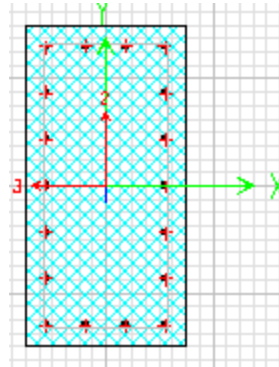
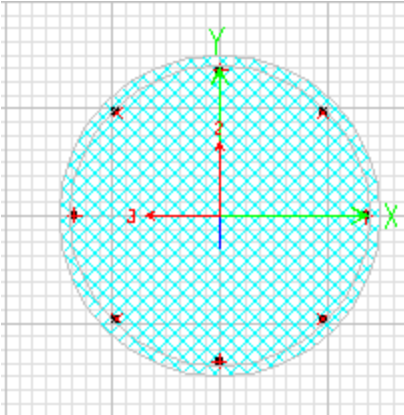


SAP2000 for Standalone Concrete Column and Beam Design

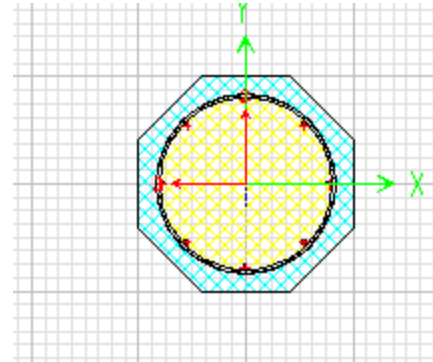


SAP2000

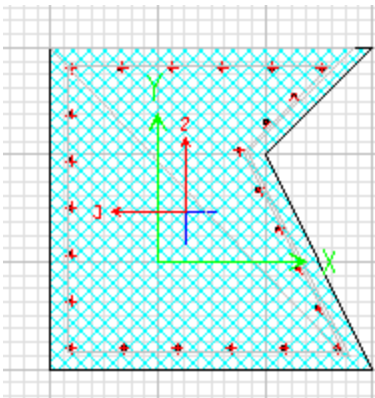
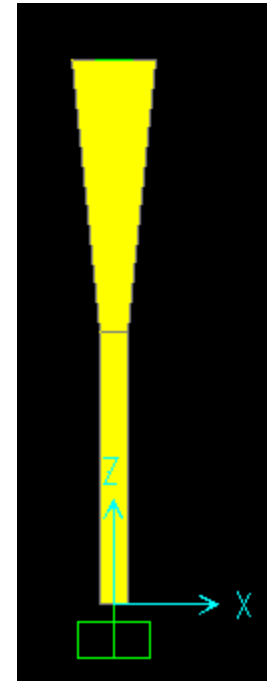
If you own any current version of SAP2000, you already have all the capabilities described in this document. If you don't want to tie up an expensive advanced of SAP2000 doing standalone column and beam design, you can purchase a basic level of SAP2000 for just \$2,000 (not including multiple copy discount) 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.



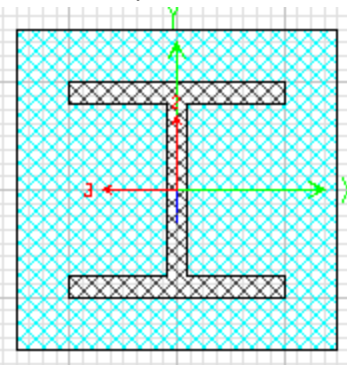
Octagon template



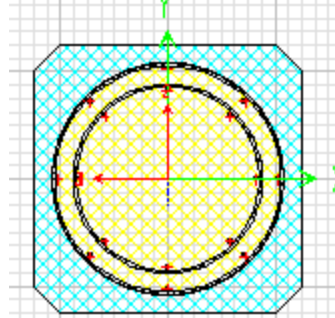
Tapered nonprismatic column with reinforcement designed at each station along the length



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

Caltrans Section Properties

Geometry

Shape: Octagon
 Chamfer: 0.25
 Height: 3.
 Width: 3.
 Small Base Dimensions
 Base Height: 3.
 Base Width: 3.
 No. of Cores: 1

Casing

Thickness: 0.
 Longit. Factor: 0.

Rings

No. of Rings: 1 Ring1 Cover: 0.1667 Ring2 Cover: Ring3 Cover:

Region	Ring	No. of Bundles	Bundle Type	Bundle Bar No.	Bundle Area	Bundle Material	Conf. Type	Conf. Spacing	Conf. Bar No.	Conf. Area	Conf. Material
Core1	Ring1	8	Single	#6	0.0031	A615Gr60	Hoop	1	#5	0.0022	A615Gr60
Prestress		0	Tendon	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A
Casing		N/A	Casing	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A

Concrete Model

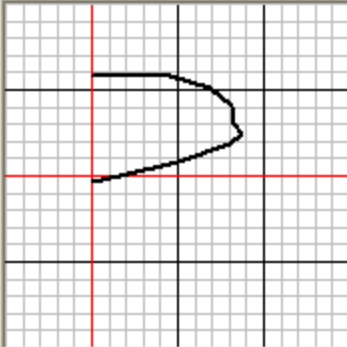
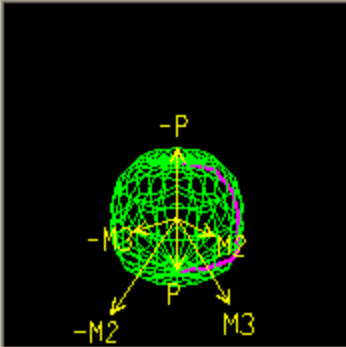
Material: 4000Psi
 Core Concrete: Core1
 Mander-Unconfin. **Outer Concrete**: Mander-Unconfin.

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.

