University of Global Village (UGV), Barishal

SAFE (Foundation Design)

Content of Laboratory Course

Prepared By

Rubieyat Bin Ali
Assistant Professor & HOD
Department of Civil Engineering
University of Global Village (UGV)

Ronok Islam
Assistant Design Engineer
Quantam Builders and Engineering Ltd. (QBEL)

Program: B.Sc. in CE

BASIC COURSE INFORMATION

Course Title	SAFE (Foundation Design)
Course Code	CE 0732-3202
Credits	01
CIE Marks	30
SEE Marks	20
Exam Hours	2 hours (Semester Final Exam)
Level	6th Semester

SAFE (Foundation Design)

COURSE CODE: CE 0732-2104

CREDIT:01

TOTAL MARKS:50

CIE MARKS: 30

Semester End Exam Hours 2

SEE MARKS: 20

Course Learning Outcomes (CLOs): After completing this course successfully, the students will be able to-

CLO 1	**Understand** concepts of Structural Design of Reinforced concrete members.
CLO 2	**Analyze** various structural components of building foundations (single/combined footing, mat foundation and pile cap/pile foundation.
CLO 3	**Develop** intellectual communication skills through working in groups in performing in different load assigning (dead, live, earthquake, wind etc.) and various Serviceability limit Check.
CLO 4	**Generate** the detailing of various structural components of buildings and bridges.

SL	Content of Course	Hrs	CLOs
1	Introduction to all Shortcuts, Introduction to Editing Command, Load and Structural frame assign	10	CLO1
2	Design of Single Column Footing	20	CLO3
3	Design of Combined Footing	20	CLO2, CLO4
4	Design of Mat Foundation	5	CLO1, CLO3
5	Design of Pile and Pile Cap	10	CLO1
6	Design of Group Pile	10	CLO3
7	Lab Test, Viva, Quiz, Overall Assessment, Skill Development Test (Competency)	10	CLO1

Text Book:

1. Design of Concrete Structures by Arthur H. Nilson, David Darwin, Charles W. Dolan (Mc Graw Hill) – 13th edition.

2. Design of Concrete Structures by Arthur H. Nilson – 7th edition.

3. Design of Reinforced Concrete by Jack C. McCormac, Russell H. Brown – 9th edition

4. The American Society of Civil Engineers, code-7-05

5. User's Guide SAFE® 2016

6. SAFE User's Manual

7. Gazetted-BNBC-2020-Enhanced-file-published-by-Dr.-Khan-Mahmud-Amanat-Follow-Design-Integrity-for-Civil-Engg-info.

ASSESSMENT PATTERN

CIE- Continuous Internal Evaluation (30 Marks)

SEE- Semester End Examination (20 Marks)

SEE- Semester End Examination (40 Marks) (should be converted in actual marks (20))

Bloom's Category	**Tests**
Remember	**05**
Understand	**07**
Apply	**08**
Analyze	**07**
Evaluate	**08**
Create	**05**

CIE- Continuous Internal Evaluation (100 Marks) (should be converted in actual marks (30))

Bloom's Category Marks (out of 100)	Lab Final (30)	Lab Report (10)	**Continuous lab performance** (30)	Presentation & Viva (10)	External Participation in Curricular/**Final Project Exhibition** (10)
Imitation	05		05	02	Attendance 10
Manipulation	05	05	05	03	
Precision	05		05		
Articulation	05		05		
Naturalisation	05	05	05		
Create	05		05	05	

Couse plan specifying content, CLOs, teaching learning and assessment strategy mapped with CLOs

Week	Topic	Teaching-Learning Strategy	Assessment Strategy	Corresponding CLOs
1	Basic introduction about SAFE software	Lecture, discussion, Experiment	Quiz, Lab Test	CLO1
2-3	Introduction to all Shortcuts and Editing Command	Oral Presentation, Project Exhibition	Lab Report Assessment, viva	CLO3
4	Load Transferring Mechanism and, Load and Structural frame assign	Presentation, Field visit	Skill Development Test	CLO2, CLO4
5-7	Design of Single Column Footing	Lecture, discussion, Experiment, Demonstration	Quiz, Lab Test	CLO1, CLO3
8-10	Design of Combined Footing	Oral Presentation, Project Exhibition	Lab Report Assessment, viva	CLO1
11-12	Design of Mat Foundation	Presentation, Field visit	Skill Development Test	CLO3
13-14	Design of Pile and Pile Cap	Lecture, discussion, Experiment	Quiz, Lab Test	CLO2, CLO4

Couse plan specifying content, CLOs, teaching learning and assessment strategy mapped with CLOs

Week	Topic	Teaching-Learning Strategy	Assessment Strategy	Corresponding CLOs
15-16	Design of Group Pile	Lecture, discussion, Experiment	Quiz, Lab Test	CLO1
17	Lab Test, Viva, Quiz, Overall Assessment, Skill Development Test (Competency)	Lecture, discussion, Experiment	Quiz, Lab Test	CLO2, CLO4

Basic introduction about SAFE software

Week 1

Pages 9-11

SAFE SKILL TRANING (FOUNDATION DESIGN)

Training Outline

- ❖ Basic Concept on SAFE Software
- ❖ Single Column Footing Design by SAFE
- ❖ Combined Footing Design by SAFE
- ❖ Mat Foundation Design by SAFE
- ❖ Design of Pile & Pile Cap by SAFE
- ❖ Discussion on BNBC 2020/ASCE-7-05

Introduction of SAFE Software

SAFE = Slab Analysis by the Finite Element Method.

Latest Version = SAFE V22.4

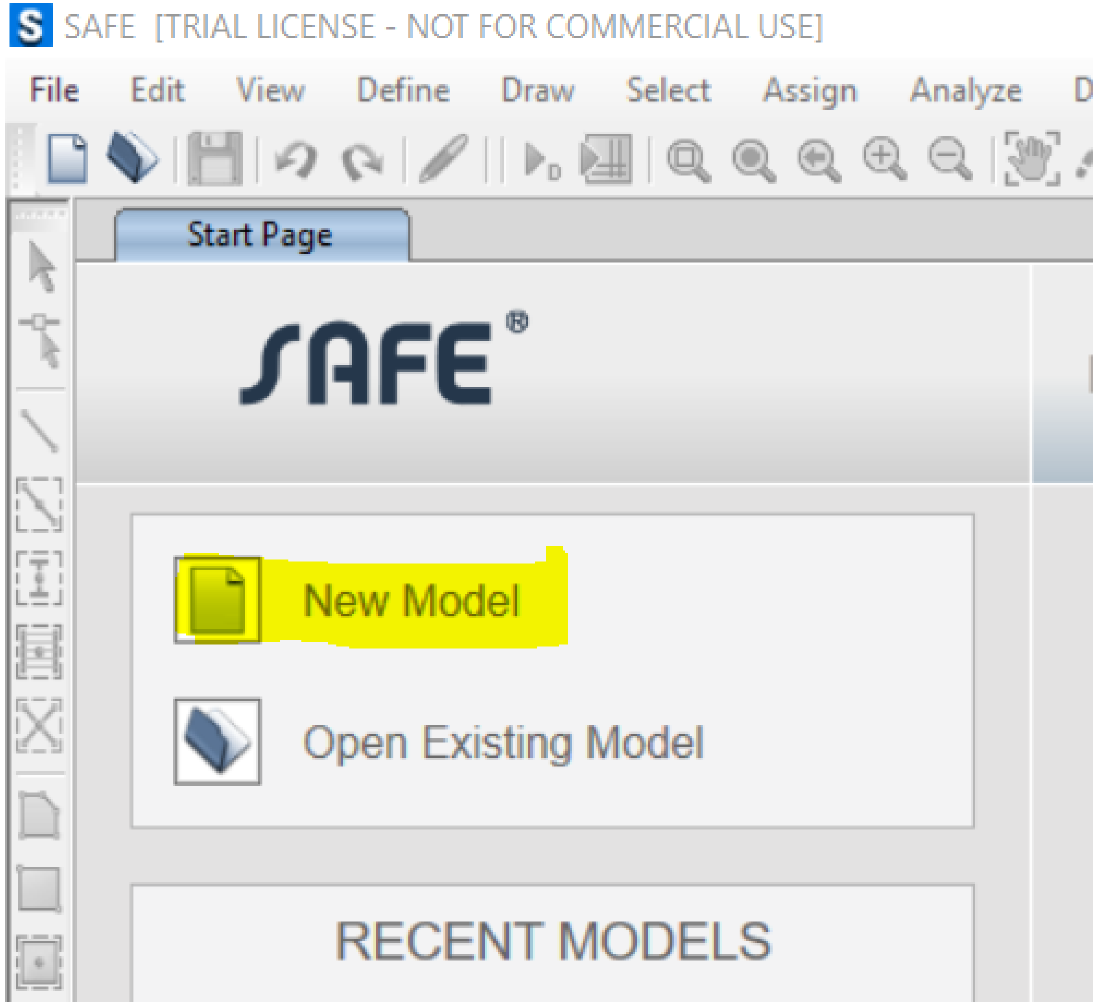
We Use SAFE 2016

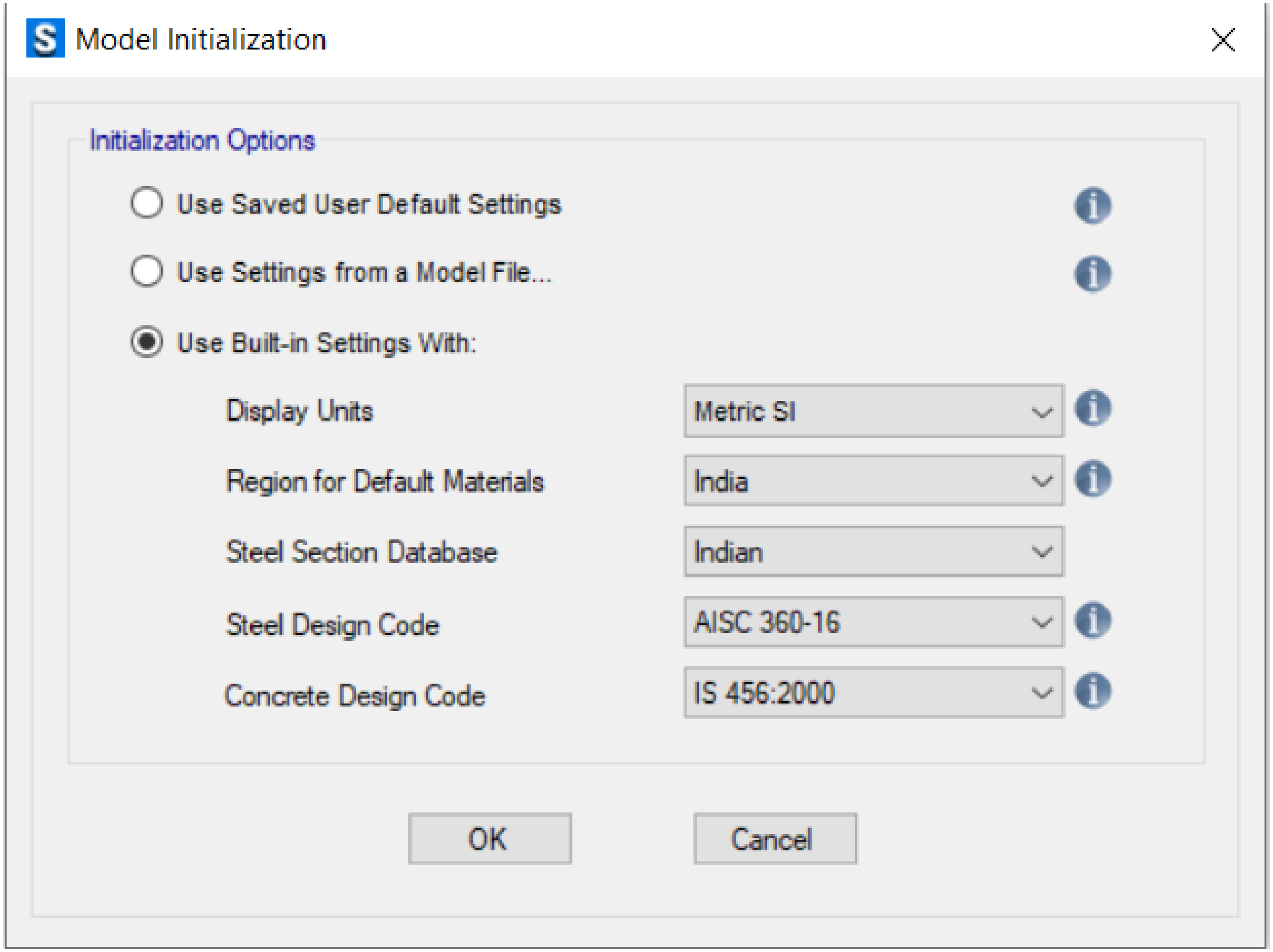
This software is used for the design of slab and foundation of a structure.

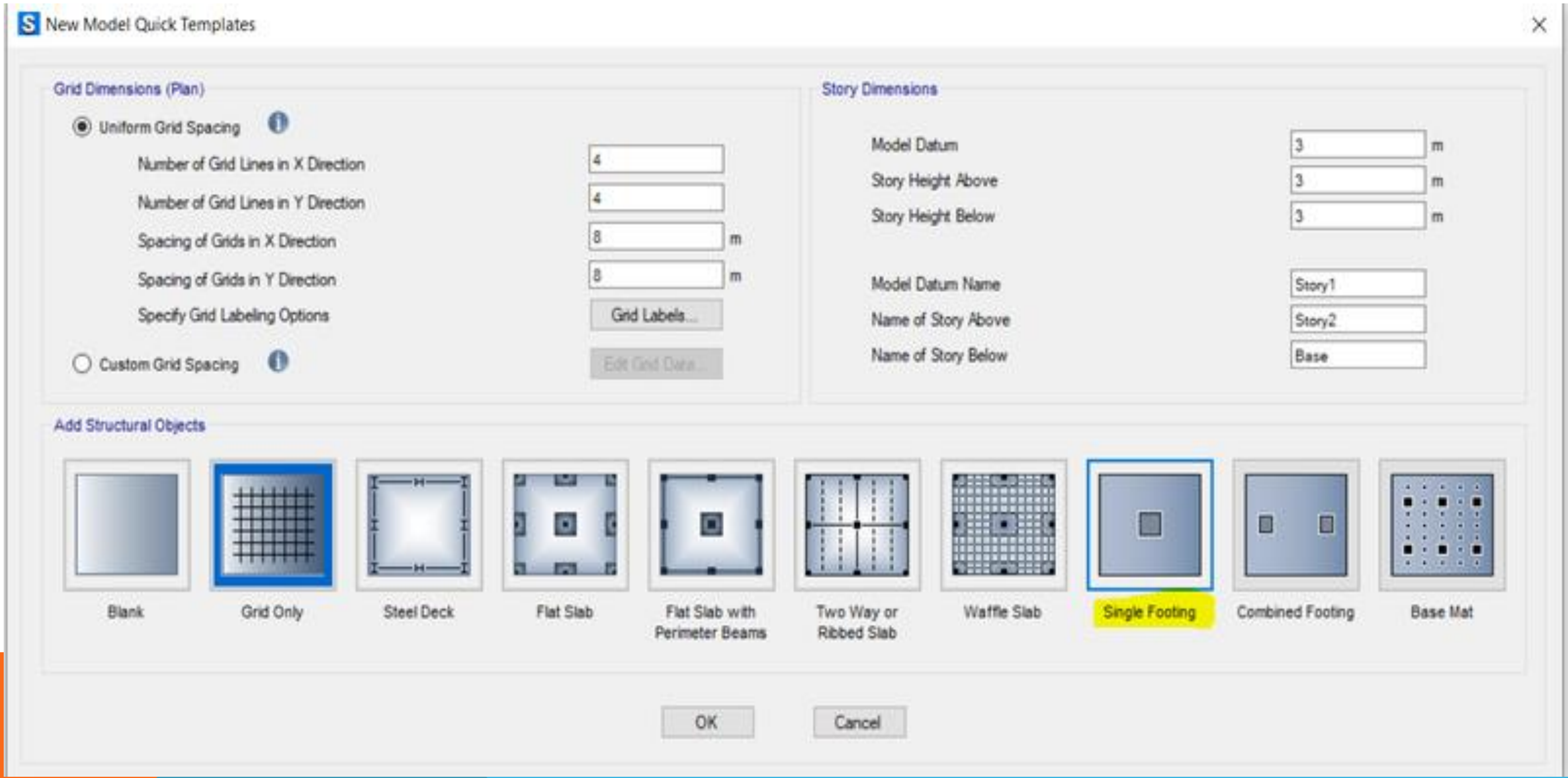
Introduction to all Shortcuts and Editing Command

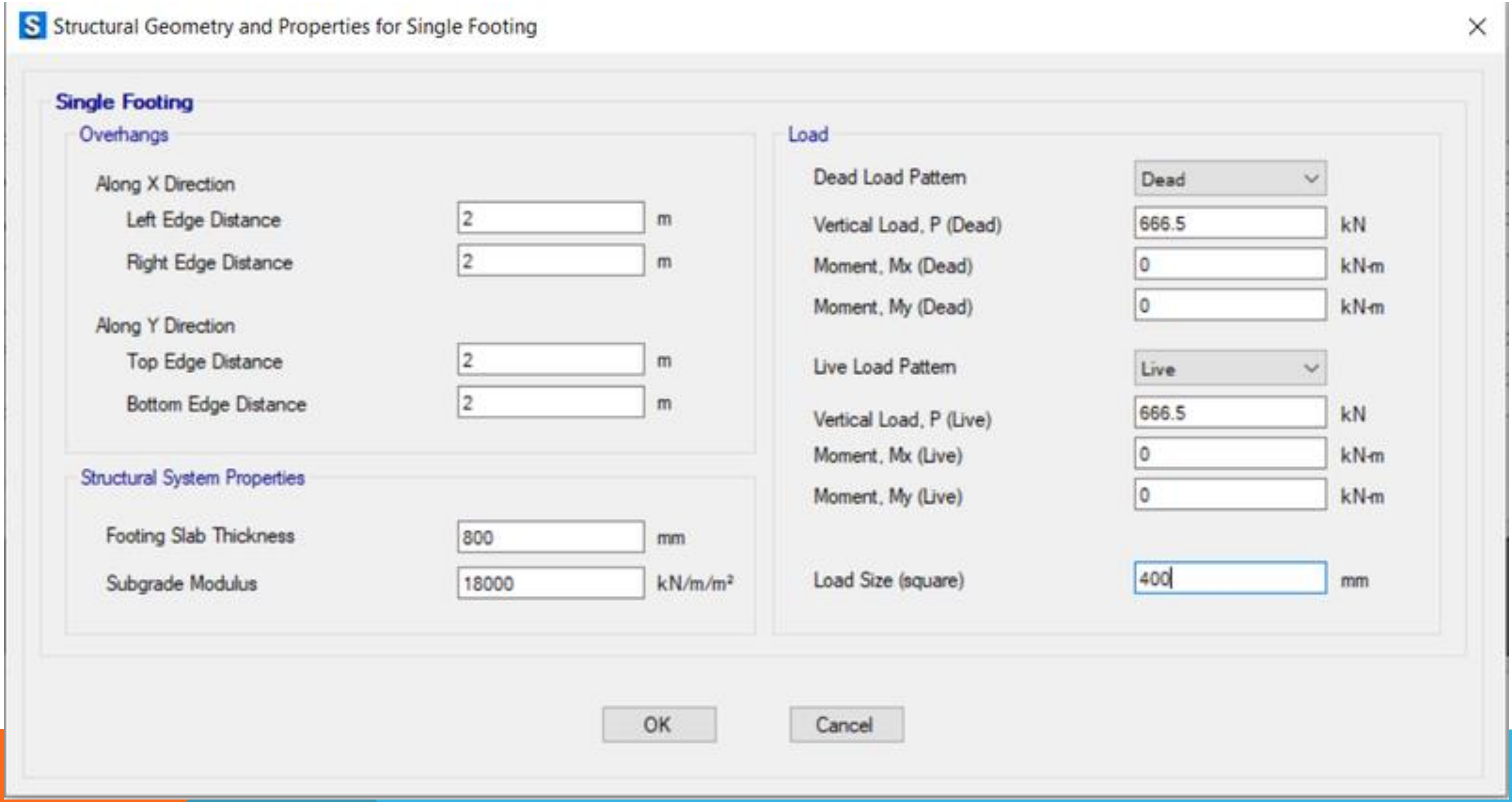
Week 2

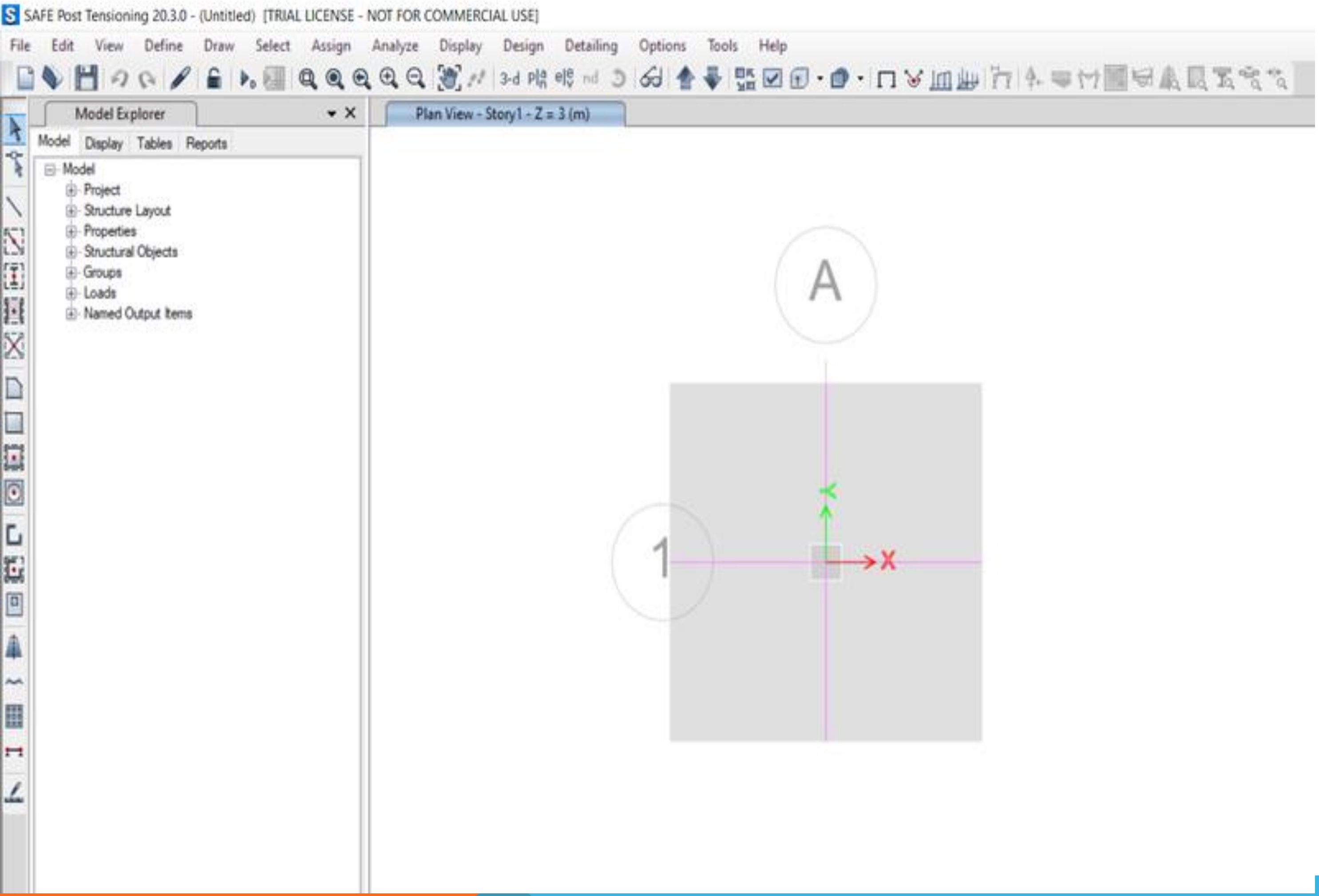
Pages 13-16


SAFE [TRIAL LICENSE - NOT FOR COMMERCIAL USE]
File Edit View Define Draw Select Assign Analyze D
Start Page
SAFE®
New Model
Open Existing Model
RECENT MODELS

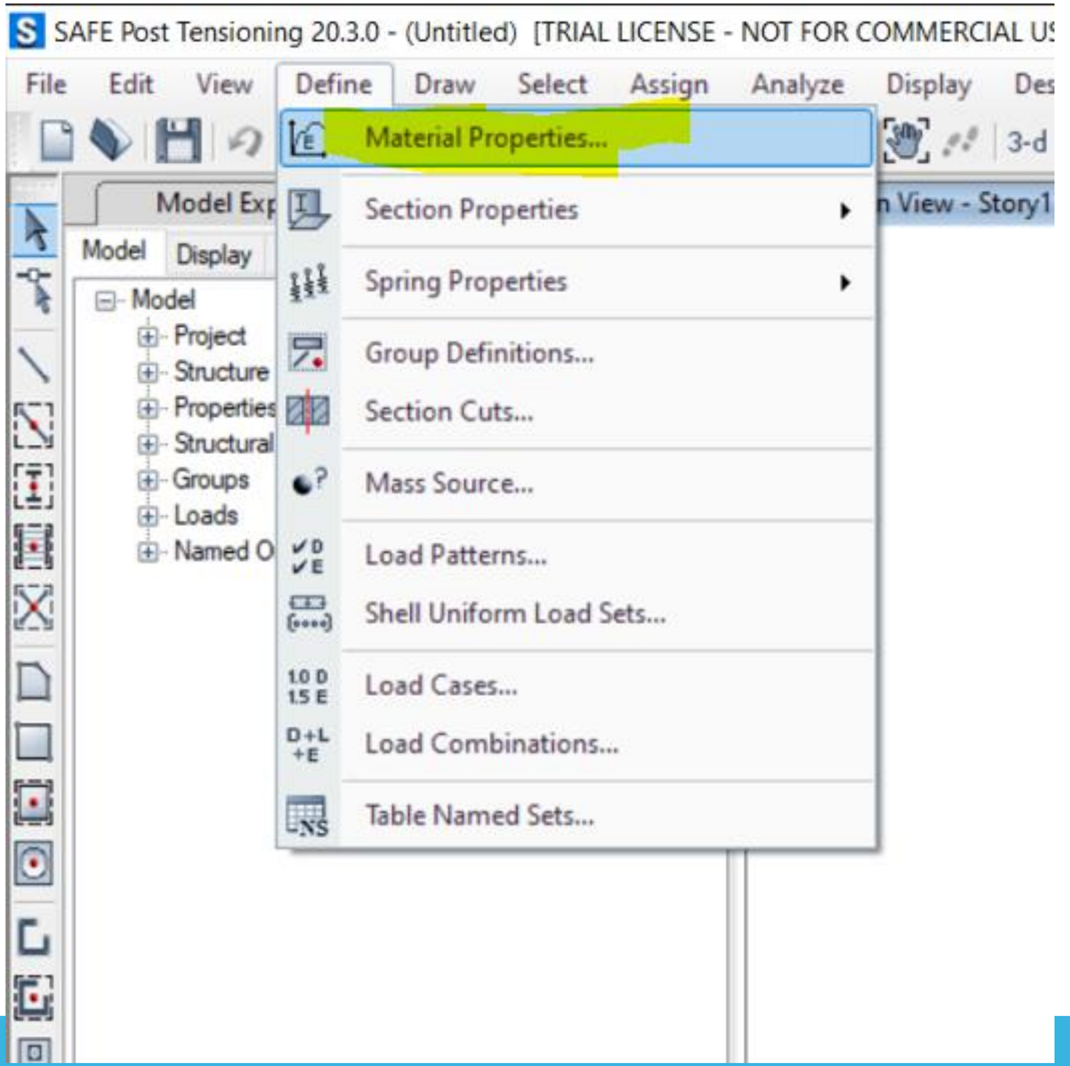

Model Initialization
Initialization Options
Use Saved User Default Settings
Use Settings from a Model File...
Use Built-in Settings With:
Display Units
Metric SI
Region for Default Materials
India
Steel Section Database
Indian
Steel Design Code
AISC 360-16
Concrete Design Code
IS 456:2000
OK
Cancel


New Model Quick Templates
Grid Dimensions (Plan)
Uniform Grid Spacing
Number of Grid Lines in X Direction
4
Number of Grid Lines in Y Direction
4
Spacing of Grids in X Direction
8
m
Spacing of Grids in Y Direction
8
m
Specify Grid Labeling Options
Grid Labels...
Custom Grid Spacing
Edit Grid Data...
Story Dimensions
Model Datum
3
m
Story Height Above
3
m
Story Height Below
3
m
Model Datum Name
Story1
Name of Story Above
Story2
Name of Story Below
Base
Add Structural Objects
Blank
Grid Only
Steel Deck
Flat Slab
Flat Slab with Perimeter Beams
Two Way or Ribbed Slab
Waffle Slab
Single Footing
Combined Footing
Base Mat
OK
Cancel


Structural Geometry and Properties for Single Footing
Single Footing
Overhangs
Along X Direction
Left Edge Distance
2
m
Right Edge Distance
2
m
Along Y Direction
Top Edge Distance
2
m
Bottom Edge Distance
2
m
Structural System Properties
Footing Slab Thickness
800
mm
Subgrade Modulus
18000
kN/m/m²
Load
Dead Load Pattern
Dead
Vertical Load, P (Dead)
666.5
kN
Moment, Mx (Dead)
0
kN-m
Moment, My (Dead)
0
kN-m
Live Load Pattern
Live
Vertical Load, P (Live)
666.5
kN
Moment, Mx (Live)
0
kN-m
Moment, My (Live)
0
kN-m
Load Size (square)
400
mm
OK
Cancel



SAFE Post Tensioning 20.3.0 - (Untitled) [TRIAL LICENSE - NOT FOR COMMERCIAL USE]
File Edit View Define Draw Select Assign Analyze Display Design Detailing Options Tools Help
Model Explorer
Model Display Tables Reports
Model
Project
Structure Layout
Properties
Structural Objects
Groups
Loads
Named Output Items
Plan View - Story1 - Z = 3 (m)
A
1
X

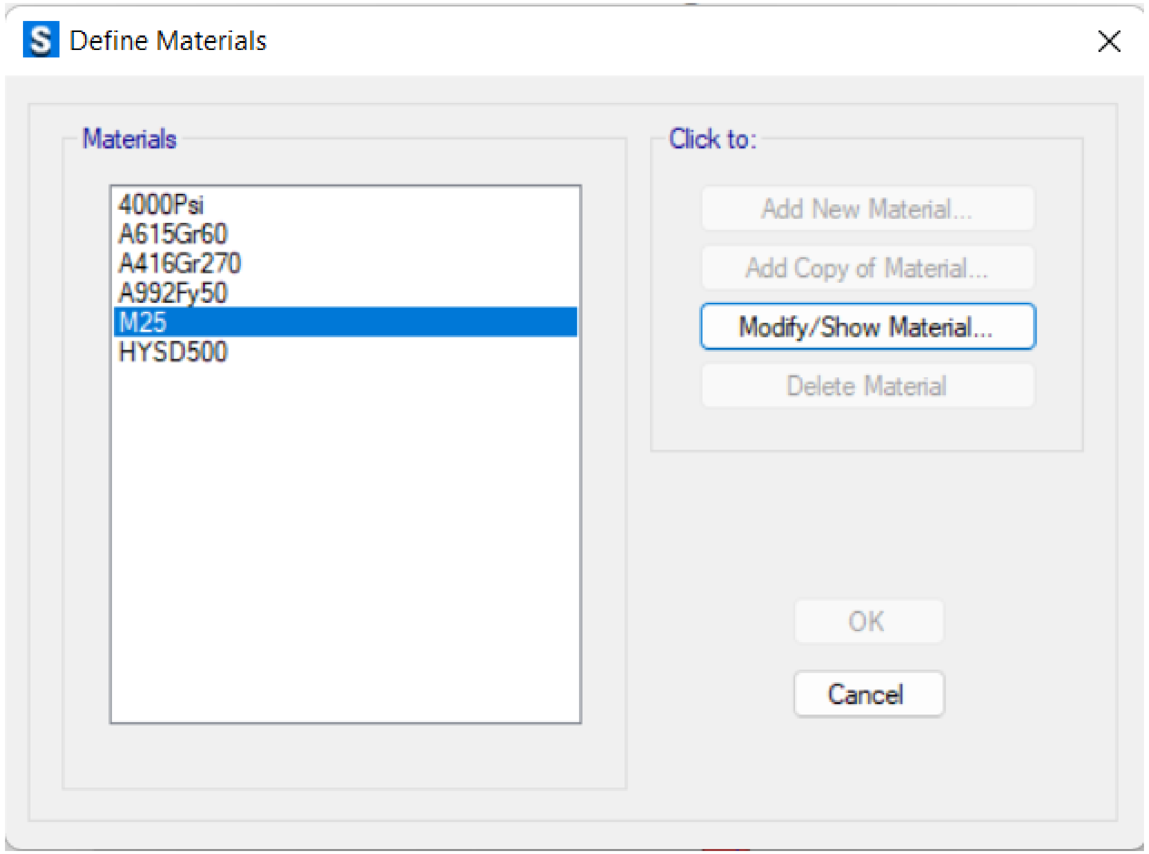


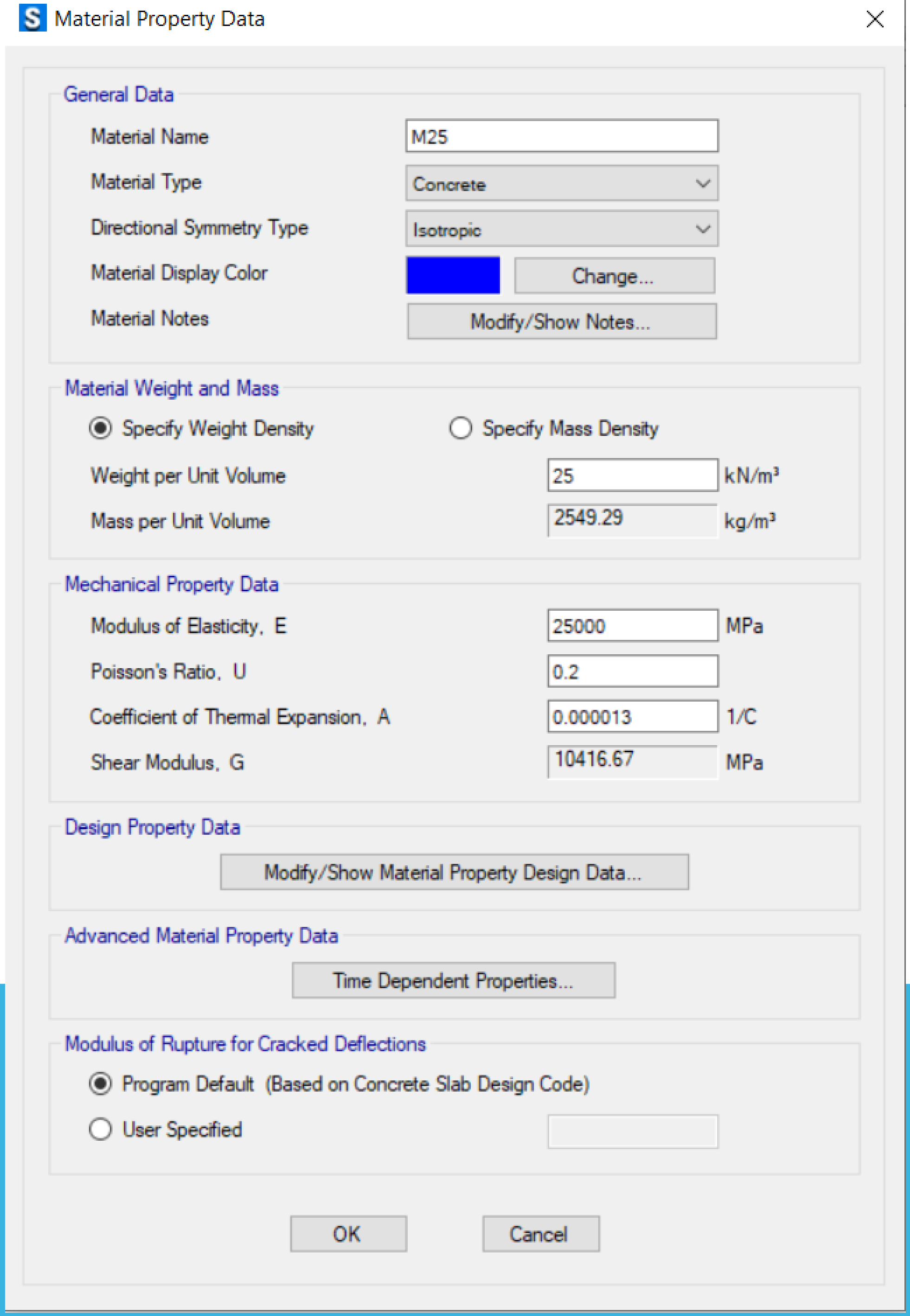
SAFE Post Tensioning 20.3.0 - (Untitled) [TRIAL LICENSE - NOT FOR COMMERCIAL US
File Edit View Define Draw Select Assign Analyze Display Des
Material Properties...
Section Properties
Spring Properties
Group Definitions...
Section Cuts...
Mass Source...
Load Patterns...
Shell Uniform Load Sets...
Load Cases...
Load Combinations...
Table Named Sets...
Model
Display
Project
Structure
Properties
Structural
Groups
Loads

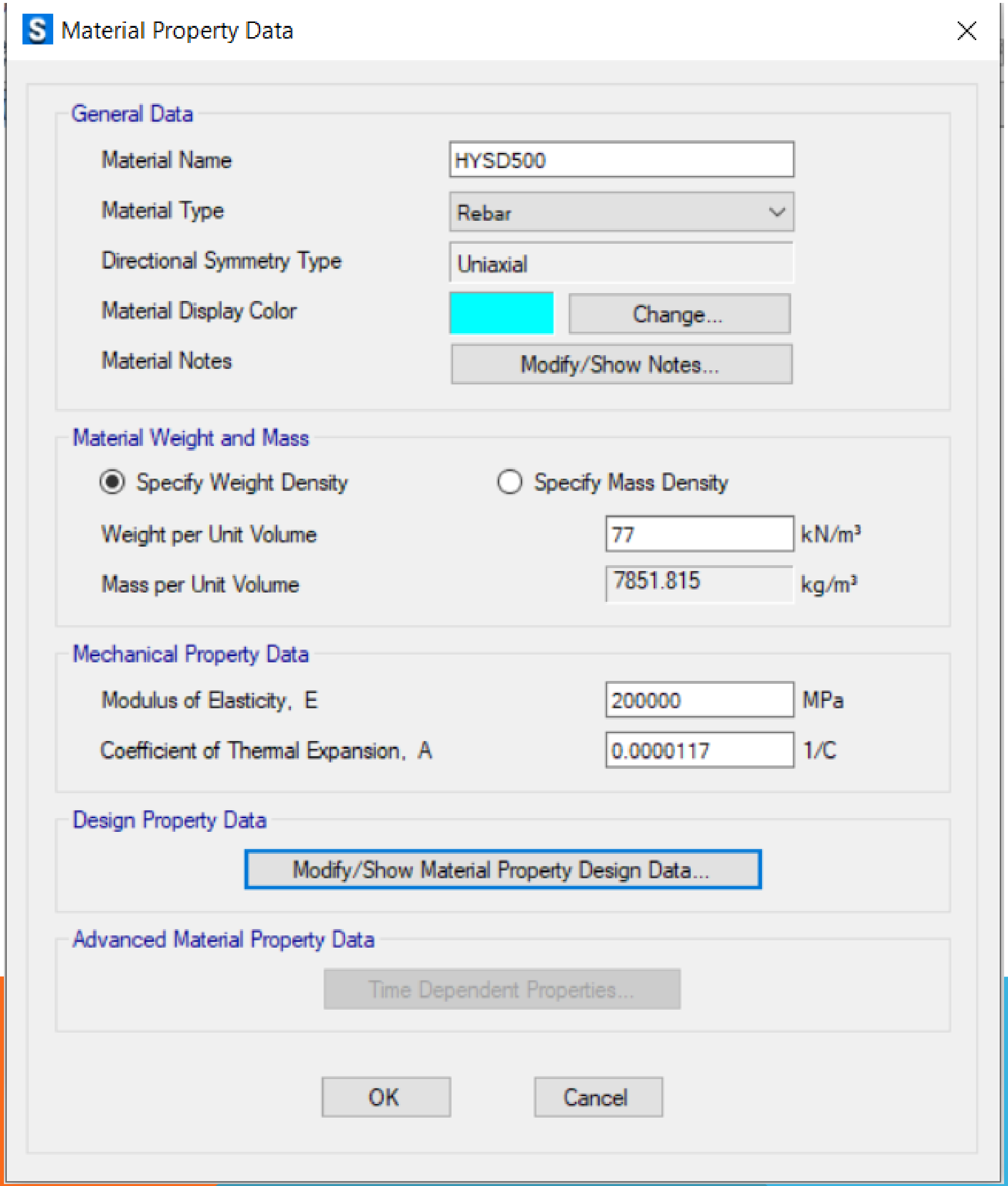
Introduction to all Shortcuts and Editing Command

