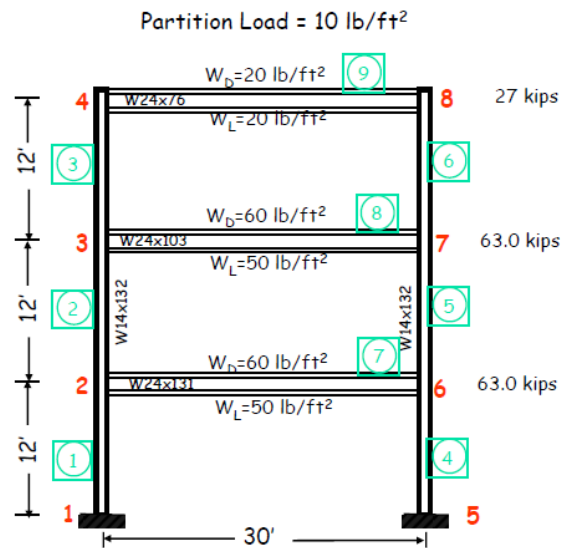


Using SAP2000 Software Package in Earthquake Engineering (Part I: Basics)

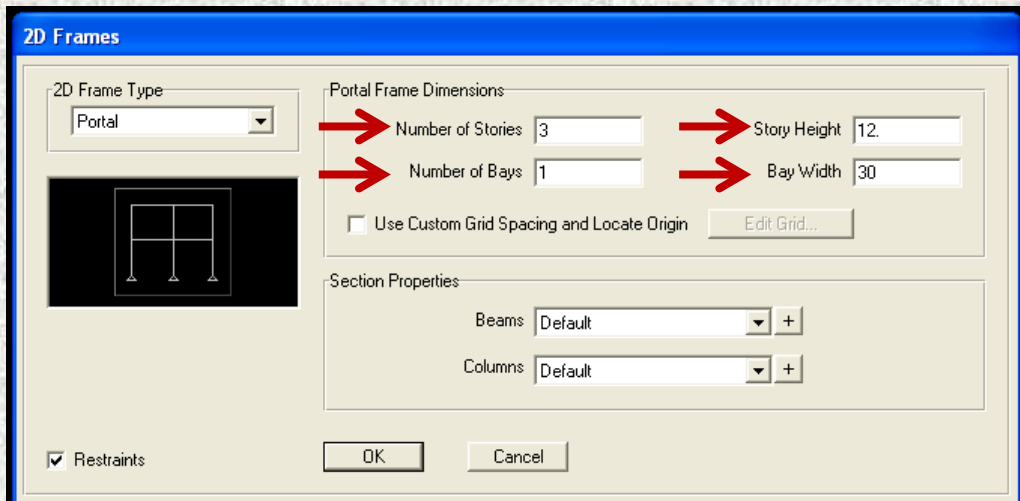
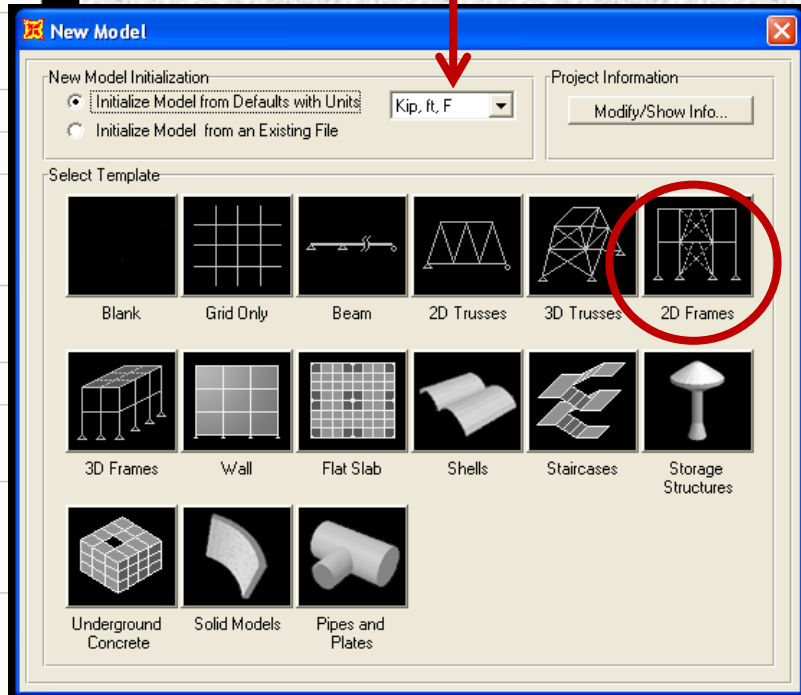
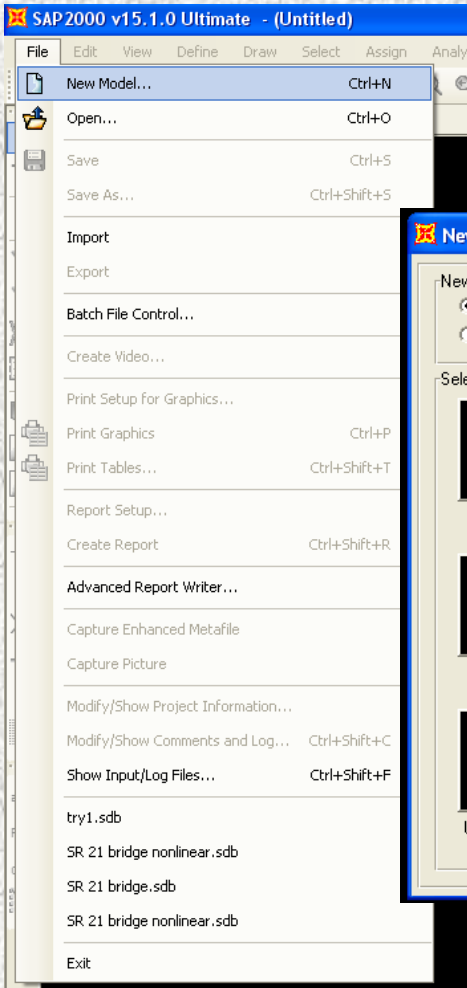
Example

Consider the Special Moment Resisting Frame shown below located in Memphis, Tennessee. This building is located in a soil with a weighted shear wave velocity of 650 ft/sec. This building is an office building and the frame shown below is a typical interior frame with a span of 30 ft between frames. Determine NEHRP lateral forces, check design considering various load combinations, determine drift, P-delta, etc.

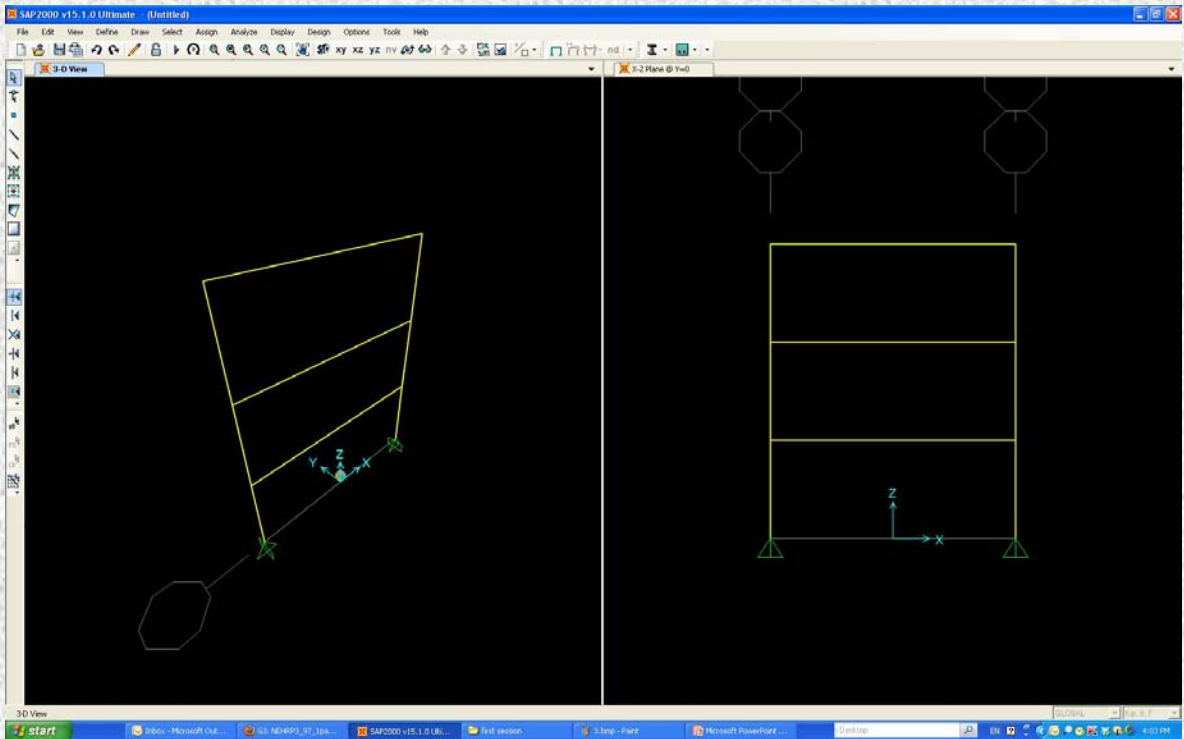
Use Seismic Use Group I, three bays, $r_{max} = 0.33$



