Advanced Application 2

Seismic Design for Reinforced Concrete Building

Seismic Design for Reinforced Concrete Building

Overview

This example problem is meant to demonstrate the design of a Reinforced Concrete building structure subjected to floor loads, wind loads and seismic loads.

Description

Seismic Design Data

- Dual system (special reinforced concrete structural walls with special moment frame) in the transverse direction
- Special moment frame in the longitudinal direction
- Assigned to a high seismic zone

Methodology

- Response spectrum analysis
- P-Delta analysis

Model

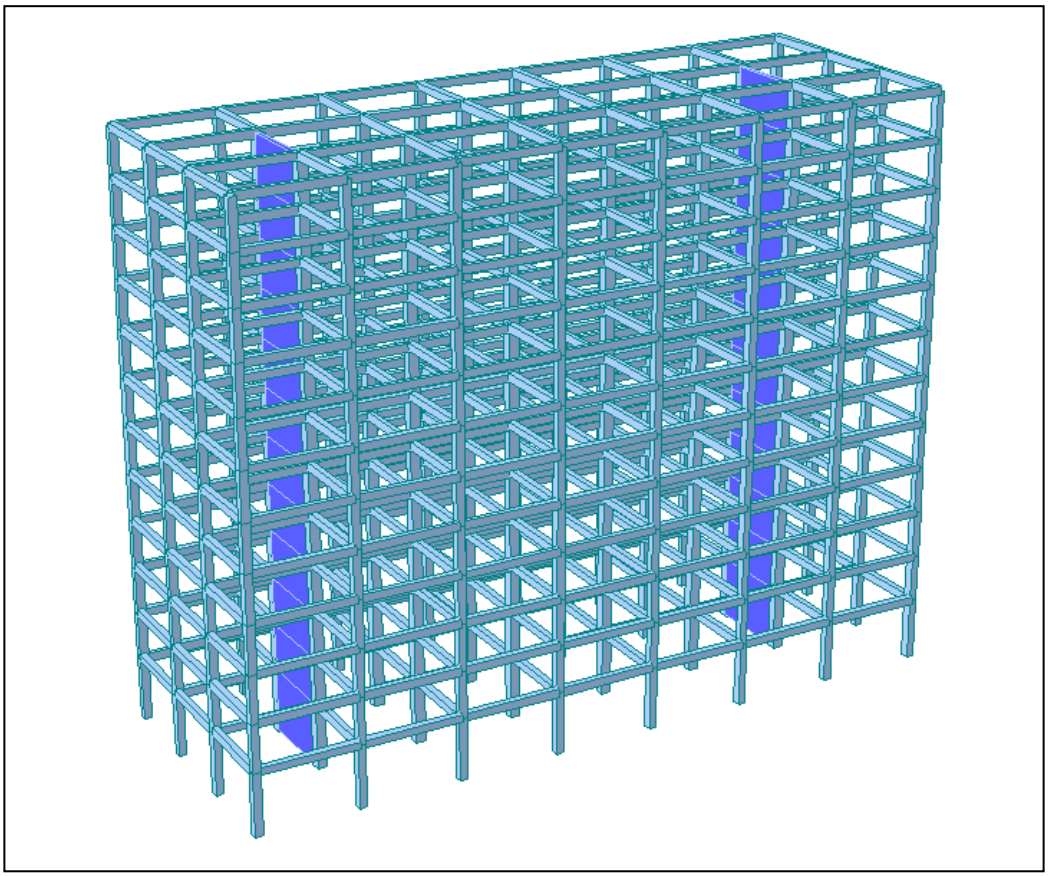


Figure 1 : Reinforced Concrete Building Model

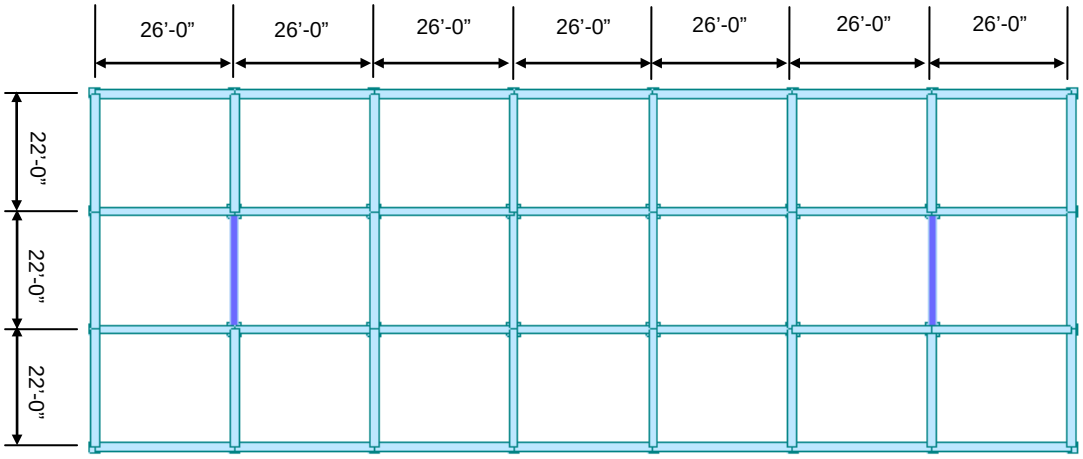


Figure 2 : Typical Floor Plan

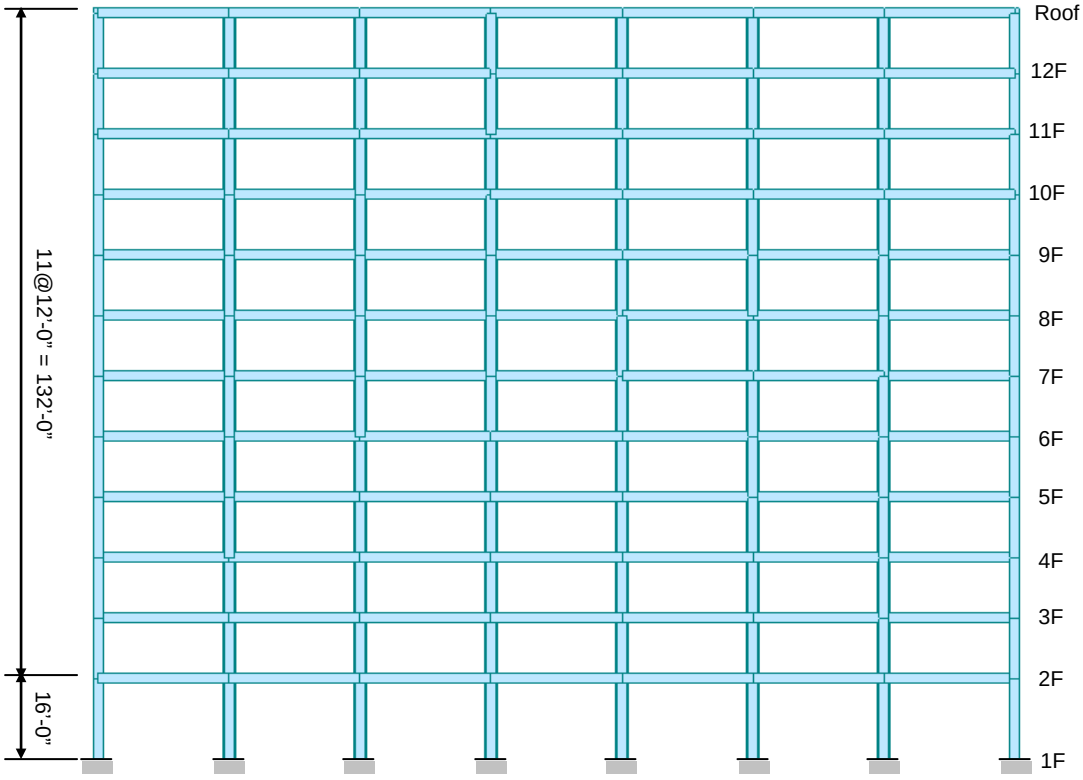


Figure 3 : Longitudinal Section

Design Procedure

1. Material & Section Properties Input

Material
- Concrete fc' = 4,000 psi
- Reinforcement fy = 60,000 psi

Section
- Edge columns 24×24 in.
- Interior columns 30×30 in.
- Beams 20×24 in.
- Walls 18 in. (In-plane & Out-of-plane)

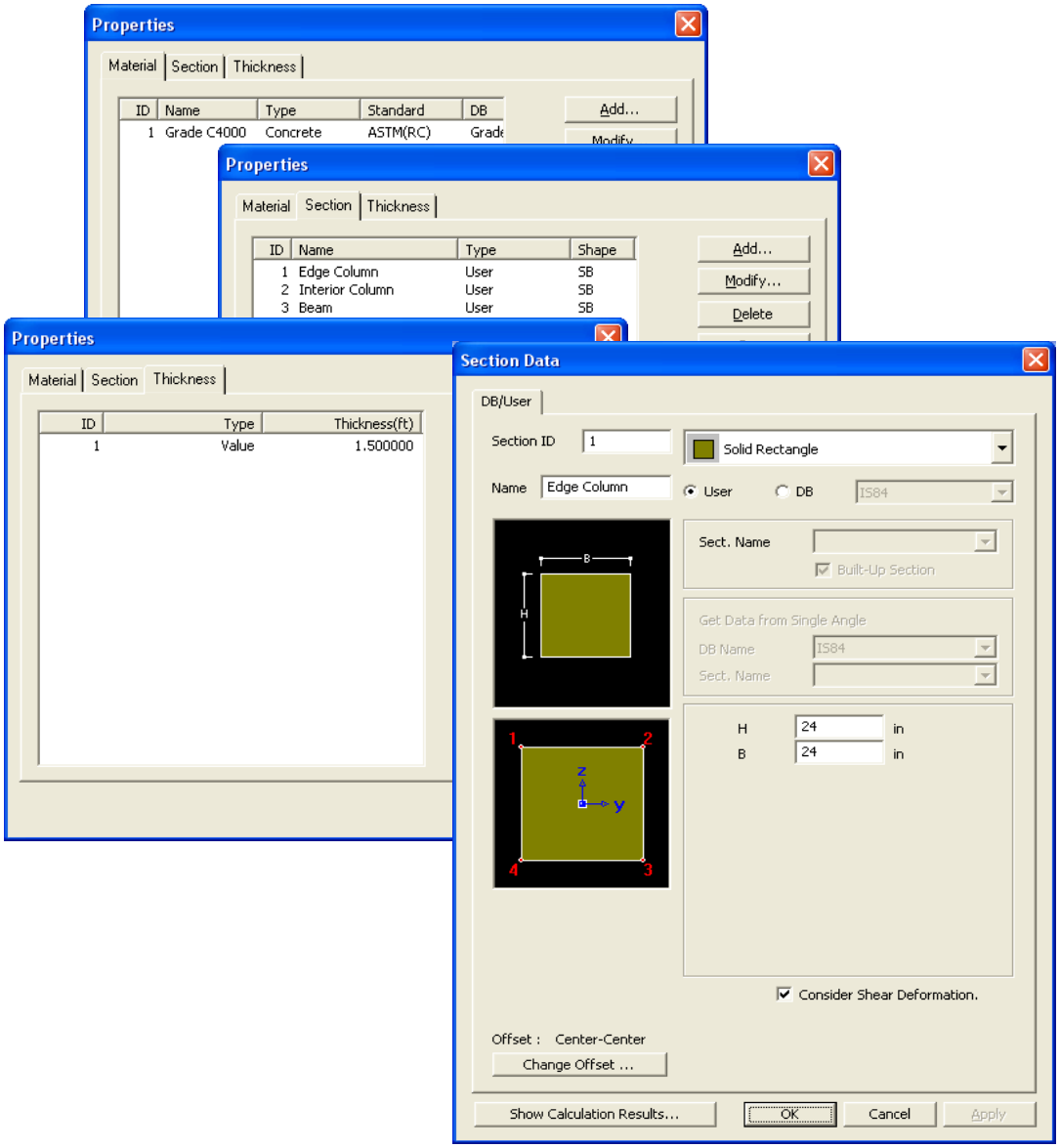


Figure 4 : Material & Section Properties Input

2. Create Model

Units : Length > ft

Set UCS to X-Y Plane

Origin : 0, 0, 16

Change View Direction > (on)

