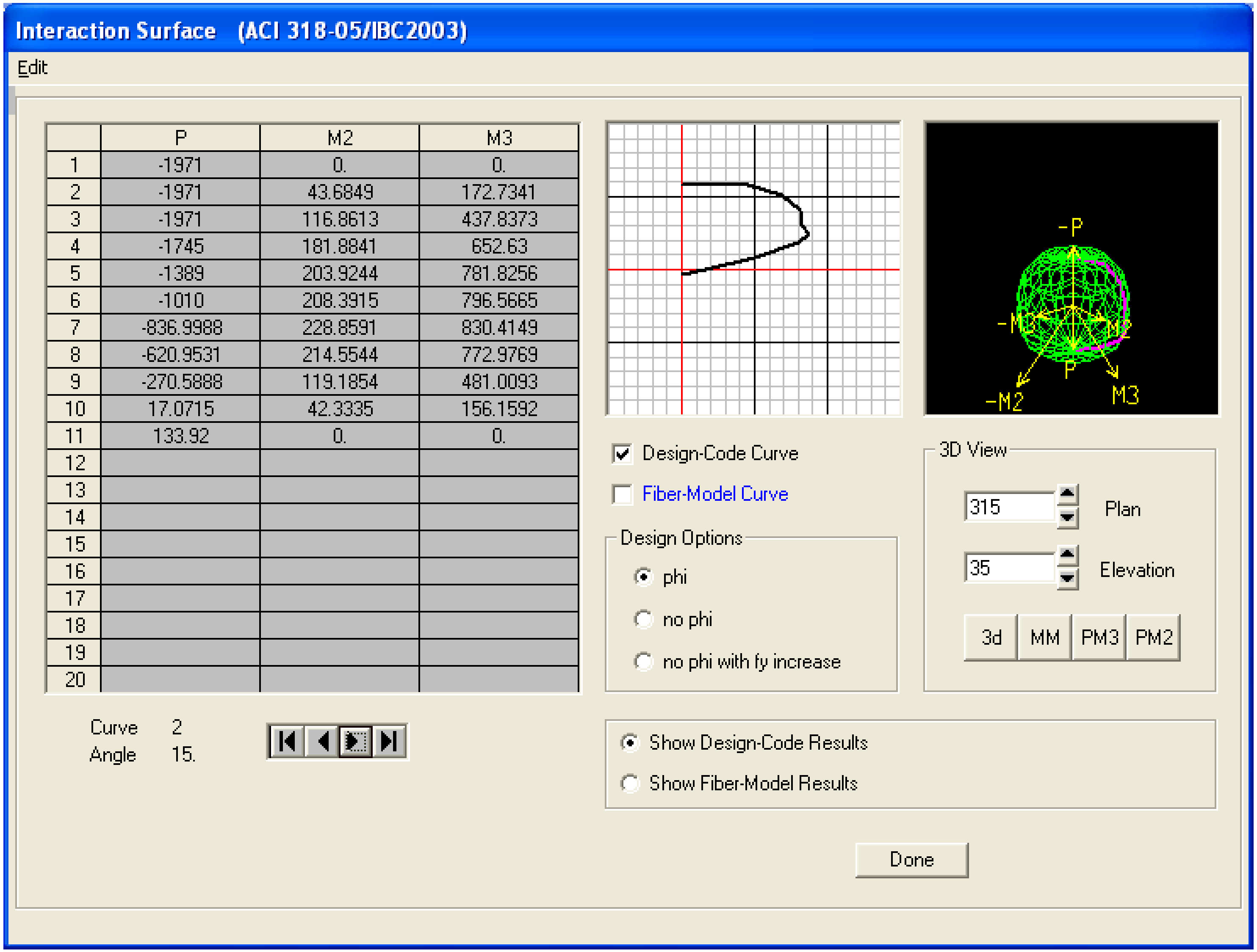
Define square sections with chamfers and confinement options



Although originally developed for Caltrans, the octagon and hexagon SD design shapes have widespread applicability to a number of industries

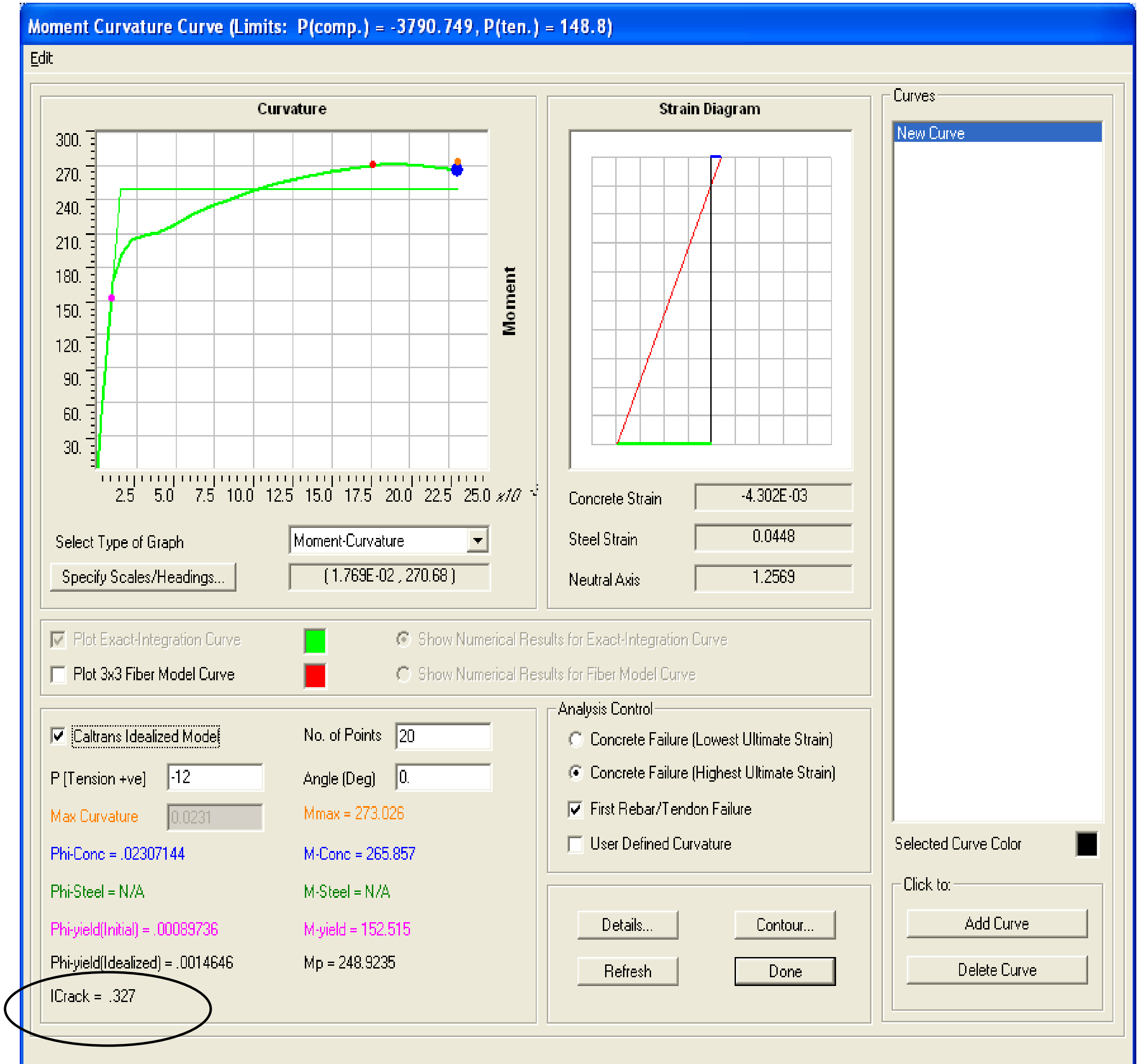


Each concrete section automatically generates a code specific P-M-M interaction surface within the SD which can be used for design. You can define a section and obtain a P-M-M interaction surface like this in less than a minute with SAP2000 SD.