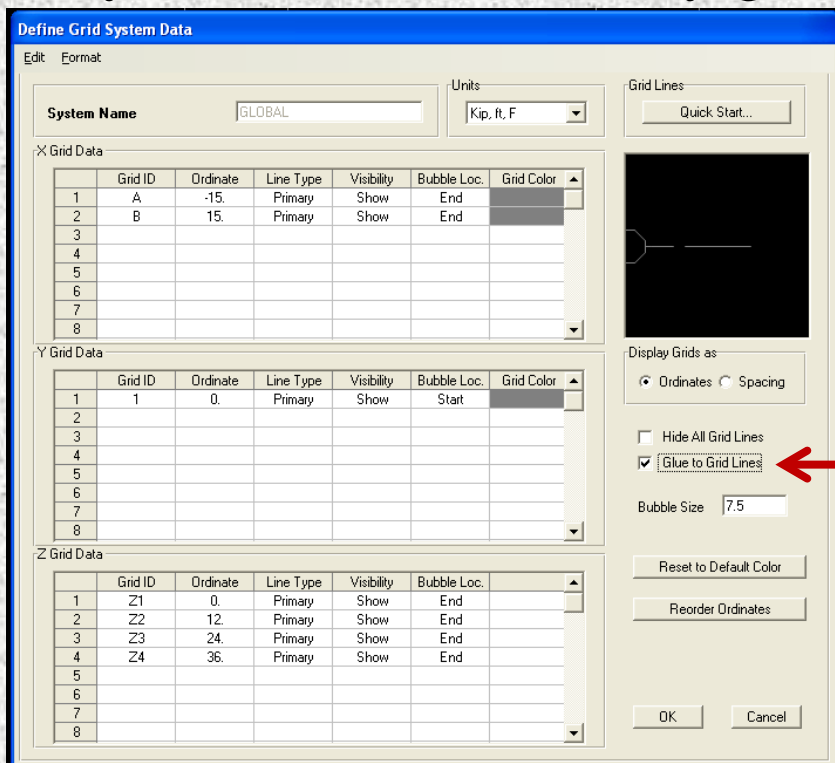
1- Geometry



1- Geometry

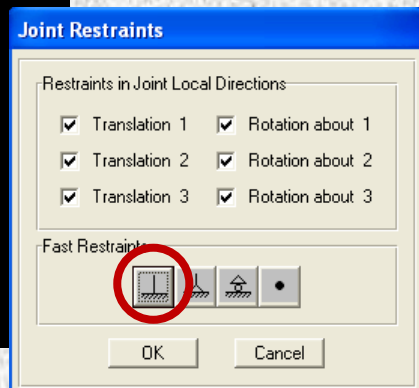
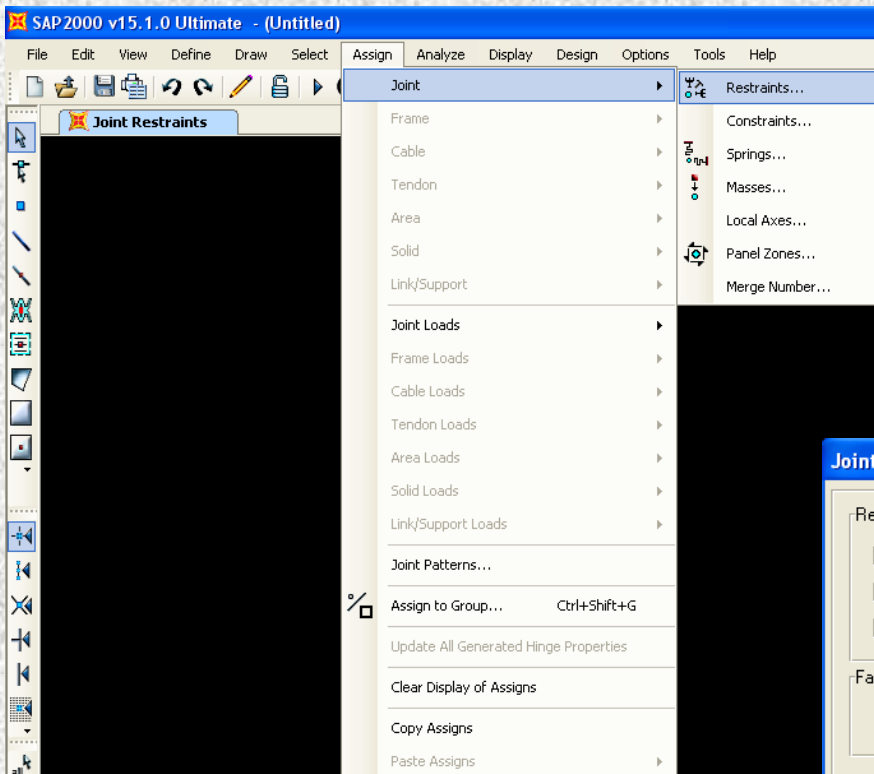
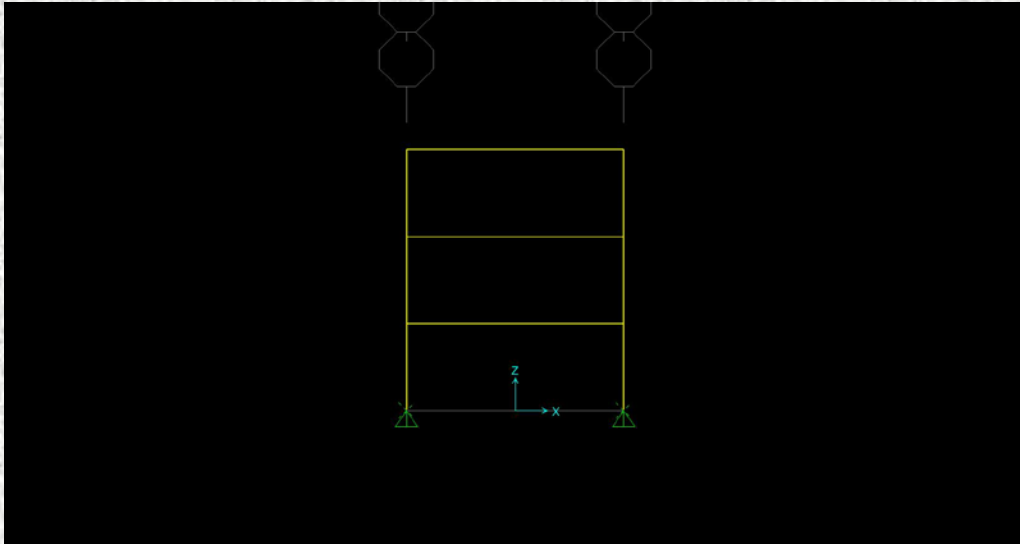


** To modify: double click on any grid line

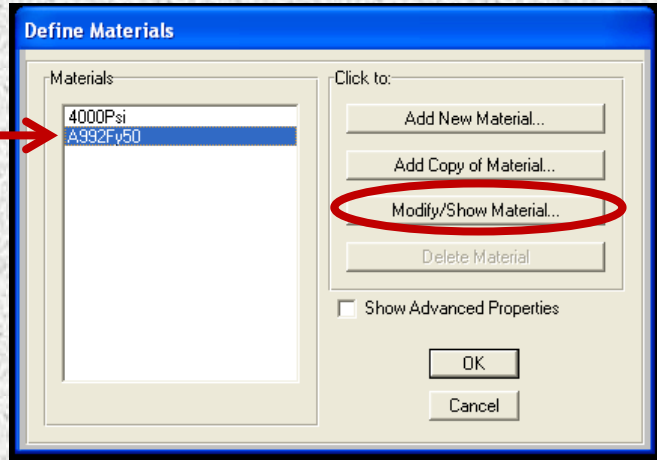
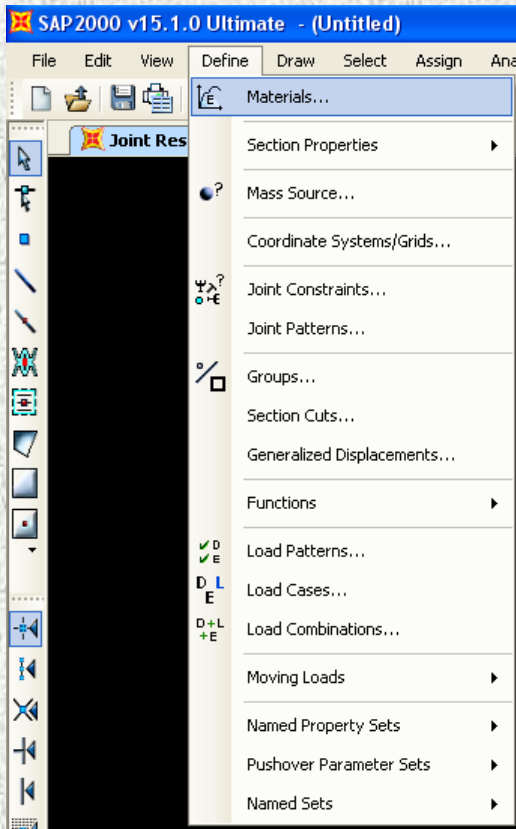


2- Fixities

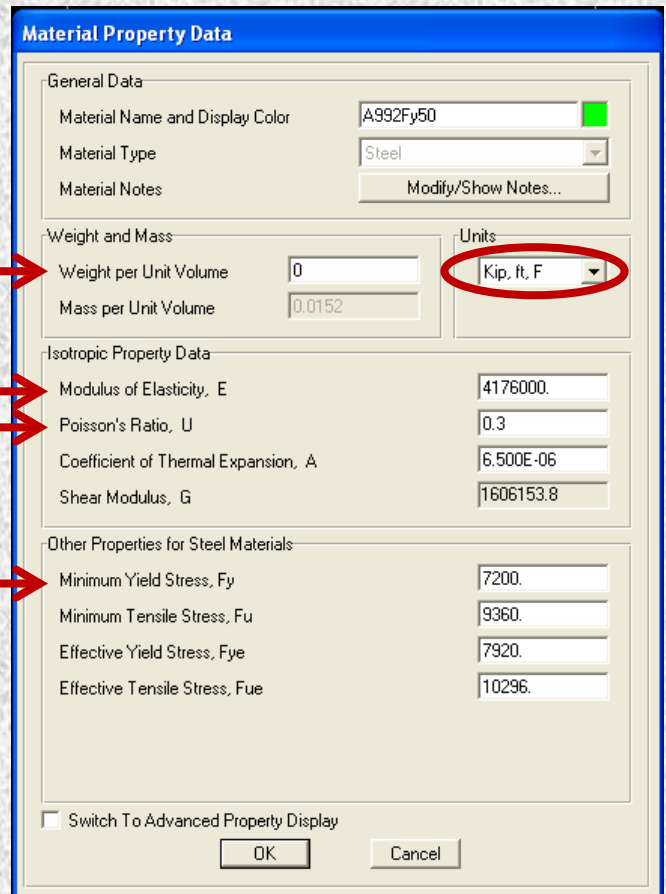
Select support nodes:



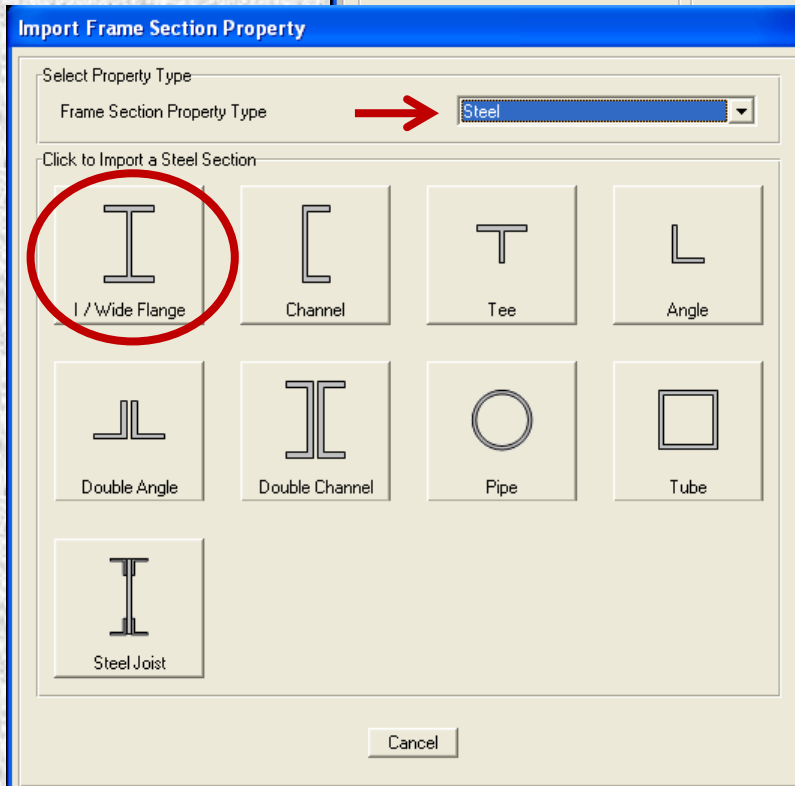
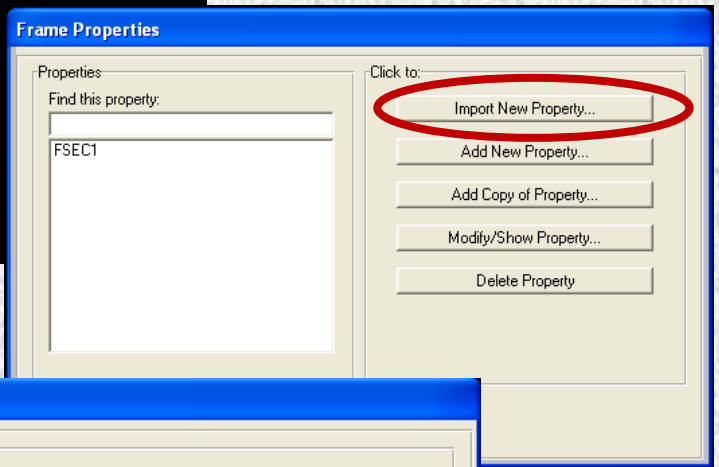
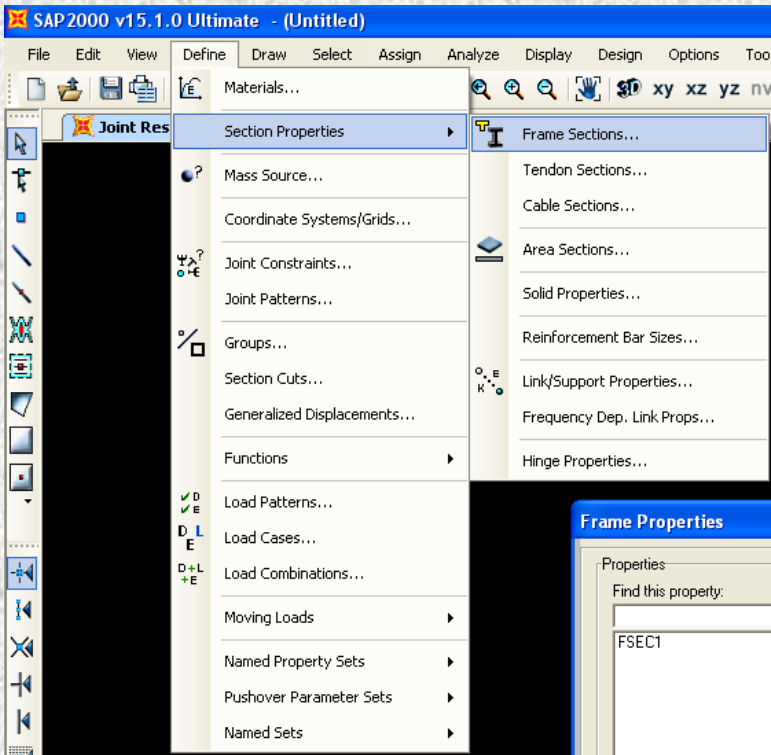
3- Define Materials



