UNIVERSITY OF ASIA PACIFIC
Department of Civil Engineering

Fall 2023

CE 419

Structural Engineering VII

Project Title: Calculation of Stiffness and Natural Frequency by Etabs and Staad Pro

Group Members:

Name	Registration Number
Usayed Islam	20105062
Lamia Ahmed Sadia	20105084

Submitted to:

Dr. Iftekhar Anam

Professor, Department of Civil Engineering,

University of Asia Pacific

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Manual Calculation (Project-1,2)

Horizontal Stiffness (Project-01)

Shape Function $\psi = \sin(\frac{\pi x}{L})$

Deflection at A ≠ 0, C = 0

So,

$$\psi(x) = \sin(\frac{\pi x}{L})\ ;\ \psi(0) = 0; \psi(L) = 0$$

$$\psi'(x) = (\frac{\pi}{L})\cos(\frac{\pi x}{L})\ ;\ \psi(0) = 1; \psi(L) = 0$$

$$\psi''(\mathrm{x}) = -(\frac{\pi}{L})^2 \sin(\frac{\pi x}{L})$$

Here,

R=$\frac{84+62}{2} = 73$

E=8475 ksi

=1229499 ksf

$$I_{AB} = \frac{12 * 50^3}{12} ft^4 = 125000\ ft^4$$

$$I_{AB} = \frac{\pi * 60^3}{64} ft^4 = 636174\ ft^4$$

N=2, (Gauss)

$$k^* = \int_0^L EI(\psi''(x))^2\, dx$$

$$= \int_0^{80} EI_{AB}(\psi''(x))^2\, dx + \int_{80}^{95} EI_{BC}(\psi''(x))^2\, dx$$

n	$\pm \xi_i$	A_i
1	0.0	2.0
2	± 0.57735	1.0
3	± 0.77460	0.55556
	0.0	0.88889
4	± 0.86114	0.34785
	± 0.33998	0.65215
5	± 0.90618	0.23693
	± 0.53847	0.47863
	0.0	0.56889

$$So, \xi_1 = 0.57735; \xi_2 = -0.57735$$
$$A_1 = 1; A_2 = 1$$

$$We\ know,\ \int_0^l f(x)dx = \frac{b-a}{2}\sum A_i f(x)$$

$$And$$

$$x_i = \frac{b+a}{2} + \frac{b-a}{2}\xi$$

For AB [0~80] portion,

$$x_1 = \frac{80+0}{2} + \frac{80-0}{2} * 0.57735 = 63.094$$

$$x_2 = \frac{0.3+0}{2} - \frac{0.3-0}{2} * 0.57735 = 16.906$$

For AB [80~95] portion,

$$x_1 = \frac{95+80}{2} + \frac{95-80}{2} * 0.57735 = 91.83$$

$$x_2 = \frac{95+80}{2} - \frac{95-80}{2} * 0.57735 = 83.16$$

Now,

$$k^* = \int_0^L EI(\psi''(x))^2\,dx$$

$$= \int_0^{80} EI_{AB}(\psi''(x))^2\,dx + \int_{80}^{95} EI_{BC}(\psi''(x))^2\,dx$$

$$= 1220400 * 125000 * \frac{80}{2}\int_0^{80}\{-1 * \left(\frac{\pi}{80^2}\right)^2 \sin(\frac{\pi*63.094}{80})\}^2\,dx + \int_0^{80}\{-1 * \left(\frac{\pi}{80^2}\right)^2 \sin(\frac{\pi*16.90}{80})\}^2\,dx + 1220400 * 636174 * \frac{95-80}{2} * \int_{80}^{95}\{-1 * \left(\frac{\pi}{15^2}\right)^2 \sin(\frac{\pi*91.83}{15})\}^2\,dx + \int_{80}^{95}\{-1 * \left(\frac{\pi}{15^2}\right)^2 \sin(\frac{\pi*83.16}{15})\}^2\,dx$$

$$= 1.257 * 10^{10}\ \text{kip/ft}$$

Natural Frequency (Project-02)

We know, $Natural\ Frequency,\ \omega = \sqrt{\frac{k^*}{m^*}}$

$$m^* = \int_0^L \mu(\psi(x))^2\, dx$$

$$= \left(\int_0^L \mu\left(\psi(x)\right)^2\, dx\right)$$

$$= \left(\int_0^{80} \mu_{AB}\left(\psi(x)\right)^2\, dx + \int_{80}^{90} \mu_{BC}\left(\psi(x)\right)^2\, dx\right)$$

P=173 $\frac{\mathrm{k}}{ft}$

$$\mu = \frac{173}{32.2} = 5.37\ \frac{k * s^2}{ft^2}$$

For AB[0~80] portion,

$$\int_0^{80} \mu_{AB}\left(\psi(x)\right)^2\, dx$$

$$= \int_0^{80} 5.37 * \sin(\frac{\pi x}{80})^2\, dx$$

$$= 214.8\ K\frac{s^2}{ft}$$

For BC[80~95] portion,

$$\int_{80}^{95} \mu_{BC}\left(\psi(x)\right)^2\, dx$$

$$= \int_{80}^{95} 5.37 * \sin(\frac{\pi x}{15})^2 \, dx$$

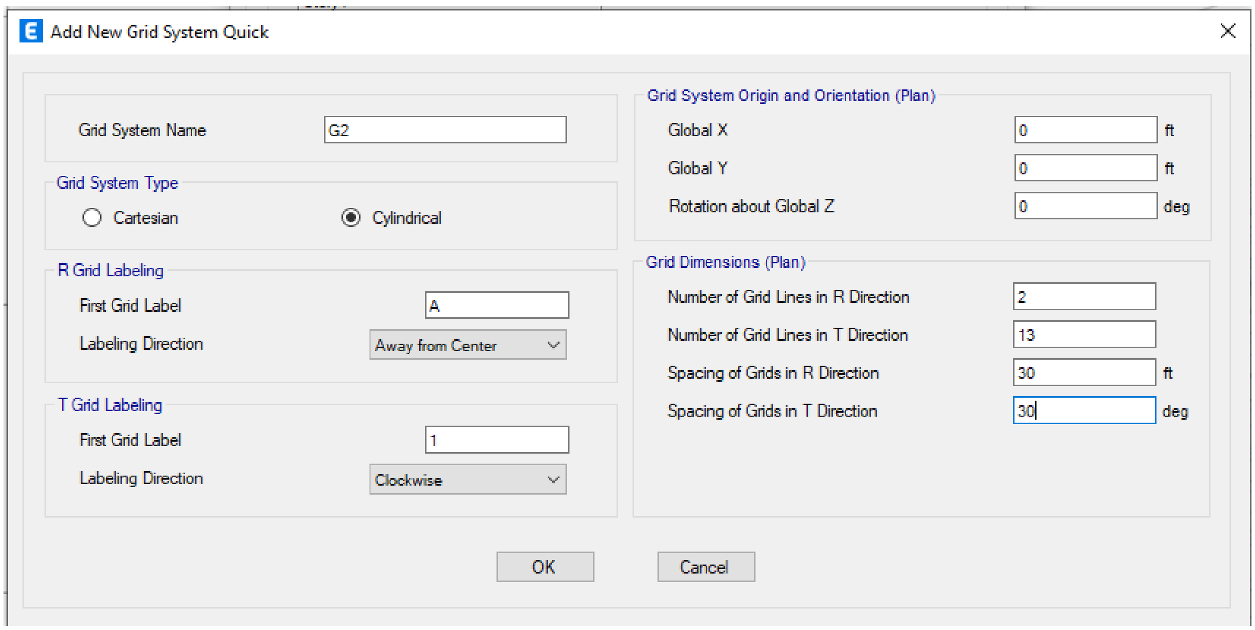
= 40.275 $K \frac{s^2}{ft}$

$m^* = 214.8 + 40.275$ = 255.075 $K \frac{s^2}{ft}$

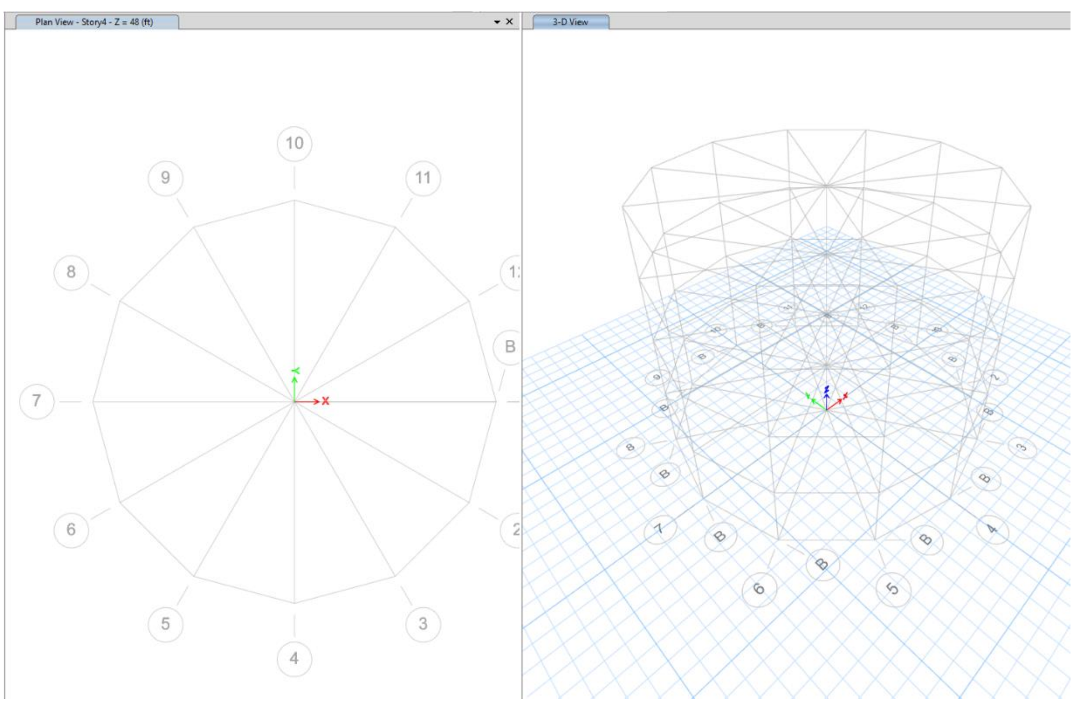
ω = $\sqrt{\frac{K}{m}}$ =$\sqrt{\frac{1.256 * 10^{10}}{255.075}}$ = 7017.15 rad/sec

Steps From Etabs(Project-01)

Step 01:



Step 02:



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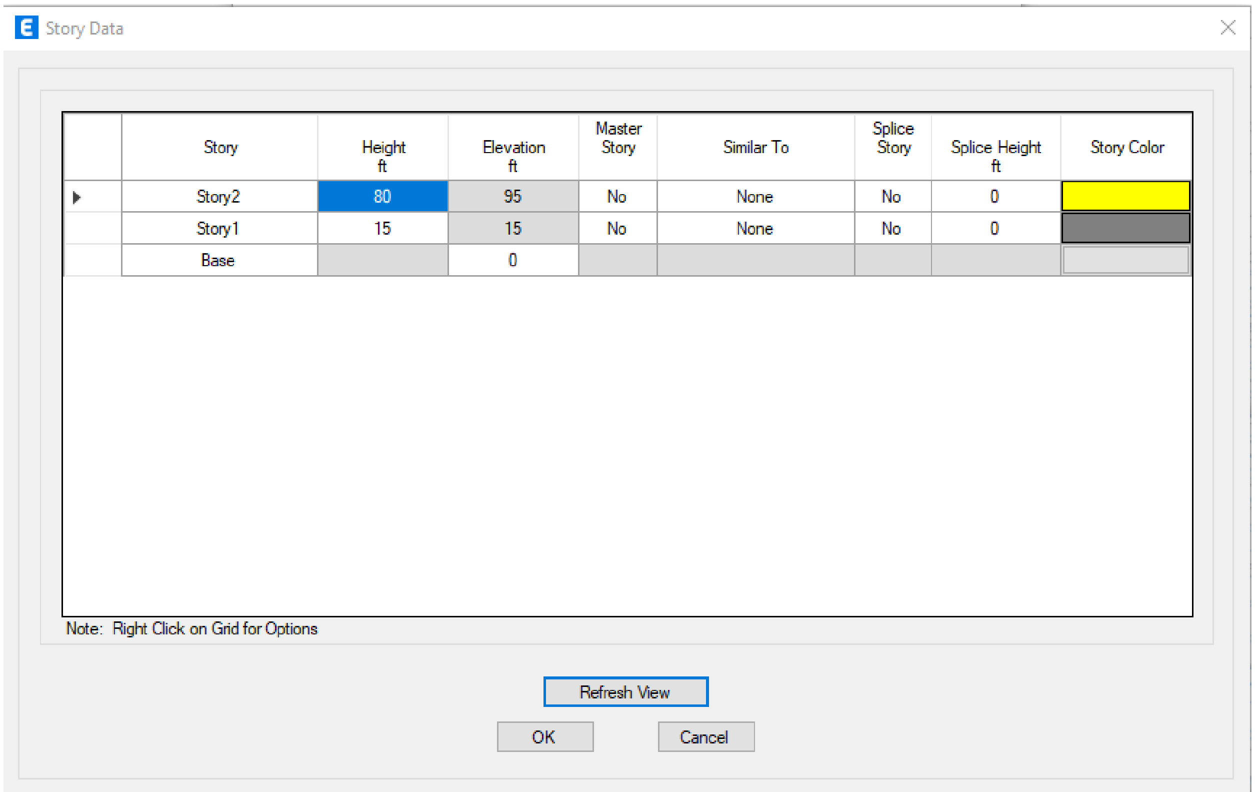

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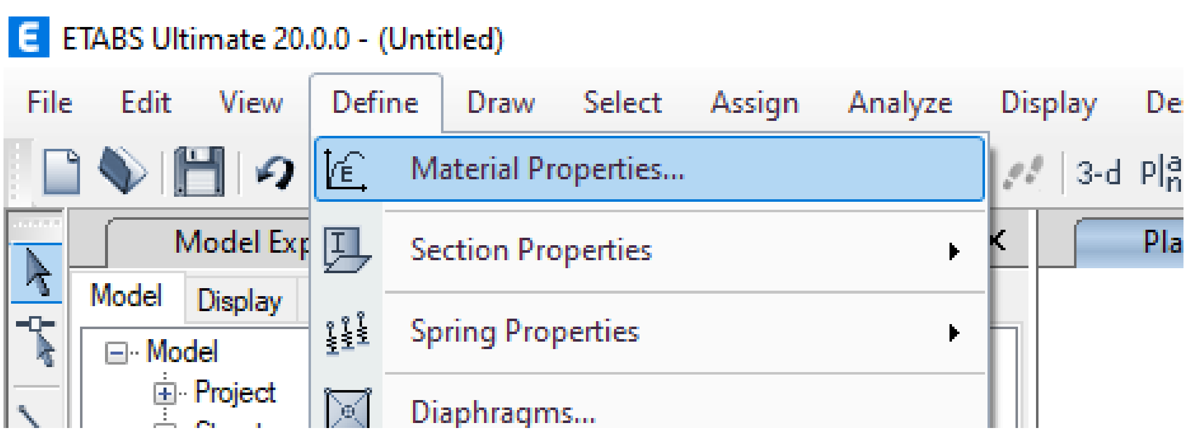

