

Training Guide

25 & STRU

Modeling, Analysis, and Design of Pipe Rack

Structures Using SAP2000

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JAP2000

Using the attached pdf drawings (PR1.pdf and PR2.pdf), this tutorial will show you how to model, analyze and design the 6 bay pipe rack structure shown below supporting air cooled heat exchangers. This is an extruded view of the structure, color coded by sections.



Click new model button or **File>New** to begin. The first screen that appears enables you to select units and offers a number of template options. In most cases you will want to define grids. Select Kip, ft, F units and click 'Grid only'. Input uniform spaced grid lines and spacing shown below right, including the 7'6" architectural units in Y direction grid spacing then press OK. You can input using architectural units and tab or press OK for SAP2000 to convert to current units



Quick Grid Lines	
Cartesian	Cylindrical
Coordinate System Name	e
GLOBAL	
Number of Grid Lines	
× direction	7
Y direction	5
Z direction	2
- Grid Spacing	
X direction	20
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Z direction	40
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X direction	0.
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	Jo.
ОК	Cancel

3

By default, you will see a split-screen view. If you click the planar view on the left, you will see a blue outline on the 3D model highlighting the planar view location. Press the down arrow to move to plan view Z = 0



Next, double click any gridline with your mouse to display the Define grid screen below. Type in values in Z grid direction as shown below for main beam locations shown on the PR2.pdf drawing and press OK

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Click yz button $\frac{1}{2}$ to switch planar view to elevation and press arrows $\frac{1}{2}$ to move to X = 0 Y-Z plane as shown below



Before we import our sections, use the main menu to review the **Define>Materials** where we see two default materials, 4000 psi concrete material and A992 steel material. You can add new materials using the 'Add new material quick' button to select from a material library, or use the 'Add New Material' button to add a material not found in the libraries. In a concrete structure, typically multiple concrete materials need to be used for different strengths and weights.

	Define Materials	Ciela	
	4000Psi A992Fy50		Add New Material Quick Add New Material Add Copy of Material
Quick Material Def	inition		fy/Show Material Delete Material
Material Type	Steel	•	Ivanced Properties
Specification	ASTM A992, Fy 50 ASTM A53 Grade B ASTM A500 Grade B, Fy 42 (HSS Round) ASTM A500 Grade B, Fy 42 (HSS Rect.) ASTM A572 Grade 50	• •	OK Cancel
	ASTM A913 Grade 50 ASTM A992, Ev 50		

Cancel out of the Define Materials dialogue to accept the default materials, then go to **Define**>**Section properties**>**Frame sections** where you will see the screen on the bottom left. For standard steel sections and joists, you use the 'Import New Property' button. First, click *I/Wide Flange* button to import those sections.

2n 📃 🗖 🔍 🧃	Import Frame Section Property
Frame Properties Find this property: Import New Property	Select Property Type Frame Section Property Type Steel
Add New Property Add Copy of Property Modify/Show Property Delete Property	Image: Internal intern
OK Cancel	JL JL O D Double Angle Double Channel Pipe Tube
	Steel Joist Cancel

In order to utilize the latest AISC sections, go to the directory where SAP2000 is installed and click the SECTIONS8.PRO file. As you can see, SAP2000 offers libraries for several international steel shapes, as well as aluminum shapes and a joist library. After clicking to open this file, you will see a dialogue like the one on the bottom right. Use your mouse and drag to select all W sections from W8 through W21's and press OK



Press OK again to add these sections to the working list. Next, click 'Import New Property' button and click the 'Tee' button to view the Tee sections, select WT4X9 and WT4X12 and press OK twice to add these sections to the working list.



::\program files\computers and structures\sa	
Section Type Tee Material + A992Fy50	
WT3X4.25 WT4X5 WT4X9 WT4X12 WT4X12 WT4X14 WT4X20 WT4X20 WT4X24 WT4X29 WT4X5.5 WT4X10.5 WT4X15.5 WT4X17.5 WT4X17.5 WT4X17.5 WT5X6 WT5X11 WT5X13	
WT5X15 WT5X27 WT5X30	

As a learning exercise, click 'Add New Property' button, then click I/Wide Flange. As you can see on the right, you can change dimensions to define a nonstandard steel section and even change material to concrete. Use of the Add options are needed to add/define concrete sections, nonstandard steel sections, nonprismatic steel shapes, and auto-select lists. Cancel out of this Add I/Wide Flange screen

Properties		Click to:
Find this property:		Import New Property
W8X10 W21X83 W21X93	<u>^</u>	Add New Property
W21X101 W21X111 W21X122		Add Copy of Property
W21X132 W21X147		Modify/Show Property
W21X166 W21X182 W21X201 WT4X9 WT4X9		Delete Property
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Add Frame Section Pro	perty					
Select Property Type						
Frame Section Property	Frame Section Property Type Steel					
Click to Add a Steel Section	on					
I / Wide Flange	Channel	Tee	LAngle			
 Double Angle	Double Channel	Pipe	Tube			
Auto Select List	Steel Joist					
	Car	ncel				

Section Name	PLATE	GIRDER
Section Notes		Modify/Show Notes
Properties	Property Modifiers	Material
Section Properties	Set Modifiers	+ A992Fy50 -
Dimensions]
Outside height(t3)	1	
Top flange width (t2)	.9	
Top flange thickness (tf)	.04	
Web thickness (tw)	0.0208	
Bottom flange width(t2b)	.5	
Bottom flange thickness (tfb)	0.0317	Display Color

As another learning exercise, click 'Add new property' again, change Frame Section Property type to 'Built-Up Steel', can click Cover Plated I as shown below. Here you can quickly add top and/or bottom cover plates to Wide flange sections which are used for design as well as analysis. Cancel this as we are using only standard sections for this exercise, although it's useful to know this tool is available for design.

Add Frame Section Property	
Select Property Type	
Frame Section Property Type	Built-Up Steel
Click to Add a Built-Up Steel Section	
Cover Plated I	
	Cancel

🕺 Built Up I-Section With Cover Plates	
Section Name BUILT-UP	
I-Section Data W8×10 ▼ Fy 7200. Overwrite Top Flange Fy Overwrite Web Fy Overwrite Bottom Flange Fy Top Cover Plate Data ✓ Include Top Cover Plate Material + A992Fy50 ▼ Width .5 Thickness .02	Section 3
Bottom Cover Plate Data Include Bottom Cover Plate Material ± Width Thickness OK Cancel	Section Properties Property Modifiers Set Modifiers Section Notes Modify/Show Notes

Click 'Add new property' again and change Frame section property type to 'Other'. Here is where you can define general sections, nonprismatic sections, or access the section designer. Click 'Section Designer' button, and when you select a 'Base material', you have the option to include it in the design. Click 'Section designer' button shown in 2nd screen shot below

Add Frame Section Prop	erty	
Select Property Type	IIDe	Other 🗸
Frame Section Property T	ype	Lither
	Ca	ncel

) Secti	ion Data			
Sec	tion Name BUILTUPSECT	_		
Sect	ion Notes Modify/Show Notes			
Base	e Material + A992Fy50	•		
– Desig	gn Type			
0	No Check/Design			
•	General Steel Section 🔫			
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- Conc	rete Column Check/Design			
\odot	Reinforcement to be Checked			
0	Reinforcement to be Designed			
Defin	e/Edit/Show Section			
	Section Designer			
Section	on Properties Property Modifiers Set Modifiers Display Color			

Use the shape options below to create built-up combined sections. Use reshaper tool Trans and right click the individual sections to move them, rotate, or modify dimensions to help you combine them. SAP2000 automatically calculates combined areas, moments of inertia, etc. and uses this combined section not only for analysis, but also for design. Cancel out and return to Define frame section property dialogue to continue.

R CSISD - RUN TUPSFCT				Properties	
Ele Edit Yew Define Draw Select Display Options Help				Base Material	A 9925-150
		I CSISD - BUIL TUPS	ECT	Xca	A352F950
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				122	1.085
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	Туре	USER DEFINED		AS2	0.74
	Material	A992Fy50		AS3 S33(#face)	1.4449
	Color			S33(-face)	0.8682
	X Center	<u> </u>		S22(+face)	0.868
	Y Lenter	<u> </u>		S22(-face)	0.868
	Height	2.		Z33	1.2783
	Top Width	<u> </u>	8	<u>Z22</u>	1.2115
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	Tiotadori	0.			OK
			X = -0.41 Y	= 2.80 Kip-ft 💌	Done
Ready X = -8.63 Y = 2.74 Kip-ft	C Model	S Model			
					14
		Cancel			

The drawings call for W14 columns. The exact section is not specified which means that the engineer needs to size the most economical W14 section which meets design requirements. We will do this by defining and assigning Auto select lists which SAP2000 will use to optimize for lightest section during design. We will define separate Auto select lists for W14's, W16's, W18's and W21's. Click 'Add New Property' button, and using frame section type Steel, click Auto Select List. Change the Auto Section Name to AUTO14 in order to help us remember, then select all W14 sections as shown below, then click Add-> to add them to the Auto Selections list

Add Frame Section Pro	perty			
Select Property Type Frame Section Property	Туре	Steel	T	4
Click to Add a Steel Secti	on			
I / Wide Flange	Channel	Tee	Angle	
 Double Angle	Double Channel	Pipe	Tube	
Auto Select List	Steel Joist			
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Auto Selection Sections	
Auto Section Name	AUT014
Auto Section Type	Steel
Section Notes	Modify/Show Notes
Choose Sections:	
List of Sections	Auto Selections
W12×279 ▲ W12×305 ₩12×336 W14×22 ₩14×26 W14×30 ₩14×34 W14×34 ₩14×38 W14×34 ₩14×48	Add -> <- Remove Show
Starting Section	
Median	Overwrite
ОК	Cancel

Change the Auto Section Name as shown below, select all the W16 sections on the left, then press Add-> to place them on the right, the press OK to accept. Repeat this process to create an auto select list for the W18's, then one more for the W21's. Don't forget to name each Auto Section list differently (AUTO14, AUTO16, AUTO18, AUTO21), then press OK until you return to the main menu screen shown below right

Auto Selection Sections					
		JK: SAP2000 v12.0.1 Advanced - (Untitled) Ele Edt Yew Define BrIM Draw Select Assign	Analyze Display Design Options Iools Help		
Auto Section Name AUTO1	6	C → 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	A A A A A A A A A A A A A A A A A A A	₩ 0 % ₅ ⊡ 7 M·rd ₅ ⊡ % ₅ I • G • 5 <mark>M</mark> 3 D View	
Auto Section Type Steel					
Section Notes 1	dodify/Show Notes				
Choose Sections:					
List of Sections	Auto Selections				
W8×10 ▲ W8×13 ▲ W8×15 ▲ W8×18 ▲ W8×21 < W8×24 W8×28 Show W8×35 ✓ W8×40 ✓	₩16×31 ₩16×36 ₩16×40 ₩16×45 ₩16×50 ₩16×57 ₩16×67 ₩16×77 ₩16×100	a ^{pin} da ^t Ma da ^t Ma T → X + Ma T → X			
Starting Section		3-D View		X0.00 Y0.00 2	20.00 GLOBAL 💌 Kip, R, F 💌
Median	Overwrite				

Click the 'Draw Frame/Cable object' buttor as shown, click Section in the floating properties box to select AUTO14, moment release continuous, then in Y-Z window X= 0 ft, click once on the bottom left as shown and then click once more at the top. Instead of assigning an individual section, for example W14X90 or another section, the W14 Auto Select list enables SAP2000 to optimize to choose the lightest section in that list which meets design code and user specified drift requirements.