OK

Set Line Grid Add

Grid Name = 2F

X-Grid Lines Add

Relative > (on)

'7@26' OK

Y-Grid Lines Add

Relative > (on)

'3@22' OK

Add/Modify Grid Lines OK

Define Grids OK

Line Grid, Line Grid Snap (toggle on)

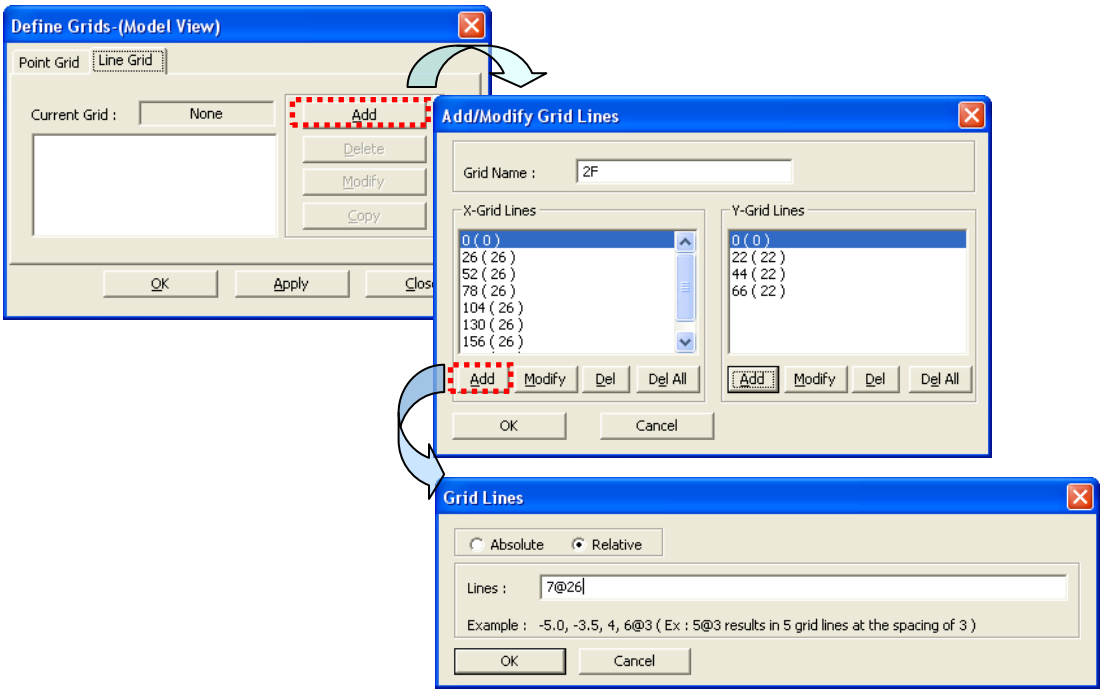


Figure 5 : Create Grid Lines

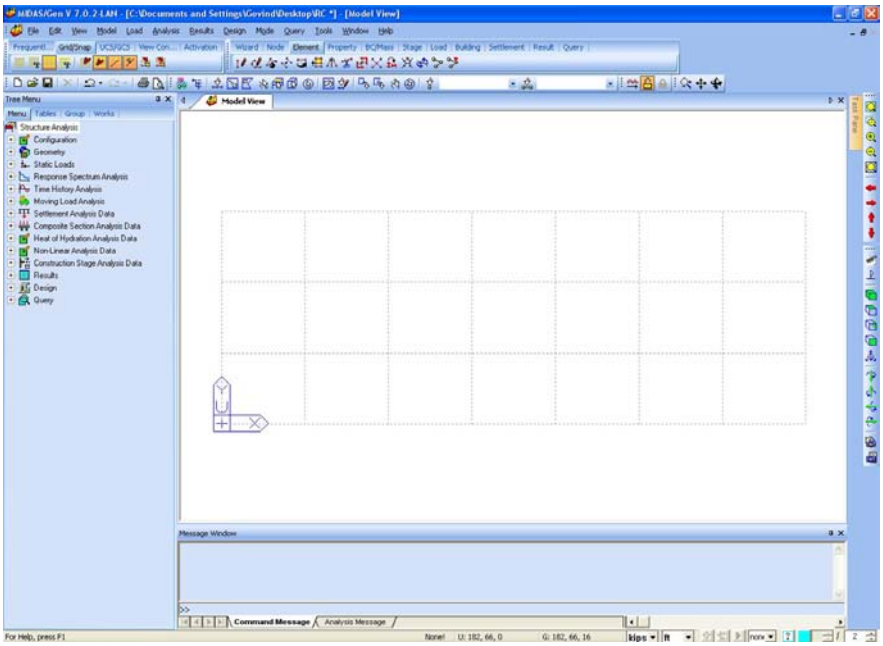


Figure 5 : Grid Lines in X-Y Plane

Generate Floor Plan

Hidden, Node Number, Element Number (toggle on)

Create Elements

Element Type = General Beam / Tapered Beam

Section Name = 3 : Beam

Draw Elements as shown (Refer Figure 6)

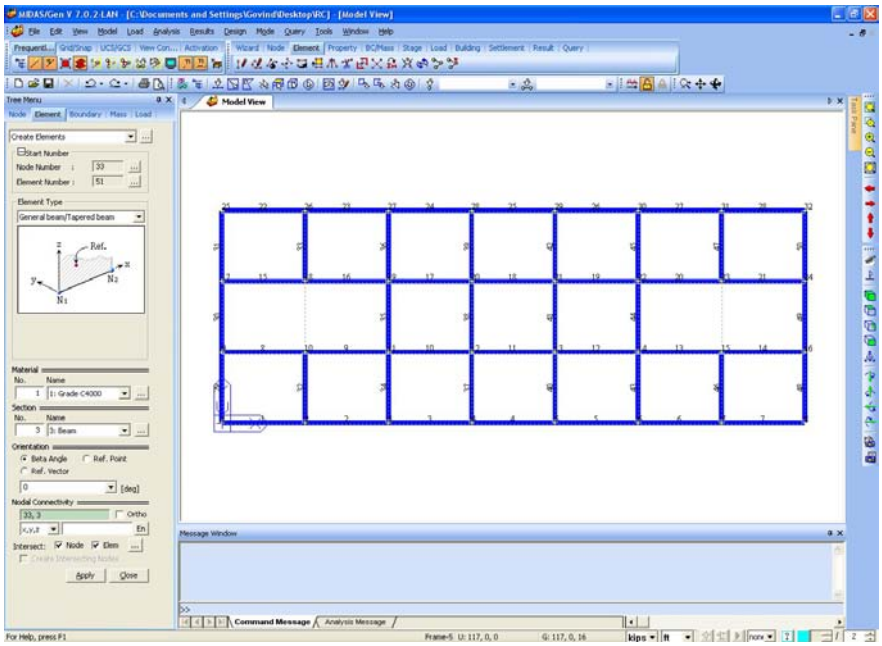


Figure 6 : Floor Plan

Generate Columns

Change to GCS

Select All

Extrude Element

Node → Line Element

Reverse I-J > (on)

Element Type = Beam

Material = 1 : Grade C4000

Section = 1 : Edge column

d_x, d_y, d_z = 0, 0, -16

Apply

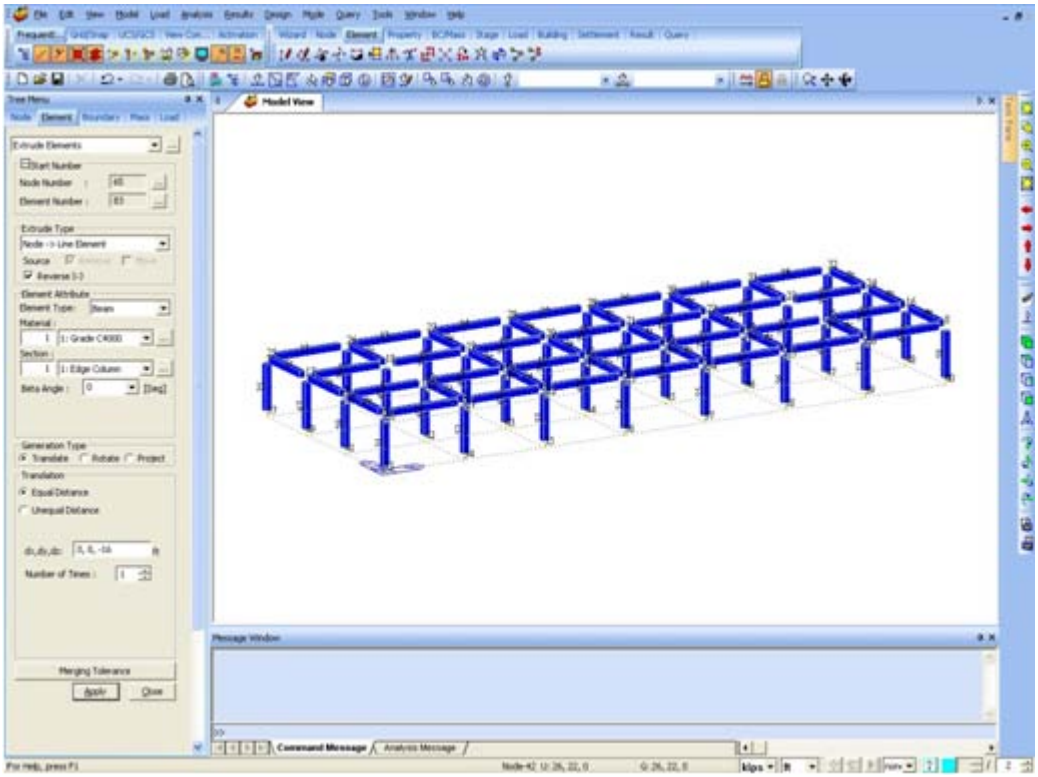


Figure 7 : Generate Columns

Change Properties of Interior Columns

Work > Properties > Section : 1 : Edge column = Active

Display > Property > Property Name > (on)

OK

Isometric View (Refer Figure 8)

Top View > Select Window > Select Interior Columns

Work > Properties > Section = 2 : Interior column

Drag & Drop (Refer Figure 9)

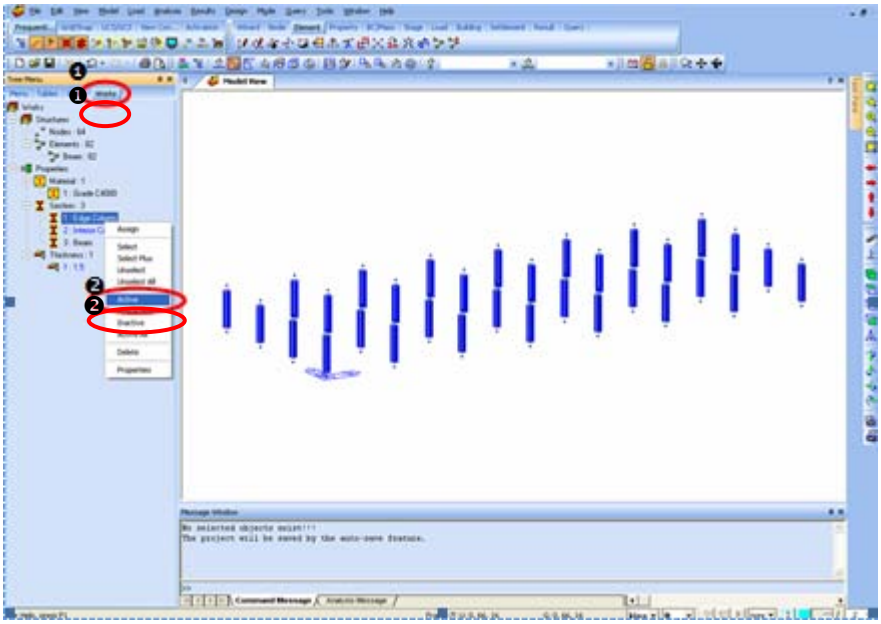


Figure 8 : Inactivate Beams

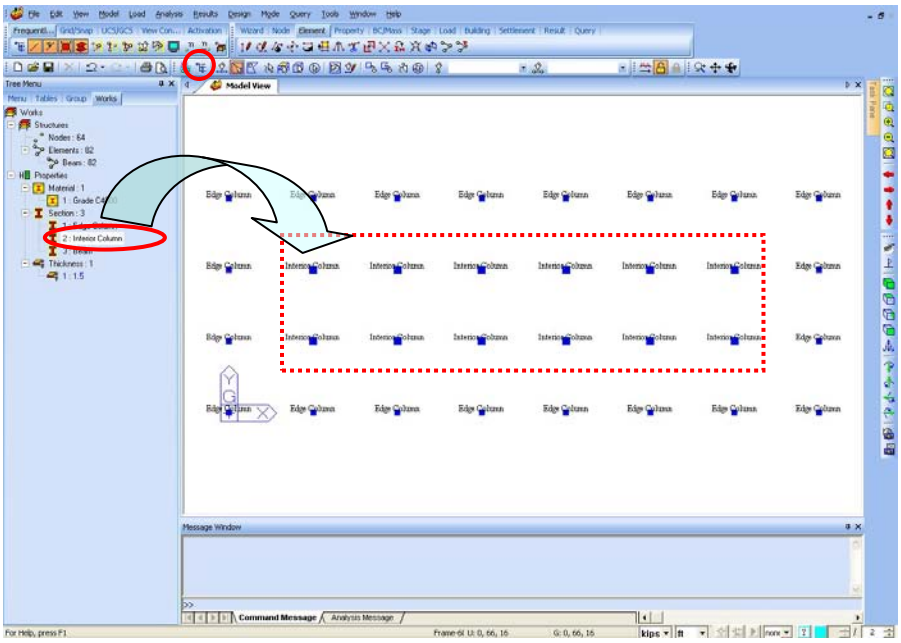


Figure 9 : "Drag & Drop" Interior Column Properties

Drop

Generate Walls

Hidden (toggle off) ; Node Number (toggle on)