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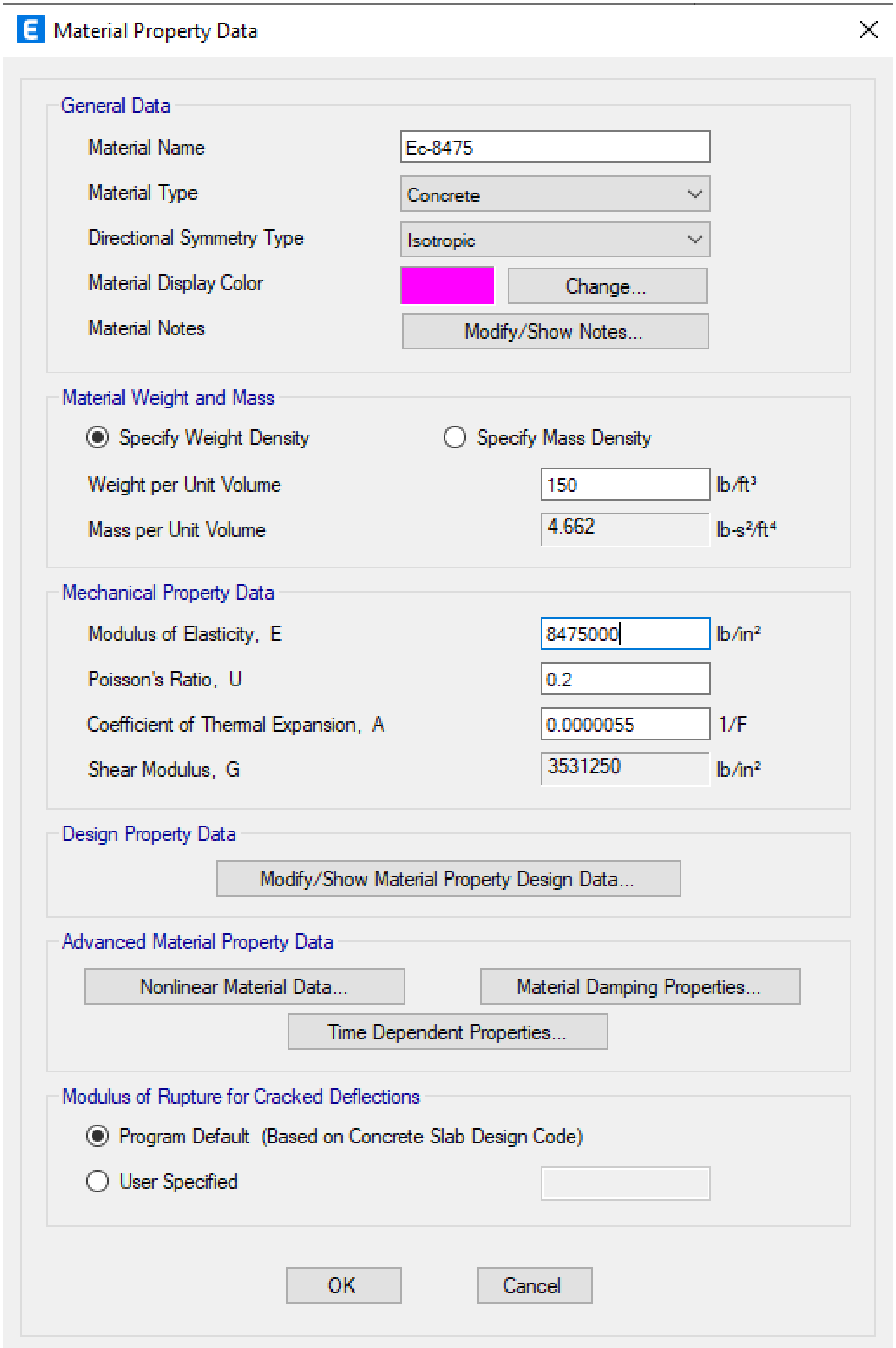
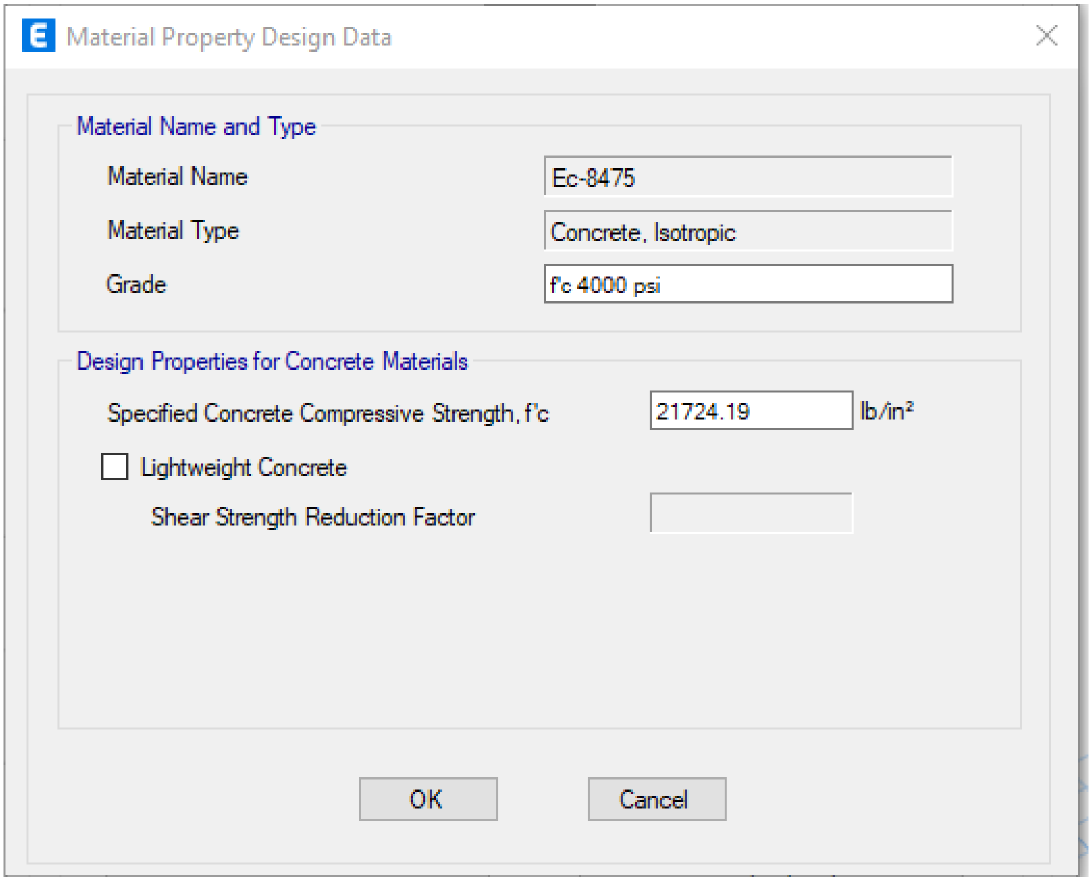


Material Property Data
General Data
Material Name
Ec-8475
Material Type
Concrete
Directional Symmetry Type
Isotropic
Material Display Color
Change...
Material Notes
Modify/Show Notes...
Material Weight and Mass
Specify Weight Density
Specify Mass Density
Weight per Unit Volume
150
lb/ft³
Mass per Unit Volume
4.662
lb-s²/ft⁴
Mechanical Property Data
Modulus of Elasticity, E
8475000
lb/in²
Poisson's Ratio, U
0.2
Coefficient of Thermal Expansion, A
0.0000055
1/F
Shear Modulus, G
3531250
lb/in²
Design Property Data
Modify/Show Material Property Design Data...
Advanced Material Property Data
Nonlinear Material Data...
Material Damping Properties...
Time Dependent Properties...
Modulus of Rupture for Cracked Deflections
Program Default (Based on Concrete Slab Design Code)
User Specified
OK
Cancel

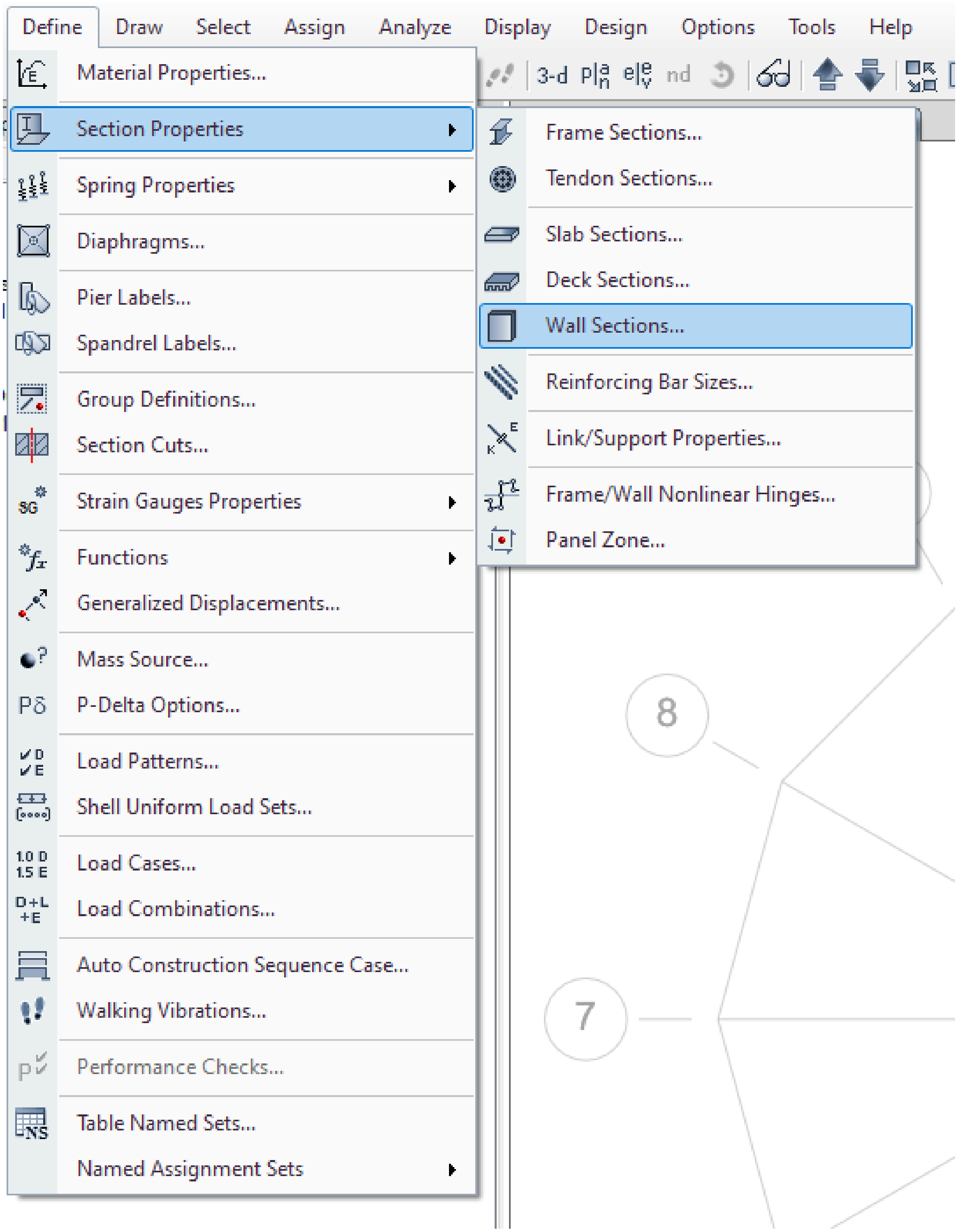
Step 06:



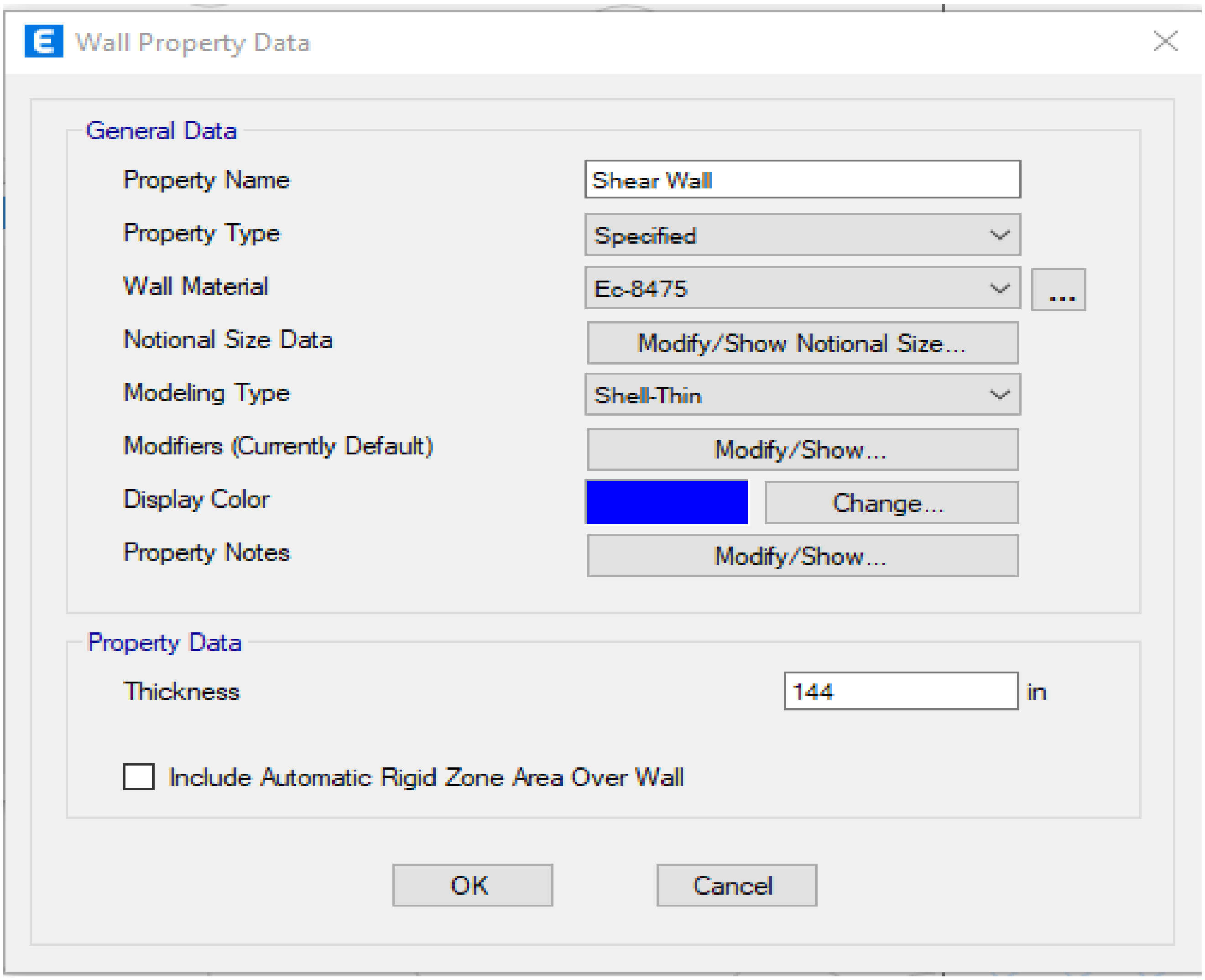
8475*1000 =57500 $\sqrt{f'c}$

⇨f'c = 21724.19 $\frac{lb}{lb^2}$

Step 07:

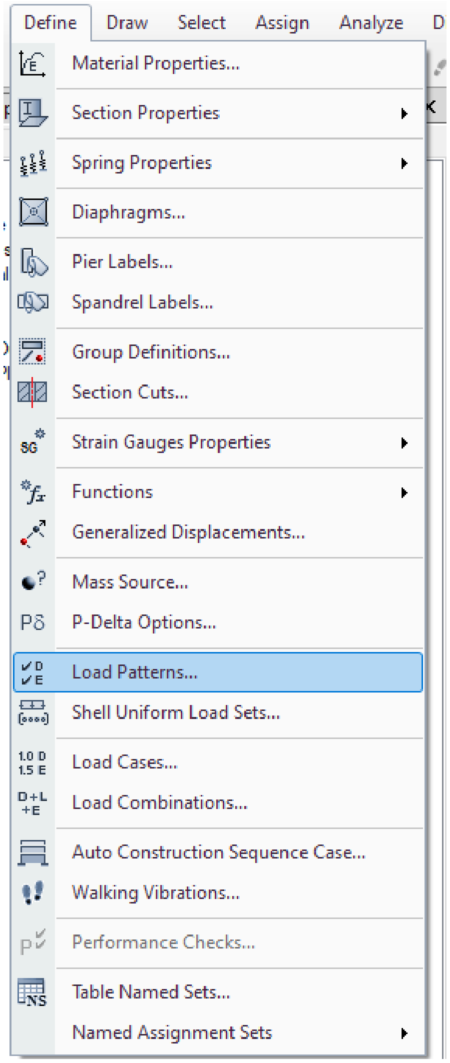

Define
Draw
Select
Assign
Analyze
Display
Design
Options
Tools
Help
Material Properties...
Section Properties
Spring Properties
Diaphragms...
Pier Labels...
Spandrel Labels...
Group Definitions...
Section Cuts...
Strain Gauges Properties
Functions
Generalized Displacements...
Mass Source...
P-Delta Options...
Load Patterns...
Shell Uniform Load Sets...
Load Cases...
Load Combinations...
Auto Construction Sequence Case...
Walking Vibrations...
Performance Checks...
Table Named Sets...
Named Assignment Sets
Frame Sections...
Tendon Sections...
Slab Sections...
Deck Sections...
Wall Sections...
Reinforcing Bar Sizes...
Link/Support Properties...
Frame/Wall Nonlinear Hinges...
Panel Zone...
8
7