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After clicking the top to complete drawing the column, right-click to move your cursor and draw another column along 5A. Click zoom-out button ² to view grid labels



This is what your model should look like. Next, we will draw the W21 moment connected continuous beam as per the drawing. Click the Section and select AUTO21 and draw a beam left to right as shown. SAP2000 will internally create a joint at the beam/column intersection in order to transfer shear and moments, but SAP will then reformulate the results to report and design the columns using the length which was used to draw them (40 ft. tall columns)



Right click to move your cursor, change section to AUTO18 as shown below, and draw another beam as shown. As you can see, the grids help you snap to draw



Change the Section to AUTO16, and since this beam is not designated M.C., the moment release needs to be changed to Pinned. Draw the third beam as shown.

Properties of Object	×
Line Object Type	Straight Frame
Section	AUTO16
Moment Releases	Pinned 🗾
XY Plane Offset Normal	U.
Drawing Control Type	None <space bar=""></space>



Change Section to AUTO14, keep the Moment releases as Pinned, and draw the 4th beam as shown along the top gridline just above the beam which was previously drawn



Press the Esc key on your keyboard or click the select button as shown below left in order to go into Select mode. While holding down the mouse key, drag to window a box around the bottom two joints to select them. Next, go to **Assign menu>Joint>Restraints** and add pin restraints as shown below. Press OK

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R	🍂 Y-Z Plane @ X=0						
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Joint Restraints							
Restraints in Joint Local Directions							
🔽 Translation 1 🔲 Rotation about 1							
🔽 Translation 2 🔲 Rotation about 2							
🔽 Translation 3 🔲 Rotation about 3							
Fast Restraints							
<u> </u>							





Click anywhere inside the 2D planar view window on the left to make sure it's the 'active' window, then click 'set display options' button at the top, checkbox/activate the Releases option as shown and press OK in order to graphically view moment releases

Display Options For Active Window									
Joints Frames/Cables/Tendons		General	View by Colors of						
Γ	Labels	Labels	🕞 Shrink Objects	 Objects 					
F	Restraints	Sections	Extrude View	C Sections					
F	Springs		Fill Objects	C Materials					
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F	 Invisible 	Frames Not in View	🔽 Show Ref. Lines	O White Background, Black Objects					
ſ	Not in View	Cables Not in View	Show Bounding Boxes	C Selected Groups Select Groups					
		Tendons Not in View							
A	reas	Solids	Links	Miscellaneous					
Г	Labels	🗖 Labels	🗖 Labels	🔲 Show Analysis Model (If Available)					
Г	Sections	E Sections	Properties	🔲 Show Joints Only For Objects In View					
Г	Local Axes	🗖 Local Axes	🗖 Local Axes						
Г	Not in View	🔲 Not in View	🔲 Not in View						
F Apply to All Windows									
	OK Cancel								



Next, click set display options button again, but this time uncheck the Releases and activate the Extrude view option as shown to create a rendered view. Note the option below to 'Apply to All Windows'. Each display option can apply to the active window only or to all windows. In this example, we will apply only to our active planar view window.





We will next adjust the beams to be dimensioned to top of steel (T.O.S. in drawing). Holding down the mouse key, drag your mouse right to left to window intersect the 4 beams. Dragging right to left is a convenient method to select elements and joints which are intersected.





Next, use **Assign menu>Frame>Insertion Point** to assign the 'cardinal point' type of connection. You can press F1 with this dialogue open to read the Help menu for more information. In this case, we want top of steel, so select #8, top center and press OK. Based on frame section size and type of insertion point, SAP2000 moves the frame and adds a rigid link to account for the offset/eccentricity which will change analysis results compared to centerline connection. You can toggle back and forth with undo/redo in extruded view to visualize what SAP2000 is doing. Next, use the 'set display options' to deactivate the extruded view for the time being. You may have to press the F4 key on your keyboard to clear the screen if the insertion point assignments are in view after deactivating extruded view



After assigning insertion point, use Set display options to uncheck Extruded view



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Per the drawings, there are two 24" diameter pipe loads dimensioned from the left side beam column intersection on the W18 beam, one 15' feet from the left beam/column intersection and the other 3' away in the Y direction from the centerline of the first pipe. Left click the AUTO18 beam and use **Assign>Frame loads>Point**. With this option, you can assign one or more point loads along selected frames based on percentage or actual distances from I to J end using current units. Click + sign to add additional load pattern for pipe loads as shown. Name the Load Pattern "PIPE", type DEAD, Self weight multiplier of 0 to avoid double counting self-weight of the structure, then press 'Add new load pattern' to add it to the list and press OK. Alternatively, we could have used **Define>Load Patterns** beforehand



Click + sign to define additional load patterns

Load Pattern N	lame)		•	Units Kip.	it, F 💌
Load Type and	d Direction		Option	ns	
 Forces 	C Momen	its	0	Add to Exist	ing Loads
Coord Sys	GLOBAL	-		Replace Ex	isting Loads
Direction	Gravity	•	0	Delete Exist	ing Loads
Point Loads	1	2		2	4
Distance).	0.25	0.1	75	4.
Load).	0.	0.		0.
 Relativ 	e Distance fr	om End-l	С АЬ	solute Dista	nce from End-I
				1	
			_	OK	Cancel



Switch Load Pattern to PIPE, select 'Absolute distance' from End I with Kip, ft units and assign a 2.5 Kip load at 15 ft. and 18 ft. as shown below in the gravity direction and press OK.

Frame Point Loads							
Load Pattern Name + PIPE Load Turne and Direction							
Forces Moments Coord Sys GLOBAL Direction Gravity	Add to Existing Loads Replace Existing Loads Delete Existing Loads						
Point Loads 1. 2. Distance 15. 18. Load 2.5 2.5	3. 4. 0. 0. 0. 0.						
C Relative Distance from End-I OK Cancel							



Right click any element or any joint to review or modify information. Here you can modify any parameter on the form using any of the tabs by double clicking with your left mouse key in the white area. Go ahead and press OK or Cancel without modifying anything at this time.

	Object Model - Line Information	
Object Model - Line Information Location Assignments Identification Label 5 Design Procedure Steel Frame Section Property W18x106 (AUT018) Property Modifiers None Material Overwrite None	Location Assignments Loads Design Identification Label 5 Design Procedure Steel Fr	irame
Heleases None Patial Fixity Springs None Local Axes Default End Length Offsets None Max. Station Spacing 2. Station at Elm Intersect Yes Station at Conc Loads Yes P-Delta Force None Noninear Hinges None Line Mass None Automatic Mesh Mone Material Temp Default Group ALL Double click white background cell to edit item.	Coordinate System GLOBAL Load Direction Gravity Point Force 2.5 at 15. Point Force GLOBAL Load Direction Gravity Point Force 2.5 at 18. Double click white background cell to edit item.	Load Pattern Name Units + PIPE Image: Straig Load Strai

We will use a different joint load assignment method for the load assignment on the W16 beam. Per the drawing, the pipe load is 2'6" away from the right side intersection of the W16 beam and the column, so click the 'Draw special joint' button • and type -2'6" in the Y direction as shown. Next, click the intersection of the W16 beam and column as shown below with the grid point bubble to add a joint. The Draw special joint option will draw joints offset from wherever you mouse click. Since drawings often reference offset dimensions, this can be a useful option for assigning joint loads or to create joints in order to connect the dots to model frames.

Properties of Object (
0.	
-2'6'	
0.	



Press select arrow or Esc key to go into select mode, then click the joint to select and Assign>Joint load>Forces. Change load pattern name to PIPE or add a new load pattern if you wish to create separate load cases for different size pipe loads, then assign a 3 Kip joint load in the –Z (gravity) direction and press OK. Press F4 to clear load assignment.

Joint Forces		
Load Pattern Name	•	Units Kip, ft, F
Force Global X	0.	GLOBAL
Force Global Z	3	Options C Add to Existing Loads
Moment about Global X Moment about Global Y	ju. 0.	Replace Existing Loads Delete Existing Loads
Moment about Global Z	0.	OK Cancel



Click 'Select all' button as shown, then from the main menu **Edit>Replicate** and type dx 20' increment 6 to replicate the selected elements and joints 6 times at 20 ft. each in the X direction. As an exercise, click the 'Modify/Show Replicate Options button. Here you can pick and choose what you want to replicate what you don't (load assignments, local axis rotation, restraints, etc). Cancel or Press OK on the Replicate Options to accept all, then press Ok on the Replicate screen





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This is what your model should now look like. Click once in the 3D view window to make it the 'active' window. Use 'set display options' \square to activate extruded view, click the zoom button^P and hold down your mouse key to window into the area in the far X direction (see next page).

In a real design, we would adjust the pipe loads to account for different tributary area load distribution, but for this example, we will leave all bays with the same pipe loads as assigned on the end frame. By selecting frames, users can **Assign>Frame loads>Distributed** or **Assign>Frame>Fireproofing** to assign other loads which we will ignore for this exercise



SAP2000 offers an automated feature to assign fire cladding weight which can save time compared to manual calculation and assignment of fire cladding

ssign Frame Fireproofing		
 Type Sprayed On Fireproofing with Auto Perimeter Fireproofing Thickness 	0.1667	
No Fireproofing On Top Flange		
 Sprayed Un Fireproofing with User Perimeter Fireproofing Thickness Fireproofing Perimeter (At Center of Fireproofing) 		
 Encased In Concrete Box Fireproofing Cover Thickness No Fireproofing On Top Flange 		
Density Fireproofing Weight per Unit Volume	15.	
Options C Replace Existing Fireproofing C Delete Existing Fireproofing	Units	
OK Cancel		

If the extruded view does not appear, press F4 and try again. Next, we are going to learn how to rotate the local axis of frames. Left click the column shown below to select as shown below right and **Assign>Frame>Local axes**, type 90 degrees and press OK.





If you zoom in on the extruded view, you can view how the local axis has been rotated. By rotating the local axis, you may activate the red/white/blue local axis arrows in the planar view. Local Axes 1, 2 and 3 correspond to the arrow colors red, white and blue, just like the American flag. Frames, joints, links and area finite elements each have their own local axes which can be viewed anytime using the 'set display options' dialogue. Press F4 to clear the arrows and press undo button to undo the rotation.


Next we will draw the grating spans for the air coolers. Click anywhere in the left window to make it active, then press the xy button to switch to plan view. You may have to click the up/down arrows $\Phi = \Phi$ in order to move XY plane to Z = 40 ft top level as shown. In order to view full 3D window, click once in the 3D window to make it active, then press 3-d button or press F3 for full view



Press 'Quick draw frame/cable element' as shown, click to change section of W10X17 Pinned, hold down your left mouse and window around gridline 5 as shown. Repeat this draw procedure one-strip-at-a-time for grids 1 - 4 too. The quick draw frame element enables you to window around an area to draw multiple frames very quickly, but it divides each frame at visible gridlines. So each W10X17 beam is divided at each gridline B through F. Since the 'Quick draw' frame option draws and divides the frames at each grid intersection, we draw one strip at a time to avoid drawing beams along the Y direction at grid intersections.