Week 3

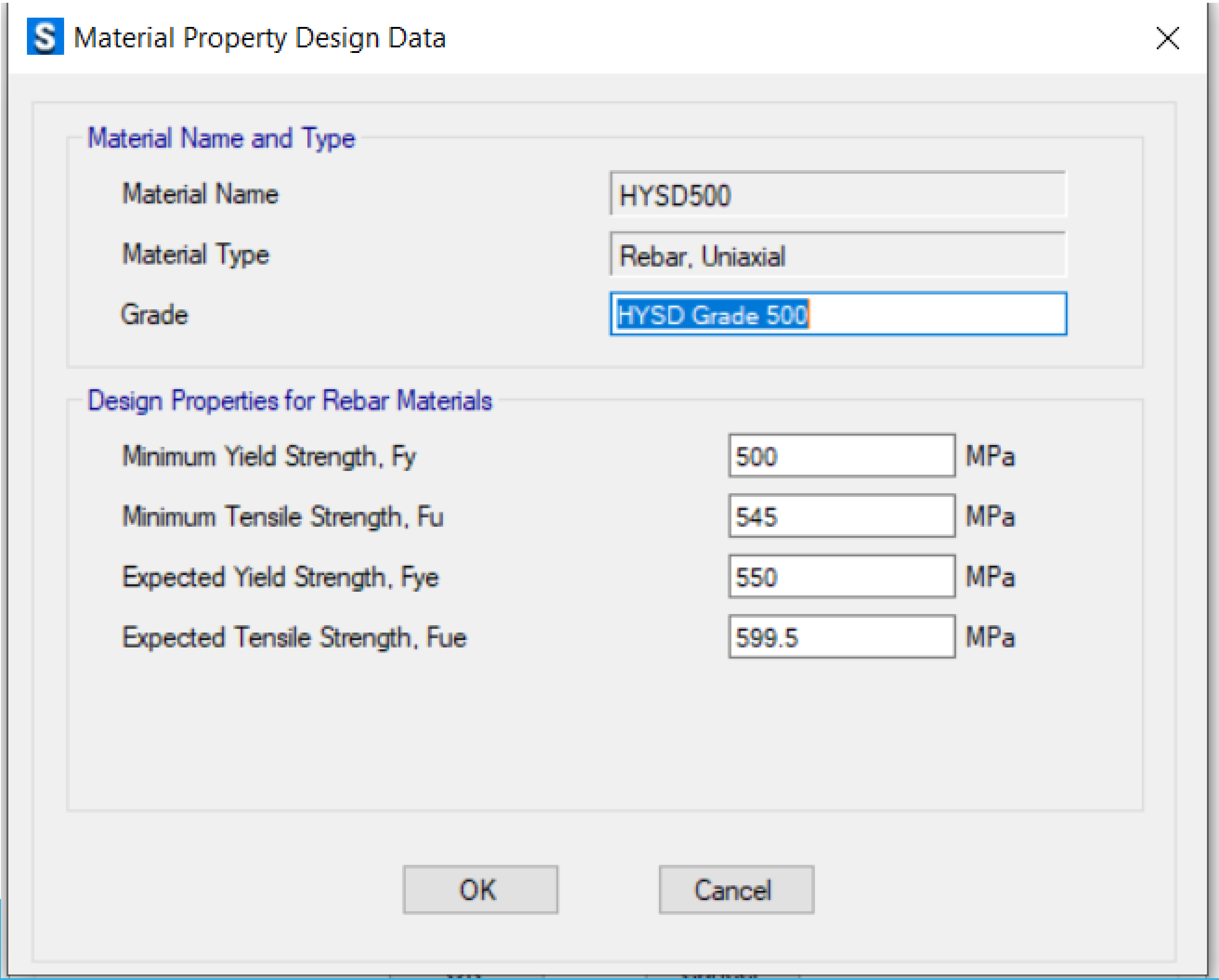
Pages 17-23


Define Materials
Materials
4000Psi
A615Gr60
A416Gr270
A992Fy50
M25
HYSD500
Click to:
Add New Material...
Add Copy of Material...
Modify/Show Material...
Delete Material
OK
Cancel

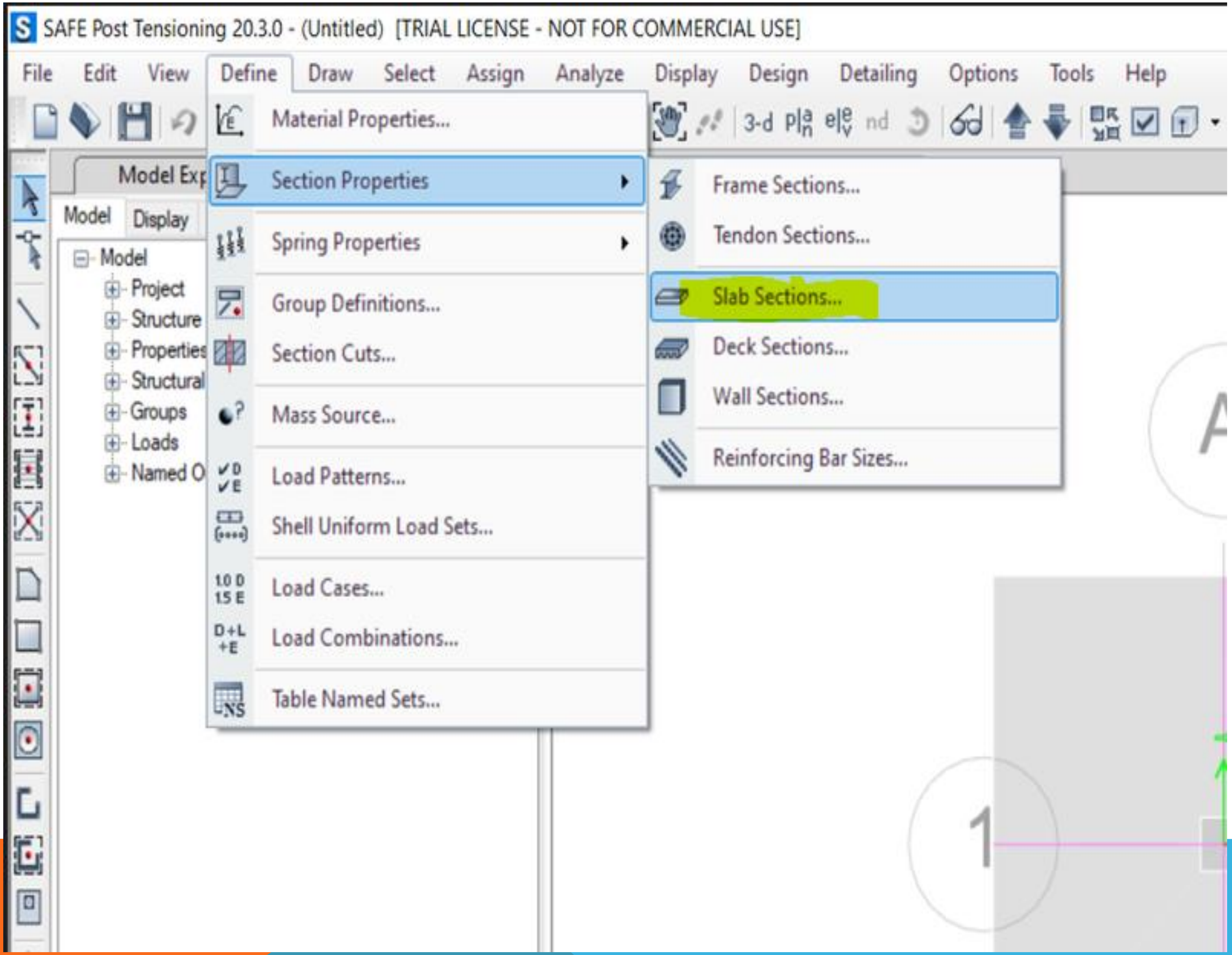

Material Property Data
General Data
Material Name
M25
Material Type
Concrete
Directional Symmetry Type
Isotropic
Material Display Color
Change...
Material Notes
Modify/Show Notes...
Material Weight and Mass
Specify Weight Density
Specify Mass Density
Weight per Unit Volume
25
kN/m³
Mass per Unit Volume
2549.29
kg/m³
Mechanical Property Data
Modulus of Elasticity, E
25000
MPa
Poisson's Ratio, U
0.2
Coefficient of Thermal Expansion, A
0.000013
1/C
Shear Modulus, G
10416.67
MPa
Design Property Data
Modify/Show Material Property Design Data...
Advanced Material Property Data
Time Dependent Properties...
Modulus of Rupture for Cracked Deflections
Program Default (Based on Concrete Slab Design Code)
User Specified
OK
Cancel



Material Property Data
General Data
Material Name
HYSD500
Material Type
Rebar
Directional Symmetry Type
Uniaxial
Material Display Color
Change...
Material Notes
Modify/Show Notes...
Material Weight and Mass
Specify Weight Density
Specify Mass Density
Weight per Unit Volume
77
kN/m³
Mass per Unit Volume
7851.815
kg/m³
Mechanical Property Data
Modulus of Elasticity, E
200000
MPa
Coefficient of Thermal Expansion, A
0.0000117
1/C
Design Property Data
Modify/Show Material Property Design Data...
Advanced Material Property Data
Time Dependent Properties...
OK
Cancel



Material Property Design Data
Material Name and Type
Material Name
HYSD500
Material Type
Rebar, Uniaxial
Grade
HYSD Grade 500
Design Properties for Rebar Materials
Minimum Yield Strength, Fy
500
MPa
Minimum Tensile Strength, Fu
545
MPa
Expected Yield Strength, Fye
550
MPa
Expected Tensile Strength, Fue
599.5
MPa
OK
Cancel


SAFE Post Tensioning 20.3.0 - (Untitled) [TRIAL LICENSE - NOT FOR COMMERCIAL USE]
File Edit View Define Draw Select Assign Analyze Display Design Detailing Options Tools Help
Material Properties...
Section Properties
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Group Definitions...
Section Cuts...
Mass Source...
Load Patterns...
Shell Uniform Load Sets...
Load Cases...
Load Combinations...
Table Named Sets...
Frame Sections...
Tendon Sections...
Slab Sections...
Deck Sections...
Wall Sections...
Reinforcing Bar Sizes...
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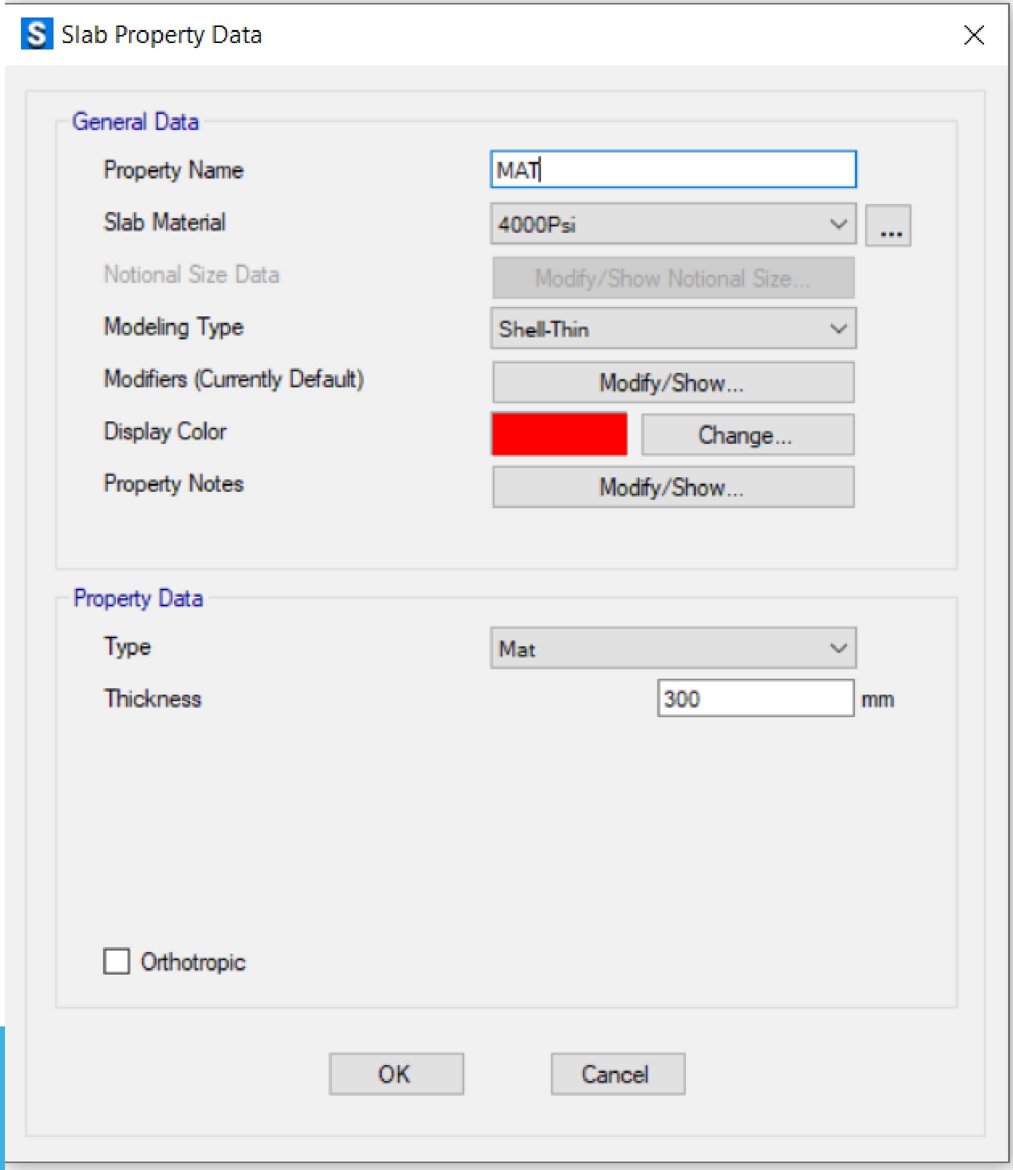
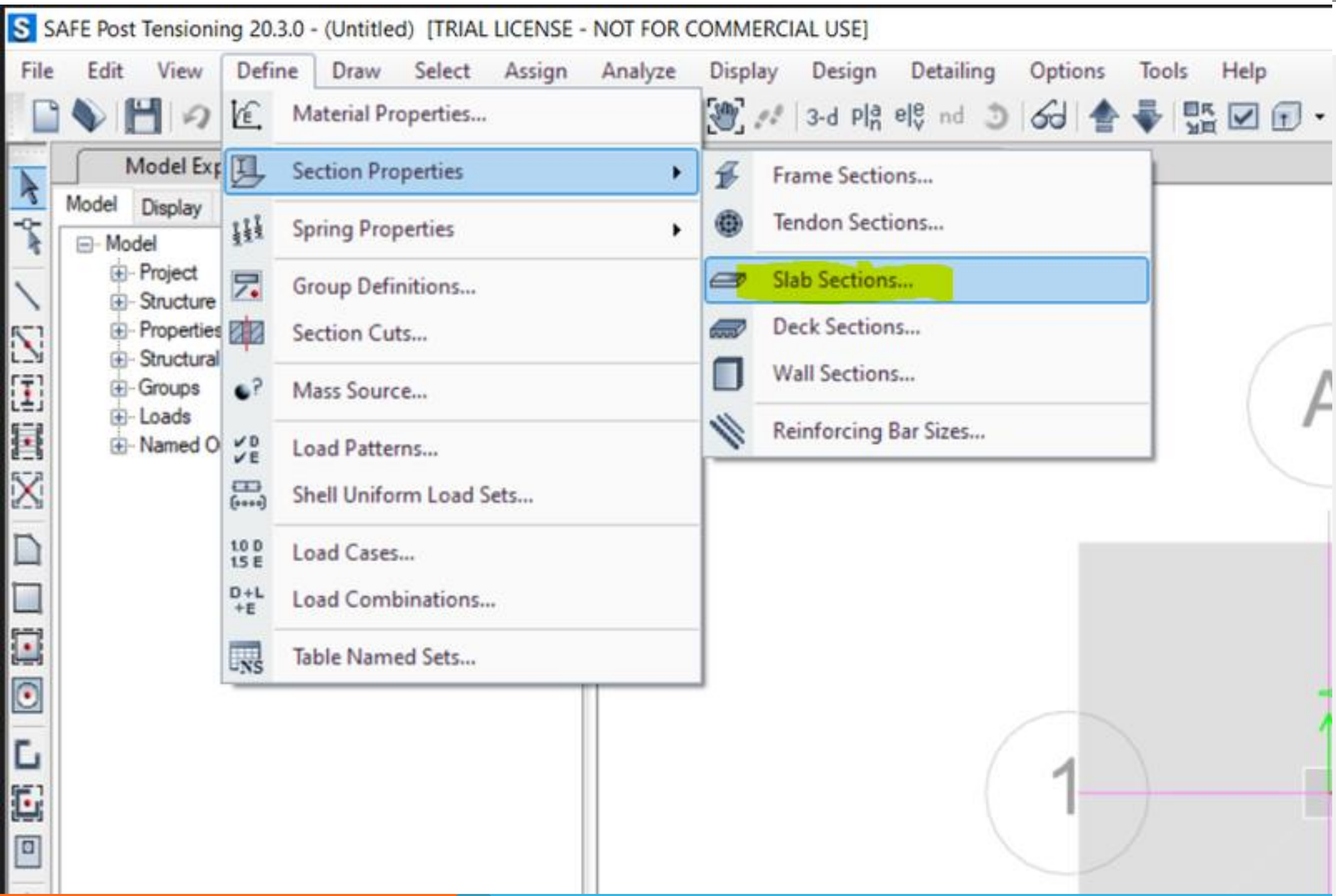

Slab Property Data
General Data
Property Name MAT
Slab Material 4000Psi
Notional Size Data Modify/Show Notional Size...
Modeling Type Shell-Thin
Modifiers (Currently Default) Modify/Show...
Display Color Change...
Property Notes Modify/Show...
Property Data
Type Mat
Thickness 300 mm
Orthotropic
OK
Cancel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Shell Uniform Load Sets...
Load Cases...
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Table Named Sets...
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Tendon Sections...
Slab Sections...
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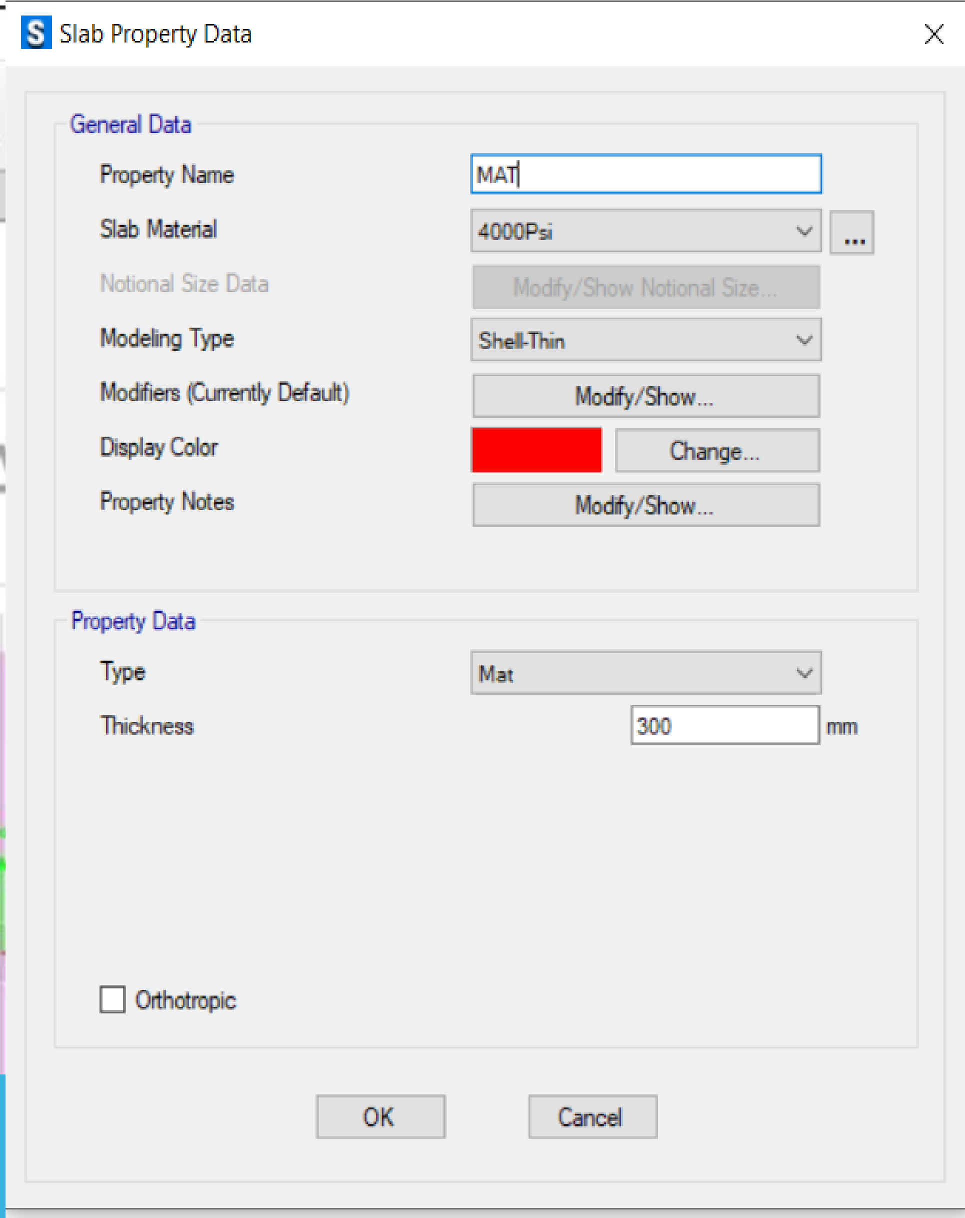
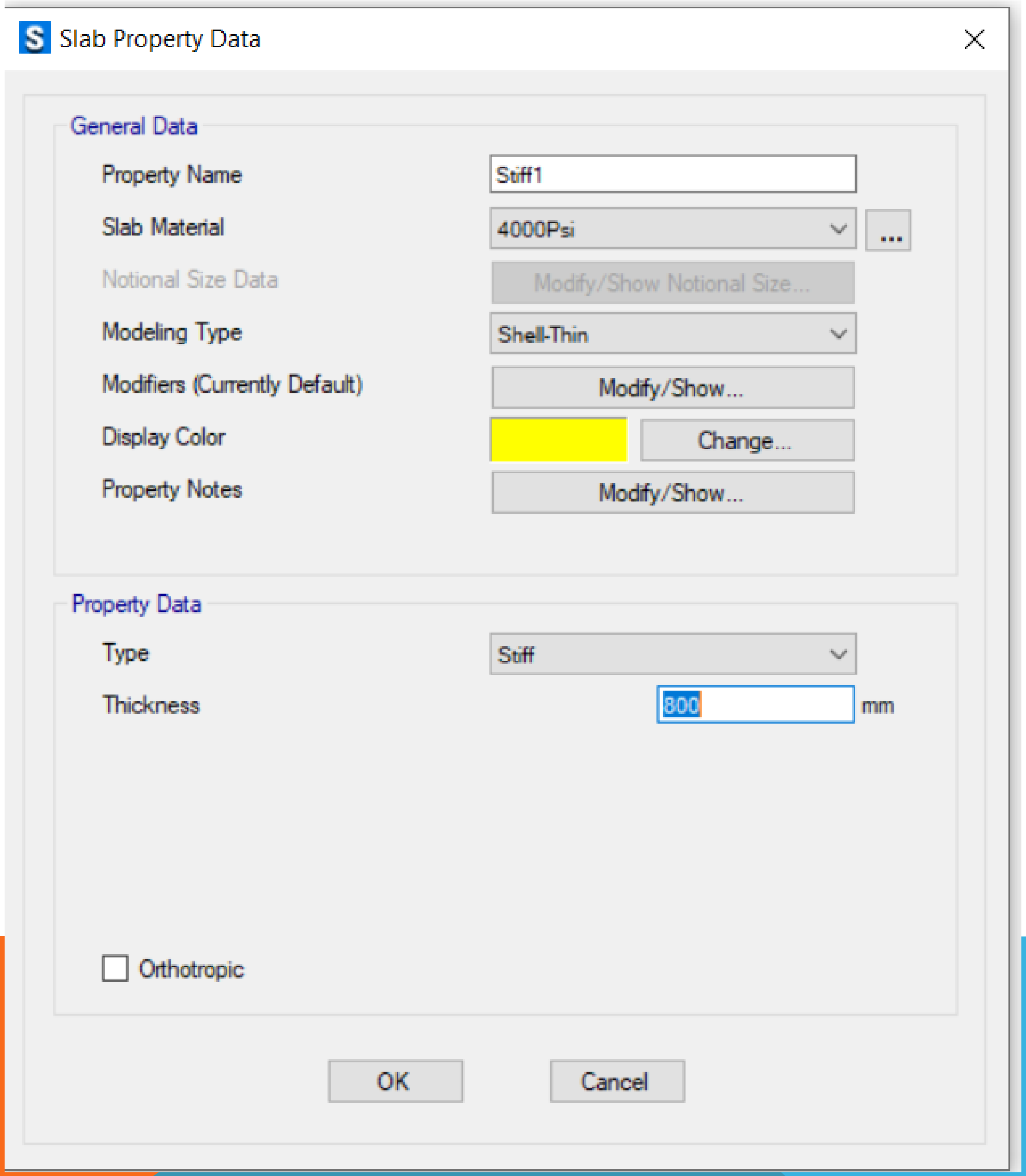
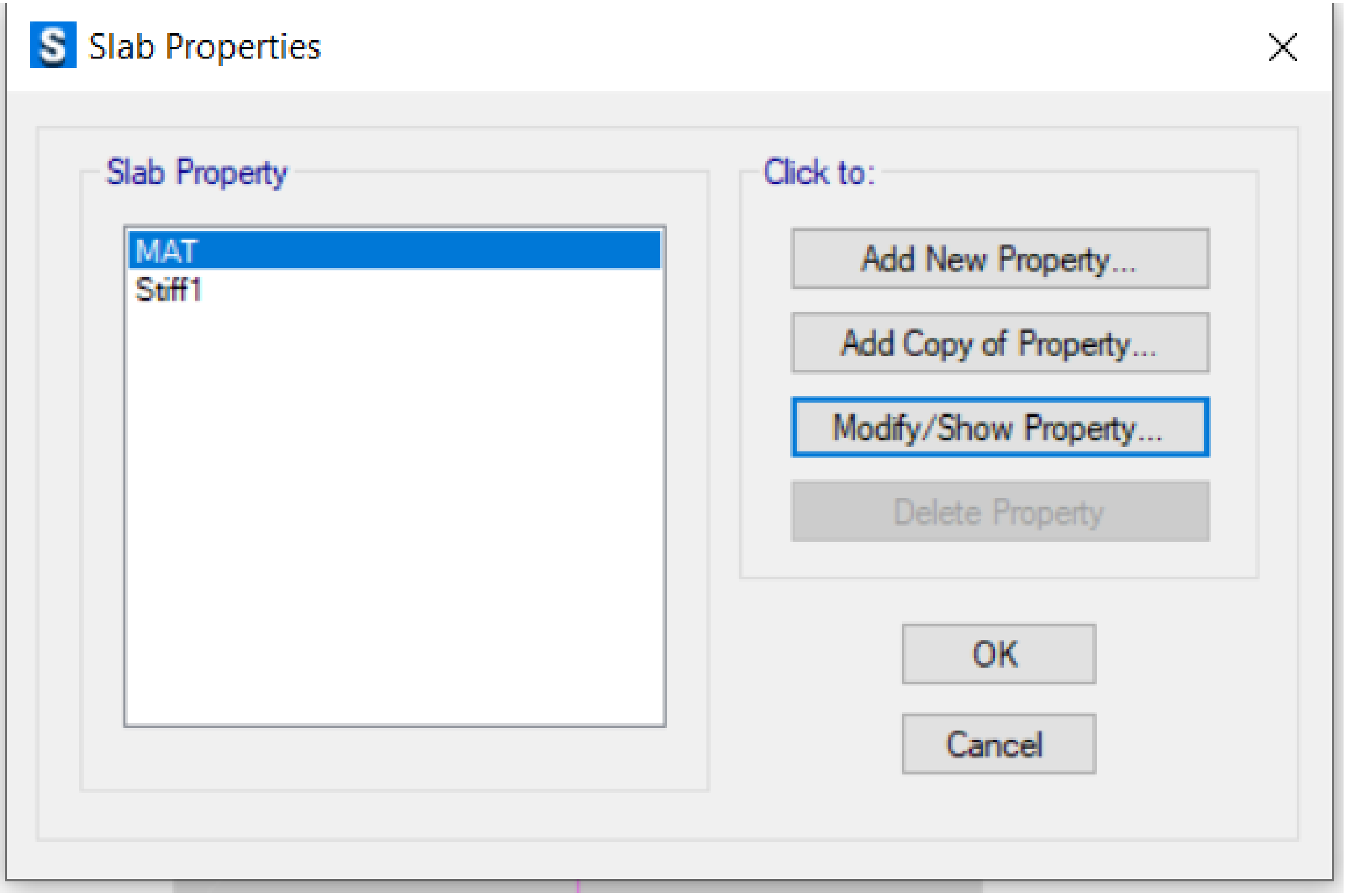
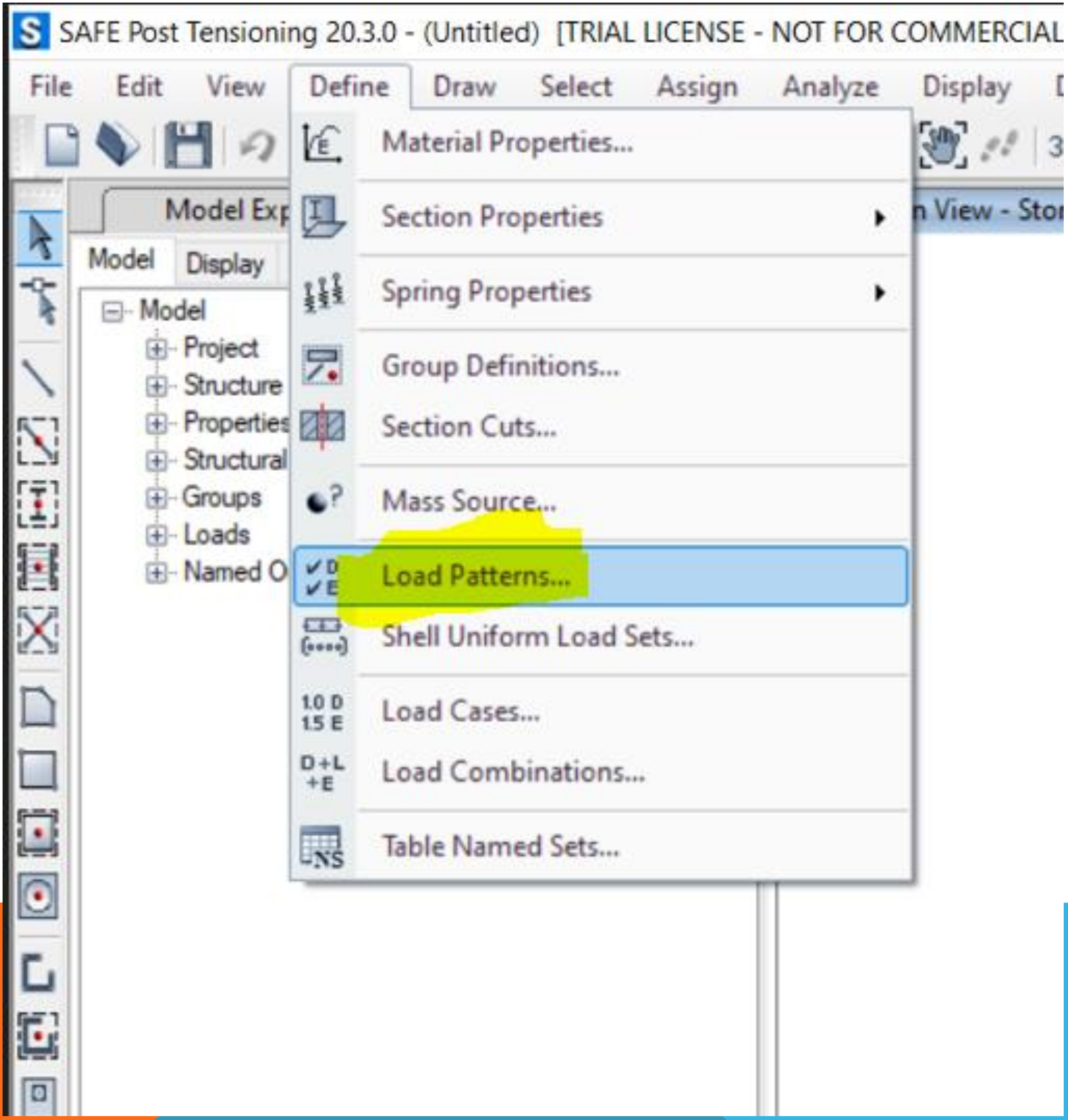

Slab Property Data
General Data
Property Name
MAT
Slab Material
4000Psi
Notional Size Data
Modify/Show Notional Size...
Modeling Type
Shell-Thin
Modifiers (Currently Default)
Modify/Show...
Display Color
Change...
Property Notes
Modify/Show...
Property Data
Type
Mat
Thickness
300
mm
Orthotropic
OK
Cancel


Slab Property Data
General Data
Property Name
Stiff1
Slab Material
4000Psi
...
Notional Size Data
Modify/Show Notional Size...
Modeling Type
Shell-Thin
Modifiers (Currently Default)
Modify/Show...
Display Color
Change...
Property Notes
Modify/Show...
Property Data
Type
Stiff
Thickness
800
mm
Orthotropic
OK
Cancel


Slab Properties
Slab Property
MAT
Stiff1
Click to:
Add New Property...
Add Copy of Property...
Modify/Show Property...
Delete Property
OK
Cancel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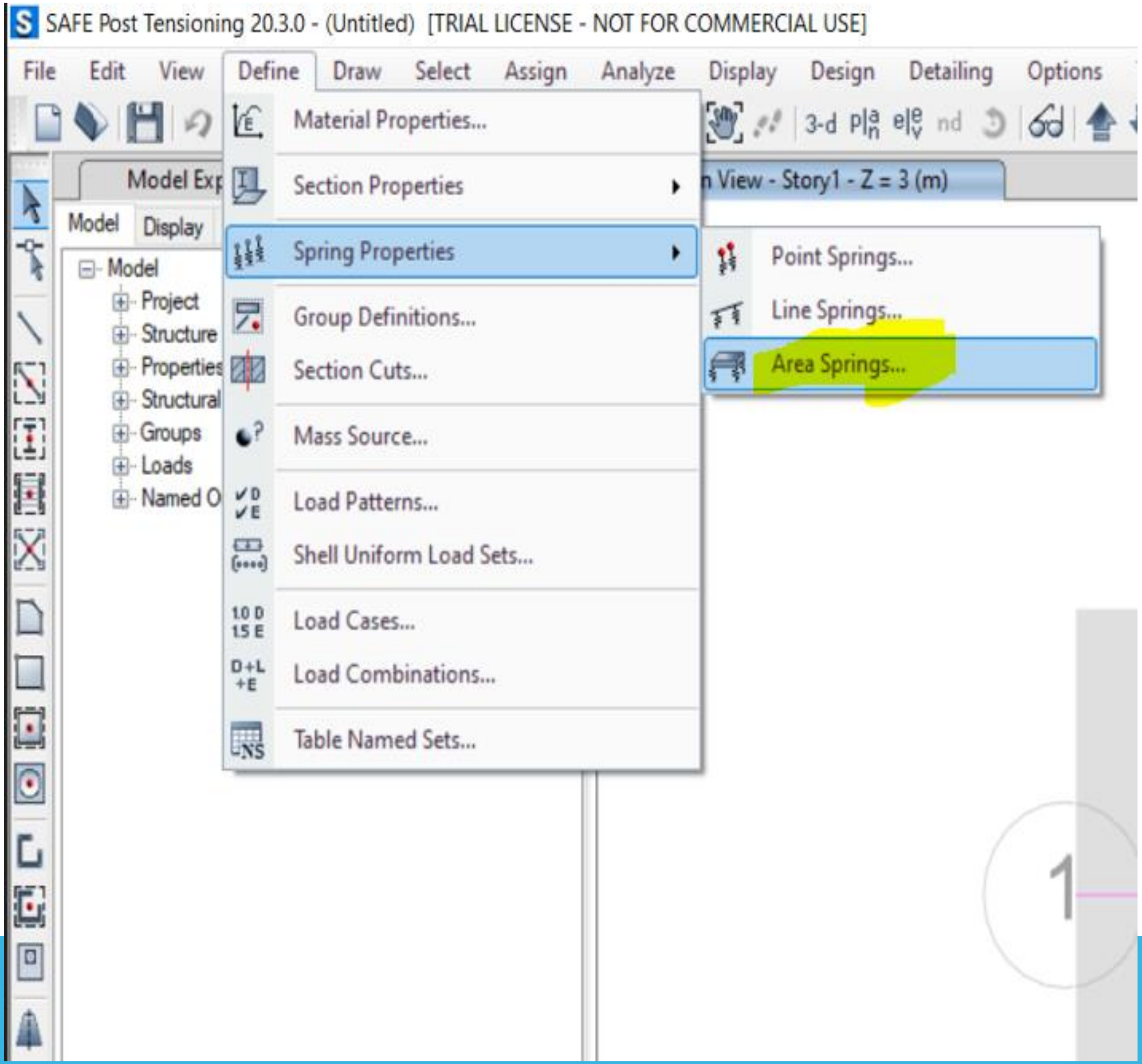
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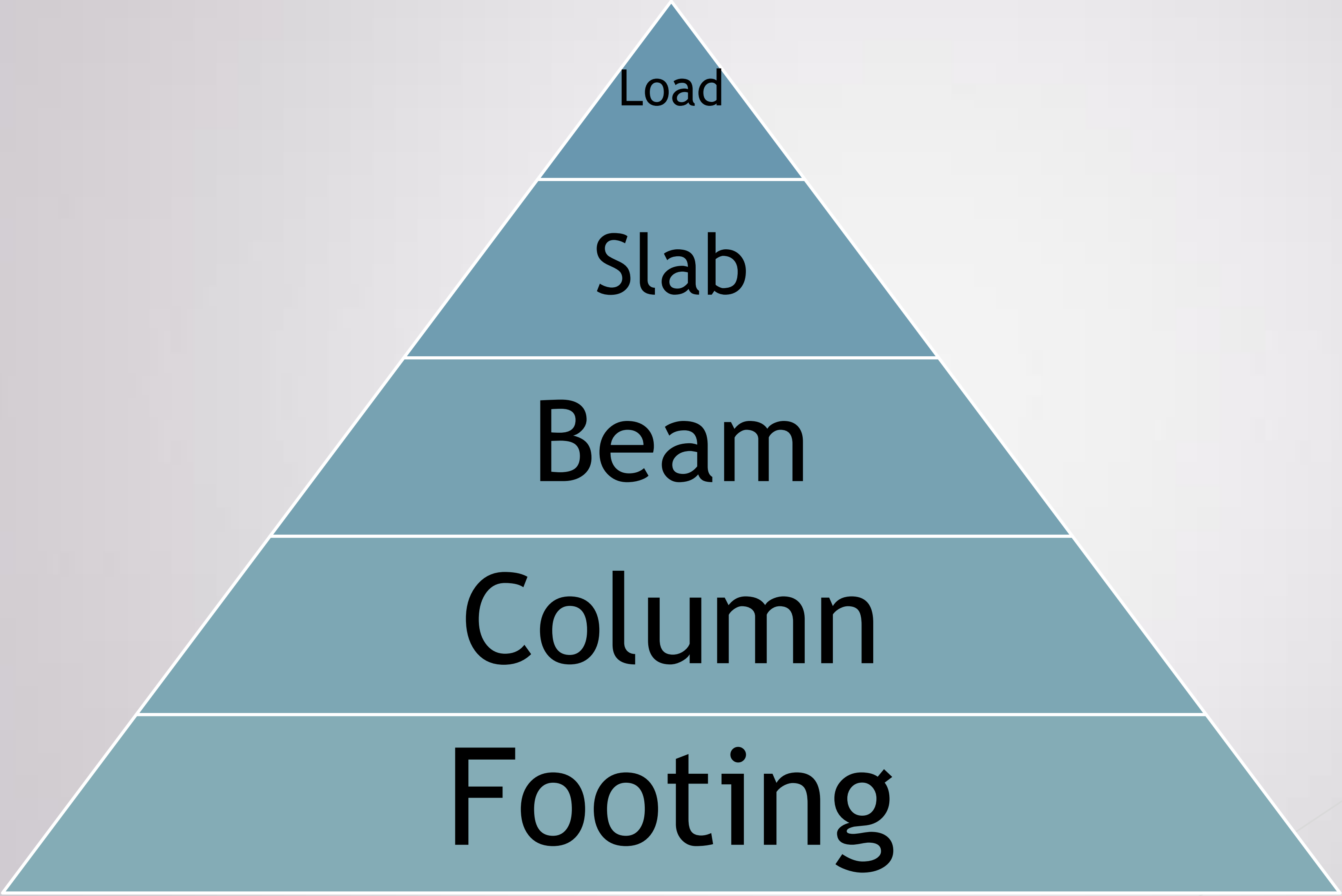
Group Definitions...
Section Cuts...
Mass Source...
Load Patterns...
Shell Uniform Load Sets...
Load Cases...
Load Combinations...
Table Named Sets...
Point Springs...
Line Springs...
Area Springs...
n View - Story1 - Z = 3 (m)