Step 08:



12*12=144

Step 09:



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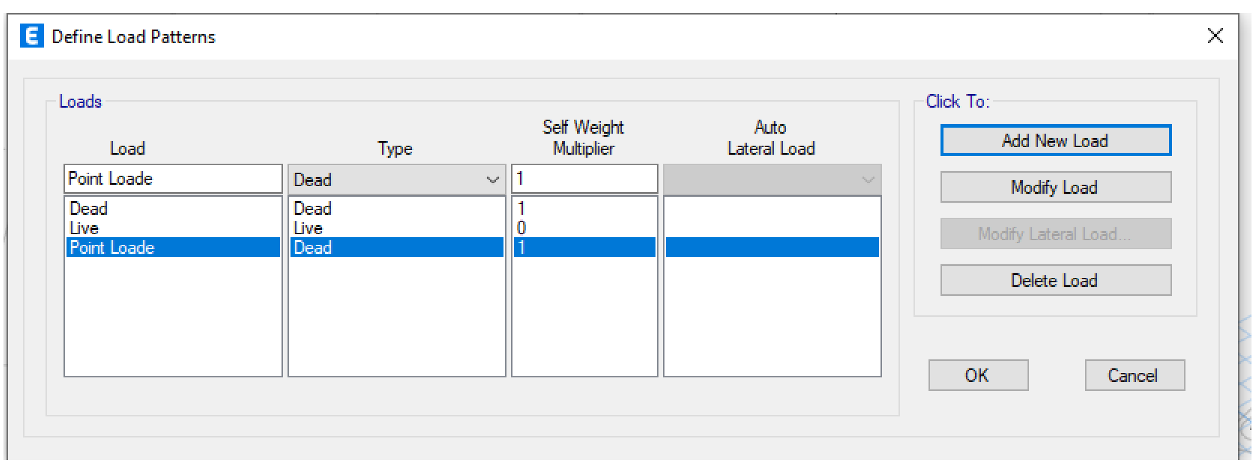

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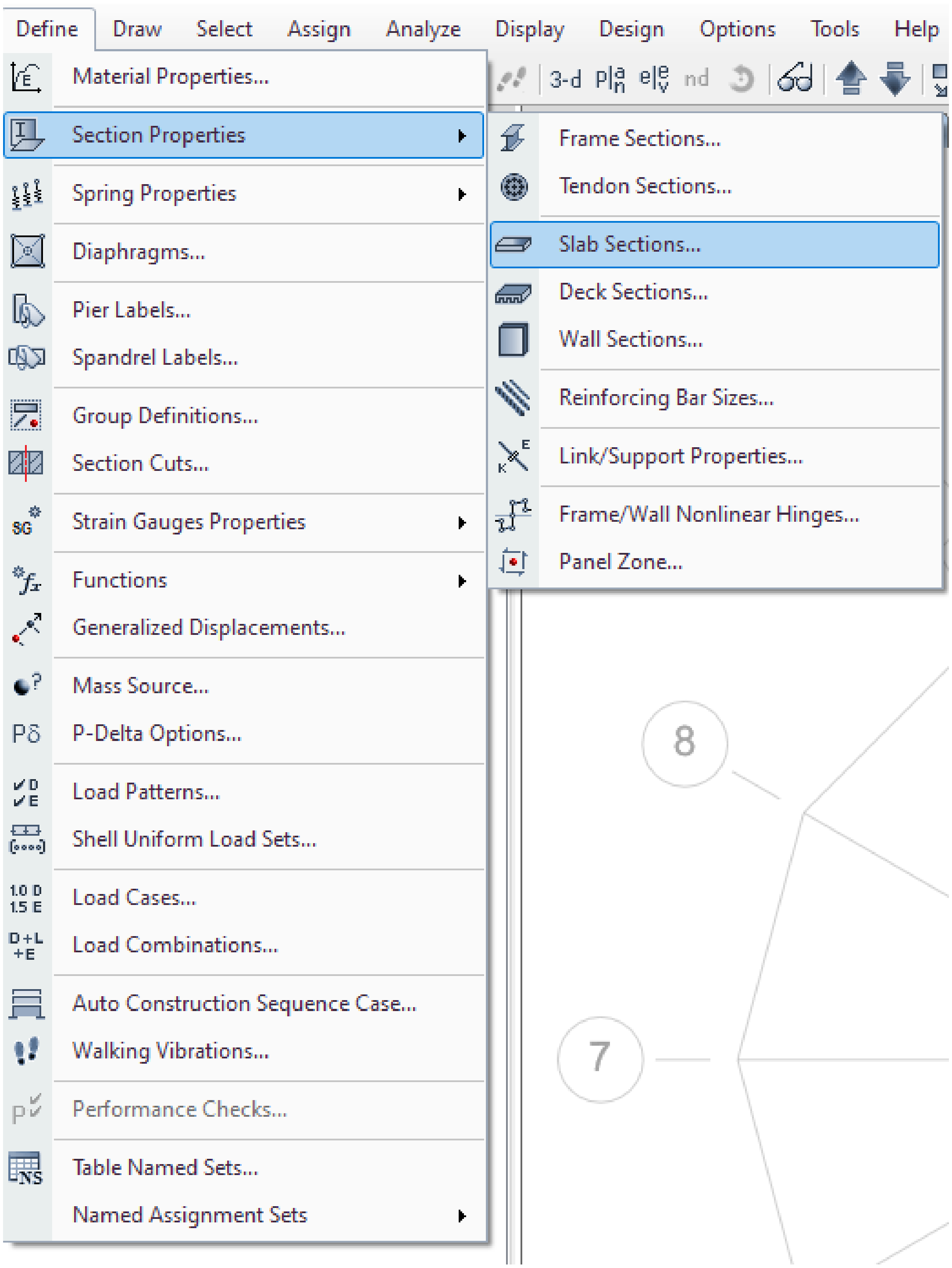
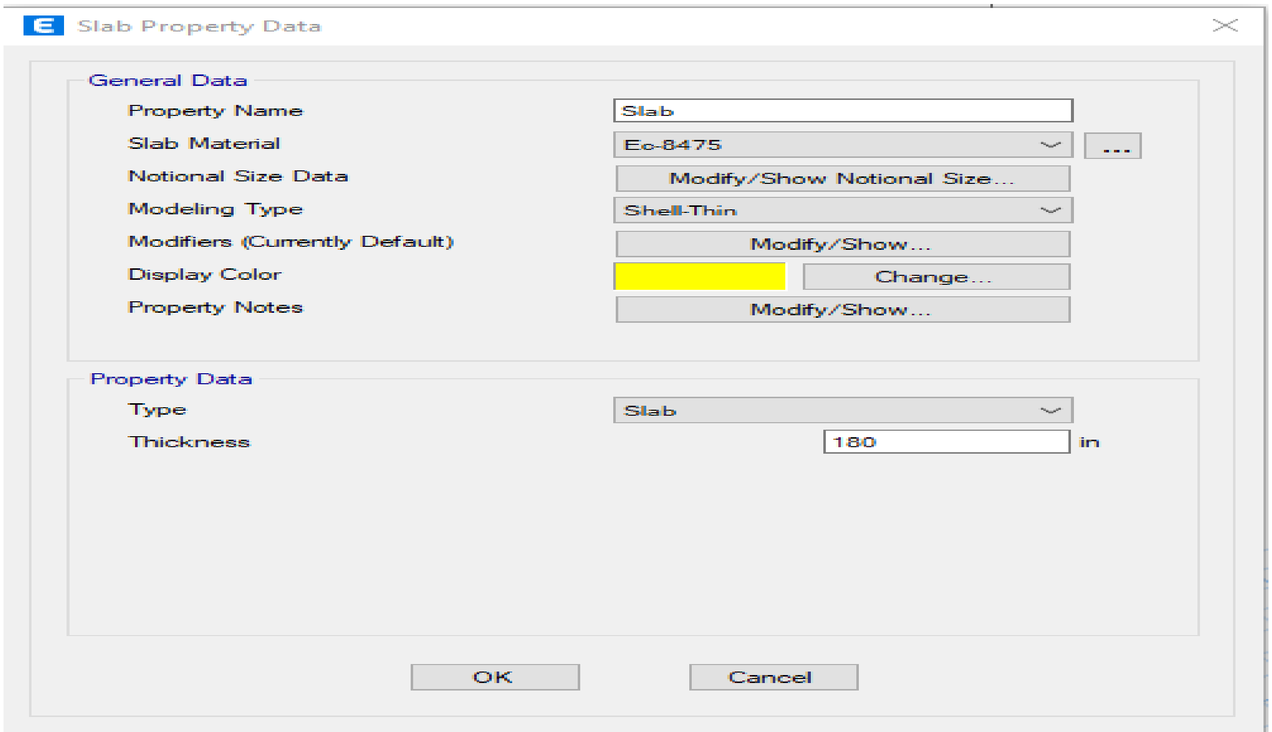
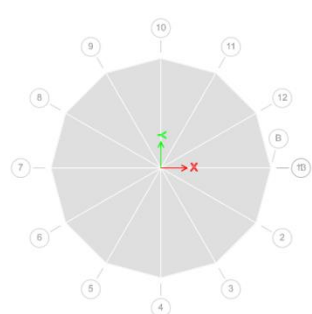

Define
Draw
Select
Assign
Analyze
Display
Design
Options
Tools
Help
Material Properties...
Section Properties
Spring Properties
Diaphragms...
Pier Labels...
Spandrel Labels...
Group Definitions...
Section Cuts...
Strain Gauges Properties
Functions
Generalized Displacements...
Mass Source...
P-Delta Options...
Load Patterns...
Shell Uniform Load Sets...
Load Cases...
Load Combinations...
Auto Construction Sequence Case...
Walking Vibrations...
Performance Checks...
Table Named Sets...
Named Assignment Sets
Frame Sections...
Tendon Sections...
Slab Sections...
Deck Sections...
Wall Sections...
Reinforcing Bar Sizes...
Link/Support Properties...
Frame/Wall Nonlinear Hinges...
Panel Zone...
8
7

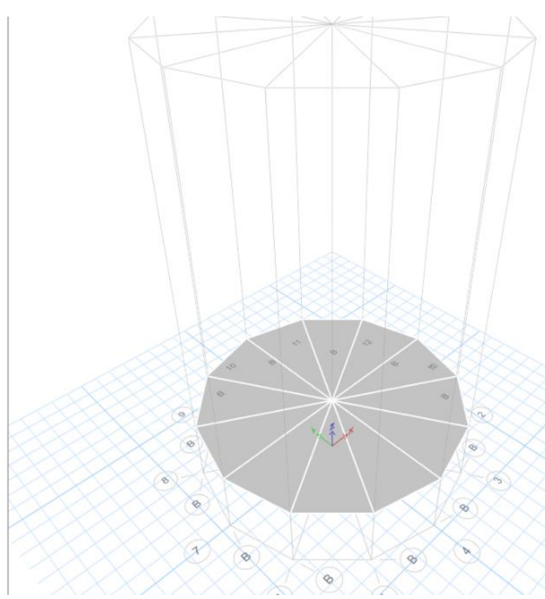
Step 12:



15*12=180

Step 13:





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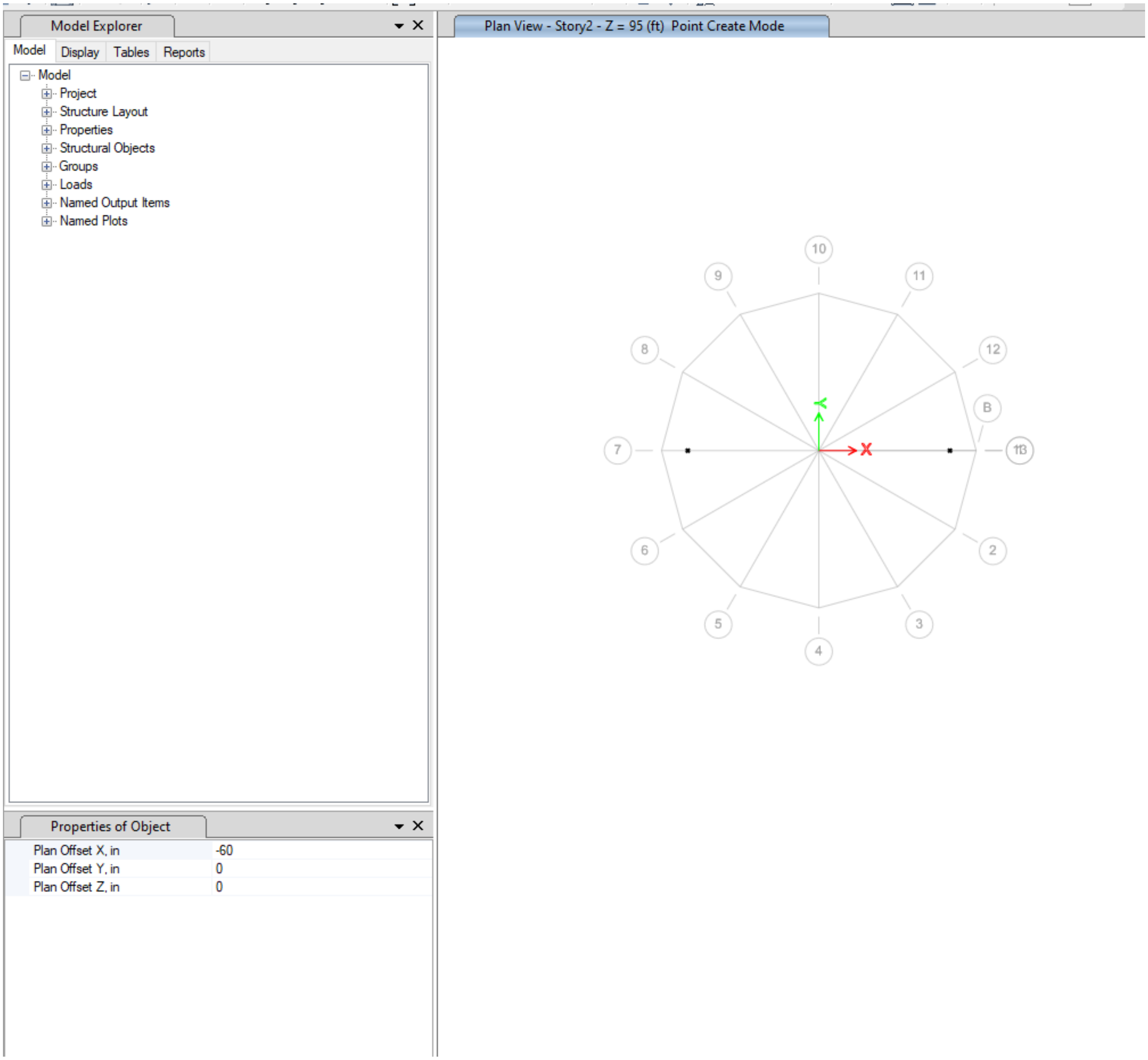
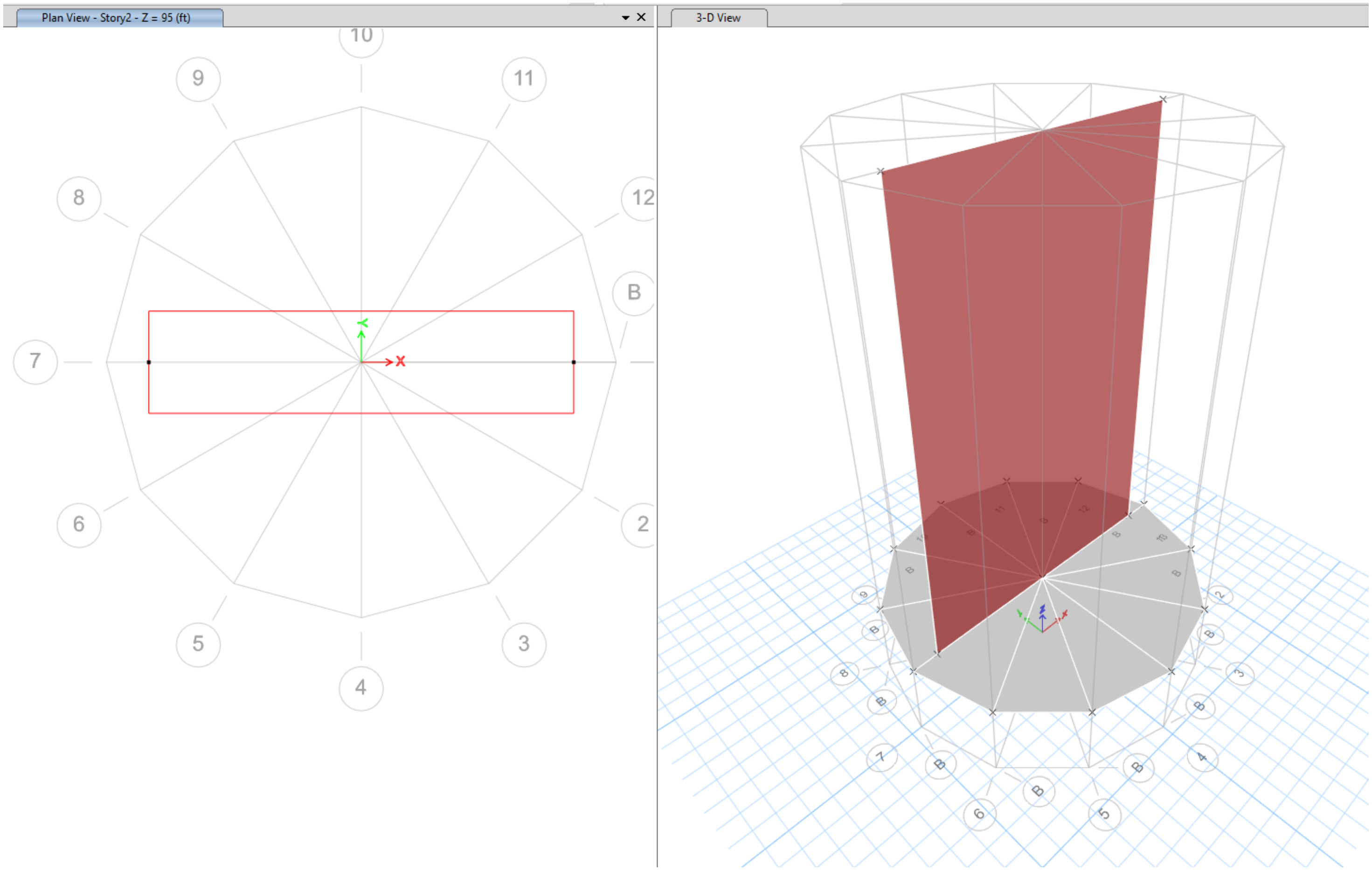