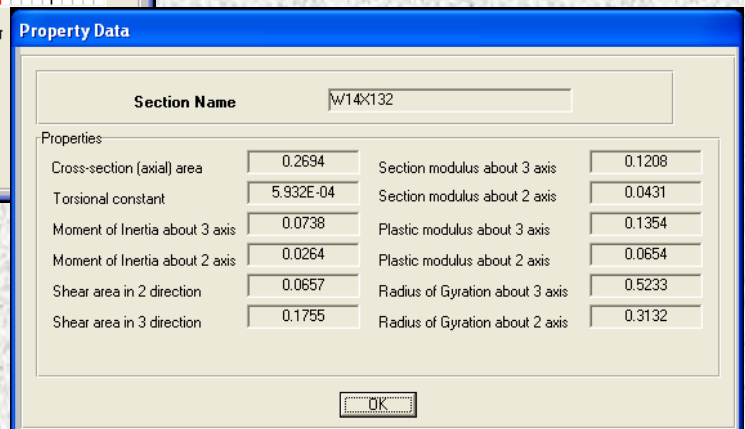
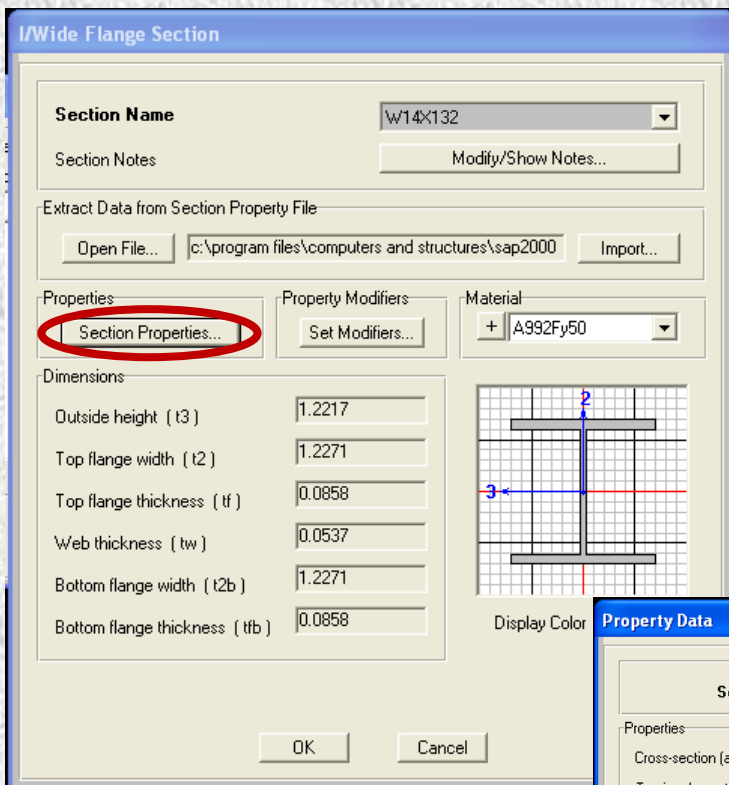
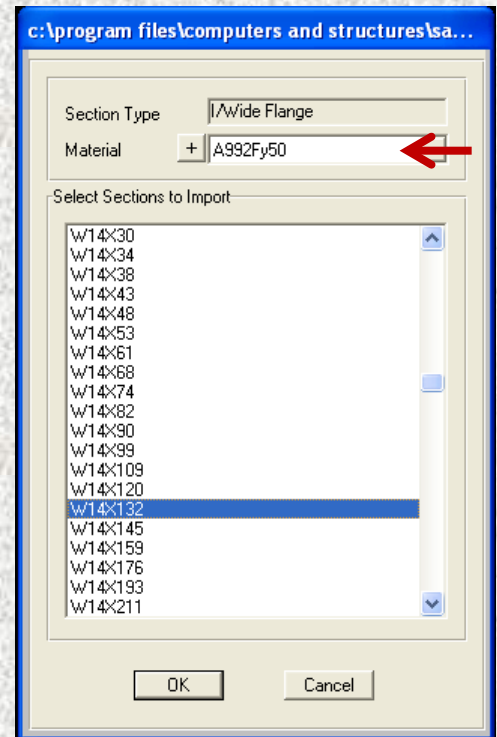
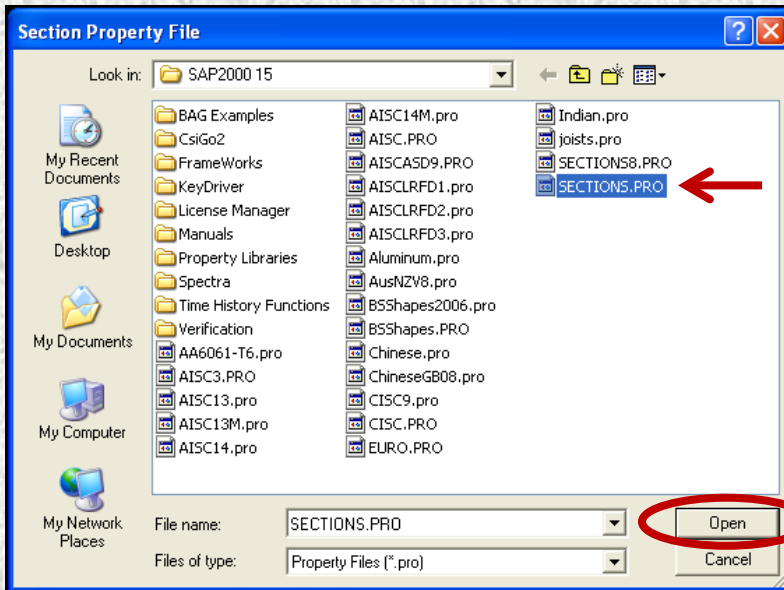
We choose to apply materials' self-weight as part of external dead loads.



4- Define Sections

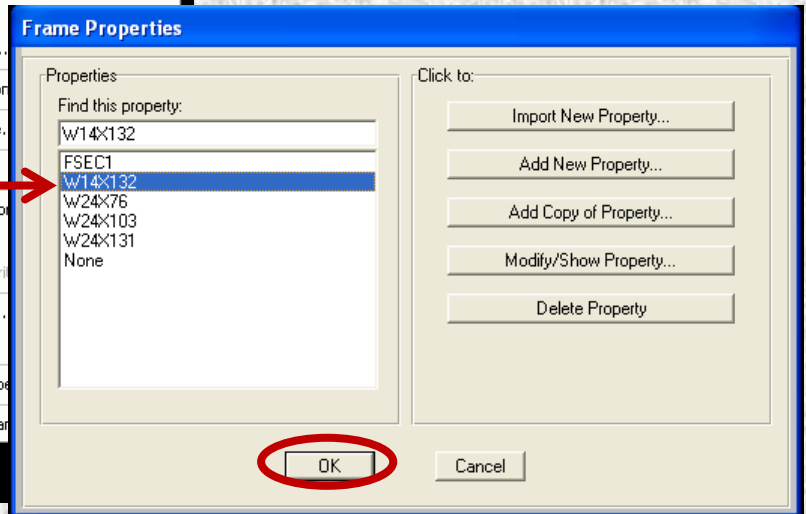
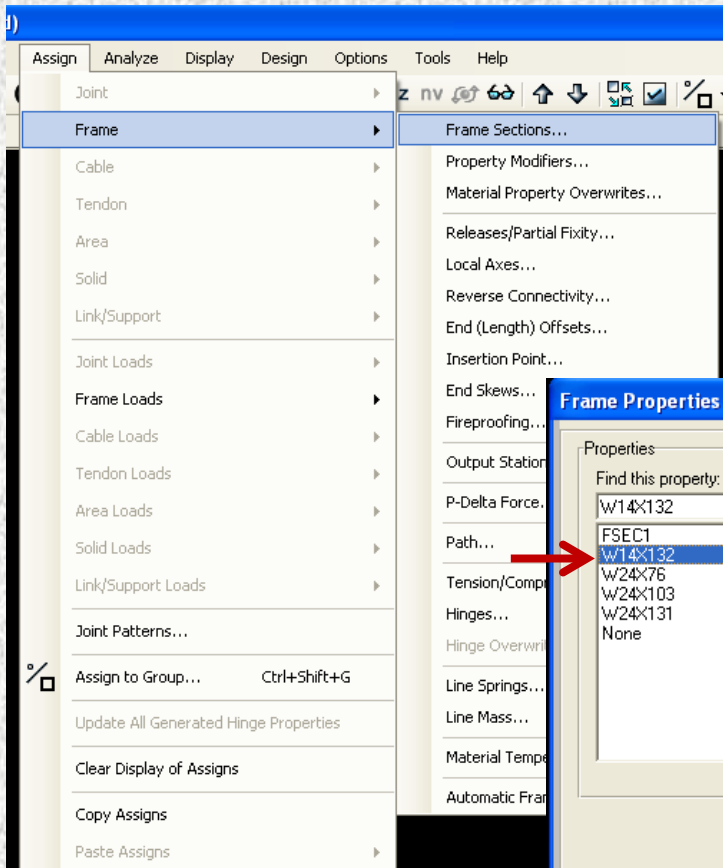
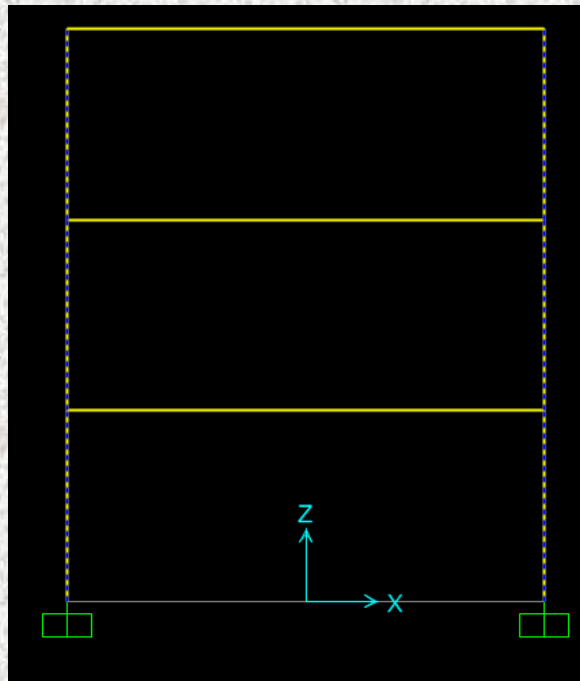