Display > Property > Property Name > (off)

Select Window (Refer Figure 10)

Active

Create Elements

Element Type : Wall

Membrane > (on)

Wall ID > Auto Inc. > 1

Material Name > 1:Grade C4000

Thickness > 1:1.5000

Intersect Node > (on)

Nodal Connectivity > 50, 42, 10, 18 (Refer ❶ on Figure 11)

Select Single > Wall Element 1

Translate Element > Copy

Equal Distance (d_x, d_y, d_z) > 130, 0, 0 Apply

Wall ID Increment = 1 OK

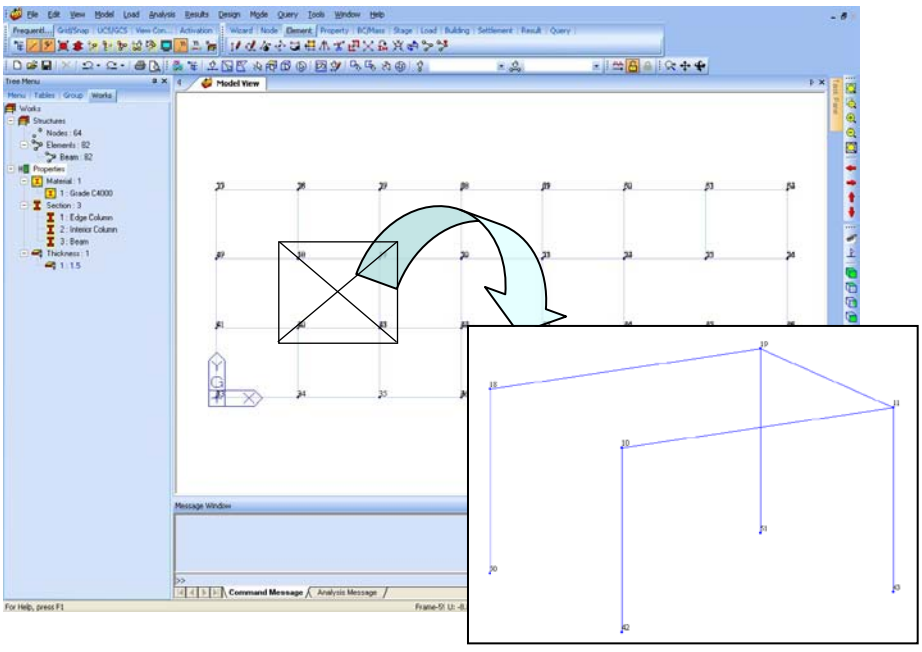


Figure 10 : Location of Wall Element

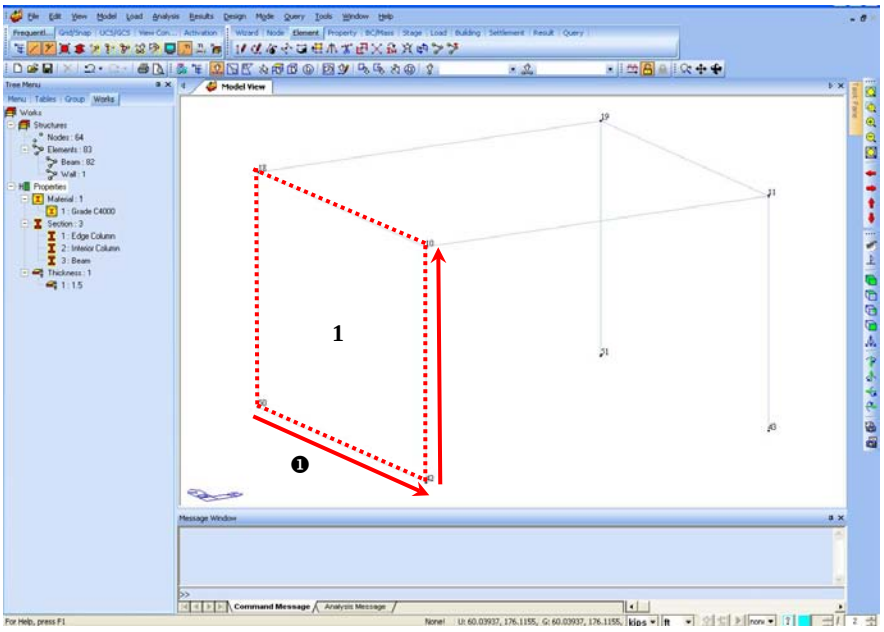


Figure 11 : Nodal Connectivity of Wall Element

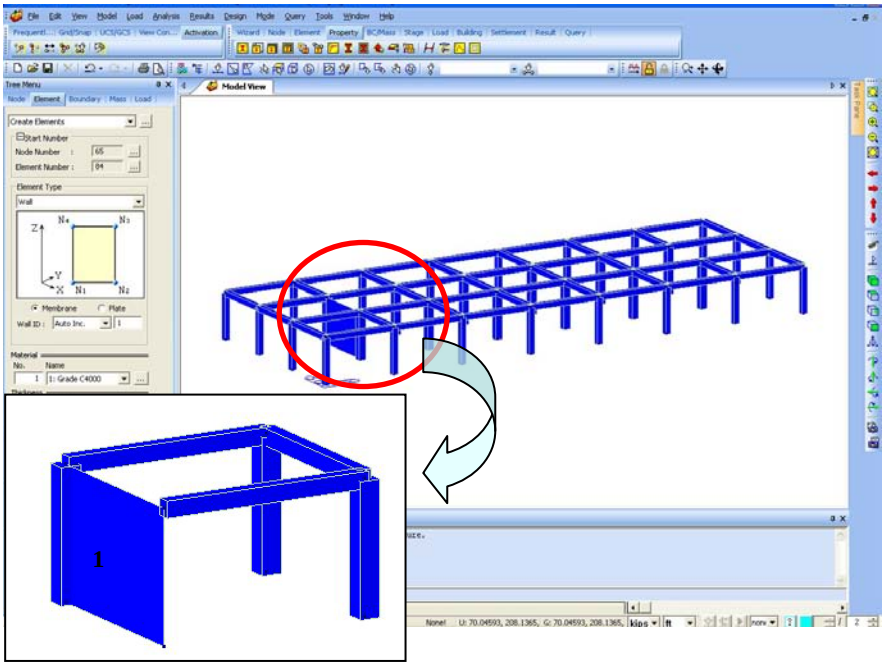


Figure 12 : Generation of Wall Element

Building Generation

Select All

Model > Building > Building Generation

Number of Copies = 11

Distance(Global Z) = 12 Add Apply

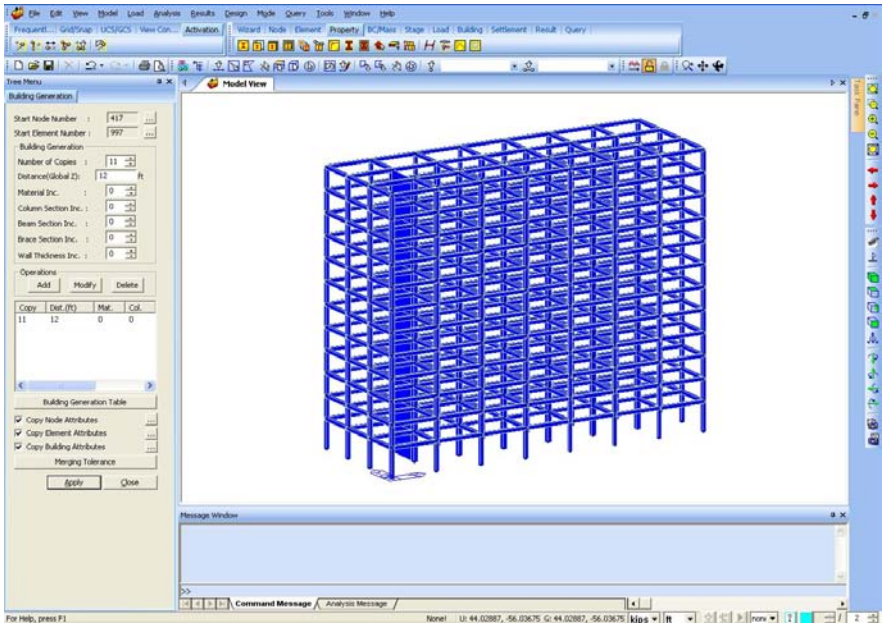


Figure 13 : Building Generation

Generate Story Data

Model > Building > Story

Auto Generate Story Data...

OK

Close

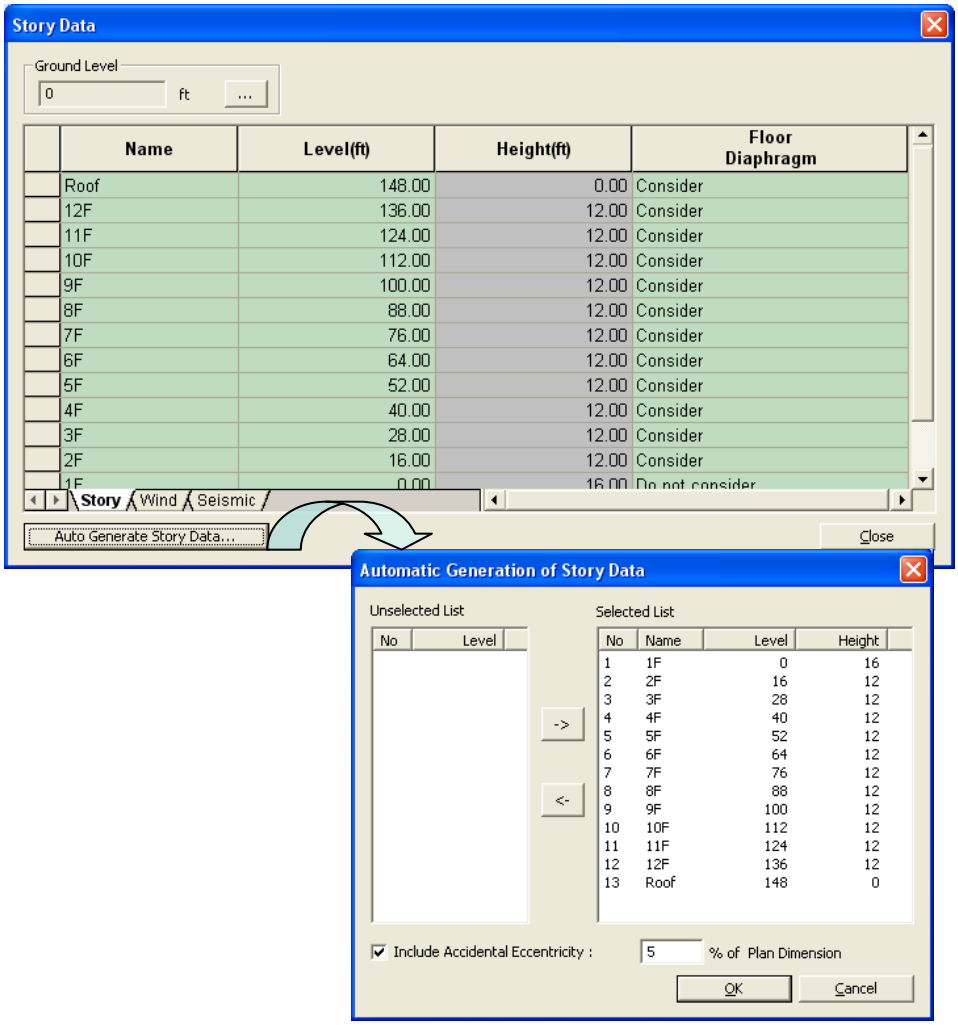


Figure 14 : Generation of Story Data

3. Boundary Conditions Input

The lower ends of the columns are assumed fixed.