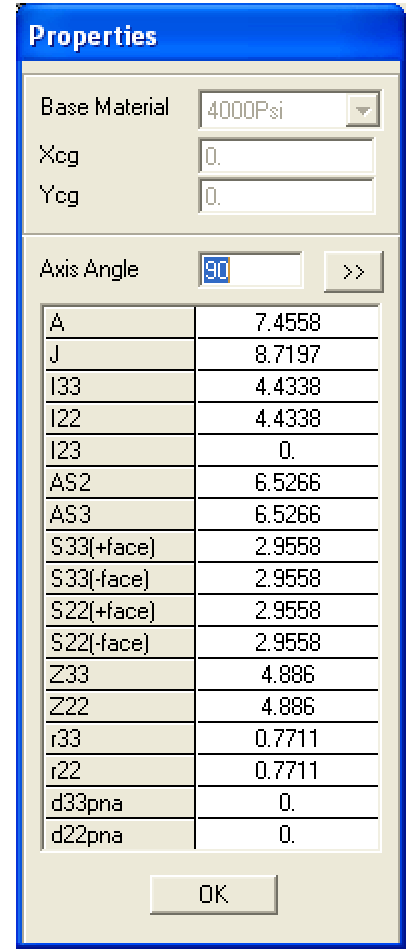


	P	M2	M3
1	-1971	0.	0.
2	-1971	43.6849	172.7341
3	-1971	116.8613	437.8373
4	-1745	181.8841	652.63
5	-1389	203.9244	781.8256
6	-1010	208.3915	796.5665
7	-836.9988	228.8591	830.4149
8	-620.9531	214.5544	772.9769
9	-270.5888	119.1854	481.0093
10	17.0715	42.3335	156.1592
11	133.92	0.	0.
12			
13			
14			
15			
16			
17			
18			
19			
20			

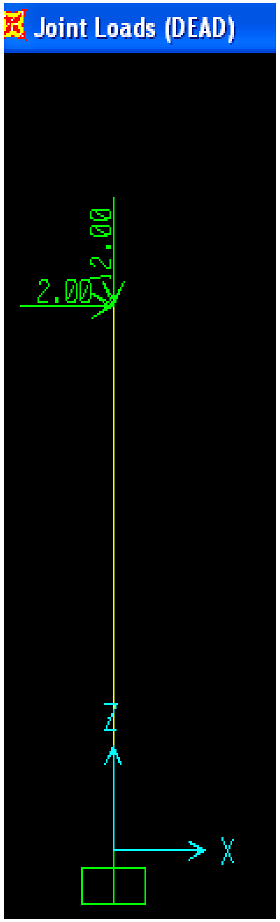
Moment curvature analysis in SD is a method to accurately determine the load-deformation behavior of a concrete section using nonlinear material stress-strain relationships.



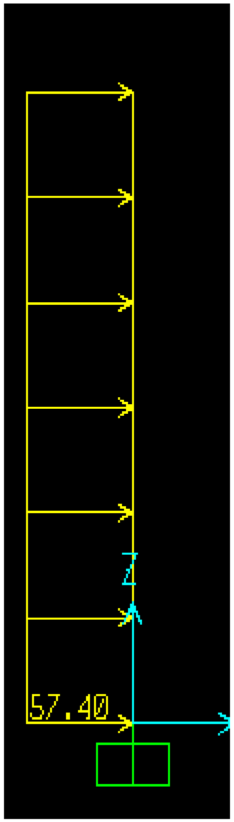
Properties automatically generated within SD



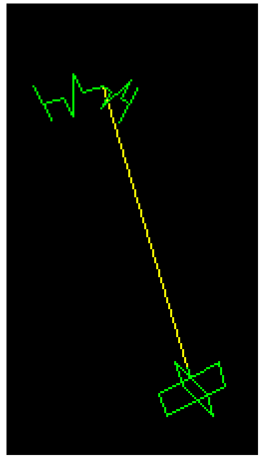
Assign or import joint loads, uniform distributed load, trapezoidal distributed load, multiple of gravity in any direction, and/or imposed displacement loading. Easily assign reduction factors to EI for cracking. Option to analyze with nonlinear P-Delta in lieu of manually determining K-factors as allowed by ACI and other design codes. Create more detailed 2D or 3D models if there are concerns about beam/column stiffness assumptions.



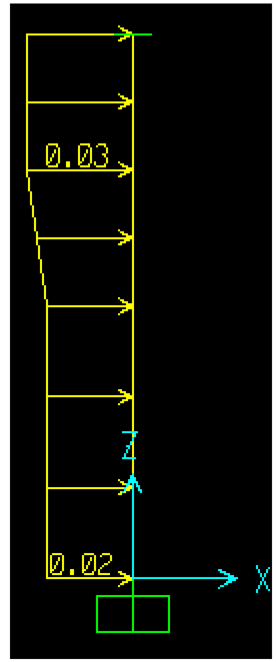
Uniform Distributed



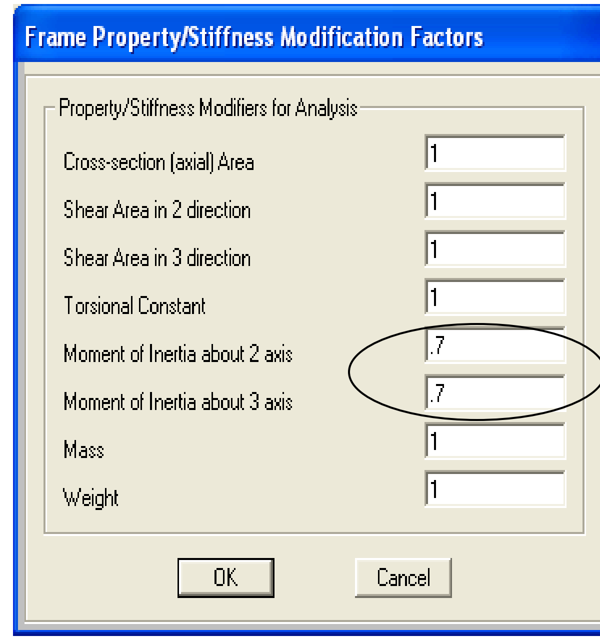
Option to use spring supports in lieu of restraints