Next, we will replicate joints to make modeling of stitch bracing easier. In plan view, click each of the 4 joints shown below left to select, then **Edit>Replicate** to replicate 24 times (increments) 5 ft. each in the X direction. Press OK



Replicate	
Linear Radial Increments dx 5. dy 0. dz 0. Increment Data Number 24	Mirror Replicate Options Modify/Show Replicate Options 2 of 2 active boxes are selected Delete Original Objects
ОК	Cancel

Click 'Draw frame/cable element', change section to WT4X9 Pinned as shown and draw the stitch bracing by "connecting the dots" as shown below. Remember to right click in order to move your cursor while in draw mode. The additional joints which were not used to draw bracing will not affect the model at all since they are associated with a frame/beam element object.



Next, go to **Define menu>Section properties>Area properties** to create a shell finite element for our grating. Change material to A992 steel and type .5" in the membrane and bending stiffness fields. Next, press the Set Modifiers button where we will zero out the weight and mass while minimizing the stiffness, since we do not want to consider the grating as part of our structural system, only a modeling tool to transfer area loads to beams while avoiding load distribution to bracing underneath. Type .01 in every field except Mass and Weight where you type 0 to zero out the weight and mass as we will assign grating self weight and live load manually based on vendor data and known loading.

Shell type area finite elements distribute loads only at meshed joint locations. We will not mesh this Grating shell at locations where there is bracing underneath to avoid distributing load to the bracing

Shell Section Data			
Section Name GRATING Section Notes Modify/Show		Use .01 to reduce section properties the weight and mass	and zero
Display Color	P	roperty/Stiffness Modification Factor	S
o Shell - Thin		Property/Stiffness Modifiers for Analysis	
C Shell - Thick		Membrane f11 Modifier	.01
C Plate Thick		Membrane f22 Modifier	.01
C Membrane		Membrane f12 Modifier	.01
Modify/Show Layer Definition		Bending m11 Modifier	.01
Material If y	vou are in ft. its. 5" will	Bending m22 Modifier	.01
Material Name + A992Fy50 CO	nvert to ft	Bending m12 Modifier	.01
Material Angle JU. Uni	its	Shear v13 Modifier	.01
Membrane 0.0417		Shear v23 Modifier	.01
Bending .5"		Mass Modifier	0
Concrete Shell Section Design Parameters		Weight Modifier	0
Modify/Show Shell Design Parameters			
Set Modifiers Thermal Properties		OK Car	ncel
OK Cancel	_		

Click 'Quick draw area element' button as shown, making sure the section is the GRATING section we just defined and hold down your mouse and window around the entire top level in plan view as shown to draw grating. The Quick draw area element, like the quick draw frame tool, divides the elements at each visible grid intersection. Press Esc key on your keyboard or Select button to switch to select mode



Use **Select>Select>Properties>Area sections** to select GRATING and click OK to select them. Next, use **Edit >Edit areas>Divide areas** and type in a 1 X 3 mesh as shown below in order to divide the mesh into thin strips forcing it to distribute load one-way and press OK. If we wanted the grating to distribute two-way, or one-way in the Y direction, we would have meshed differently or not meshed at all. This exercise helps demonstrate how users can control load distribution.

	Divide Selected Areas	
Select Sections	Divide Area Into This Number of Objects (Quads and Triangles Only) Along Edge from Point 1 to 2 Along Edge from Point 1 to 3	Units Kip, ft, F
GRATING	C Divide Area Into Objects of This Maximum Size (Quads and Triangles Only) Along Edge from Point 1 to 2 Along Edge from Point 1 to 3	
OK Cancel	 Divide Area Based On Points On Area Edges (Quads and Triangles Only) Points Determined From: Intersections of Visible Straight Grid Lines With Area Edges Intersections of Selected Straight Line Objects With Area Edges Selected Point Objects On Area Edges 	
	C Divide Area Using Cookie Cut Based On Selected Straight Line Objects Extend All Lines To Intersect Area Edges	
	C Divide Area Using Cookie Cut Based On Selected Point Objects Rotation of Cut Lines From Area Local Axes (Deg)	
	C Divide Area Using General Divide Tool Based On Selected Points and Lines Maximum Size of Divided Object	
	Local Axes For Added Points Make same on Edge if adjacent corners have same local axes definition Make same on Face if all corners have same local axes definition	
	Restraints and Constraints For Added Points Add on Edge when restraints/constraints exist at adjacent corner points (Applies if added edge point and adjacent corner points have same local axes definition) Add on Face when restraints/constraints exist at all corner points (Applies if added face point and all corner points have same local axes definition)	OK Cancel

Below is what your plan view should look like now. Next, window around the entire plan view to select area elements in order to assign loads. Don't worry if you also select frame elements and joints along with the areas.

With SAP2000, you can assign area loads before or after meshing. SAP2000 keeps track of area load assignments no matter how the areas are meshed afterward.





Go to **Define>Load patterns** and define load patterns (which used to be called 'load cases' in previous versions) as shown below and press OK. Earlier we added the PIPE load case while assigning loads. This is the more conventional way of defining load patterns. Careful not to have more than 1 load case with self weight multiplier of 1 or you will double count or triple count the self weight of the structure.

Define Load Patterns					
Load Patterns Load Pattern Name AIRCOOLER	Type DEAD 🔽	Self Weight Multiplier	Auto Lateral Load Pattern		Click To: Add New Load Pattern Modify Load Pattern
DEAD PIPE GRATINGSELFWT GRATINGLIVE AIRCOOLER	DEAD DEAD DEAD LIVE DEAD	1 0 0 0		•	Modify Lateral Load Pattern Delete Load Pattern
				•	Show Load Pattern Notes OK
	· 				Cancel

Next, go to **Assign>Assign area loads>Uniform (shell),** change load pattern name to GRATINGLIVE and type 90psf in the load field and press OK. SAP2000 will automatically convert to current units. Click previous selection button to reselect and **Assign> Assign area loads>Uniform** (shell), change load pattern to GRATINGSELFWT enter 15psf and press OK. This is a faster, less error prone method of load distribution as compared to assigning the grating loads as distributed frame loads based on tributary area. Press F4 to clear screen of load assignments if the screen appears cluttered. Save model and name it SAPTutorial. It's a good idea to save your model often

Area Uniform I	oads			
Load Pattern N				
	INGLIVE			
Load	90psf		C Add	to Existing Loads
Coord System	GLOBAL	•	Rep	lace Existing Loads
Direction	Gravity	•	C Dele	ete Existing Loads
	OK		Cano	el

Area Uniform Loads	
Loa d Pattern Name + GRATINGSELFWT	Vnits Kip, ft, F
Uniform Load	Options
Load 15psf	Add to Existing Loads
Coord System GLOBAL	Replace Existing Loads
Direction Gravity 💌	C Delete Existing Loads
OK	Cancel

Press F4 to clear screen of clutter from assignments

	\heartsuit	\sim			\checkmark	\sim		/ Ÿ
5)-				RUNL RUNL -R.S.	<u>A 10. 14</u>	-8.35 1 83	n. n.hrn.h. A	1.10. 0.400.50 A
	0.00		.ce, 6.ce, -8	1.00, 1.00, -8.3	A	-8.35	10, 0.00, -8. IL	8.59, 0.50, -5.35
		8, 88, - A ₁ 34	.cs, 8.ce, -b,a	6,8% 0,80, -8,35	9,09, 8,88,		W, D.CO, -B, 35	9.87, 0.80, -8.3
			CE 0 CE -0.35	0.183, 0.183, -8.35	8 199, 8 69,	-0.15 01	18,8 66,-8 25 18,8 66,-8 75	0.00, 0.00, -0.26
	/	-0.15 F	68 8 68 -8.25	0.80, 0.80, -8 35	8 69, 8 69	-0.15 81	18, 8 68, -8 25	0.80, 0.80, -8.35
<u>J</u> –	8.88.	8,88, 10,35	.08. 8.088.35	0.80, 0.80, -8.35	8,68, 8,68,	-6.35 8.0	8, 8,68, 18,35	9.80. 0.808.35
Ă	8.88.	8.680.35	.08. 8.088.35	0.80, 0.80, -8.35	8,68, 8,68,	-8.35 8.1	10. 0.008.25	9.89. 0.808.35
2)-		8,88, *0,35 8	108, 8,08, 18,09	COROL CURCH TRUCK	8,08, 8,08,	-8440 84	0, 0,00, 18,23 8, 8,98, -8,5	9-04-0400-18-04 9-04-0400-18-04
		. m, /a.u. /	.ce, 8.ce, 8.L	0.80 0.80, 18.36	8.66, 8.68,	10.35 10.	18, 8.66, 8.3	4.80, 0.80, /8.36
	8.88,	NBK -0.35	.68, 8,69, -8.35	0.83, 0.83, -8.36	8.66, 6,6%	-8.35 8.1	88, 8,00% -8,35	9.89, 6.89 -8.36
Ŀſ								

Next, we will add side beams and bracing, so we need to add gridlines to facilitate modeling. Click anywhere in your plan view window to make sure that it's the active window and press xz button. You may need to use up/down arrow keys to move to Y=30 ft. Double click any gridline to display the Define grids dialogue



Add gridlines in the Z direction for 13, 19, 25, and 31 feet as shown to facilitate drawing the new beams and bracing. SAP2000 will sort out the sequence when you press OK

📕 De	efine G	irid System	ı Data					\mathbf{X}
<u>E</u> dit	<u>F</u> ormat	t						
								Grid Lines
s	System	Name	GL	.0BAL		Kip.	. ft, F 📃 💌	Quick Start
	- M Grid Data							
		Grid ID	Ordinate	Line Type	Visibility	Bubble Loc.	Grid Color 🔺	
	1	A	0.	Primary	Show	End		
	2	В	20.	Primary	Show	End		\sim γ γ γ γ γ γ γ γ
	3	C	40.	Primary	Show	End		
	4	D	60.	Primary	Show	End		3=
	5	E	80.	Primary	Show	End		
	6	F	100.	Primary	Show	End		
	7	G	120.	Primary	Show	End		
	8							
EY	Grid Da	ta						Display Grids as
		Grid ID	Ordinate	Line Tupe	Visibilitu	Bubble Loc	Grid Color 🔺	G. Ordinatos C. Spacing
	1	1	0	Primaru	Show	Start		to ordinates to opacing
	$\frac{1}{2}$	2	75	Primary	Show	Start		
	3	3	15	Primary	Show	Start		Hide All Grid Lines
	4	4	22.5	Primary	Show	Start		
	5	5	30	Primary	Show	Start		Glue to Grid Lines
	6				0.1011			
	7							Bubble Size 5.5
	8						-	
	Grid Dal	ta		· · · · ·		1		
ے _ا								Reset to Default Color
		Grid ID	Ordinate	Line Type	Visibility	Bubble Loc.	▲	
	3		28.	Primary	Show	Start		Reorder Ordinates
	4		34.	Primary	Show	Start		
	5	Z2	40.	Primary	Show	End		
	6		13					
	7		19					
	8		25					
	9		31					OK Cancel
	10						-	

No sections were specified on the drawing for the side beams and bracing, so we will use W10X17 beams and W8X21's for the bracing. Alternatively, we could have assigned an Autoselect list in order to have the program optimize for lightest section. Click the 'Quick draw frame' option and window around the gridline at Z elevation 19 ft. per the drawing. This will draw 6 frames/beams inside the window area, dividing them at each visible gridline.