Interaction Surface (ACI 318-05/IBC2003)

Edit

	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			

Design-Code Curve
 Fiber-Model Curve

Design Options

phi
 no phi
 no phi with fy increase

3D View

Plan: 315

Elevation: 35

3d MM PM3 PM2

Show Design-Code Results
 Show Fiber-Model Results

Curve 2
Angle 15.

Done

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

Moment Curvature Curve (Limits: P(comp.) = -3790.749, P(ten.) = 148.8)

Edit

Curvature

Select Type of Graph: Moment-Curvature

Specify Scales/Headings...: (1.769E-02, 270.68)

Strain Diagram

Concrete Strain: -4.302E-03

Steel Strain: 0.0448

Neutral Axis: 1.2569

Plot Exact-Integration Curve ■
 Show Numerical Results for Exact-Integration Curve
 Plot 3x3 Fiber Model Curve ■
 Show Numerical Results for Fiber Model Curve

Caltrans Idealized Model

No. of Points: 20

P (Tension +ve): -12 Angle (Deg): 0.

Max Curvature: 0.0231 Mmax = 273.026

Phi-Conc = .02307144 M-Conc = 265.857

Phi-Steel = N/A M-Steel = N/A

Phi-yield(Initial) = .00089736 M-yield = 152.515

Phi-yield(Idealized) = .0014646 Mp = 248.9235

ICrack = .327

Analysis Control

Concrete Failure (Lowest Ultimate Strain)
 Concrete Failure (Highest Ultimate Strain)
 First Rebar/Tendon Failure
 User Defined Curvature

Details...

Contour...

Refresh

Done

Curves

New Curve

Selected Curve Color:

Click to:

Add Curve

Delete Curve

Properties

Base Material: 4000Psi

Xcg: 0.

Ycg: 0.

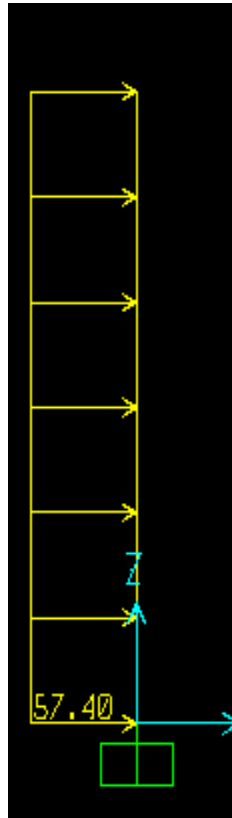
Axis Angle: 90 >>

A	7.4558
J	8.7197
I33	4.4338
I22	4.4338
I23	0.
AS2	6.5266
AS3	6.5266
S33(+face)	2.9558
S33(-face)	2.9558
S22(+face)	2.9558
S22(-face)	2.9558
Z33	4.886
Z22	4.886
r33	0.7711
r22	0.7711
d33pna	0.
d22pna	0.

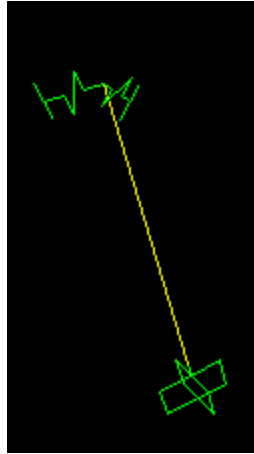
OK

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.

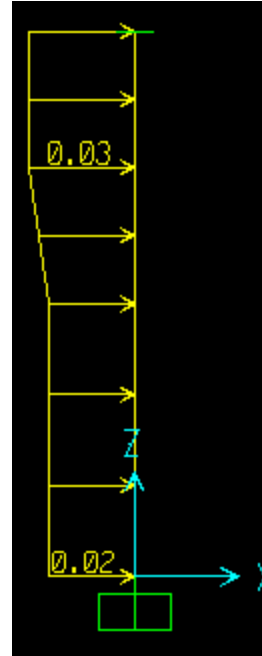
Uniform Distributed



Option to use spring supports in lieu of restraints



Trapezoidal distributed



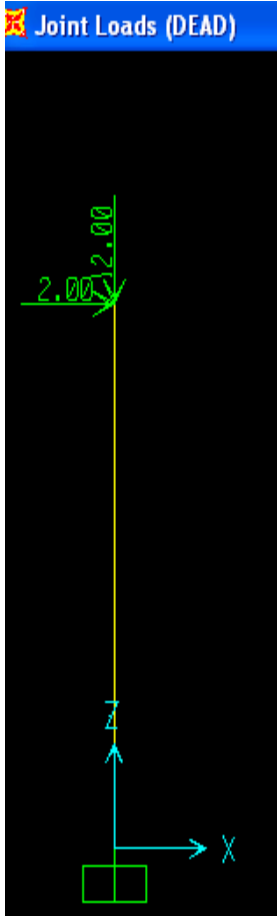
Reduced EI for cracking

Frame Property/Stiffness Modification Factors

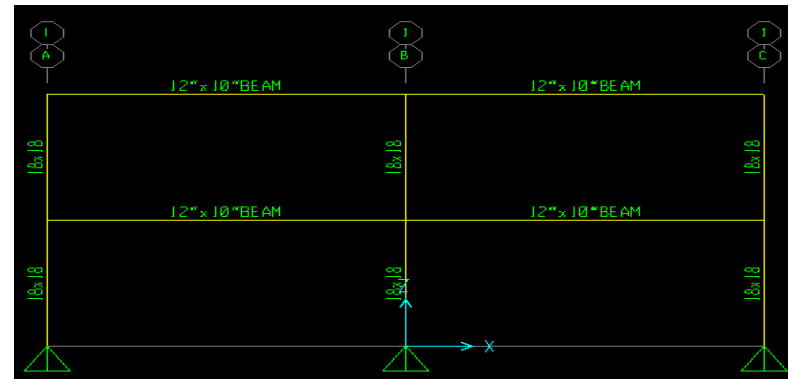
Property/Stiffness Modifiers for Analysis