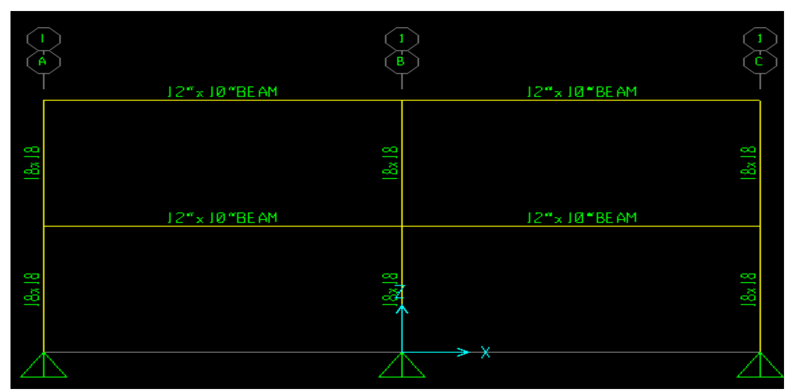
Trapezoidal distributed



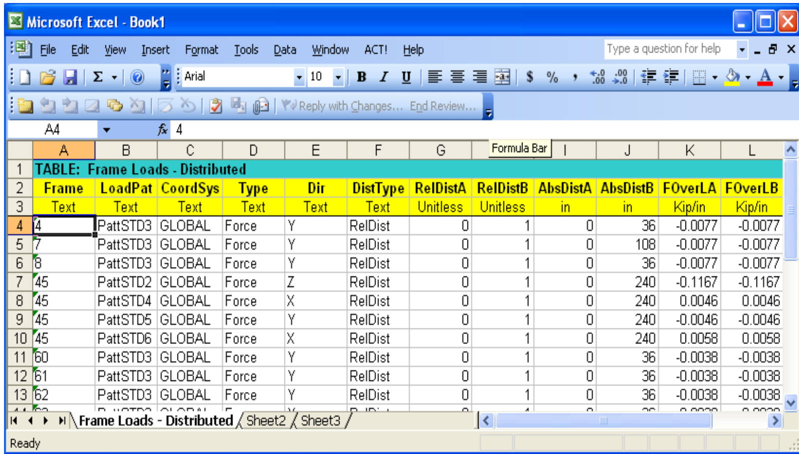
Reduced EI for cracking



Create 2D or 3d models if needed →

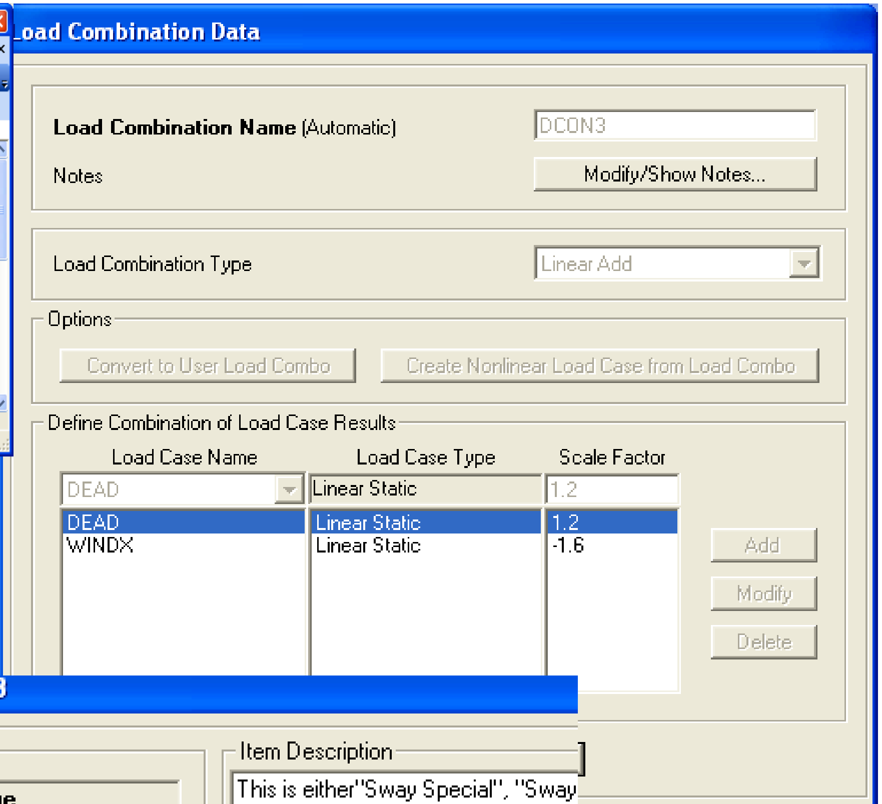


Loads can be assigned graphically, through spreadsheets within SAP2000, or imported from Excel

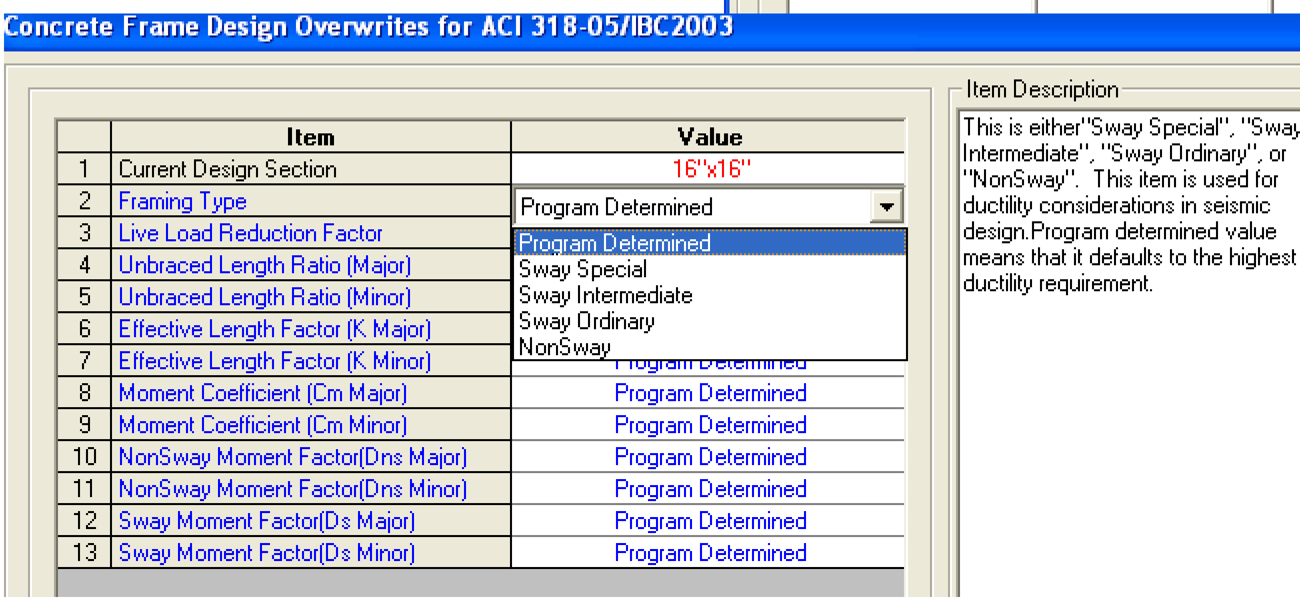


	A	B	C	D	E	F	G	H	I	J	K	L
1	TABLE: Frame Loads - Distributed											
2	Frame	LoadPat	CoordSys	Type	Dir	DistType	RelDistA	RelDistB	AbsDistA	AbsDistB	FOverLA	FOverLB
3	Text	Text	Text	Text	Text	Text	Unitless	Unitless	in	in	Kip/in	Kip/in
4	4	PattSTD3	GLOBAL	Force	Y	RelDist	0	1	0	36	-0.0077	-0.0077
5	7	PattSTD3	GLOBAL	Force	Y	RelDist	0	1	0	108	-0.0077	-0.0077
6	8	PattSTD3	GLOBAL	Force	Y	RelDist	0	1	0	36	-0.0077	-0.0077
7	45	PattSTD2	GLOBAL	Force	Z	RelDist	0	1	0	240	-0.1167	-0.1167
8	45	PattSTD4	GLOBAL	Force	X	RelDist	0	1	0	240	0.0046	0.0046
9	45	PattSTD5	GLOBAL	Force	Y	RelDist	0	1	0	240	-0.0046	-0.0046
10	45	PattSTD6	GLOBAL	Force	X	RelDist	0	1	0	240	0.0058	0.0058
11	60	PattSTD3	GLOBAL	Force	Y	RelDist	0	1	0	36	-0.0038	-0.0038
12	61	PattSTD3	GLOBAL	Force	Y	RelDist	0	1	0	36	-0.0038	-0.0038
13	62	PattSTD3	GLOBAL	Force	Y	RelDist	0	1	0	36	-0.0038	-0.0038

Factored load combinations automatically generated per design code, or users can define or import their own load combinations



Interactive design enables users to change sections or design parameters and instantaneously view changed design results



Concrete Frame Design Overwrites for ACI 318-05/IBC2003

	Item	Value
1	Current Design Section	16"x16"
2	Framing Type	Program Determined
3	Live Load Reduction Factor	
4	Unbraced Length Ratio (Major)	
5	Unbraced Length Ratio (Minor)	
6	Effective Length Factor (K Major)	
7	Effective Length Factor (K Minor)	
8	Moment Coefficient (Cm Major)	Program Determined
9	Moment Coefficient (Cm Minor)	Program Determined
10	NonSway Moment Factor(Dns Major)	Program Determined
11	NonSway Moment Factor(Dns Minor)	Program Determined
12	Sway Moment Factor(Ds Major)	Program Determined
13	Sway Moment Factor(Ds Minor)	Program Determined

Design required reinforcement with shear design checks.