Repeat this draw technique at elevations 25 ft and 31 ft. as well as at 13ft in the two bays between 5B and 5C and 5E and 5F. With gridlines so close together, it may be easier to toggle off your default 'snap to points and grid intersections' button temporarily by clicking it.



Click to activate snap tools for snap to 'points and intersections' as well as the 'ends and midpoints' snap tool just below it. Click 'Draw frame/cable element' button, change the section to W8X21 Pinned and draw bracing as shown below. SAP2000 will create joints internally to connect the bracing to the beams to transfer shear, but SAP's object based modeling will reformulate the output in order to report and design the beams as they were drawn without dividing the beams into two pieces in the output.

R	🔀 3-D View			
- <mark>0</mark> - k				
•				
×		Properties of Object		×
		Line Object Type	Straight Frame	
\bigtriangledown	Both of these snap tools	Section Moment Beleases	W8X21 Pinned	
	should be activated in order	XY Plane Offset Normal	0.	
	intersections	Drawing Control Type	None <space bar=""></space>	_
all [®]				
ps ^R				
- 1				
-••	Mid Point Let	X 10		
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×				
- •				
M				Δ_



Next, we will select these newly drawn beams and braces in order to replicate them to the other side. Press Esc key or the select button to switch into Select mode, then use **Select>Select>Properties>Frame sections** and select W8X21 as shown. Press OK





The first graphic shows the W8X21's's selected. Next, window around the area moving the mouse left to right as shown below in the bottom left in order to select the beams without selecting the columns. Note that this selection technique selects some additional joints, but replicating joints won't hurt anything as along as the joints are associated with a frame and not disconnected out in space.



Next, use **Edit>Replicate** in order to copy the selected beams and bracing to the other side, 1 increment 30 ft. in the –Y direction (-30 dy) as shown below. Next, we will add an IBC2006 seismic load and a wind load in order to demonstrate SAP2000's auto-lateral load generation.

Replicate		
Linear	Radial	Mirror
Increments		Replicate Options
dx 0		Modify/Show Replicate Options
dy -30		10 of 10 active boxes are selected
dz 0.		Delete Original Objects
- Increment Data	•	
Number 1		-
	ПК	Cancel



As an alternative to manually calculating seismic and wind loads applied as joint loads or distributed loads, SAP2000 offers options for automatic generation of wind and seismic loads per IBC, ASCE and other standards. Go to Define>Load patterns, add a load case named QX, type Quake, Auto lateral load IBC2006 as shown below and press 'Add new load pattern' button to add it, then press 'Modify Lateral load pattern' to specify IBC parameters. Select option to lookup Ss and S1 values based on zip code using 79901 zip code below for El Paso, TX. Press OK until you return to the Define load pattern dialogue

Define Load Patterns				
Load Patterns Load Pattern Name	Type QUAKE	Self Weight Multiplier	Auto Lateral Load Pattern	Click To:
DEAD PIPE GRATINGSELFWT GRATINGLIVE AIRCOOLER	DEAD DEAD DEAD LIVE DEAD			Modify Lateral Load Pattern Delete Load Pattern
QX	QUAKE	0	IBC 2006	Show Load Pattern Notes
,				Cancel

Zip Code Data			
Location Data			
State (or Equivalent)	Texas		
Zip Code	79901		
Data For Selected Zip Co	de		
Zip Code	79901		
State (or Equivalent)	Texas		
Latitude	31.7609		
Longitude	-106.479		
OK - Use Selected Zip Code Cancel			

Load Direction and Diaphragm Eccentricity Global X Direction	Seismic Coefficients Ss and S1 from USGS - by Latitude/Longitude
Global Y Direction Ecc. Ratio (All Diaph.) 0.05 0verride Diaph. Eccen. 0verride	Ss and S1 from USUS - by 2 p Lode Ss and S1 User Specified Site Latitude (degrees) Site Longitude (degrees) 2 [106.479]
Time Period C Approx. Period Ct (ft), x = © Program Calc Ct (ft), x = 0.028; 0.8 C User Defined T =	Site Zip Code (5-Digits) [2] 79901 0.2 Sec Spectral Accel, Ss 0.3325 1 Sec Spectral Accel, S1 0.1067 Long-Period Transition Period 8.
Lateral Load Elevation Range Program Calculated User Specified Max Z Min Z	Site Class B Site Coefficient, Fa Site Coefficient, Fv Calculated Coefficients
Factors 8. Response Modification, R 8. System Overstrength, Omega 3. Deflection Amplification, Cd 5.5 Occupancy Importance, I 1.	SDS = (2/3) * Fa * Ss 0.2217 SD1 = (2/3) * Fv * S1 0.0712 Update Data OK Cancel

Next, add load pattern named WY type Wind using Auto Lateral load pattern ASCE 7-05 and press 'Modify Lateral load pattern' to specify parameters. Change the default to 'Exposure from Frame and area objects' Include Area objects which we will add later for the air cooler and include Frame objects (open structure). Wind direction angle 90 degrees (Y direction) for the wind load generation on the frame elements, 110 mph and press OK. Later we will assign wind load coefficients to area objects which simulate the dimensions of the air coolers

De

fine Load Patterns					
Load Patterns Load Pattern Name WY DEAD PIPE GRATINGSELFWT GRATINGELVE AIRCOOLER QX WY	Type WIND ▼ DEAD DEAD LIVE DEAD QUAKE WIND	Self Weight Multiplier	Auto Lateral Load Pattern ASCE 7-05		iick To: Add New Load Pattern Modify Load Pattern Modify Lateral Load Pattern Delete Load Pattern Show Load Pattern Notes
ASCE 7- Expo © Wind Win Lee Cas e1 F e2 F	Co Wrmd Load Pattern Sure and Pressure Coefficier Exposure from Extents of R Exposure from Frame and A Include Area Objects Include Frame Objects Include Frame Objects Exposure Parameters d Direction Angle dward Coeff, Cp e (ASCE 7-05 Fig. 6-9) Ratio (ASCE 7-05 Fig. 6-9) Ratio (ASCE 7-05 Fig. 6-9) Ratio (ASCE 7-05 Fig. 6-9) Modify/Show Exposu Sure Height Program Calculated User Specified Maximum Global Z Minimum Global Z	nts igid Diaphragms rea Objects (Open Structure) 90 90 90 90 90 90 90 90 90 90	Wind Coef Wind Spi Exposure Important Topograp Gust Fac Direction Solid / Gi	ficients eed (mph) ce Factor ohical Factor, Ka tor ality Factor, Kd ross Area Ratio	110 B 1. 1. 0.85 0.85 0.2

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Next, as a modeling technique we will add "dummy" area elements and joint loads to simulate air cooler wind exposure. Double click a grid to display Define grid dialogue and add Z grids at 50 ft and 60 ft. and an X grid at 19.9 ft. The purpose of the 19.9 X grid is to create aircooler areas for wind load that are disconnected from one another, as we will replicate them 20' apart and keep them separate. Press OK to add the grids.

Edit Format System Name GLOBAL Units Gid Lines X Grid Data X Grid Data Quick Start X Grid Data Y Grid Data Gid Color Quick Start X Grid Data Primary Show End Grid Color Y Grid Data Primary Show End Grid Color Y Grid Data Primary Show End Display Grids as Y Grid Data T Ordinate Une Type Visibility Bubble Loc. Grid Color Y Grid Data T Ordinate Une Type Visibility Bubble Loc. Grid Color Display Grids as Y Grid Data T Ordinate Une Type Visibility Bubble Loc. Grid Color Hide All Grid Lines Y Grid Data T Show Start Hide All Grid Lines	Define (Grid System	Data					X
System Name GLOBAL Units Gid Lines X Grid Data X Grid Data Image Visibility Bubble Loc. Grid Color Image Visibility Display Grids as Image Visibility Display Grids as Image Visibility Grid Color Image Visibility Display Grids as Image Visibility Image Visibi	dit <u>F</u> orma	at						
System Name GLOBAL Kip, ft, F Quick Stat X Grid Data						Units		Grid Lines
System Name Product Product <td>Custom</td> <td>n Mama</td> <td>6</td> <td></td> <td></td> <td>- Vin</td> <td>9 E -</td> <td>Duick Start</td>	Custom	n Mama	6			- Vin	9 E -	Duick Start
X Grid Data Image: A grid ID Ordinate Line Type Visibility Bubble Loc. Grid Color 1 A 0. Primary Show End 3 C 40. Primary Show End 4 D 60. Primary Show End 5 E 80. Primary Show End 6 F 100. Primary Show End 7 G 20. Primary Show End Y Grid Data Instructure Instructure Display Grids as Y Grid Data To Primary Show Stat 3 3 15 Primary Show Stat	System	ii Naliie	Į.	LODAL		IviP,	.u, r 🔄	
Grid ID Ordinate Line Type Visibility Bubble Loc. Grid Color 1 A 0. Primary Show End 3 C 40. Primary Show End 4 D 60. Primary Show End 5 E 80. Primary Show End 6 F 100. Primary Show End 7 G 20. Primary Show End 9 Grid Data 19.9	-X Grid Da	lata						
Girid ID Urdinate Line Type Visibility Bubble Loc. Girid Color 1 A 0. Primary Show End 2 B 20. Primary Show End 3 C 40. Primary Show End 4 D 60. Primary Show End 5 E 80. Primary Show End 6 F 100. Primary Show End 7 G 20. Primary Show End 9 Girid Data 19.3								
1 A U. Primary Show End 2 B 20. Primary Show End 3 C 40. Primary Show End 4 D 60. Primary Show End 5 E 80. Primary Show End 6 F 100. Primary Show End 7 G 20. Primary Show End 9 Grid Data 13.3 Image Image Image Y Grid Data Image Yisibility Bubble Loc. Grid Color Image 1 1 0. Primary Show Statt Image Image 3 3 15 Primary Show Start Image Image		Grid ID	Urdinate	Line Type	Visibility	Bubble Loc.	Grid Color 🔺	
2 B 20. Primary Show End 3 C 40. Primary Show End 4 D 60. Primary Show End 5 E 80. Primary Show End 6 F 100. Primary Show End 7 G 20. Primary Show End 8 19.3 Primary Show End Primary Y Grid Data T 0. Primary Show Stat Display Grids as 2 2 7.5 Primary Show Stat Hide All Grid Lines		A	U.	Primary	Show	End		0000000
3 C 40. Primary Show End 4 D 60. Primary Show End 5 E 80. Primary Show End 6 F 100. Primary Show End 7 G 20 Primary Show End 8 19.9 Primary Show End Display Grids as Y Grid Data I 0. Primary Show Start Display Grids as 2 2 7.5 Primary Show Start Hide All Grid Lines	2	В	20.	Primary	Show	End		
4 U b0. Primary Show End 5 E 80. Primary Show End 7 G 100. Primary Show End 7 G 20. Primary Show End 8 19.9 Primary Show End 7 Grid ID Ordinate Line Type Visibility Bubble Loc. Grid Color 1 1 0. Primary Show Start C Ordinates C Spacing 3 3 15 Primary Show Start Hide All Grid Lines	3	U	40.	Primary	Show	End		8=====
5 E 80. Primary Show End 6 F 100. Primary Show End 7 6 120. Primary Show End 8 19.9 Image: Show End Image: Show Image: Show Y Grid Data Image: Show Stat Image: Show Stat 1 1 0. Primary Show Stat 3 3 15 Primary Show Stat	4	D	60.	Primary	Show	End		8
b F IUU. Primary Show End 7 G 120. Primary Show End 8 19.9 Image: Show End Image: Show Image: Show Y Grid Data Image: Show State Image: Show State 1 1 0. Primary Show State 3 3 15 Primary Show State	5	E	80.	Primary	Show	End		
Image Image Show End Y Grid Data 19.3 Image Display Grids as Y Grid Data Image Visibility Bubble Loc. Grid Color 1 1 0. Primary Show Statt 2 2 7.5 Primary Show Statt 3 3 15 Primary Show Start	6	F	100.	Primary	Show	End		
Ø 13.3 Y Grid Data I 1 0. 2 2. 7.5 Primary Show Start		b	10.0	Primary	Show	End		
Y Grid Data V Grid Data V Grid Data Visibility Bubble Loc. Grid Color ▲ 1 1 0. Primary Show Start 2 2 7.5 Primary Show Start 3 3 15 Primary Show Start	8		13.9					
Grid ID Ordinate Line Type Visibility Bubble Loc. Grid Color ▲ 1 1 0. Primary Show Start ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■<	-Y Grid Da	ata	\bigcirc					Display Grids as
1 1 0. Primary Show Start 2 2 7.5 Primary Show Start 3 3 15 Primary Show Start		Grid ID	Ordinate	Line Type	Visibility	Bubble Loc.	Grid Color 🔺	Ordinates C Spacing
2 2 7.5 Primary Show Start	1	1	0.	Primary	Show	Start		
3 3 15 Primaru Show Start	2	2	7.5	Primary	Show	Start		
o o o o o o o o o o o o o o o o o o o	3	3	15.	Primary	Show	Start		🔲 Hide All Grid Lines
4 4 22.5 Primary Show Start	4	4	22.5	Primary	Show	Start		E Glue to Grid Lines
5 5 30. Primary Show Start	5	5	30.	Primary	Show	Start		
6	6							
7 Bubble Size 5.5	7							Bubble Size 5.5
8	8						•	
Z Grid Data	Z Grid Da	ata						
Reset to Default Color		Grid ID	Ordinato	Line Turc	Visibility	Bubble Loo		Reset to Default Color
5 25 Primaru Show Start	5	ununu	25	Primaru	Show	Start		
6 28 Primary Show Start Reorder Ordinates	6		23.	Primary	Show	Start		Reorder Ordinates
7 31 Primary Show Start	7		31	Primary	Show	Start		
8 34 Primary Show Start	8		34	Primary	Show	Start		
9 72 ATT Primary Show End	9	72	41	Primary	Show	End		
10 50. Primary Show Start	10		50.	Primary	Show	Start		
11 60. Primary Show Start OK Cancel	11		60.	Primary	Show	Start		OK Cancel
	12		\square				-	