Load Transferring Mechanism

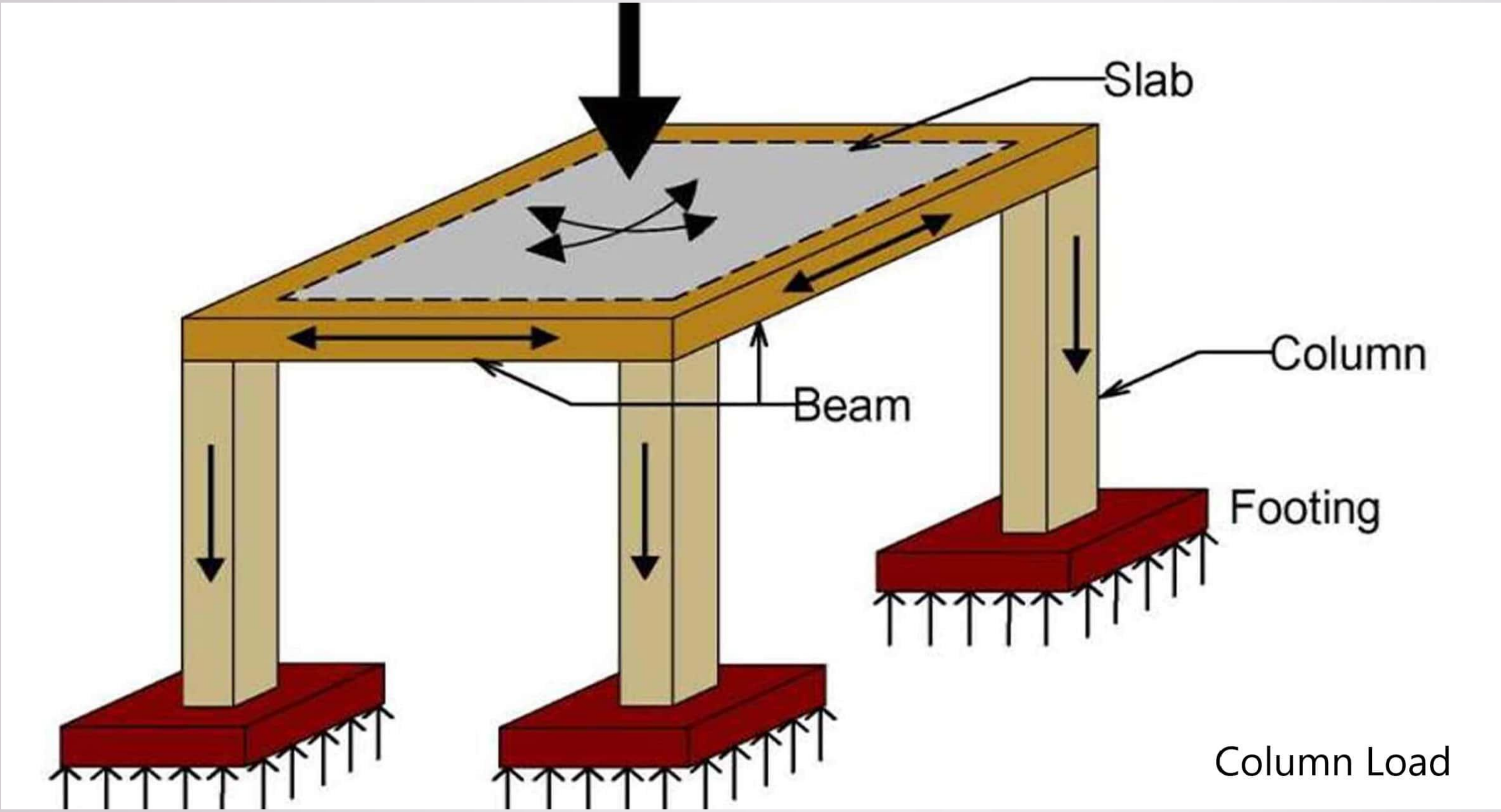
Week 4

Pages 24-31

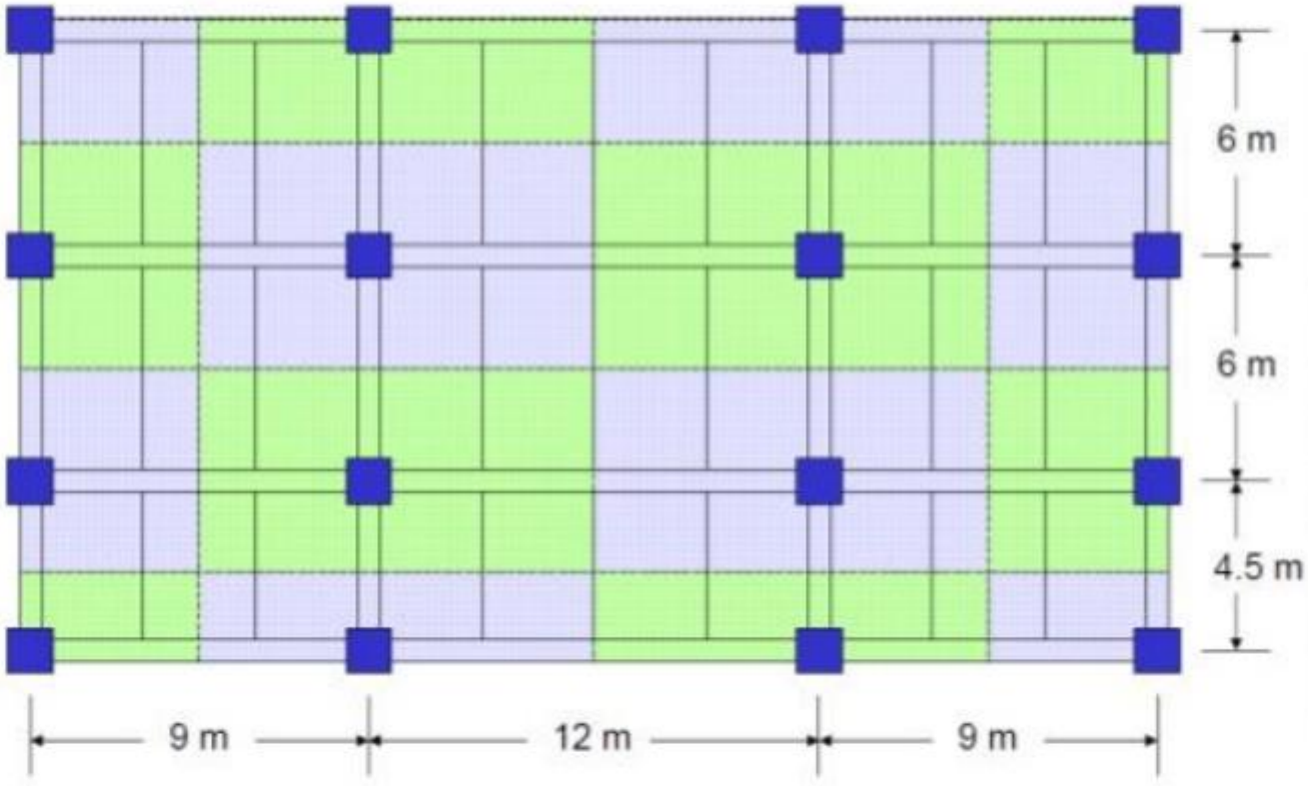
Load Transferring Mechanism of Building Structure



Continue…



Tributary Area of Column



All area must be tributed to columns

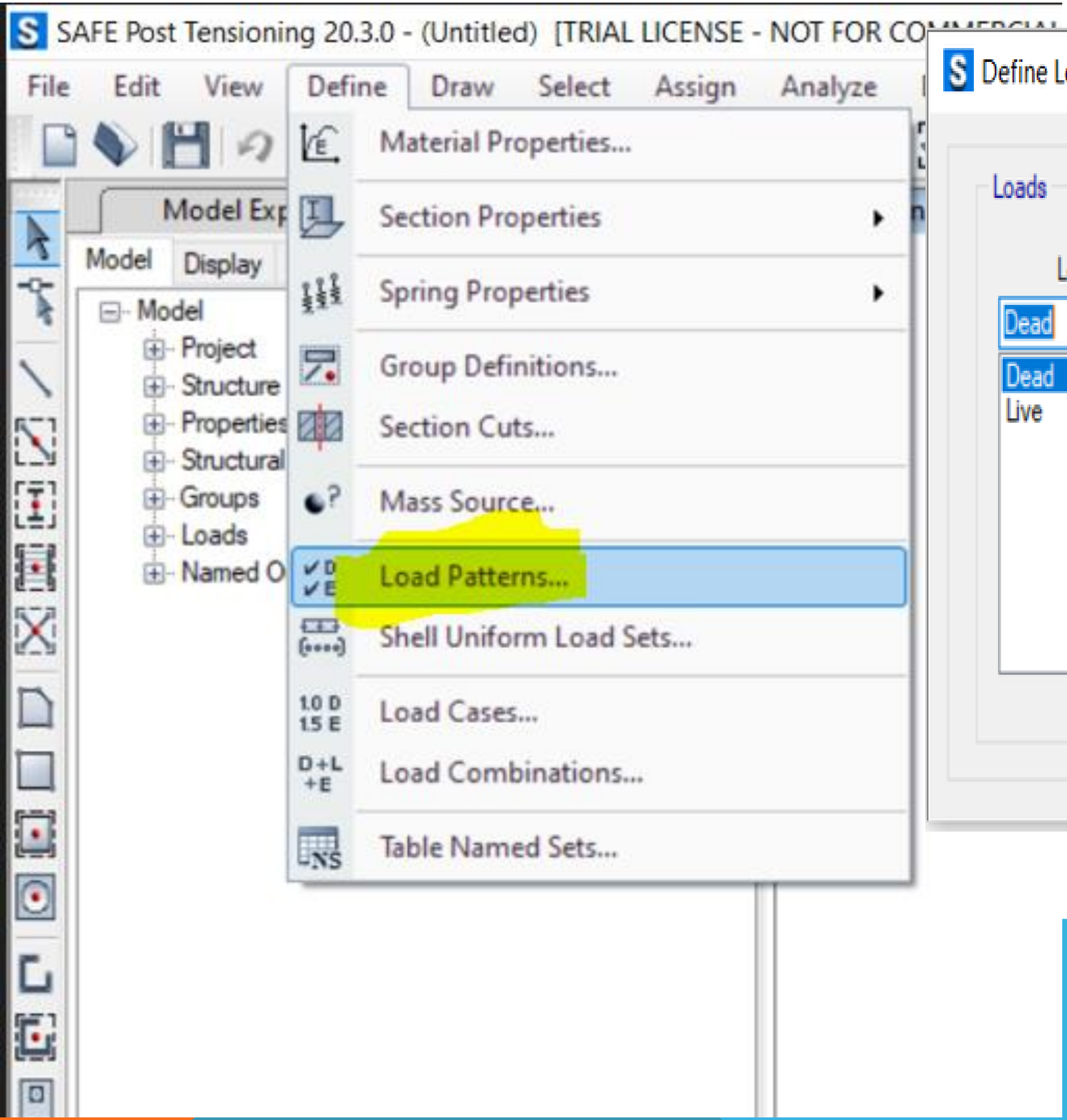

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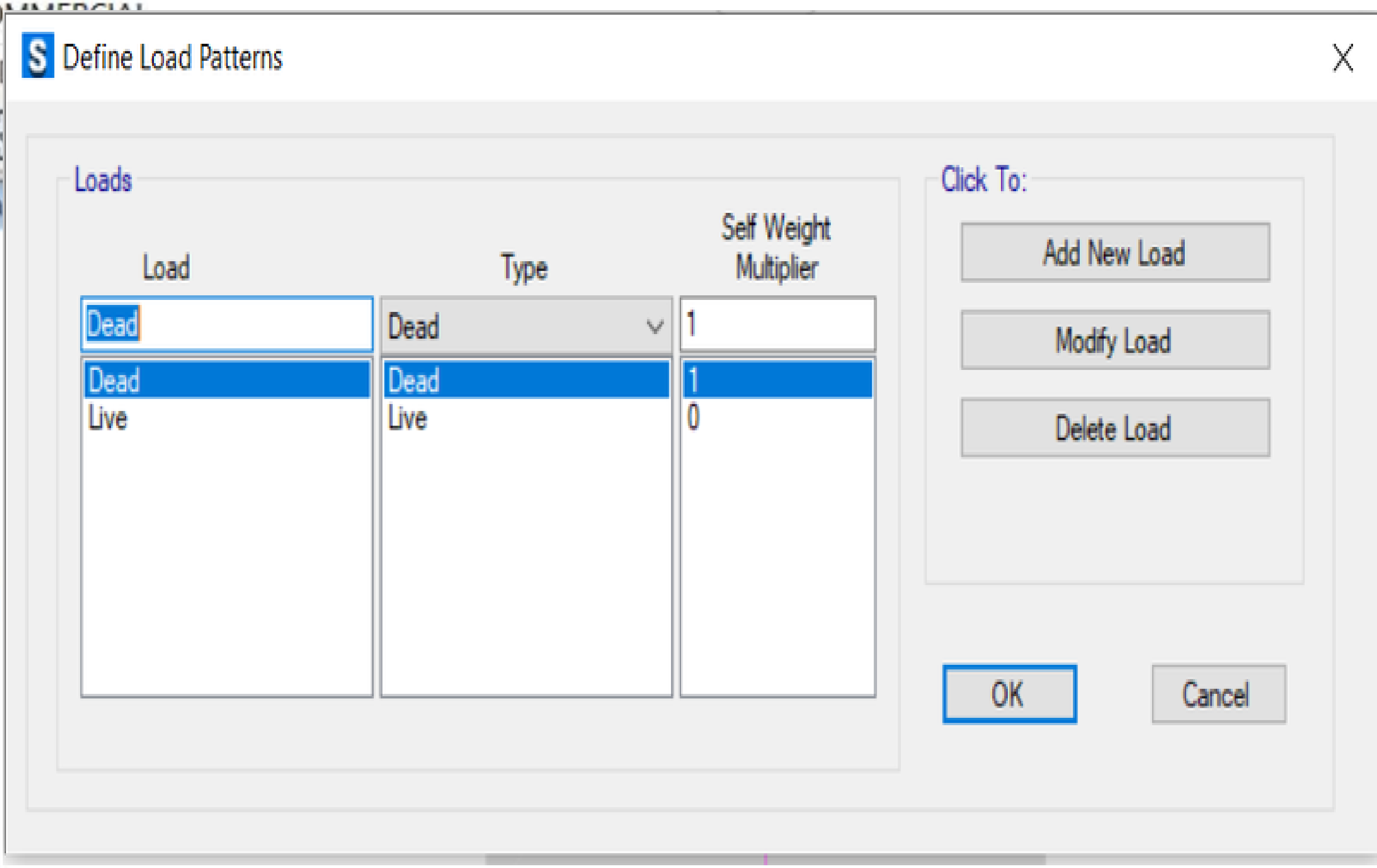
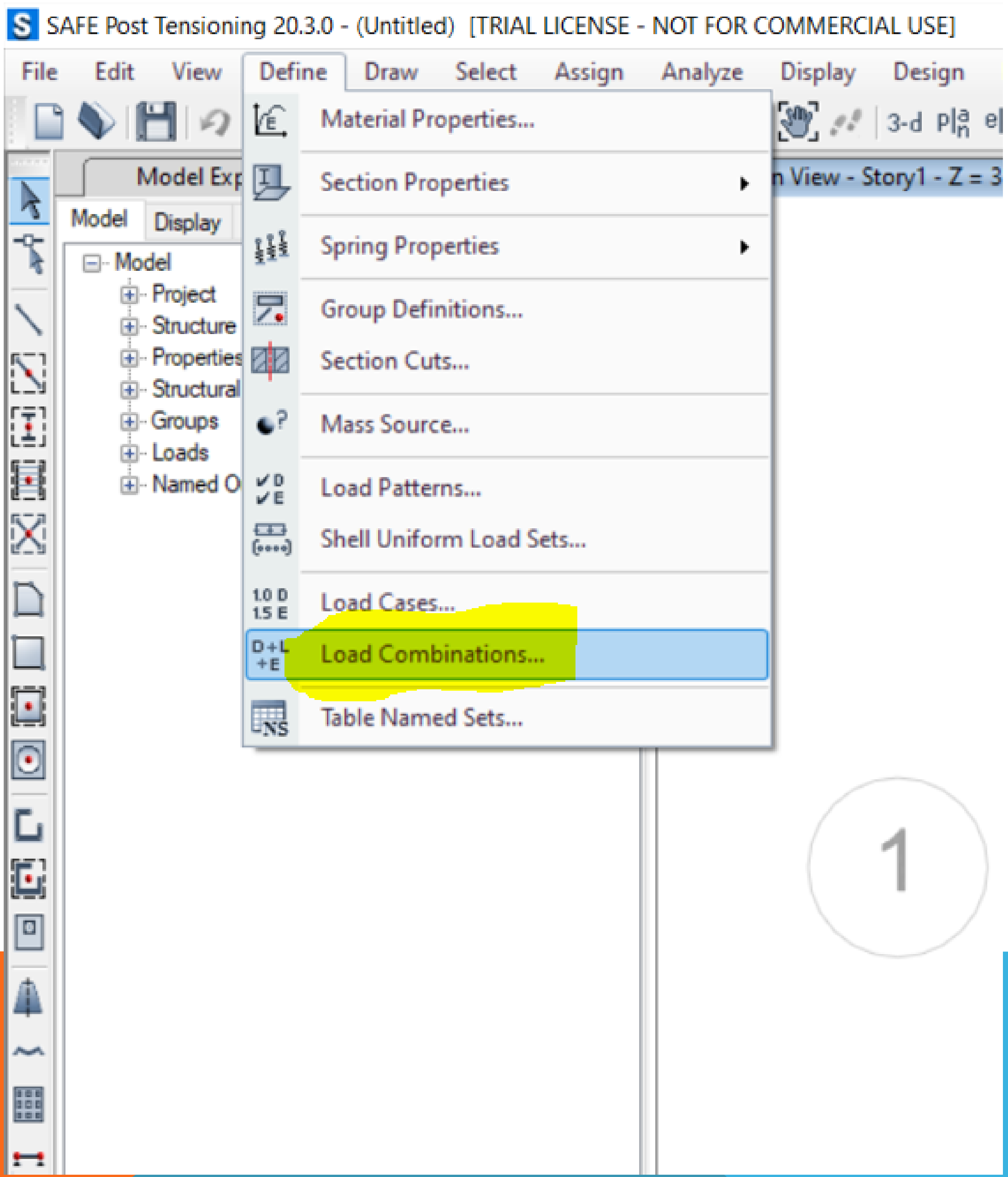
Table Named Sets...


Define Load Patterns
Loads
Load
Type
Self Weight Multiplier
Dead
Dead
1
Dead
Dead
1
Live
Live
0
Click To:
Add New Load
Modify Load
Delete Load
OK
Cancel


SAFE Post Tensioning 20.3.0 - (Untitled) [TRIAL LICENSE - NOT FOR COMMERCIAL USE]
File Edit View Define Draw Select Assign Analyze Display Design
Material Properties...
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Section Cuts...
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Shell Uniform Load Sets...
Load Cases...
Load Combinations...
Table Named Sets...
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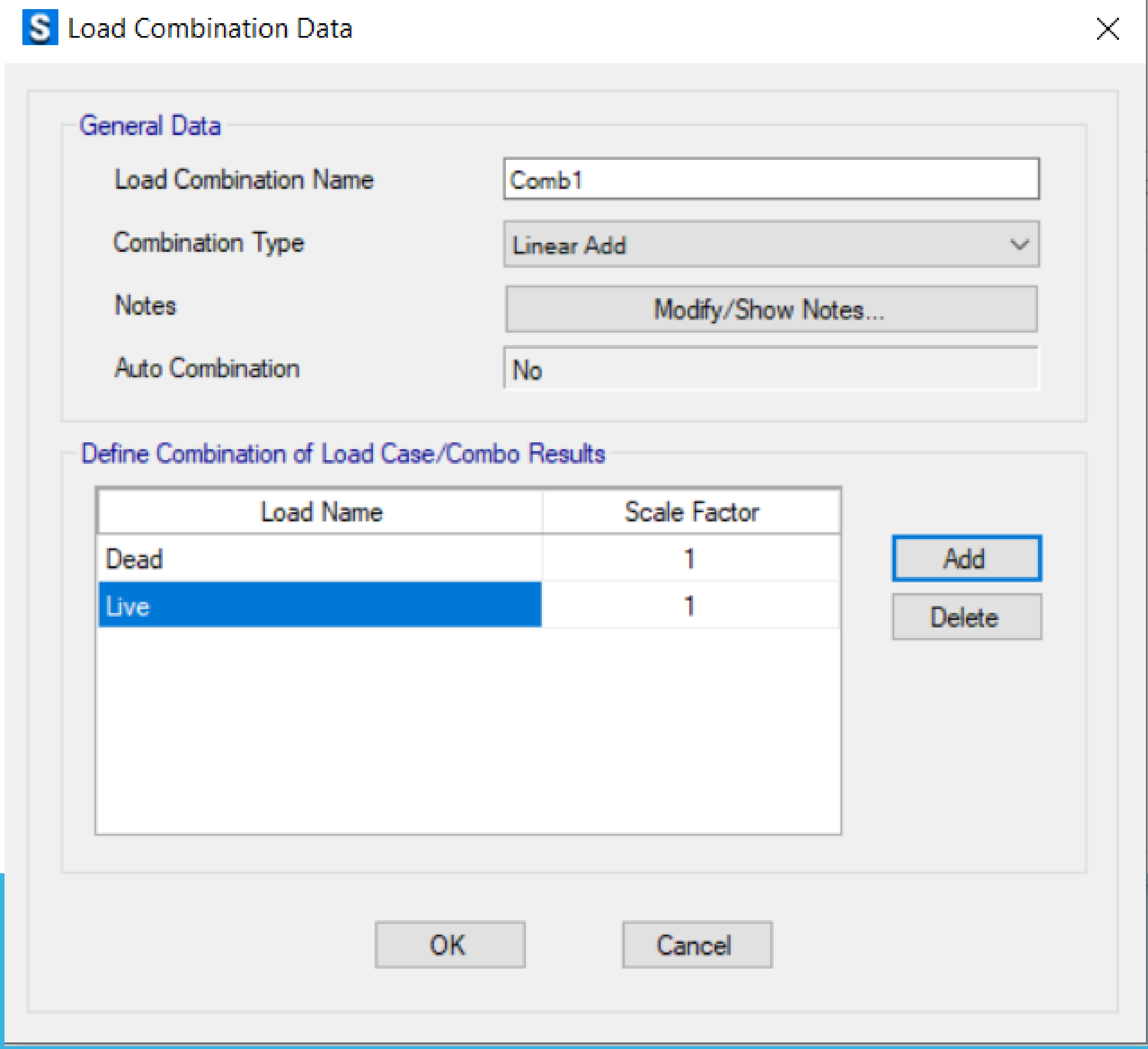
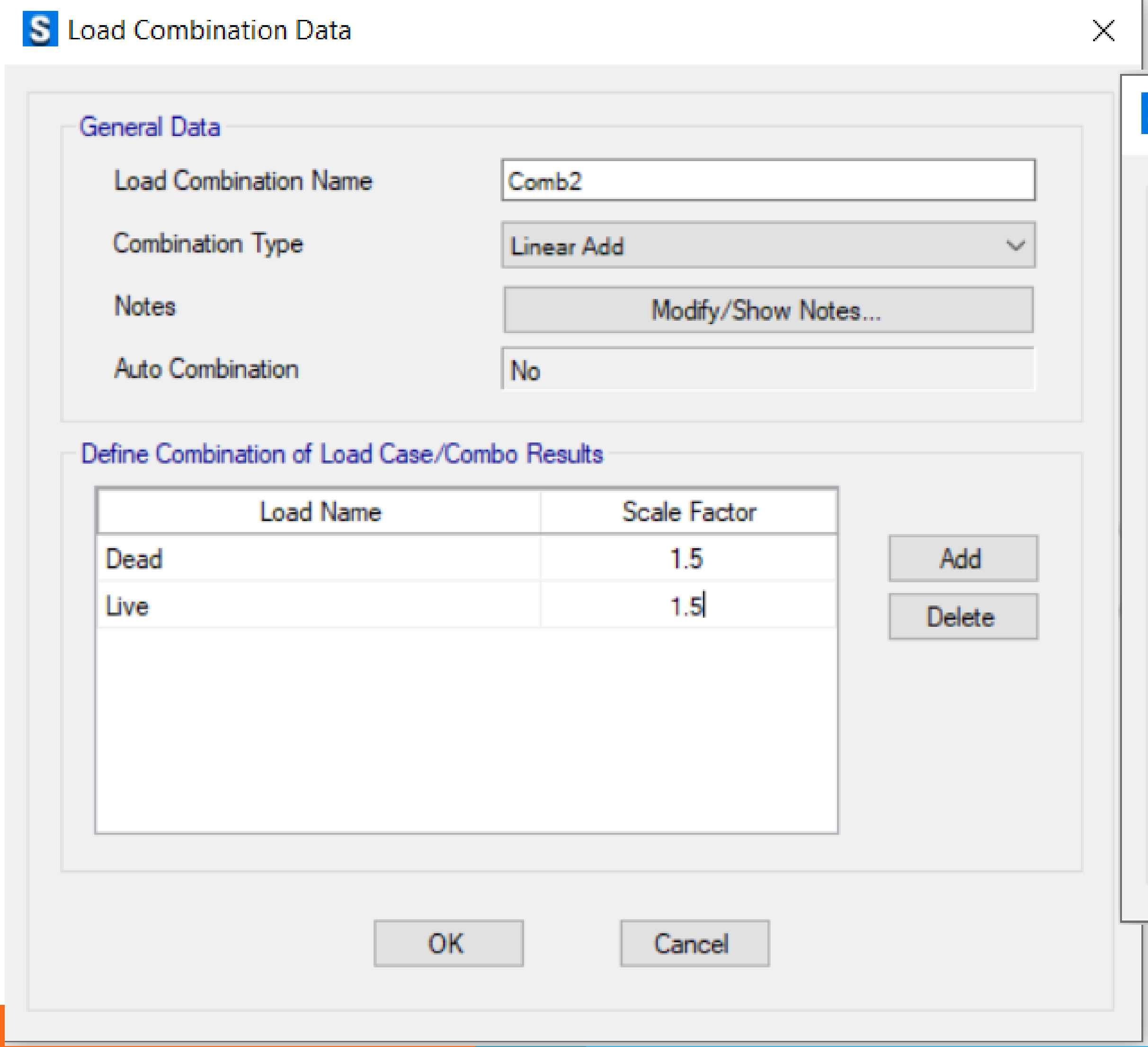
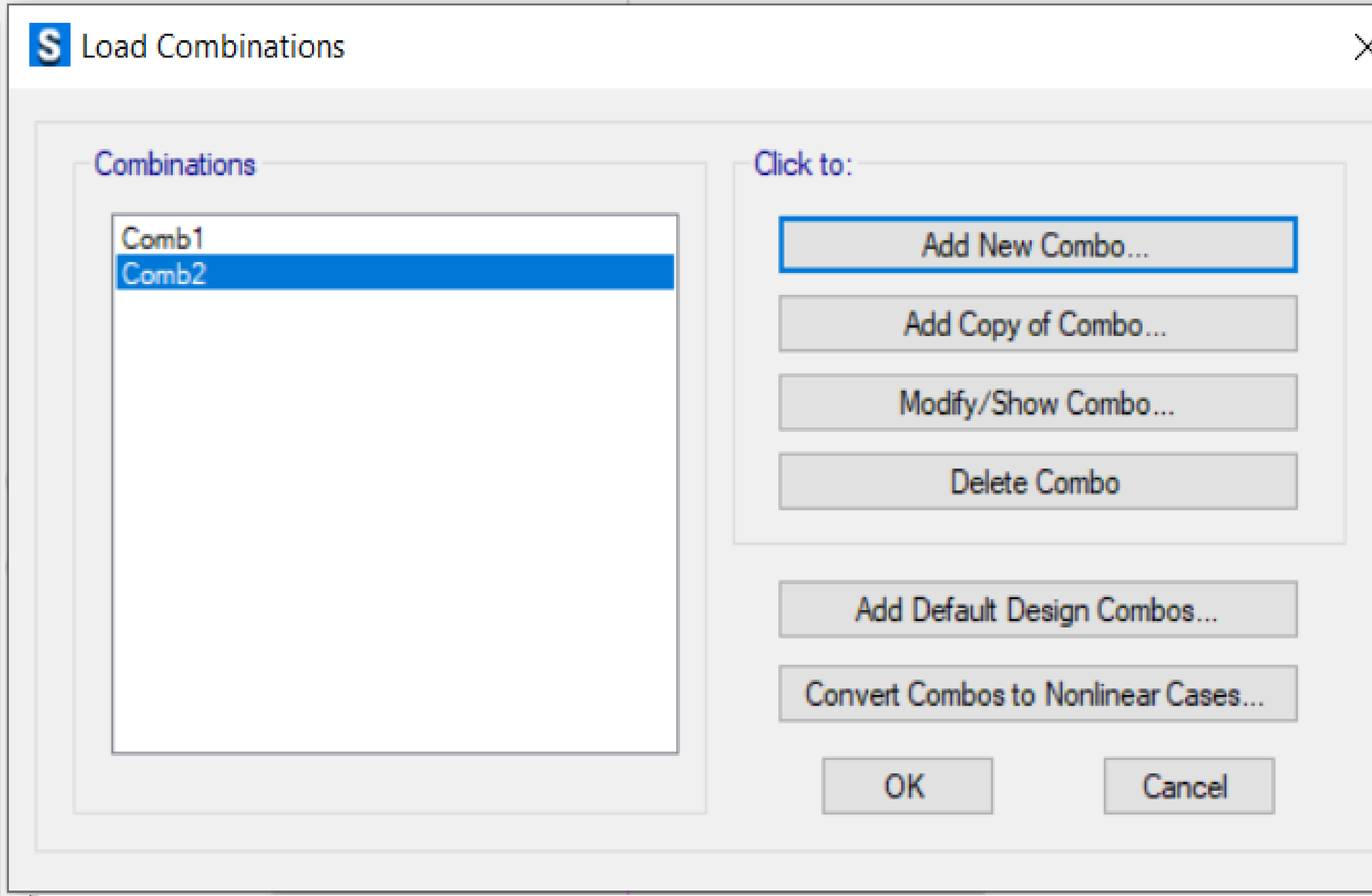
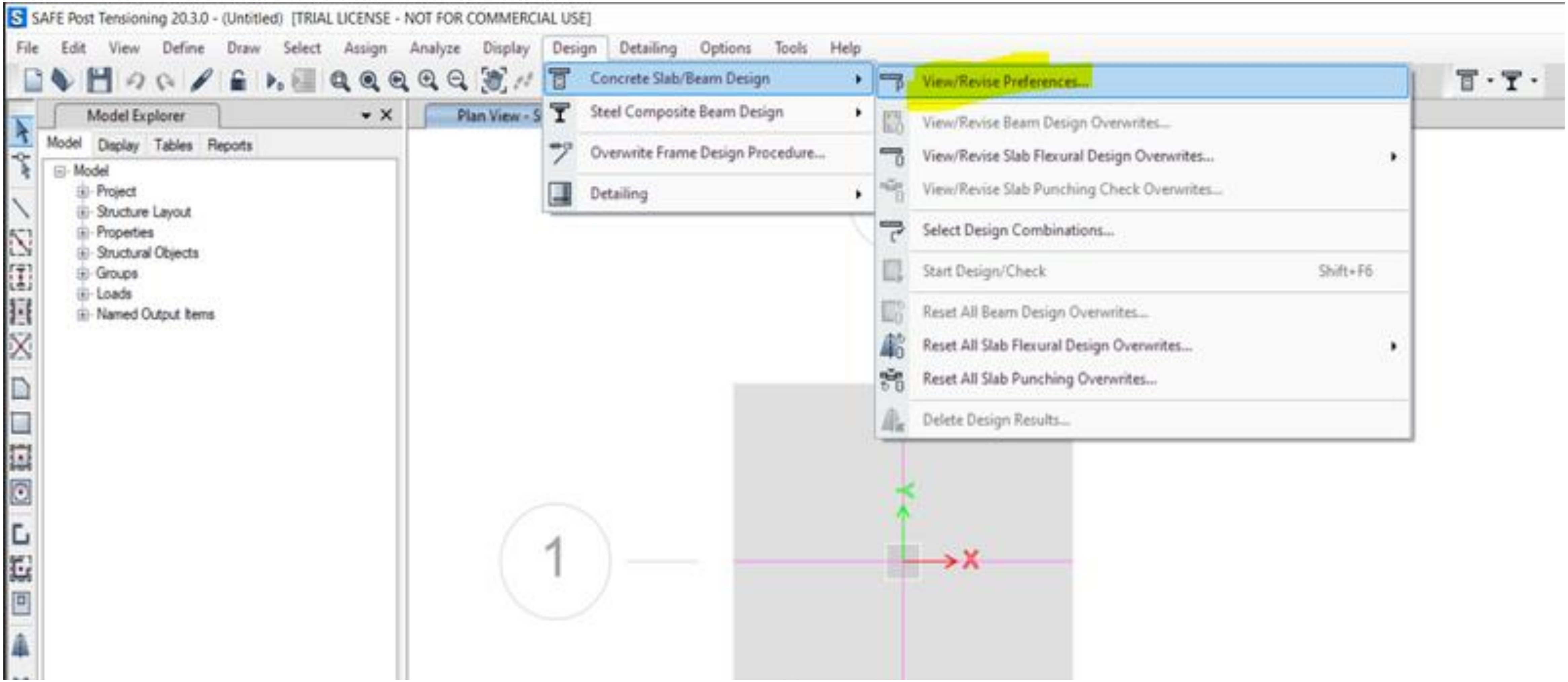

Load Combination Data
General Data
Load Combination Name
Comb1
Combination Type
Linear Add
Notes
Modify/Show Notes...
Auto Combination
No
Define Combination of Load Case/Combo Results
Load Name
Scale Factor
Dead
1
Live
1
Add
Delete
OK
Cancel



Load Combination Data
General Data
Load Combination Name
Comb2
Combination Type
Linear Add
Notes
Modify/Show Notes...
Auto Combination
No
Define Combination of Load Case/Combo Results
Load Name
Scale Factor
Dead
1.5
Live
1.5
Add
Delete
OK
Cancel



Load Combinations
Combinations
Comb1
Comb2
Click to:
Add New Combo...
Add Copy of Combo...
Modify/Show Combo...
Delete Combo
Add Default Design Combos...
Convert Combos to Nonlinear Cases...
OK
Cancel


SAFE Post Tensioning 20.3.0 - (Untitled) [TRIAL LICENSE - NOT FOR COMMERCIAL USE]
File
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Model Explorer
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Structure Layout
Properties
Structural Objects
Groups
Loads
Named Output Items
Plan View - S
Concrete Slab/Beam Design
Steel Composite Beam Design
Overwrite Frame Design Procedure...
Detailing
View/Revise Preferences...
View/Revise Beam Design Overwrites...
View/Revise Slab Flexural Design Overwrites...
View/Revise Slab Punching Check Overwrites...
Select Design Combinations...
Start Design/Check
Shift+F6
Reset All Beam Design Overwrites...
Reset All Slab Flexural Design Overwrites...
Reset All Slab Punching Overwrites...
Delete Design Results...
1
X

Concrete Slab Design Preferences - IS 456:2000

Factors | Min. Cover for Slabs | Min. Cover for Beams | P/T Stress Check

Item	Value
Non-Prestressed Reinforcement:	
Clear Cover Top, mm	50
Clear Cover Bottom, mm	50
Preferred Bar Size	12
Inner Slab Rebar Layer	Layer B
Post Tensioning	
CGS of Tendon Top, mm	25
CGS of Tendon for Bottom of Exterior Bay, mm	40
CGS of Tendon for Bottom of Interior Bay, mm	25
Minimum Reinforcement	
Slab Type for Minimum Reinforcing	Two Way

Design Code: IS 456:2000

Item Description

Preferred Bar Size for non-prestressed reinforcement in slab.

Explanation of Color Coding for Values

Blue: Default Value

Black: Not a Default Value

Red: Value that has changed during the current session

Set To Default Values: All Items | Current Tab

Reset To Previous Values: All Items | Current Tab

OK | Cancel

Design of Single Column Footing-I

Week 5-6

Pages 34-56

Single Column Footing

Skill Details:

- Understanding the design procedure of single column footing (hand calculation)
- Assigning the loads/structural frame
- Assigning area of footing according to soil test report
- Assigning grade of concrete and steel
- Run the model
- Checking the accuracy of results
- Detecting the problems and solving the error in cost-effective way (reducing or increasing the footing area/increasing concrete/steel grade)
- Detailing of the reinforcements

<u>Single Column Footing</u>

Definition: *Single Column footings are typically square, rectangular, or even a geometric frustum block of concrete that carries the load of a single column or pillar. The width of individual footings depends on the weight that will be carried and the bearable capacity of the soil.* It is also known as isolated or individual footing.

Design Consideration

Footing must be design to carry the column loads and transmit them to the soil safely. The design procedure must take the following strength requirements into consideration:

i. The area of the footing based on the allowable bearing soil capacity.
ii. One-way shear
iii. Two-way shear or punching shear
iv. Bending moment and steel reinforcement required
v. Bearing capacity of columns at their base and dowel requirements
vi. Development length of bars
vii. Differential settlement

Size of Footing

$$\text{Area of } Footing = \frac{Total\ Service\ Load}{Allowable\ Soil\ Pressure}$$

$$\Rightarrow \text{Area} = \frac{P\ (Dead+Live)}{q_a}$$

One-way Shear

The factored shearing force at the critical section

$$V_u = q_u b(\frac{L}{2} - \frac{c}{2} - d)$$

Where,

$$q_u = \frac{Pu\ (1.2DL + 1.6LL)}{Area\ of\ footing}$$

The allowable shear force

$$\emptyset V_c = 2\emptyset\lambda\sqrt{f'_c}bd$$

To avoid one-way shear failure of foundations, the shearing force (V_u) at the critical section of footing should be less than the allowable shear force ($\emptyset V_c$) of concrete.
i.e., $\emptyset V_c \geq V_u$

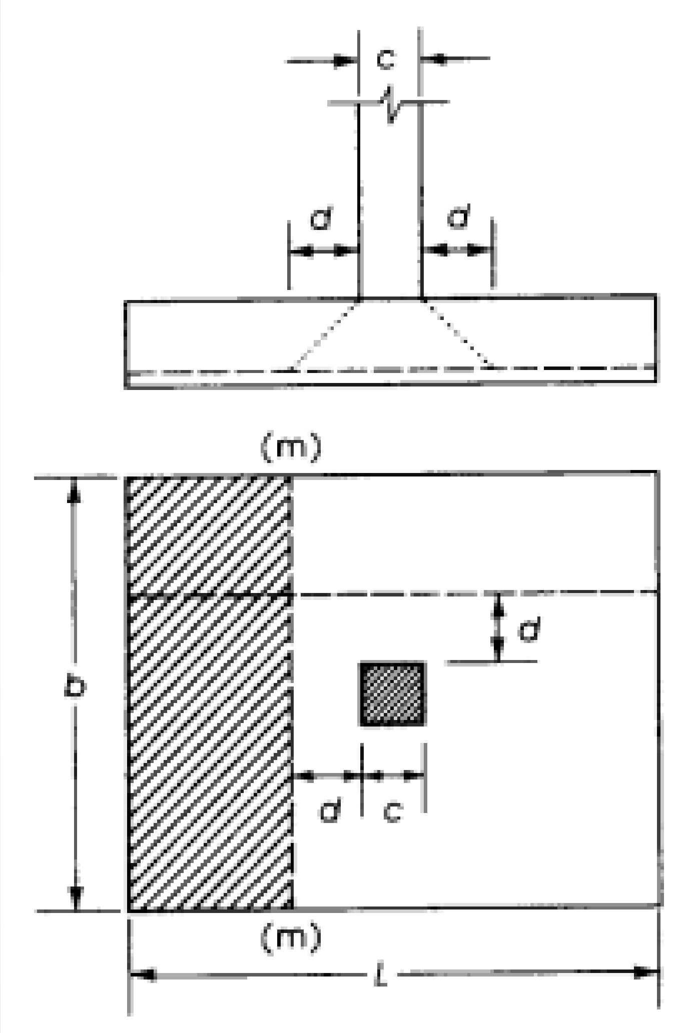


Fig.: One-way Shear

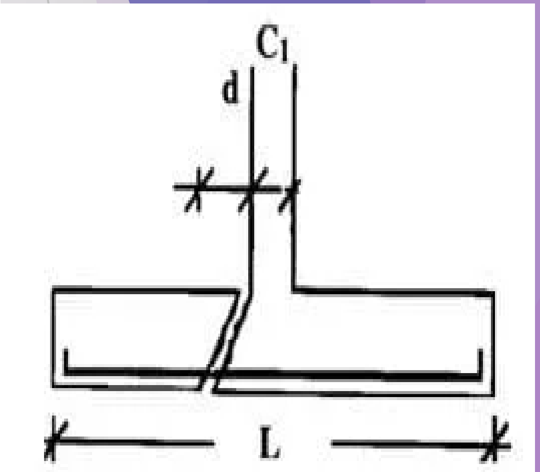


Fig.: One-way Shear Failure

Two-way Shear

The factored shearing force at the critical section

$V_u = P_u - q_u(c+d)^2$ for square column

$V_u = P_u - q_u(c_1+d)(c_2+d)$ for rectangular column

Where,

$$q_u = \frac{Pu\ (1.2DL + 1.6LL)}{Area\ of\ footing}$$

The allowable shear force

$$\emptyset V_c = 4\emptyset\lambda\sqrt{f'_c}\,b_0 d$$

Where,

$b_0 \quad = perimeter\ of\ critical\ section$

$\quad = 2X((c+d)+(c+d))$

To avoid two-way shear failure of foundations, the shearing force (V_u) at the critical section of footing should be less than the allowable shear force ($\emptyset V_c$) of concrete.

i.e., $\emptyset V_c \geq V_u$

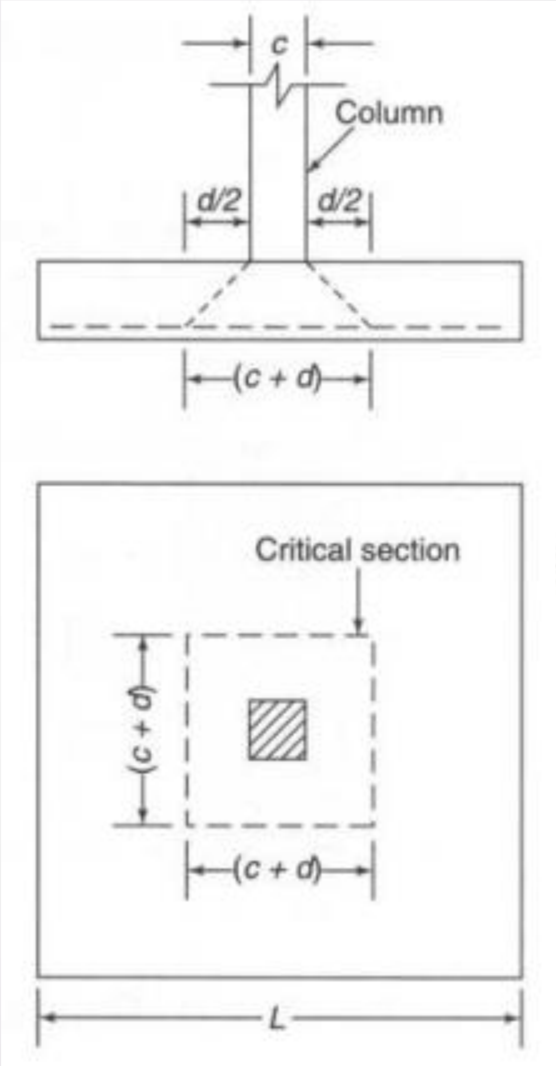


Fig.: Two-way Shear

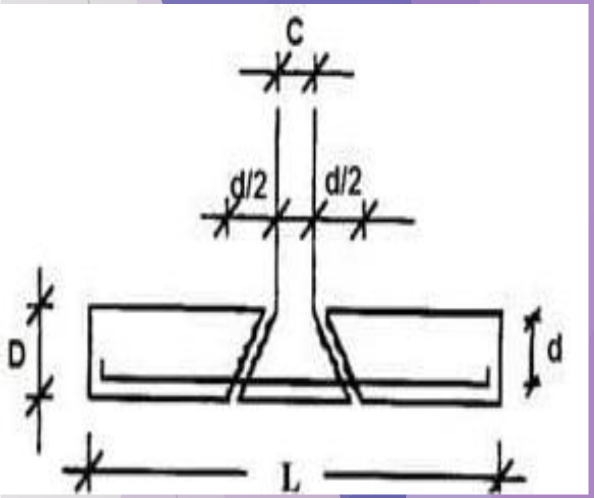


Fig.: Two-way Shear Failure

Flexural Strength and Footing Reinforcement

The bending moment at the critical section

$$M_u = \frac{1}{2} q_u b \left(\frac{L}{2} - \frac{c}{2}\right)^2$$

Where,

$$q_u = \frac{Pu\ (1.2DL + 1.6LL)}{Area\ of\ footing}$$

For design,

$$M_u = \emptyset A_s f_y \left(d - \frac{a}{2}\right)$$

Where,

$$a = \frac{A_s f_y}{0.85 f'_c b}$$

From this equation calculate the required area of reinforcement.