Model > Boundary > Supports
D – All > (on)
R – All > (on)
Select Window
Apply

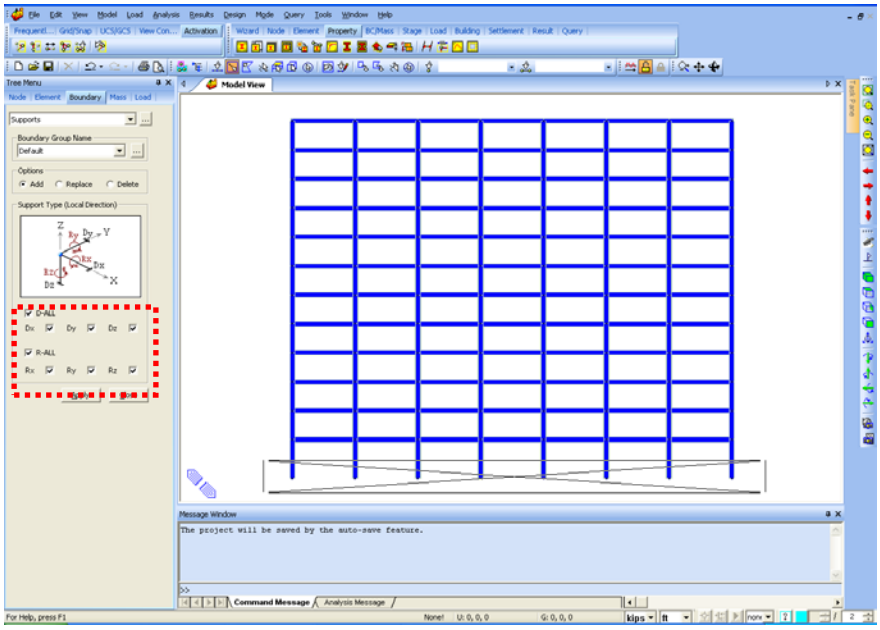


Figure 15 : Boundary Supports

4. Loading Data Input

Load > Static Load Cases

- Dead Load
- Live Load
- Wind Load (X-direction)
- Wind Load (Y-direction)
- Earthquake Load (X-direction, Eccentricity direction-Positive)
- Earthquake Load (X-direction, Eccentricity direction-Negative)
- Earthquake Load (Y-direction, Eccentricity direction-Positive)
- Earthquake Load (Y-direction, Eccentricity direction-Negative)

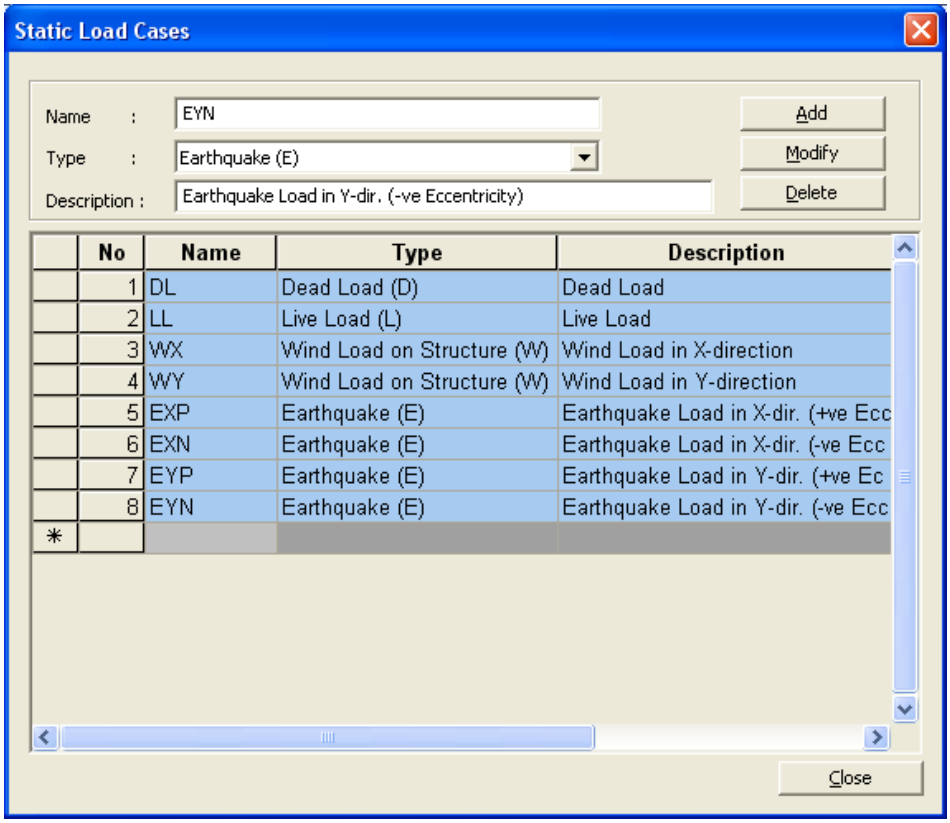


Figure 16 : Loading Data Input

Self Weight

Load > Self Weight

Z = -1 Add

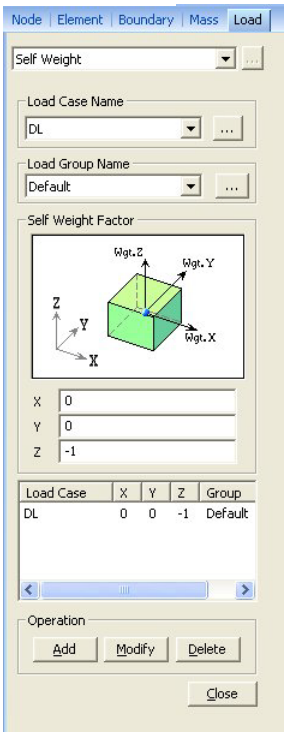


Figure 17 : Self Weight Load

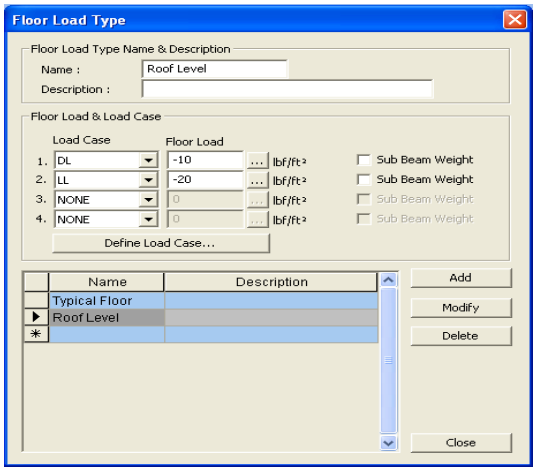
Floor Load

Load > Define Floor Load Type
- Name > Typical Floor : DL = -30 psf, LL = -75 psf Add
- Name > Roof Level : DL = -10 psf, LL = -20 psf Add

Load > Assign Floor Load
- Load Type > Typical Floor
- Two Way Distribution
- Copy Floor Load > (on)
- Axis > z (on)
- Distance > 10@12
- Assign Nodes Defining Loading Area > (1, 8, 32, 25)

Similarly, assign floor load at roof level :
- Load Type > Roof Level
- Copy Floor Load > (off)
- Assign Nodes Defining Loading Area > (386, 387, 417, 410)

OK Close



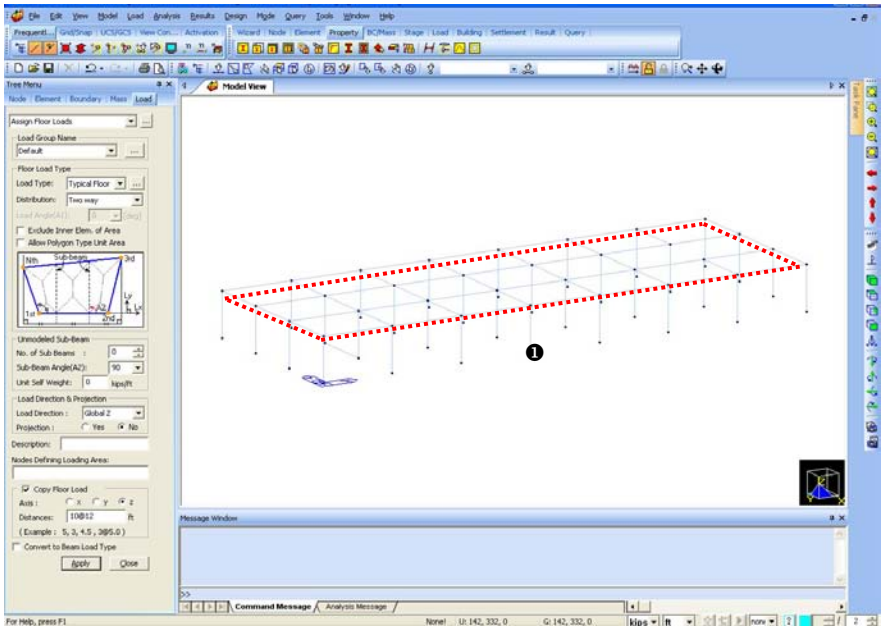


Figure 18 : Assign Floor Loads

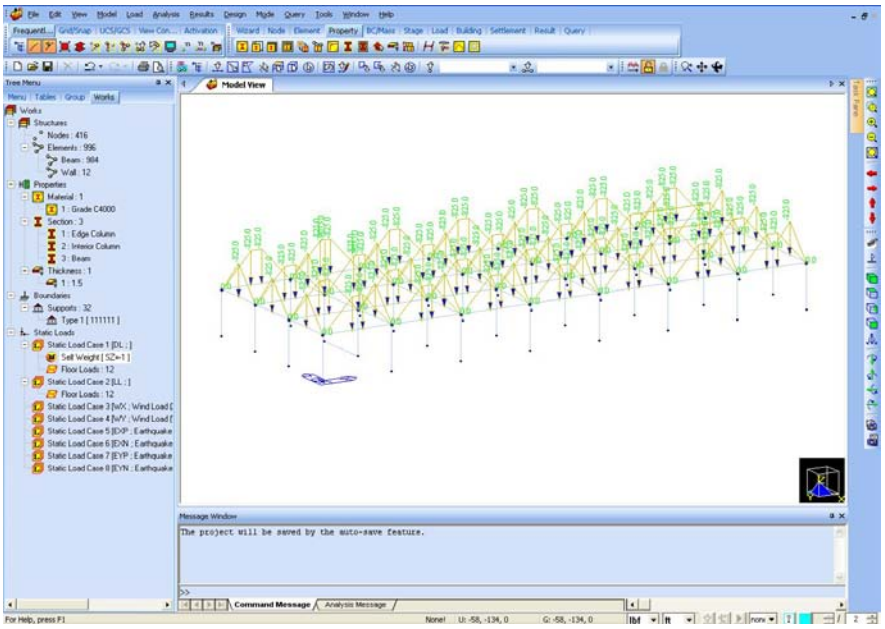


Figure 19 : Floor Load Distribution

Wind Loads

Load > Lateral Loads > Wind Loads

Add

- Load Case Name > WX
- Wind Load Code > IBC2000 (ASCE7-98)
- Simplified Procedure > (on)
- Basic Wind Speed > 85 mile/h
- Importance Factor > 1
- Exposure Category > B
- Scale Factor in Global X > 1
- Scale Factor in Global Y > 0