Concrete Design Data ACI 318-05/IBC2003

File

```
ACI 318-05/IBC2003 COLUMN SECTION DESIGN  Type: Sway Special  Units: Kip, in, F  (Summary)

Element      : 1                B=36.000        D=36.000        dc=0.000
Section ID   : OCTAGON COL      E=3604.997      fc=4.000        Lt.Wt. Fac.=1.000
Combo ID     : DCON5            L=156.000       fy=60.000       fys=60.000
Station Loc  : 156.000          RLLF=1.000

Phi(Compression-Spiral): 0.700
Phi(Compression-Tied):   0.650
Phi(Tension Controlled): 0.900
Phi(Shear):              0.750
Phi(Seismic Shear):      0.600
Phi(Joint Shear):        0.850

AXIAL FORCE & BIAXIAL MOMENT DESIGN FOR PU, M2, M3
                Rebar      Design      Design      Design     Minimum     Minimum
                 Area          Pu          M2          M3          M2          M3
               10.736      31.500       0.000     -53.003      52.920      52.920

AXIAL FORCE & BIAXIAL MOMENT FACTORS
                               Cm    Delta_ns     Delta_s           K           L
                           Factor      Factor      Factor      Factor      Length
   Major Bending(M3)        1.000       1.002       1.000       1.000     156.000
   Minor Bending(M2)        1.000       1.002       1.000       1.000     156.000

SHEAR DESIGN FOR V2,V3
                            Rebar       Shear       Shear       Shear       Shear
                             Av/s          Vu     phi*Vc      phi*Vs          Vp
   Major Shear(V2)          0.000       0.000      90.468       0.000       0.000
   Minor Shear(V3)          0.000       0.000      90.468       0.000       0.000

JOINT SHEAR DESIGN
                      Joint Shear       Shear       Shear       Shear       Joint
                            Ratio       VuTop       VuTot     phi*Vc        Area
   Major Shear(V2)            N/A         N/A         N/A         N/A         N/A
   Minor Shear(V3)            N/A         N/A         N/A         N/A         N/A