With new gridlines added



Go to Define>Section Properties>Area sections and Add new section, name it AIRCOOLER, material A992, with both membrane and Bending thickness 1". Next, click 'Set Modifiers' button and enter 0 for mass and weight as we will assign the aircooler weights later at joint locations

hell Section Data			
Section Name AIRCOOLER Section Notes Modify/Show Display Color		Property/Stiffness Modification Fac	tors
Type • Shell - Thin • Shell - Thick • Plate - Thin • Plate - Thin • Plate Thick • Plate Thick • Plate Thick • Plate Thick • Membrane • Shell - Layered/Nonlinear • Modify/Show Layer Definition Material Material Name • A992Fy50 Material Angle • Thickness Membrane • B.3333333333 Bending	Type 1" which will convert to ft units	Membrane f11 Modifier Membrane f22 Modifier Membrane f12 Modifier Bending m11 Modifier Bending m22 Modifier Bending m12 Modifier Shear v13 Modifier Shear v23 Modifier Mass Modifier Weight Modifier	1 1 1 1 1 1 1 1 1 0 0
Concrete Shell Section Design Parameters Modify/Show Shell Design Parameters Stiffness Modifiers Set Modifiers OK Cancel		ОК	Cancel

Switch your left side planar view to xz elevation view Y=0. Next click 'Quick draw area', change section to AIRCOOLER, and click just once in the upper left area shown below to the right of 1A. The addition of the 19.9 ft gridline keeps this area disconnected from the next bay by .1 ft. We will assume that the air cooler will catch wind load between 40' and 50' and transfer it to the structure below



Click to select this AIRCOOLER area and Edit>Replicate as shown 30' in the Y direction to copy it to the other side. Next, switch your planar view to yz with X=0, click 'Draw rectangular area element' and then click once on upper left corner and drag it down to the right corner as shown below. This draws 1 area element without dividing it at every visible gridline





Use 'Set display option' to activate 'Fill objects' view and press OK. The color of the area objects indicate the local 3 axis. The pink color shown below right indicates that the local +3 direction for that area element is = +X direction since +3 is perpendicular outward and away from the red face whereas -3 is outward and away from the pink face. When assigning area wind load coefficients, you must know the local 3 direction. Select the area shown below in pink and replicate it 19.9 ft one time in the X direction to complete the air cooler box

Display Options For Active W	'indow					
Joints	Frames/Cables/Tendons	General	View by Colors of			
🔲 Labels	🗖 Labels	🔲 Shrink Objects	Objects			
🔽 Restraints	Sections	Extrude View	C Sections			
🗹 Springs	🗌 Releases	Fill Objects	C Materials			
🔲 Local Axes	🔲 Local Axes	🔽 Show Edges	C Color Printer			
🔲 Invisible	Frames Not in View	🔽 Show Ref. Lines	C White Background, Black Objects			
Not in View	🗖 Cables Not in View	🔲 Show Bounding Boxes	C Selected Groups Select Groups			
	Tendons Not in View					
Areas	Solids	Links	Miscellaneous			
🔲 Labels	🗖 Labels	🗖 Labels	🔽 Show Analysis Model (If Available)			
🔲 Sections	🗖 Sections	Properties	Show Joints Only For Objects In View			
🗌 Local Axes	📕 Local Axes	🗖 Local Axes				
Not in View	📕 Not in View	🔲 Not in View				
🧮 Apply to All Windows						
Cancel						



Next go to Select menu>Select>Properties>Area properties and click AIRCOOLER to select. Then Edit>Replicate the selected areas 20ft in the X direction 5 times/increments.



Next, switch to xy plan view Z=50 ft. Here click 'draw special joint' to add joints at the aircooler CG to assign weight. Input Offset X = 10' and Offset Z = .3 ft as shown, then click the intersection of gridlines 3 and A, and click refresh to view the joint. By default, SAP2000 enables you to view any object .83 ft on either side of the 2D planar view. You can change the .83 ft. viewing tolerance default with the Options menu>Dimensions/Tolerances. Next, press Esc key to go into select mode, select the new joint, and replicate it 20 ft. in the X direction 5 times/increments



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Still in xy plan view, zoom in and zoom out to select the 4 bottom corner joints of the aircooler elements plus the CG joint (5 joints per bay) where we will later assign the aircooler weight at the CG joint location. Then Assign>Joint>Constraints, body type to rigidly link the CG joint to the 4 corners one bay at a time. The body constraint rigidly links the joints with consideration of the moments from the offset distance. You need to assign a joint body constraint to the CG joint of each aircooler "box" in each bay. You will need to zoom in to each of the 6 bays one at a time, because the edge joints are so close together. You will need to assign a different joint body constraint for each bay which means that you will have a BODY1, BODY2, etc.



Body Constraint						
Constraint Name	BODY1					
Coordinate System GLOBAL -						
Constrained DOFs						
🔽 Translation X	Rotation X					
🔽 Translation Y	Rotation Y					
✓ Translation Z	Rotation Z					
Cancel						



Add a different BODY constraint to each 5 joints (4 bottom corners of air cooler + 1 CG joint) for each bay Left click to select each of the 6 aircooler CG load joints as shown on bottom left, then Assign>Joint loads>forces 210 kips in the –Z direction under Load pattern AIRCOOLER as shown on bottom right. According to the PR2.pdf drawing, each aircooler should be considered 350psf. Given that each bay is 20' X 30', that makes the weight of each air cooler 210 kips, which we lump at the CG of each air cooler cooler



Joint Forces		
Load Pattern Name + AIRCOOLER		Units Kip, ft, F
Loads		Coordinate System
Force Global X	0.	GLOBAL
Force Global Y	0.	
Force Global Z	-210.	Options C Add to Existing Loads
Moment about Global X	0.	Replace Existing Loads
Moment about Global Y	0.	C Delete Existing Loads
Moment about Global Z	0.	OK Cancel

Next step is to link the aircoolers to the structure. You can link the aircooler to the structure using frame elements (W14 or whatever section) or link it rigidly with joint constraints. In this exercise, we will assume that the aircooler manufacturer has already designed the legs and will deliver each aircooler as a pre-designed module. Therefore, we will link each cooler to the structure using an alternative to the joint constraint method we used before using a "DUMMYLINK" zero weight frame/column element. Go to Define>Section properties>Frame sections and click 'Add new property'. Change frame property section type to Concrete, then click circular. Change Material to A992 steel, .5 ft. diameter, then click 'Set modifiers' button. Enter 0 for Mass and Weight which we lump at the CG joint, and enter 5 multiplier for area and EI as shown below to define a stiff, but not completely rigid zero weight section. Click OK until the section is added to the working list



Frame Property/Stiffness Modification Factors							
Property/Stiffness Modifiers for Analysis							
Cross-section (axial) Area	5						
Shear Area in 2 direction	1						
Shear Area in 3 direction	1						
Torsional Constant	1						
Moment of Inertia about 2 axis	5						
Moment of Inertia about 3 axis	5						
Mass	0						
Weight	0						
OK Cancel							

Go to xz planar view Y=0 and press F4 to clear the screen. Click 'draw frame/cable element' then change section to 'DUMMYLINK' frame section which we just defined. You will need to zoom in tight in order to draw the frames to the same joint shown below, connecting the AIRCOOLER joints to structure. Both (2) air cooler joints will need to be attached to the structure in this fashion. In this screenshot, only 1 of the two are attached.



As you can see, you will need to connect both closely spaced DUMMYLINK columns to the same structural joint below where the W14 column is located. After finishing this, press Esc key or Select arrow to switch to select mode. Draw these aircooler DUMMYLINK columns for each bay in xz view Y=0.