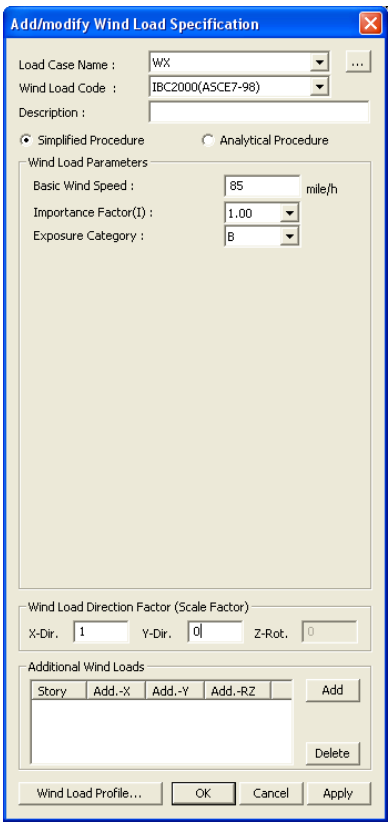
Apply

- Load Case Name > WY
- Scale Factor in Global X > 0
- Scale Factor in Global Y > 1

Apply

OK

Close



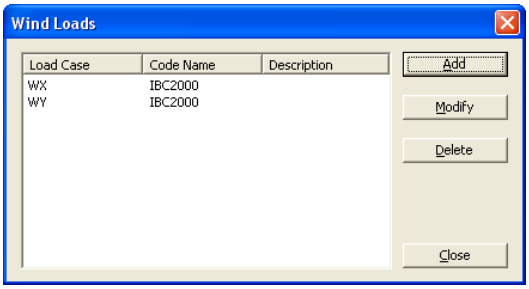


Figure 20 : Input Wind Loads

Convert Model Weight & Loads to Masses

Model > Structure Type
- Structure Type > 3-D (on)
- Convert to X, Y (on)
- Gravity Acceleration > 32.1719 (ft/sec^2)

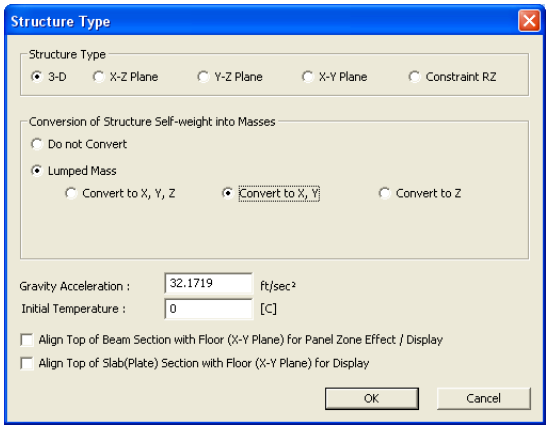


Figure 21 : Convert Model Weight to Masses

Model > Masses > Loads to Masses
- Mass Direction > X, Y (on)
- Load Type for Converting > *All* (on)
- Gravity > 32.1719 (ft/sec^2)
- Load Case > DL
- Scale Factor > 1

  Add
- Load Case > LL
- Scale Factor > 0.25

  Add OK

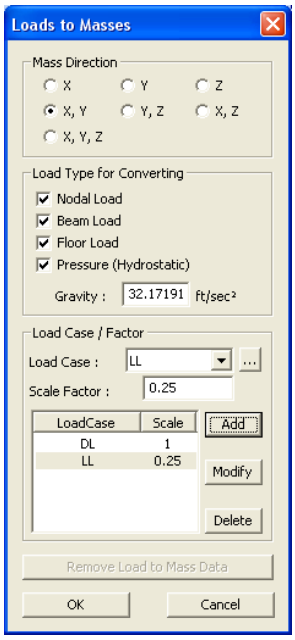


Figure 22 : Covert Model Loads to Masses

Static Seismic Loads

Load > Lateral Loads > Static Seismic Loads

Add

- Load Case Name > EXP
- Seismic Load Code > IBC2000 (ASCE7-98)
- Seismic Design Category > E
- Site Class > C
- Ss = 1.0
- S1 = 0.3
- Importance Factor (I) = 1
- Period (Code) > X-Dir. = 1.2 ; Y-Dir. = 0
- Response Modification Coef. (R) > X-Dir. = 8 (Special moment frame), Y-Dir. = 8 (Dual system: special reinforced concrete structural walls with special moment frame)
- Scale Factor in Global X = 1
- Scale Factor in Global Y = 0
- Accidental Eccentricity in X-direction > Positive (on)
- Accidental Eccentricity in Y-direction > Positive (on)

Apply

- Load Case Name > EXN
- Period (Code) > X-Dir. = 1.2 ; Y-Dir. = 0
- Scale Factor in Global X = 1
- Scale Factor in Global Y = 0
- Accidental Eccentricity in X-direction > Negative (on)
- Accidental Eccentricity in Y-direction > Negative (on)

Apply

- Load Case Name > EYP
- Period (Code) > X-Dir. = 0 ; Y-Dir. = 1.2
- Scale Factor in Global X = 0
- Scale Factor in Global Y = 1
- Accidental Eccentricity in X-direction > Positive (on)
- Accidental Eccentricity in Y-direction > Positive (on)

Apply

- Load Case Name > EYN
- Period (Code) > X-Dir. = 0 ; Y-Dir. = 1.2
- Scale Factor in Global X = 0
- Scale Factor in Global Y = 1
- Accidental Eccentricity in X-direction > Negative (on)
- Accidental Eccentricity in Y-direction > Negative (on)

OK

Close

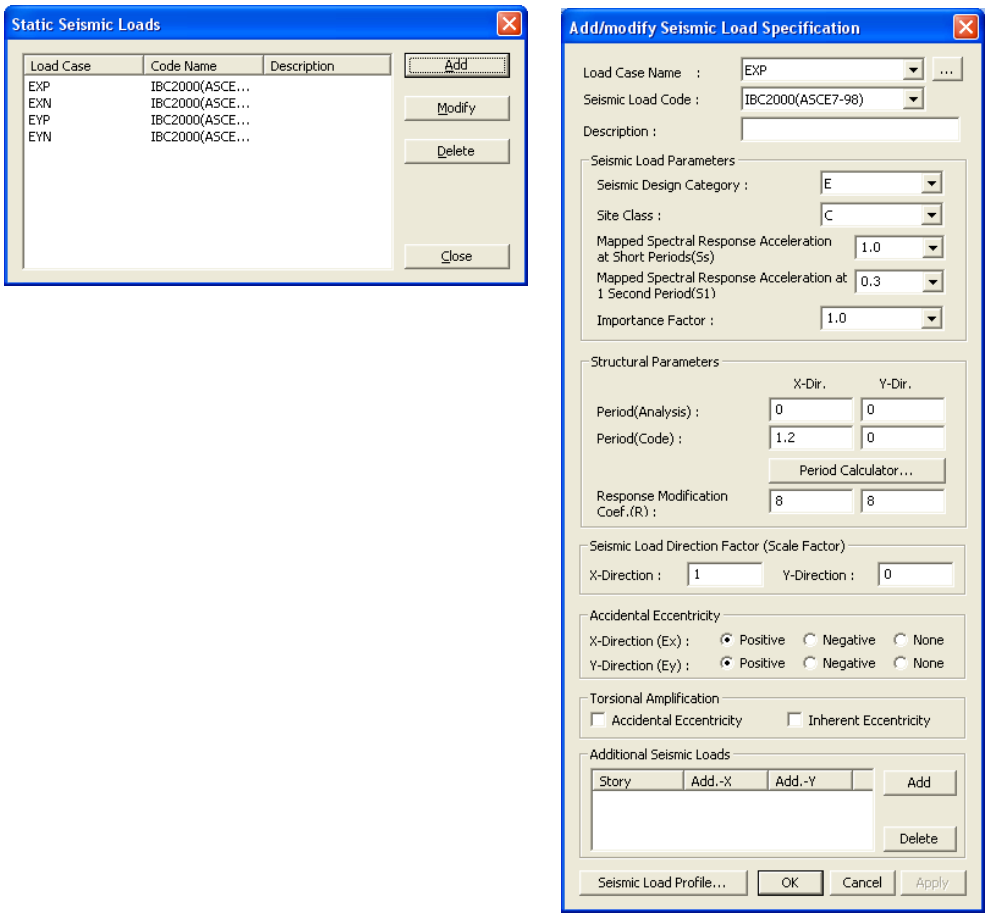


Figure 23 : Input Static Seismic Loads

Response Spectrum Load

Load > Response Spectrum Analysis Data > Response Spectrum Functions

Add

Design Spectrum

- Design Spectrum > IBC2000 (ASCE7-98)
- Site Class > C
- Ss = 1.0
- S1 = 0.3

OK

OK

Close

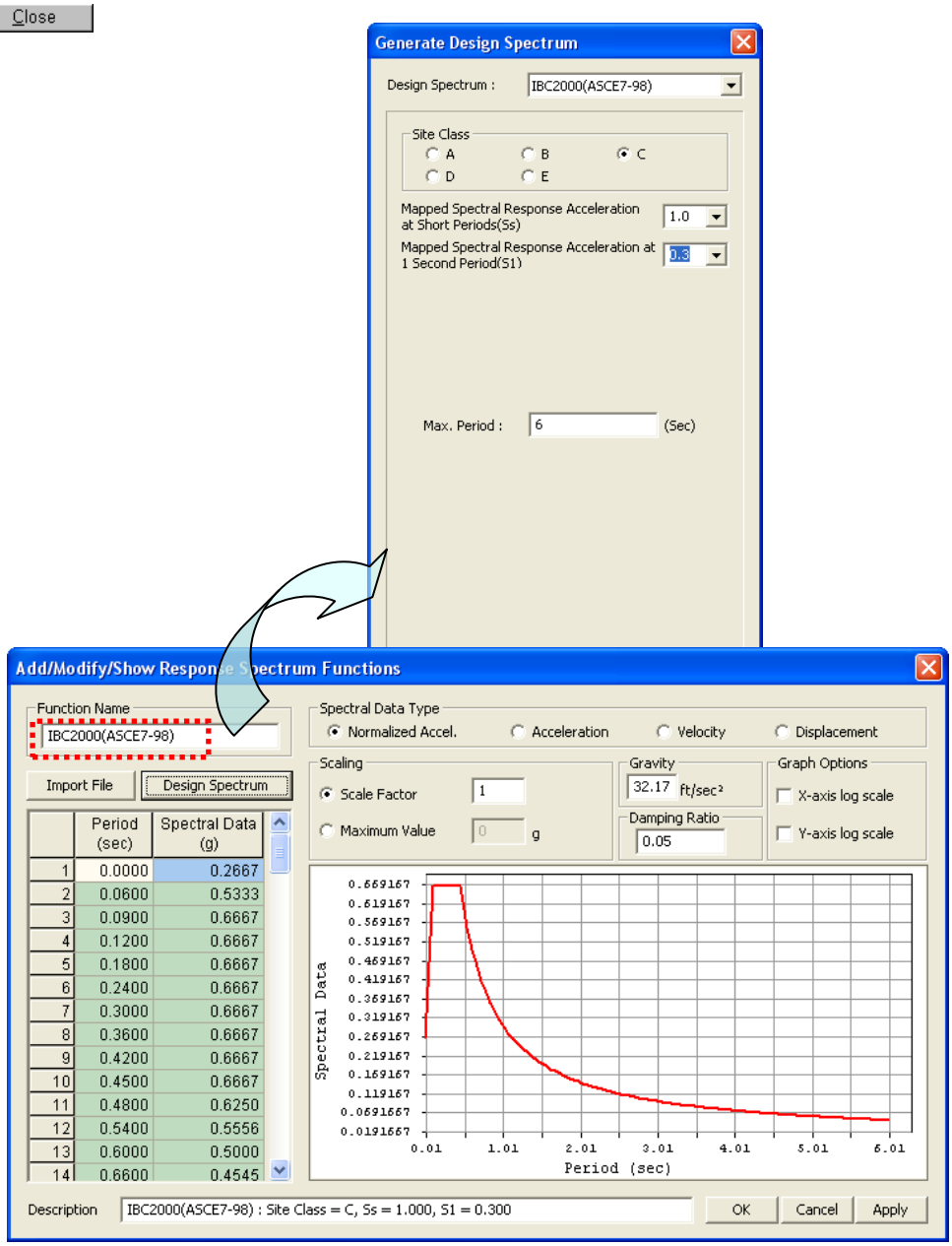


Figure 24 : Response Spectrum Loads

Load > Response Spectrum Analysis Data > Response Spectrum Load Cases

- Load Case Name > RX
- Direction > X-Y
- Excitation Angle = 0 (deg.)
- Scale Factor (I/R) > 1/8 = 0.125
- Period Modification Factor = 1
- Function Name (Damping Ratio) > IBC2000(ASCE7-98) (0.05) > (on)
- Interpolation of Spectral Data > Linear (on)
- Accidental Eccentricity > (on)
- Modal Combination Type > SRSS