(6/5) BEAM/COLUMN CAPACITY RATIOS
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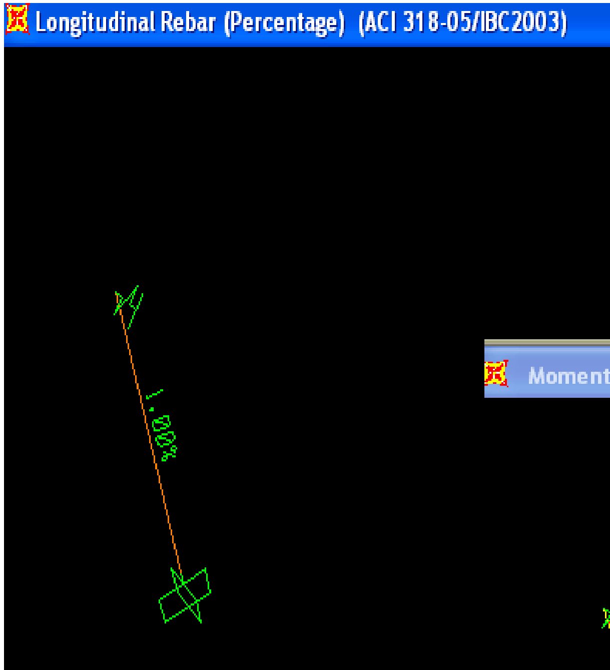
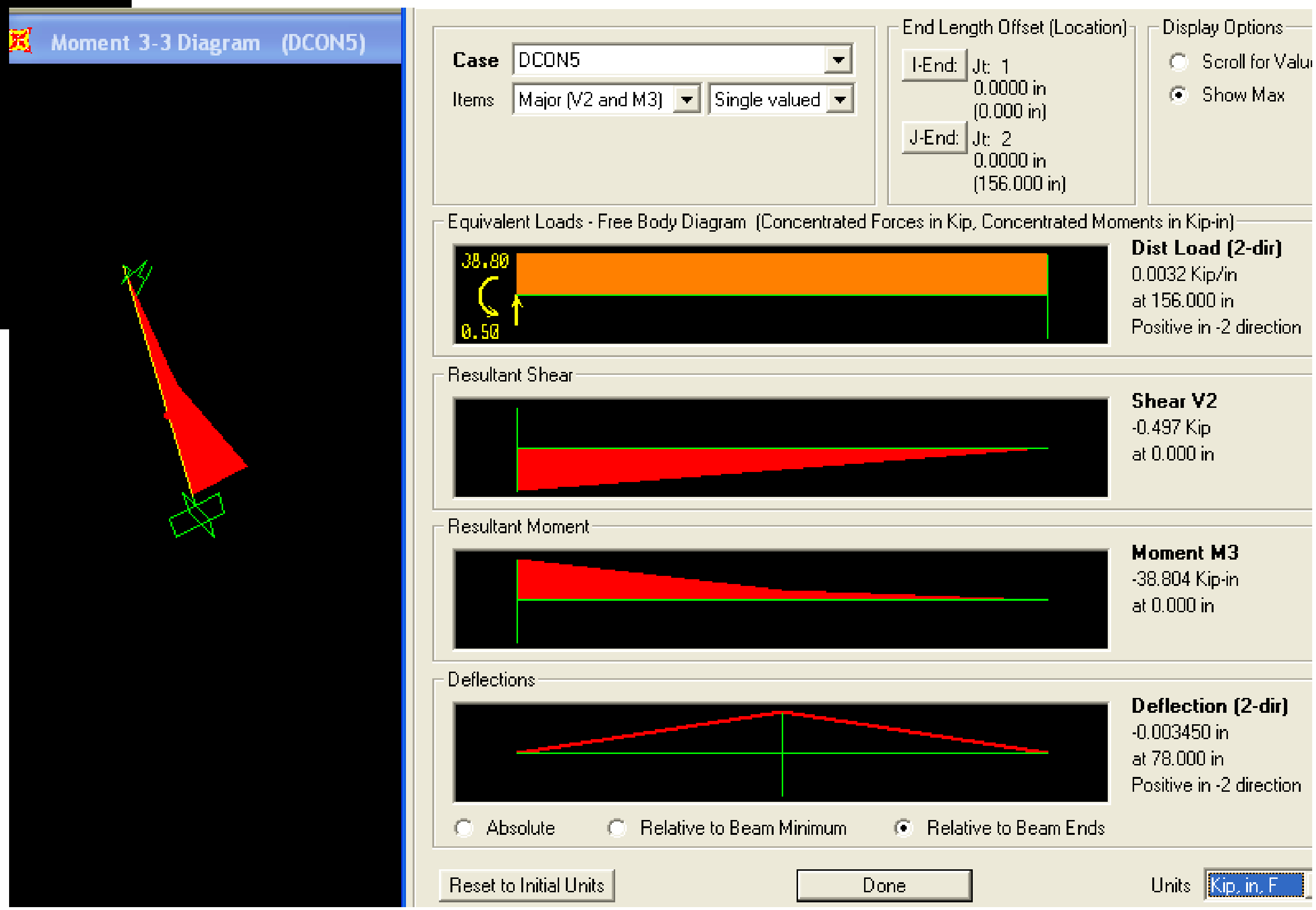
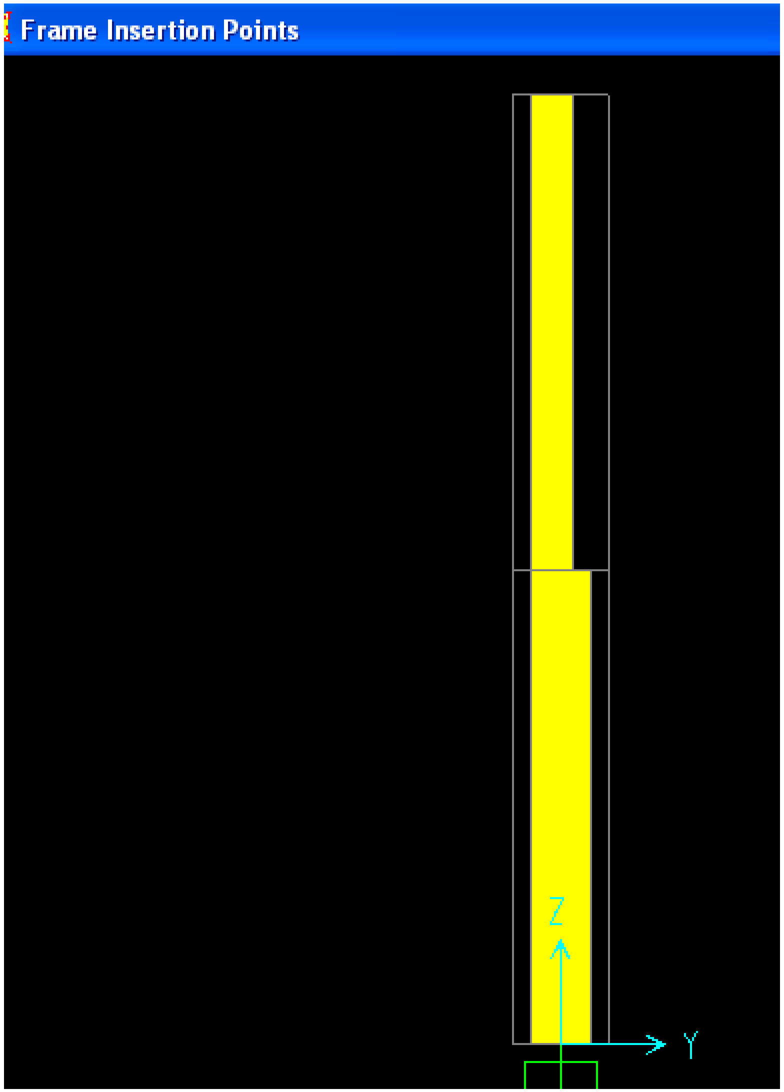
Graphically display calculated longitudinal reinforcing, rebar percentage, shear reinforcing, or torsion reinforcing with moment diagrams. Output reports have automatic link to Excel



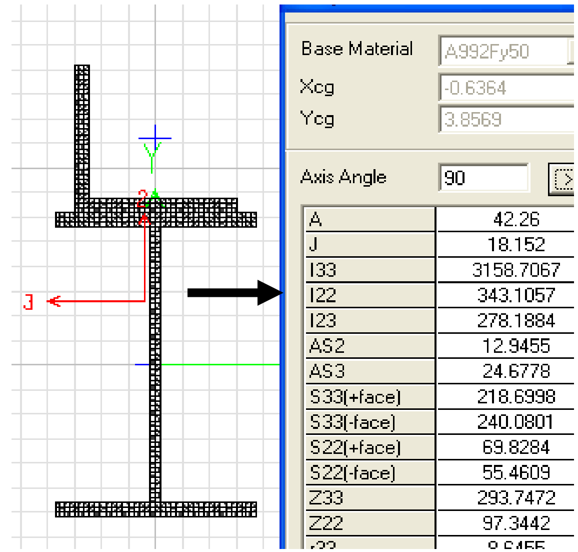


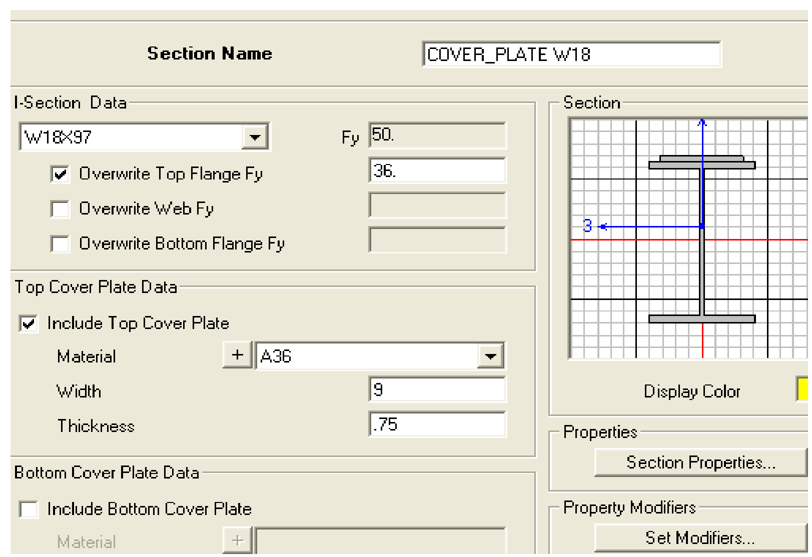
Utilize frame insertion points to automatically consider offset-from-centerline moments cranked into the lower column when a smaller column above is aligned to the same face as the larger column below. In addition to concrete design, the SD can be used to generate properties for built-up steel sections. Limited steel design is also available for built-up steel sections

Elevation view of 14”x14” column above 20”x20” aligned to the same face

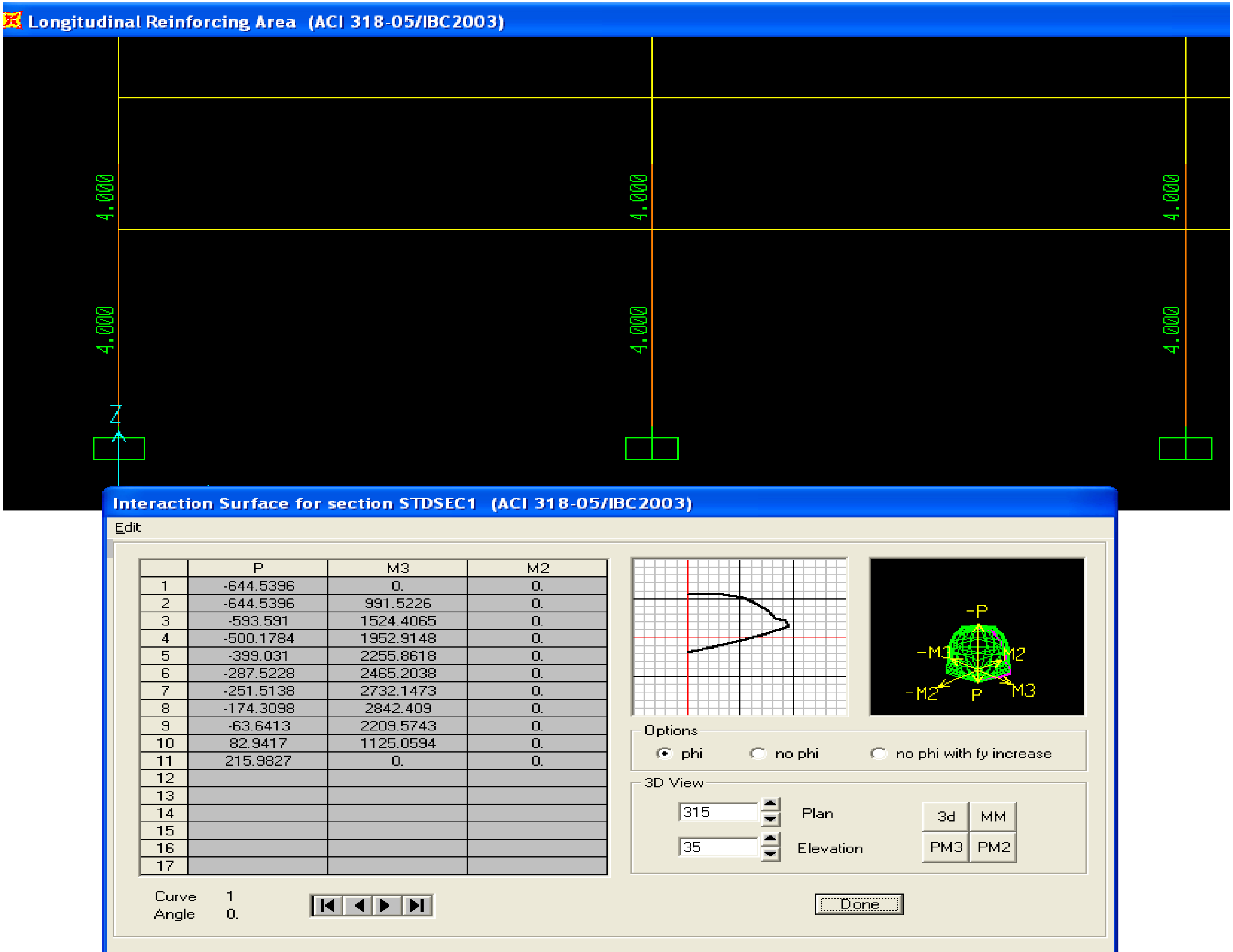


Built-up steel shapes

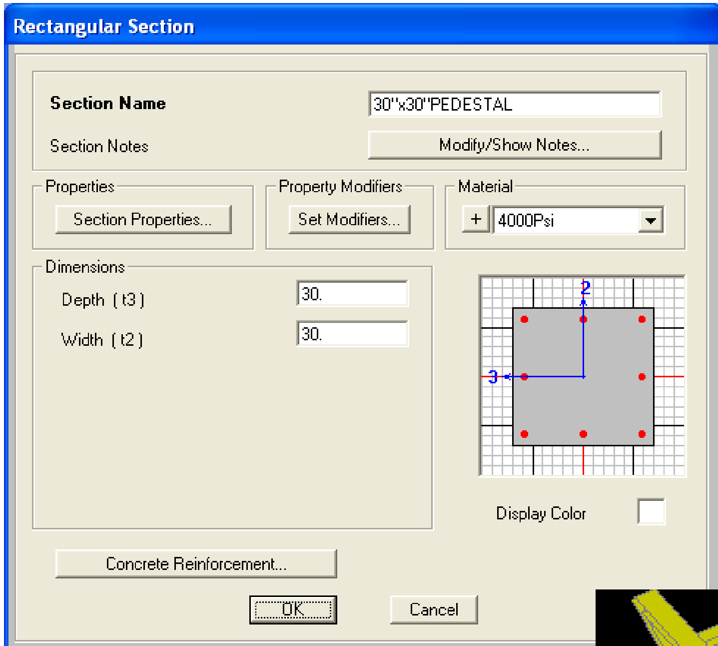


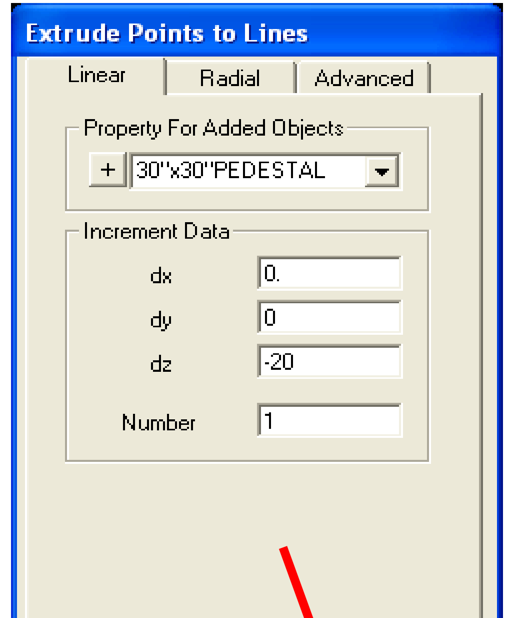


Multiple columns and beams designed in one shot with SAP2000. Right click columns to view P-M-M interaction surface as shown below

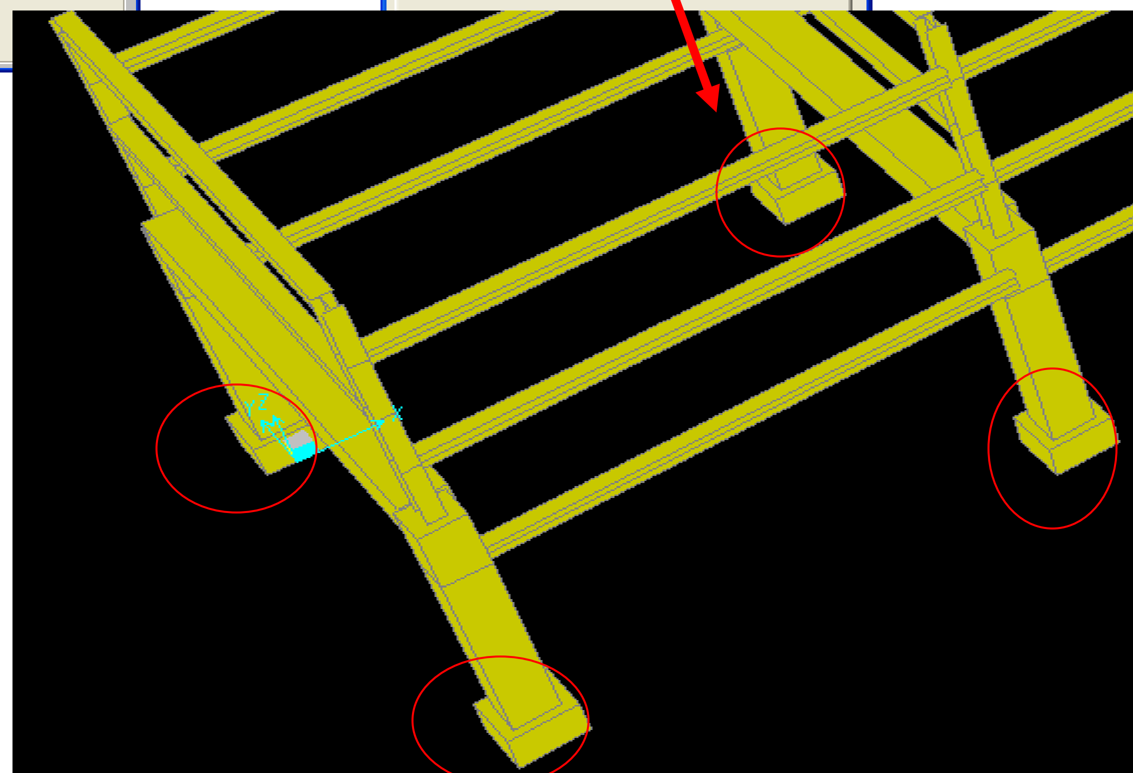


Pedestal section

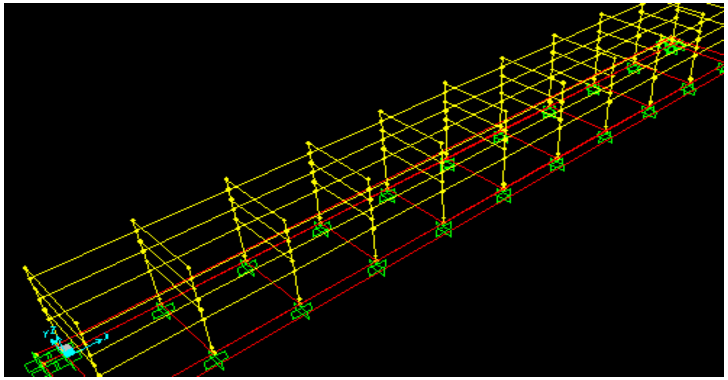




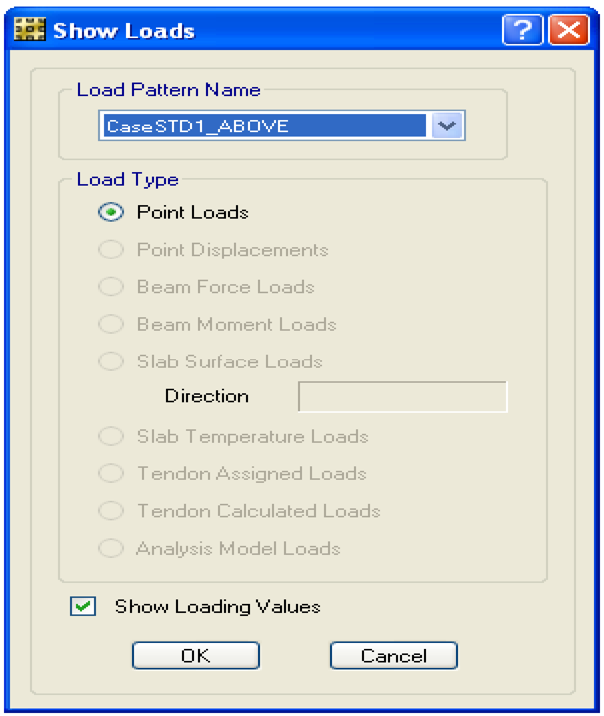
Integration with SAFE for foundation design: To prepare the model for export to SAFE, delete supports, then define a new section for pedestals, select base joints, then extrude points to lines the distance from top of pedestal to slab centerline in order to model the pedestals at the base as shown. The benefit of modeling the pedestals is that it saves the user from manually calculating moments for each lateral load case to account for pedestal height distance to basemat or footing centerline



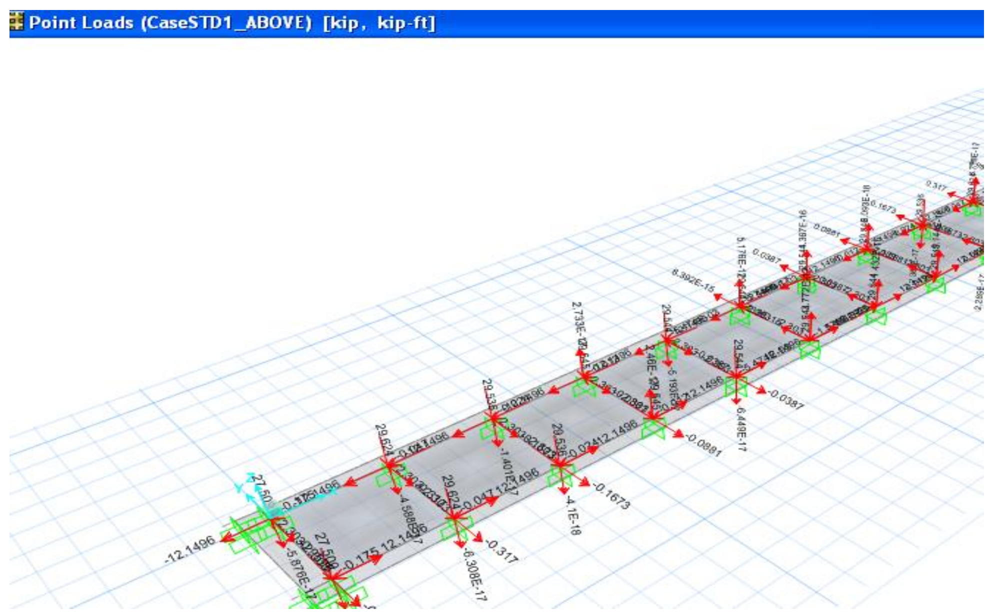
It's optional to model the basemat