4- Define Sections

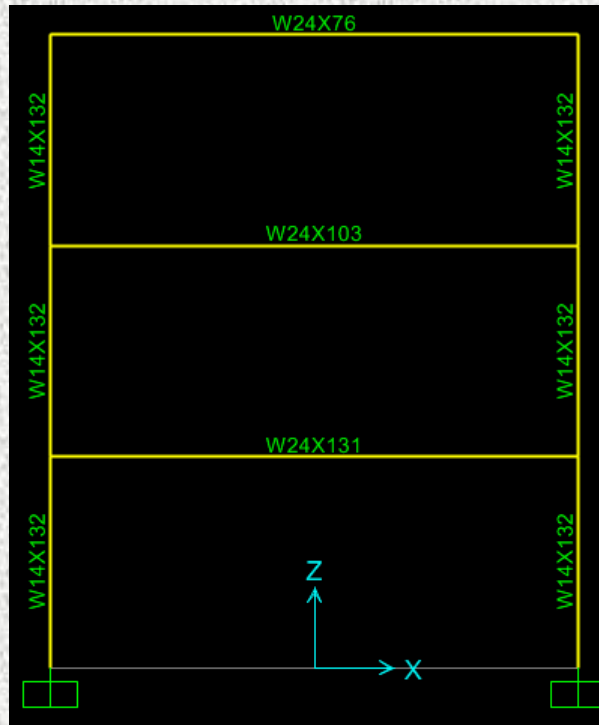


5- Assign Sections

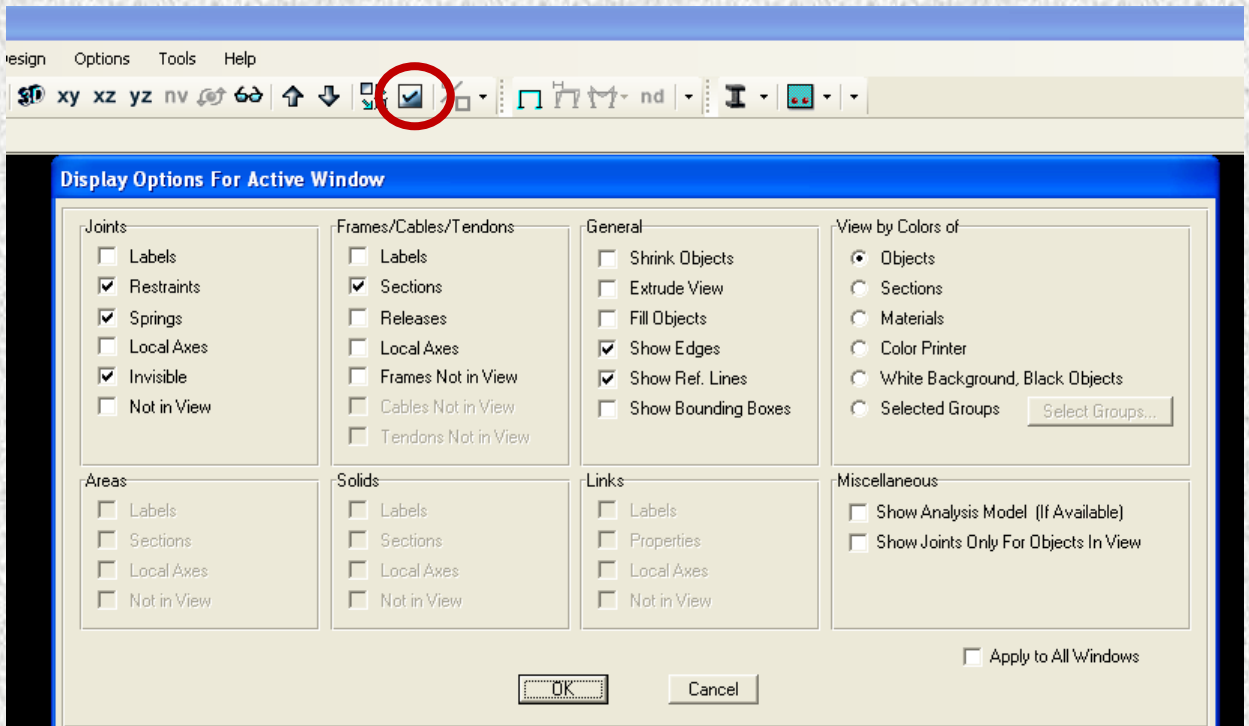
Select elements:



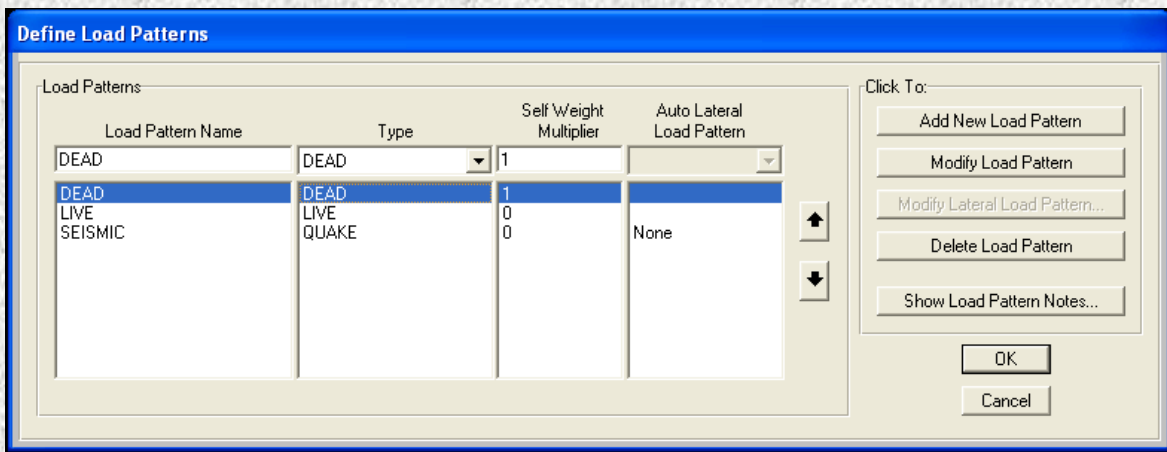
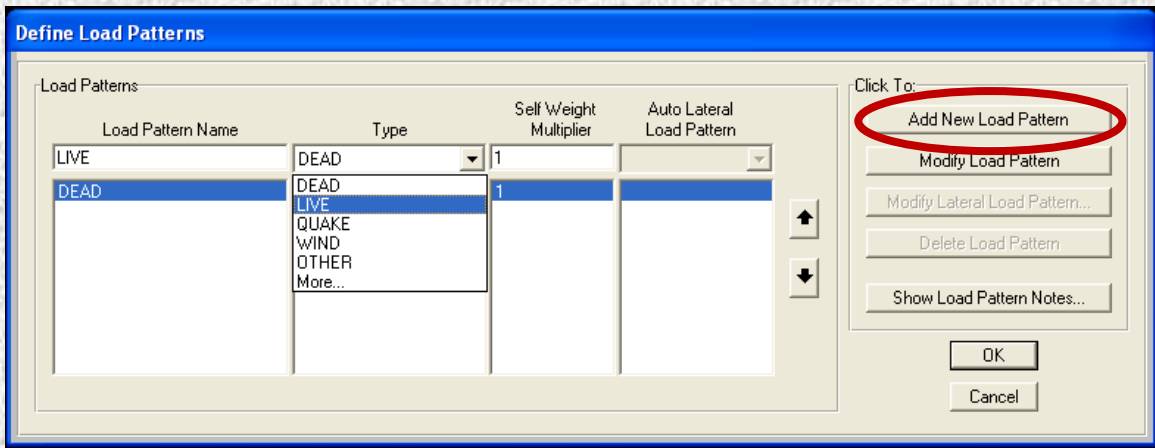
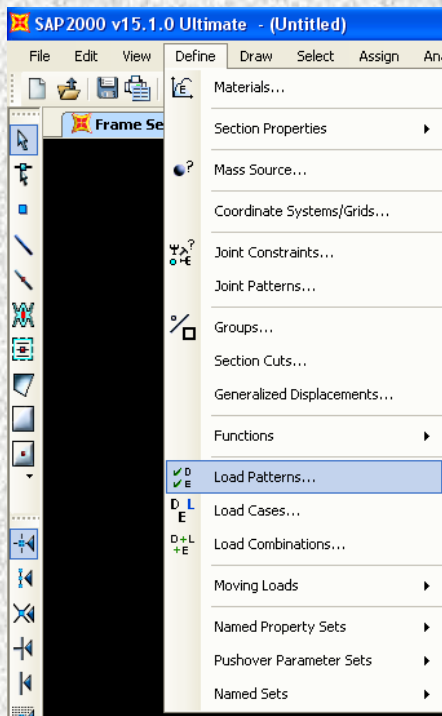
5- Assign Sections



**** Display Options:**

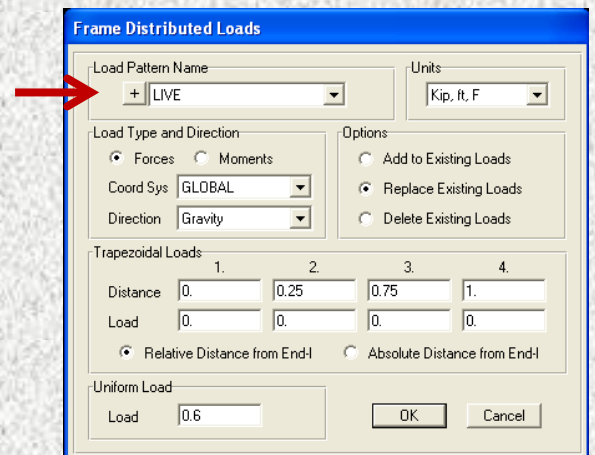
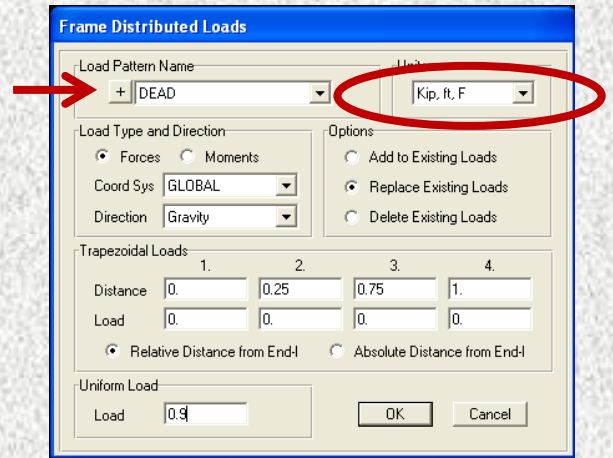
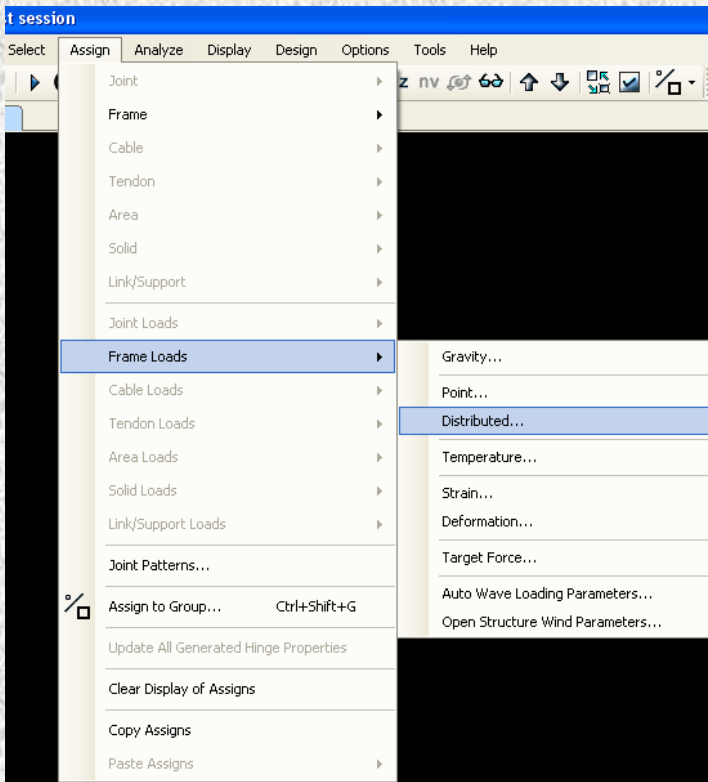
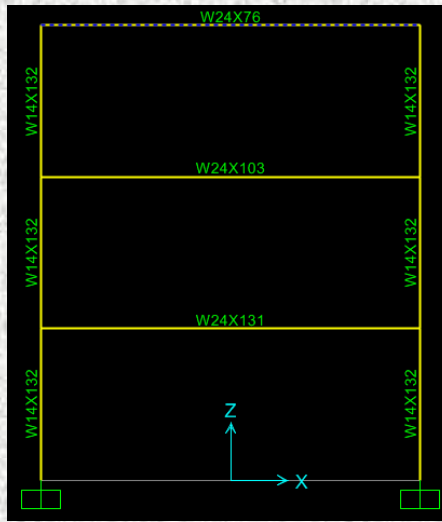


6- Define Load Patterns



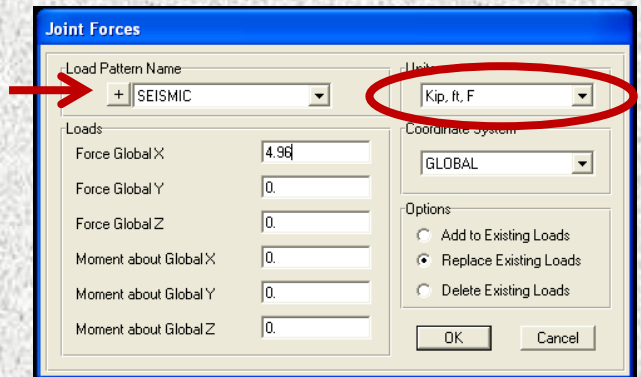
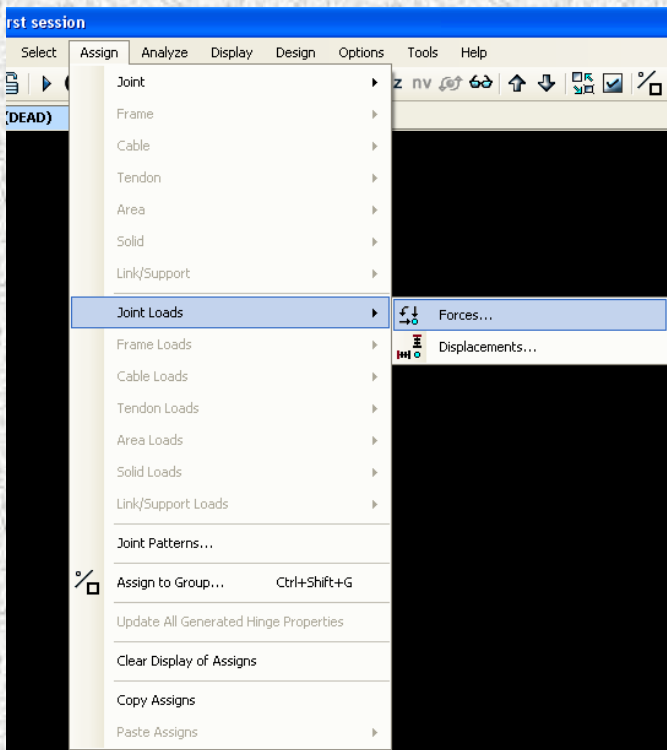
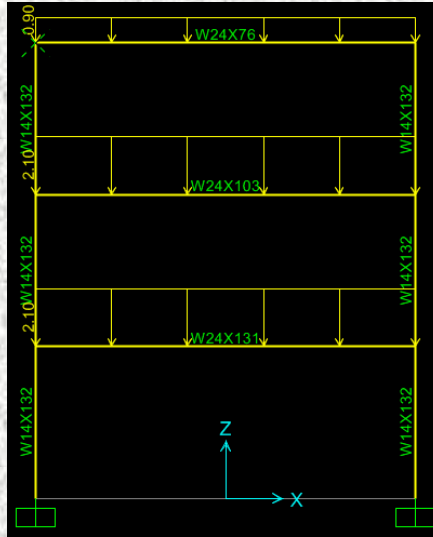
7- Assign Gravity Loads