8	📕 X-Z Plane @ Y=0		
È,		₽ @ Y =0	
• 💌 🕫 장 장 장 🕫 🖯 🛄 🖌 🛄 🕱 🖊 🖉 • •		Properties of Object Line Object Type Straight Fran Section DUMMYLIN Moment Releases Continuous XY Plane Offset Normal 0. Drawing Control Type None <space Careful as joints are spaced close together</space 	Properties of Object Line Object Type Straight I Section DUMMY Moment Releases Continu XY Plane Offset Normal 0. Drawing Control Type None <spa< th=""></spa<>
🚽 🖾 🖛 🛣 🕭		Both joints from aircooler above connect to the same column joint here	68

Use Select menu>Select to select by frame property "DUMMYLINK" to select these newly drawn columns. Next, use **Edit>Replicate** to copy 30 ft in the Y direction 1 time/increment in order to copy to the other side. Next, go to xz elevation view Y=0 and select the AIRCOOLER <u>areas</u> in that view along gridline 1 as shown below by clicking them.



The red face of the AIRCOOLER area elements in this plane tells us that the local perpendicular axis of the selected elements is (+3) is = -Y according to the way we modeled these area shell elements. Use Assign>Area loads>Wind pressure coefficients (Shell). Since we are assigning a windward load in the +Y direction to areas which have a local axis of +3 = -Y, we will need to assign a windward Cp of -.8 (which is +Y direction) to area elements in XZ plane Y=0. Area wind pressure coefficients are relative to the local 3 direction of each area. Press F4 on the keyboard to clear this load assignment.

Next, use arrow keys to move to XZ plane Y=30' to select aircooler areas for leeward wind assignment

Area Wind Pressure Coefficients					
Wind Load Case Name					
Pressure Coefficient Cp8 Windward (press varies over ht) Other (press constant over ht)	Options Replace Existing Loads Delete Existing Loads				
OK	Cancel				

In X-Z, Y=30 ft. view, select the areas along gridline 5 in order to assign the leeward side of WY load case. Assign>area loads>wind pressure coefficients as shown below on bottom right using Cp of -.5 in the "other" (leeward) direction for the same wind load case. You can use 'Set display options' to check local axes of area elements. Blue arrows = +3 area/shell axis ASCE wind load generation on frames is automatic, but wind loads on area elements require an additional assignment. With this in mind, we could have also modeled pipes and/or vessels using frame elements (with or without zero weight sections) and had SAP2000 automatically generate wind load for them too.



For auto lateral load calculation of static equivalent IBC seismic loads, SAP2000 has to determine fundamental periods of the structure, which means that a dynamic modal analysis will be performed. Typically you will want to modify the mass model using **Define>Mass model**. SAP2000 offers an option to convert load cases into mass. Please specify your mass model as shown below and press OK

Define Load Pattern	ıs					
Load Patterns Load Pattern WY DEAD PIPE GRATINGSELFWT GRATINGLIVE AIRCOOLER QX	Name	Type WIND DEAD DEAD DEAD LIVE DEAD GUAKE WIND	Self Weigh Multiplier	t Auto Lateral Load Pattern ASCE 7-05 	•	Click To: Add New Load Pattern Modify Load Pattern Modify Lateral Load Pattern Delete Load Pattern Show Load Pattern Notes
	Mass Definitio	ource ment and Additional Ma ads ment and Additional Ma Multiplier for Loads d Multipl I ELFWT A VE OK	isses and Loads			Cancel
Since this design will be performed using 2005 AISC code, we will need to generate "notional" lateral loads, which is a new AISC code requirement to account for out-of-plumbness. SAP2000 offers the capability to automatically generate lateral notional loads, but users must specify the gravity loads to be used. Add a load pattern named NotDeadX, type Notional (you may have to click 'Other' before notional type appears) and press 'Add new load pattern button' then press 'modify lateral load pattern to specify parameters. For this example, let's generate notional loads based on DEAD and AIRCOOLER load patterns since these are the two most significant gravity loads in this model

Define Load Patterns					
Load Patterns Load Pattern Name NotDeadX	Type	Self Weight Multiplier	Auto Lateral Load Pattern]	Click To: Add New Load Pattern Modify Load Pattern
DEAD PIPE GRATINGSELFWT GRATINGLIVE AIRCOOLER	DEAD DEAD DEAD LIVE DEAD	1 0 0 0 0		•	Modify Lateral Load Pattern Delete Load Pattern
QX WY NotDeadX	QUAKE WIND NOTIONAL		IBC 2006 ASCE 7-05 Auto		Show Load Pattern Notes OK
	~				Cancel

Auto Notional Load Pattern Generation
Notional Load Pattern Value Base Load Pattern DEAD
Load Ratio 2.000E-03
Notional Load Pattern Direction
Global X
C Global Y
OK Cancel

Below are the auto notional load patterns named NotDeadY (notional Y direction DEAD case), NotACoolX and NotACoolY for the air cooler notional loads. SAP2000 will automatically generate the notional lateral loads at each level

Auto Notional Load Pat	tern Generation
Notional Load Pattern Va Base Load Pattern	Iue DEAD
Load Ratio	2.000E-03
Notional Load Pattern Dir C Global X C Global Y	rection
ОК	Cancel

Auto Notional Load Pa	attern Generation
Notional Load Pattern V Base Load Pattern	AIRCOOLER
Load Ratio	2.000E-03
Notional Load Pattern D	Direction
C Global X	
Global Y	
ОК	Cancel

Aut	to Notional Load Patt	ern Generation
Г	Notional Load Pattern Valu	ie
	Base Load Pattern	AIRCOOLER 🚽
	Load Ratio	2.000E-03
	Notional Load Pattern Dire	ction
	Global X	
	🔿 Global Y	

Define Load Patterns

Load Patterns		Self Weight	Auto Lateral		Click To: Add New Load Pattern
Load Pattern Name	Туре	Multiplier	Load Pattern	_	
IDEAD	DEAD	1	ļ	T	Modify Load Pattern
PIPE GRATINGSELFWT	DEAD DEAD				Modify Lateral Load Pattern
AIRCOOLER 0X	DEAD QUAKE	0	IBC 2006		Delete Load Pattern
WY ≣ NotDeadX NotDeadY	WIND NOTIONAL NOTIONAL	0 = 0 0	ASCE 7-05 Auto Auto		Show Load Pattern Notes
NotACoolX NotACoolY	NOTIONAL NOTIONAL		Auto Auto	~	[0K]
					Cancel

Next we will specify design parameters. For this example we will use the 2005 AISC Direct analysis method which enables us to avoid the time consuming task of determining K factors from alignment charts while often times achieving more economical designs compared to ELM. Go to Design>Steel frame design>View/Revise overwrites and input design code and other parameters as shown, OMF Framing type, Tau-B variable Direct analysis. You can select individual frame elements and assign design parameters using Design>Steel frame design>View/Revise overwrites. There is an excellent steel frame design manual which installs with each version of SAP2000 V12 under the 'Manuals' subdirectory.

				Item Description
	ltem	Value	•	This is either "SMF", "IMF", "OMF",
1	Design Code	AISC360-05/IBC2006		This item is used for ductility
2	Time History Design	Envelopes		considerations in the design.
3	Framing Type	OMF	7	-
4	Seismic Design Category	SME	-	
5	Importance Factor	IMF		
6	Design System Rho	OMF		
7	Design System Sds	SCBF		
8	Design System R	OCBF		
9	Design System Omega0	EBF		
10	Design System Cd	5.5		
11	Design Provision	LRFD		
12	Analysis Method	Direct Analysis		
13	Second Order Method	General 2nd Order		
14	Stiffness Reduction Method	Tau-b Variable		
15	Phi(Bending)	0.9		
16	Phi(Compression)	0.9		
17	Phi(Tension-Yielding)	0.9		
18	Phi(Tension-Fracture)	0.75		
19	Phi(Shear)	0.9		
20	Phi(Shear-Short Webed Rolled I)	1.		
21	Phi(Torsion)	0.9		×
22	Ignore Seismic Code?	No		- Explanation of Color Coding for Values
23	Ignore Special Seismic Load?	No		Explanation of Color County for Values
24	Is Doubler Plate Plug-Welded?	Yes	•	Blue: Default Value
		·		Black: Not a Default Value
et To	Default Values	Reset To Previous Values		
A	Il Items Selected Items	All Items Selected Ite	ms	Red: Value that has changed during the current session
		OK Cancel		

Next we will go to **Define>Load combinations**. Users can define their own load combos, or they can let SAP2000 create factored load combos for them based on the design code and load type. Click the 'Default design combos' option then select Steel frame design and press OK. This automatically generate factored load combos which can be reviewed or modified. Alternatively, users can create their own load combo spreadsheets in Excel and import.

Add Code-Generated User Load Combinations	Define Load Combinat	tions	
Select Design Type for Load Combinations Steel Frame Design Concrete Frame Design Aluminum Frame Design Cold Formed Frame Design Bridge Design Set Load Combination Data DK Cancel	Load Combinations	Click to: Add Ne Add Cop Modify/Si Dele	w Combo y of Combo how Combo te Combo Design Combos to Nonlinear Cases OK Cancel
	Load Combination Name (User-Generated) UDSTL12 Notes Modify/Show Not Load Combination Type Linear Add Options Create Nonlinear Load Case from Load Define Combination of Load Case Results Create Nonlinear Load Case from Load Define Combination of Load Case Results Linear Static Defact Linear Static DEAD ↓ Linear Static PIPE Linear Static GRATINGSELFWT Linear Static AIRCOOLER1 Linear Static WY Linear Static Unear Static 1.2 Unear Static 1.2	tes	You will use this Convert combos to Vonlinear cases' putton in the next slide
	Cancel		76

The 2005 AISC code requires either a nonlinear P-delta analysis, or a time consuming 1st order amplification procedure which has a number of limitations in its permitted use. For this exercise we will perform a P-delta analysis. Since P-delta is a nonlinear analysis, loads cannot be superimposed. This same concern is also true whenever modeling nonlinear tension only bracing and other NL applications. SAP2000 enables you to convert factored load combos to NL cases considering P-delta by clicking the 'convert to nonlinear cases' button and selecting which combos you wish to convert to NL. In most instances, you will want to convert all load combos to NL so select/highlight them all with your mouse as shown below and press OK. You will then see a message similar to the one below indicating how many combos were converted. You can then go to Define>Load cases to review the NL load cases which SAP2000 has automatically generated like the example below right:





Load Case Name		Notes	Load Case Type
UDSTL12-NL	Set Def Name	Modify/Show	Static Design
Initial Conditions			Analysis Type
 Zero Initial Condition 	ons - Start from Unstressed (State	C Linear
C Continue from Stat	e at End of Nonlinear Case		 Nonlinear
Important Note: L c	oads from this previous cas urrent case	e are included in the	Nonlinear Staged Construction
Modal Load Case			Geometric Nonlinearity Parameters
All Modal Loads Applie	ed Use Modes from Case	MODAL -	C None
Loads Applied			P-Delta
Load Type L	oad Name Scale Fact	or	C P-Delta plus Large Displacements
Load Patterr 💌 DE	AD 🔽 1.2		
Load Pattern DE/	AD 1.2	Add	
Load Pattern GR	ATINGSELF 1.2		
Load Pattern AIR	COOLER 1.2	Modify	
		Delete	
Other Parameters			
Load Application	Full Load	Modify/Show	<u> </u>
Results Saved	Final State Only	Modify/Show	Cancel
	D-f-ut		

SAP2000's frame element formulation automatically accounts for both big P-delta sway as well as little pdelta local member deformation as required by AISC benchmark problems. In many cases no additional intermediate joints are required for good results. But in some cases, one additional intermediate joint may be required to accurately capture little p-delta reactions. Unlike most other structural software products which do not incorporate little p-delta analysis in the element formulation, with SAP2000, you never need to add more than one intermediate joint to accurately capture p-delta effects, no matter how complicate the loading. Automatically generate 1 intermediate joint for internal analysis only by selecting all in the Assign>Frame>Automatic frame mesh using the parameters shown below with minimum number of segments 2 and press OK. Press F4 to remove the automatic mesh assignments from the graphics



Press F4 to remove these assignments from the graphics



Click 'Run analysis' button, then press 'Run Now'. After the analysis is completed, next click the 'Start steel design' button I to perform the AISC steel design check. With SAP2000, analysis is run separate from design.