before exporting to SAFE



Graphically display imported loads from SAP2000 in SAFE



Ready for design of basemat foundation



Following 6 slides from SAP2000 ACI 318 design manual

3.3.1 Generation of Biaxial Interaction Surfaces

The column capacity interaction volume is numerically described by a series of discrete points that are generated on the three-dimensional interaction failure surface. In addition to axial compression and biaxial bending, the formulation allows for axial tension and biaxial bending considerations. A typical interaction surface is shown in Figure 3-1.

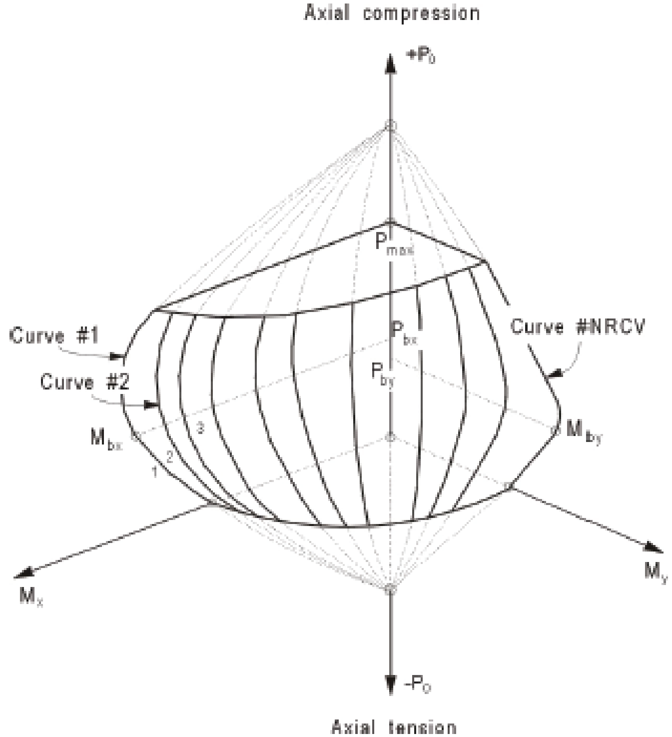


Figure 3-1 A typical column interaction surface

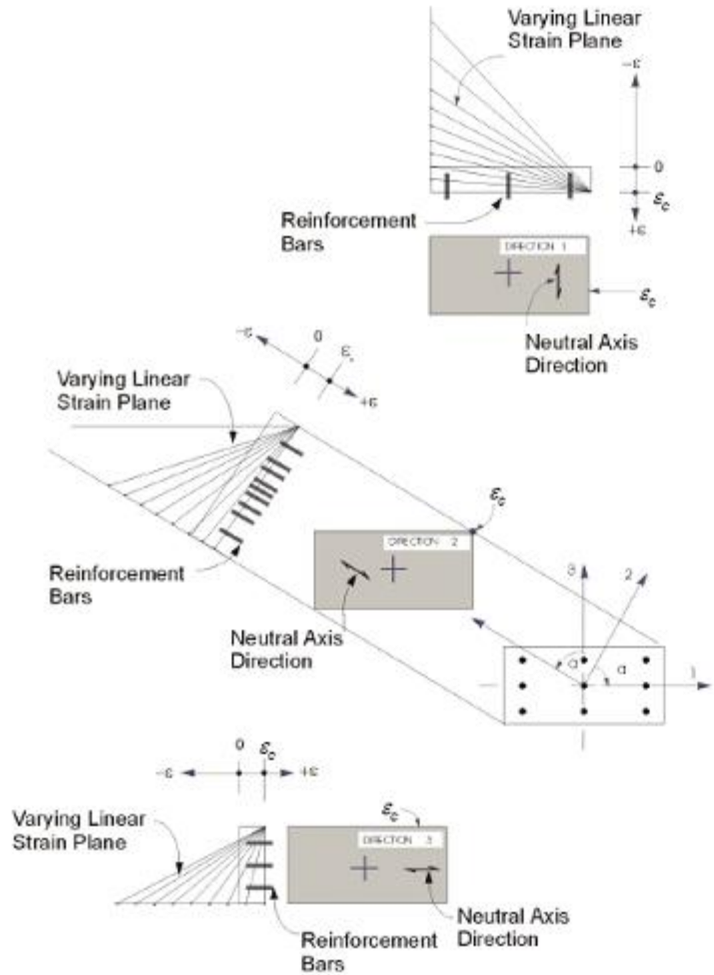


Figure 3-2 Idealized strain distribution for generation of interaction surface

The coordinates of these points are determined by rotating a plane of linear strain in three dimensions on the section of the column, as shown in Figure 3-2. The linear strain diagram limits the maximum concrete strain, ε_c, at the extremity of the section, to 0.003 (ACI 10.2.3).

The formulation is based consistently upon the general principles of ultimate strength design (ACI 10.3).

The stress in the steel is given by the product of the steel strain and the steel modulus of elasticity, $\varepsilon_s E_s$, and is limited to the yield stress of the steel, f_y (ACI 10.2.4). The area associated with each reinforcing bar is assumed to be placed at the actual location of the center of the bar, and the algorithm does not assume any further simplifications with respect to distributing the area of steel over the cross-section of the column, as shown in Figure 3-2.

The concrete compression stress block is assumed to be rectangular, with a stress value of $0.85f'_c$ (ACI 10.2.7.1), as shown in Figure 3-3. The interaction algorithm provides correction to account for the concrete area that is displaced by the reinforcement in the compression zone. The depth of the equivalent rectangular block, a, is taken as:

$$a = \beta_1 c \qquad \text{(ACI 10.2.7.3)}$$

where c is the depth of the stress block in compression strain and,

$$\beta_1 = 0.85 - 0.05\left(\frac{f'_c - 4000}{1000}\right), \quad 0.65 \le \beta_1 \le 0.85. \qquad \text{(ACI 10.2.7.3)}$$

The effect of the strength reduction factor, ϕ, is included in the generation of the interaction surface. The value of ϕ used in the interaction diagram varies from compression controlled ϕ to tension controlled ϕ based on the maximum tensile strain in the reinforcing at the extreme edge, ε_t (ACI 9.3.2.2).

Sections are considered compression controlled when the tensile strain in the extreme tension steel is equal to or less than the compression controlled strain limit at the time the concrete in compression reaches its assumed strain limit of $\varepsilon_{c.max}$, which is 0.003. The compression controlled strain limit is the tensile strain in the reinforcement at balanced strain condition, which is taken as the yield strain of the steel reinforcing, $\frac{f_y}{E}$ (ACI 10.3.3).

Sections are tension controlled when the tensile strain in the extreme tension steel is equal to or greater than 0.005, just as the concrete in compression reaches its assumed strain limit of 0.003 (ACI 10.3.4).

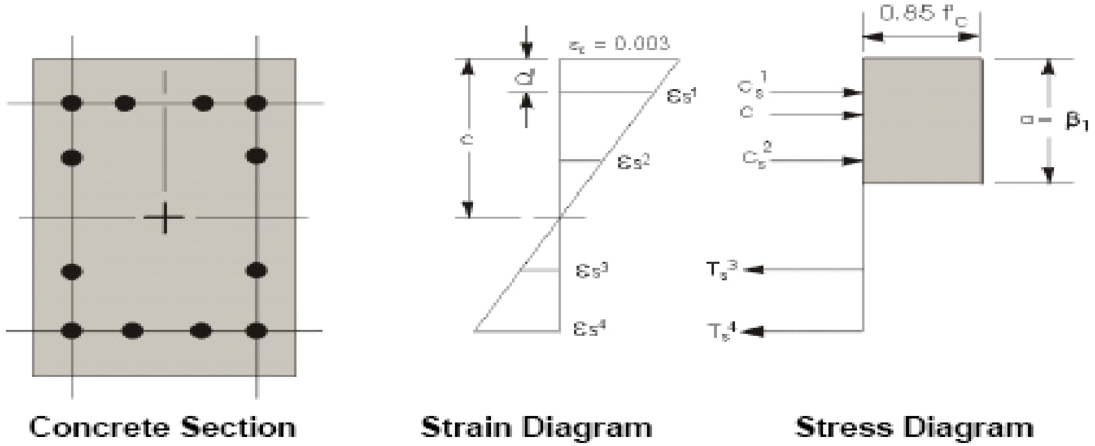


Figure 3-3 Idealization of stress and strain distribution in a column section

Sections with ε_t between the two limits are considered to be in a transition region between compression controlled and tension controlled sections (ACI 10.3.4).

When the section is tension controlled, a ϕ factor for tension-control is used. When the section is compression controlled, a ϕ factor for compression control is used. When the section is within the transition region, ϕ is linearly interpolated between the two values (ACI 9.3.2), as shown in the following:

$$\phi_c = \begin{cases} \phi_c & \text{if } \varepsilon_t \le \varepsilon_y \\ \phi_t - (\phi_t - \phi_c)\left(\dfrac{0.005 - \varepsilon_t}{0.005 - \varepsilon_y}\right) & \text{if } \varepsilon_y < \varepsilon_t \le 0.005, \\ \phi & \text{if } \varepsilon_t \ge 0.005, \text{ where} \end{cases} \qquad \text{(ACI 9.3.2)}$$

ϕ_t = ϕ for tension controlled sections, which is 0.90 by default (ACI 9.3.2.1)

ϕ_c = ϕ for compression controlled sections

= 0.70 (by default) for column sections with spiral reinforcement (ACI 9.3.2.2a)

= 0.65 (by default) for column sections

3.4.1.2.1 Design for Rectangular Beam

In designing for a factored negative or positive moment, M_u (i.e., designing top or bottom steel), the depth of the compression block is given by a (see Figure 3-7), where,

$$a = d - \sqrt{d^2 - \frac{2|M_u|}{0.85 f'_c \phi b}}, \qquad \text{(ACI 10.2)}$$

where, the value ϕ is taken as that for a tension controlled section, which is 0.90 by default (ACI 9.3.2.1) in the preceding and the following equations.

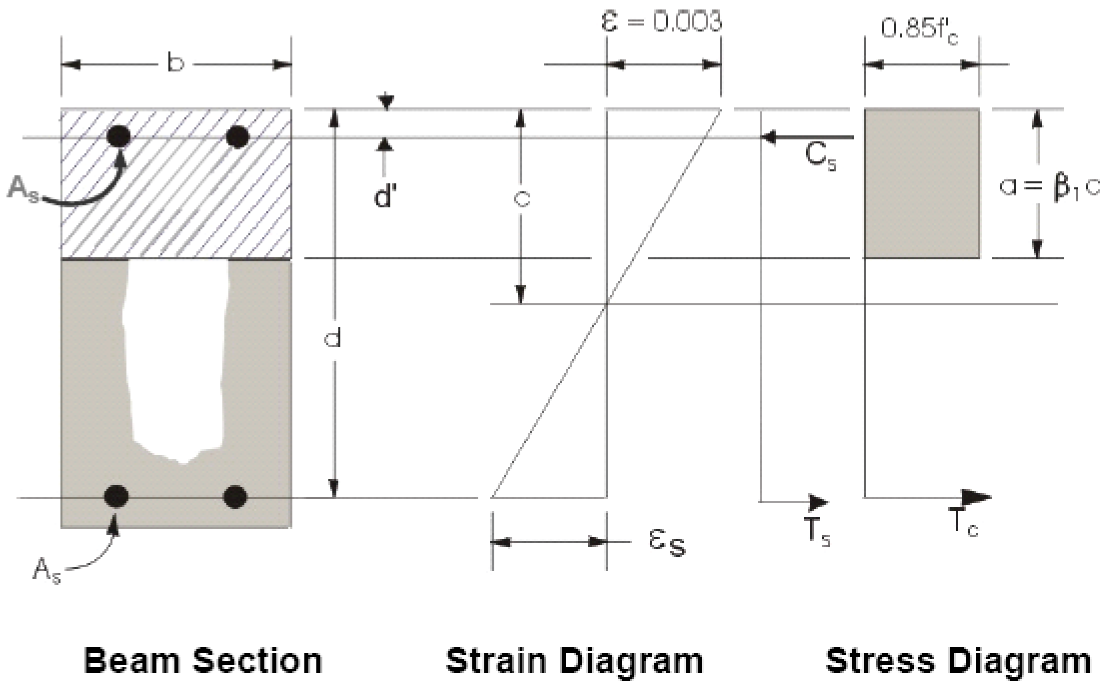


Figure 3-7 Rectangular beam design

The maximum depth of the compression zone, c_{max}, is calculated based on the limitation that the tensile steel tension shall not be less than $\varepsilon_{s,min}$, which is equal to 0.005 for tension controlled behavior (**ACI** 10.3.4):

$$c_{\max} = \frac{\varepsilon_{c\max}}{\varepsilon_{c,\max} + \varepsilon_{s,\min}} d \quad \text{where,} \qquad \text{(ACI 10.2.2)}$$

$$\varepsilon_{c,max} = 0.003 \qquad \text{(ACI 10.2.3)}$$

$$\varepsilon_{s,min} = 0.005 \qquad \text{(ACI 10.3.4)}$$

The maximum allowable depth of the rectangular compression block, a_{max}, is given by

$$a_{\max} = \beta_1 c_{\max} \qquad \text{(ACI 10.2.7.1)}$$

where β_1 is calculated as follows:

$$\beta_1 = 0.85 - 0.05\left(\frac{f'_c - 4000}{1000}\right), \quad 0.65 \le \beta_1 \le 0.85 \qquad \text{(ACI 10.2.7.3)}$$

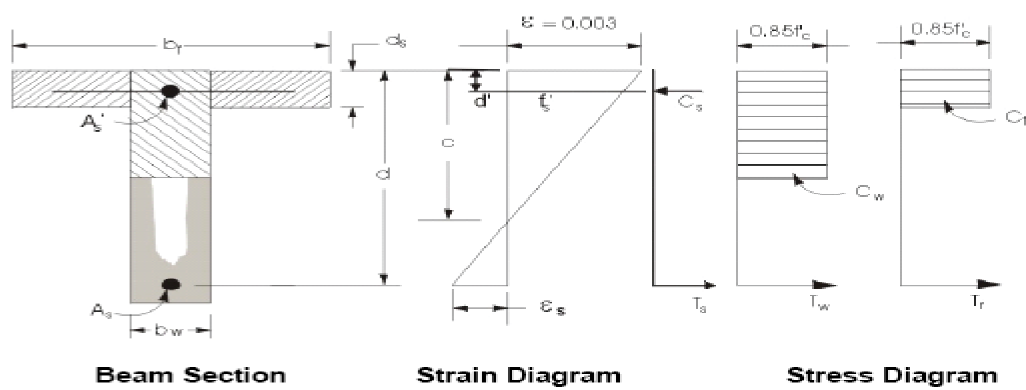


Figure 3-8 T beam design