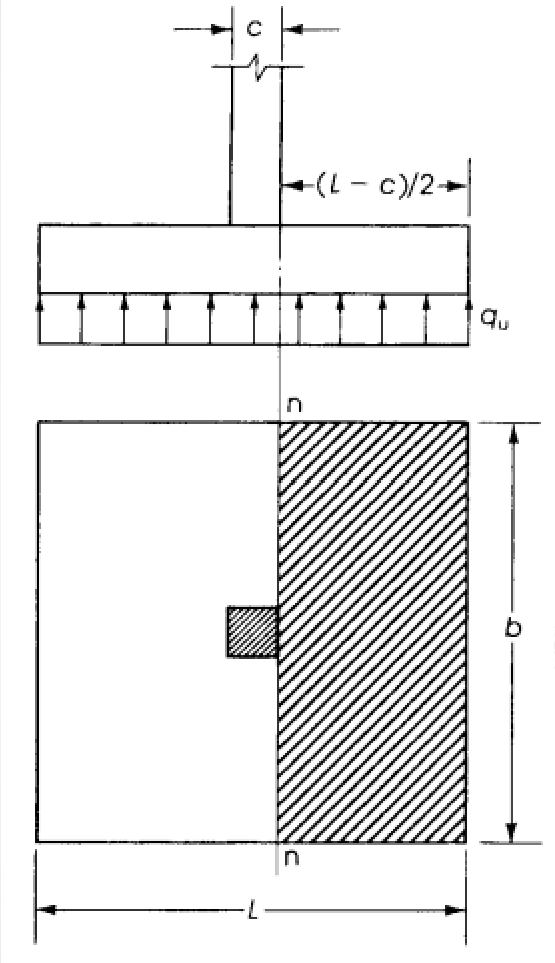


Fig.: Critical Section of Bending

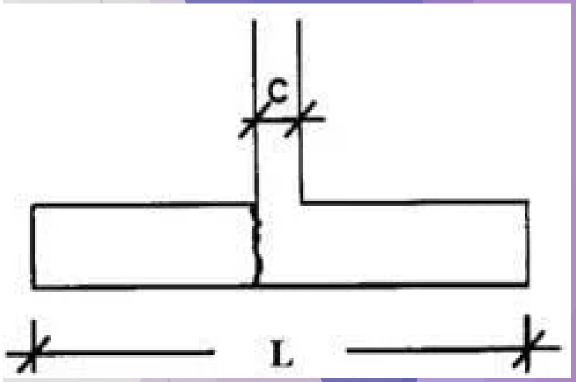
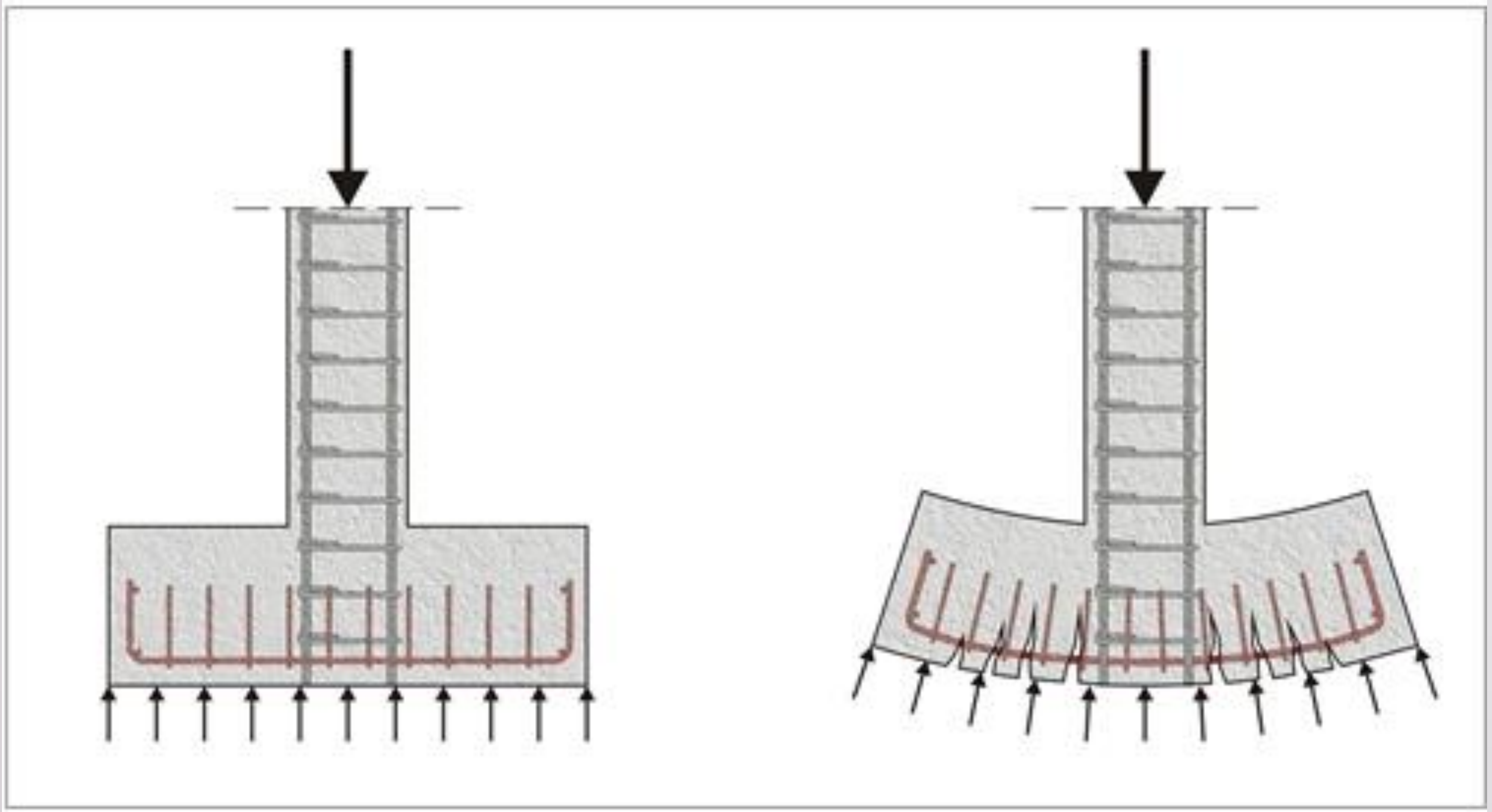
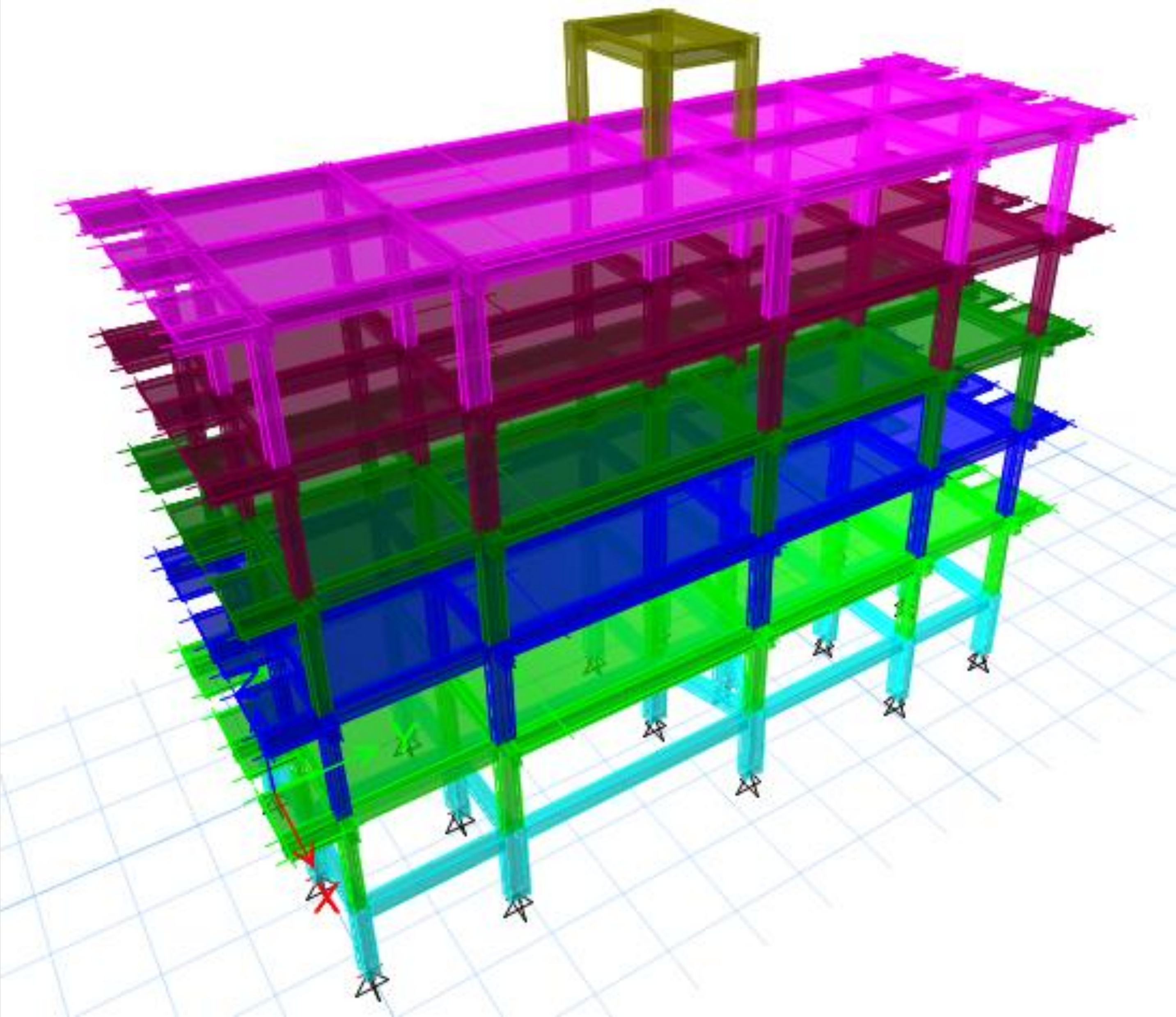


Fig.: Bending Failure

Single Column Footing Under Loading Condition



ETABS Model of a Building



Reaction Load of Footing From ETABS Model

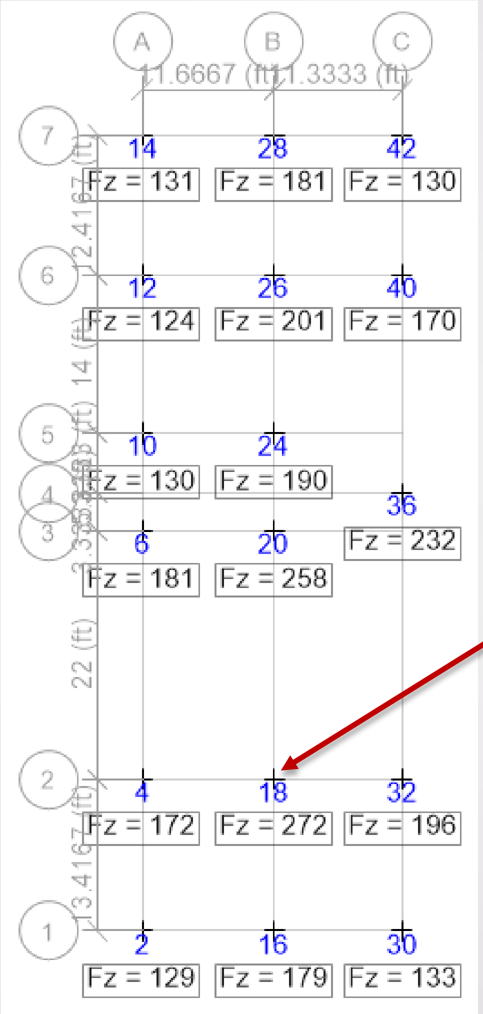


Fig.: Reaction for Service Load (DL+LL)

P=272 kips

P_U=347 kips

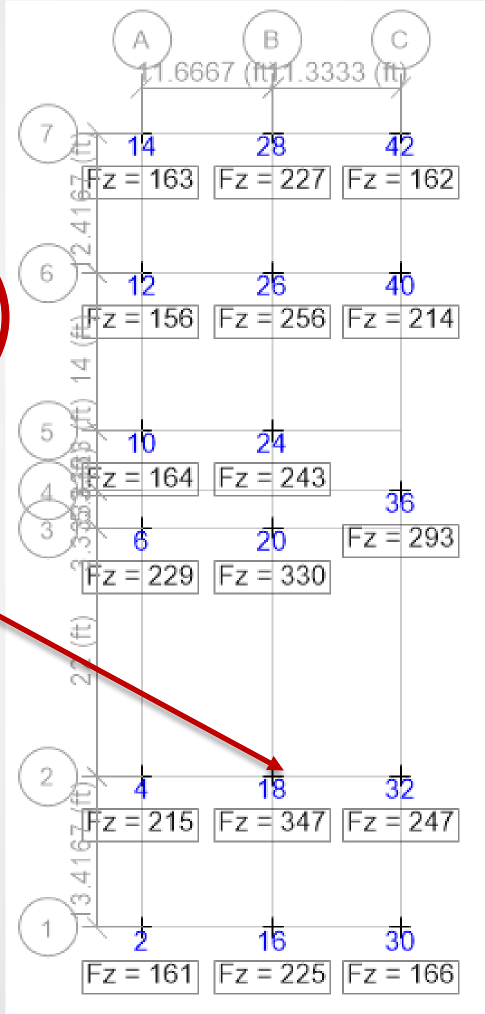


Fig.: Reaction for Factored Load (1.2DL+1.6LL)

Example

Data:

- ❖ **Service Load = 272 kips**
- ❖ **Factored Load = 347 kips**
- ❖ **Allowable Bearing Capacity of Soil = 3.0 ksf**

Solution:

Area of Footing:

$$\text{Area of } Footing = \frac{Total\ Service\ Load}{Allowable\ Soil\ Pressure}$$

$$= \frac{272}{3.0} = 90.67 \text{ ft}^2$$

Length of Footing $=\sqrt{90.67} = 9.52$ ft ≈ 10 ft

Size of Footing = 10’-0” X 10’-0”

So, Area of footing = 100 $\text{ft}^2 > 90.67 \text{ ft}^2$

Continue…

One-way Punching:

The factored shearing force at the critical section

$$V_u = q_u b(\frac{L}{2} - \frac{c}{2} - d)$$

$$=q_u b(\frac{L}{2} - \frac{c}{2} - d)$$

$$=3.47 \times 10 \times (\frac{10}{2} - \frac{15}{2\times12} - \frac{15}{12})$$

=108.44 kips

The allowable shear force

$$\emptyset V_c = 2\emptyset\lambda\sqrt{f'_c}bd$$

$$=2 \times 0.75 \times 1 \times \sqrt{3500} \times (10 \times 12) \times 15$$

$$=159734\ lb$$

$$=159.734\ kips$$

Here, $\emptyset V_c > V_u$

So, d=15" is **Ok**.

$$q_u = \frac{Pu\ (1.2DL + 1.6LL)}{Area\ of\ footing}$$

$$= \frac{347}{100}$$

=3.47 ksf > 3.0 ksf

b=10 ft

L=10 ft

Column Size= 15" X 15"

c=15"

Let, d = 15"

Continue…

Two-way Punching:

The factored shearing force at the critical section

$V_u \quad = P_u - q_u(c+d)^2$ for square column

$=347 - 3.47 \times \left(\frac{15}{12} + \frac{15}{12}\right)^2$

=325.31 kips

The allowable shear force

$\emptyset V_c = 4\emptyset\lambda\sqrt{f'_c}b_0 d$

$=4 \times 0.75 \times 1 \times \sqrt{3500} \times 120 \times 15$

$=319468\ lb$

$=319.468\ kips$

Here, $\emptyset V_c < V_u$

So, d=15” is **Not Ok**. Increase the effective thickness of footing.

$q_u = \frac{Pu\ (1.2DL + 1.6LL)}{Area\ of\ footing}$

$= \frac{347}{100}$

=3.47 ksf > 3.0 ksf

b=10 ft

L=10 ft

Column Size= 15” X 15”

c=15”

Let, d = 15”

b_0= 4 X (15+15) = 120”

Continue…

Two-way Punching:

The factored shearing force at the critical section

$V_u \quad = P_u - q_u(c+d)^2$ for square column

$=347 - 3.47 \times \left(\frac{15}{12} + \frac{17}{12}\right)^2$

$=322.32$ kips

The allowable shear force

$\emptyset V_c = 4\emptyset\lambda\sqrt{f'_c}b_0 d$

$=4 \times 0.75 \times 1 \times \sqrt{3500} \times 128 \times 17$

$=386201\ lb$

$=386.201\ kips$

Here, $\emptyset V_c > V_u$

So, d=17" is **Ok**.

Total thickness of footing = 17+3 = 20" = 1'-8"

Now, Footing Dimension = 10'-0" X 10'-0" X 1'-8"

$q_u = \frac{Pu\ (1.2DL + 1.6LL)}{Area\ of\ footing}$

$= \frac{347}{100}$

=3.47 ksf > 3.0 ksf

b=10 ft

L=10 ft

Column Size= 15" X 15"

c=15"

Let, d = 17"

b_0= 4 X (15+17) = 128"

Continue…

Reinforcement Design:

The bending moment at the critical section

$$M_u = \frac{1}{2} q_u b \left(\frac{L}{2} - \frac{c}{2}\right)^2$$

$$= \frac{1}{2} \times 3.47 \times 10 \times \left(\frac{10}{2} - \frac{15}{2\times12}\right)^2$$

$$= 332.09\ kip - ft$$

$$= 3985\ kip - inch$$

Now,

$$M_u = \emptyset A_s f_y \left(d - \frac{a}{2}\right)$$

Or, $A_s = \frac{M_u}{\emptyset f_y \left(d - \frac{a}{2}\right)}$

$$= \frac{3985}{0.9\times60\times\left(17-\frac{1}{2}\right)}$$ (Say a=1)

$$= 4.47 in^2$$

$$q_u = \frac{Pu\ (1.2DL + 1.6LL)}{Area\ of\ footing}$$

$$= \frac{347}{100}$$

=3.47 ksf > 3.0 ksf

b=10 ft

L=10 ft

Column Size= 15” X 15”

c=15”

d=17”

Continue…

Check $a = \frac{A_s f_y}{0.85 f'_c b}$

$= \frac{4.47 \times 60}{0.85 \times 3.5 \times (10 \times 12)}$

$= 0.693 < a$

So do it again considering a =0.69

$$A_s = \frac{M_u}{\emptyset f_y \left(d - \frac{a}{2}\right)}$$

$= \frac{3985}{0.9 \times 60 \times \left(17 - \frac{0.69}{2}\right)}$ (Say a=0.69)

$= 4.43 in^2$

Check $a = \frac{A_s f_y}{0.85 f'_c b}$

$= \frac{4.43 \times 60}{0.85 \times 3.5 \times (10 \times 12)}$

$= 0.687 \approx a$

So, As = 4.43 in^2

$$q_u = \frac{Pu\ (1.2DL + 1.6LL)}{Area\ of\ footing}$$

$= \frac{347}{100}$

=3.47 ksf > 3.0 ksf

b=10 ft

L=10 ft

Column Size= 15” X 15”

c=15”

d=17”

Continue…

Minimum Area of Reinforcement:

$$A_s(Shrinkage\ Steel) = 0.0018bD$$
$$= 0.0018 \times (10 \times 12) \times 20$$
$$= 4.32\ in^2 < 4.43\ in^2 \text{ Ok.}$$

$$A_s(Flexure) = \left(\frac{200}{f_y}\ or\ \frac{3\sqrt{f'_c}}{f_y}\right) bD$$
$$= \left(\frac{200}{60000}\ or\ \frac{3\sqrt{3500}}{60000}\right) \times (10 \times 12) \times 20$$
$$= (0.00333\ or\ 0.00295) \times (10 \times 12) \times 20$$
$$= 7.992\ in^2 > 4.43\ in^2$$

So, Required area of reinforcement, As = 7.992 in^2

Spacing of reinforcement $= \frac{ba_s}{A_s}$

$$= \frac{10 \times 12 \times 0.31}{7.992}$$
$$= 4.65\ in$$

Provide 16mmØ @ 4.5 inch c/c.

$$q_u = \frac{Pu\ (1.2DL + 1.6LL)}{Area\ of\ footing}$$
$$= \frac{347}{100}$$

=3.47 ksf > 3.0 ksf

b=10 ft

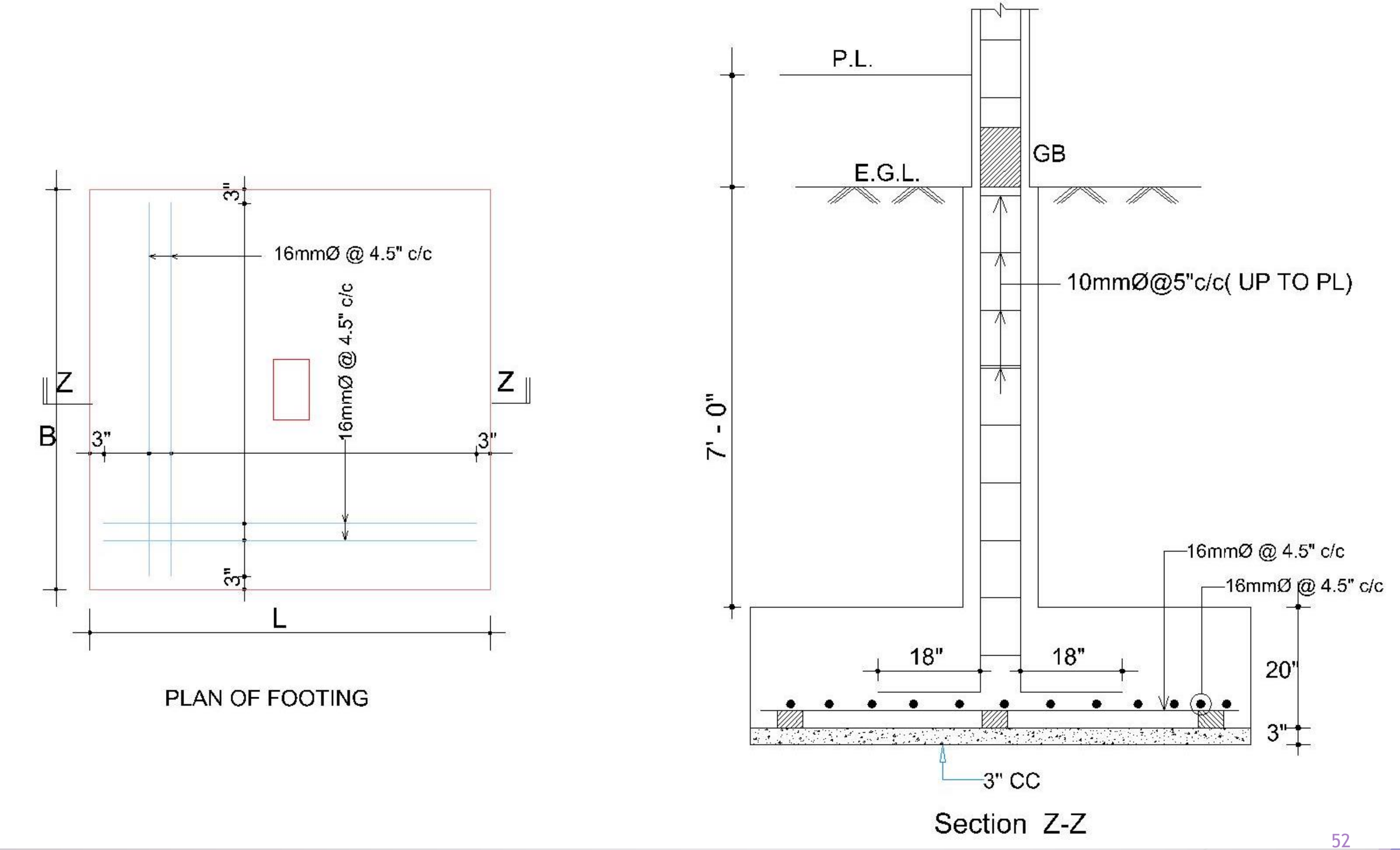
L=10 ft

Column Size= 15” X 15”

c=15”

d=17”

Detailing of Single Column Footing



Reaction Load of Footing From ETABS Model

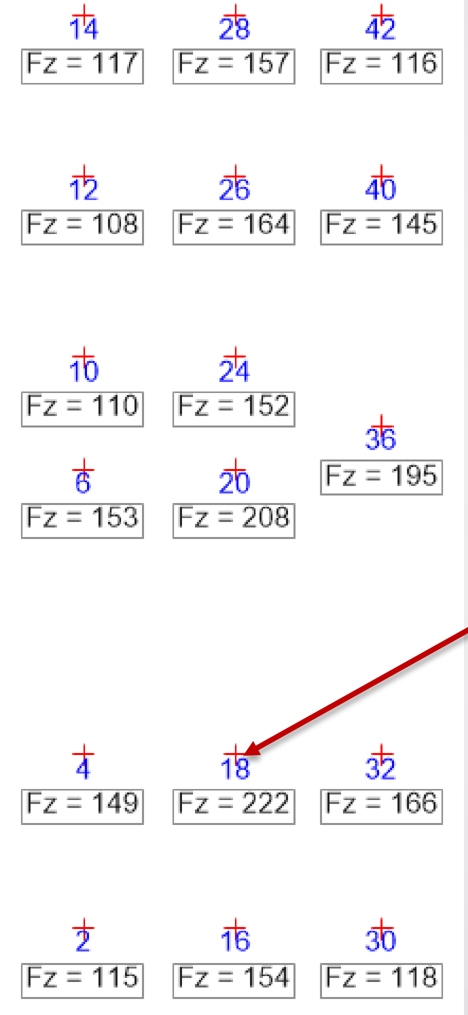


Fig.: Reaction for Dead Load (DL)

P_{DL}=222 kips

P_{LL}=50 kips

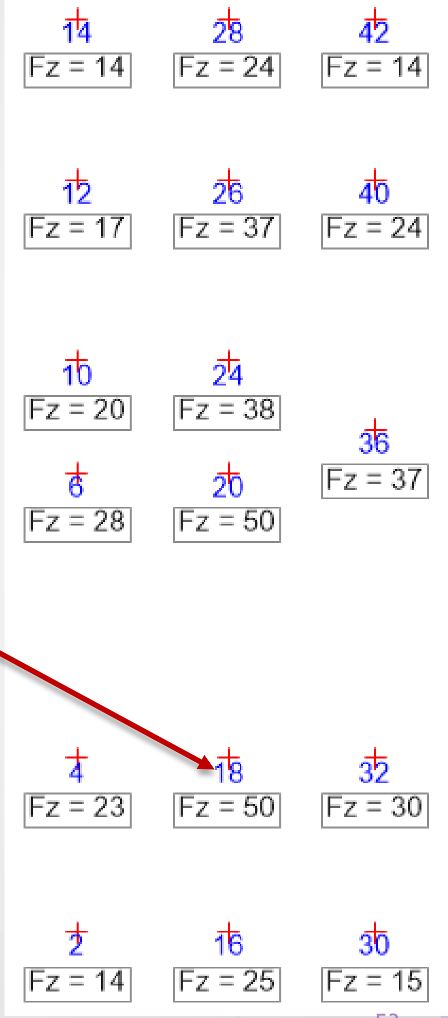


Fig.: Reaction for Live Load (LL)

Single Column Footing Design With SAFE Software

- Open SAFE software
- Take a New Model
- Select Design Code
- Select Blank
- Define Materials (Concrete & Rebar)
- Define Slab Properties (Footing as Footing)
- Define Slab Properties (Column as Stiff)
- Define Soil Subgrade Properties

Continue…

1. Define Load Pattern (Dead & Live Load)
2. Define Load Combination
3. Draw Footing & Column
4. Assign Soil Properties from Support Data in Footing
5. Assign Load in Column
6. Draw Design Strip
7. Select Design Combination from Design Menu
8. Run Analysis & Design from Run Menu

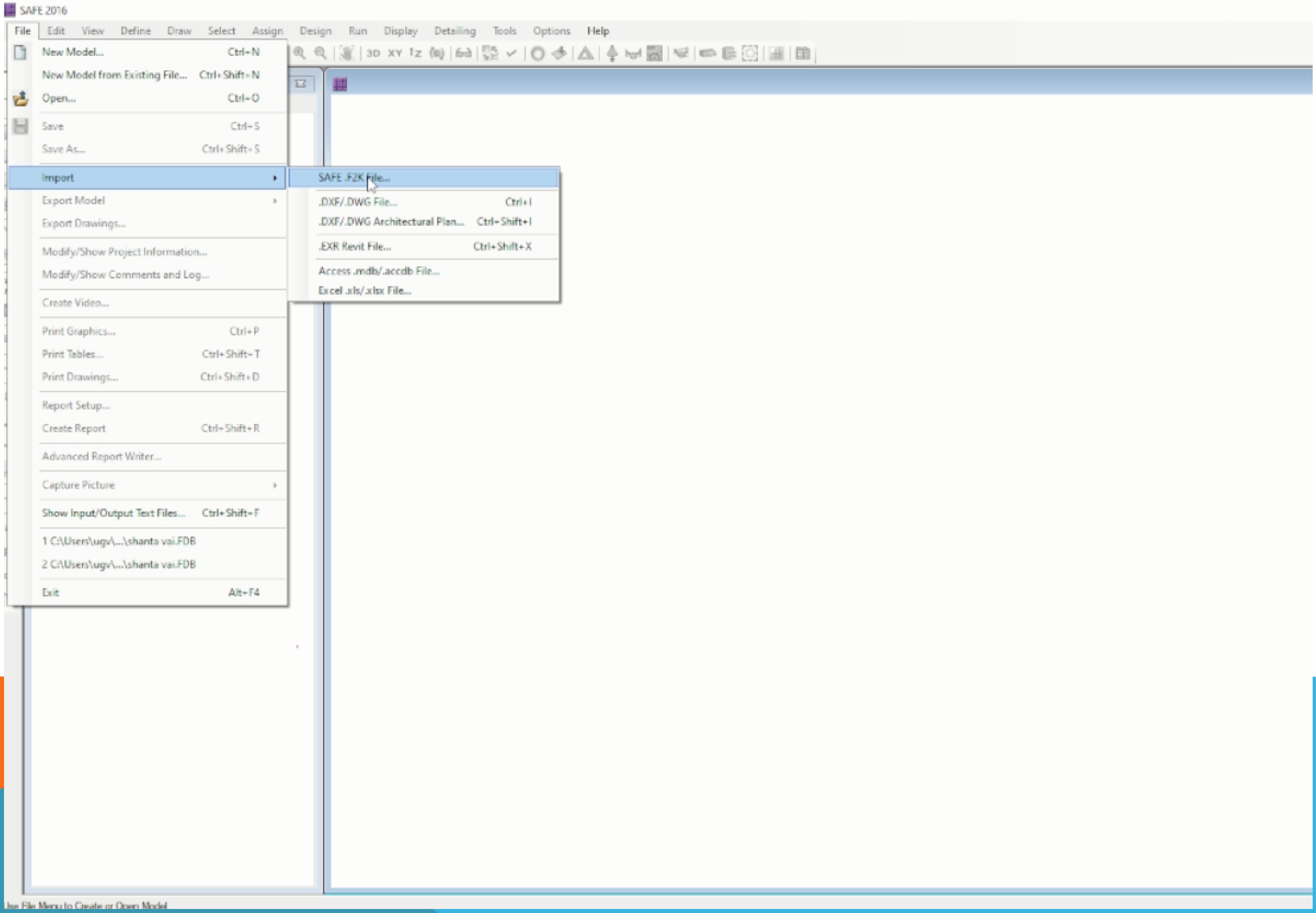
Continue…

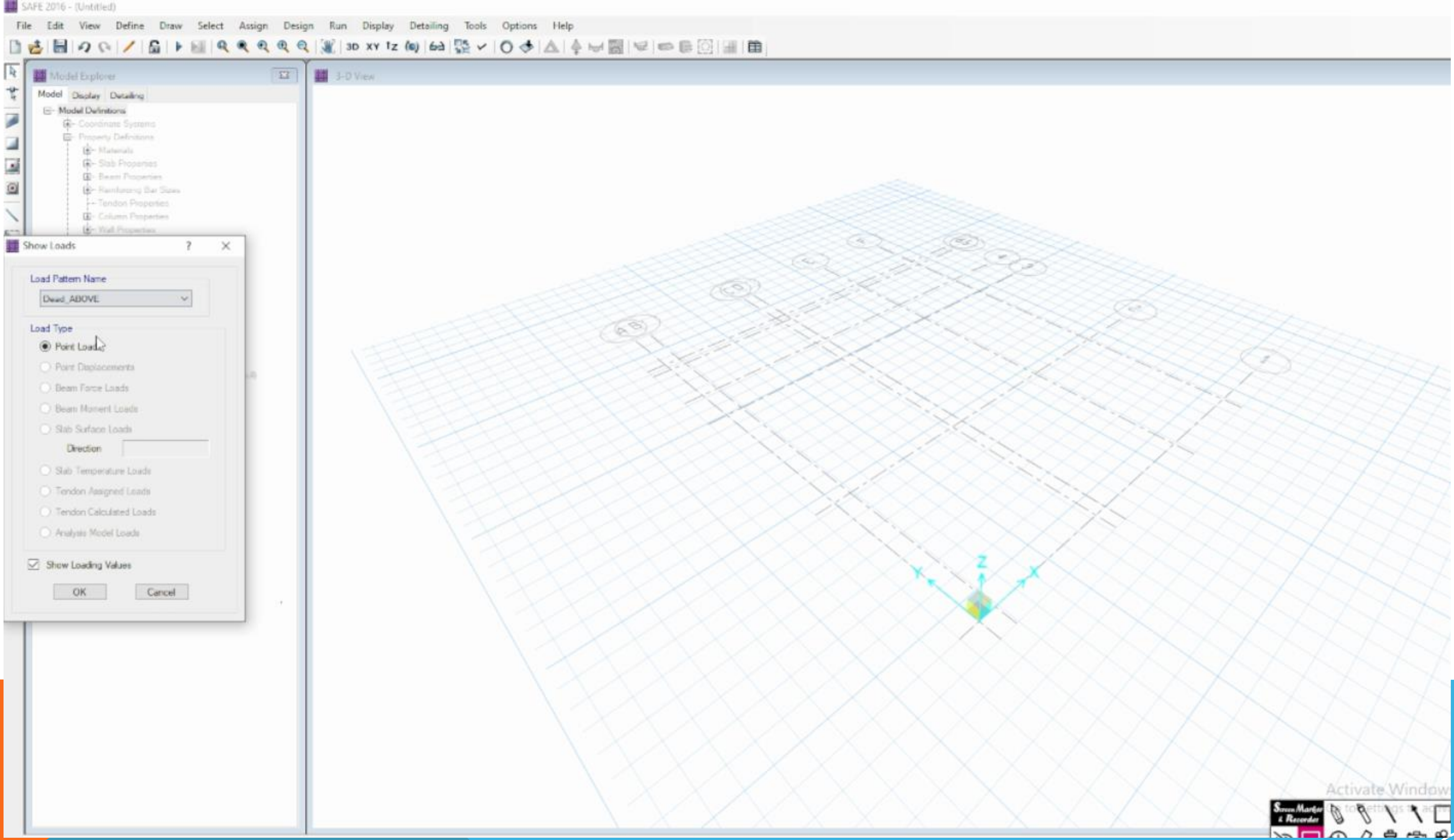
- Check Displacement
- Check Soil Pressure
- Check Moment and Shear
- Check Slab Design Value
- Chose Rebar Size and Spacing
- Detailing of Footing