Select elements:



8- Assign Lateral Loads

Select nodes:



9- Define Load Combinations

Load Combinations:

$$r_{max} = 0.33$$

$$\rho = 2 - \frac{20}{0.33\sqrt{30 \times 90}} = 0.83 \quad \text{use } \rho = 1.0$$

Load Combination 2 (COMB1):

$$5. \quad 1.2D + 1.0E + f_1L + 0.5L_r = 1.2D + 1.0(\rho Q_E + 0.2S_{DS}D) + 0.5L + 0.5L_r$$

$$(1.2 + 0.2 \times 0.93)D + 1.0Q_E + 0.5L + 0.5L_r = \underline{1.386D + Q_E + 0.5L + 0.5L_r}$$

Load Combination 6 (COMB2):

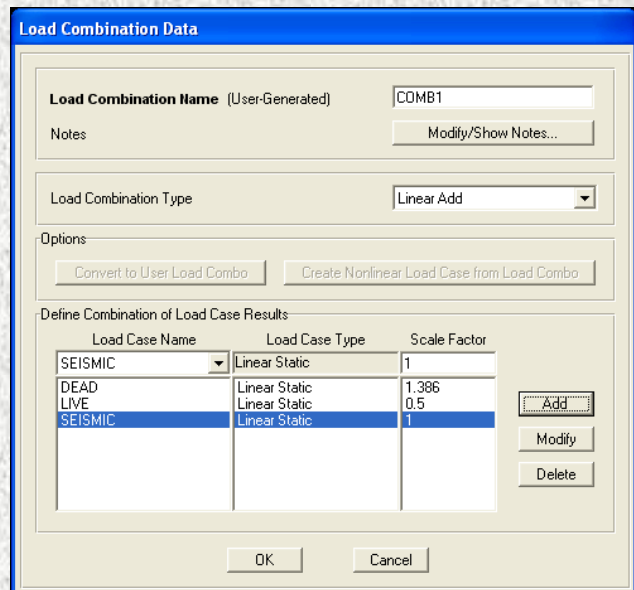
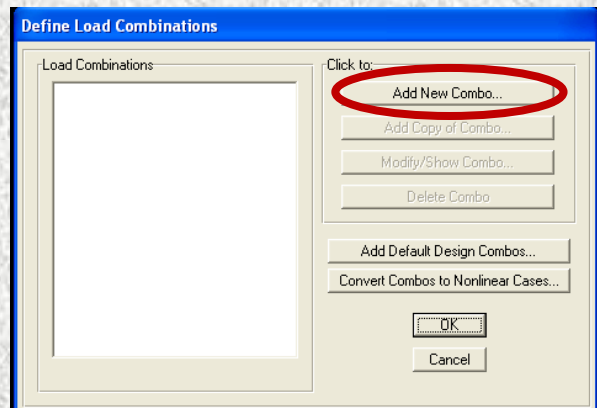
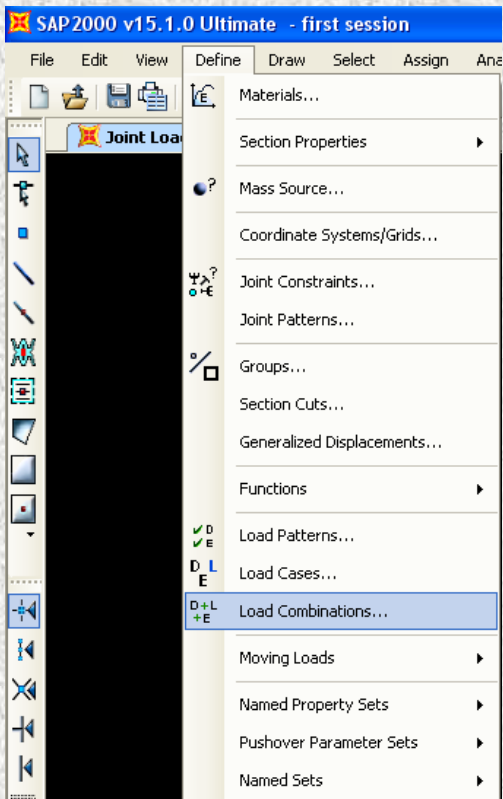
$$6. \quad 0.9D + 1.0E = 0.9D + 1.0(\rho Q_E + 0.2S_{DS}D) \quad 5.2.7-1$$

$$(0.9 + 0.2 \times 0.93)D + Q_E = 1.086D + Q_E$$

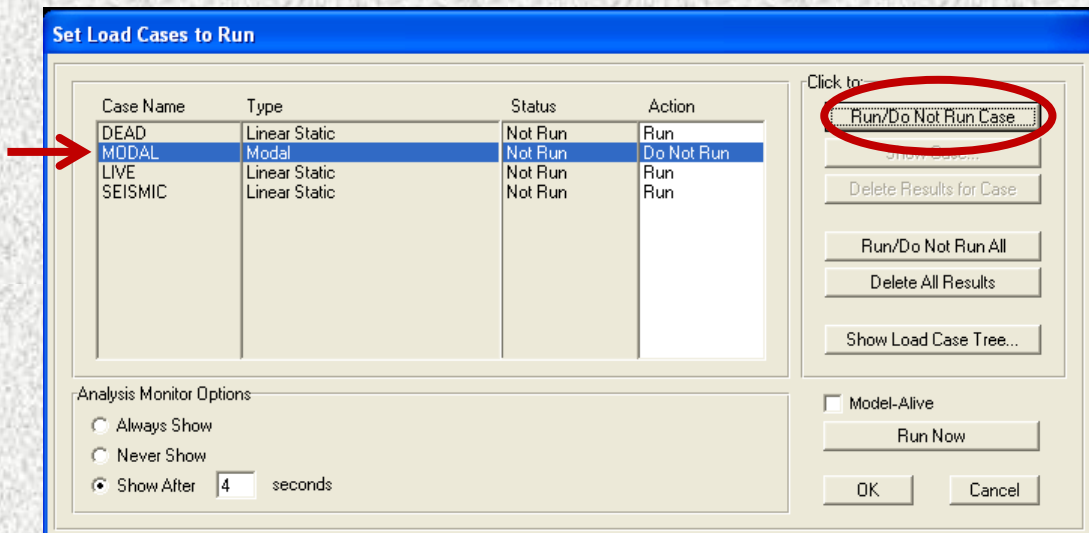
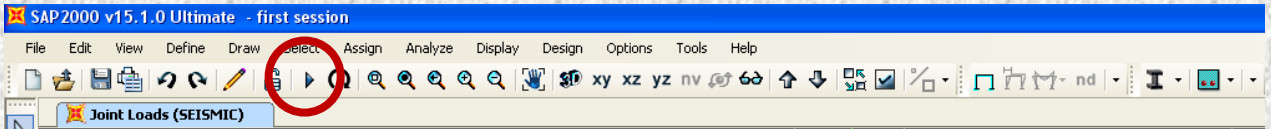
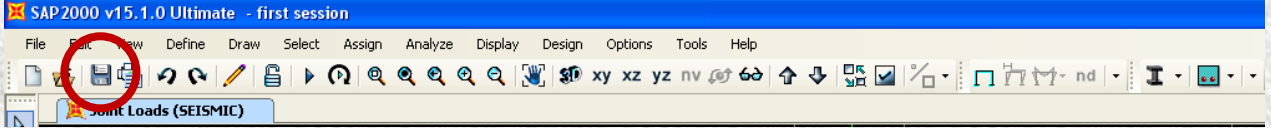
Load Combination 6 (COMB3):

$$6. \quad 0.9D + 1.0E = 0.9D + 1.0(\rho Q_E - 0.2S_{DS}D) \quad 5.2.7-2$$

$$(0.9 - 0.2 \times 0.93)D + Q_E = 0.714D + Q_E$$

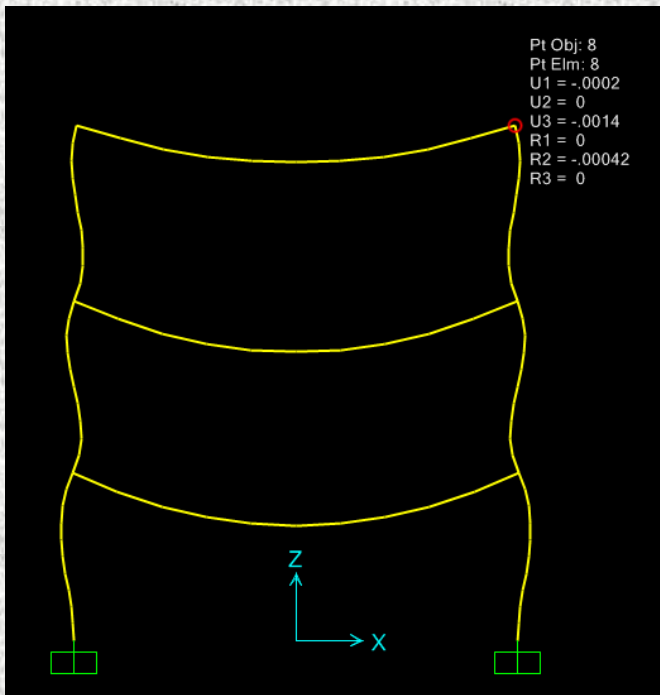
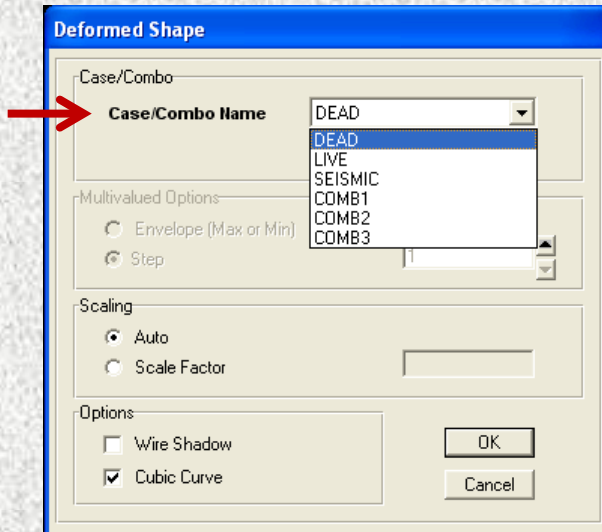


10- Save and Run



11- Results Output

Display displacement:



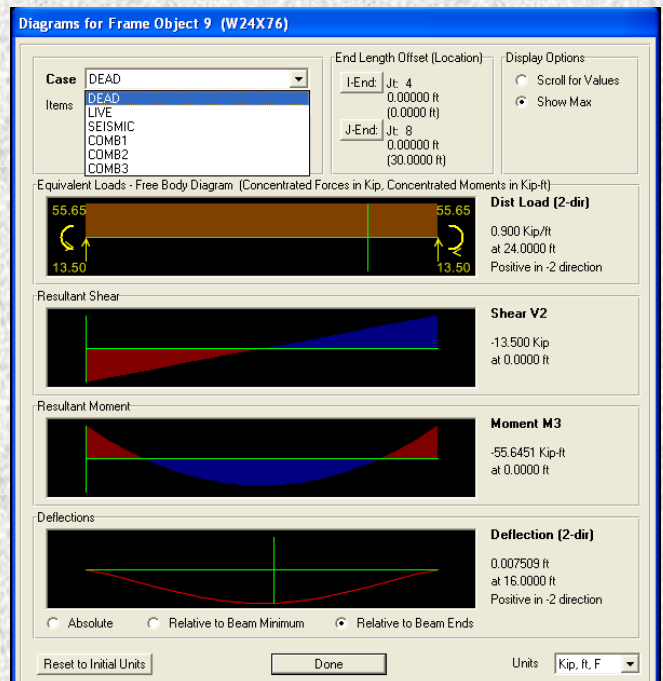
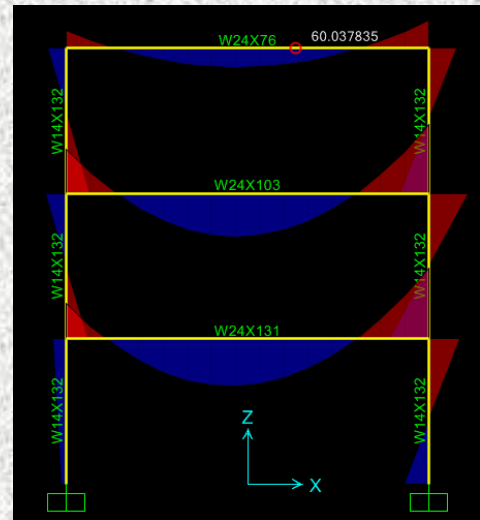
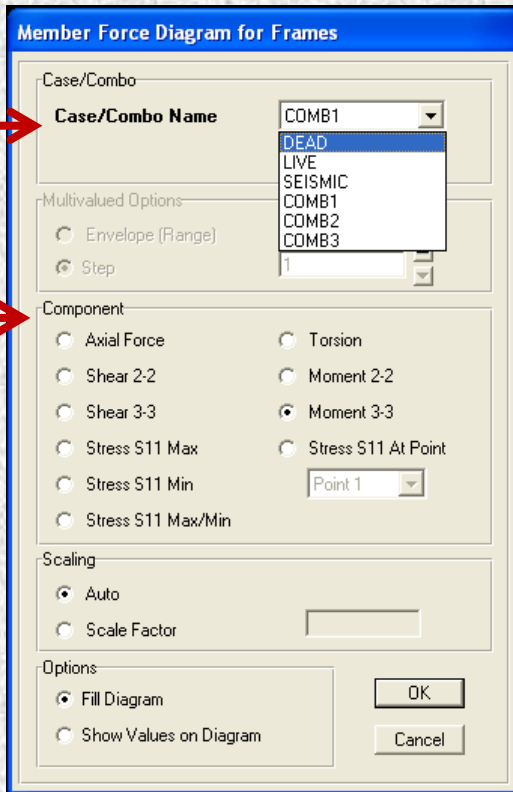
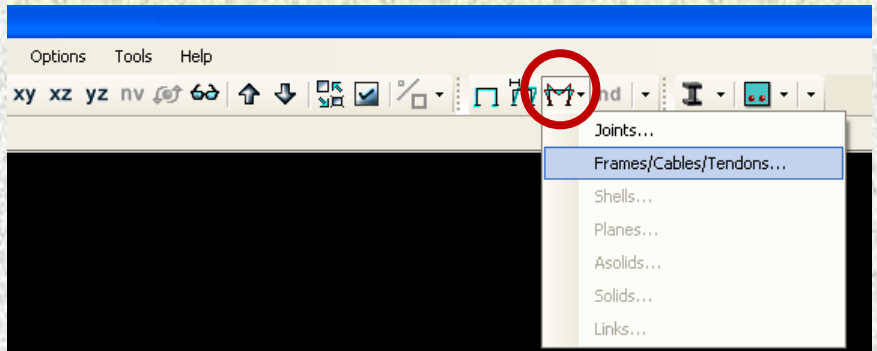
Place cursor on joints
Or right click on them:

A screenshot of the 'Joint Displacements' dialog box. It displays a table of displacement and rotation values for a specific joint object and element.

Joint Object 8		Joint Element 8		
	1	2	3	
Trans	-2.293E-04	0.00000	-0.00144	
Rotn	0.00000	-4.205E-04	0.00000	

11- Results Output

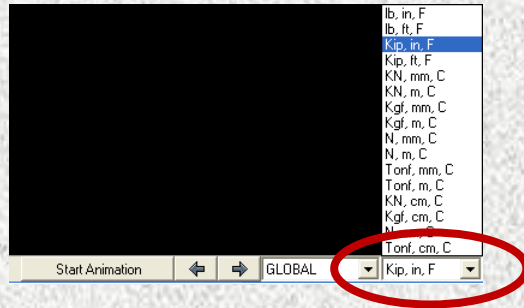
Display forces:



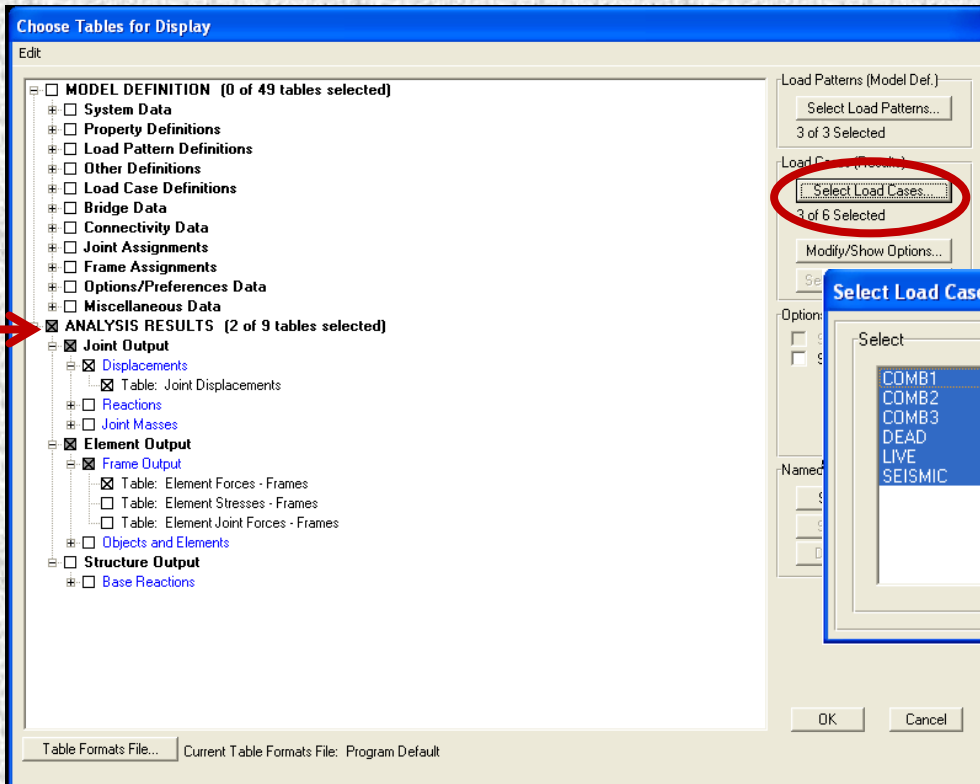
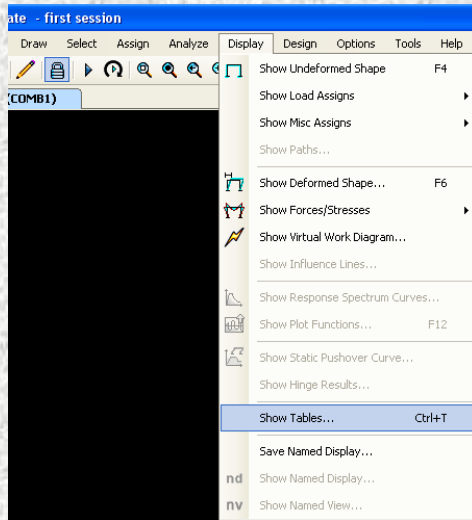
Place cursor on elements
Or right click on them:

11- Results Output

**Change units:



Result tables:



11- Results Output

Joint Displacements

File View Format-Filter-Sort Select Options

Units: As Noted

Joint Displacements

Element Forces - Frames

Joint Displacements

	Joint Text	OutputCase Text	CaseType Text	U1 in	U2 in	U3 in	R1 Radians	R2 Radians	R3 Radians
▶	1	DEAD	LinStatic	0	0	0	0	0	0
	1	LIVE	LinStatic	0	0	0	0	0	0
	1	SEISMIC	LinStatic	0	0	0	0	0	0
	1	COMB1	Combination	0	0	0	0	0	0
	1	COMB2	Combination	0	0	0	0	0	0
	1	COMB3	Combination	0	0	0	0	0	0
	2	DEAD	LinStatic	-0.000904	0	-0.00979	0	0.000598	0
	2	LIVE	LinStatic	-0.000652	0	-0.006911	0	0.000426	0
	2	SEISMIC	LinStatic	0.093292	0	0.001218	0	0.000494	0
	2	COMB1	Combination	0.091713	0	-0.015807	0	0.001536	0
	2	COMB2	Combination	0.09231	0	-0.009415	0	0.001143	0
	2	COMB3	Combination	0.092647	0	-0.005773	0	0.000921	0
	3	DEAD	LinStatic	0.000405	0	-0.015549	0	0.000574	0
	3	LIVE	LinStatic	0.000347	0	-0.010942	0	0.000415	0
	3	SEISMIC	LinStatic	0.205056	0	0.001807	0	0.000442	0
	3	COMB1	Combination	0.205792	0	-0.025215	0	0.001445	0
	3	COMB2	Combination	0.205496	0	-0.01508	0	0.001065	0
	3	COMB3	Combination	0.205346	0	-0.009295	0	0.000852	0
	4	DEAD	LinStatic	0.002752	0	-0.017277	0	0.00042	0
	4	LIVE	LinStatic	0.001898	0	-0.012094	0	0.00027	0
	4	SEISMIC	LinStatic	0.272329	0	0.001975	0	0.000254	0
	4	COMB1	Combination	0.277092	0	-0.028018	0	0.000971	0
	4	COMB2	Combination	0.275318	0	-0.016788	0	0.00071	0
	4	COMB3	Combination	0.274294	0	-0.010361	0	0.000554	0
	5	DEAD	LinStatic	0	0	0	0	0	0
	5	LIVE	LinStatic	0	0	0	0	0	0
	5	SEISMIC	LinStatic	0	0	0	0	0	0

Record: 1 of 48

Add Tables... Done

** Export to Excel:

Joint Displacements

File View Format-Filter-Sort Select Options

Export Current Table ▶ To Excel

Display Current Table ▶ To Access

Print Current Table as Text File

Export All Tables ▶

Display All Tables ▶

Print All Tables as Text File

Save Current Table Format to Table Formats File

Save All Table Formats to Table Formats File

Apply Format from File to Current Table

Apply Formats from File to All Tables

Add Tables

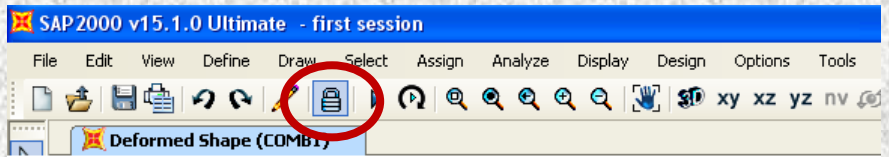
Remove Current Table

Close Form

U1 in
0
0
0
0
0
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0
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0
-0.000904
-0.000652
0.093292
0.091713
0.09231
0.092647
0.000405