Model Explorer
Model
Display
Tables
Reports
Model
Project
Structure Layout
Properties
Structural Objects
Groups
Loads
Named Output Items
Named Plots
Properties of Object
Plan Offset X, in
-60
Plan Offset Y, in
0
Plan Offset Z, in
0
Plan View - Story2 - Z = 95 (ft) Point Create Mode
10
9
11
8
12
B
7
13
6
2
5
3
4
X

Step 15:



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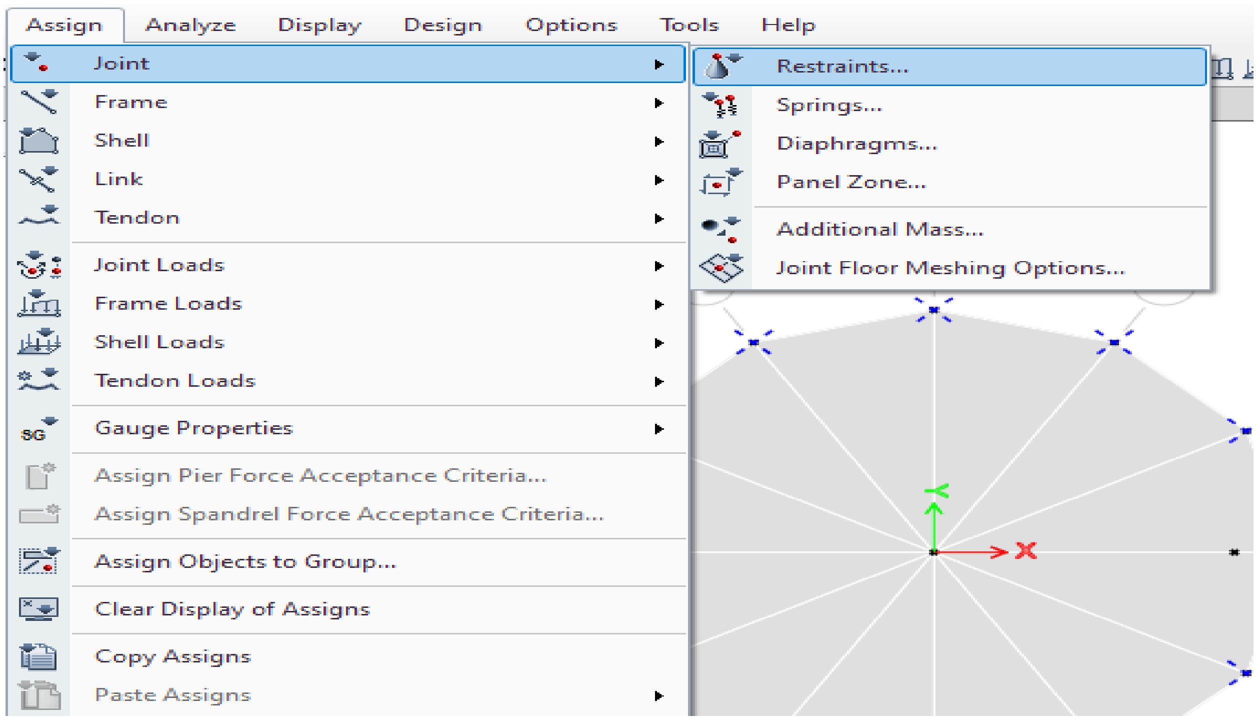
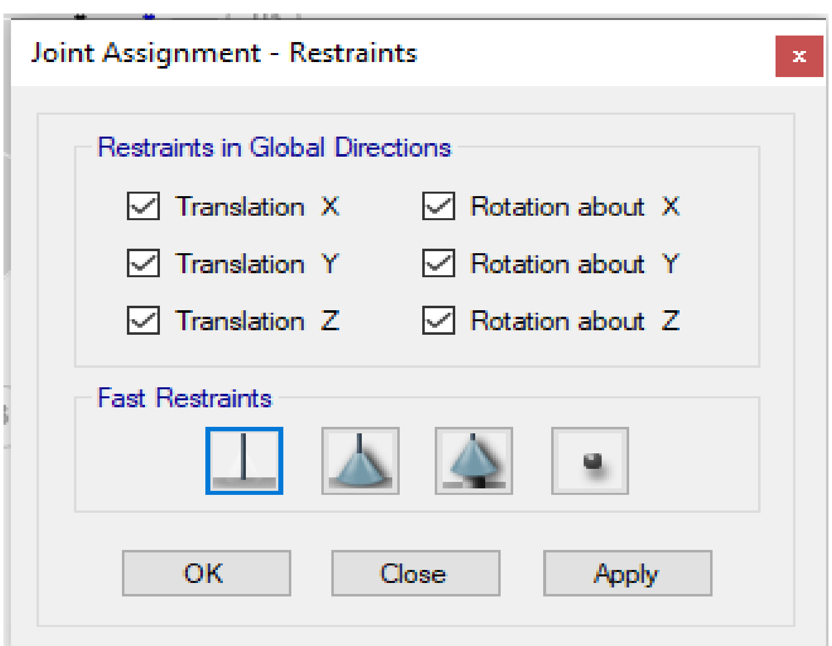
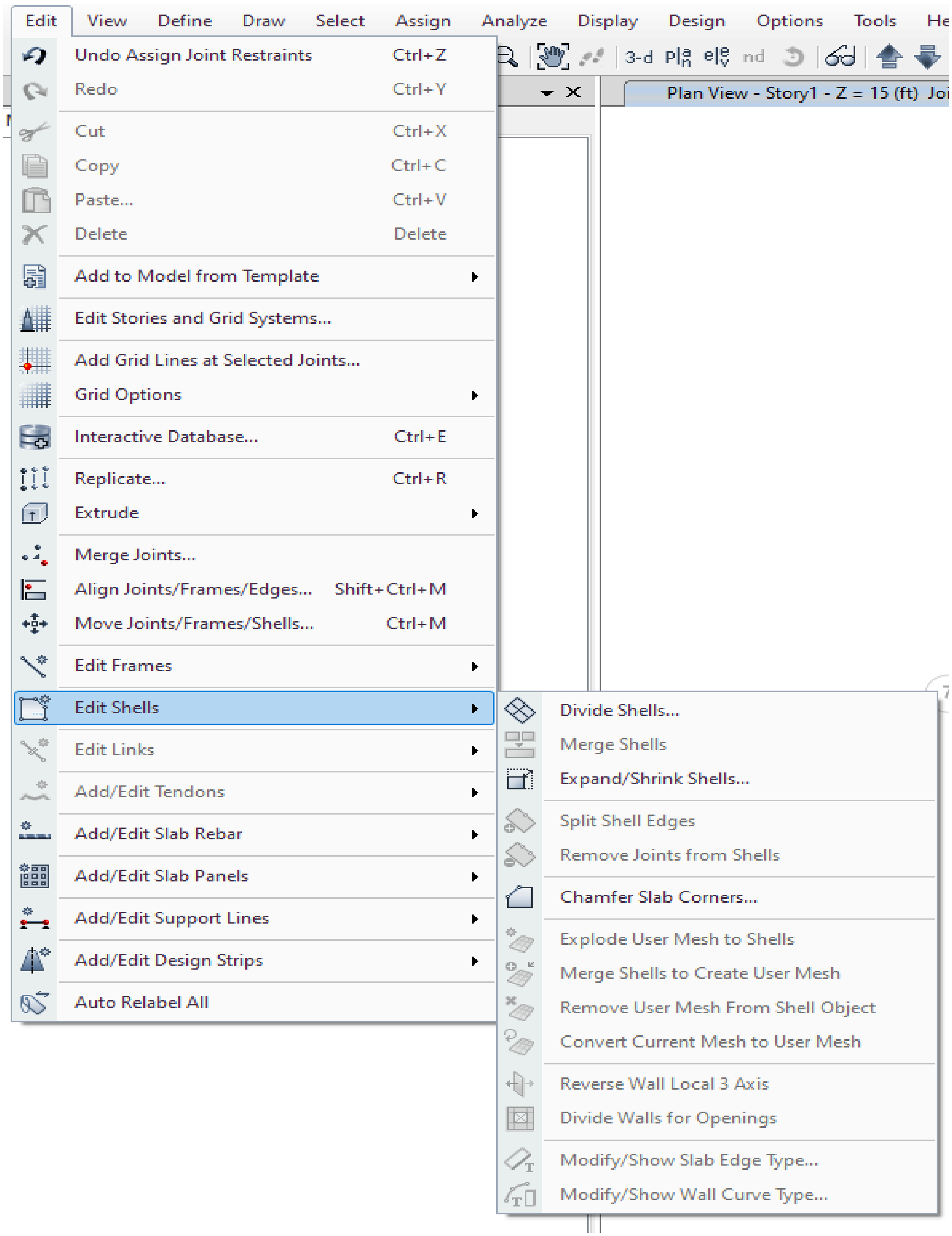


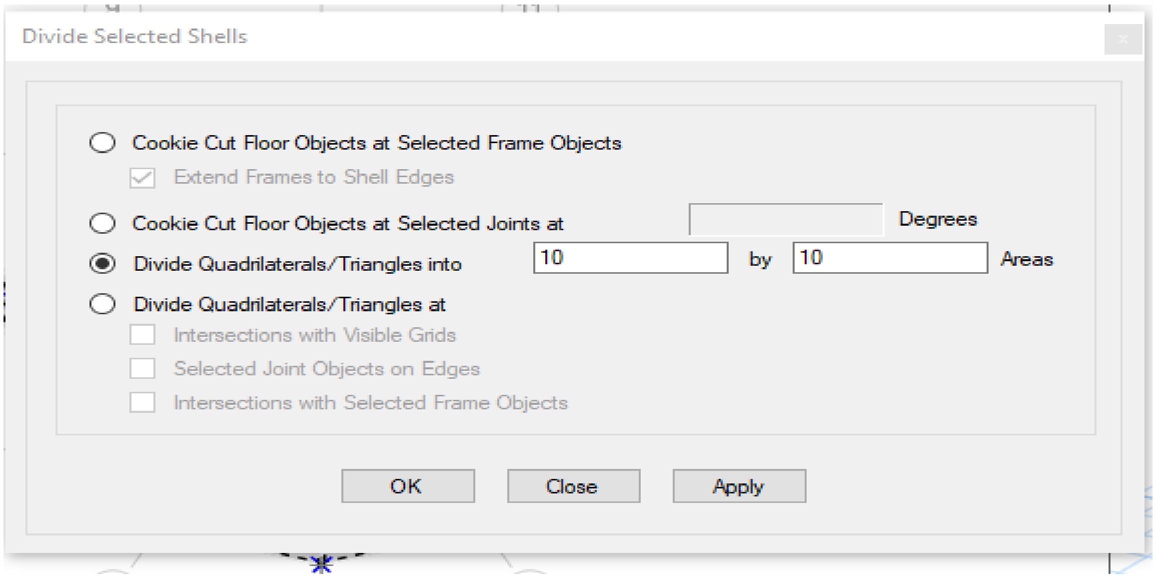
Step 17



Step 18:


Edit
View
Define
Draw
Select
Assign
Analyze
Display
Design
Options
Tools
Plan View - Story1 - Z = 15 (ft)
Undo Assign Joint Restraints Ctrl+Z
Redo Ctrl+Y
Cut Ctrl+X
Copy Ctrl+C
Paste... Ctrl+V
Delete Delete
Add to Model from Template
Edit Stories and Grid Systems...
Add Grid Lines at Selected Joints...
Grid Options
Interactive Database... Ctrl+E
Replicate... Ctrl+R
Extrude
Merge Joints...
Align Joints/Frames/Edges... Shift+Ctrl+M
Move Joints/Frames/Shells... Ctrl+M
Edit Frames
Edit Shells
Edit Links
Add/Edit Tendons
Add/Edit Slab Rebar
Add/Edit Slab Panels
Add/Edit Support Lines
Add/Edit Design Strips
Auto Relabel All
Divide Shells...
Merge Shells
Expand/Shrink Shells...
Split Shell Edges
Remove Joints from Shells
Chamfer Slab Corners...
Explode User Mesh to Shells
Merge Shells to Create User Mesh
Remove User Mesh From Shell Object
Convert Current Mesh to User Mesh
Reverse Wall Local 3 Axis
Divide Walls for Openings
Modify/Show Slab Edge Type...
Modify/Show Wall Curve Type...