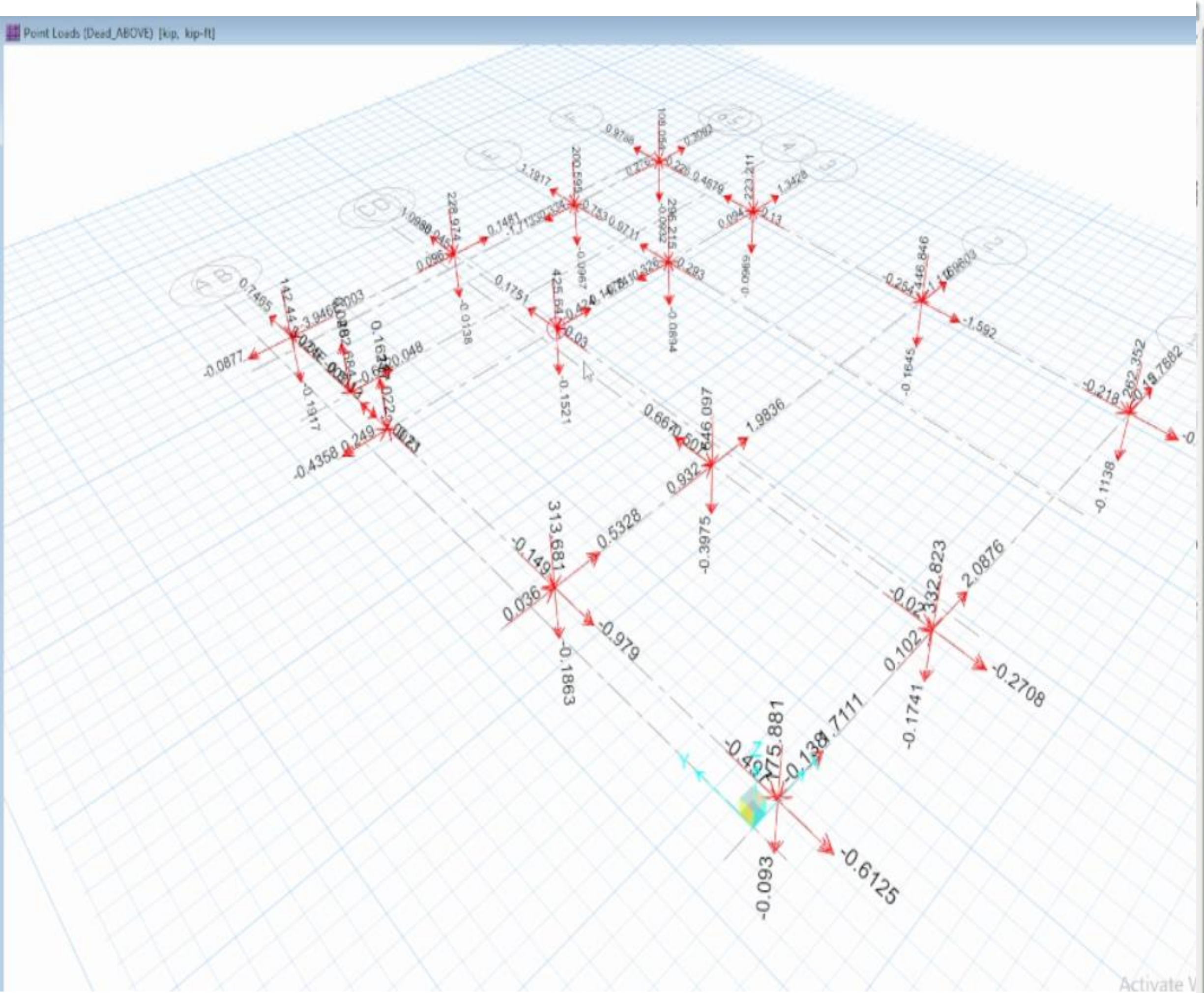
Design of Single Column Footing-II

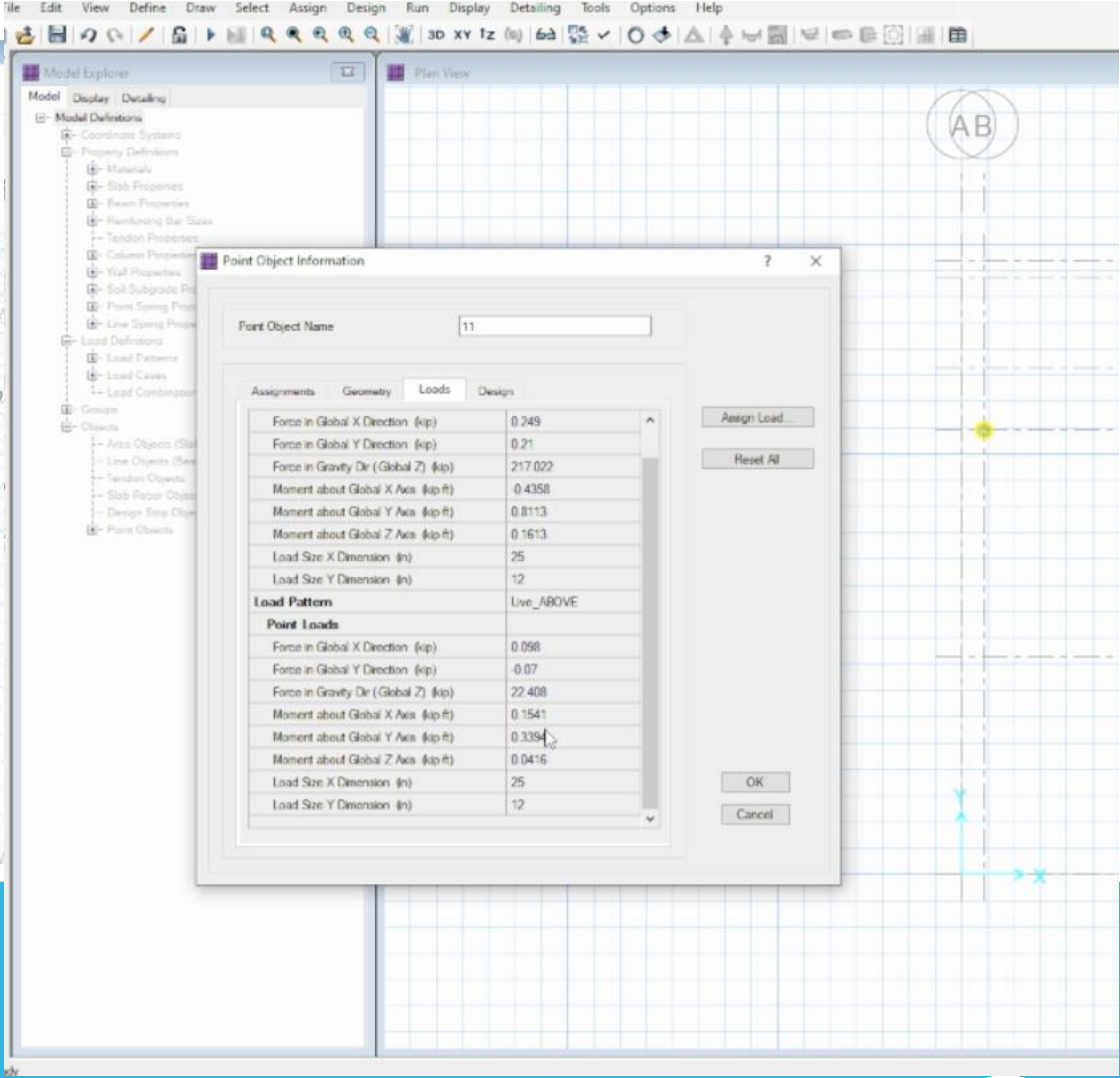
Week 7

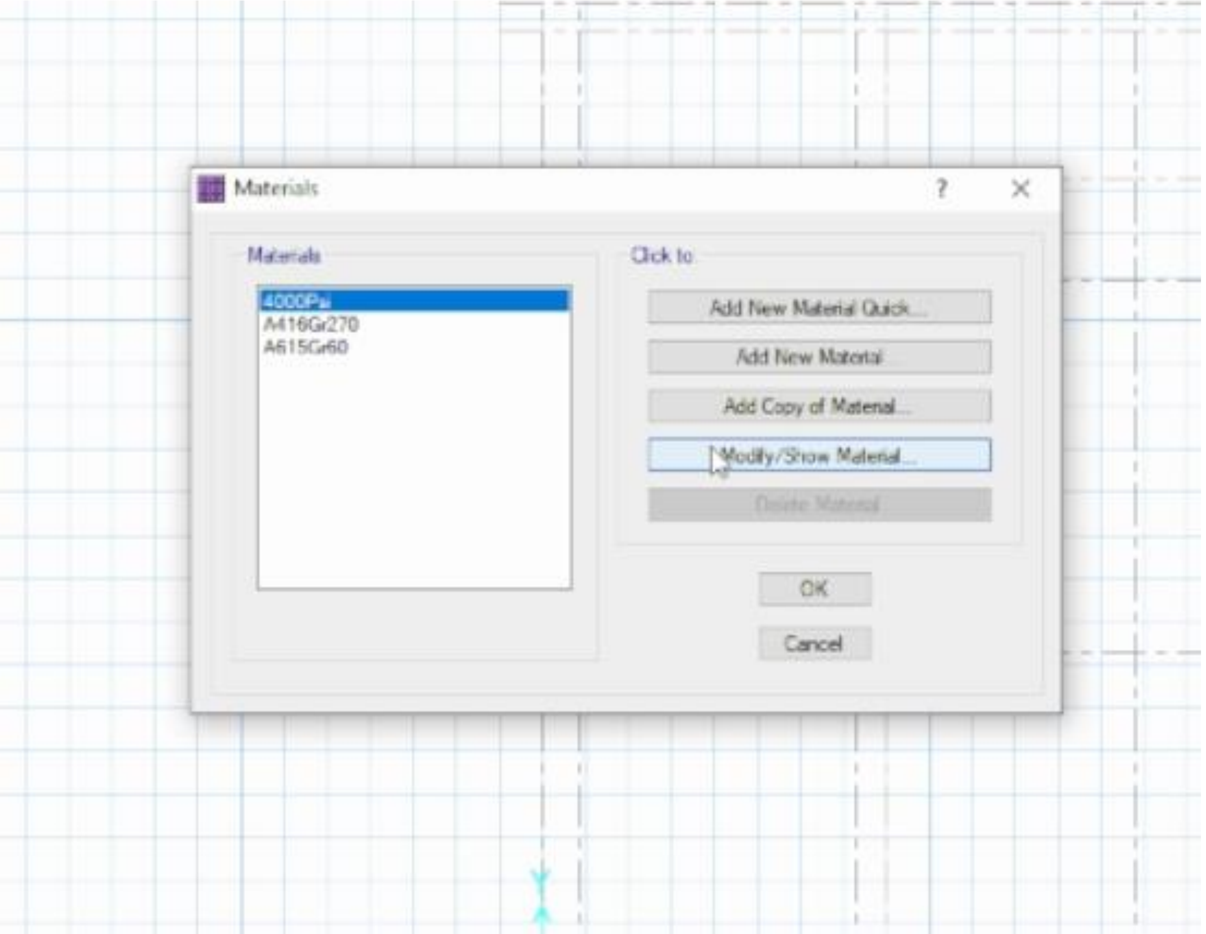
Pages 58-66

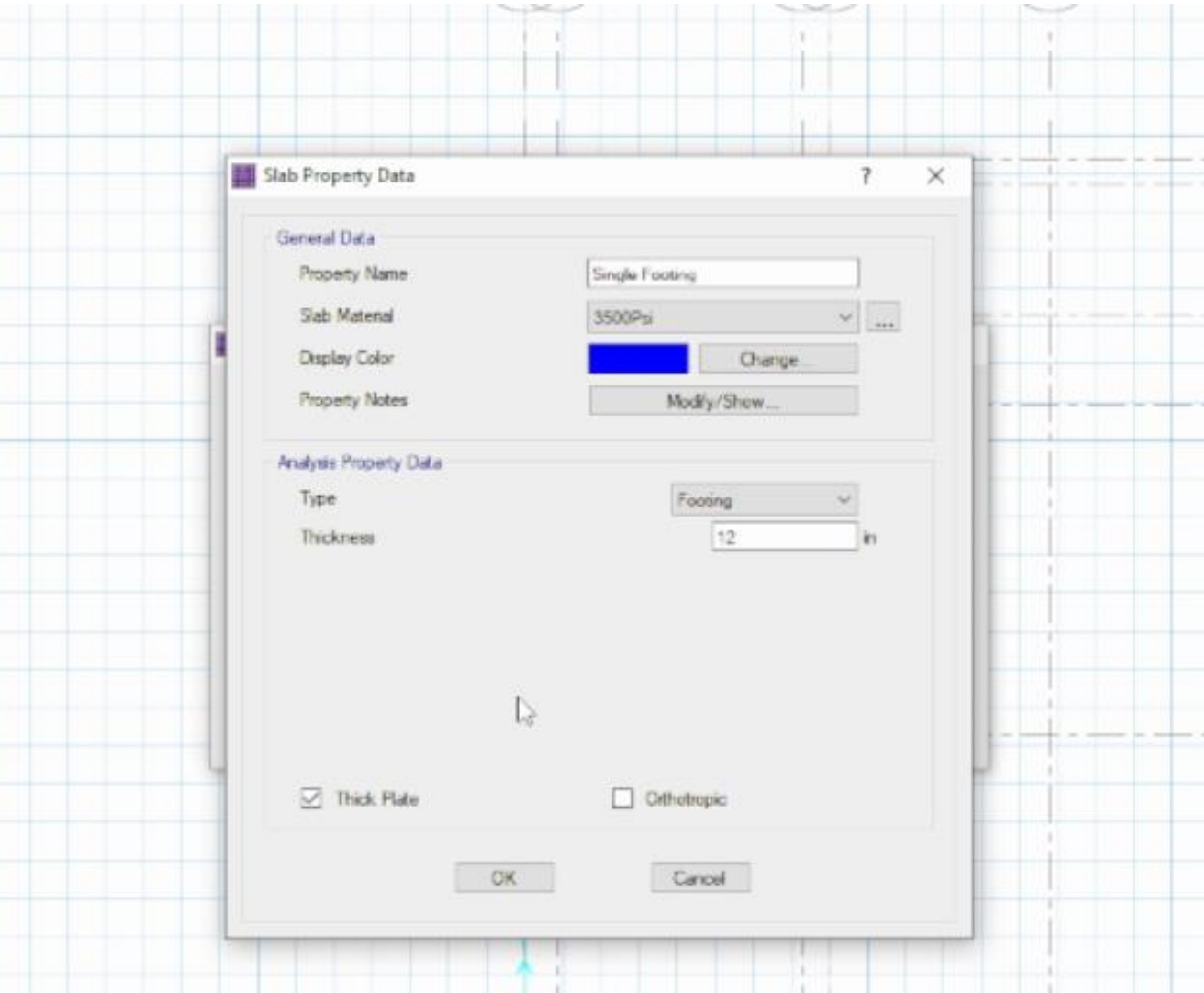

SAFE 2016
File Edit View Define Draw Select Assign Design Run Display Detailing Tools Options Help
New Model... Ctrl+N
New Model from Existing File... Ctrl+Shift+N
Open... Ctrl+O
Save Ctrl+S
Save As... Ctrl+Shift+S
Import
Export Model
Export Drawings...
Modify/Show Project Information...
Modify/Show Comments and Log...
Create Video...
Print Graphics... Ctrl+P
Print Tables... Ctrl+Shift+T
Print Drawings... Ctrl+Shift+D
Report Setup...
Create Report Ctrl+Shift+R
Advanced Report Writer...
Capture Picture
Show Input/Output Text Files... Ctrl+Shift+F
1 C:\Users\ugv\...\shanta vai.FDB
2 C:\Users\ugv\...\shanta vai.FDB
Exit Alt+F4
SAFE .F2K File...
.DXF/.DWG File... Ctrl+I
.DXF/.DWG Architectural Plan... Ctrl+Shift+I
.EXR Revit File... Ctrl+Shift+X
Access .mdb/.accdb File...
Excel .xls/.xlsx File...
Use File Menu to Create or Open Model

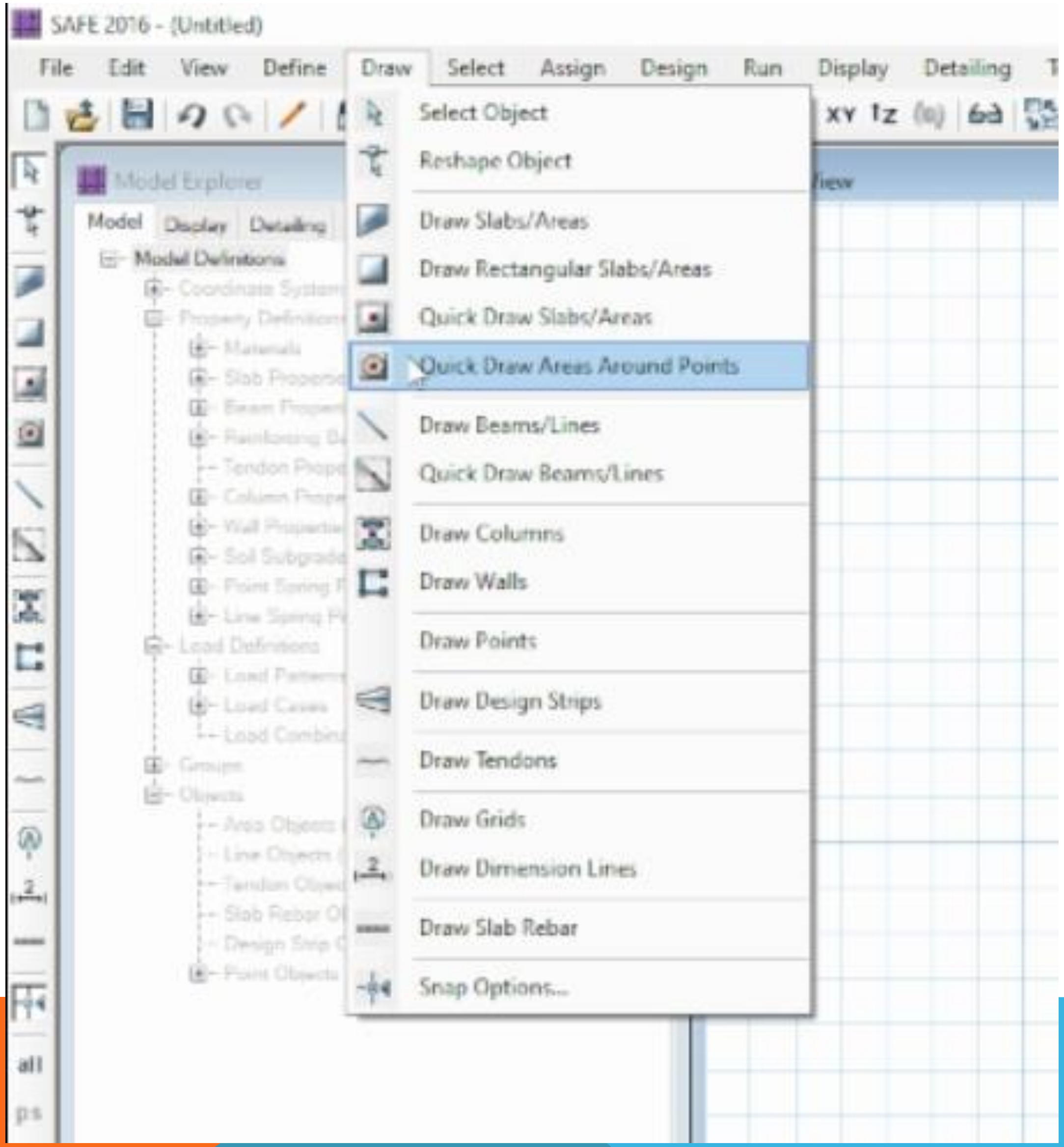

SAFE 2016 - (Untitled)
File Edit View Define Draw Select Assign Design Run Display Detailing Tools Options Help
Model Explorer
Model Display Detailing
Model Definitions
Show Loads
Load Pattern Name
Dead_ABOVE
Load Type
Point Loads
Point Displacements
Beam Force Loads
Beam Moment Loads
Slab Surface Loads
Direction
Slab Temperature Loads
Tendon Assigned Loads
Tendon Calculated Loads
Analysis Model Loads
Show Loading Values
OK
Cancel
3-D View

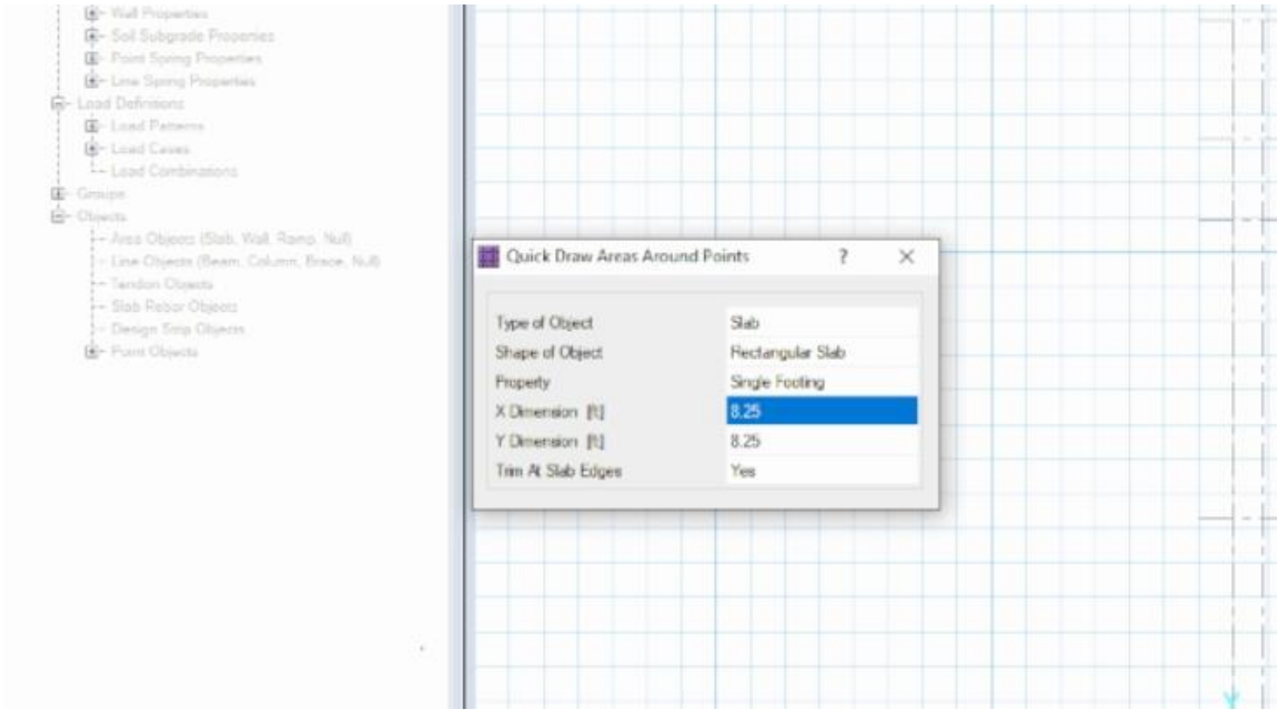

Point Loads (Dead_ABOVE) [kip, kip-ft]

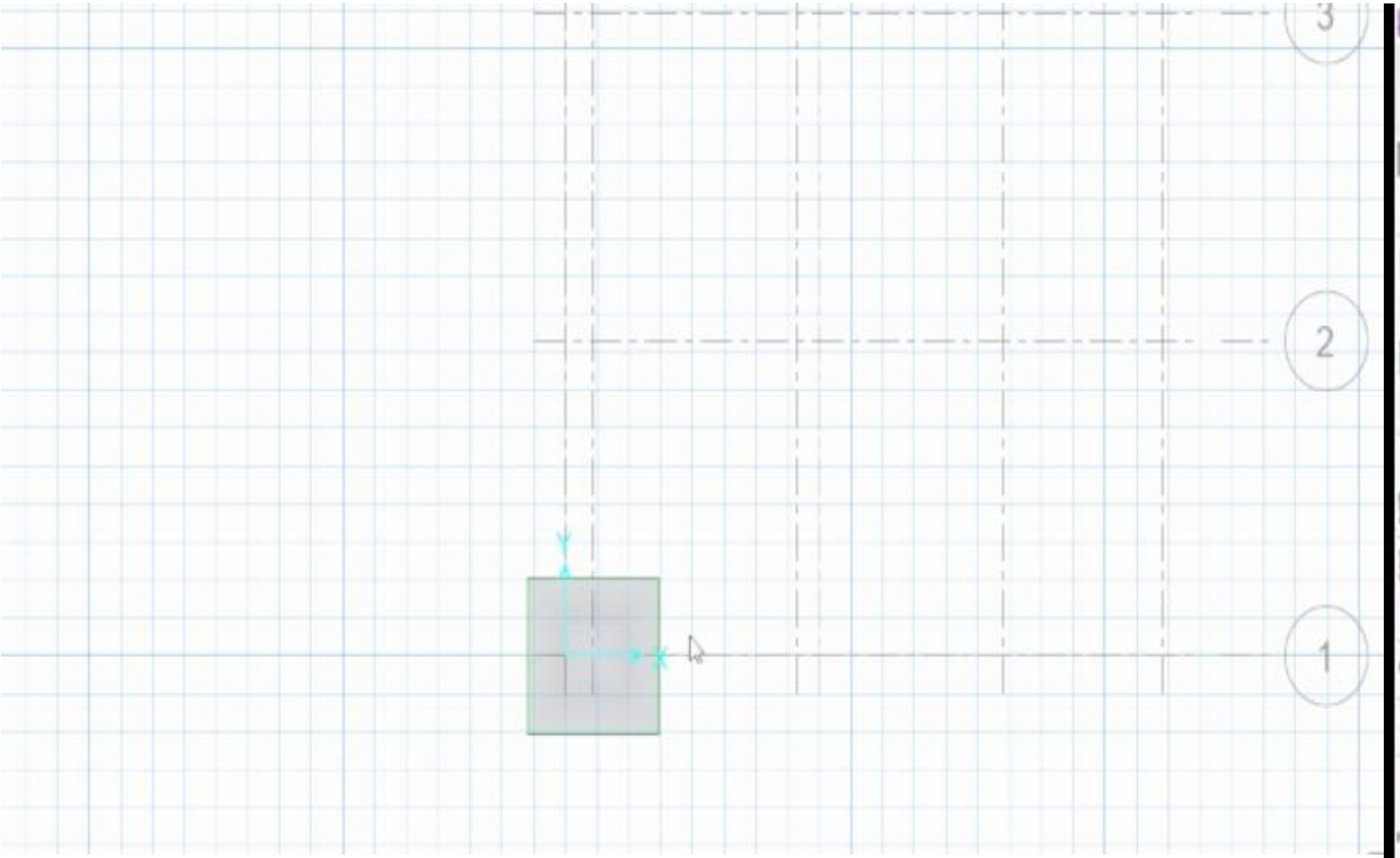

File Edit View Define Draw Select Assign Design Run Display Detailing Tools Options Help
Model Explorer
Model Display Detailing
Model Definitions
Plan View
Point Object Information
Point Object Name 11
Assignments Geometry Loads Design
Force in Global X Direction (kip) 0.249
Force in Global Y Direction (kip) 0.21
Force in Gravity Dir (Global Z) (kip) 217.022
Moment about Global X Axis (kip-ft) -0.4358
Moment about Global Y Axis (kip-ft) 0.8113
Moment about Global Z Axis (kip-ft) 0.1613
Load Size X Dimension (in) 25
Load Size Y Dimension (in) 12
Load Pattern Live_ABOVE
Point Loads
Force in Global X Direction (kip) 0.098
Force in Global Y Direction (kip) -0.07
Force in Gravity Dir (Global Z) (kip) 22.408
Moment about Global X Axis (kip-ft) 0.1541
Moment about Global Y Axis (kip-ft) 0.3394
Moment about Global Z Axis (kip-ft) 0.0416
Load Size X Dimension (in) 25
Load Size Y Dimension (in) 12
Assign Load...
Reset All
OK
Cancel

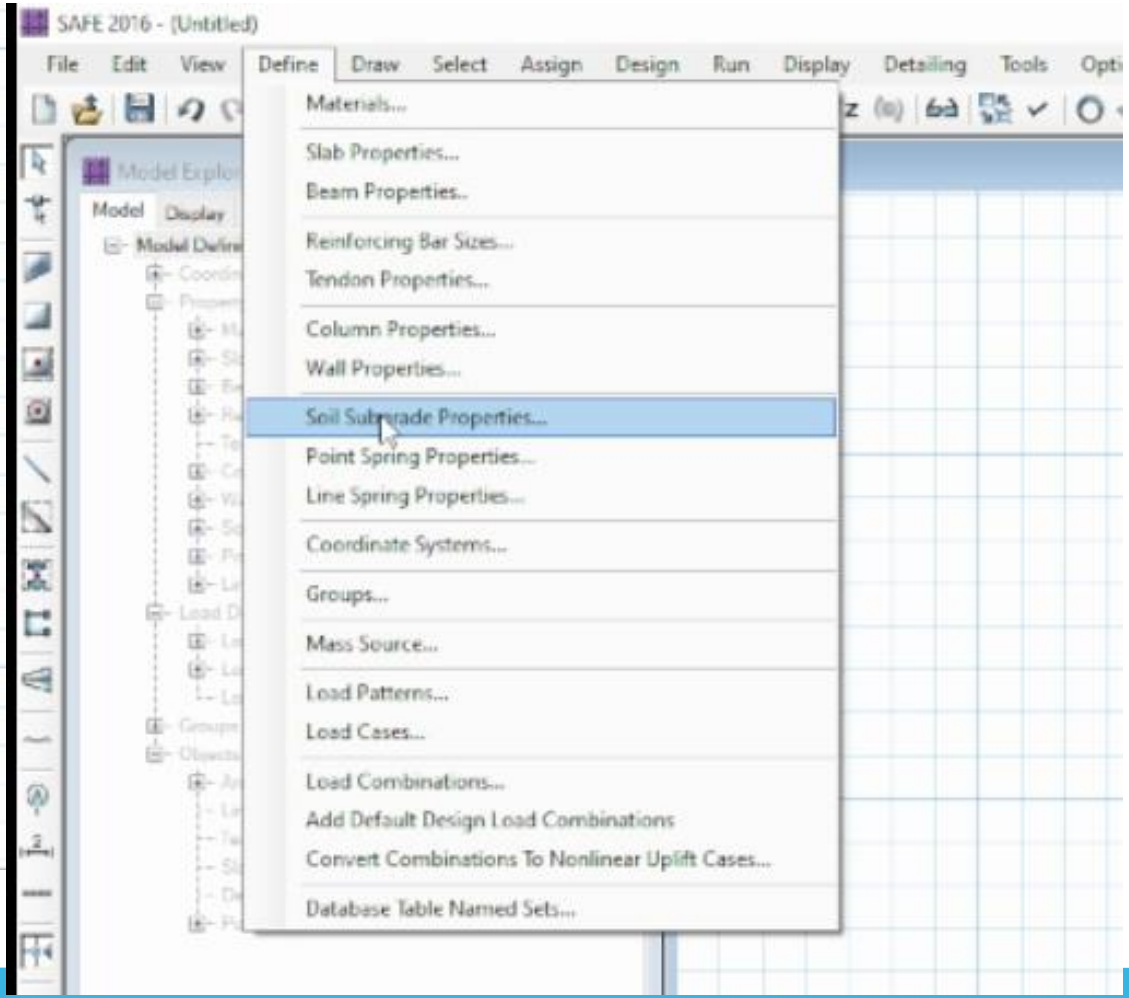

Materials
Materials
4000Psi
A416Gr270
A615Gr60
Click to:
Add New Material Quick...
Add New Material
Add Copy of Material...
Modify/Show Material...
Delete Material
OK
Cancel

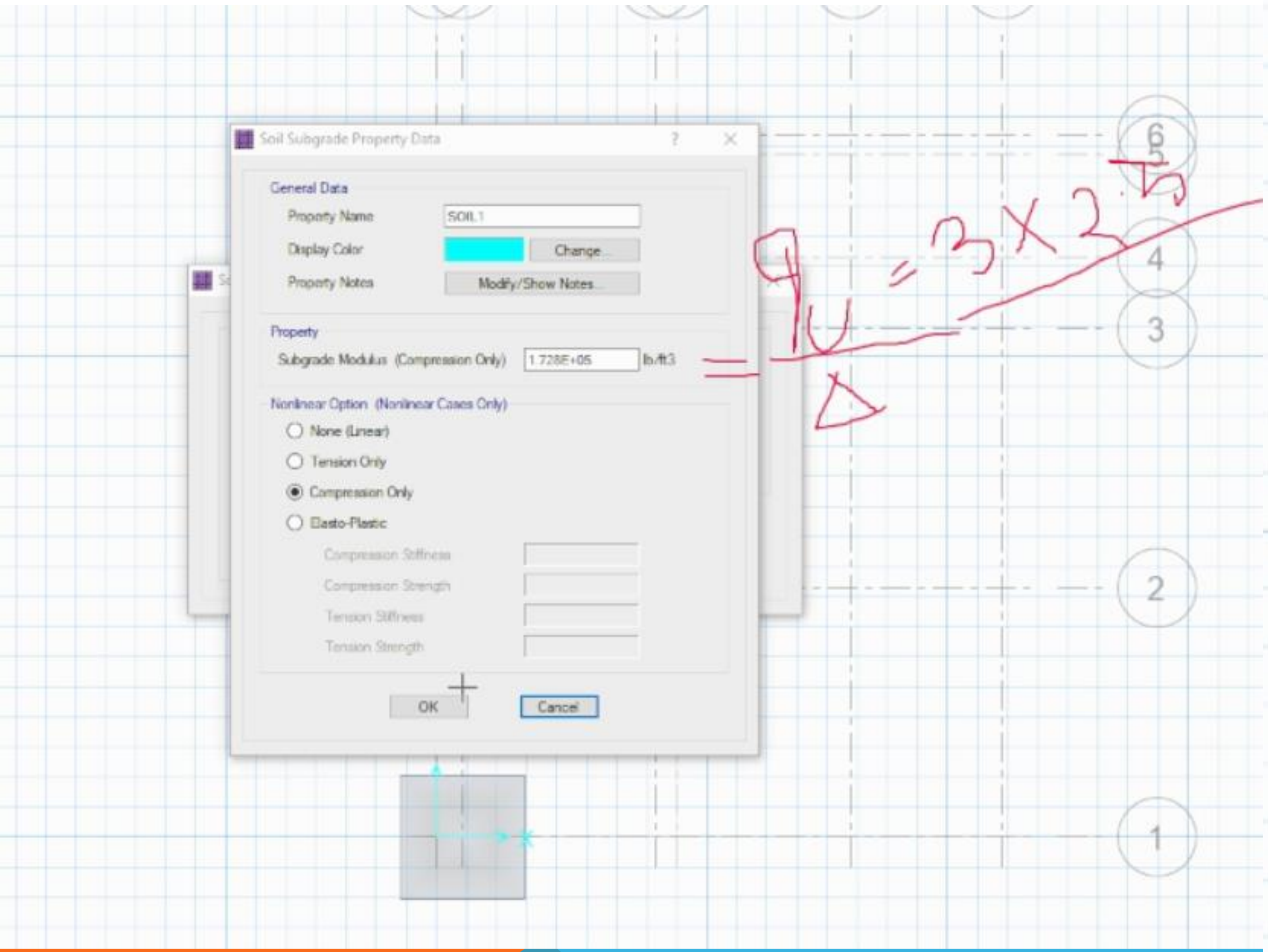
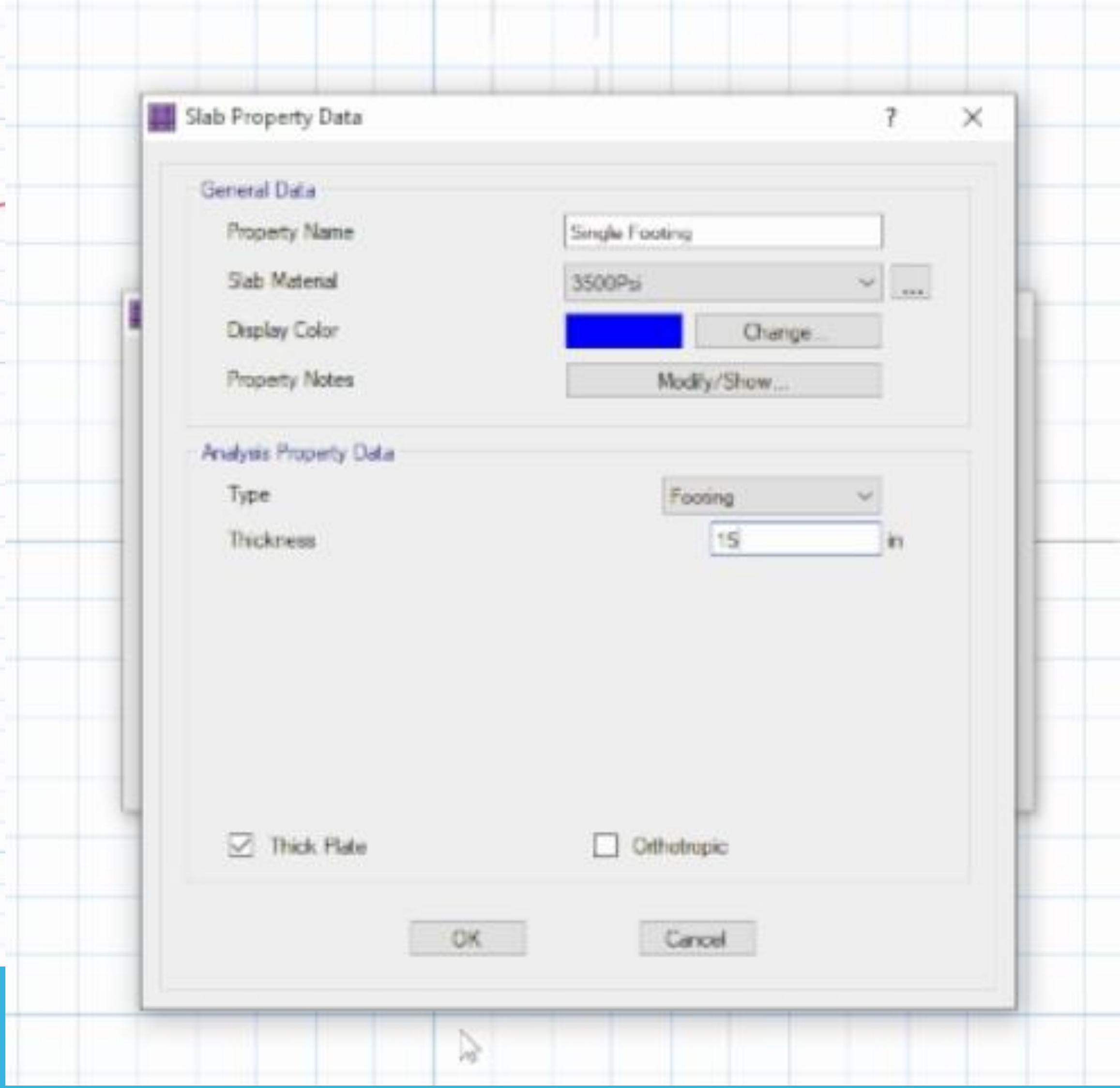

Slab Property Data
General Data
Property Name
Single Footing
Slab Material
3500Psi
Display Color
Change...
Property Notes
Modify/Show...
Analysis Property Data
Type
Footing
Thickness
12
in
Thick Plate
Orthotropic
OK
Cancel

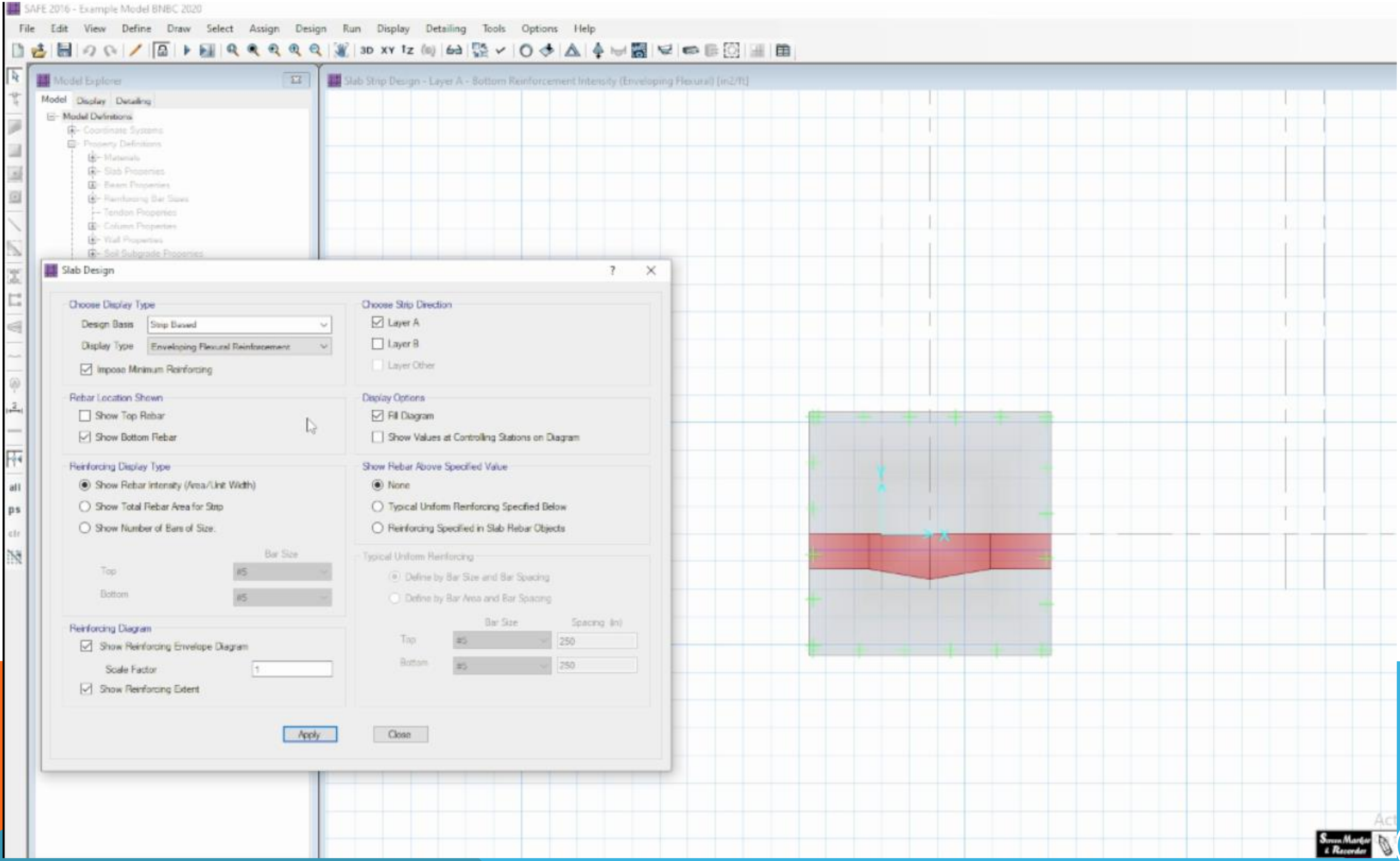

SAFE 2016 - (Untitled)
File
Edit
View
Define
Draw
Select
Assign
Design
Run
Display
Detailing
Select Object
Reshape Object
Draw Slabs/Areas
Draw Rectangular Slabs/Areas
Quick Draw Slabs/Areas
Quick Draw Areas Around Points
Draw Beams/Lines
Quick Draw Beams/Lines
Draw Columns
Draw Walls
Draw Points
Draw Design Strips
Draw Tendons
Draw Grids
Draw Dimension Lines
Draw Slab Rebar
Snap Options...
Model Explorer
Model
Display
Detailing
Model Definitions

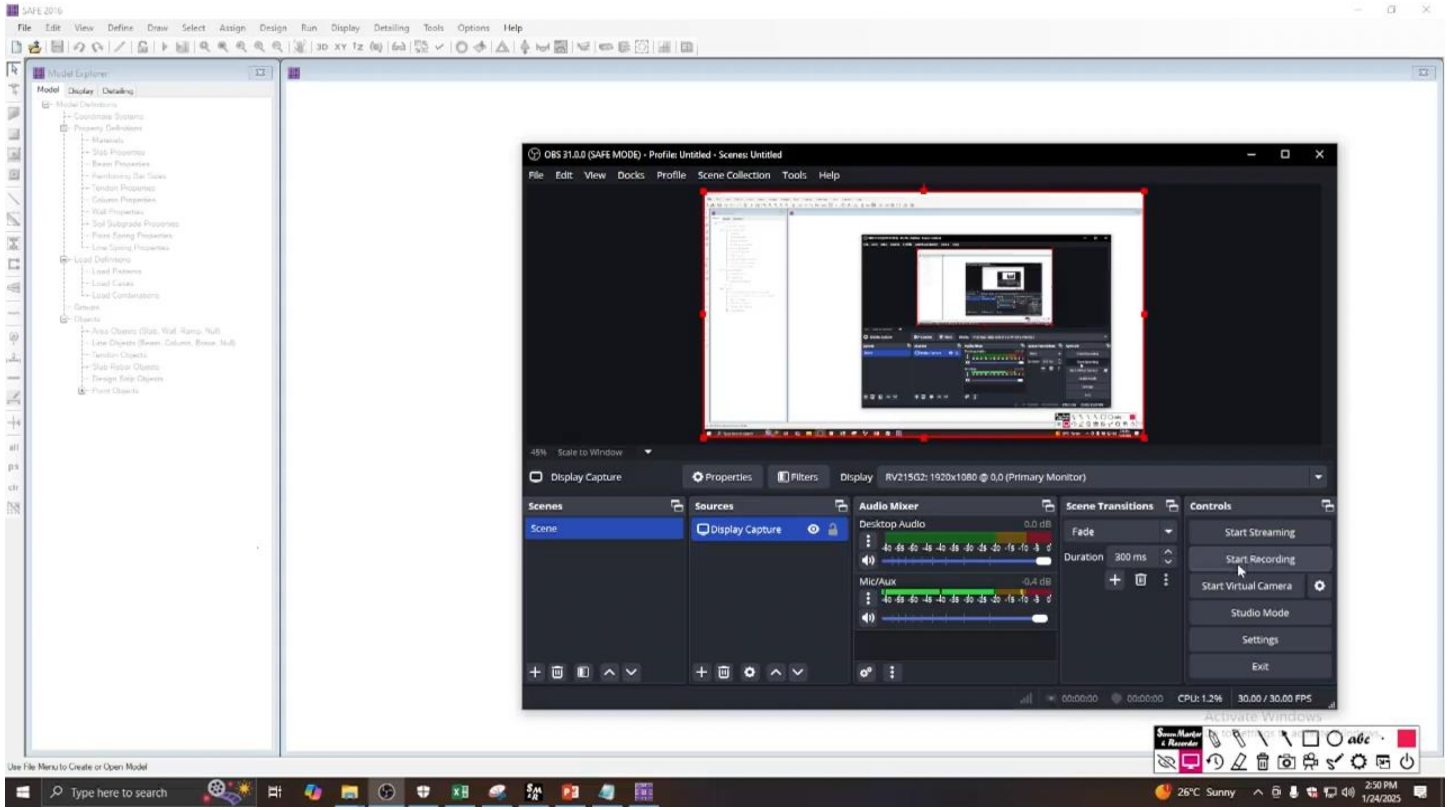

Quick Draw Areas Around Points
Type of Object
Slab
Shape of Object
Rectangular Slab
Property
Single Footing
X Dimension (ft)
8.25
Y Dimension (ft)
8.25
Trim At Slab Edges
Yes


3
2
1


SAFE 2016 - (Untitled)
File
Edit
View
Define
Draw
Select
Assign
Design
Run
Display
Detailing
Tools
Model
Display
Materials...
Slab Properties...
Beam Properties...
Reinforcing Bar Sizes...
Tendon Properties...
Column Properties...
Wall Properties...
Soil Subgrade Properties...
Point Spring Properties...
Line Spring Properties...
Coordinate Systems...
Groups...
Mass Source...
Load Patterns...
Load Cases...
Load Combinations...
Add Default Design Load Combinations
Convert Combinations To Nonlinear Uplift Cases...
Database Table Named Sets...