You can right click individual frames to review design results, but because we used autoselect lists, you can see below that a different section was selected for design than was used for the analysis. SAP2000 uses the median section in each autoselect list as a starting point to determine loads, and we need to iterate back and forth between analysis and design, typically 4 – 6 times if lateral loads are involved, in order to match the analysis sections with the design sections. You can check analysis vs design sections using **Design>Steel frame design>Verify Analysis vs Design section** shown below

								Des	gn Options Loois Help			
el Stress Che	ck Inform	ation (AISC36	0-05/IBC2	2006)				Ι	<u>S</u> teel Frame Design	→		View/Revise Preferences
Frame ID	2		 Anal	ysis Section	W14X145				Concrete Frame Design	•		View/Revise Overwrites
Design Code	AISC360-	05/IBC2006	Desi	gn Section	W14X90			óľć	<u>A</u> luminum Frame Design	•		Select Design <u>G</u> roups
COMBO	STATION ,	/MOMENT]	INTERACTI	ON CHECK	//-MAJ-SHR-	MIN-SHR-/		ე	Cold- <u>F</u> ormed Steel Frame Design	•		Select Design Combos
ID UDSTL9	40.00	RATIO = 0.214(C) =	AXL +	B-MAJ + B-M 0.000 + 0.1	MIN RATIO 164 0.002	0.008	1		Lateral <u>B</u> racing			Set Displacement Targets
UDSTL10 UDSTL10 UDSTL10	0.00 19.00	0.140(C) = 0.632(C)	0.140 + 0.068 + 0.068 +	0.000 + 0.0 0.000 + 0.5	000 0.000 64 0.000	0.013			Overwrite Frame Design Procedure			Set <u>T</u> ime Period Targets
UDSTL10 UDSTL10	20.00	0.655(C) = 0.655(C) =	0.068 +	0.000 + 0.5 0.000 + 0.5 0.000 + 0.5	587 0.000 587 0.000	0.010			Bridge Design	►	I	Start Design/Check of Structure
UDSTL10	22.00	0.700(C) =	0.067 +	0.000 + 0.6	532 0.000	0.010 💌						Interactive Steel Frame Design
_ Modify/Show	Overwrites-	Display Detai	ils for Select	ed Item	Displa	v Complete Details-						Display Design Info
Overw	vrites		Deta	ils		Tabular Data						Make <u>A</u> uto Select Section Null
C Strength	C Deflecti			Consel	Sty	lesheet: Default						Change Design Section
e ouength		JTT	<u>UK</u>	Lancel	1a	ble Format File						Reset Design Section to Last Analysis
												Verify Analysis vs Design Section

When you see this message, typically just click No, then analyze and design a few more times until analysis and design sections all match



After analysis and design sections all match, you will see color coded graphical results based on percentage of design code allowable. Right click any frame to check results. SAP2000 runs all design combos along every 24" of every frame and defaults to display the worst case load combo and worst case location along the frame. Click Details for more info. You can see that SAP2000 automatically applied reduction factors to EA and EI per the AISC code for the Direct Analysis Method.

Steel Stress Check Information (AISC360-05/IBC2006)								
	N/1 (V100		Analysis and	d desian				
Frame ID 9 Analysis Section	W14X109		 section mate 	ch				
Design Code (AISC360-05/16C2006 Design Section	JW14X109							
COMBO STATION /MOMENT INTERACTION CHE								
ID LOC RATIO = AXL + B-MAJ -	Steel Stress Check Data AIS	C360-05/IBC2006						
UDSTL10 156.00 0.668(C) = 0.096 + 0.000 -							Lipite Kip i	in F
UDSTL10 156.00 0.669(C) = 0.097 + 0.000 +	AISC360-05/IBC2006 STE	EL SECTION CHE	CK (Summary For C	ombo and Station	0			.161
UDSTL10 228.00 0.842(C) = 0.097 + 0.001 -	Units : Kip, in, F							
$\frac{10051110}{10051110} = 228.00 = 0.843(1) = 0.098 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + $	Frame : 9 X Mi	1: 240.000	Combo: UDSTL10	Design Typ	e: Column			
UDSTL10 240.00 0.862(C) = 0.098 + 0.001 +	Length: 480.000 Y Mi Loc : 264.000 Z Mi	1: 0.000 1: 240.000	Shape: W14X109 Class: Compact	Frame Type Princol Ro	: Urdinary M t: 0.000 dec	oment Fram rees		
UDSTL10 264.00 0.893(C) = 0.098 + 0.002 +								
	Provision: LRFD Anal D/C Limit=0.950 2nd	ysis: Direct A Drder: General	nalysis 2nd Order	Reduction: Tau-b	Variable			
- Modifu/Show Duerwrites Display Details for Selected Item-	AlphaPr/Py=0.122 Alph	aPr/Pe=0.107	Tau_b=1.000	EA factor=0.800	EI factor=	0.800		
Modily Show Overwrites Display Details for Selected Rein	Ignore Seismic Code? N	D	Ignore Special EQ	Load? No	D/P Plug W	elded? Yes		
Overwrites	SDC: C I=1.	000	Rho=1.000	Sds=0.500				
	R=8.000 Omeg PhiB=0.900 PhiC	a 0=3.000 = 0.900	Cd=5.500 PhiTY=0.900	PhiTE=0.750				
G Strength C Deflection OK Course	PhiS=0.900 PhiS	-RI=1.000	PhiST=0.900					
	A=32.000 I33=	1240.000	r33=6.225	\$33=173.427	AU3=20.927			
	J=7.120 I22=	447.000	r22=3.737	S22=61.233	Av2=7.508			
	E=29000.000 +y=5 RLLF=1.000 Fu=6	0.000 5.000	Ry=1.100	233=192.000 222=92.700	Cw=140.179			
	STRESS CHECK FORCES &	MOMENTS (Combo	UDSTL10)					
	Location	Pu	Mu33 Mu22	Uu2	Uu3	Tu		
	264.000 -1	75.593 -15	.277 3309.787	0.099	-3.282	0.000		
	PMM DEMAND/CAPACITY RA	TIO (H1-1b)	700					
	D/C Katio: 0.893	= 0.098 + 0.0 = (1/2)(Pr/Pc	02 + 0.793) + (Mr33/Mc33) +	(Mr22/Mc22)				
			7114 463					
	Factor		K1 K2	B1	B2	Cm		
	Major Bending	0.325 1		1.000	1.000	1.000		
	итног репотнд	0.000		1.000	1.000	1.000		
		Litb 4	Kitb Cb					
	LID	0.000	2.094					
		Pu phi	*Pnc phi*Pnt					
		THE REPORT						

In the design code check, load combo UDSTL10 was the worst case load combo for the frame we just checked, so we can spot check deflections by clicking the 'show deformed shape' button and select UDSTL10 combo. Change units to Kip-in and right click individual joints to check deflections or click 'Start animation' in the bottom right to watch the structure animate under that applied load combination. Press F4 to exit deflected shape

		_	Show deformed shape button
X SAP2000 v12.0.1 Advanced - SapTutorial			
Ele Edit View Define Brith Draw Select Assign Analyze Display Design Options Icols Help D 그 내 행 다 여 🖋 🗃 🔸 🌶 🔎 🔎 🎾 🎾 🖉 🖉 🖉 I 3d xy xz yz nv Or 6d 🐨 🕸 문급 🗹 🖧 🗐 77 😾 • nd 💂 💭 🏭 티 다		図 % <u>,</u> ⊓ ħ t	∱•nd . [Cĩ ăi .
Image: State of the state o	Pt Obi; 72	formed Shape	
	PtElm: 72 U1 = .1466 U29 7073	· Case/Combo	
	U3 = .0761 R1 = .00489	Case/Combo	
	R2 = ∶00015 R3 = .00158	Case/Combo Name	UDSTL10 -
		Multivalued Uptions	
		C Envelope (Max or Mi	nj 🛌 🛋
		💿 Step	
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the second s	changed here	Wire Shadow	UK
		Cubic Curve	Cancel
Right Click on any joint for displacement values	Start Animation 🔄 🗢 GLOBAL 💌 Kip, in, F 💌	1	80

Next, let's do a spot check on load transfer from the grating to the beams. Click the 'Show forces/stresses' for frames button M and choose GRATINGLIVE case Moment 3-3 (major). Moments show one-way load distribution to girders. Right click beams and bracing for detailed spot-checks to see that the grating did not distribute load to the bracing underneath, just like we wanted. Press F4 to exit moment diagrams



To minimize the size of the output reports, we can select just the joints and frames of interest to be included. Switch to xy plan view and use up/down arrow keys to go to the top level and select edge joints as shown by windowing around them in order to minimize output for max deflection checks. Next, use arrow keys to go to the base and window select the restraints.

Top level edges selected in plan view



Base level selected restraints



Use Display menu>Show tables to generate output tables. The output in this example will be limited to the selected joints, and further limited by selected load cases and reports chosen. Typically avoid choosing modal for analysis results except for reporting modal dynamic analysis results



This is the default report format. As an example, let's clean it up by clicking Format-Filter-Sort and formatting it first by eliminating unwanted data which may clutter the report.