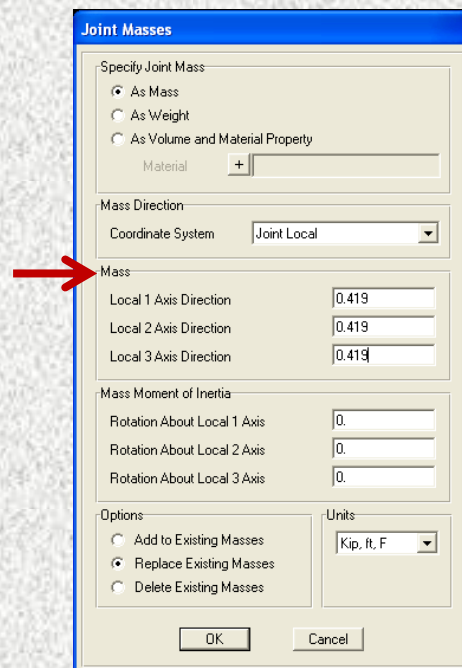
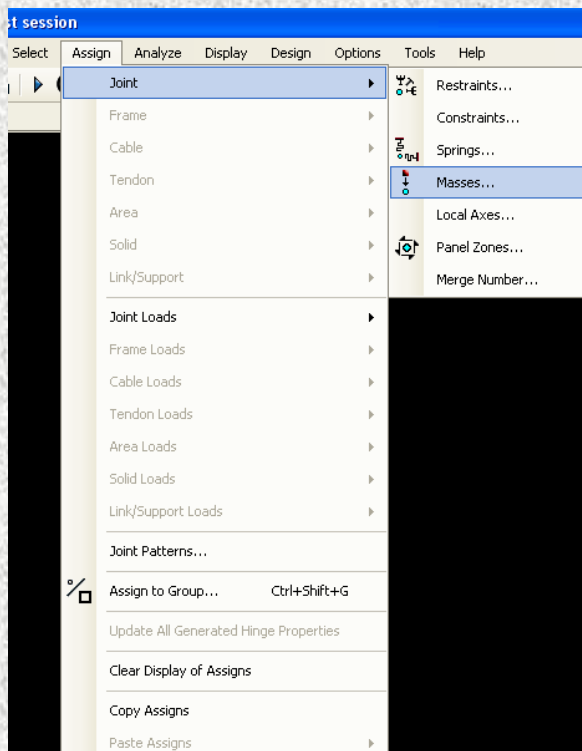
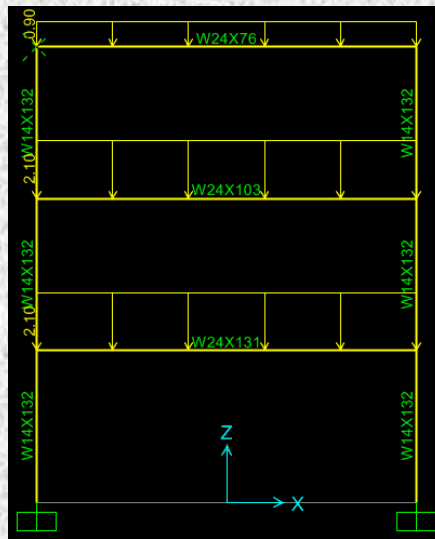
12- Modal Analysis

Unlock model:



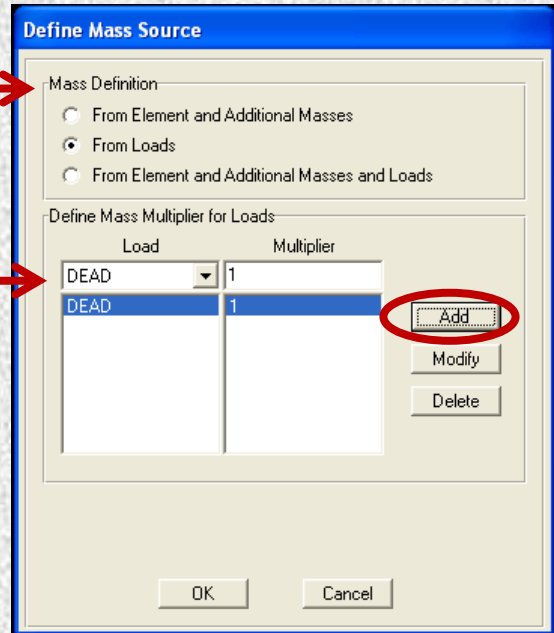
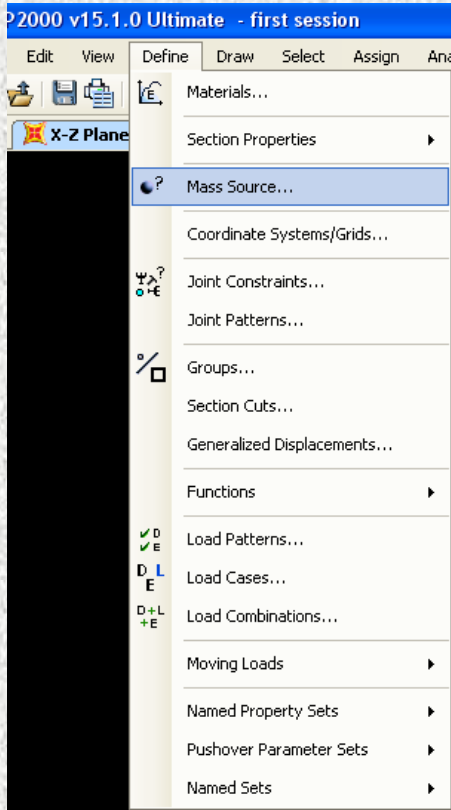
Nodal mass- Option one: Assign mass

Select nodes

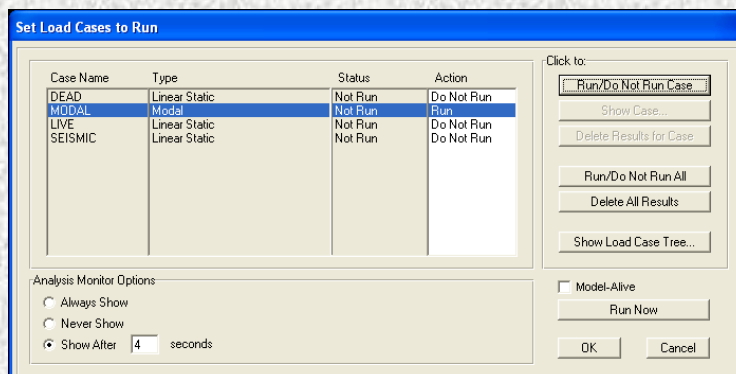
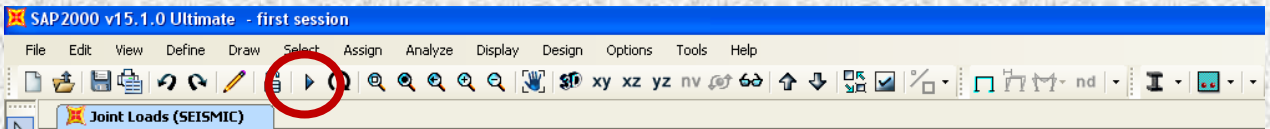


12- Modal Analysis

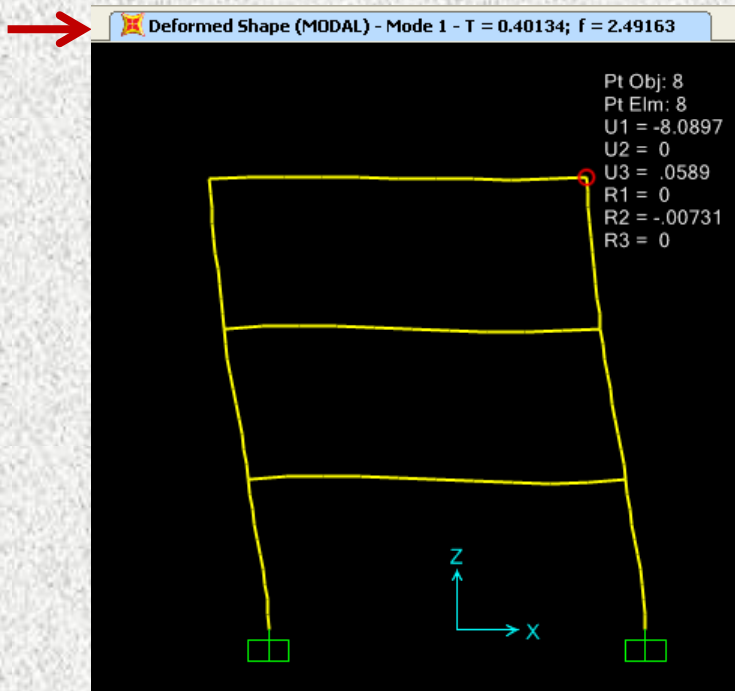
Nodal mass- Option two: Define mass source from loads



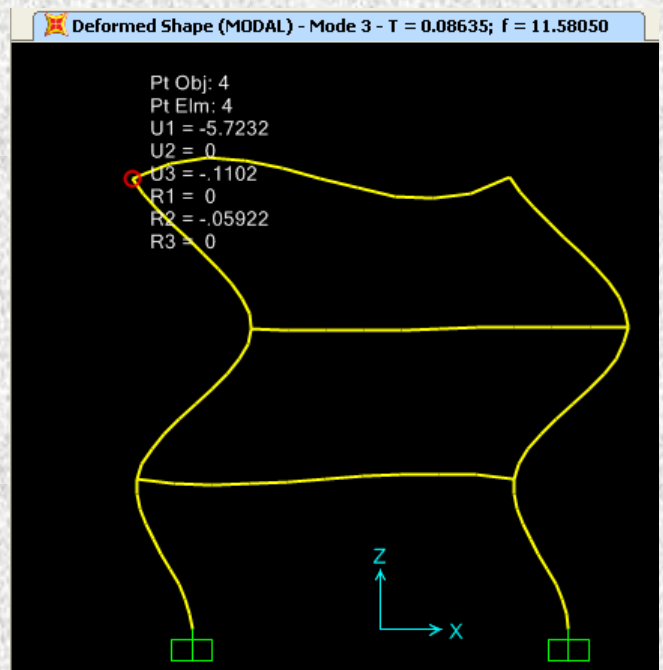
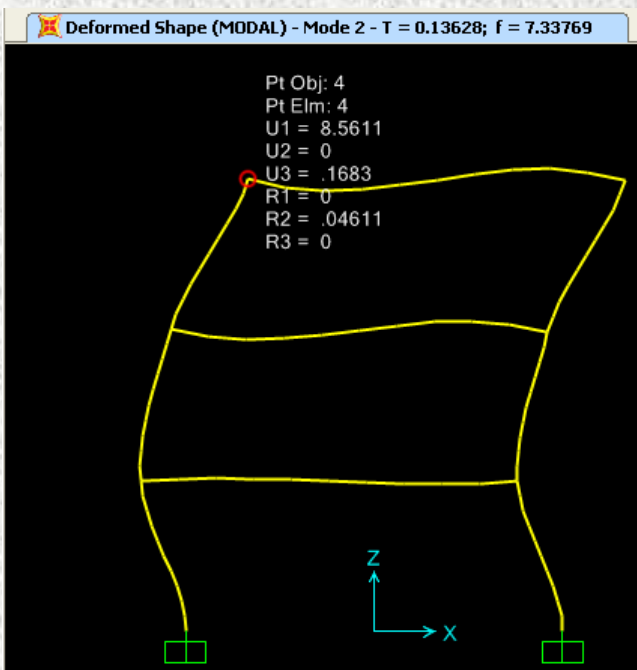
Run:



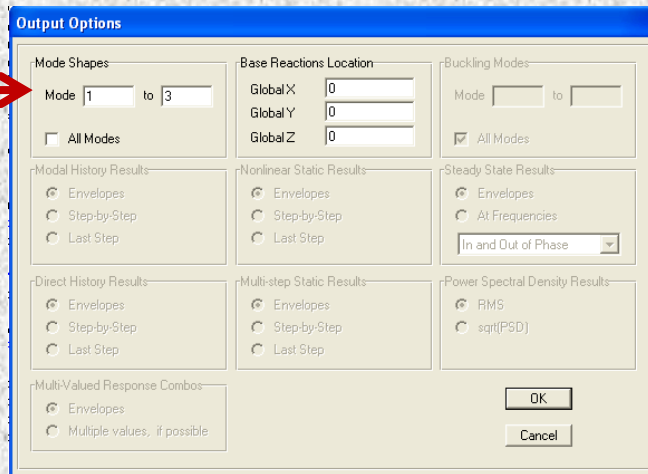
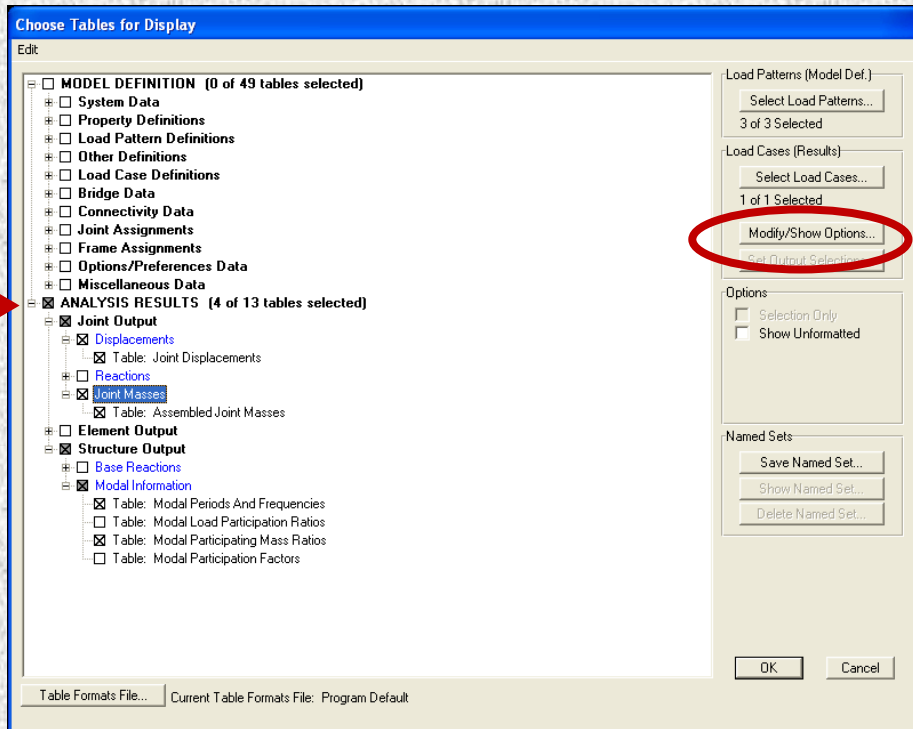
13- Modal Analysis Results