Step 19:



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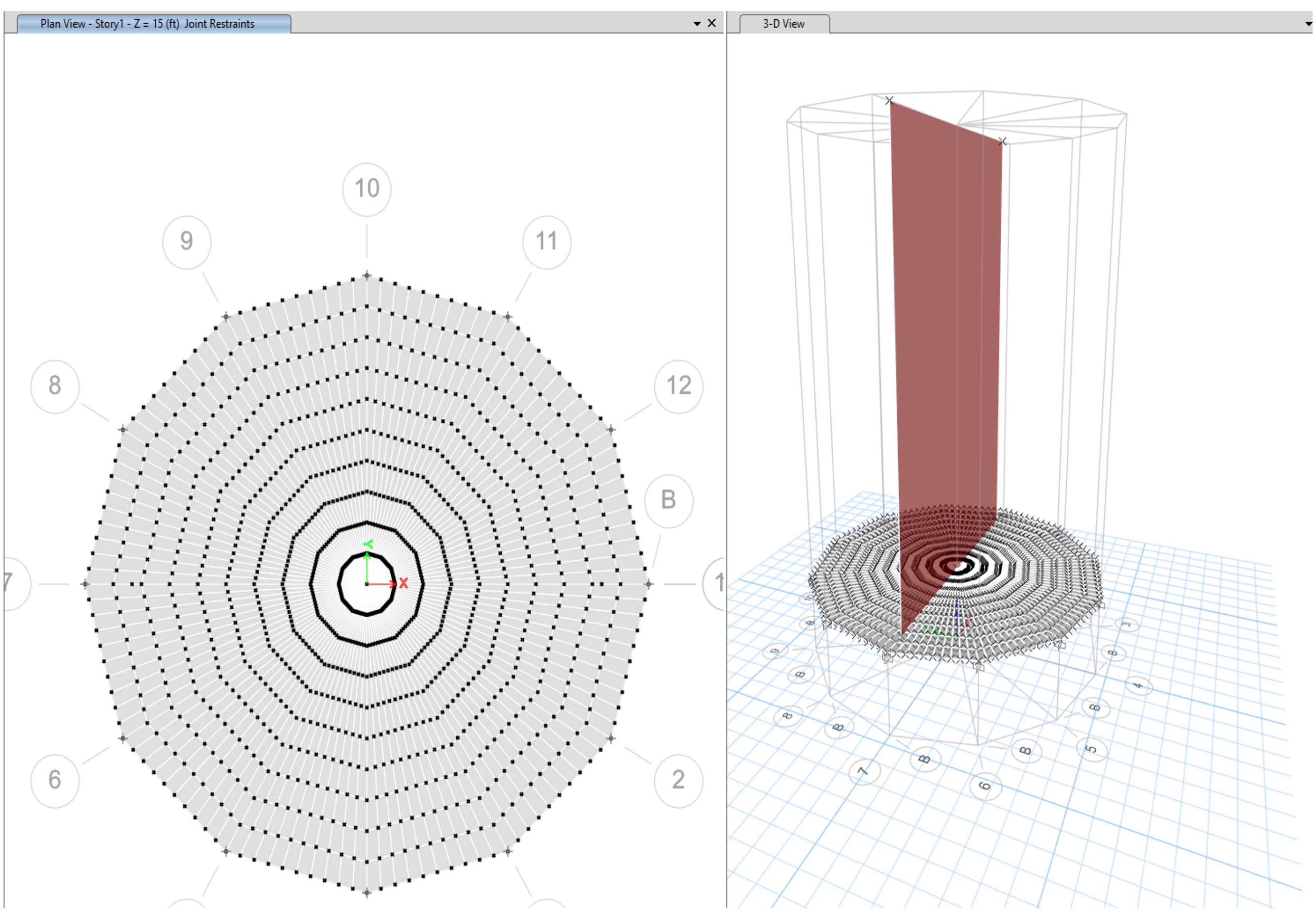

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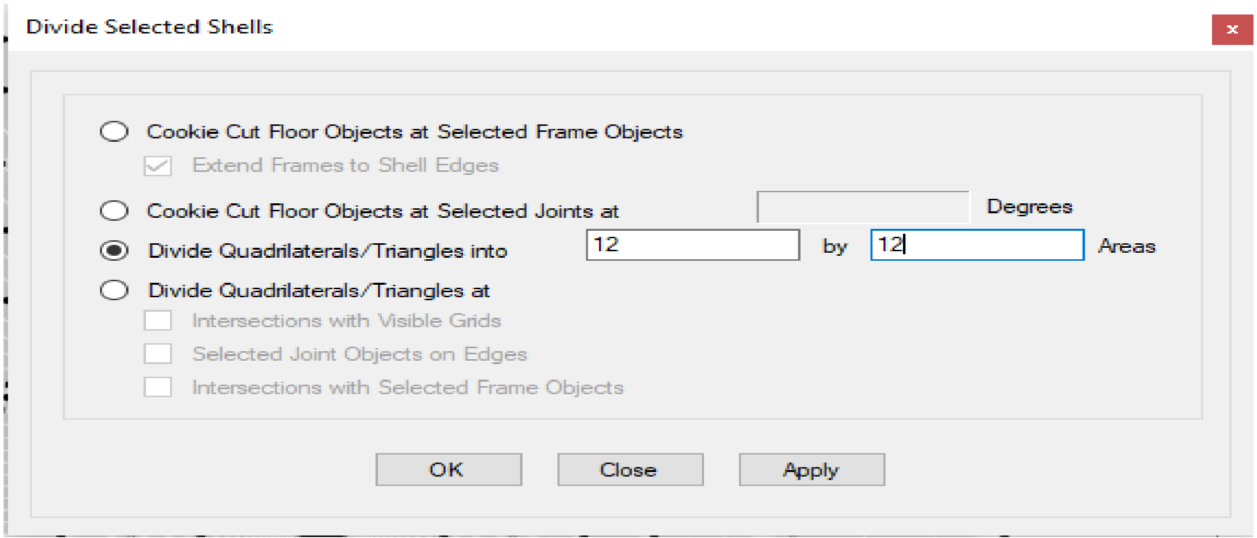

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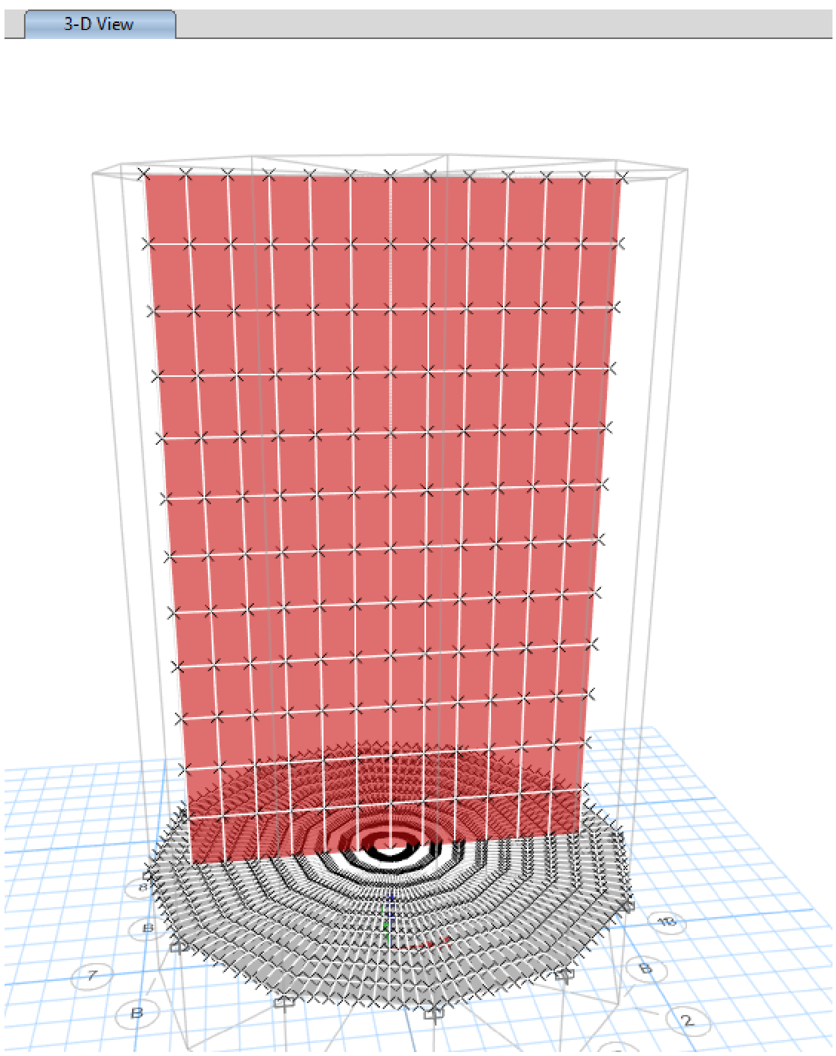

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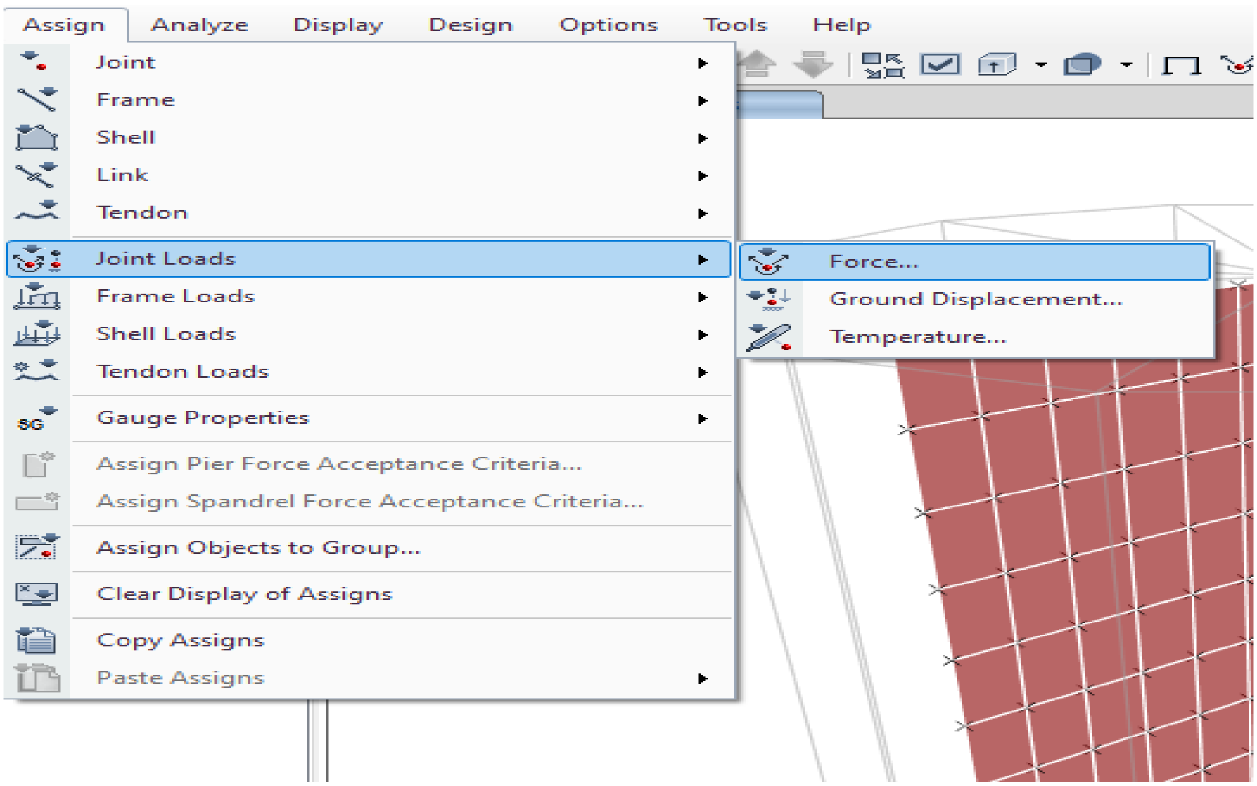

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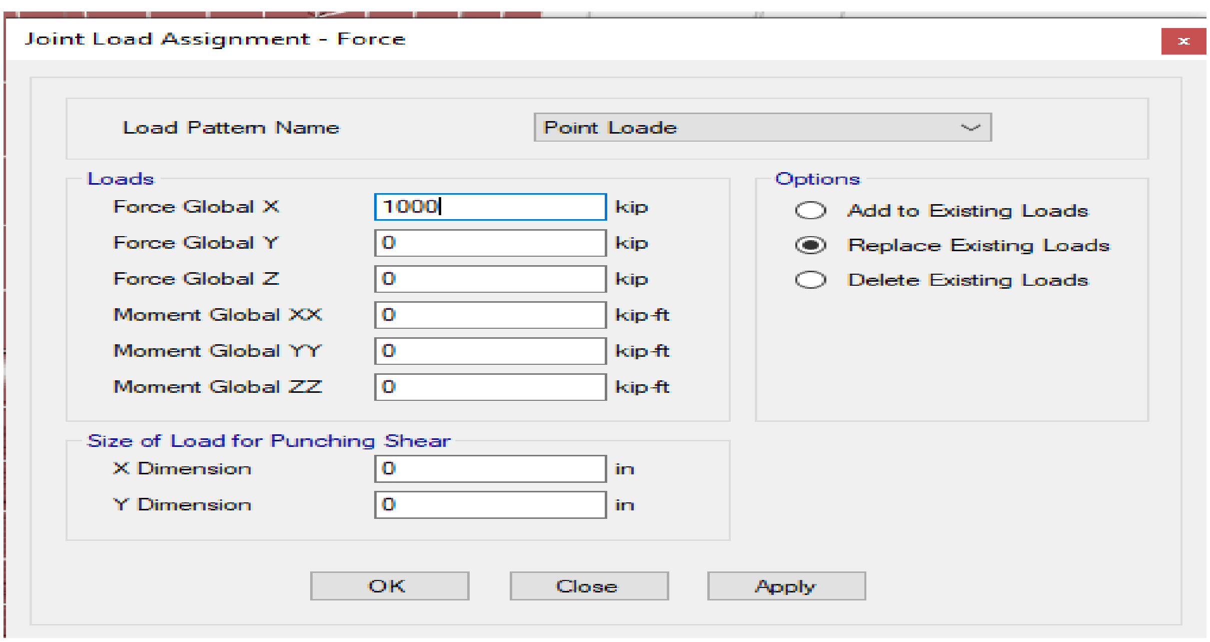

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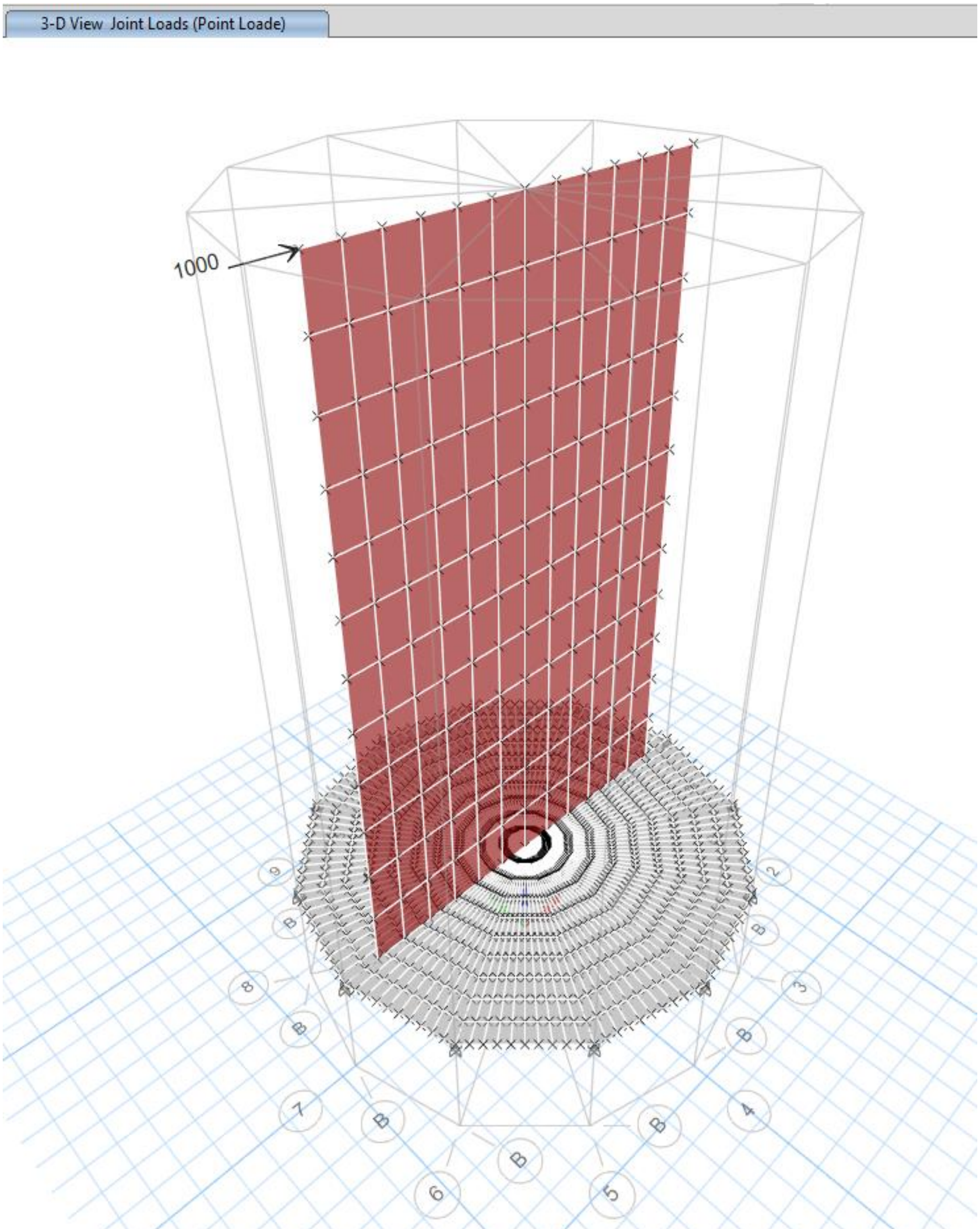