Add

- Load Case Name > RY
- Excitation Angle = 90 (deg.)
- Modal Combination Type > SRSS

Close

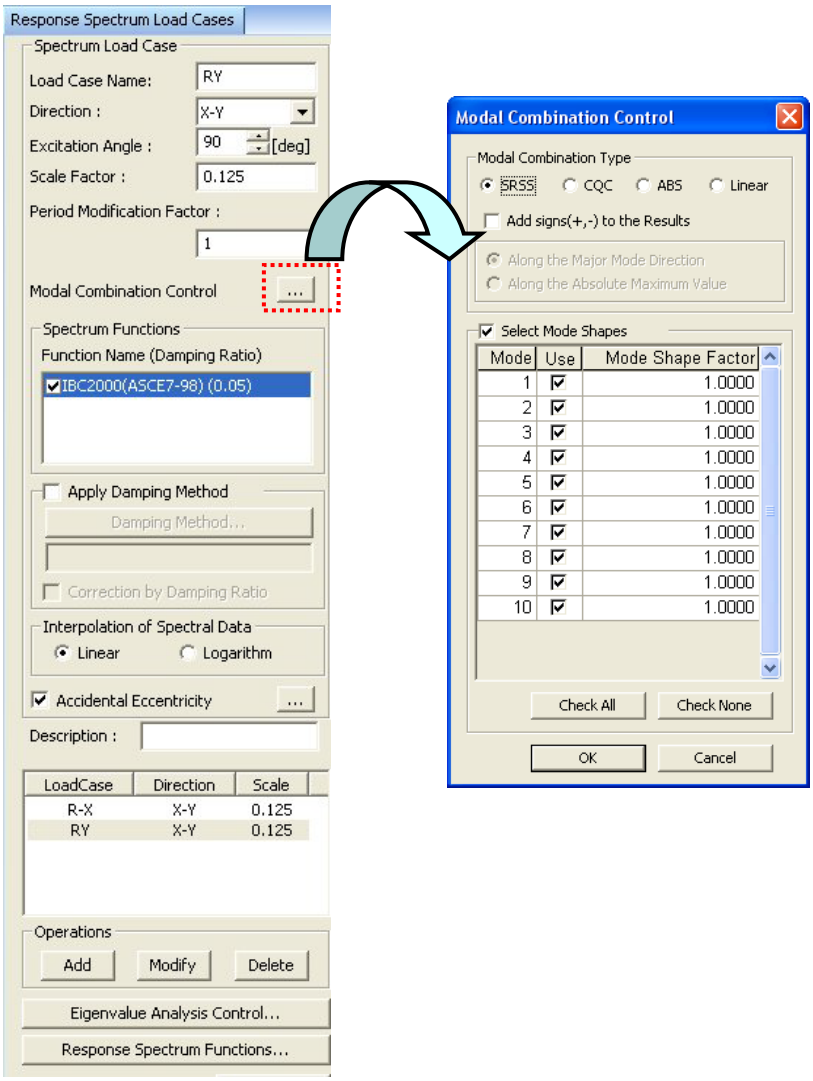


Figure 25 : Response Spectrum Analysis

5. Analysis

Analysis > P-Delta Analysis Control
- Number of Iterations = 5
- Convergence Tolerance = 1e-005
- P-Delta Combination > Load Case > DL ; Scale Factor > 1

  Add
- P-Delta Combination > Load Case > LL ; Scale Factor = 0.25

  Add

  OK

Analysis > Eigenvalue Analysis Control
- Type of Analysis > Eigen Vectors (on) > Subspace Iteration (on)
- Number of Frequencies = 10
- Number of Iterations = 20
- Subspace Dimension = 0
- Convergence Tolerance = 1e-010

  OK

Perform Analysis

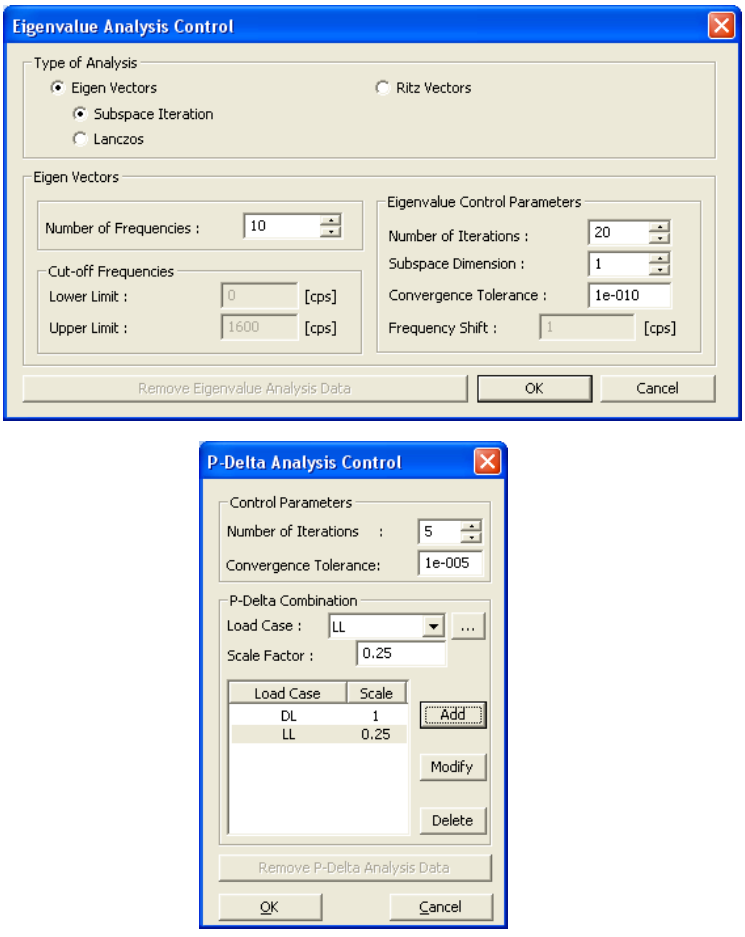


Figure 27 : P-Delta and Eigenvalue Analysis Control

6. Design Input

Results > Combinations

Concrete Design > Auto Generation

- Option > Add (on)
- Design Code > ACI318-02
- Scale Up Factor = 1.48 ; RX
- Scale Up Factor = 1 ; RY

Add

Add OK

Bi-directional combination needs to be investigated, but omitted in this tutorial.

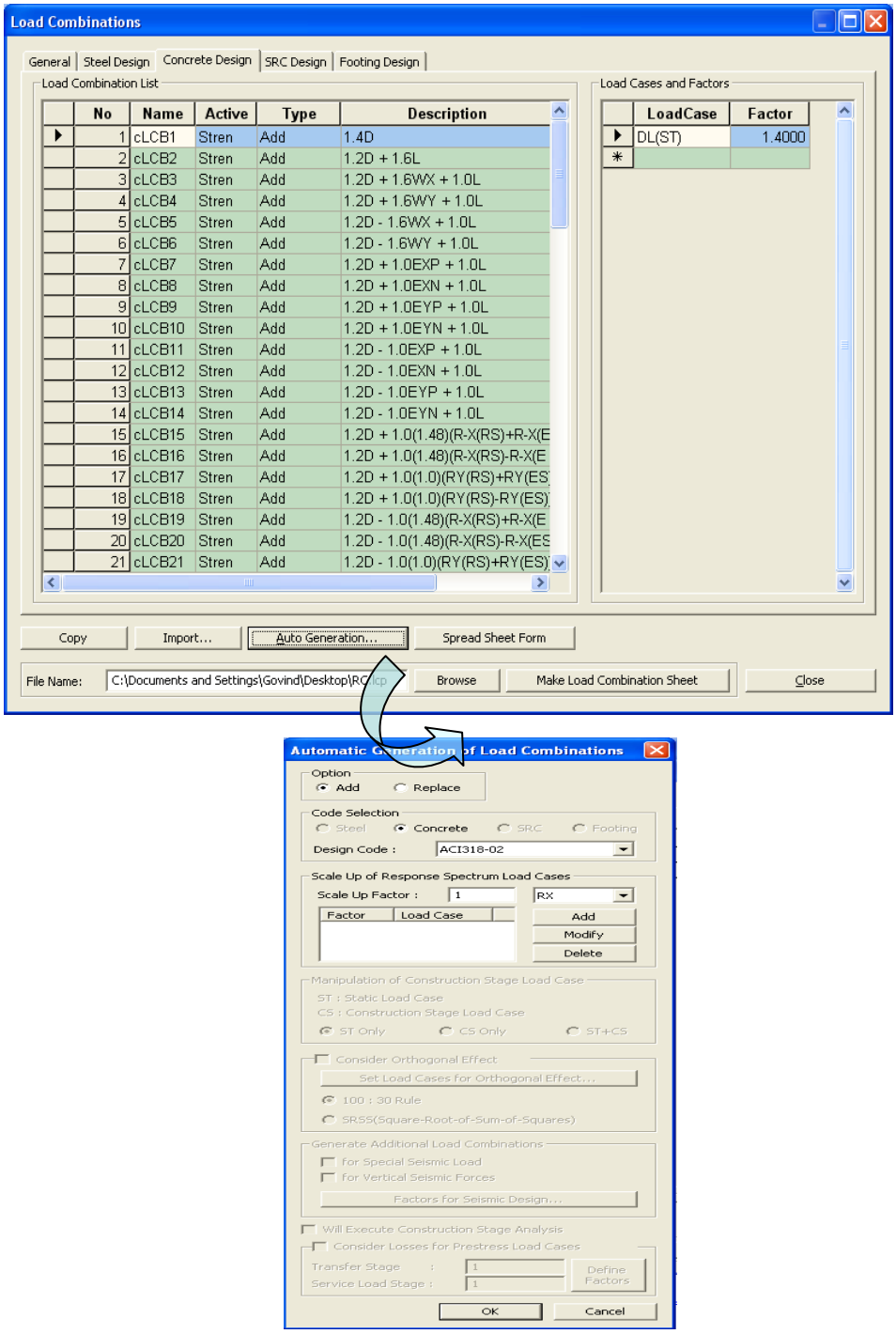


Figure 28 : Generation of Load Combinations for Concrete Design

Compare RX (RY) with EX (EY)

RX (RY):
Results > Result Tables > Story > Story Shear (Response Spectrum Analysis)
- Spectrum Load Cases > RX(RS) (on) & RY(RS) (on) OK
- Shear Force (Without Spring)