Cross-section (axial) Area	1
Shear Area in 2 direction	1
Shear Area in 3 direction	1
Torsional Constant	1
Moment of Inertia about 2 axis	.7
Moment of Inertia about 3 axis	.7
Mass	1
Weight	1

OK Cancel



Create 2D or 3d models if needed



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

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	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

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

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

Load Combination Name (Automatic) DCON3

Notes

Load Combination Type Linear Add

Options

Define Combination of Load Case Results

Load Case Name	Load Case Type	Scale Factor
DEAD	Linear Static	1.2
DEAD	Linear Static	1.2
WINDX	Linear Static	-1.6

Concrete Frame Design Overwrites for ACI 318-05/IBC 2003

Item	Value
1 Current Design Section	16"x16"
2 Framing Type	Program Determined
3 Live Load Reduction Factor	Program Determined
4 Unbraced Length Ratio (Major)	Sway Special
5 Unbraced Length Ratio (Minor)	Sway Intermediate
6 Effective Length Factor (K Major)	Sway Ordinary
7 Effective Length Factor (K Minor)	NonSway
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

Item Description

This is either "Sway Special", "Sway Intermediate", "Sway Ordinary", or "NonSway". This item is used for ductility considerations in seismic design. Program determined value means that it defaults to the highest ductility requirement.

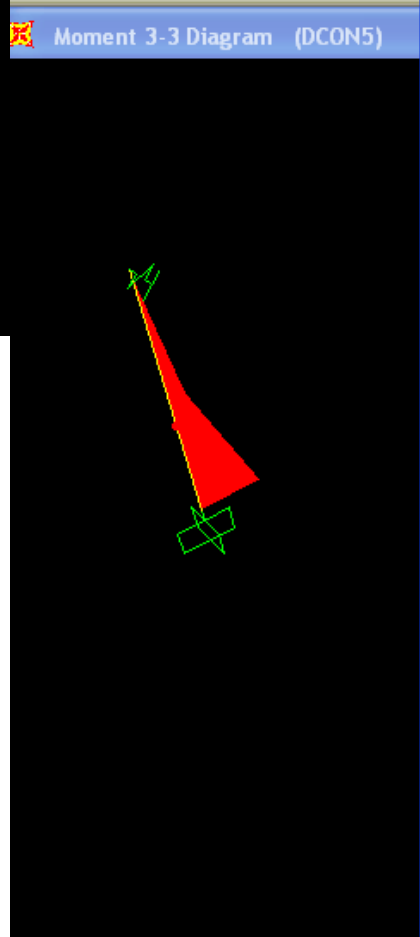
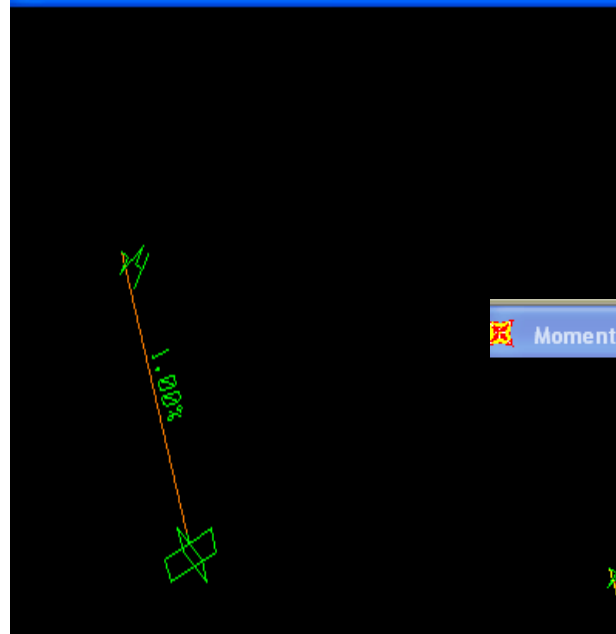
Design required reinforcement with shear design checks.

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 Area	Design Pu	Design M2	Design M3	Minimum M2	Minimum M3
	10.736	31.500	0.000	-53.003	52.920	52.920
AXIAL FORCE & BIAXIAL MOMENT FACTORS						
	Factor	Delta_ns	Delta_s	K	L	
Major Bending(M3)	1.000	Factor	Factor	Factor	Length	
Minor Bending(M2)	1.000	1.002	1.000	1.000	156.000	
		1.002	1.000	1.000	156.000	
SHEAR DESIGN FOR U2,U3						
	Rebar Au/s	Shear Uu	Shear phi*Uc	Shear phi*Us	Shear Up	
Major Shear(U2)	0.000	0.000	90.468	0.000	0.000	
Minor Shear(U3)	0.000	0.000	90.468	0.000	0.000	
JOINT SHEAR DESIGN						
	Joint Shear Ratio	Shear UuTop	Shear UuTot	Shear phi*Uc	Joint Area	
Major Shear(U2)	N/A	N/A	N/A	N/A	N/A	
Minor Shear(U3)	N/A	N/A	N/A	N/A	N/A	

Longitudinal Rebar (Percentage) (ACI 318-05/IBC2003)



Graphically display calculated longitudinal reinforcing, rebar percentage, shear reinforcing, or torsion reinforcing with moment diagrams. Output reports have automatic link to Excel

Case: DCON5
Items: Major (V2 and M3) | Single valued

End Length Offset (Location)
I-End: Jt: 1
0.0000 in (0.000 in)
J-End: Jt: 2
0.0000 in (156.000 in)

Display Options
 Scroll for Values
 Show Max

Equivalent Loads - Free Body Diagram (Concentrated Forces in Kip, Concentrated Moments in Kip-in)