Next modes



13- Modal Analysis Results



Modal Participating Mass Ratios

File View Format-Filter-Sort Select Options

Units: As Noted

Modal Participating Mass Ratios

OutputCase Text	StepType Text	StepNum Unitless	Period Sec	UX Unitless	UY Unitless	UZ Unitless	SumUX Unitless	SumUY Unitless	SumUZ Unitless
MODAL	Mode	1	0.401344	0.8608	0	0	0.8608	0	0
MODAL	Mode	2	0.136283	0.1147	0	0	0.9755	0	0
MODAL	Mode	3	0.086352	0.0245	0	0	1	0	0

Record: 1 of 3

Add Tables... Done

13- Modal Analysis Results

Mode shapes:

Joint Displacements

File View Format-Filter-Sort Select Options

Units: As Noted Joint Displacements

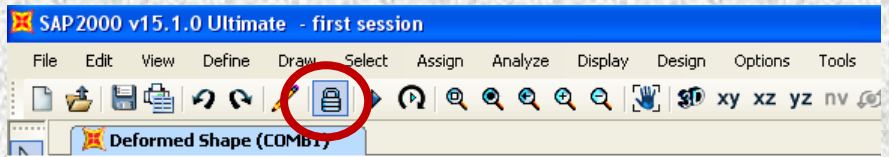
	Joint Text	OutputCase Text	CaseType Text	StepType Text	StepNum Unitless	U1 in
▶	1	MODAL	LinModal	Mode	1	0
	1	MODAL	LinModal	Mode	2	0
	1	MODAL	LinModal	Mode	3	0
	2	MODAL	LinModal	Mode	1	-2.793586
	2	MODAL	LinModal	Mode	2	-6.161151
	2	MODAL	LinModal	Mode	3	-5.270152
	3	MODAL	LinModal	Mode	1	-6.138686
	3	MODAL	LinModal	Mode	2	-2.033608
	3	MODAL	LinModal	Mode	3	5.631883
	4	MODAL	LinModal	Mode	1	-8.089736
	4	MODAL	LinModal	Mode	2	8.561087
	4	MODAL	LinModal	Mode	3	-5.723174
	5	MODAL	LinModal	Mode	1	0
	5	MODAL	LinModal	Mode	2	0
	5	MODAL	LinModal	Mode	3	0
	6	MODAL	LinModal	Mode	1	-2.793586
	6	MODAL	LinModal	Mode	2	-6.161151
	6	MODAL	LinModal	Mode	3	-5.270152
	7	MODAL	LinModal	Mode	1	-6.138686
	7	MODAL	LinModal	Mode	2	-2.033608
	7	MODAL	LinModal	Mode	3	5.631883
	8	MODAL	LinModal	Mode	1	-8.089736
	8	MODAL	LinModal	Mode	2	8.561087
	8	MODAL	LinModal	Mode	3	-5.723174

Record: 1 of 24 Add Tables... Done

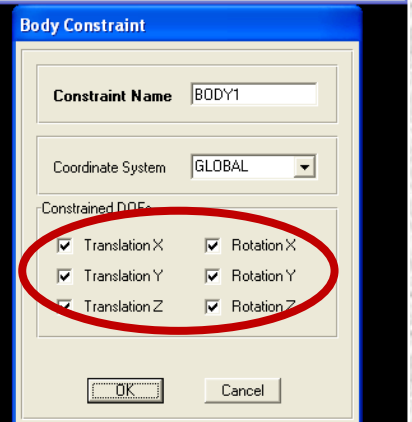
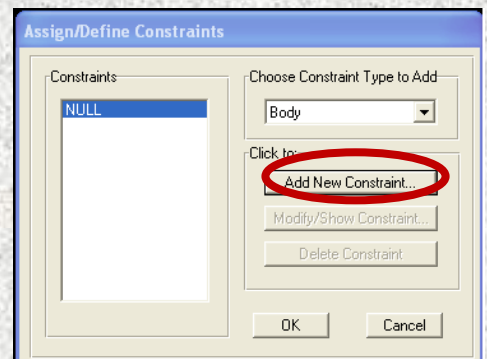
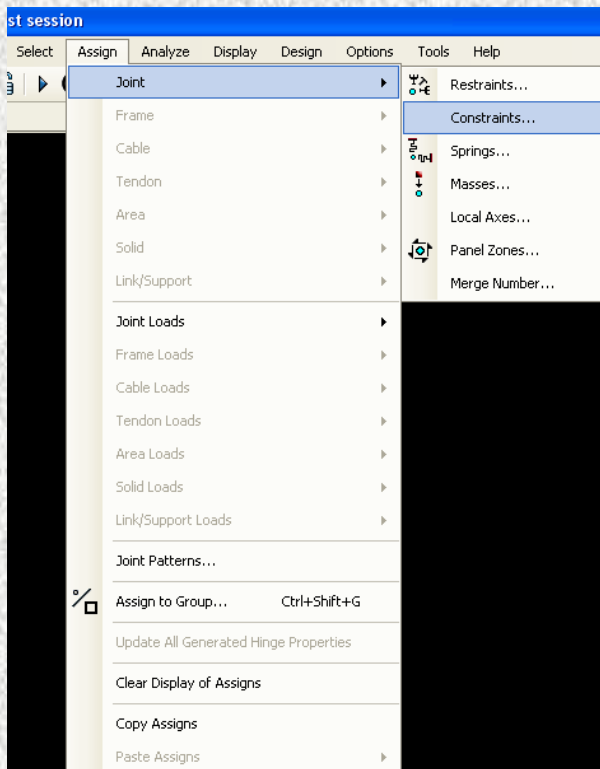
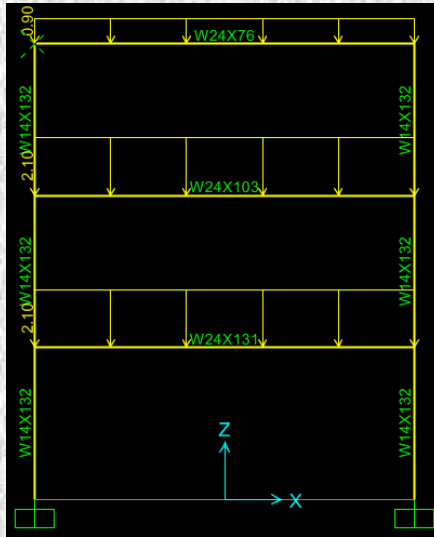
$$\phi^{(1)} = \begin{Bmatrix} 1.0 \\ 0.759 \\ 0.345 \end{Bmatrix}$$

14- Rigid Beams Mode Shapes

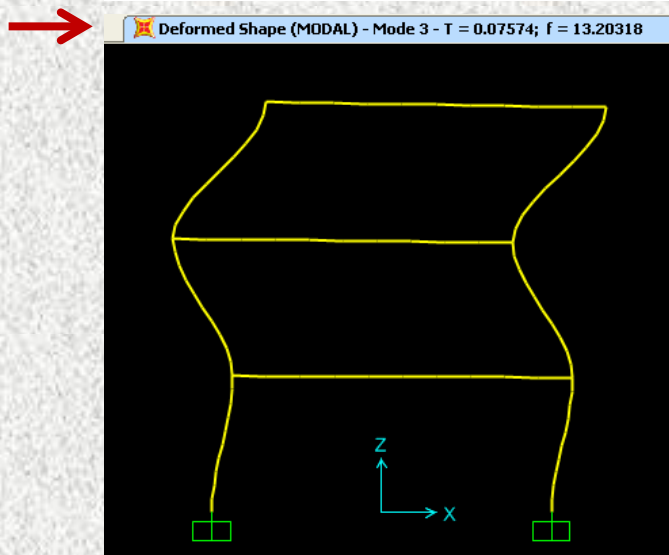
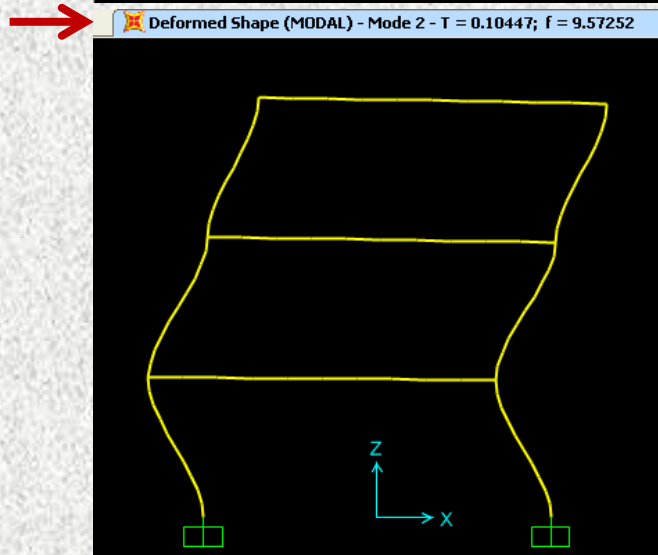
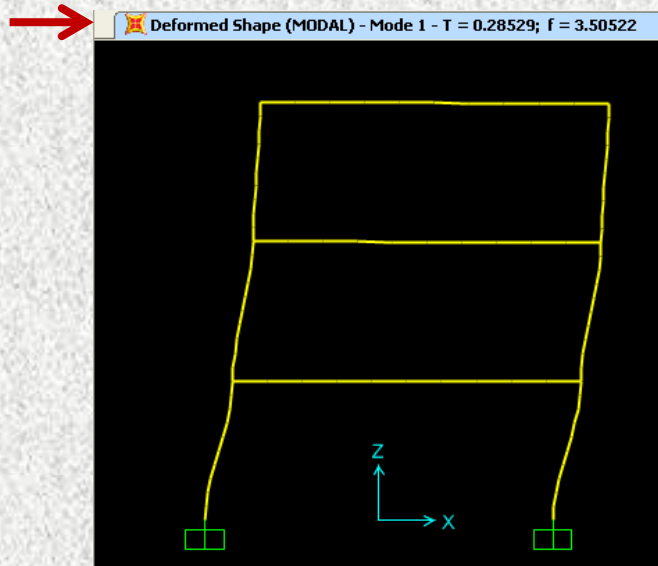
Unlock model:



Tie beam end joints together for each beam:




14- Rigid Beams Mode Shapes





14- Rigid Beams Mode Shapes

Joint Displacements

File View Format-Filter-Sort Select Options

Units: As Noted  Joint Displacements

	Joint Text	OutputCase Text	CaseType Text	StepType Text	StepNum Unitless	U1 in
▶	1	MODAL	LinModal	Mode	1	0
	1	MODAL	LinModal	Mode	2	0
	1	MODAL	LinModal	Mode	3	0
	2	MODAL	LinModal	Mode	1	3.583596
	2	MODAL	LinModal	Mode	2	-7.132602
	2	MODAL	LinModal	Mode	3	3.129977
	3	MODAL	LinModal	Mode	1	6.221936
	3	MODAL	LinModal	Mode	2	0.552178
	3	MODAL	LinModal	Mode	3	-5.873447
	4	MODAL	LinModal	Mode	1	7.158601
	4	MODAL	LinModal	Mode	2	7.188485
	4	MODAL	LinModal	Mode	3	8.234448
	5	MODAL	LinModal	Mode	1	0
	5	MODAL	LinModal	Mode	2	0
	5	MODAL	LinModal	Mode	3	0
	6	MODAL	LinModal	Mode	1	3.583596
	6	MODAL	LinModal	Mode	2	-7.132602
	6	MODAL	LinModal	Mode	3	3.129977
	7	MODAL	LinModal	Mode	1	6.221936
	7	MODAL	LinModal	Mode	2	0.552178
	7	MODAL	LinModal	Mode	3	-5.873447
	8	MODAL	LinModal	Mode	1	7.158601
	8	MODAL	LinModal	Mode	2	7.188485
	8	MODAL	LinModal	Mode	3	8.234448

Record:  1  of 24

Add Tables... Done

$$\phi^{(1)} = \begin{Bmatrix} 1.0 \\ 0.869 \\ 0.50 \end{Bmatrix}$$