Story	Level (ft)	Spectrum	Inertia Force		Shear Force						Eccentricity (ft)	Story Force (lbf)	Eccentric Moment (ft-lbf)
					Spring Reactions		Without Spring		With Spring				
			X (lbf)	Y (lbf)	X (lbf)	Y (lbf)	X (lbf)	Y (lbf)	X (lbf)	Y (lbf)			
Roof	148,0000	RX(RS)	5,1709e+004	0,0000e+000	0,0000e+000	0,0000e+000	0,000000e+00	0,000000e+00	0,0000e+000	0,0000e+000	3,3000e+000	5,1709e+004	1,7064e+005
Roof	148,0000	RY(RS)	1,0606e−005	8,2332e+004	0,0000e+000	0,0000e+000	0,000000e+00	0,000000e+00	0,0000e+000	0,0000e+000	9,1000e+000	8,2332e+004	7,4922e+005
12F	136,0000	RX(RS)	6,6489e+004	0,0000e+000	0,0000e+000	0,0000e+000	5,170940e+00	0,000000e+00	5,1709e+004	0,0000e+000	3,3000e+000	6,6489e+004	2,1941e+005
12F	136,0000	RY(RS)	1,3637e−005	1,0413e+005	0,0000e+000	0,0000e+000	1,060578e−00	8,233237e+00	1,0606e−005	8,2332e+004	9,1000e+000	1,0413e+005	9,4760e+005
11F	124,0000	RX(RS)	5,7482e+004	0,0000e+000	0,0000e+000	0,0000e+000	1,159338e+00	0,000000e+00	1,1593e+005	0,0000e+000	3,3000e+000	5,7482e+004	1,8969e+005
11F	124,0000	RY(RS)	1,1790e−005	7,9195e+004	0,0000e+000	0,0000e+000	2,377843e−00	1,858519e+00	2,3778e−005	1,8585e+005	9,1000e+000	7,9195e+004	7,2067e+005
10F	112,0000	RX(RS)	5,3392e+004	0,0000e+000	0,0000e+000	0,0000e+000	1,634063e+00	0,000000e+00	1,6341e+005	0,0000e+000	3,3000e+000	5,3392e+004	1,7619e+005
10F	112,0000	RY(RS)	1,0951e−005	6,5364e+004	0,0000e+000	0,0000e+000	3,351521e−00	2,614140e+00	3,3515e−005	2,6141e+005	9,1000e+000	6,5364e+004	5,9482e+005
9F	100,0000	RX(RS)	5,3730e+004	0,0000e+000	0,0000e+000	0,0000e+000	1,993348e+00	0,000000e+00	1,9933e+005	0,0000e+000	3,3000e+000	5,3730e+004	1,7731e+005
9F	100,0000	RY(RS)	1,1020e−005	6,6553e+004	0,0000e+000	0,0000e+000	4,088426e−00	3,139025e+00	4,0884e−005	3,1390e+005	9,1000e+000	6,6553e+004	6,0563e+005
8F	88,0000	RX(RS)	5,4505e+004	0,0000e+000	0,0000e+000	0,0000e+000	2,273778e+00	0,000000e+00	2,2738e+005	0,0000e+000	3,3000e+000	5,4505e+004	1,7987e+005
8F	88,0000	RY(RS)	1,1179e−005	7,5427e+004	0,0000e+000	0,0000e+000	4,663599e−00	3,515358e+00	4,6636e−005	3,5154e+005	9,1000e+000	7,5427e+004	6,8638e+005
7F	76,0000	RX(RS)	5,6120e+004	0,0000e+000	0,0000e+000	0,0000e+000	2,509605e+00	0,000000e+00	2,5096e+005	0,0000e+000	3,3000e+000	5,6120e+004	1,8520e+005
7F	76,0000	RY(RS)	1,1510e−005	8,2318e+004	0,0000e+000	0,0000e+000	5,147287e−00	3,840497e+00	5,1473e−005	3,8405e+005	9,1000e+000	8,2318e+004	7,4909e+005
6F	64,0000	RX(RS)	5,7092e+004	0,0000e+000	0,0000e+000	0,0000e+000	2,720390e+00	0,000000e+00	2,7204e+005	0,0000e+000	3,3000e+000	5,7092e+004	1,8840e+005
6F	64,0000	RY(RS)	1,1710e−005	8,2208e+004	0,0000e+000	0,0000e+000	5,579614e−00	4,189556e+00	5,5796e−005	4,1896e+005	9,1000e+000	8,2208e+004	7,4809e+005
5F	52,0000	RX(RS)	5,8322e+004	0,0000e+000	0,0000e+000	0,0000e+000	2,923029e+00	0,000000e+00	2,9230e+005	0,0000e+000	3,3000e+000	5,8322e+004	1,9246e+005
5F	52,0000	RY(RS)	1,1962e−005	7,3775e+004	0,0000e+000	0,0000e+000	5,995235e−00	4,581744e+00	5,9952e−005	4,5817e+005	9,1000e+000	7,3775e+004	6,7135e+005
4F	40,0000	RX(RS)	5,7401e+004	0,0000e+000	0,0000e+000	0,0000e+000	3,125463e+00	0,000000e+00	3,1255e+005	0,0000e+000	3,3000e+000	5,7401e+004	1,8942e+005
4F	40,0000	RY(RS)	1,1773e−005	5,8127e+004	0,0000e+000	0,0000e+000	6,410434e−00	4,979936e+00	6,4104e−005	4,9799e+005	9,1000e+000	5,8127e+004	5,2895e+005
3F	28,0000	RX(RS)	5,3145e+004	0,0000e+000	0,0000e+000	0,0000e+000	3,331439e+00	0,000000e+00	3,3314e+005	0,0000e+000	3,3000e+000	5,3145e+004	1,7538e+005
3F	28,0000	RY(RS)	1,0900e−005	3,8144e+004	0,0000e+000	0,0000e+000	6,832897e−00	5,321972e+00	6,8329e−005	5,3220e+005	9,1000e+000	3,8144e+004	3,4711e+005
2F	16,0000	RX(RS)	3,9772e+004	0,0000e+000	0,0000e+000	0,0000e+000	3,522904e+00	0,000000e+00	3,5229e+005	0,0000e+000	3,3000e+000	3,9772e+004	1,3125e+005
2F	16,0000	RY(RS)	8,1573e−006	1,8738e+004	0,0000e+000	0,0000e+000	7,225598e−00	5,556890e+00	7,2256e−005	5,5569e+005	9,1000e+000	1,8738e+004	1,7051e+005
1F	−0,0000	RX(RS)	0,0000e+000	0,0000e+000	0,0000e+000	0,0000e+000	3,665208e+00	0,000000e+00	3,6652e+005	0,0000e+000	0,0000e+000	0,0000e+000	0,0000e+000
1F	−0,0000	RY(RS)	0,0000e+000	0,0000e+000	0,0000e+000	0,0000e+000	7,517468e−00	5,673308e+00	7,5175e−005	5,6733e+005	0,0000e+000	0,0000e+000	0,0000e+000

Figure 29 : Story Shear (Response Spectrum Analysis)

EX (EY):
Load > Lateral Loads > Static Seismic Loads
Load Case > EXP > Modify > Seismic Load Profile
- Story Shear (on)

Similarly, select Load Cases EXN, EYP & EYN

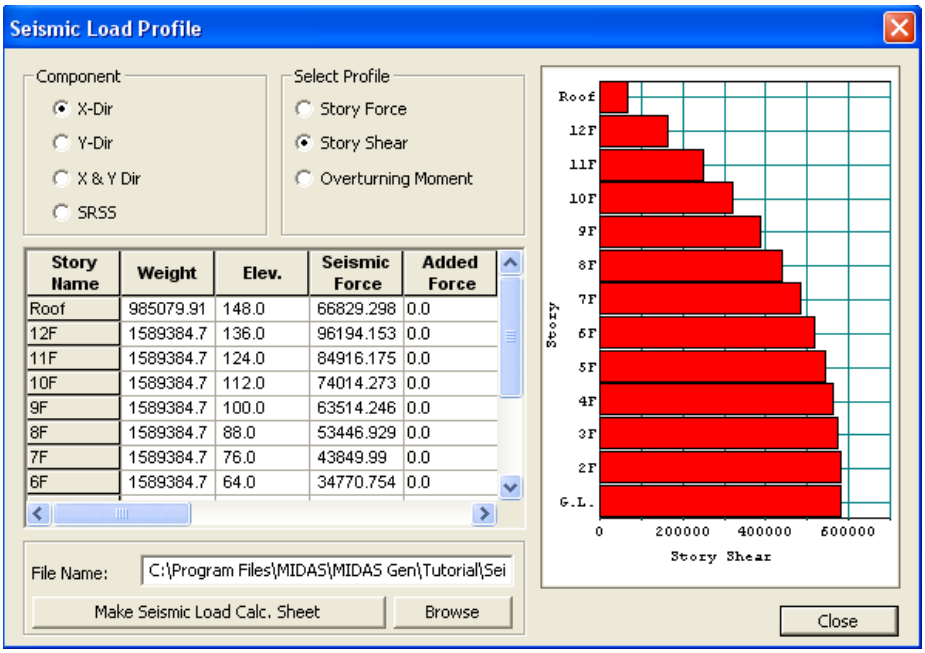


Figure 30 : Story Shear (Static Seismic Loads)

Design > General Design Parameter >Definition of Frame
- X-direction > Unbraced | Sway (on)
- Y-direction > Braced | Non-Sway (on)
- Design Type > 3-D
- Auto Calculate Effective Length Factors > (on)

OK

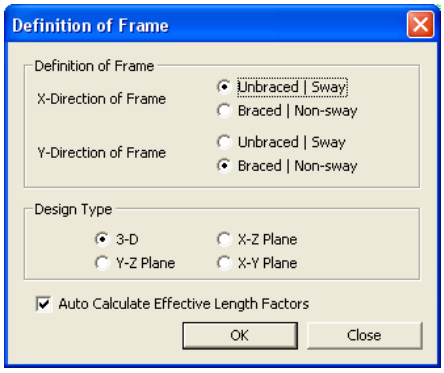


Figure 31 : Definition of Frame

Design > General Design Parameter > Modify Live Load Reduction Factor
General Tab

- Option > Add/Replace (on)
- Applied Components > Axial Force (on)
- Top View > Select Window

- Interior columns: Reduction Factor = 0.56

Apply

- Edge column: Reduction Factor = 0.69

Apply

- Corner column: Reduction Factor = 0.88

Apply

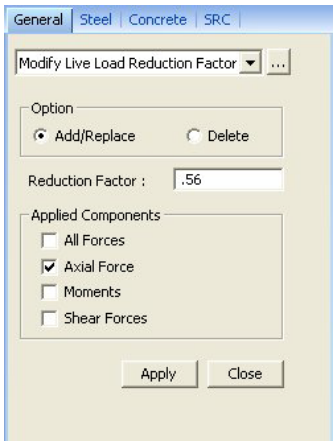


Figure 32 : Modify Live Load Reduction Factor

- Unbraced Length (L, Lb)
- Option > Add/Replace (on)
- Unbraced Length > Ly=0 ; Lx=0
- Laterally Unbraced Length > Do not consider (on)
- Select All

Apply

- Equivalent Moment Correction Factor (Cm)
- Option > Add/Replace (on)
- Moment Factor > Calculate by Program (on)
- Select All

Apply

Close

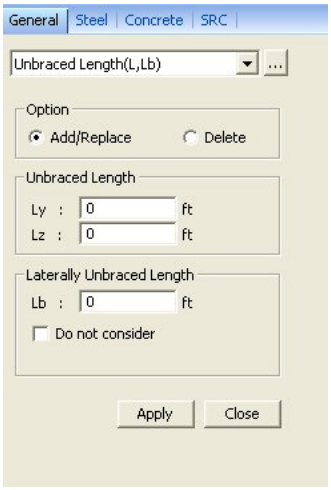


Figure 33 : Unbraced Length

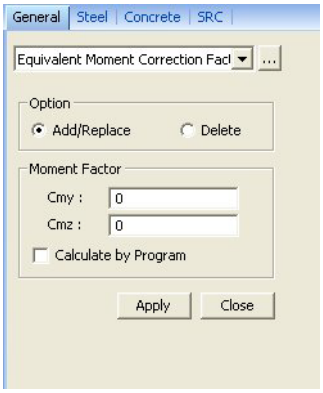


Figure 34 : Equivalent Moment Correction Factor

Design > Concrete Design Parameter > Design Code

- Design Code > ACI318-02
- Apply Special Provisions for Seismic Design > (on)
- Select Frame Type > Special Moment Frames (on)

OK

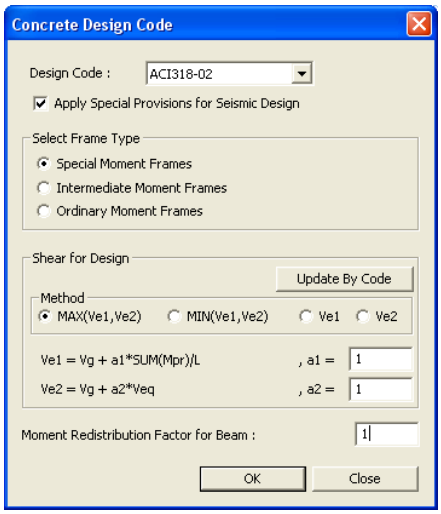


Figure 35 : Concrete Design Code

Design > Concrete Design Parameter > Strength Reduction Factors

- Update By Code

OK

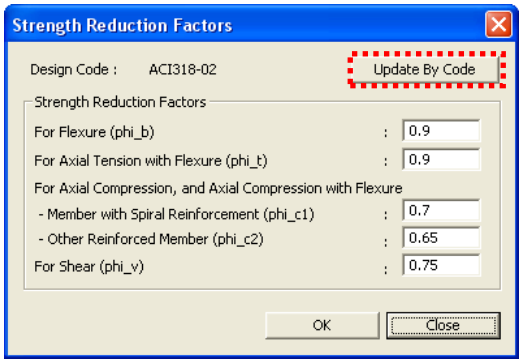


Figure 36 : Strength Reduction Factors

Design > Concrete Design Parameter > Design Criteria for Rebars (Refer Figure 37)