Dist Load (2-dir)
0.0032 Kip/in
at 156.000 in
Positive in -2 direction

Resultant Shear

Shear V2
-0.497 Kip
at 0.000 in

Resultant Moment

Moment M3
-38.804 Kip-in
at 0.000 in

Deflections

Deflection (2-dir)
-0.003450 in
at 78.000 in
Positive in -2 direction

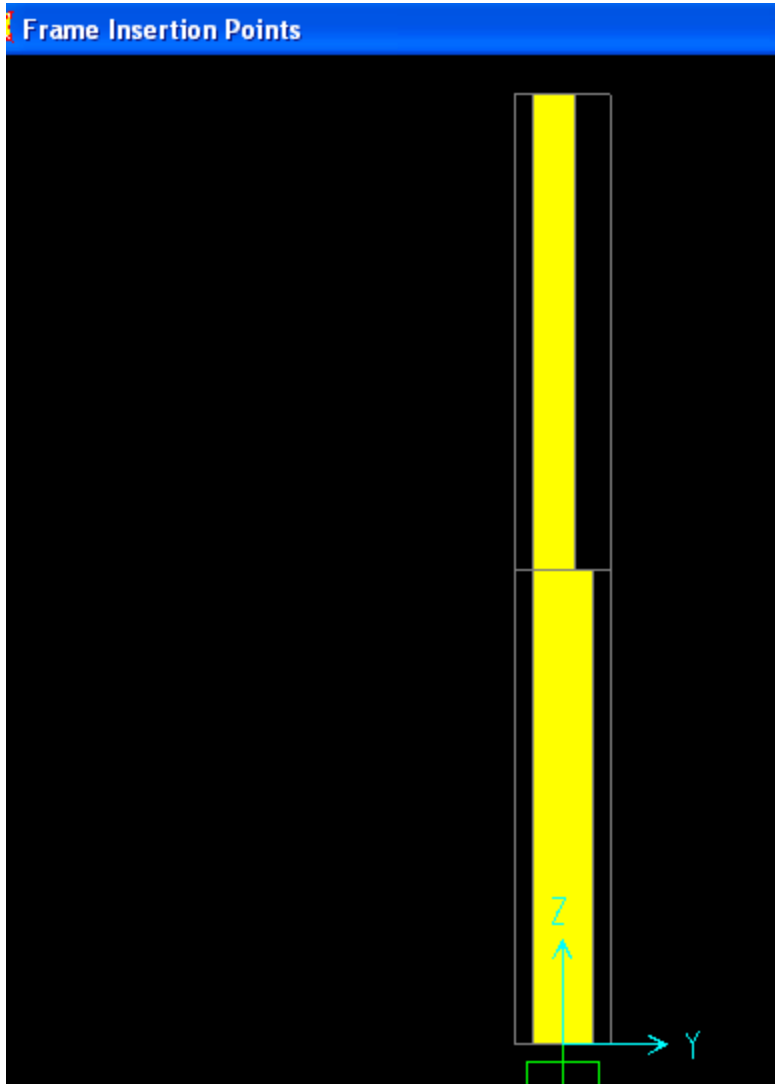
Absolute Relative to Beam Minimum Relative to Beam Ends

Reset to Initial Units Done Units: Kip, in, F

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

Built-up steel shapes

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



The image shows a built-up steel section on a grid. A table to the right lists the properties of the section. The section is composed of two I-beams (I22) and two S-shapes (S33) connected by plates (AS2, AS3, S22).

Base Material	A992Fy50
Xcg	-0.6364
Ycg	3.8569
Axis Angle	90
A	42.26
J	18.152
I33	3158.7067
I22	343.1057
I23	278.1884
AS2	12.9455
AS3	24.6778
S33(+face)	218.6998
S33(-face)	240.0801
S22(+face)	69.8284
S22(-face)	55.4609
Z33	293.7472
Z22	97.3442
Z23	0.0448

The image shows a dialog box for defining a section named "COVER_PLATE W18". It includes fields for I-Section Data, Top Cover Plate Data, and Bottom Cover Plate Data. The I-Section Data is set to W18x97 with Fy = 50. The Top Cover Plate Data includes Material (A36), Width (9), and Thickness (.75). The Bottom Cover Plate Data is currently unchecked.

Section Name: COVER_PLATE W18

I-Section Data: W18x97, Fy: 50

- Overwrite Top Flange Fy: 36
- Overwrite Web Fy
- Overwrite Bottom Flange Fy

Top Cover Plate Data:

- Include Top Cover Plate
- Material: A36
- Width: 9
- Thickness: .75

Bottom Cover Plate Data:

- Include Bottom Cover Plate
- Material: +

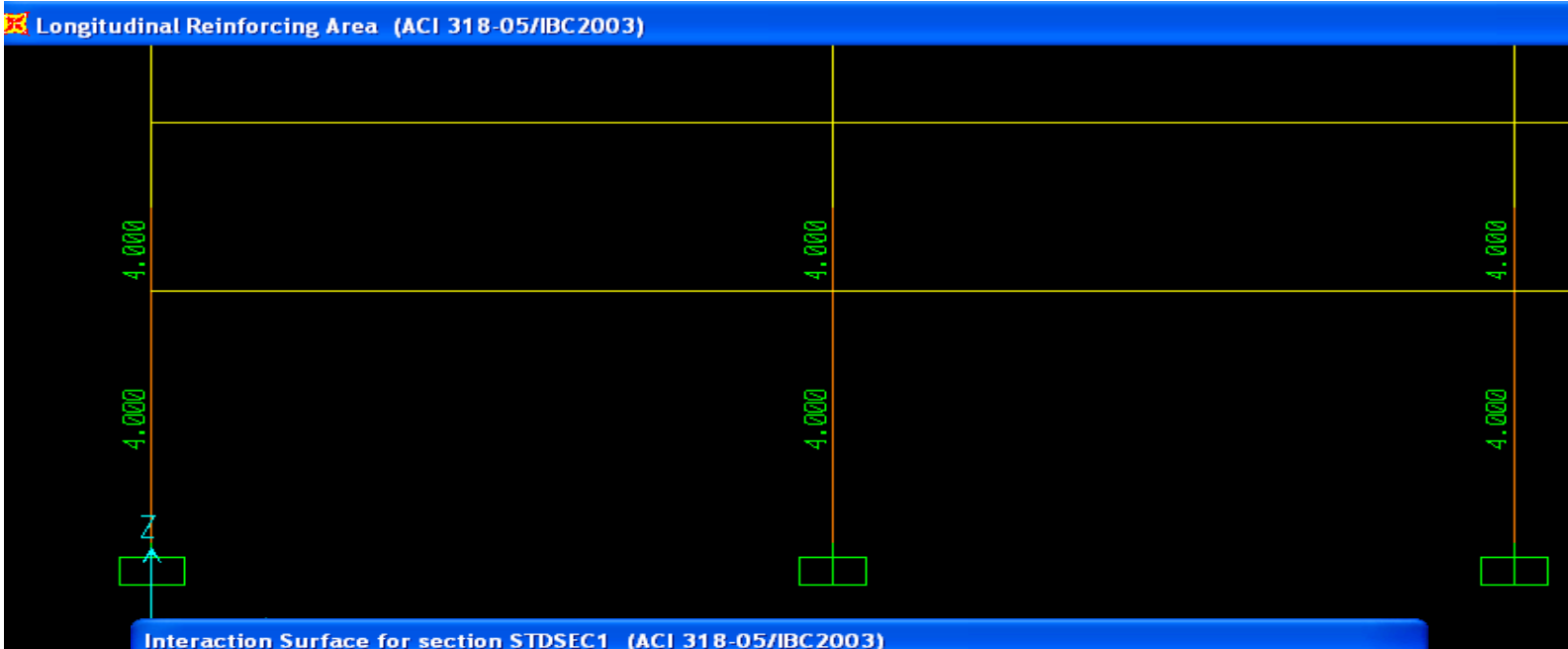
Section: A diagram showing the I-section with a cover plate on top. A blue arrow labeled '3' indicates the width of the cover plate.

Display Color: Yellow

Properties: Section Properties...

Property Modifiers: Set Modifiers...

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



Interaction Surface for section STDSEC1 (ACI 318-05/IBC2003)

Edit

	P	M3	M2
1	-644.5396	0.	0.
2	-644.5396	991.5226	0.
3	-593.591	1524.4065	0.
4	-500.1784	1952.9148	0.
5	-399.031	2255.8618	0.
6	-287.5228	2465.2038	0.
7	-251.5138	2732.1473	0.
8	-174.3098	2842.409	0.
9	-63.6413	2209.5743	0.
10	82.9417	1125.0594	0.
11	215.9827	0.	0.
12			
13			
14			
15			
16			
17			

Options

phi
 no phi
 no phi with fy increase

3D View

315 Plan 3d MM
 35 Elevation PM3 PM2

Curve 1
Angle 0.

Done

Pedestal section

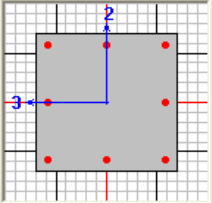
Rectangular Section

Section Name 30"x30"PEDESTAL

Section Notes

Properties: Property Modifiers: Material: + 4000Psi

Dimensions:
Depth (t3) 30.
Width (t2) 30.