Soil Subgrade Property Data
General Data
Property Name
SOIL1
Display Color
Change...
Property Notes
Modify/Show Notes...
Property
Subgrade Modulus (Compression Only)
1.728E+05
lb/ft3
Nonlinear Option (Nonlinear Cases Only)
None (Linear)
Tension Only
Compression Only
Elasto-Plastic
OK
Cancel
6
4
3
2
1

Slab Property Data
General Data
Property Name
Single Footing
Slab Material
3500Psi
Display Color
Change...
Property Notes
Modify/Show...
Analysis Property Data
Type
Footing
Thickness
15
in
Thick Plate
Orthotropic
OK
Cancel


SAFE 2016 - Example Model BNBC 2020
File Edit View Define Draw Select Assign Design Run Display Detailing Tools Options Help
Model Explorer
Model Display Detailing
Model Definitions
Slab Strip Design - Layer A - Bottom Reinforcement Intensity (Enveloping Flexural) [in2/ft]
Slab Design
Choose Display Type
Design Basis Strip Based
Display Type Enveloping Flexural Reinforcement
Impose Minimum Reinforcing
Choose Strip Direction
Layer A
Layer B
Layer Other
Rebar Location Shown
Show Top Rebar
Show Bottom Rebar
Display Options
Fill Diagram
Show Values at Controlling Stations on Diagram
Reinforcing Display Type
Show Rebar Intensity (Area/Unit Width)
Show Total Rebar Area for Strip
Show Number of Bars of Size
Bar Size
Top
Bottom
Show Rebar Above Specified Value
None
Typical Uniform Reinforcing Specified Below
Reinforcing Specified in Slab Rebar Objects
Typical Uniform Reinforcing
Define by Bar Size and Bar Spacing
Define by Bar Area and Bar Spacing
Bar Size
Spacing (in)
250
250
Reinforcing Diagram
Show Reinforcing Envelope Diagram
Scale Factor 1
Show Reinforcing Extent
Apply
Close



Design of Single Column Footing (video)

Design of Combined Footing-I

Week 8-9

Pages 68-75

Skill Details:

- Understanding the design procedure of combined column footing (hand calculation)
- Assigning the loads/structural frame
- Assigning area of footing according to soil test report
- Assigning grade of concrete and steel
- Run the model
- Checking the accuracy of results
- Detecting the problems and solving the error in cost-effective way (reducing or increasing the footing area/increasing concrete/steel grade)
- Detailing of the reinforcements

Combined Footing

Definition: *A combined footing is a type of shallow foundation where a common base is provided for two closely spaced columns.*

Combined footing supports two or more column loads. These may be continuous with rectangular or trapezoidal in plan. Need:

1) When the isolated footing overlaps.
2) When the exterior column is close to the property line such that isolated footing cannot be provided.

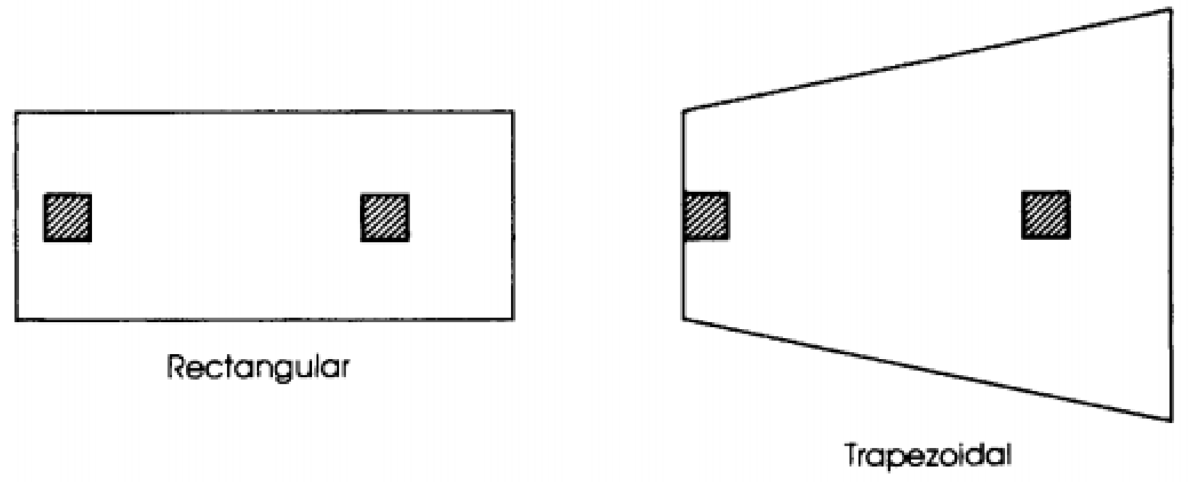


Figure Combined footings.

Design Consideration

Same as individual Column Footing

Size of Footing

$$\text{Area of } Footing = \frac{Total\ Service\ Load}{Allowable\ Soil\ Pressure}$$

$$\text{Area} = \frac{P\ (Dead+Live)}{q_a}$$

One-way and Two-way Shear

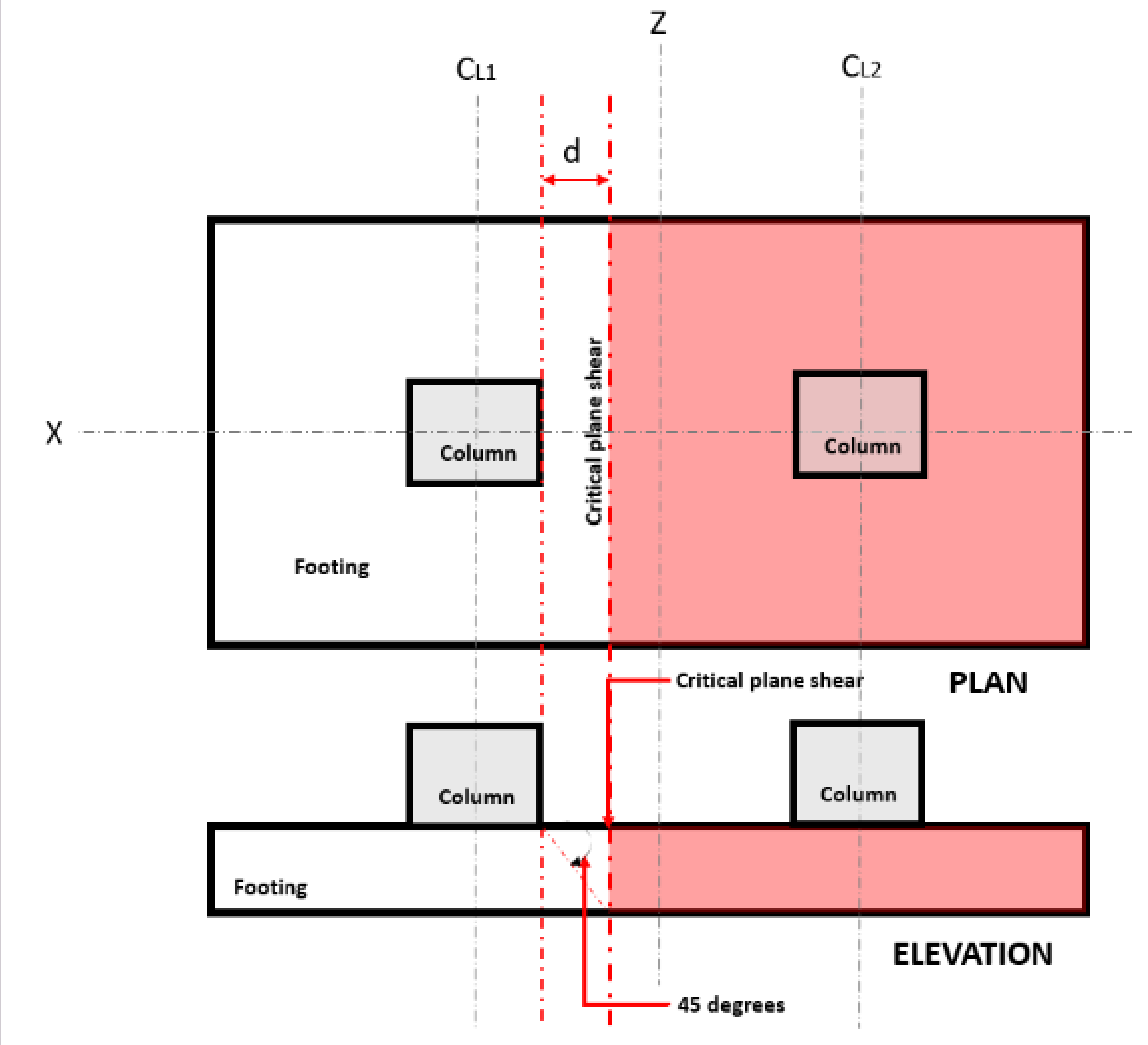


Fig.: One-way Shear

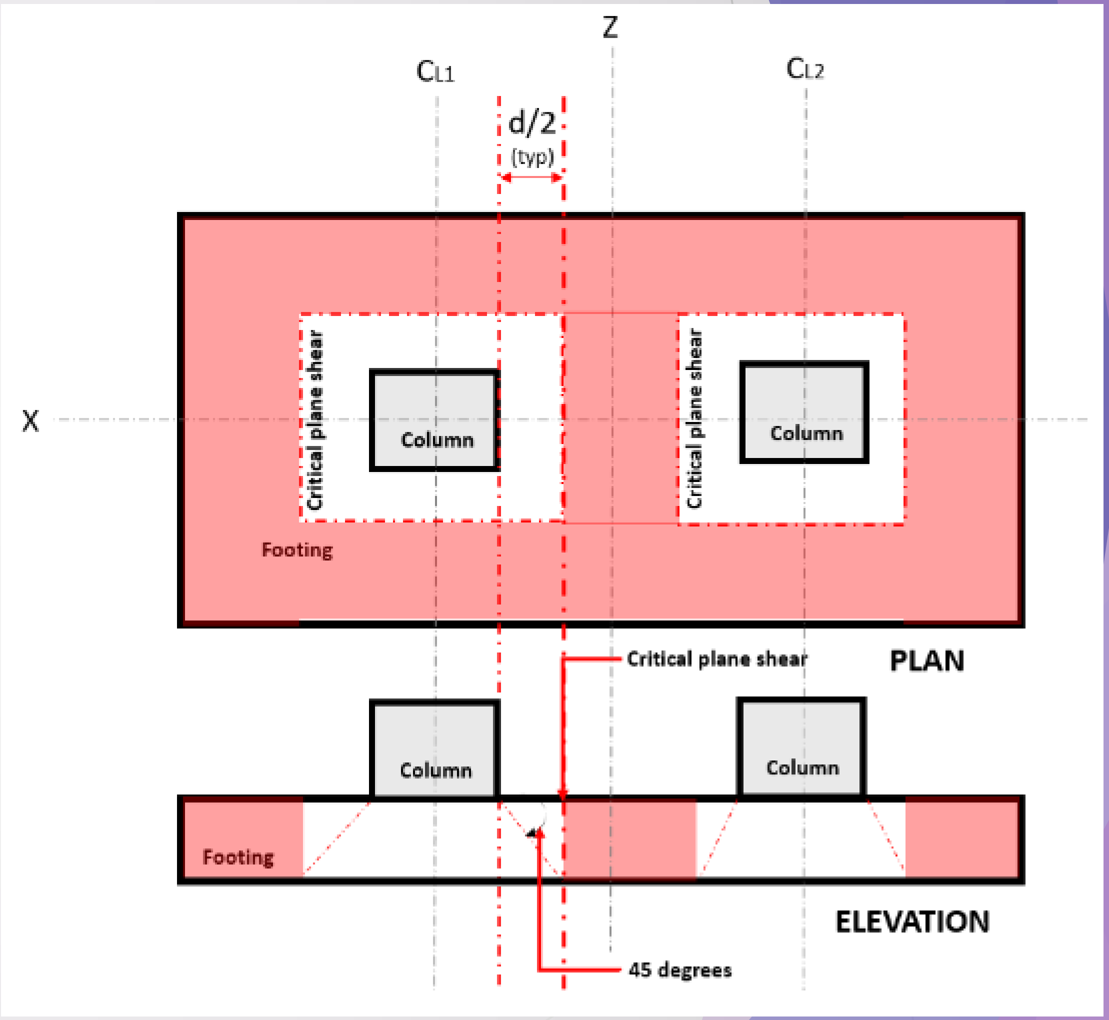


Fig.: Two-way Shear

Flexural Strength and Footing Reinforcement

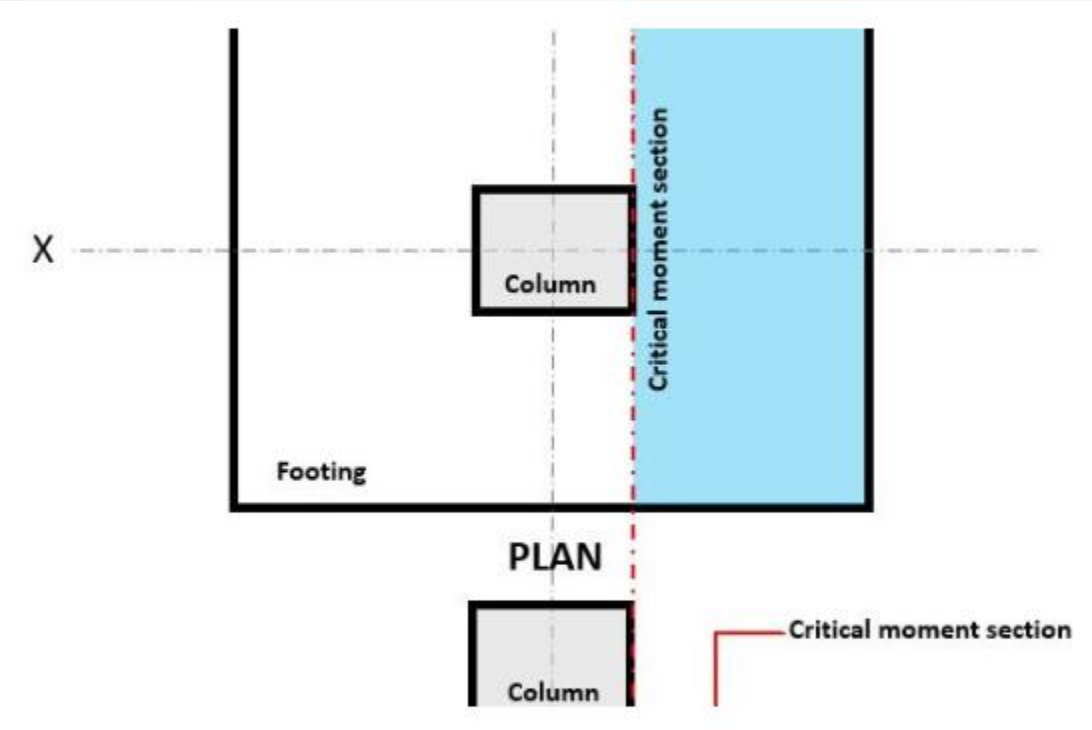
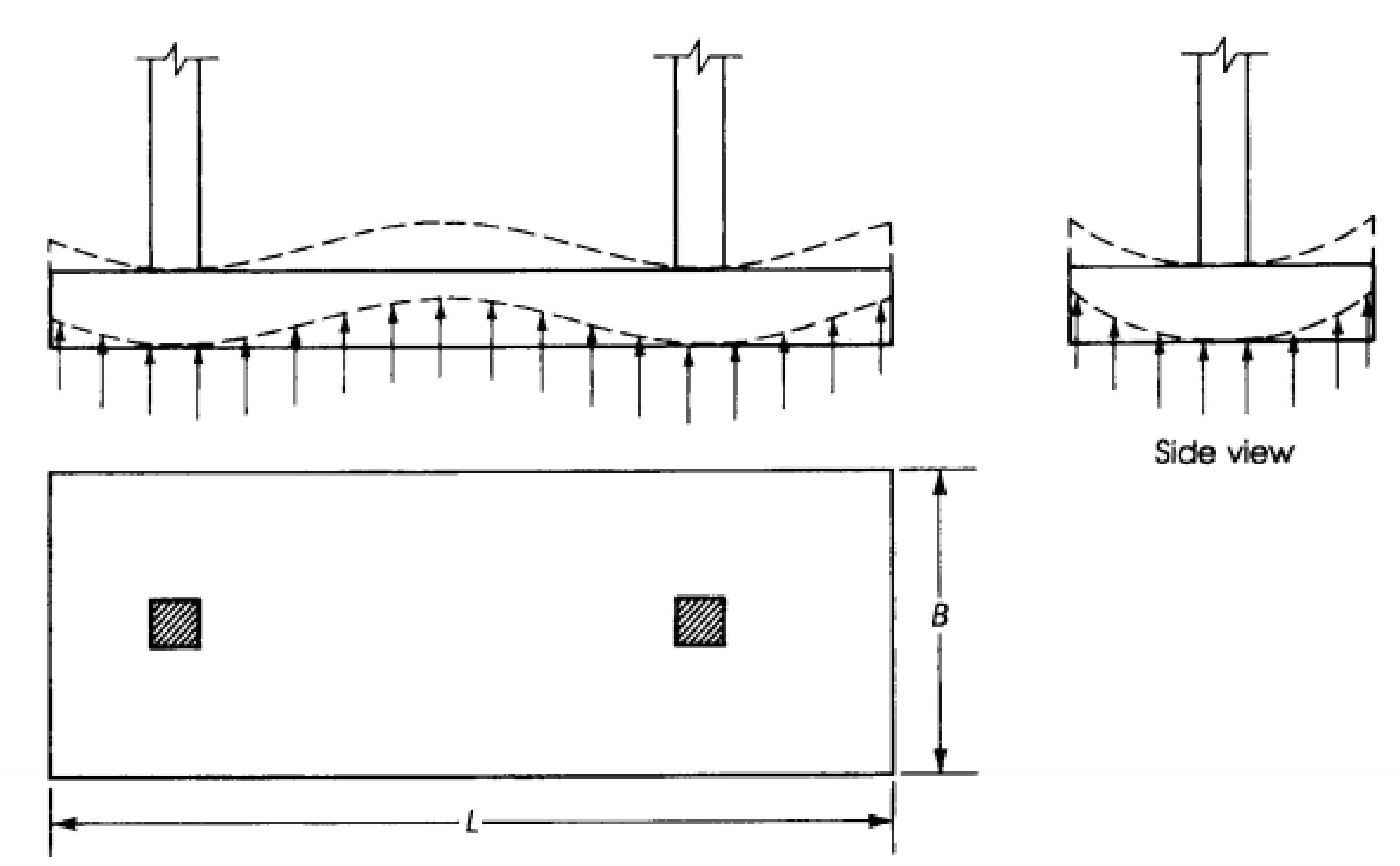
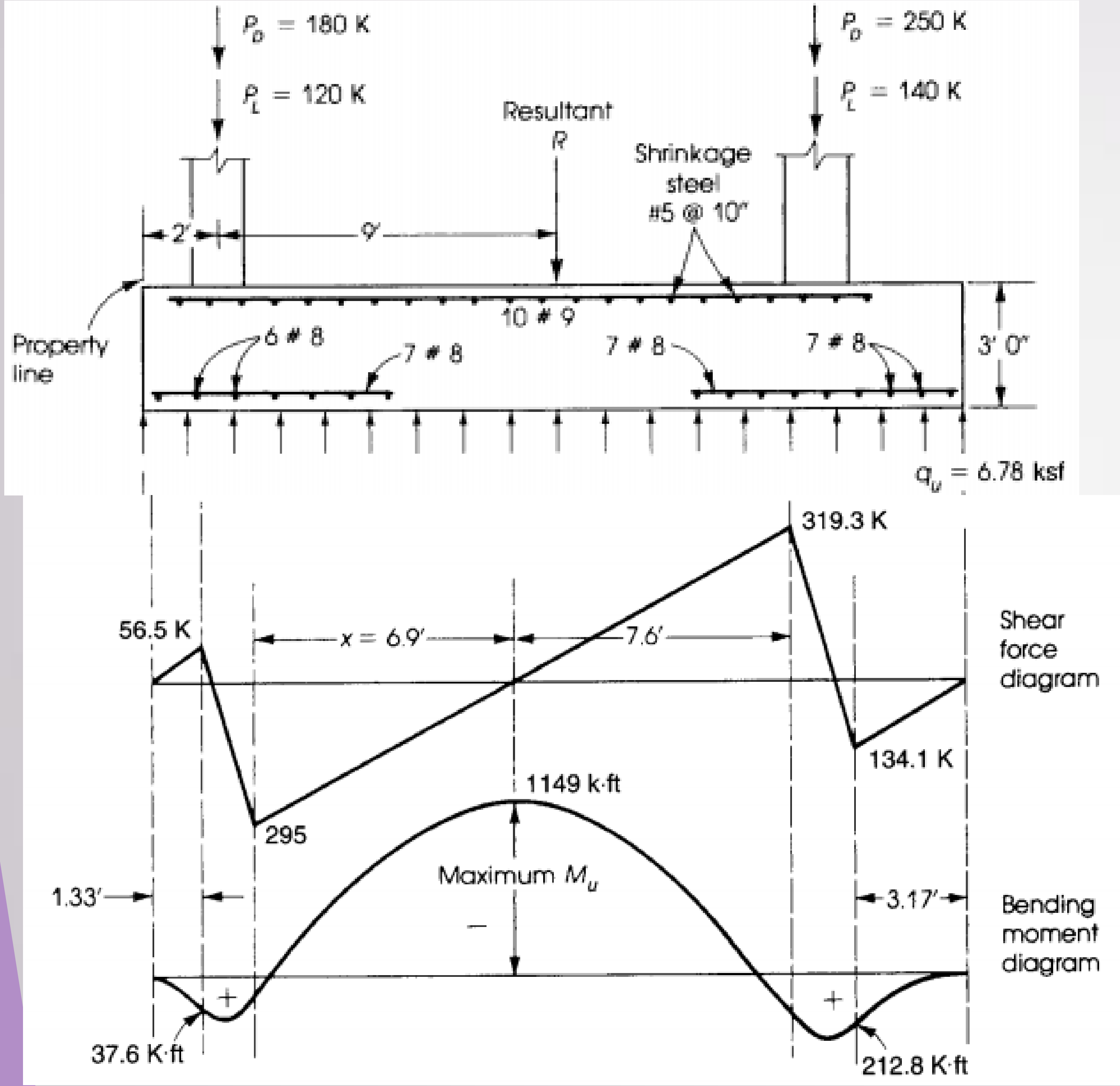


Fig.: Critical Section of Bending

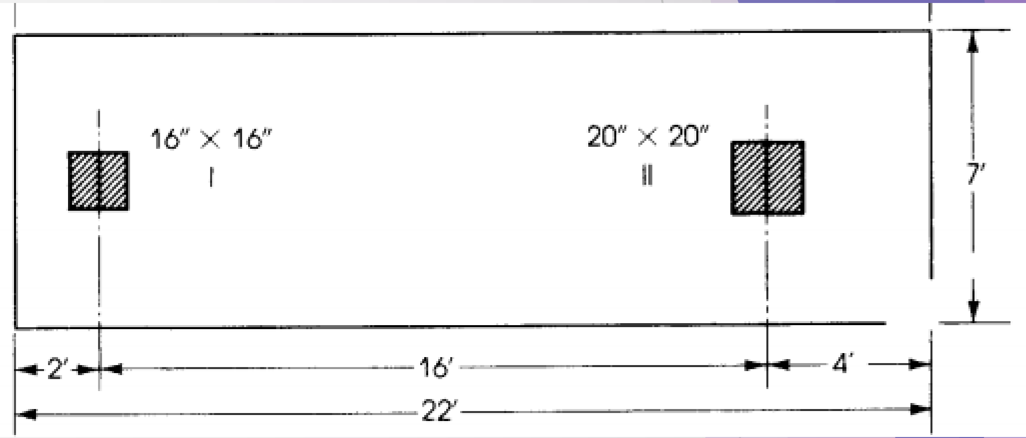
Combined Footing Under Loading Condition



Continue…



P_D = 180 K
P_L = 120 K
P_D = 250 K
P_L = 140 K
Resultant R
Shrinkage steel #5 @ 10″
2′
9′
10 # 9
6 # 8
7 # 8
7 # 8
7 # 8
Property line
3′ 0″
q_u = 6.78 ksf
56.5 K
x = 6.9′
7.6′
319.3 K
Shear force diagram
134.1 K
295
1149 k·ft
Maximum M_u
1.33′
3.17′
Bending moment diagram
37.6 K·ft
212.8 K·ft

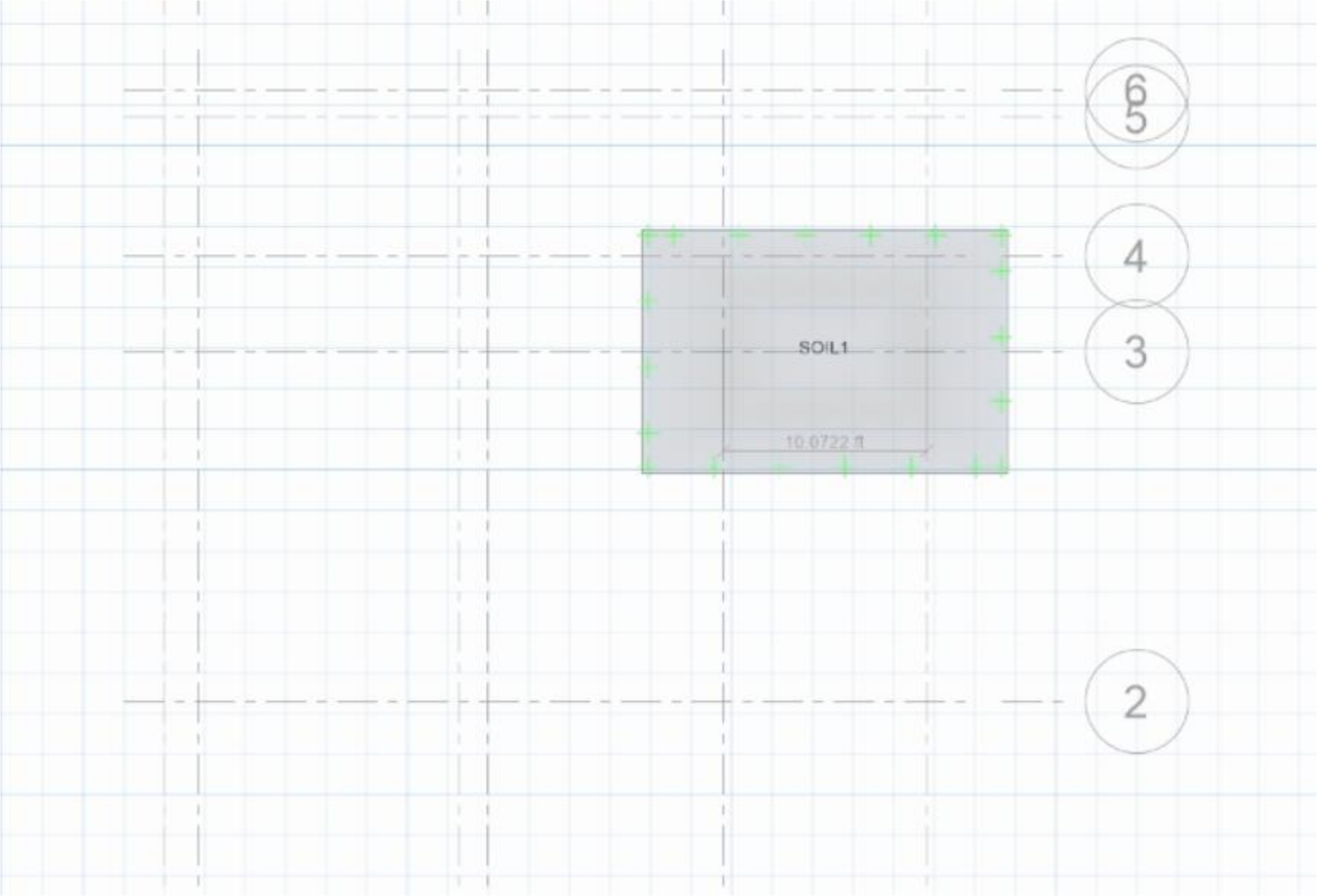


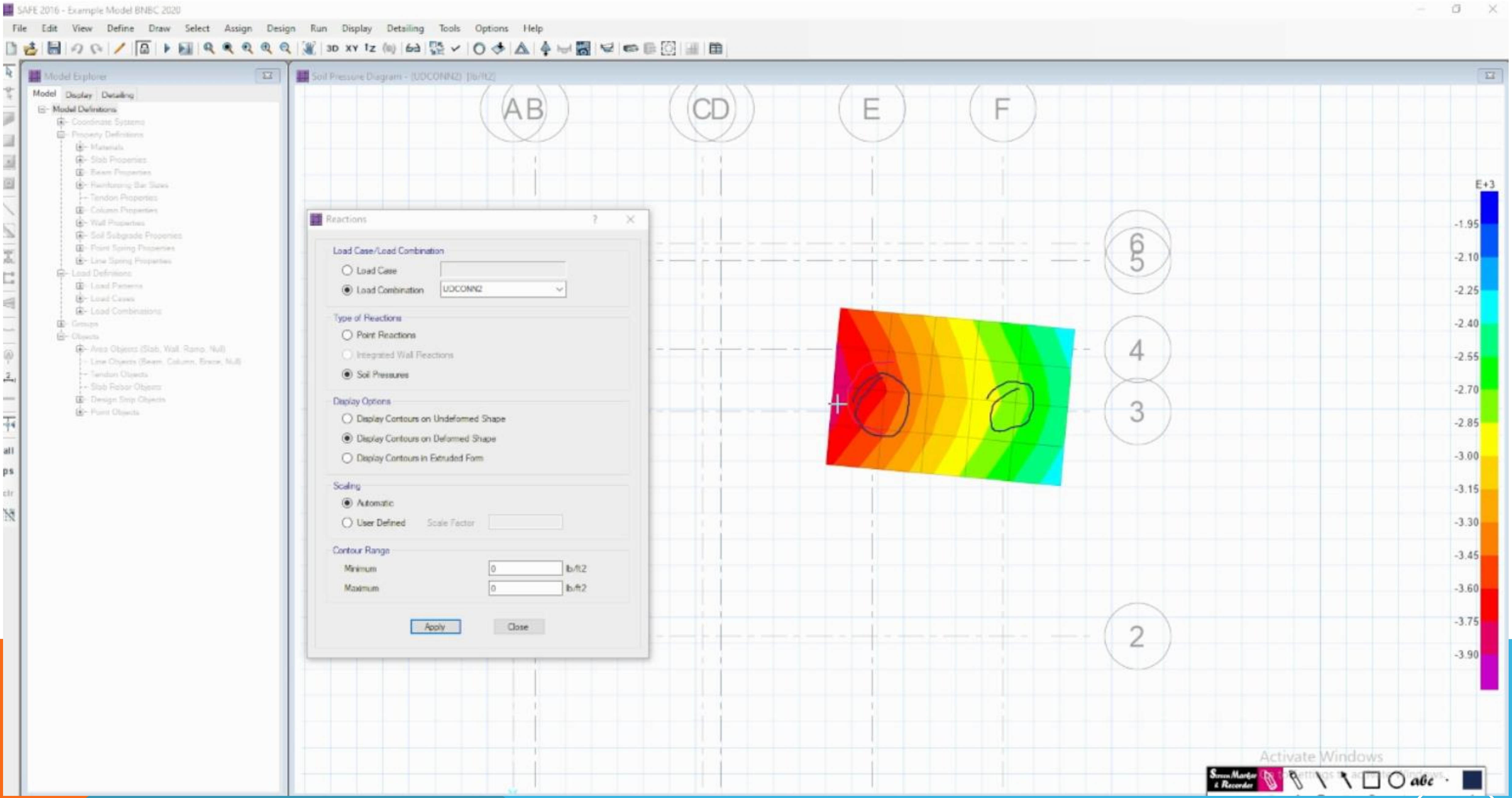
16″ × 16″
I
20″ × 20″
II
7′
2′
16′
4′
22′