Joint Displacements												
File View Format-Filter-Sort Select Options												
Units: As Noted Joint Displacements												
										Switch		
	Joint	OutputCase	CaseType	U1	U2	U3	R1 Rediana	R2	Badiana A	between		
	<u>ופאנ</u>		Combination	In O	in	In O	0 000002195	.0 000002242		reports using		
	2		Combination	0	0	0	0.000003183	0.000003342	0.000002088	this pull-dow		
	2		Combination	0	0	0	0.000001373	-0.000003123	-0.00001782			
	2	DSTL3	Combination	0	0	0	-0.026336	-0.000103	0.000134			
	2	DSTL10	Combination	0	0	0	.0.020403	-0.000057	-0.000138			
	3	DSTL12	Combination	0	0	0	0.013737	0.000033	0.00008			
	3	DSTL12	Combination	0	0	0	.0.026398	.0.000047	-0.000135			
	3	DSTL13	Combination	0	0	0	0.026300	0.000103	0.000133			
	3	DSTL14	Combination	0	0	0	0.020402	0.000030	-0.000130			
	3	DSTL15	Combination	0	0	0	0.000001474	-0.000137	0.000042			
	3	DSTL10	Combination	0	0	0	0.000003434	0.000131	-0.000043			
	3	DSTL17	Combination	0	0	0	0.0000000102	-0.000135	0.000046			
	3		Combination	0	0	0	0.000002025	-0.000133	0.000040			
	3	DSTL13	Combination	0	0	0	0.000002213	-0.00000255	0.000001486			
	4	DSTL25	Combination	0.006515	0.01386		-0.002711	aa0000.0	-0.000967			
	4	DSTL5	Combination	0.007197	0.017805	-0.075227	-0.003068	0.000073	-0.001093			
	4	DSTL9	Combination	-0.032438	5 556715	-0.062937	-0.00613	0.000015	-0.00111			
	4	DSTL10	Combination	0.045623	-5.525548	-0.074868	0.000553	0.000119	-0.000878			
	4	DSTL11	Combination	-0.013931	2,782446	-0.05538	-0.003994	0.000031	-0.000887			
	4	DSTL12	Combination	0.0251	-2.758686	-0.061346	-0.000653	0.000083	-0.000771			
	, ,	DSTL13	Combination	-0.034842	5 550042	-0.037807	-0.005084	-0.000009586	.0.000738	•		
Reco	rd: 📕 🖣	1 🕨 🔰	of 1204				[Add Tables	Done	86		

Click within the Item column to toggle certain items to be 'Not printed' (ie. not displayed) in red and press OK. Next, go back to Format-Filter-Sort and use Sort by U2 direction (U1, U2, U3 = joint axes X, Y, and Z unless local axis was rotated) with Descending check boxed to review max deflection positive Y direction. Uncheck Descending to review max deflection in negative direction Y assuming there are negative direction deflections

Mo	dify/Show Database Table Format		
Modify/Show Database Table Format Format Filter Sort Table Sorting - Sort by these Fields Sort By U2 V Descending Then By O Descending	Format Filter Sort Format for R3 Field General Include Field in Report Repeat Field if Table is Split Force a Table Split After this Field Field Alignment and Width Field Image: Split I	Display Order and Field Visibility 1 Printed Joint 2 Printed OutputCase 3 Not Printed CaseType 4 Printed U1 5 Printed U2 6 Printed U3 7 Not Printed R1 8 Not Printed R2 9 Not Printed R3 8 Not Printed R3 9 Not Printed R3	Apply Format to Table Apply Format from File Apply Program Default Format Save to DB Table Formats File Save Table Format to File
	OK Cancel		87

Sorted max deflection in the Y (U2) direction in this example. Uncheck the 'Descending' box in the sort dialogue in order to check deflections in – direction.

Joint	Joint Displacements									
<u>F</u> ile <u>y</u>	<u>/</u> iew For <u>m</u> at-f	Filter-Sort <u>S</u> elea	t <u>O</u> ptions							
Hnits:	As Noted				Joi	int Displacements	-			
	Joint	OutputCase	U1	U2	U3					
	504		.0.031867	6 247816	-0.050085					
	507		-0.02241	6 235791	-0.030003					
	504	UDSTL13	-0.027613	5 852513	-0.043107					
	507	UDSTL13	-0.019323	5 839539	-0.0305.2					
	506	UDSTL9	-0.018775	5.70478	-0.03577					
	474	UDSTL9	0.021455	5.66011	-0.053464	Max deflection +Y				
	503	UDSTL9	-0.02348	5.602197	-0.039194	direction using				
	469	UDSTL9	0.031723	5.449352	-0.05883	Sort				
	473	UDSTL9	0.017897	5.439364	-0.041216					
	506	UDSTL13	-0.016182	5.361576	-0.023965					
	474	UDSTL13	0.018556	5.342057	-0.03756					
	468	UDSTL9	0.024044	5.327109	-0.045137					
	503	UDSTL13	-0.0204	5.275389	-0.026316					
	505	UDSTL9	-0.014094	5.163004	-0.025406					
	469	UDSTL13	0.027554	5.15597	-0.041266					
	473	UDSTL13	0.015517	5.129132	-0.028946					
	472	UDSTL9	0.013353	5.06225	-0.028591					
	502	UDSTL9	-0.016228	5.061541	-0.027727					
	468	UDSTL13	0.020831	5.032279	-0.031618					
	467	UDSTL9	0.016965	4.979019	-0.031285		_			
	~139		.0 027027	4 858767	363360.0-		` _			
Recor	rd: 📕 🖣	1 🕨 📕	of 7112			Add Tables	Done			

Use File menu to automatically export to Excel as shown below without any manual copy & pasting or editing of text files. Every single aspect of the model input and analysis and design results can be automatically exported to Excel or Access or imported from Excel or Access. SAP2000 also comes with a well documented application programming interface (API) which facilitates integrating SAP2000 with 3rd party applications as well as plug-in options. API documentation installs in the SAP2000 directory in a file named *SAP2000_API_Documentation.chm*

oint Displaceme	nts				
ile View Format-I	Filter-Sort Selec	t Options			
Export Current Ta	ble	Þ	To Excel	Joint Displacements	
Display Current Ta	ble	۱.	To Access		
Print Current Table	e as Text File	L			
			02	U3	
Export All Tables		•	6 247916	.0.050095	
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Apply Formats from		,	5.449352	-0.05883	
Add Tables			5.439364	-0.041216	
Remove Current T	able		5.361576	-0.023965	
			5.342057	-0.03756	
Close Form			5.327109	-0.045137	
503	UDSIL13	-0.0204	5.275389	-0.026316	
505	UDSTL9	-0.014094	5.163004	-0.025406	
469	UDSTL13	0.027554	5.15597	-0.041266	
473	UDSTL13	0.015517	5.129132	-0.028946	
472	UDSTL9	0.013353	5.06225	-0.028591	
502	UDSTL9	-0.016228	5.061541	-0.027727	
468	UDSTL13	0.020831	5.032279	-0.031618	
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~139		-0.027027	4 858767	aeaaen n.	
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1	TABLE: J	oint Displace	ments					-	
2	Joint	OutputCase	U1	U2	U3				
3	Text	Text	in	in	in				
4	504	UDSTL9	-0.031867	6.247816	-0.050085				
5	507	UDSTL9	-0.02241	6.235791	-0.045767				
6	504	UDSTL13	-0.027613	5.852513	-0.033472				
7	507	UDSTL13	-0.019323	5.839539	-0.030562				
8	506	UDSTL9	-0.018775	5.70478	-0.03577				
9	474	UDSTL9	0.021455	5.66011	-0.053464				
10	503	UDSTL9	-0.02348	5.602197	-0.039194				
11	469	UDSTL9	0.031723	5.449352	-0.05883				
12	473	UDSTL9	0.017897	5.439364	-0.041216				
13	506	UDSTL13	-0.016182	5.361576	-0.023965				
14	474	UDSTL13	0.018556	5.342057	-0.03756				
15	468	UDSTL9	0.024044	5.327109	-0.045137				
16	503	UDSTL13	-0.0204	5.275389	-0.026316				
17	505	UDSTL9	-0.014094	5.163004	-0.025406				
18	469	UDSTL13	0.027554	5.15597	-0.041266				
19	473	UDSTL13	0.015517	5.129132	-0.028946				
20	472	UDSTL9	0.013353	5.06225	-0.028591				
21	502	UDSTL9	-0.016228	5.061541	-0.027727				
22	468	UDSTL13	0.020831	5.032279	-0.031618			~	
н н	Di N N	int Displacem	ents / Program	Control	100)	>		
Read	ły								

Use the pull-down to switch from joint displacements to joint reactions and Format-Filter-Sort, then Sort for F3 Descending as shown. F1, F2, F3 correspond to global X, Y, and Z unless local axis of joints have been rotated.

Aodify/Show Database Table Format	
Format Filter Sort	
Table Sorting - Sort by these Fields	Apply Format to Table
Sort By F3 🔽 Descending	Apply Format from File
Then By 🔽 Descending	Apply Program Default Format
Then By	Save to DB Table Formats File
Then By	Save Table Format to File
Then By Descending	
<u>Clear Sort</u>	
	Cancel

Joint reactions now sorted by max vertical reaction. Alternatively use File menu>Create report to generate output reports using SAP2000's default settings for output report generation. You can generate custom output reports and save formats using the Advanced report writer.

Joint	Reactions									
<u>File</u>	<u>File View</u> For <u>m</u> at-Filter-Sort <u>S</u> elect <u>Options</u>									
Units:	As Noted				Joir	nt Reactions				-
										_
						50				
	Joint Text	UutputCase Text	Caselype Tevt	F1 Kin	F2 Kin	F3 Kin	M1 Kin-in	M2 Kin-in	M3 Kin-in	4
	16	UDSTL16	Combination	4.347	0.032	354.35	0	0	0	
<u> </u>	27	UDSTL15	Combination	-4.315	0.03	354.065	0	0	0	
	62	UDSTL15	Combination	-4.325	-0.05	353.727	Max ve	rtical 0	0	
	51	UDSTL16	Combination	4.34	-0.045	353.615	reaction	n for	0	
	18	UDSTL16	Combination	4.469	-0.045	353.177	selecter		0	
	49	UDSTL16	Combination	4.16	0.021	352.393	combos		0	
	29	UDSTL15	Combination	-4.211	-0.047	351.342	-	0	0	
	40	UDSTL15	Combination	0.071	-0.061	348.689	0	0	0	
	40	UDSTL16	Combination	-0.073	-0.061	348.681	0	0	0	
	60	UDSTL15	Combination	-4.486	0.016	348.659	0	0	0	
	40	UDSTL1	Combination	-0.001082	-0.062	345.272	0	0	0	
	40	UDSTL9	Combination	0.03	-6.904	342.337	0	0	0	
	40	UDSTL5	Combination	-0.000736	-0.059	340.868	0	0	0	
	62	UDSTL9	Combination	-3.002	-6.311	339.787	0	0	0	
	27	UDSTL10	Combination	-2.614	7.739	338.264	0	0	0	
	29	UDSTL9	Combination	-2.511	-7.787	335.704	0	0	0	
	60	UDSTL10	Combination	-3.147	6.326	335.139	0	0	0	
	16	UDSTL1	Combination	0.4	0.034	334.597	0	0	0	
	27	UDSTL1	Combination	-0.361	0.032	334.227	0	0	0	
	51	UDSTL1	Combination	0.391	-0.046	333.985	0	0	0	
	62	LIDSTI 1	Combination	-0.382	-0.052	333 805	0	0	0	<u> </u>
Reco	rd: 📕 🖣	1 🕨 📕	of 196				A	Add Tables	Done]

Please feel free to contact me with any modeling questions regarding SAP2000, or our SAFE program for design of basemat foundations on soil or piles. Also, feedback on this tutorial would be appreciated, as we can customize similar tutorials to meet your needs. We are very interested in working with you to increase usage of SAP2000 and SAFE wherever you believe it may improve your work process. As you can see from this tutorial, SAP2000 can be effectively used for day-to-day modeling and design applications as well as for advanced nonlinear and dynamic analysis.

We encourage you to check out our design and user manuals which install in the Manuals subdirectory of the SAP2000 installation folder

Watch & Learn video tutorials here: http://www.csiberkeley.com/support_watch&learn.html



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