Display Color

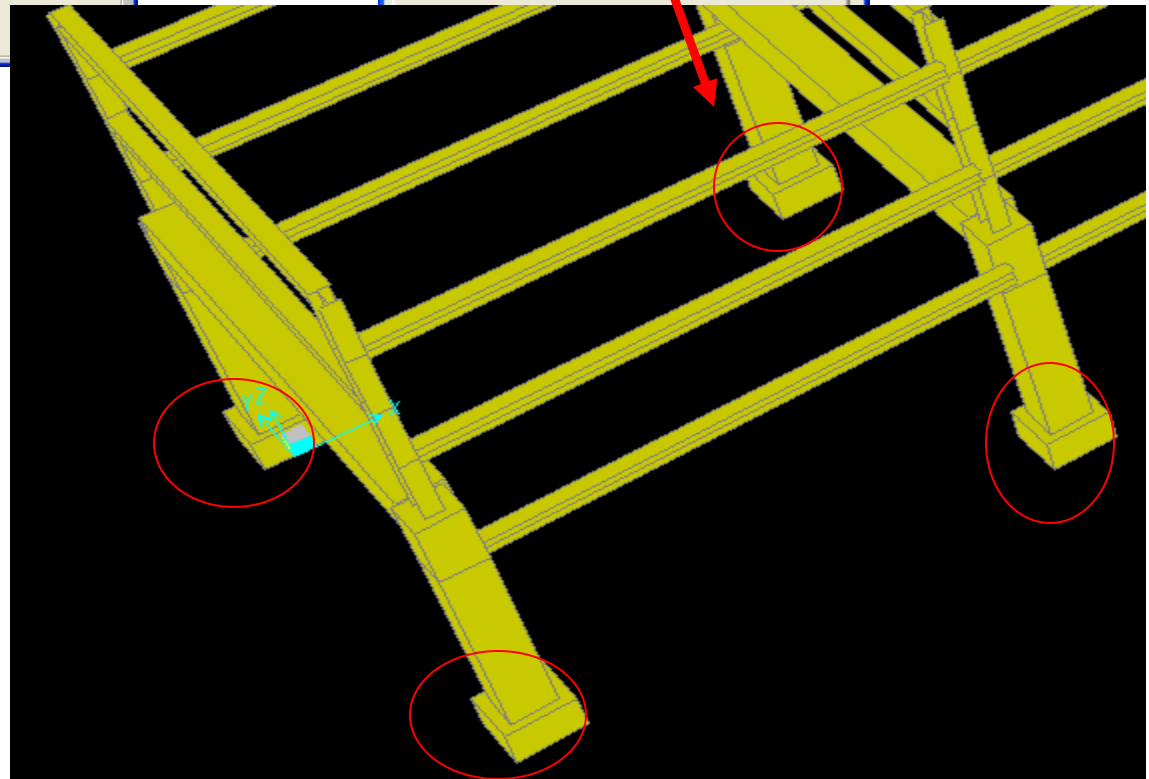
Extrude Points to Lines

Linear | Radial | Advanced

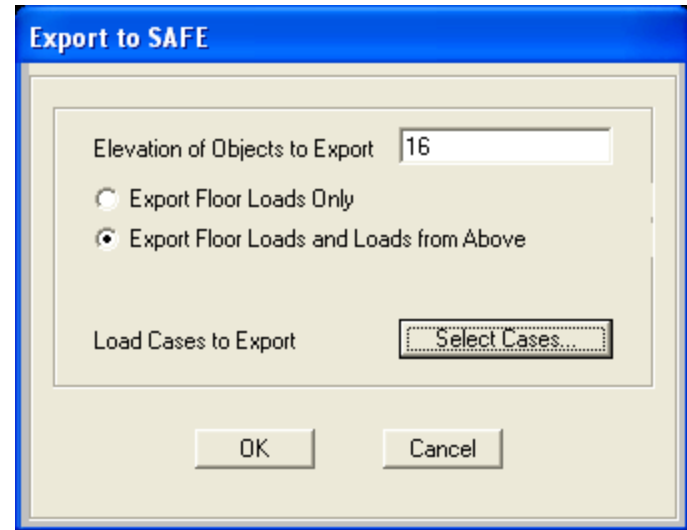
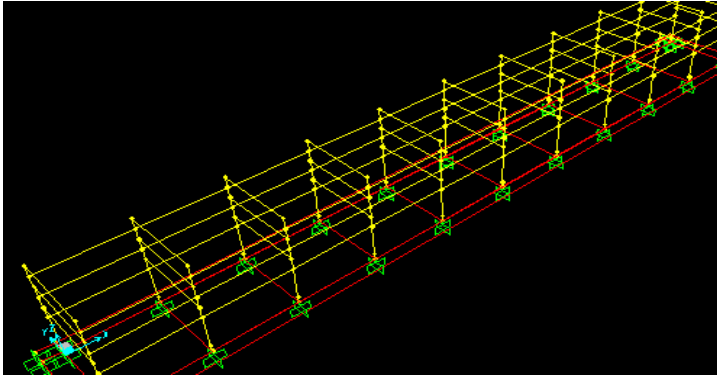
Property For Added Objects
+ 30"x30"PEDESTAL

Increment Data
dx 0.
dy 0
dz -20
Number 1

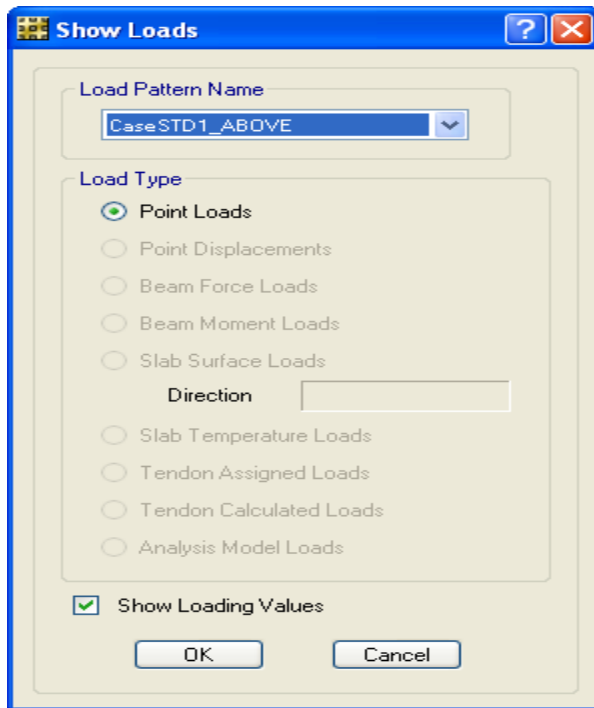
Integration with SAFE for foundation design: To prepare the model for export to SAFE, delete supports, then define a new section for pedestals, select base joints, then extrude points to lines the distance from top of pedestal to slab centerline in order to model the pedestals at the base as shown. The 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



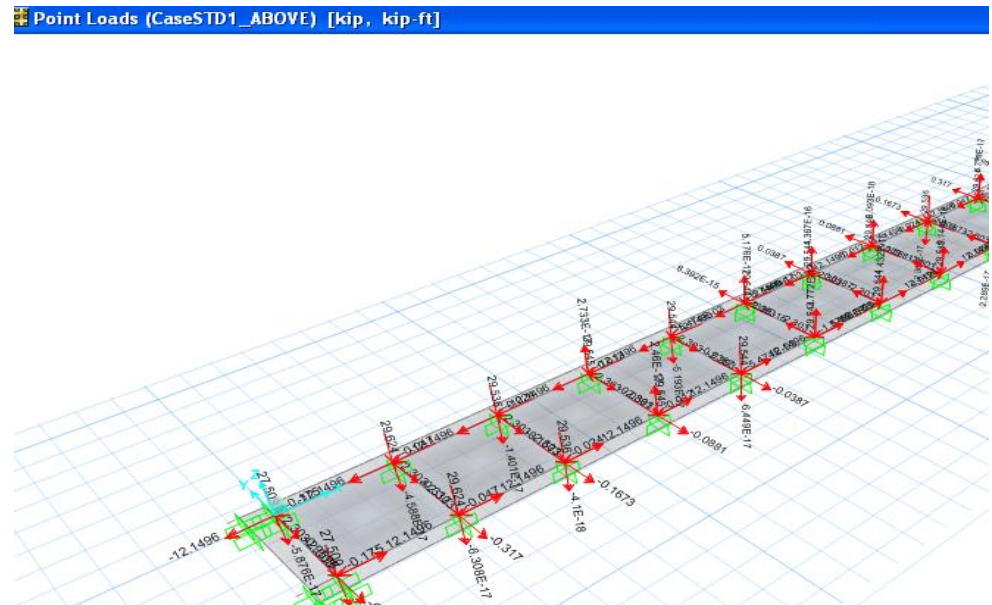
It's optional to model the basemat before exporting to SAFE



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.