Design of Combined Footing-II

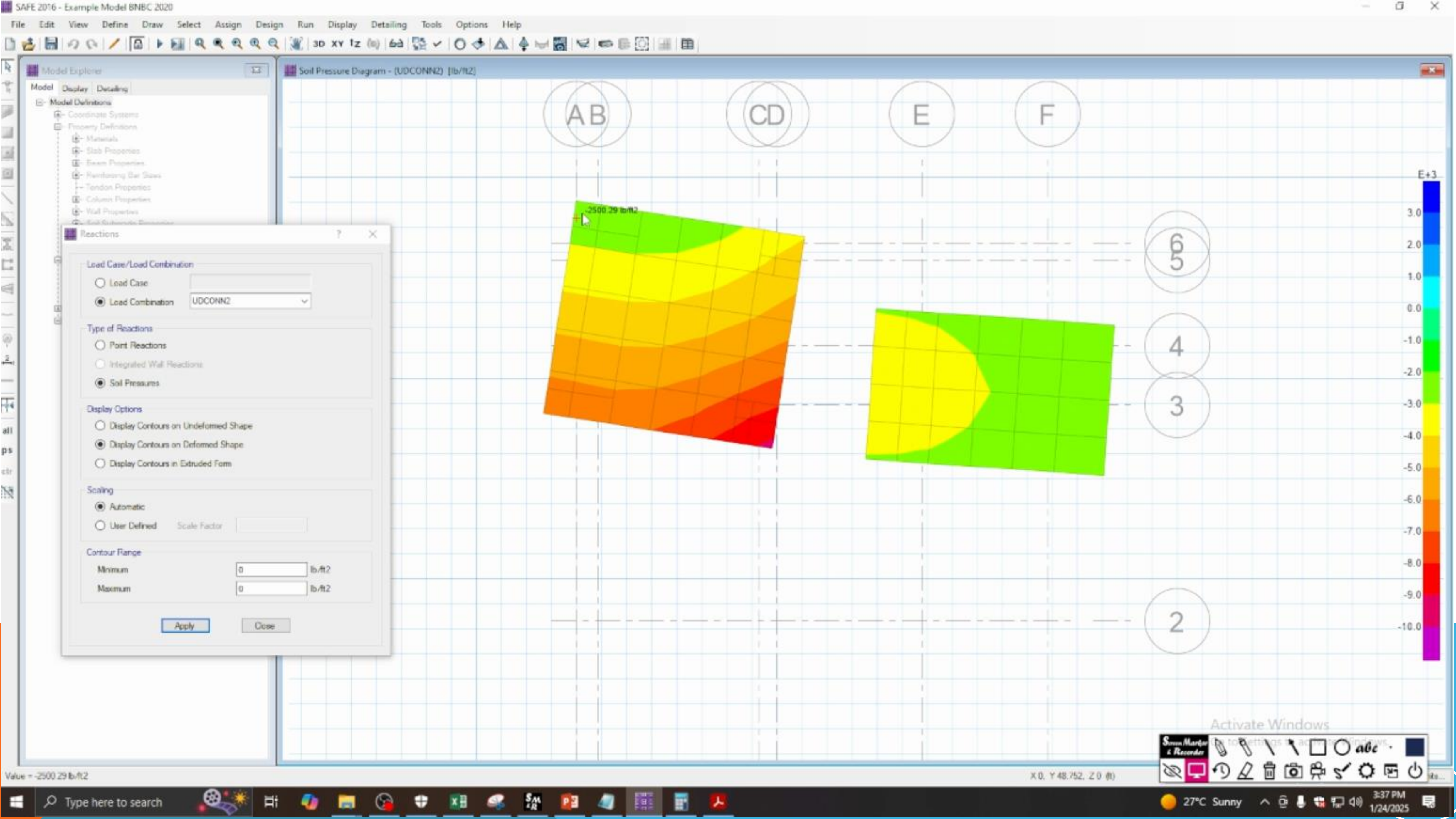
Week 10

Pages 77-81

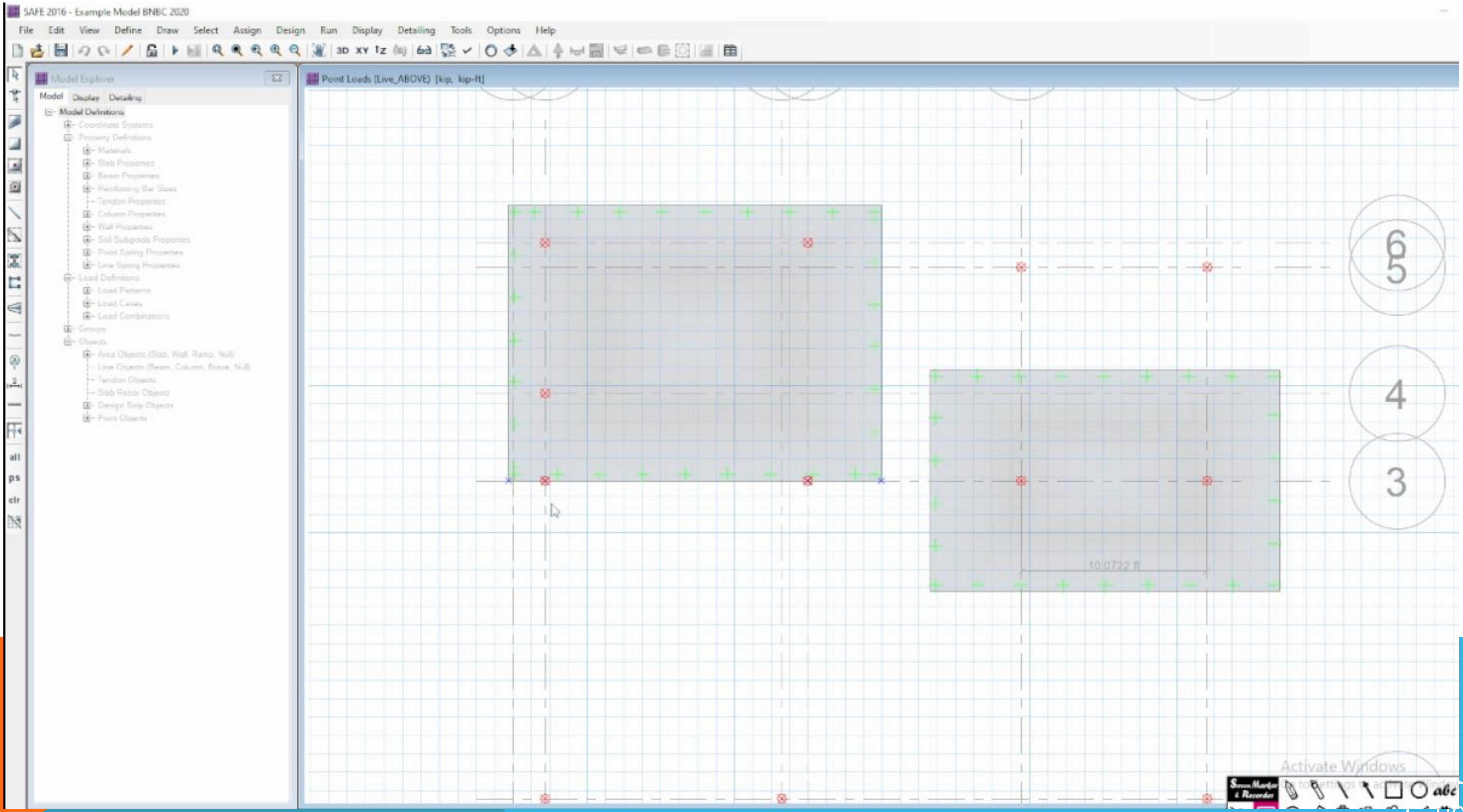

6
5
4
3
2
SOIL1
10.0722 ft

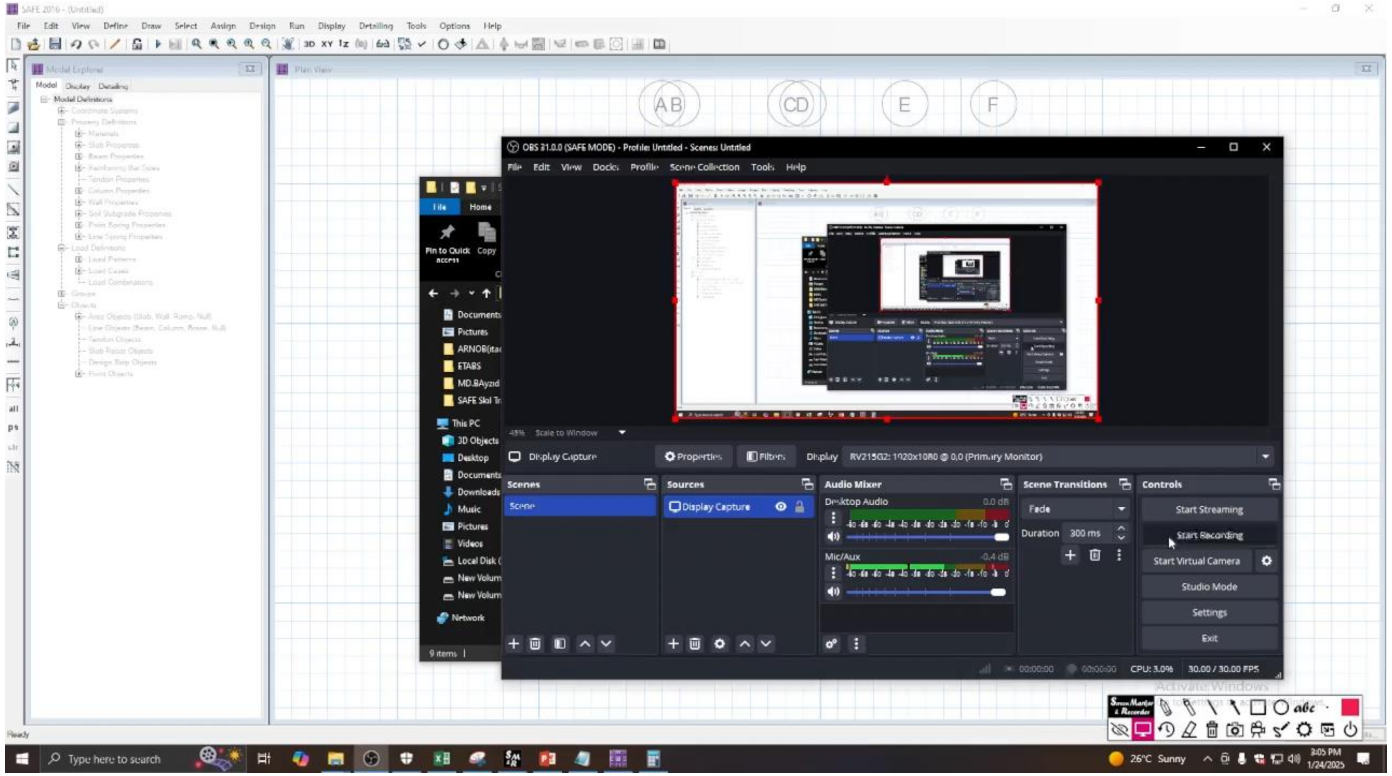


SAFE 2016 - Example Model BNBC 2020
File Edit View Define Draw Select Assign Design Run Display Detailing Tools Options Help
Model Explorer
Soil Pressure Diagram - (UDCONN2) [lb/ft2]
Reactions
Load Case/Load Combination
Load Case
Load Combination
UDCONN2
Type of Reactions
Point Reactions
Integrated Wall Reactions
Soil Pressures
Display Options
Display Contours on Undeformed Shape
Display Contours on Deformed Shape
Display Contours in Extruded Form
Scaling
Automatic
User Defined
Scale Factor
Contour Range
Minimum
Maximum
lb/ft2
Apply
Close
AB
CD
E
F
6
5
4
3
2
E+3
-1.95
-2.10
-2.25
-2.40
-2.55
-2.70
-2.85
-3.00
-3.15
-3.30
-3.45
-3.60
-3.75
-3.90



SAFE 2016 - Example Model BNBC 2020
File Edit View Define Draw Select Assign Design Run Display Detailing Tools Options Help
Model Explorer
Model Display Detailing
Model Definitions
Soil Pressure Diagram - (UDCONN2) [lb/ft2]
Reactions
Load Case/Load Combination
Load Case
Load Combination
UDCONN2
Type of Reactions
Point Reactions
Integrated Wall Reactions
Soil Pressures
Display Options
Display Contours on Undeformed Shape
Display Contours on Deformed Shape
Display Contours in Extruded Form
Scaling
Automatic
User Defined
Scale Factor
Contour Range
Minimum
Maximum
lb/ft2
Apply
Close
-2500.29 lb/ft2
AB
CD
E
F
6
5
4
3
2
E+3
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
-8.0
-9.0
-10.0
Value = -2500.29 lb/ft2
Activate Windows
Type here to search
27°C Sunny
3:37 PM
1/24/2025


SAFE 2016 - Example Model BNBC 2020
File Edit View Define Draw Select Assign Design Run Display Detailing Tools Options Help
Model Explorer
Model Display Detailing
Model Definitions
Point Loads (Live_ABOVE) [kip, kip-ft]
6
5
4
3
Activate Windows



Design of Combined Footing and Mat Foundation (Video)

Design of Mat foundation

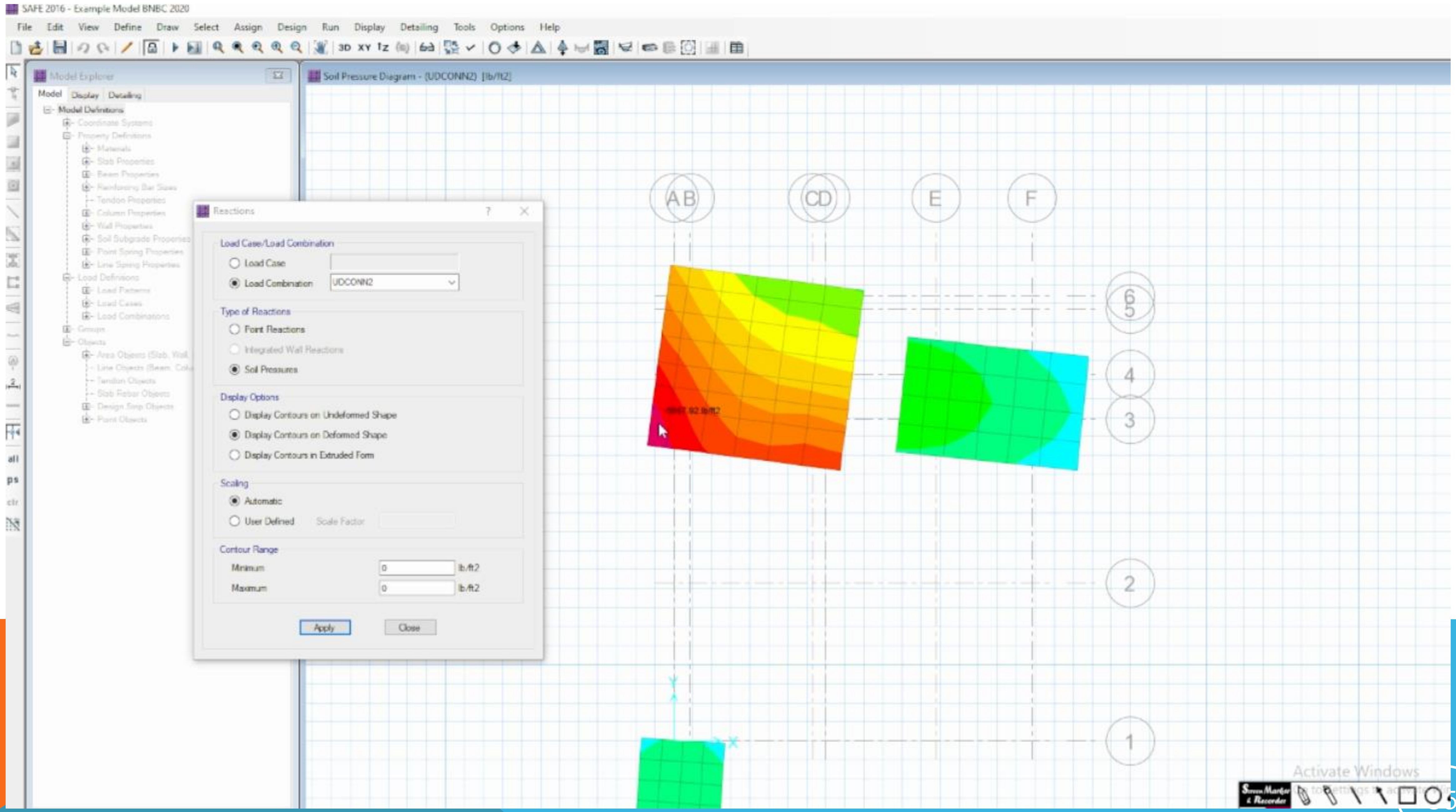
Week 11-12

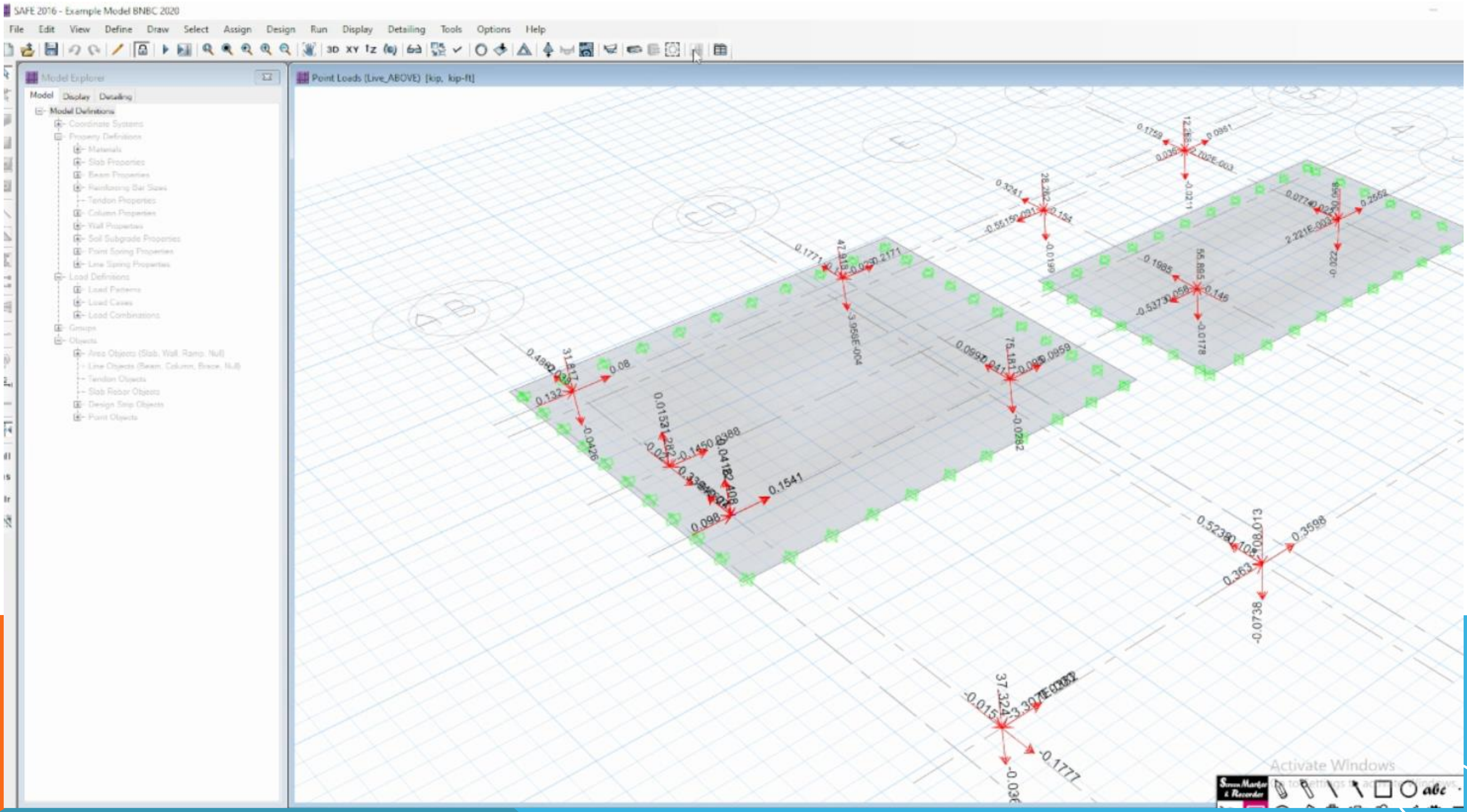
Pages 82-90

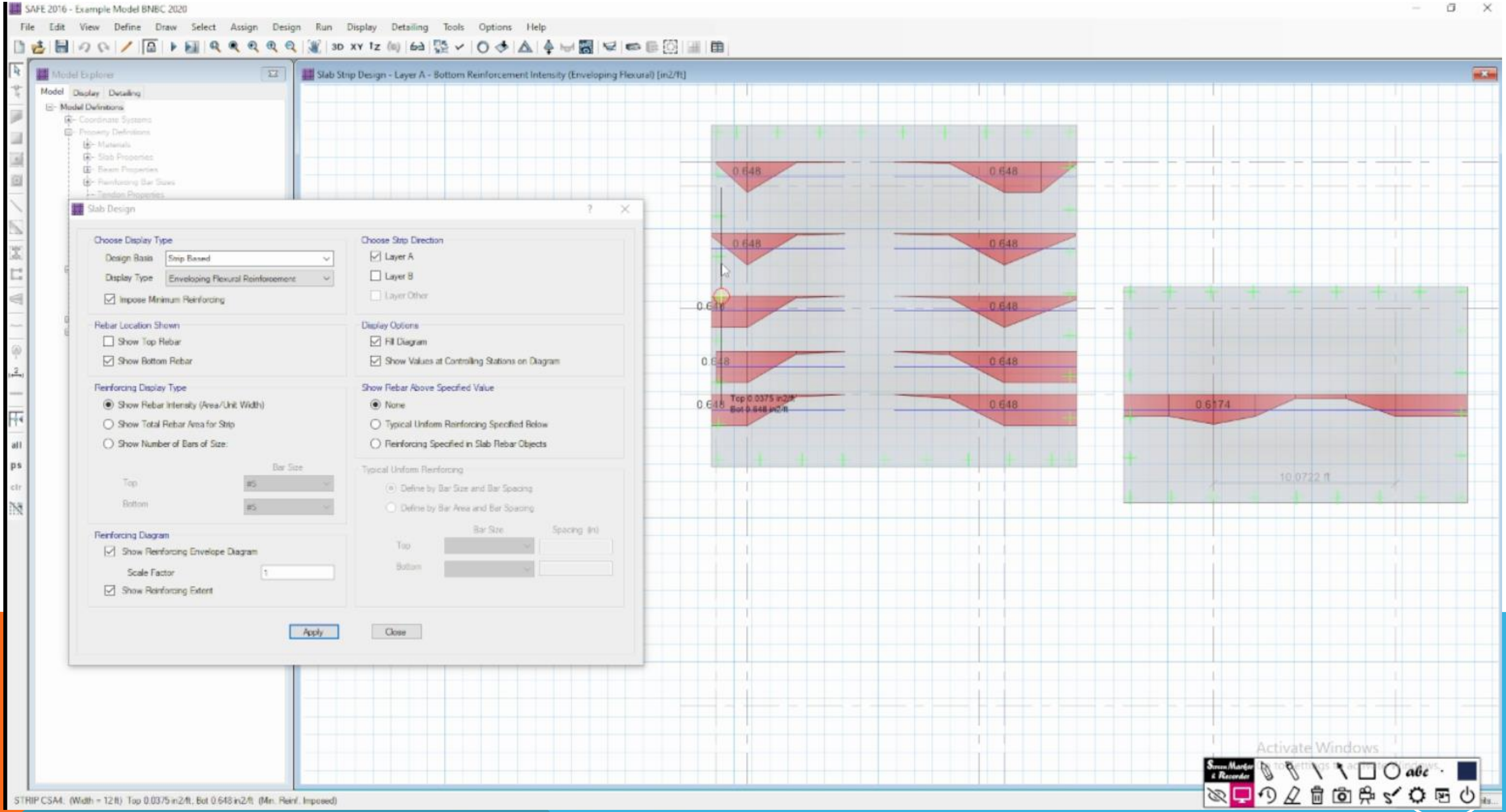
Mat Foundation

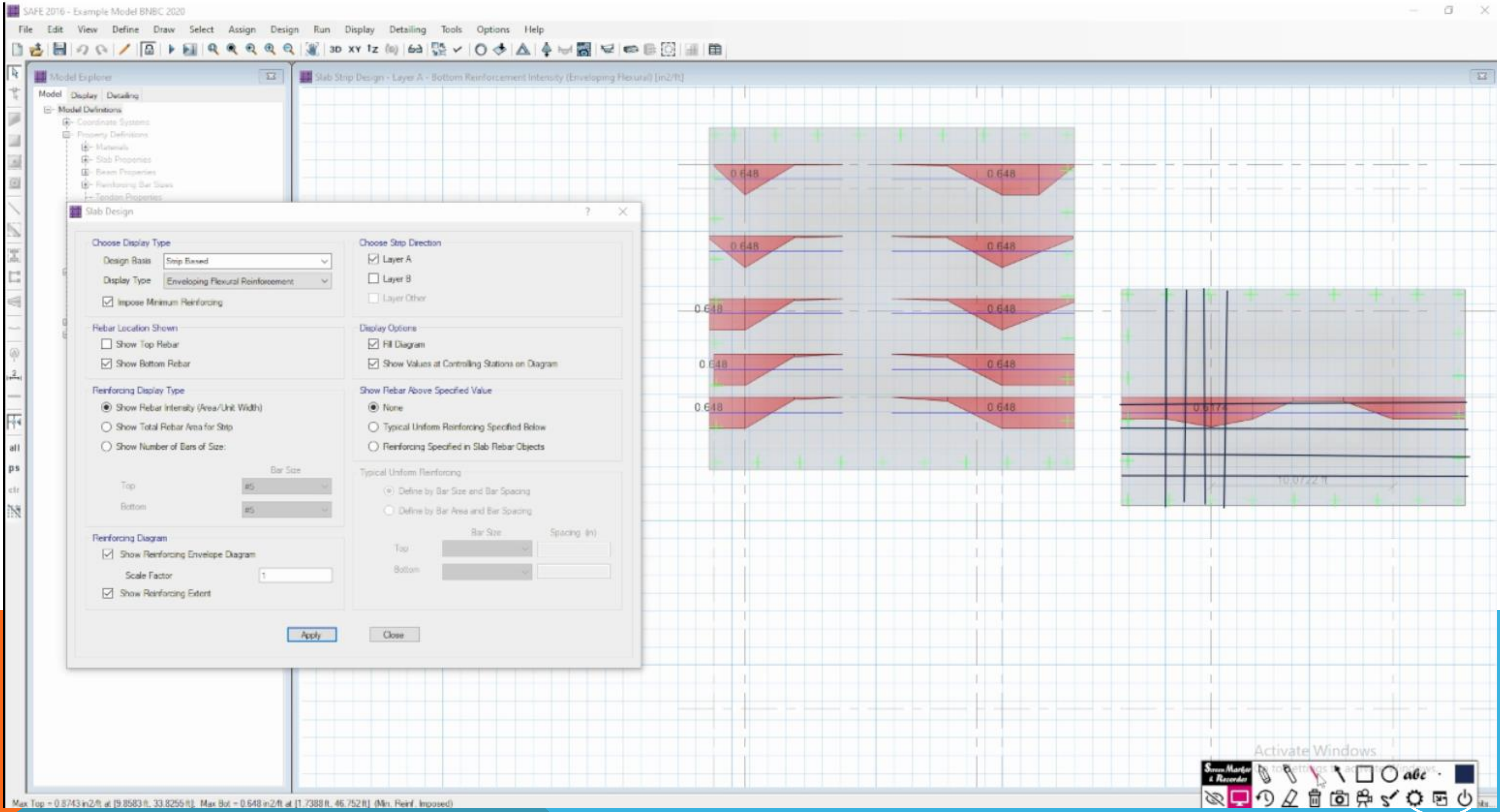
Skill Details:

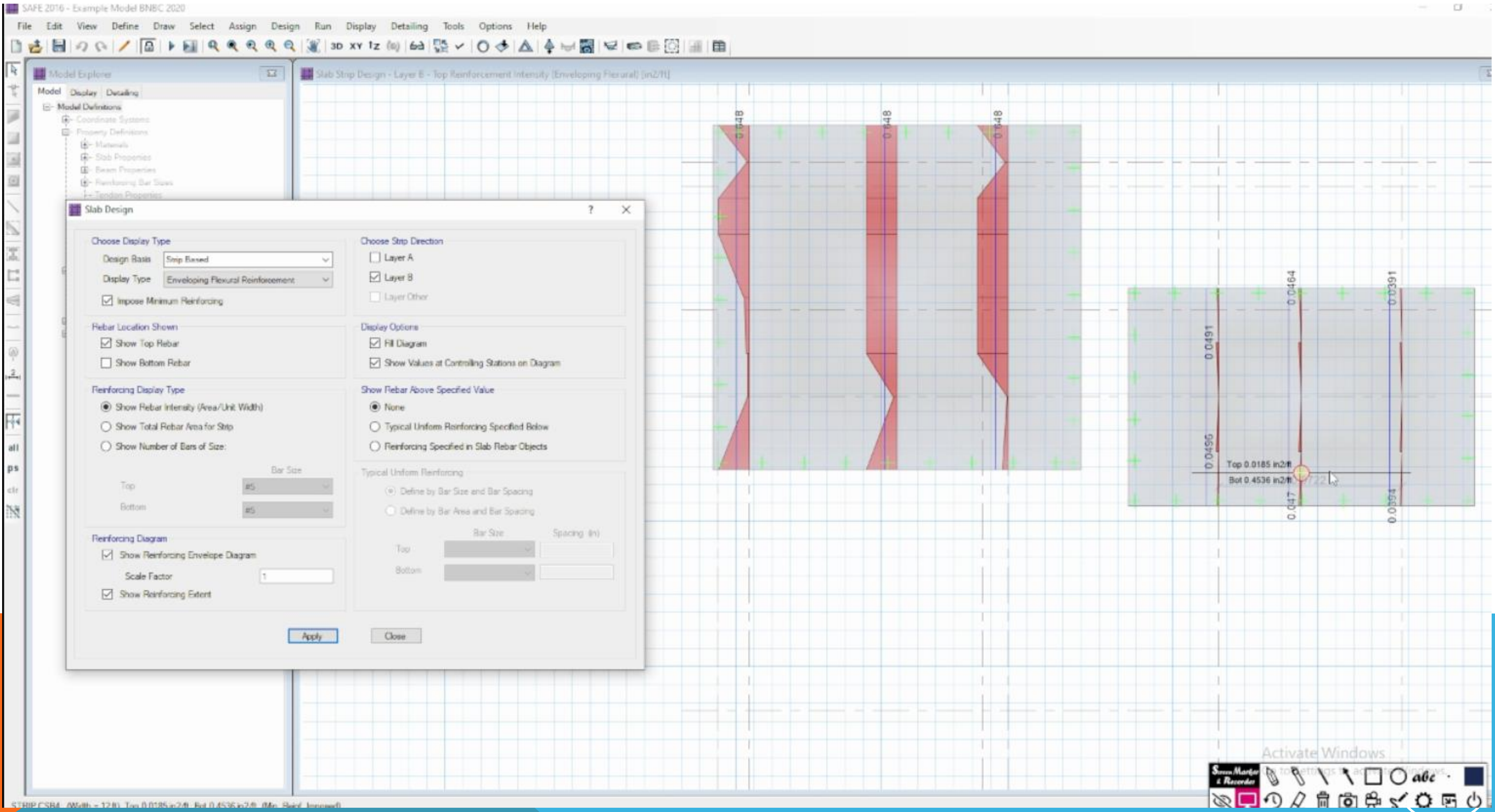
- Understanding the design procedure of Mat foundation (hand calculation)
- Assigning the loads/structural frame
- Assigning area of foundation according to soil test report
- Assigning grade of concrete and steel
- Run the model
- Checking the accuracy of results
- Detecting the problems and solving the error in cost-effective way (reducing or increasing the footing area/increasing concrete/steel grade)
- Detailing of the reinforcements

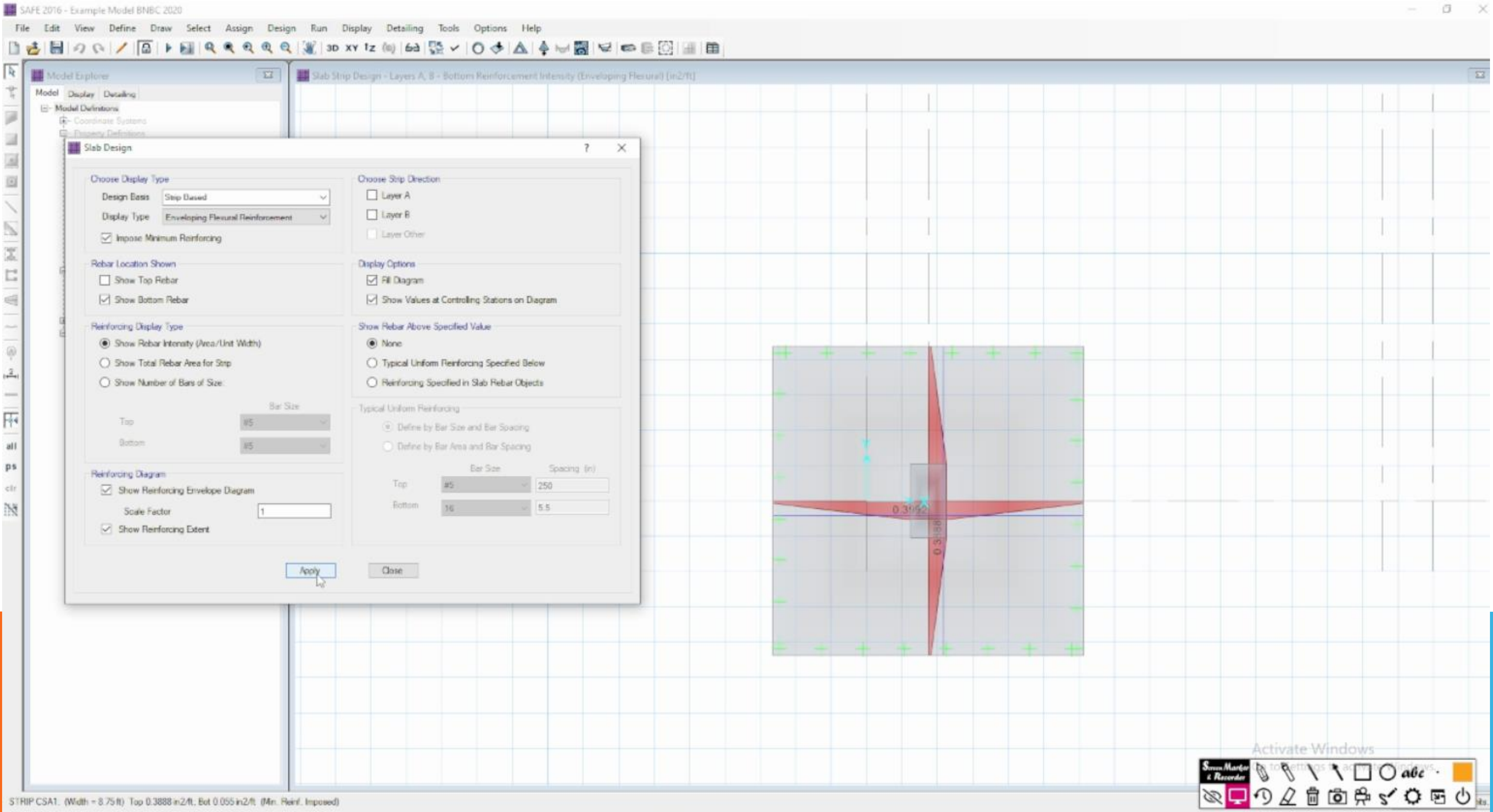

SAFE 2016 - Example Model BNBC 2020
File Edit View Define Draw Select Assign Design Run Display Detailing Tools Options Help
Model Explorer
Model Display Detailing
Model Definitions
Soil Pressure Diagram - (UDCONN2) [lb/ft2]
Reactions
Load Case/Load Combination
Load Case
Load Combination
UDCONN2
Type of Reactions
Point Reactions
Integrated Wall Reactions
Soil Pressures
Display Options
Display Contours on Undeformed Shape
Display Contours on Deformed Shape
Display Contours in Extruded Form
Scaling
Automatic
User Defined
Scale Factor
Contour Range
Minimum
0
lb/ft2
Maximum
0
lb/ft2
Apply
Close
AB
CD
E
F
6
5
4
3
2
1
Activate Windows


SAFE 2016 - Example Model BNBC 2020
File Edit View Define Draw Select Assign Design Run Display Detailing Tools Options Help
Model Explorer
Model Display Detailing
Model Definitions
Point Loads (Live_ABOVE) [kip, kip-ft]
0.1541
0.3598
-0.0738
0.1777
Activate Windows


SAFE 2016 - Example Model BNBC 2020
File Edit View Define Draw Select Assign Design Run Display Detailing Tools Options Help
Model Explorer
Model Display Detailing
Model Definitions
Slab Strip Design - Layer A - Bottom Reinforcement Intensity (Enveloping Flexural) [in2/ft]
Slab Design
Choose Display Type
Design Basis Strip Based
Display Type Enveloping Flexural Reinforcement
Impose Minimum Reinforcing
Choose Strip Direction
Layer A
Layer B
Layer Other
Rebar Location Shown
Show Top Rebar
Show Bottom Rebar
Display Options
Fill Diagram
Show Values at Controlling Stations on Diagram
Reinforcing Display Type
Show Rebar Intensity (Area/Unit Width)
Show Total Rebar Area for Strip
Show Number of Bars of Size:
Show Rebar Above Specified Value
None
Typical Uniform Reinforcing Specified Below
Reinforcing Specified in Slab Rebar Objects
Typical Uniform Reinforcing
Define by Bar Size and Bar Spacing
Define by Bar Area and Bar Spacing
Bar Size
Spacing (in)
Top
Bottom
Reinforcing Diagram
Show Reinforcing Envelope Diagram
Scale Factor
Show Reinforcing Extent
Apply
Close
0.648
0.6174
Top 0.0375 in2/ft
Bot 0.648 in2/ft
10.0722 ft
STRIP CSA4: (Width = 12 ft) Top 0.0375 in2/ft, Bot 0.648 in2/ft (Min. Reinf. Imposed)


SAFE 2016 - Example Model BNBC 2020
File Edit View Define Draw Select Assign Design Run Display Detailing Tools Options Help
Model Explorer
Model Display Detailing
Model Definitions
Slab Strip Design - Layer A - Bottom Reinforcement Intensity (Enveloping Flexural) [in2/ft]
Slab Design
Choose Display Type
Design Basis Strip Based
Display Type Enveloping Flexural Reinforcement
Impose Minimum Reinforcing
Rebar Location Shown
Show Top Rebar
Show Bottom Rebar
Reinforcing Display Type
Show Rebar Intensity (Area/Unit Width)
Show Total Rebar Area for Strip
Show Number of Bars of Size:
Bar Size
Top
Bottom
Reinforcing Diagram
Show Reinforcing Envelope Diagram
Scale Factor 1
Show Reinforcing Extent
Choose Strip Direction
Layer A
Layer B
Layer Other
Display Options
Fill Diagram
Show Values at Controlling Stations on Diagram
Show Rebar Above Specified Value
None
Typical Uniform Reinforcing Specified Below
Reinforcing Specified in Slab Rebar Objects
Typical Uniform Reinforcing
Define by Bar Size and Bar Spacing
Define by Bar Area and Bar Spacing
Bar Size
Spacing (in)
Top
Bottom
Apply
Close
0.648
0.648
0.648
0.648
0.648
0.648
0.648
0.648
0.648
0.648
Max Top = 0.8743 in2/ft at (9.8583 ft, 33.8255 ft); Max Bot = 0.648 in2/ft at (1.7388 ft, 46.752 ft) (Min. Reinf. Imposed)
Activate Windows


SAFE 2016 - Example Model BNBC 2020
File Edit View Define Draw Select Assign Design Run Display Detailing Tools Options Help
Model Explorer
Model Display Detailing
Model Definitions
Slab Strip Design - Layer B - Top Reinforcement Intensity (Enveloping Flexural) [in2/ft]
Slab Design
Choose Display Type
Design Basis
Strip Based
Display Type
Enveloping Flexural Reinforcement
Impose Minimum Reinforcing
Choose Strip Direction
Layer A
Layer B
Layer Other
Rebar Location Shown
Show Top Rebar
Show Bottom Rebar
Display Options
Fill Diagram
Show Values at Controlling Stations on Diagram
Reinforcing Display Type
Show Rebar Intensity (Area/Unit Width)
Show Total Rebar Area for Strip
Show Number of Bars of Size:
Show Rebar Above Specified Value
None
Typical Uniform Reinforcing Specified Below
Reinforcing Specified in Slab Rebar Objects
Typical Uniform Reinforcing
Define by Bar Size and Bar Spacing
Define by Bar Area and Bar Spacing
Bar Size
Spacing (in)
Top
Bottom
#5
Reinforcing Diagram
Show Reinforcing Envelope Diagram
Scale Factor
1
Show Reinforcing Extent
Apply
Close
0.0491
0.0464
0.0391
0.0496
0.047
0.0394
Top 0.0185 in2/ft
Bot 0.4536 in2/ft
Activate Windows


SAFE 2016 - Example Model BNBC 2020
File Edit View Define Draw Select Assign Design Run Display Detailing Tools Options Help
Model Explorer
Model Display Detailing
Model Definitions
Slab Strip Design - Layers A, B - Bottom Reinforcement Intensity (Enveloping Flexural) (in2/ft)
Slab Design
Choose Display Type
Design Basis Strip Based
Display Type Enveloping Flexural Reinforcement
Impose Minimum Reinforcing
Choose Strip Direction
Layer A
Layer B
Layer Other
Rebar Location Shown
Show Top Rebar
Show Bottom Rebar
Display Options
Fill Diagram
Show Values at Controlling Stations on Diagram
Reinforcing Display Type
Show Rebar Intensity (Area/Unit Width)
Show Total Rebar Area for Strip
Show Number of Bars of Size:
Bar Size
Top #5
Bottom #5
Show Rebar Above Specified Value
None
Typical Uniform Reinforcing Specified Below
Reinforcing Specified in Slab Rebar Objects
Typical Uniform Reinforcing
Define by Bar Size and Bar Spacing
Define by Bar Area and Bar Spacing
Bar Size Spacing (in)
Top #5 250
Bottom 16 5.5
Reinforcing Diagram
Show Reinforcing Envelope Diagram
Scale Factor 1
Show Reinforcing Extent
Apply Close
STRIP CSA1. (Width = 8.75 ft) Top 0.3888 in2/ft. Bot 0.055 in2/ft (Min. Reinf. Imposed)

Design of Pile foundation and pile cap

Week 13-14

Pages 92-105

Skill Details:

- Understanding the design procedure of pile foundation (hand calculation)
- Assigning the loads/structural frame
- Assigning area of foundation according to soil test report
- Assigning grade of concrete and steel
- Run the model
- Checking the accuracy of results
- Detecting the problems and solving the error in cost-effective way (reducing or increasing the footing area/increasing concrete/steel grade)
- Detailing of the reinforcements

Introduction

A pile is a slender structural member made of concrete, steel, wood or composite material.

A pile is either driven into the soil or formed in-site by excavating a hole and filling it with concrete.

General Information

- The maximum length/diameter ratio should not exceed 50 for a single segmental pile.

- If the skin friction is greater than about 80% of the end bearing load capacity, the pile is deemed a friction pile and, if the reverse, an end bearing pile.

- If the end bearing is neglected, the pile is called a “floating pile”.

- The minimum center-to-center pile spacing of 2.5B is recommended.

- The tops of all piles shall be embedded not less than 75 mm into pile caps and the cap shall extend at least 100 mm beyond the edge of all piles.

- For bored pile all shafts should be sized in 50 mm increments with a minimum shaft diameter of 400 mm.