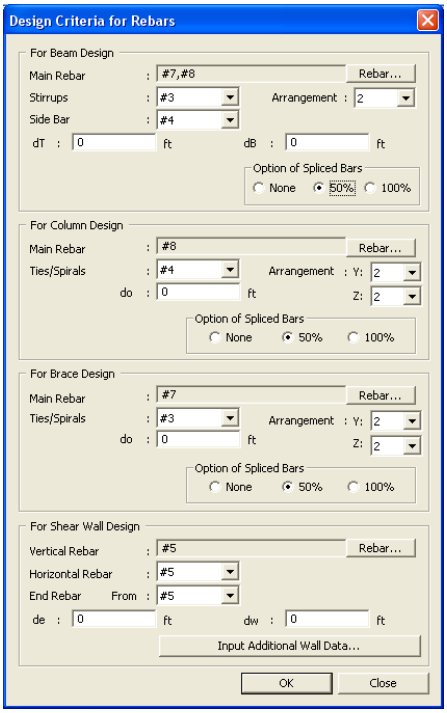


Figure 37 : Design Criteria for Rebars

Design > Concrete Design Parameter > Modify Concrete Materials

Select material ID #1
Rebar Selection
- Code > ASTM (RC)
- Grade of Main Rebar > Grade 60
- Grade of Sub-Rebar > Grade 40

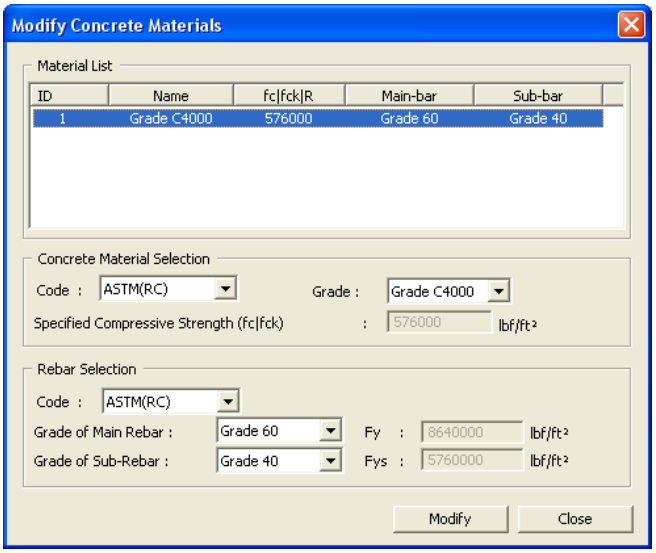


Figure 38 : Modify Concrete Materials

7. Design Output

Design > Concrete Code Design > Beam Design
Sorted by > Member (on) >>

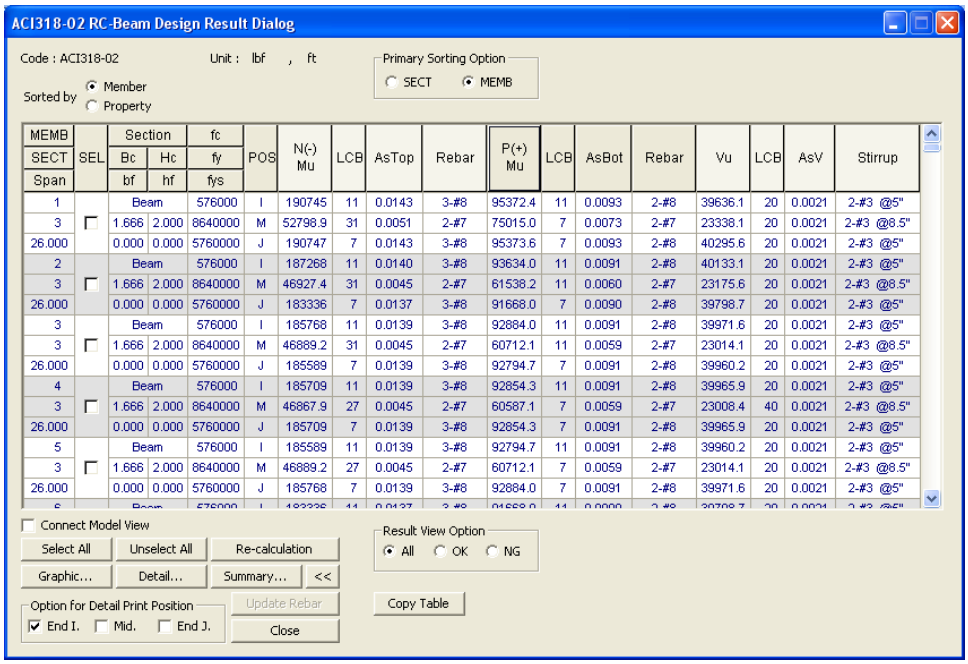


Figure 39 : Concrete Beam Design

Design > Concrete Code Design > Column Design
Sorted by > Member (on) >>

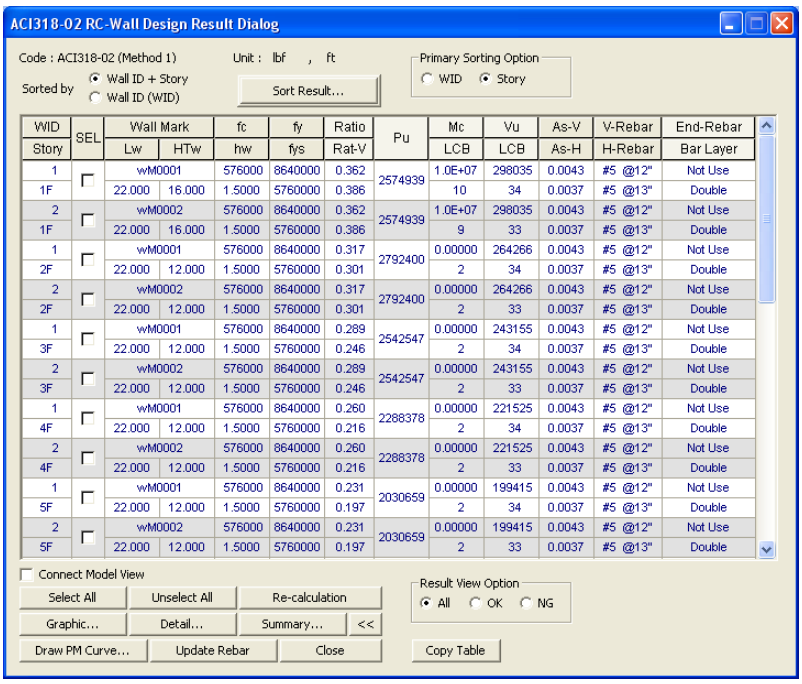


Figure 40 : Concrete Column Design

Design > Concrete Code Design > Wall Design
Sorted by > Wall ID + Story (on) >>
SEL (Select) > WID (Wall ID) = 1 ; Story = 1F
Graphic

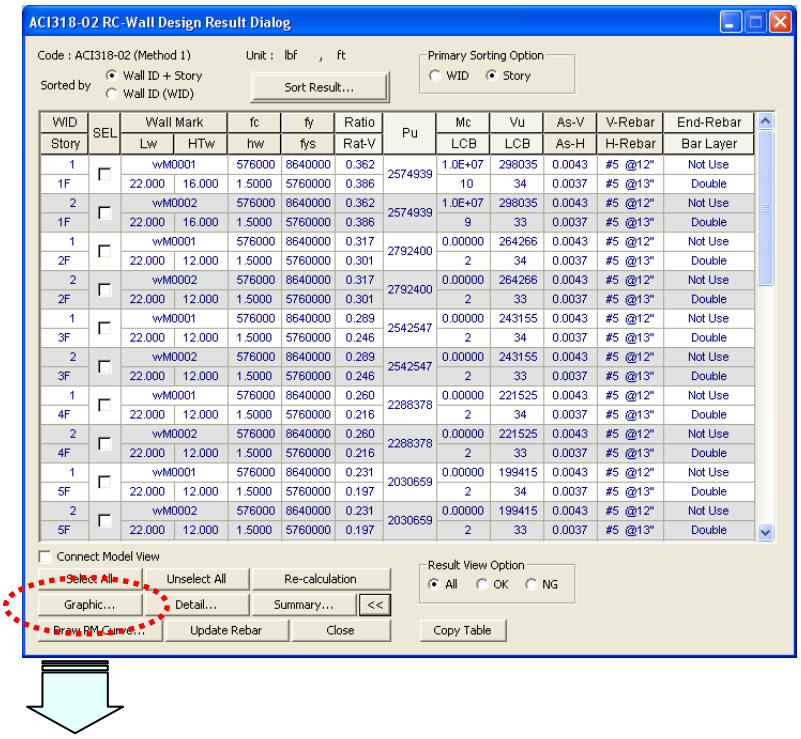


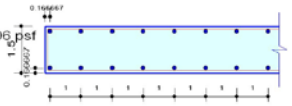
Figure 41 : Concrete Wall Design

MIDAS/Gen **RC Wall Design Result Output**

Company		Project Title	
Author	WAGLE	File Name	C:\...\Models\Seismic-RC-702.mgb

1. Design Condition

Design Code ACI318-02
Unit System lbf, ft
Wall ID 1 (Wall Mark : wM0001)
Story 1F (Height = 16 ft)
Material Data fc = 576000, fy = 8.64e+006, fys = 5.76e+006 psf
Wall Dim. (Length*Thk) 22*1.5 ft
Vertical Rebar : #5 @12" (AsV = 0.00431 ft²/ft)



2. Applied Loads

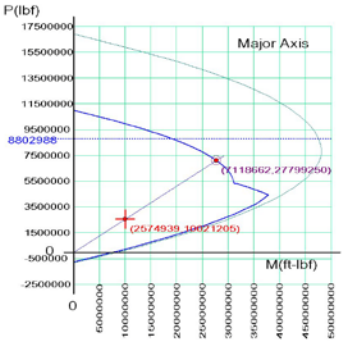
Load Combination 10
Pu = 2574939 lbf
Mcy = 10021205, Mcz = 0.00000 ft-lbf

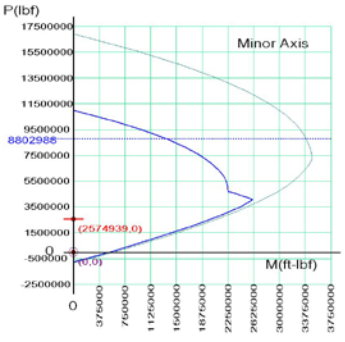
3. Axial Forces and Moments Capacity Check

Concentric Max. Axial Load PhiPn-max = 8802988 lbf
Major Axis
- Design Axial Load Strength PhiPny = 7118662 lbf
- Axial Ratio Pu/PhiPny = 0.362 < 1.000 ..... O.K
- Design Moment Strength PhiMny = 27799250 ft-lbf
- Moment Ratio Mcy/PhiMny = 0.360 < 1.000 ..... O.K

Minor Axis
- Design Axial Load Strength PhiPnz
- Axial Ratio Pu/PhiPnz = 0.000 < 1.000 ..... O.K
- Design Moment Strength PhiMnz
- Moment Ratio Mcz/PhiMnz = 0.000 < 1.000 ..... O.K

4. P-M Interaction Diagram





5. Shear Force Capacity Check

Applied Shear Strength Vu = 298035 lbf (Load Combination 34)
Design Shear Strength PhiVc+PhiVs = 482038 + 290987 = 773025 lbf (As-H_req = 0.00375 ft²/ft, #5 @13")
Shear Ratio Vu/PhiVn = 0.386 < 1.000 ..... O.K

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Figure 42 : Typical Output of Concrete Wall Design