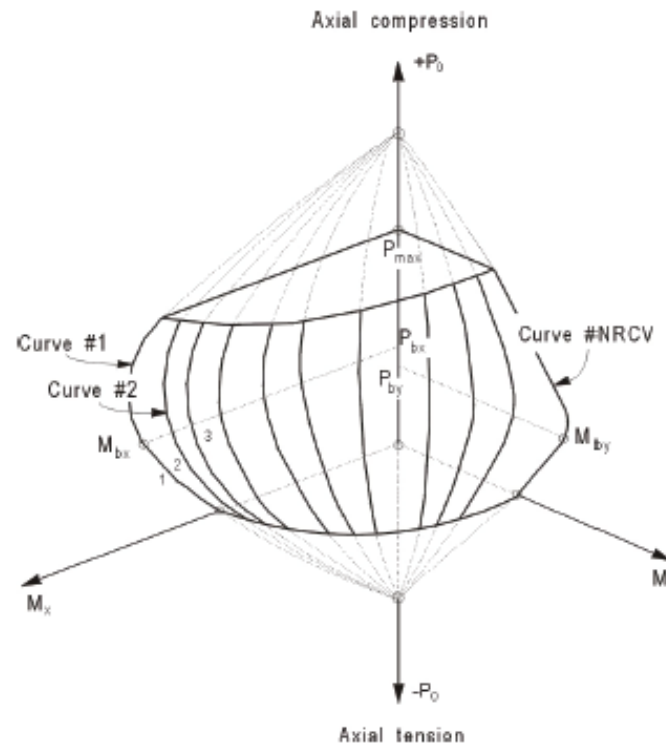


Figure 3-1 A typical column interaction surface

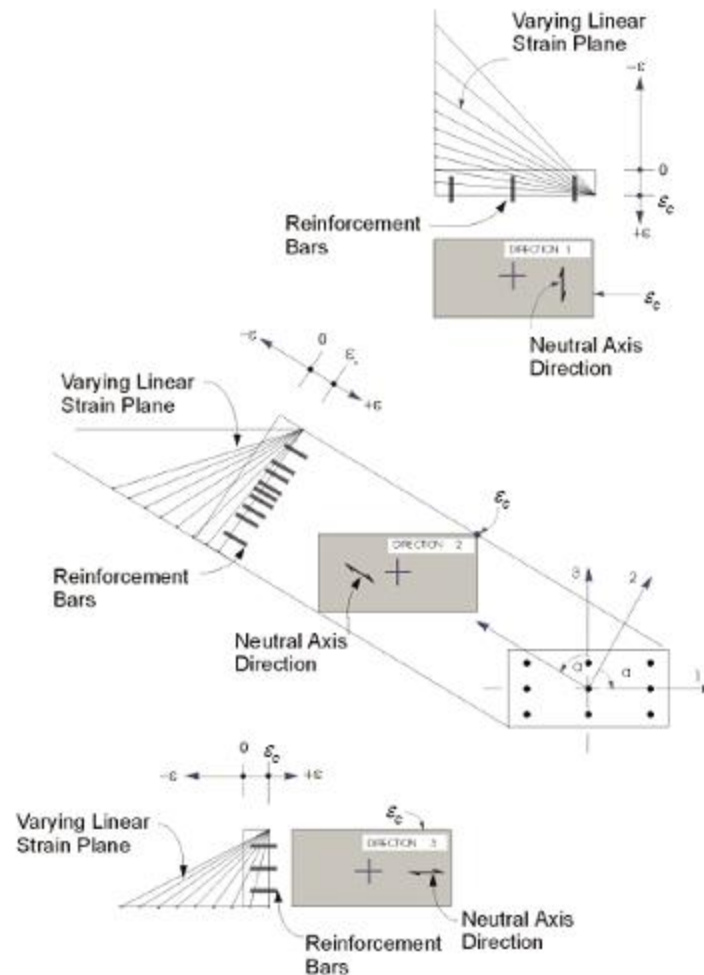


Figure 3-2 Idealized strain distribution for generation of interaction surface

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:

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

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

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

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).

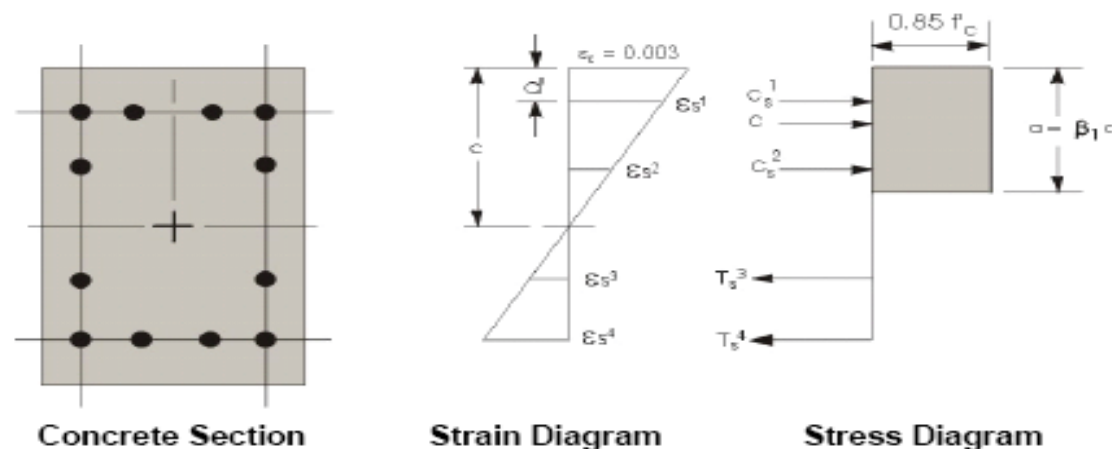


Figure 3-3 Idealization of stress and strain distribution in a column section

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:

$$\phi_c = \begin{cases} \phi_c & \text{if } \varepsilon_t \leq \varepsilon_y \\ \phi_t - (\phi_t - \phi_c) \left(\frac{0.005 - \varepsilon_t}{0.005 - \varepsilon_y} \right) & \text{if } \varepsilon_y < \varepsilon_t \leq 0.005, \\ \phi & \text{if } \varepsilon_t \geq 0.005, \text{ where} \end{cases} \quad (\text{ACI 9.3.2})$$

$$\phi_t = \begin{cases} \phi & \text{for tension controlled sections,} \\ & \text{which is 0.90 by default} \end{cases} \quad (\text{ACI 9.3.2.1})$$

$$\begin{aligned} \phi_c &= \phi && \text{for compression controlled sections} \\ &= 0.70 && \text{(by default) for column sections} \\ &&& \text{with spiral reinforcement} \\ &= 0.65 && \text{(by default) for column sections} \end{aligned} \quad (\text{ACI 9.3.2.2a})$$

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,

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

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.

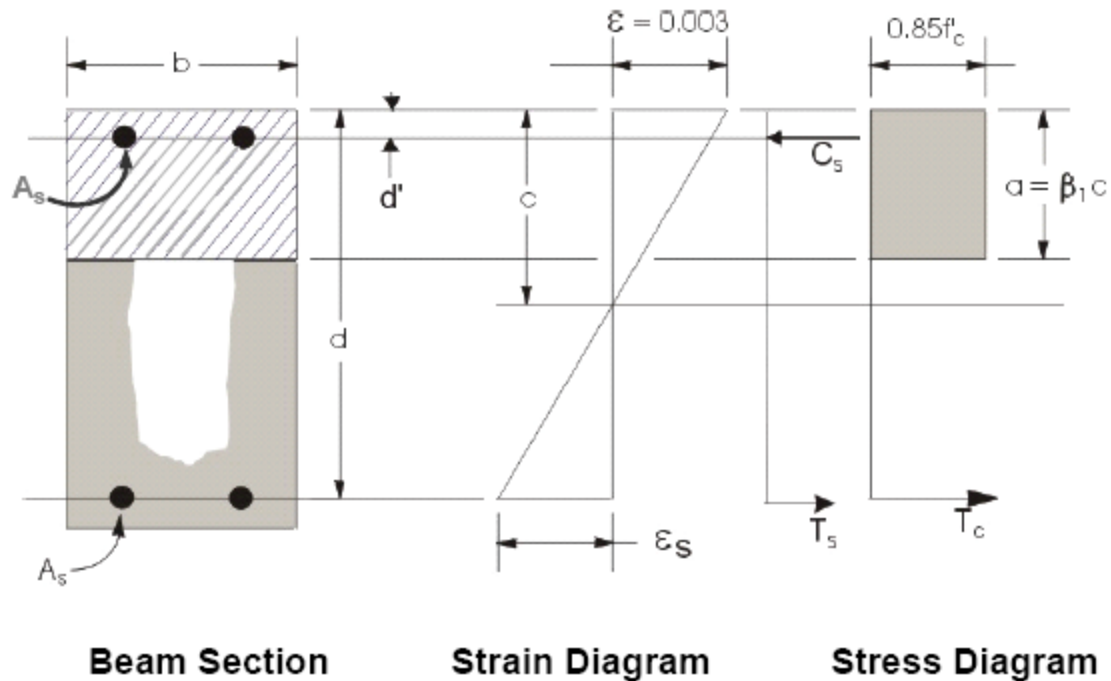


Figure 3-7 Rectangular beam design

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):

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

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

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

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

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

where β_1 is calculated as follows:

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

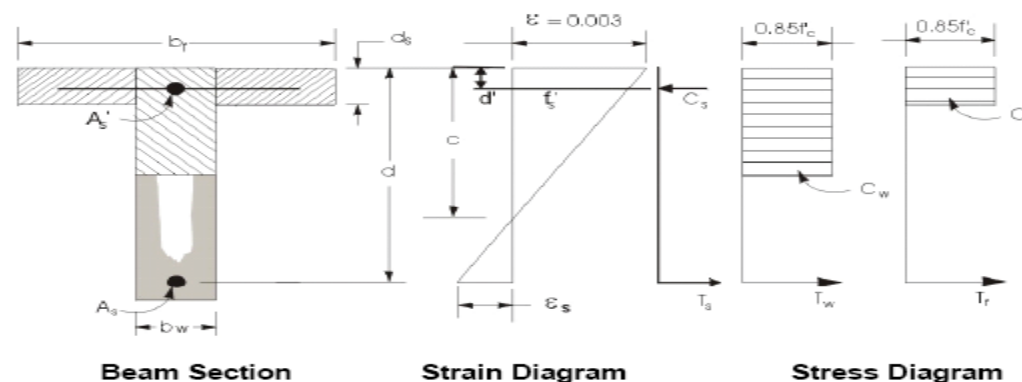


Figure 3-8 T beam design