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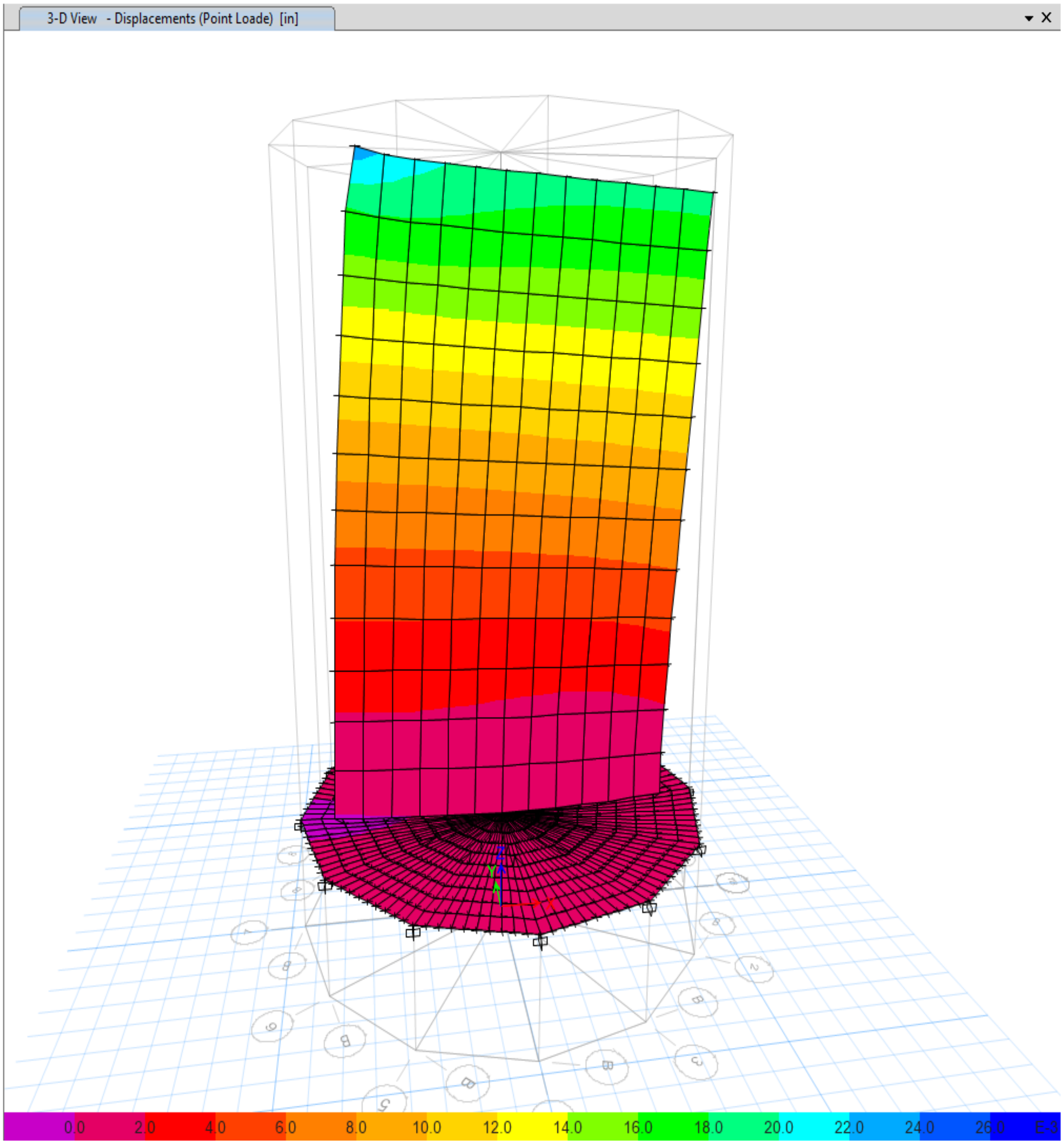
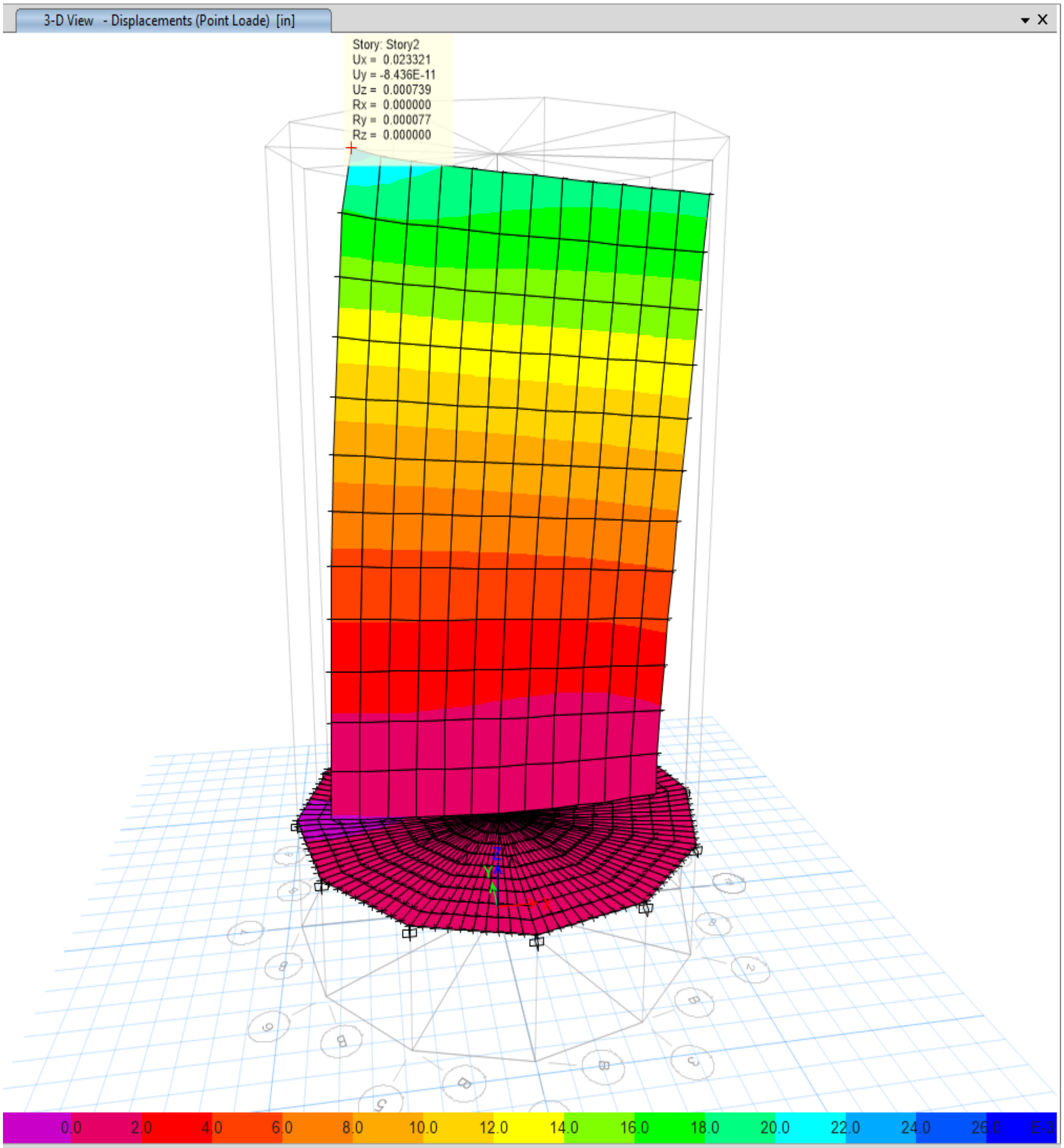

3-D View - Displacements (Point Loade) [in]
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
E-3

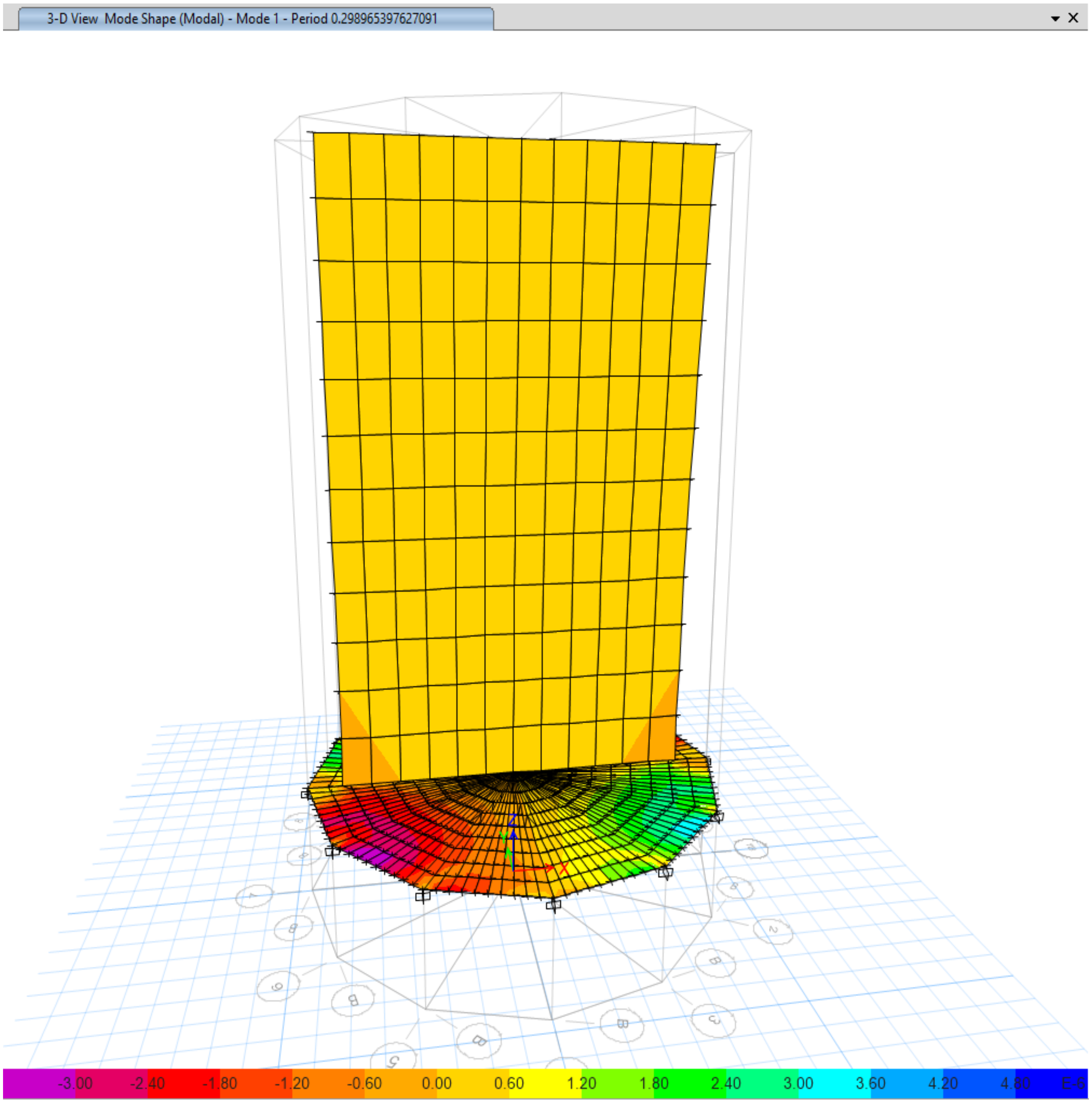
Step 27:



$$\text{Stiffness}=\frac{1000}{0.023321} = 42.87 * 10^3 \text{ Kip/ft}$$

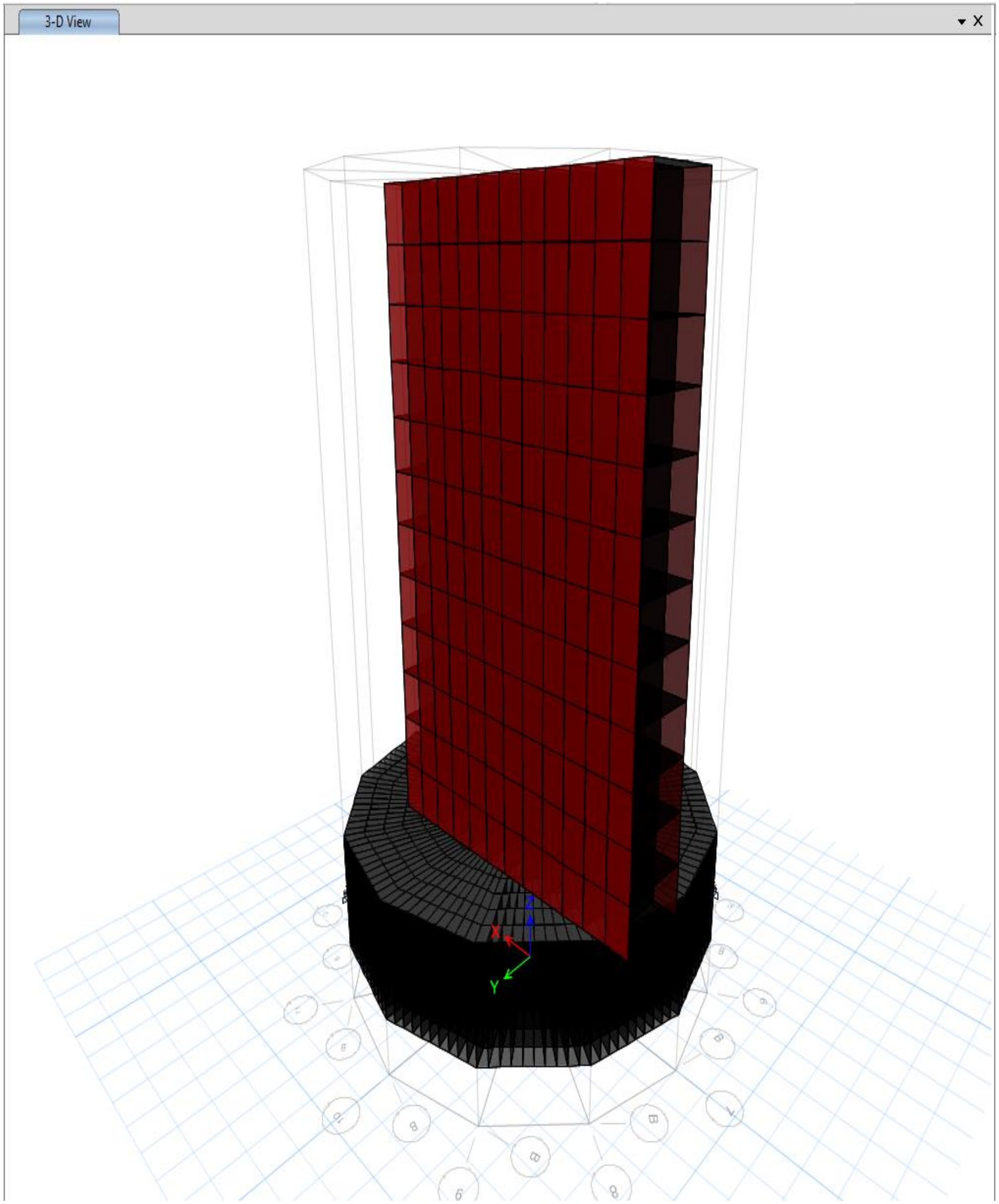
Steps From Etabs (Project-02)

Step 01:



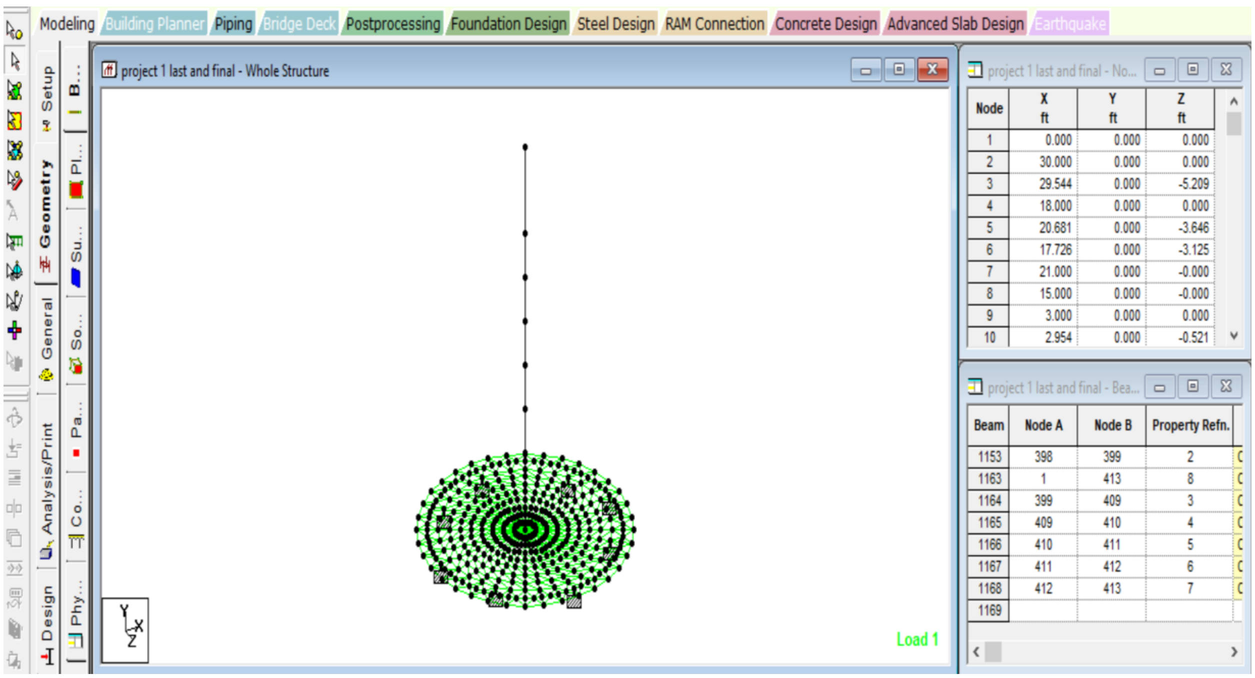
Frequency=$\frac{2*\pi}{0.299} = 21.01$ rad/sec

3D View:



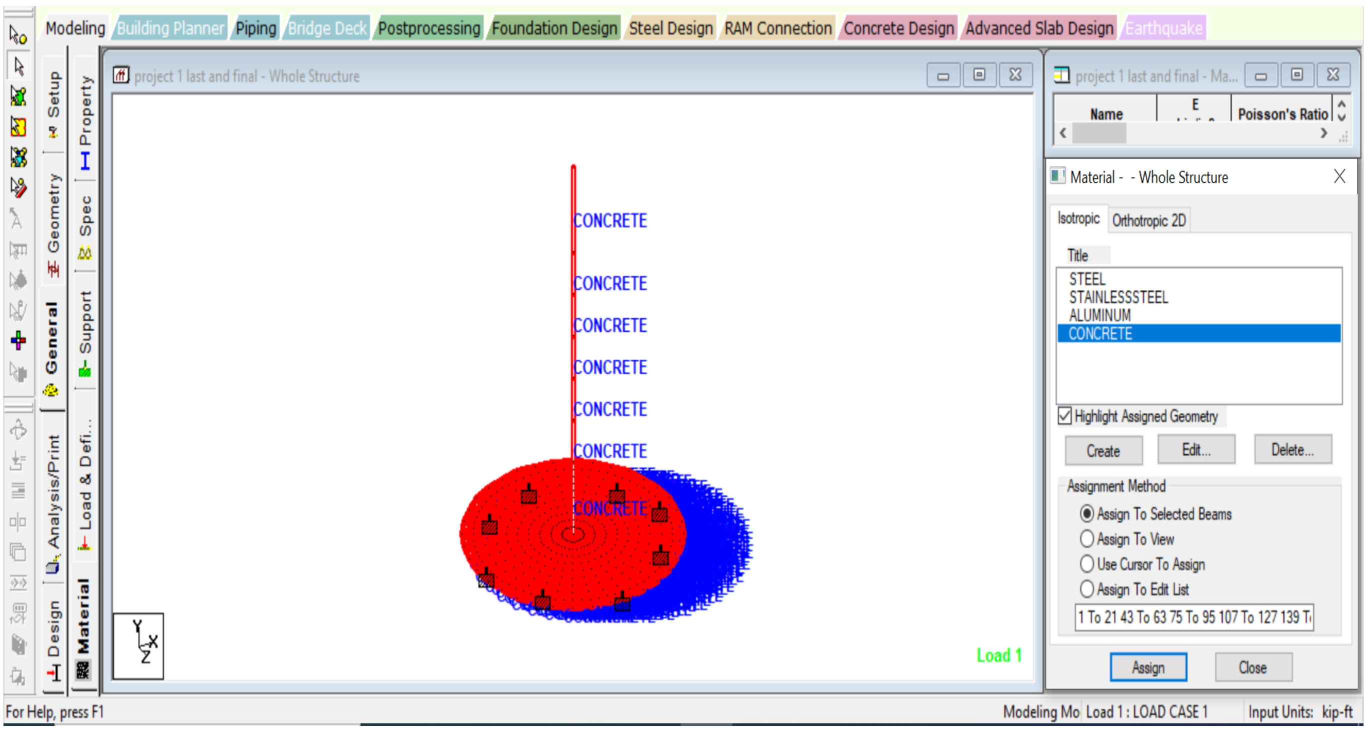
Steps From Staad Pro (Project-01)

Step 01:



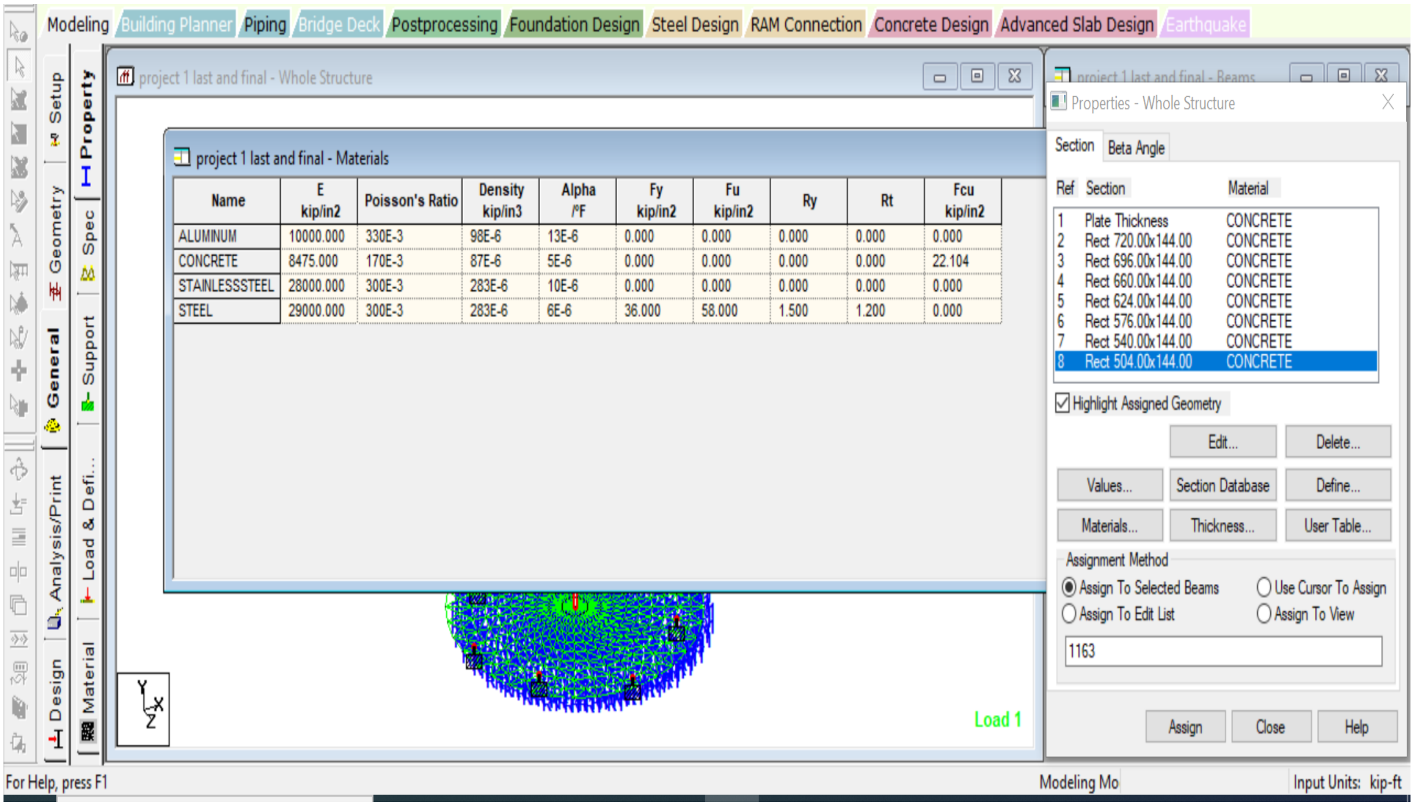
Geometric Property Including 413 nodes

Step 02:



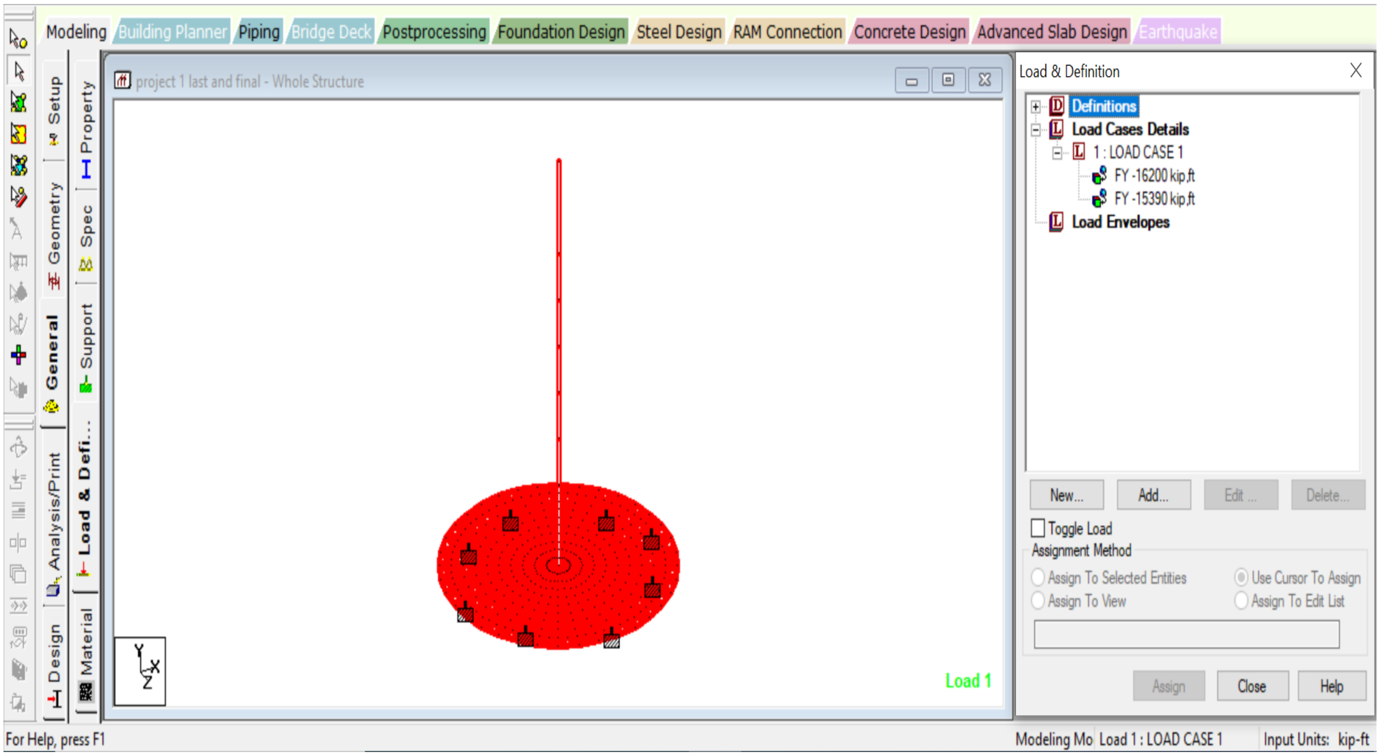
Using Concrete as material other materials were not included.

Step 03:



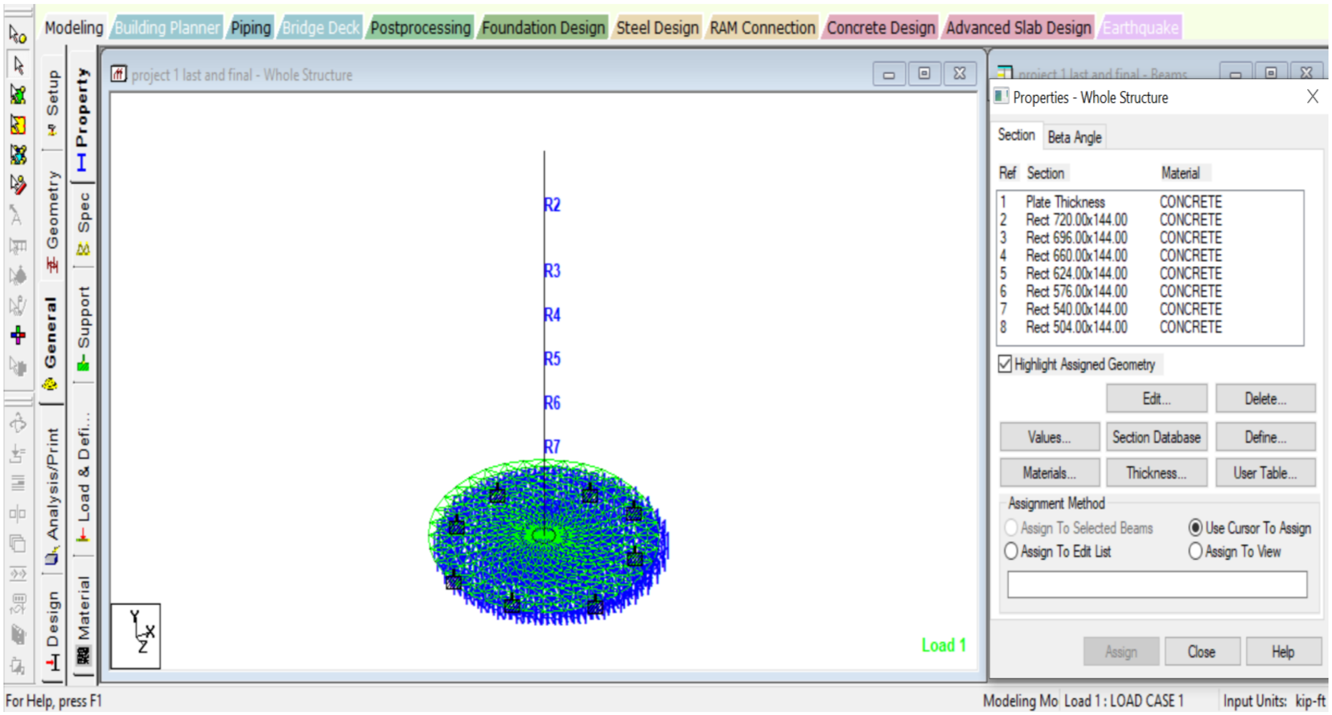
Modulus of Elasticity of Concrete Assignee= 8475 kip/in^2

Step 04:



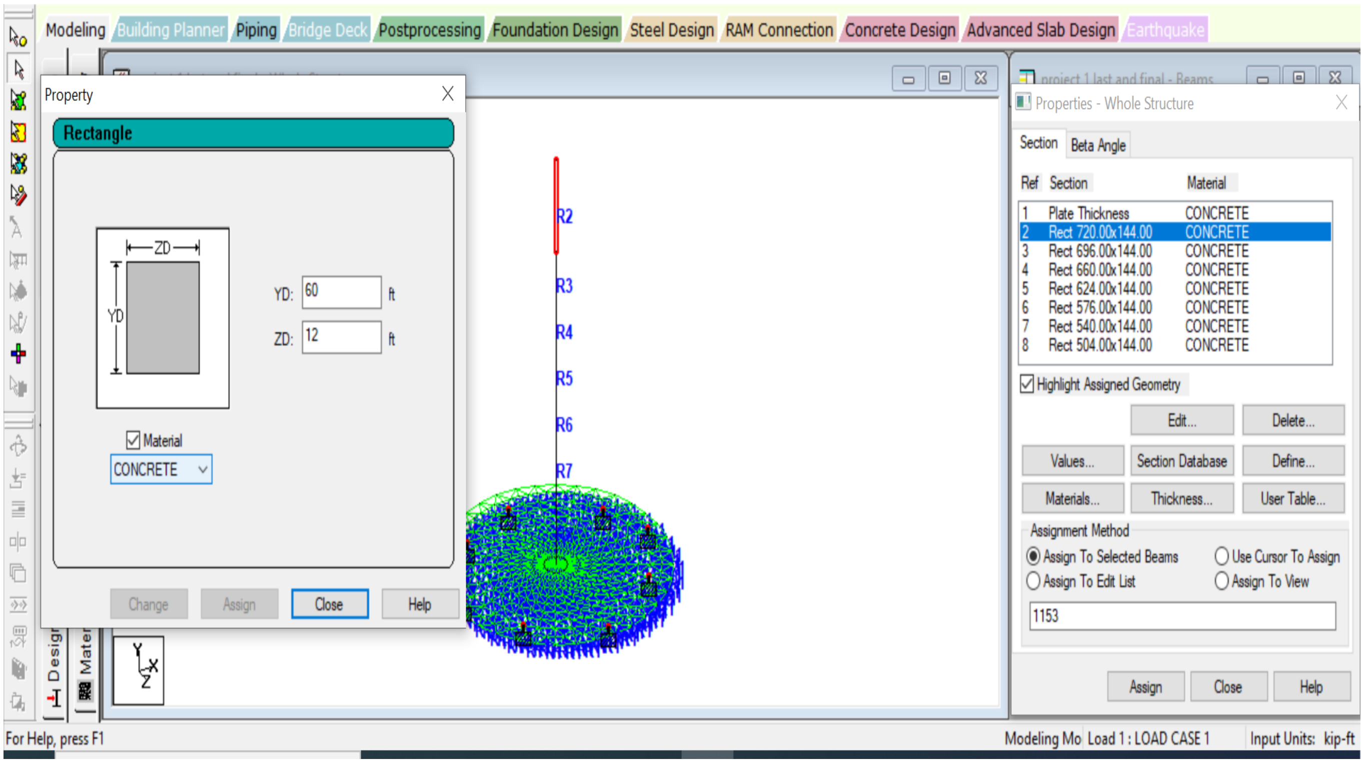
Two Load was assigned 16200 kip/ft (slab weight) and 15490 kip/ft (Pile cap weight)

Step 05:



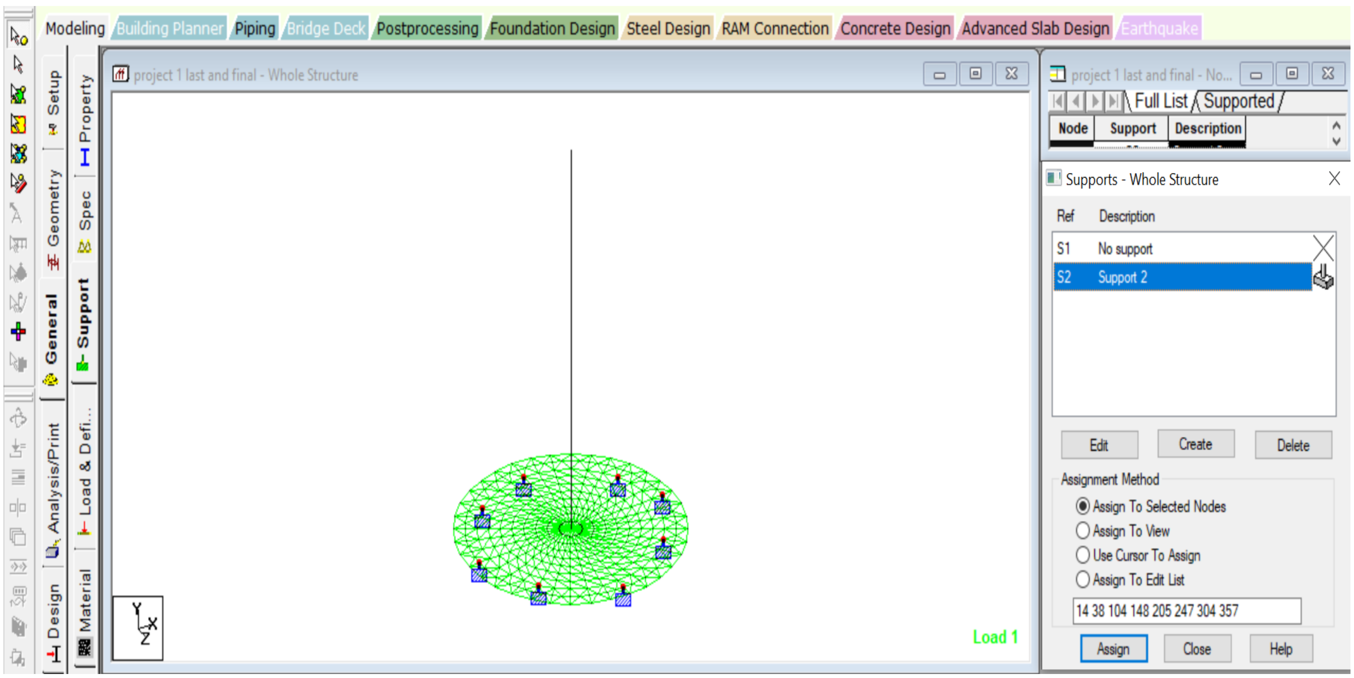
Different Plate Thickness as pile was a variable section.

Step 06:



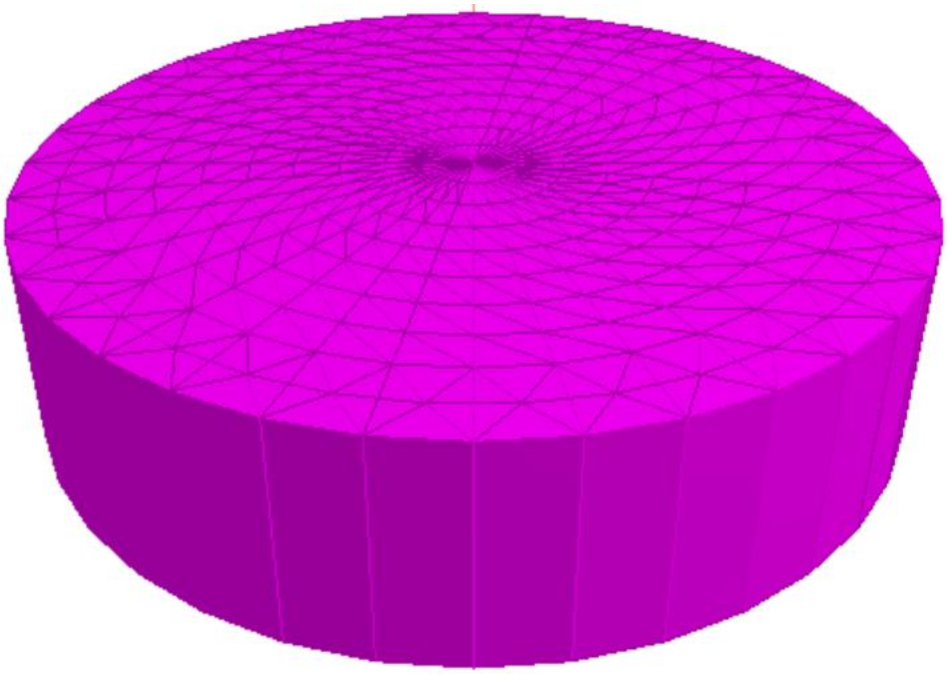
Pile cross section (60*12)

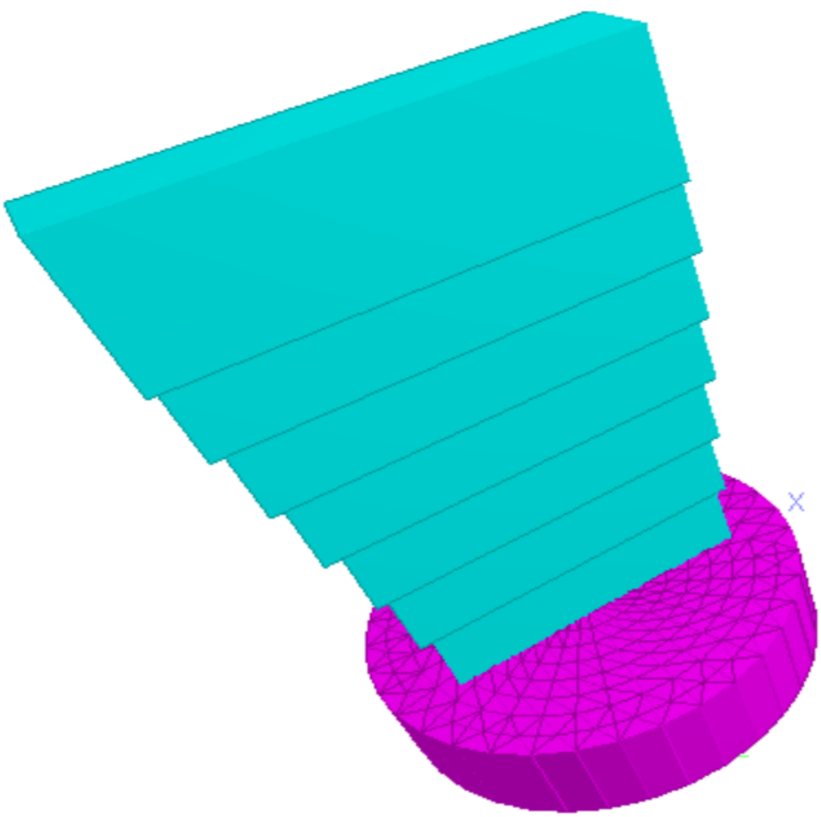
Step 07:



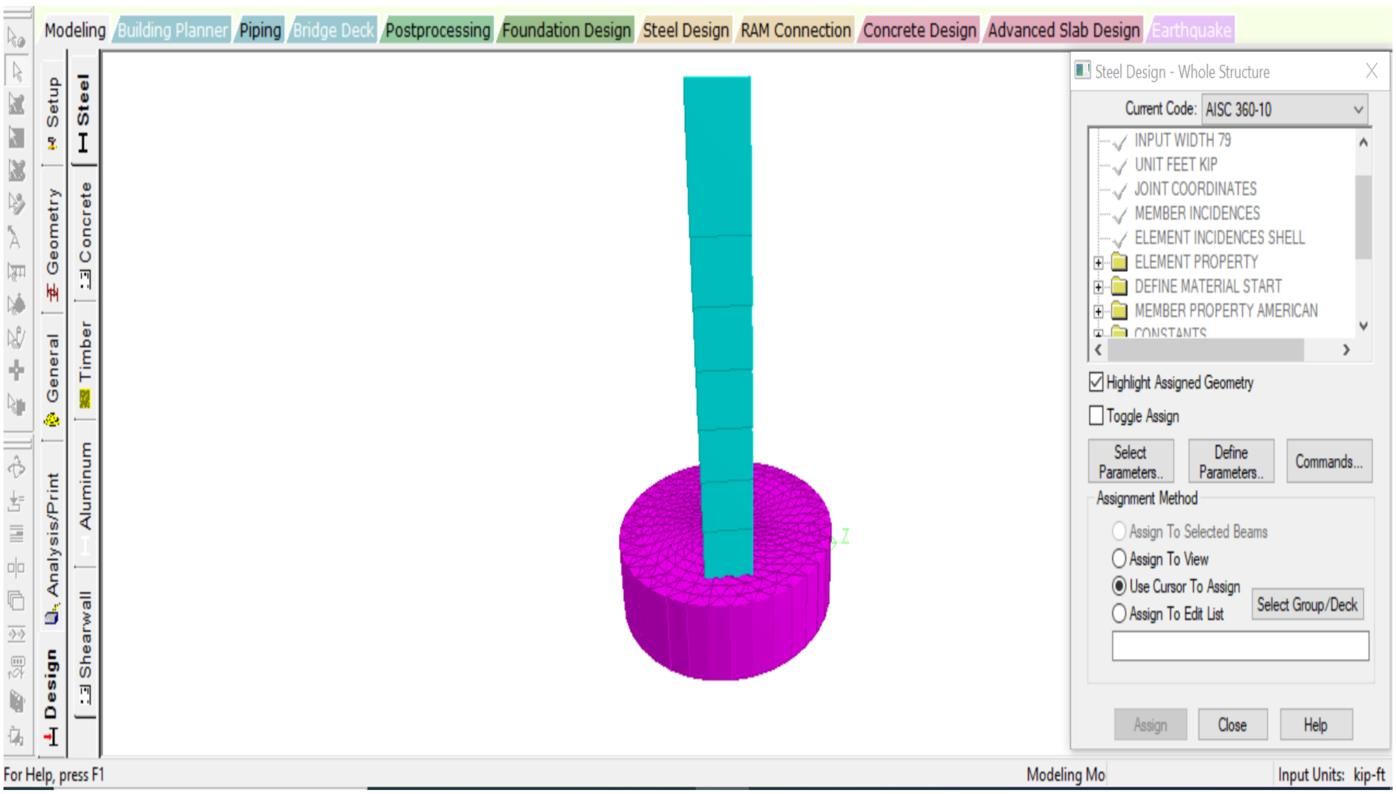
8 Fixed Support was included in pile cap section.

3D View:





3D View:


Modeling
Building Planner
Piping
Bridge Deck
Postprocessing
Foundation Design
Steel Design
RAM Connection
Concrete Design
Advanced Slab Design
Earthquake
Setup
Geometry
General
Analysis/Print
Design
Steel
Concrete
Timber
Aluminum
Shearwall
Steel Design - Whole Structure
Current Code: AISC 360-10
INPUT WIDTH 79
UNIT FEET KIP
JOINT COORDINATES
MEMBER INCIDENCES
ELEMENT INCIDENCES SHELL
ELEMENT PROPERTY
DEFINE MATERIAL START
MEMBER PROPERTY AMERICAN
Highlight Assigned Geometry
Toggle Assign
Select Parameters..
Define Parameters..
Commands...
Assignment Method
Assign To Selected Beams
Assign To View
Use Cursor To Assign
Assign To Edit List
Select Group/Deck
Assign
Close
Help
For Help, press F1
Modeling Mo
Input Units: kip-ft

Analysis Data:

```
***TOTAL APPLIED LOAD ( KIP  FEET ) SUMMARY (LOADING     1 )
    SUMMATION FORCE-X =          0.00
    SUMMATION FORCE-Y =     -31590.00
    SUMMATION FORCE-Z =          0.00

   SUMMATION OF MOMENTS AROUND THE ORIGIN-
   MX=  0.0000000E+00  MY=  0.0000000E+00  MZ=  0.0000000E+00


***TOTAL REACTION LOAD( KIP  FEET ) SUMMARY (LOADING     1 )
    SUMMATION FORCE-X =          0.00
    SUMMATION FORCE-Y =      31590.00
    SUMMATION FORCE-Z =          0.00

   SUMMATION OF MOMENTS AROUND THE ORIGIN-
   MX= -1.9402554E-10  MY= -6.5872507E-13  MZ=  1.2417635E-09


MAXIMUM DISPLACEMENTS ( INCH /RADIANS) (LOADING     1)
          MAXIMUMS    AT NODE
   X = -1.08819E-03     398
   Y = -9.76744E-02     398
   Z =  2.91341E-03     398
   RX=  8.32207E-05     108
   RY= -2.30287E-21     319
   RZ=  8.25163E-05      17
```

Maximum Horizontal Displacement was, $2.9134{*}10^{-3}inch.$

And Maximum Force was, 31590 kip.

So,

Horizontal Stiffness= $\frac{f}{u}$ =$\frac{31590*12}{2.9134*10^{-3}}$= $1.3*10^{8}$ k/ft

Result Comparison (project-01)

The horizontal stiffness from manual calculation is $1.257*10^{10}$ k/ft, but using Q4 elements in Etabs it is $42.87*10^{3}$k/ft and using Q4 Element in Staad pro it is $1.3*10^{8}$k/ft.

The Variation is huge because in Etabs we do not include Axial forces (self-weight of span). Only a horizontal force of 1000 k has been added because of the limitation of Etabs.

On the other hand, Staad pro cannot mesh properly a vertical member (pile). Inaccuracy of shape function can differ the result also.

Result Comparison (Project-02)

The natural frequency for manual calculation is 7017.15 rad/s and Natural frequency for Etabs is 21.01 rad/s. Unfortunately, we could not calculate natural frequency for Staad pro. Without any Earthquake data it is not possible to calculate natural frequency in Staad pro.

In Etabs Horizontal stiffness was different than manual calculation so, inaccuracy occurs.

Moreover, mass calculation in Etabs was not accurate as self-weight of Pile cap was not assigned in Etabs.