Number of Pile Calculation

$$Nos\ of\ Pile = \frac{Total\ Service\ Load}{Allowable\ capcity\ of\ each\ pile}$$

Point Spring Constant of Pile

$$Point\ Spring\ Constant = \frac{EA}{L}$$

Where, E = Modulus of Elasticity of Concrete
A= Area of Pile
L= Length of Pile

Example-1

Data:

- Column Size 21”X28”
- Dead Load= 467 kips
- Live Load= 137 kips
- Capacity of each pile 200 kips with factor of safety (FS)=3.0
- Pile length 90 ft
- Pile diameter 20 inch
- Compressive strength of concrete, f'_c = 3500 psi
- Grade of rebar= 60 Grade

Example

Solution:

$$Nos\ of\ Pile = \frac{Total\ Service\ Load}{Allowable\ capcity\ of\ each\ pile}$$

$$= \frac{(467+137)X1.1}{200}$$

$$= 3.32$$

$$\approx 4$$

$$Point\ Spring\ Constant = \frac{EA}{L}$$

$$= \frac{57000\times\sqrt{3500}\times\frac{\pi\times20^2}{4}}{90\times12}$$

$$= 980.923\ kip/inch$$

Example-2

Data:

- Column Size 21”X23”
- Dead Load= 327 kips
- Live Load= 138 kips
- Capacity of each pile 200 kips with factor of safety (FS)=3.0
- Pile length 90 ft
- Compressive strength of concrete, f'_c = 3500 psi
- Grade of rebar= 60 Grade

Example

Solution:

$$Nos\ of\ Pile = \frac{Total\ Service\ Load}{Allowable\ capcity\ of\ each\ pile}$$

$$= \frac{(327+138)X1.1}{200}$$

$$= 2.55$$

$$\approx 3$$

$$Point\ Spring\ Constant = \frac{EA}{L}$$

$$= \frac{57000\times\sqrt{3500}\times\frac{\pi\times20^2}{4}}{90\times12}$$

$$= 980.923\ kip/inch$$

Pile Foundation Design With SAFE Software

Open SAFE software

↓

Take a New Model

↓

Select Design Code

↓

Select Blank

↓

Define Materials (Concrete & Rebar)

↓

Define Slab Properties (Pile & Pile cap as Mat)

↓

Define Slab Properties (Column as Stiff)

↓

Define Point Spring Properties

↓

Continue…

Define Load Pattern (Dead & Live Load)

↓

Define Load Combination

↓

Draw Pile Cap, Pile & Column

↓

Assign Point Spring Properties from Support Data in Pile

↓

Assign Load in Column

↓

Draw Design Strip

↓

Select Design Combination from Design Menu

↓

Run Analysis & Design from Run Menu

↓

Continue…

Check Punching

↓

Check Point Reaction

↓

Check Moment and Shear

↓

Check Slab Design Value

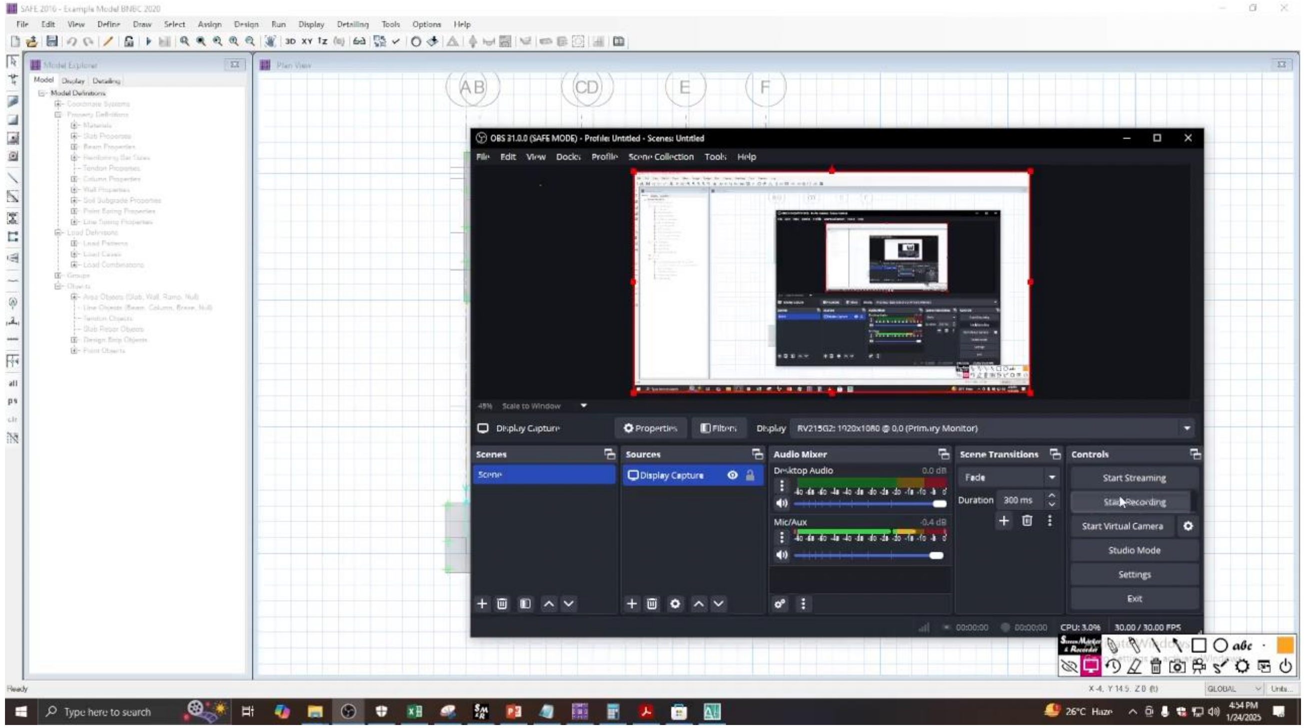
↓

Chose Rebar Size and Spacing

↓

Detailing of Pile Cap

UNIVERSITY OF GLOBAL VILLAGE

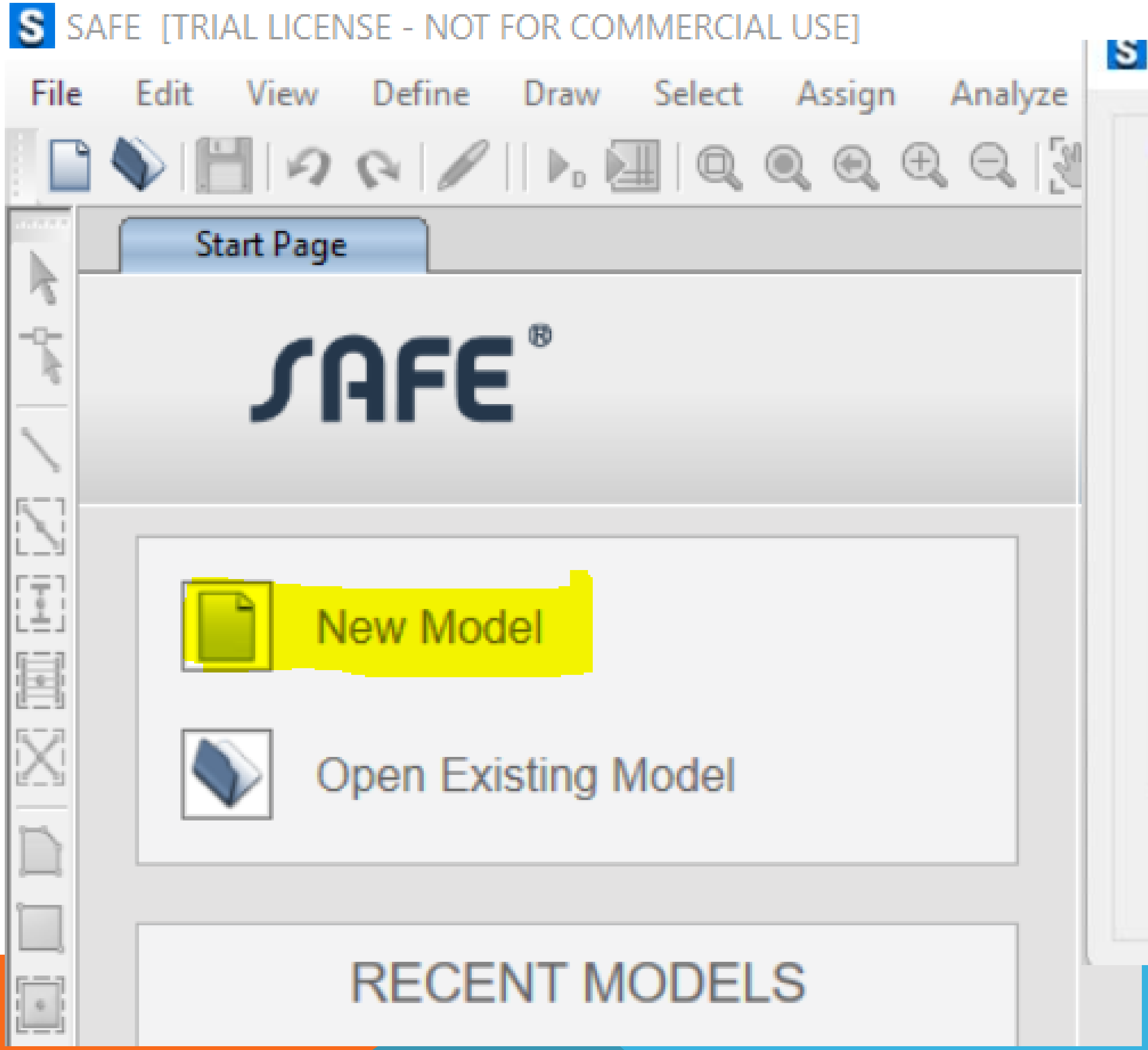


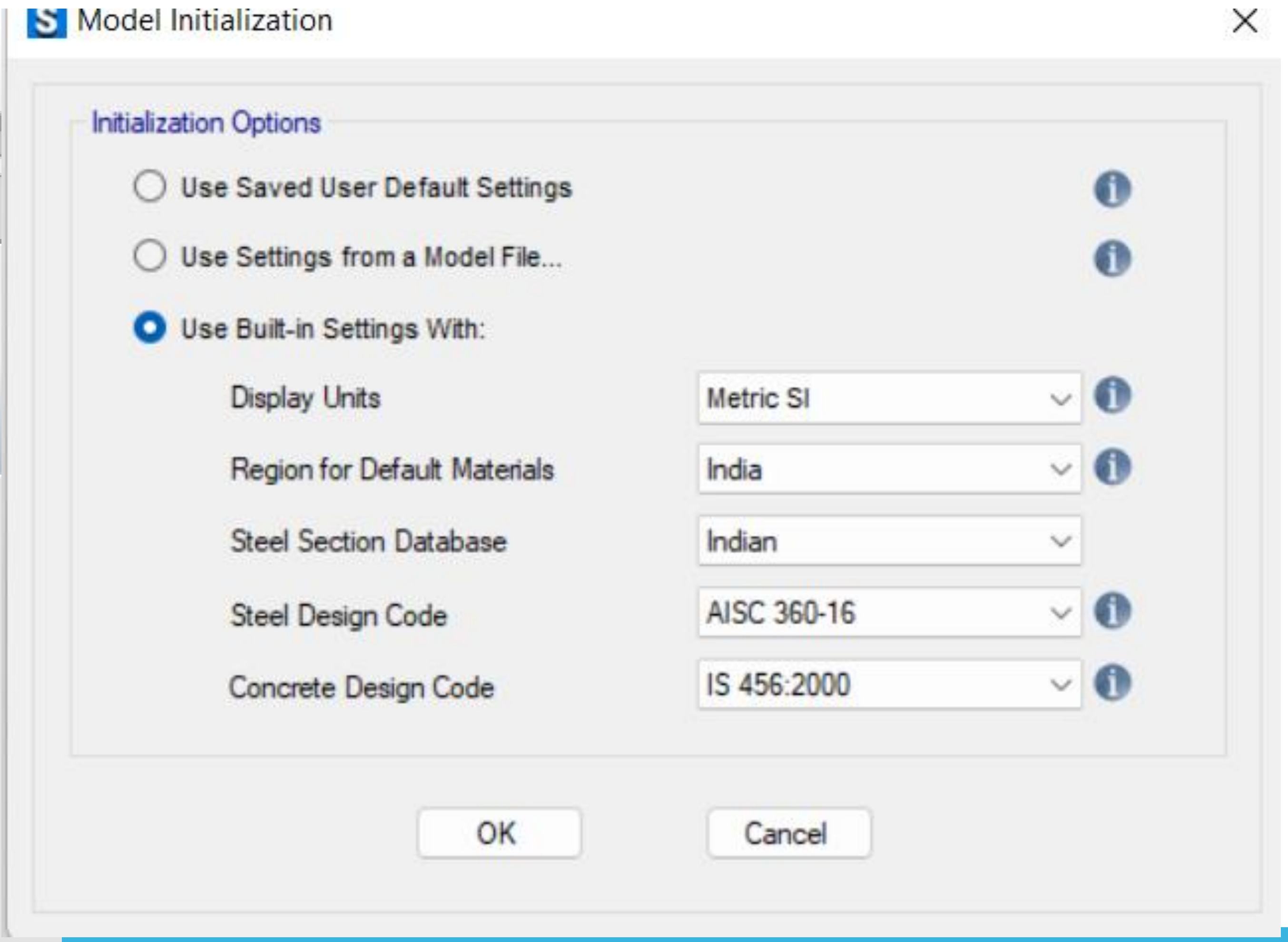
Design of pile foundation (Video)

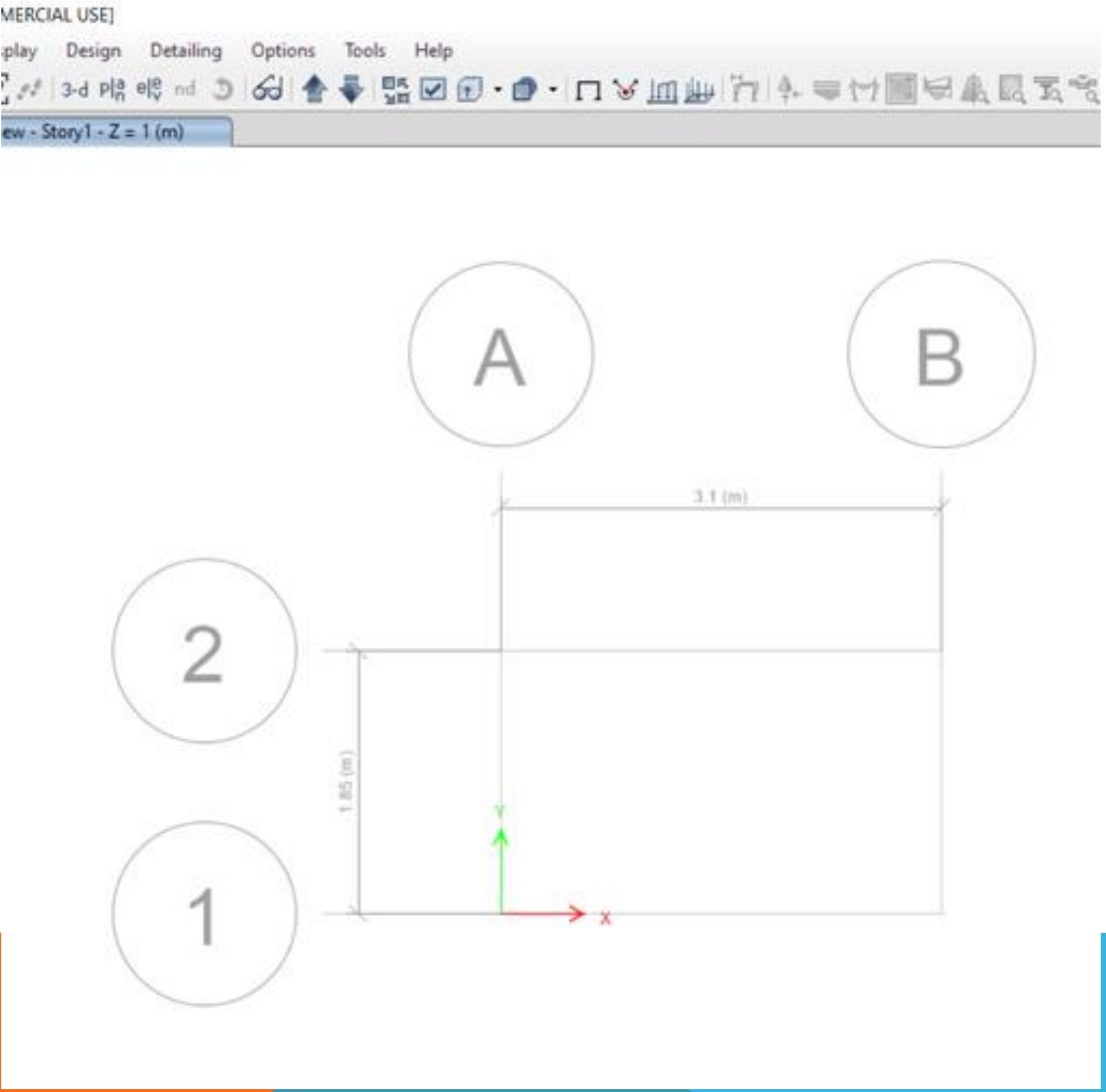
Design of Group Pile

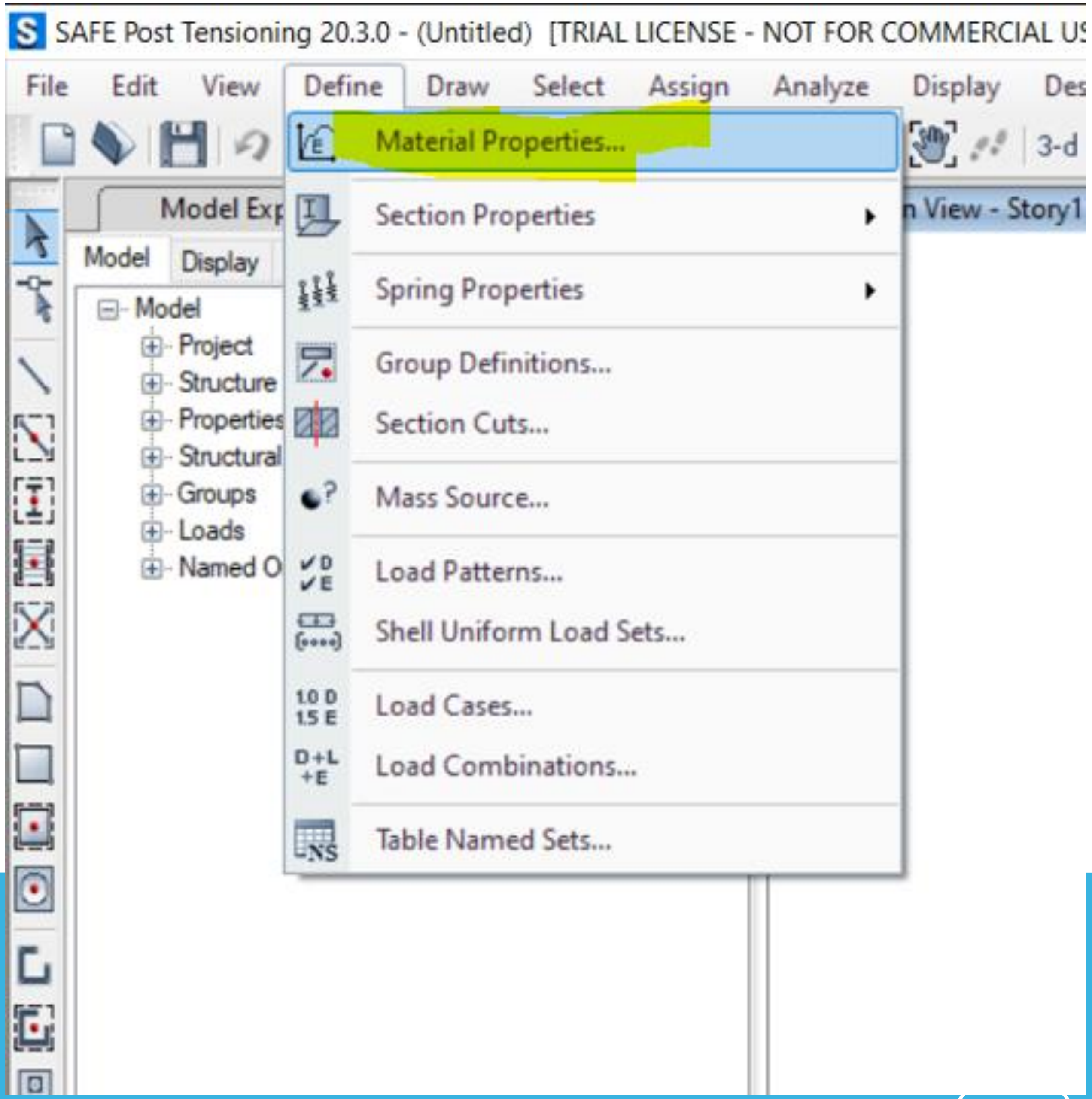
Week 15-16

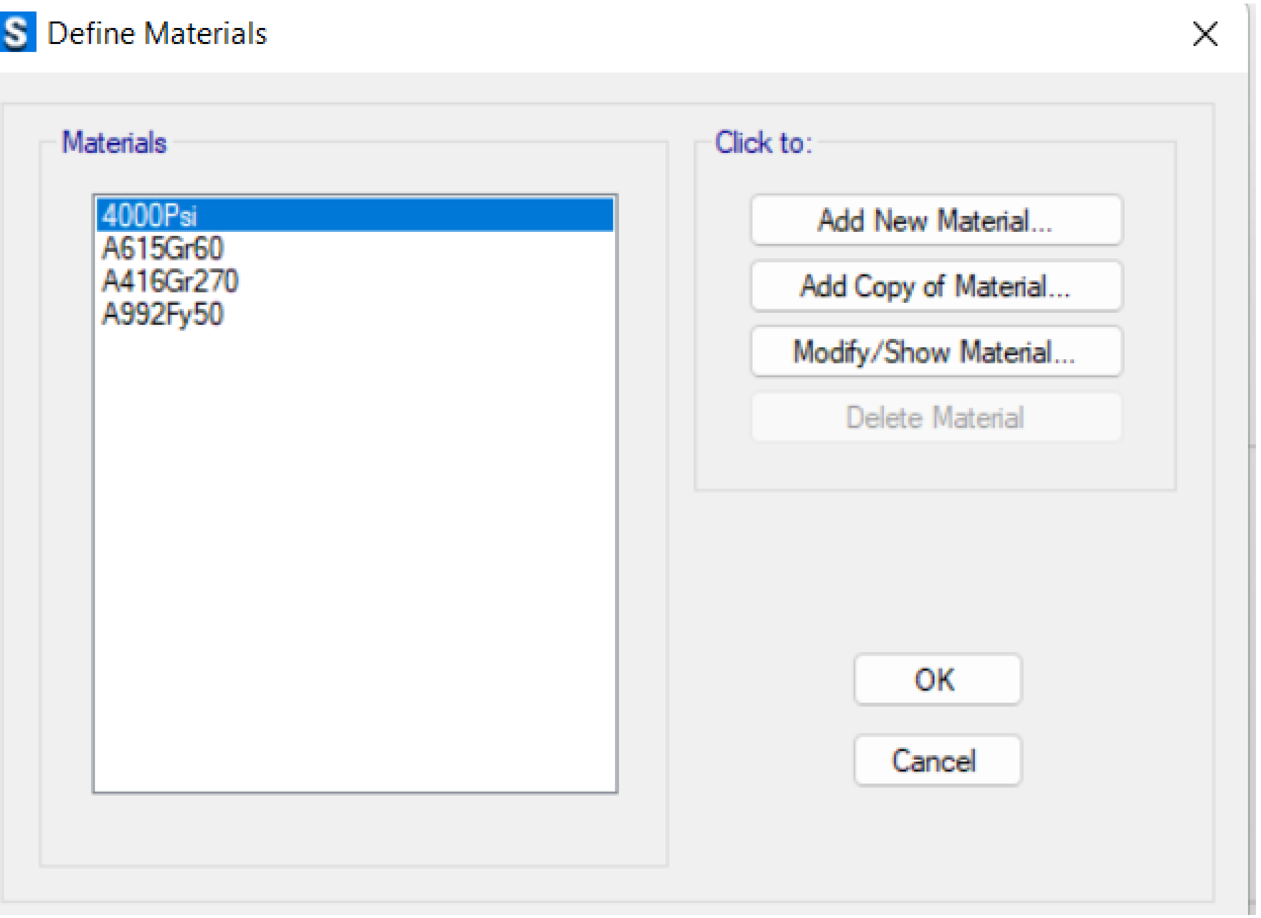
Pages 106-122

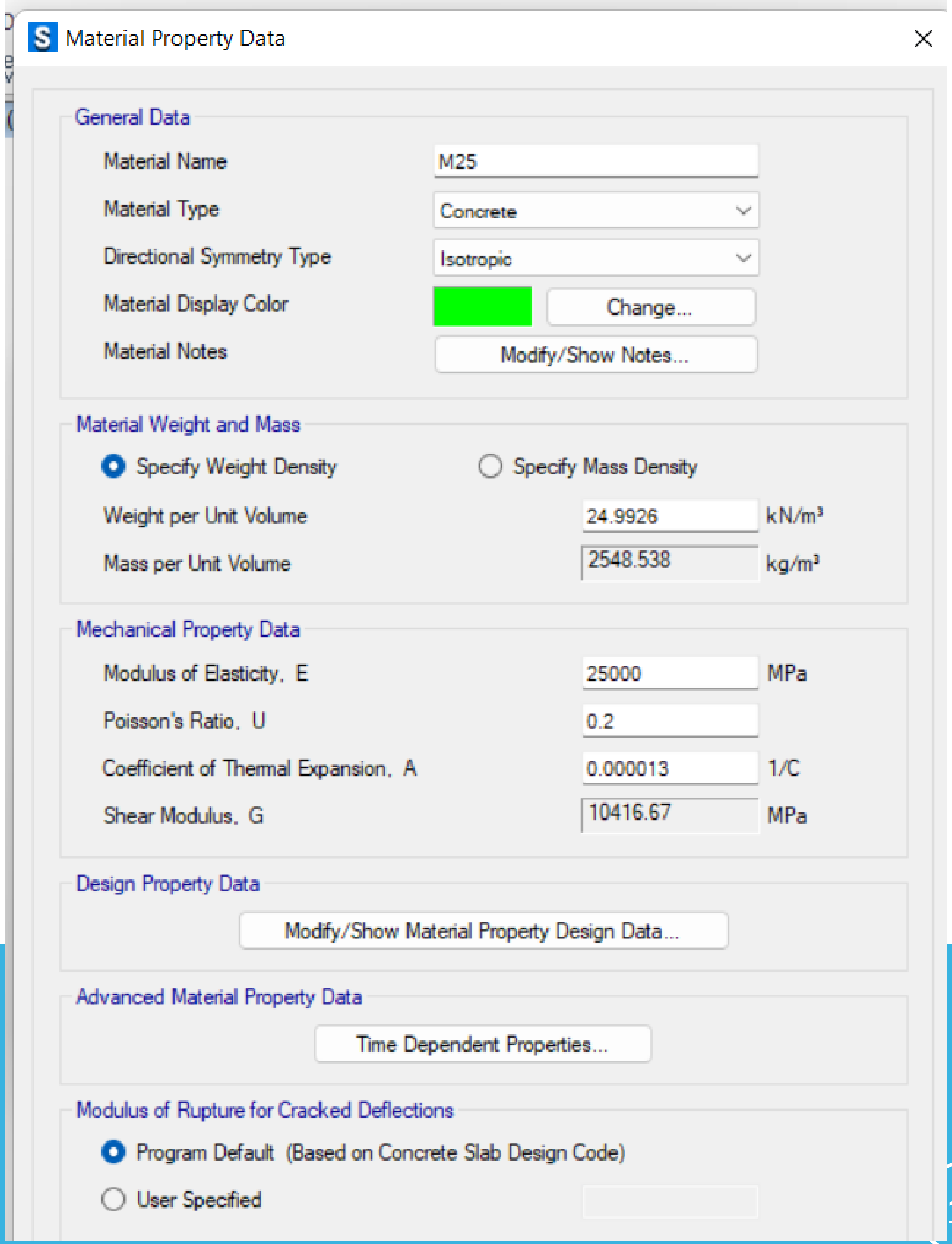

SAFE [TRIAL LICENSE - NOT FOR COMMERCIAL USE]
File Edit View Define Draw Select Assign Analyze
Start Page
SAFE®
New Model
Open Existing Model
RECENT MODELS

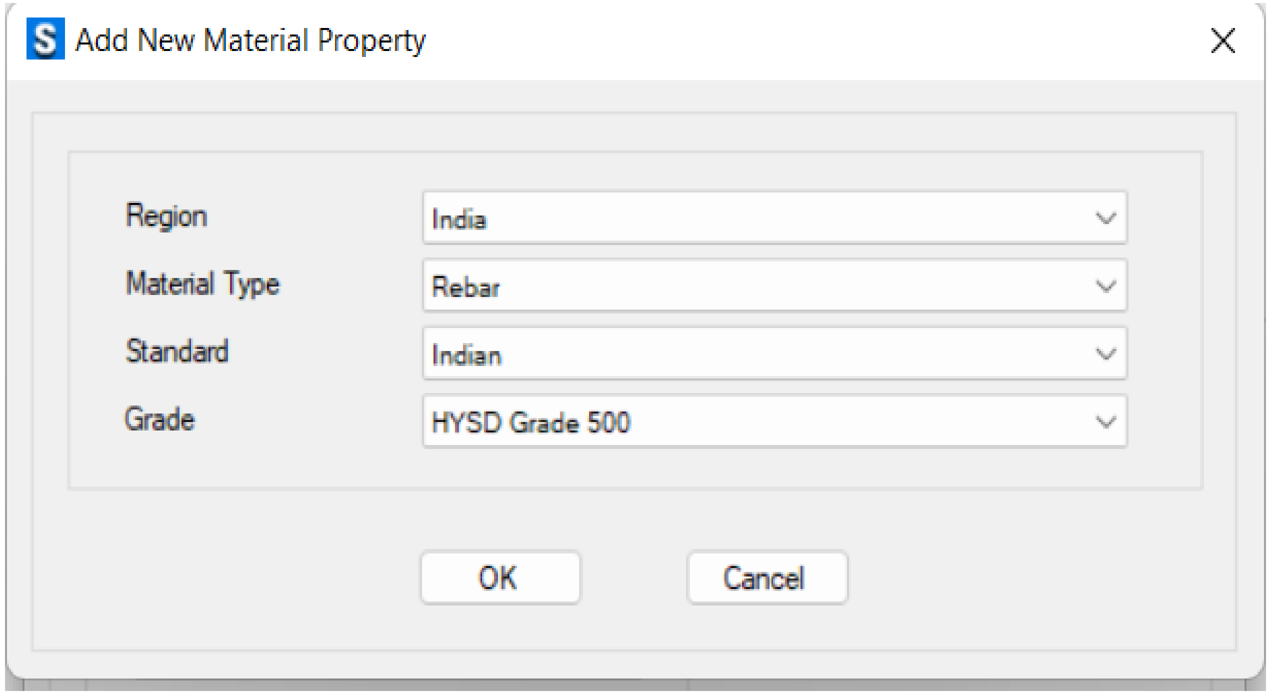

Model Initialization
Initialization Options
Use Saved User Default Settings
Use Settings from a Model File...
Use Built-in Settings With:
Display Units
Metric SI
Region for Default Materials
India
Steel Section Database
Indian
Steel Design Code
AISC 360-16
Concrete Design Code
IS 456:2000
OK
Cancel

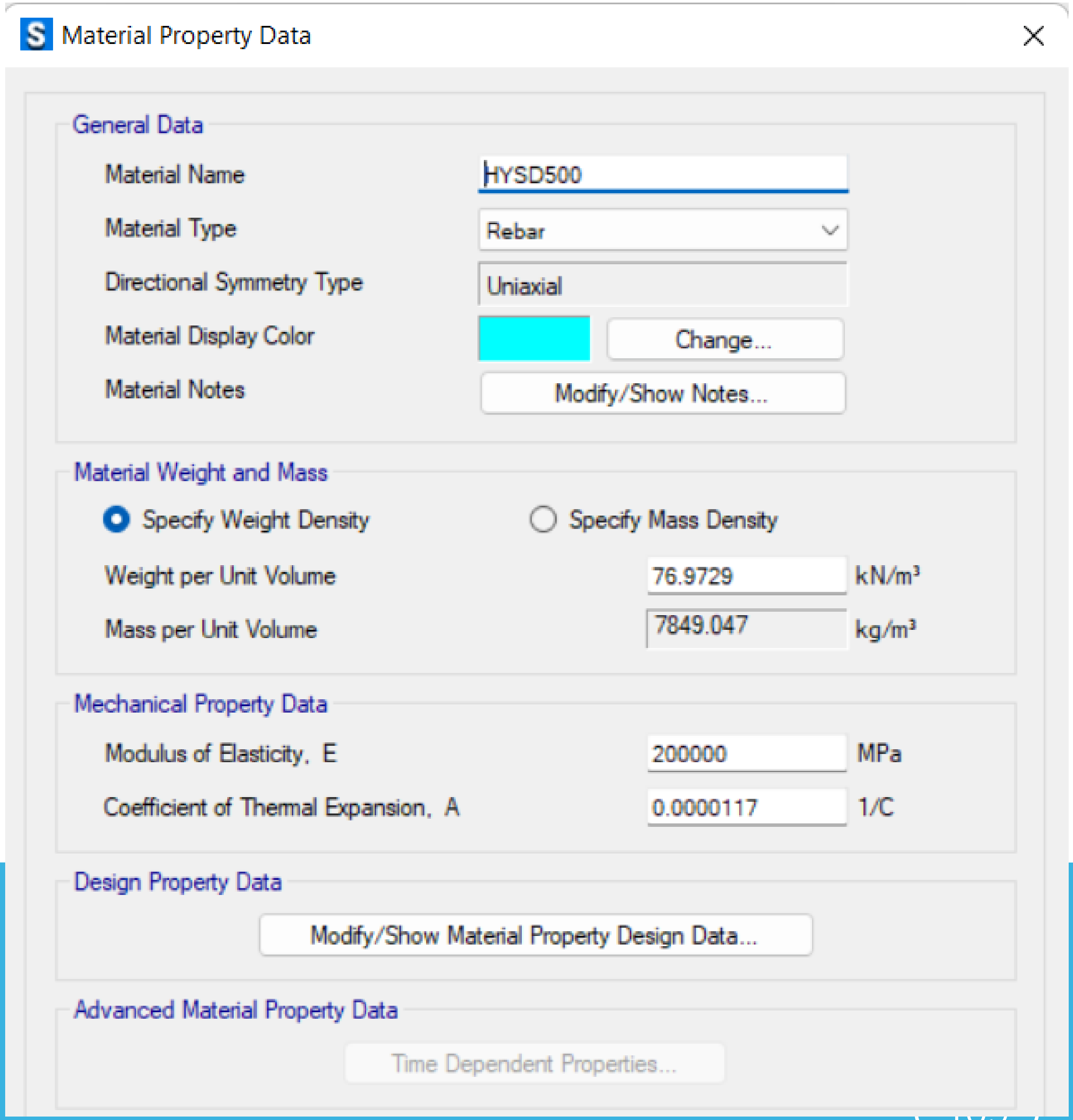

MERCIAL USE]
play Design Detailing Options Tools Help
ew - Story1 - Z = 1 (m)
A
B
3.1 (m)
2
1.85 (m)
1
Y
X

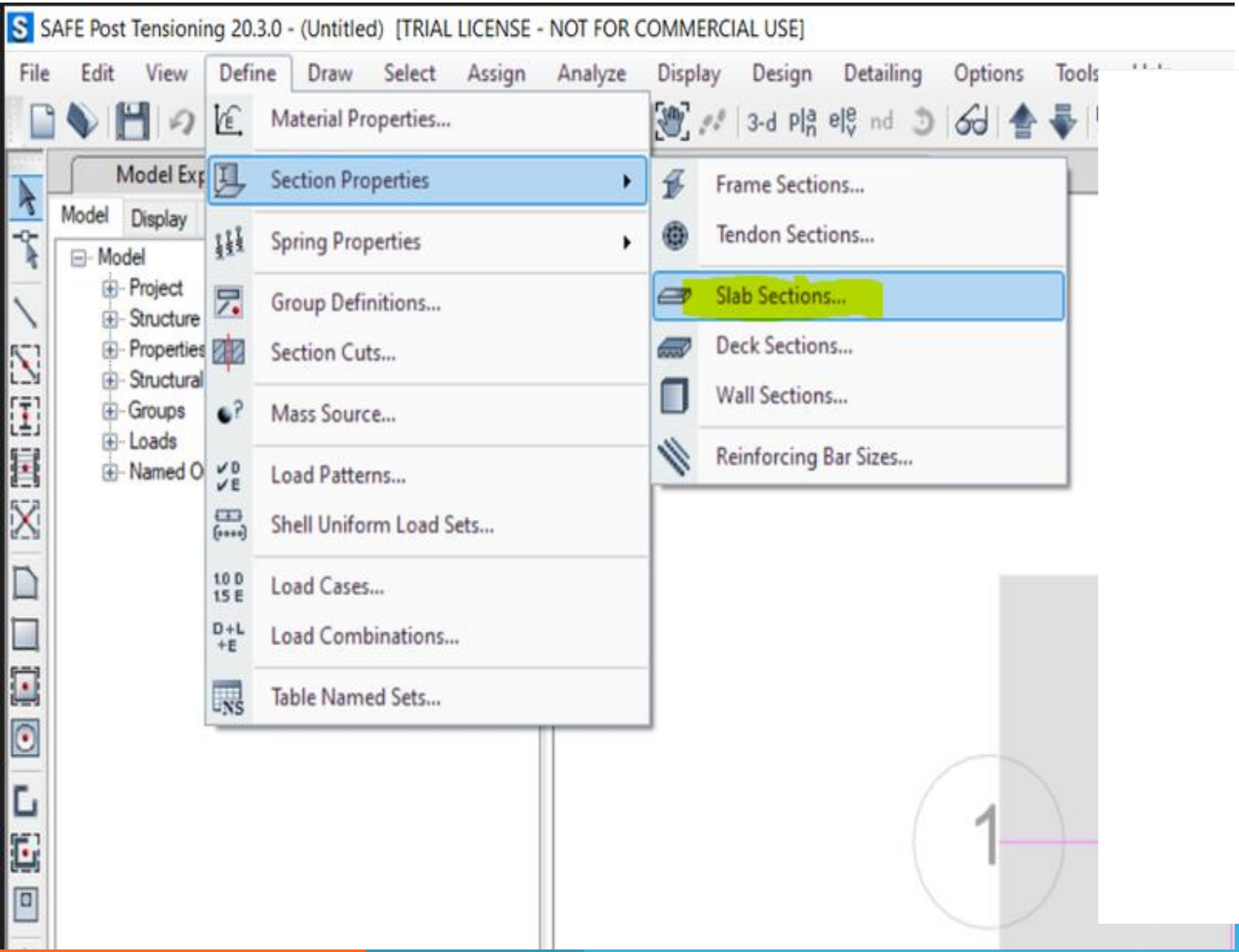

SAFE Post Tensioning 20.3.0 - (Untitled) [TRIAL LICENSE - NOT FOR COMMERCIAL US
File Edit View Define Draw Select Assign Analyze Display Des
Material Properties...
Section Properties
Spring Properties
Group Definitions...
Section Cuts...
Mass Source...
Load Patterns...
Shell Uniform Load Sets...
Load Cases...
Load Combinations...
Table Named Sets...
Model Exp
Model Display
Model
Project
Structure
Properties
Structural
Groups
Loads
Named O
n View - Story1
3-d

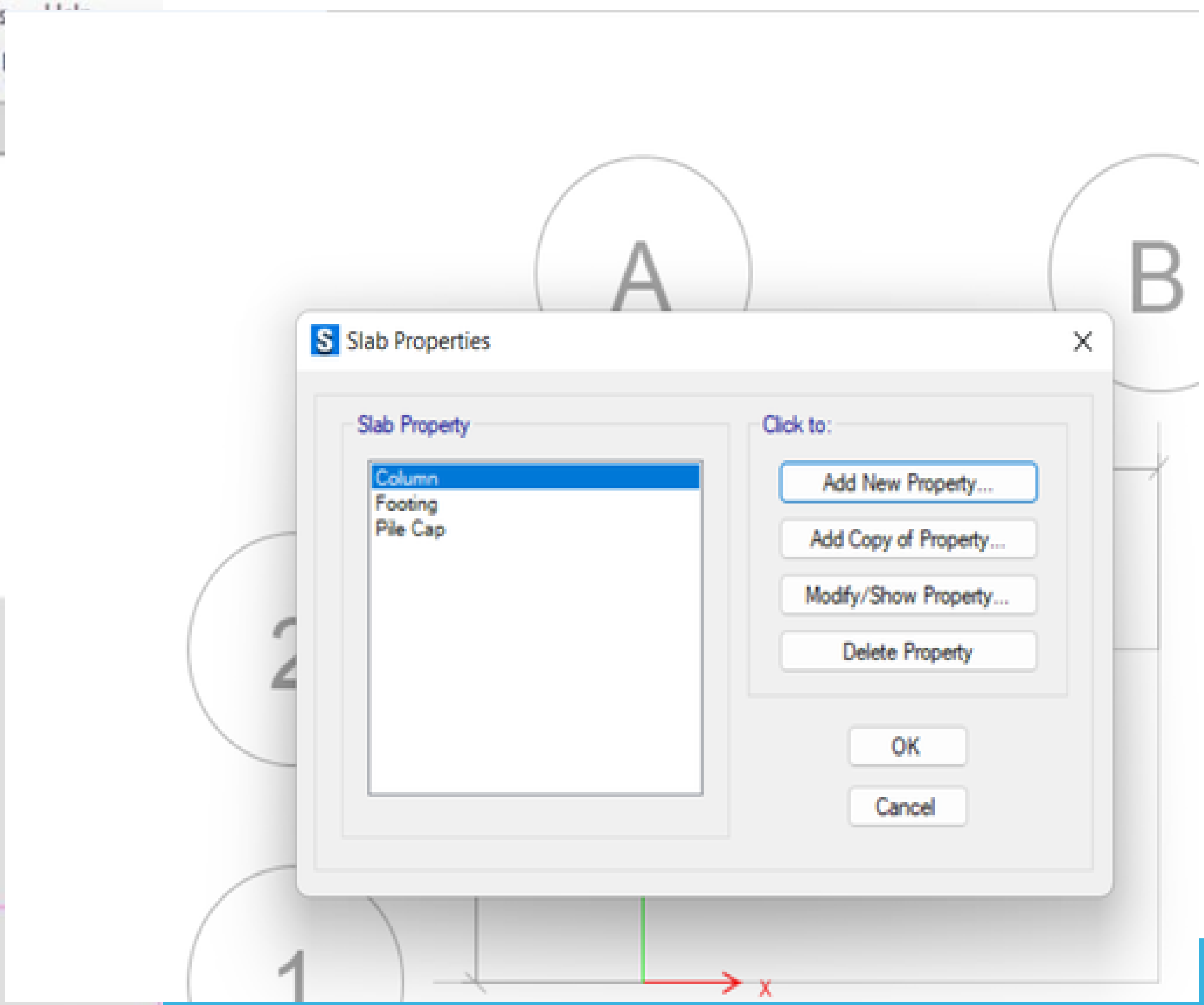

Define Materials
Materials
4000Psi
A615Gr60
A416Gr270
A992Fy50
Click to:
Add New Material...
Add Copy of Material...
Modify/Show Material...
Delete Material
OK
Cancel

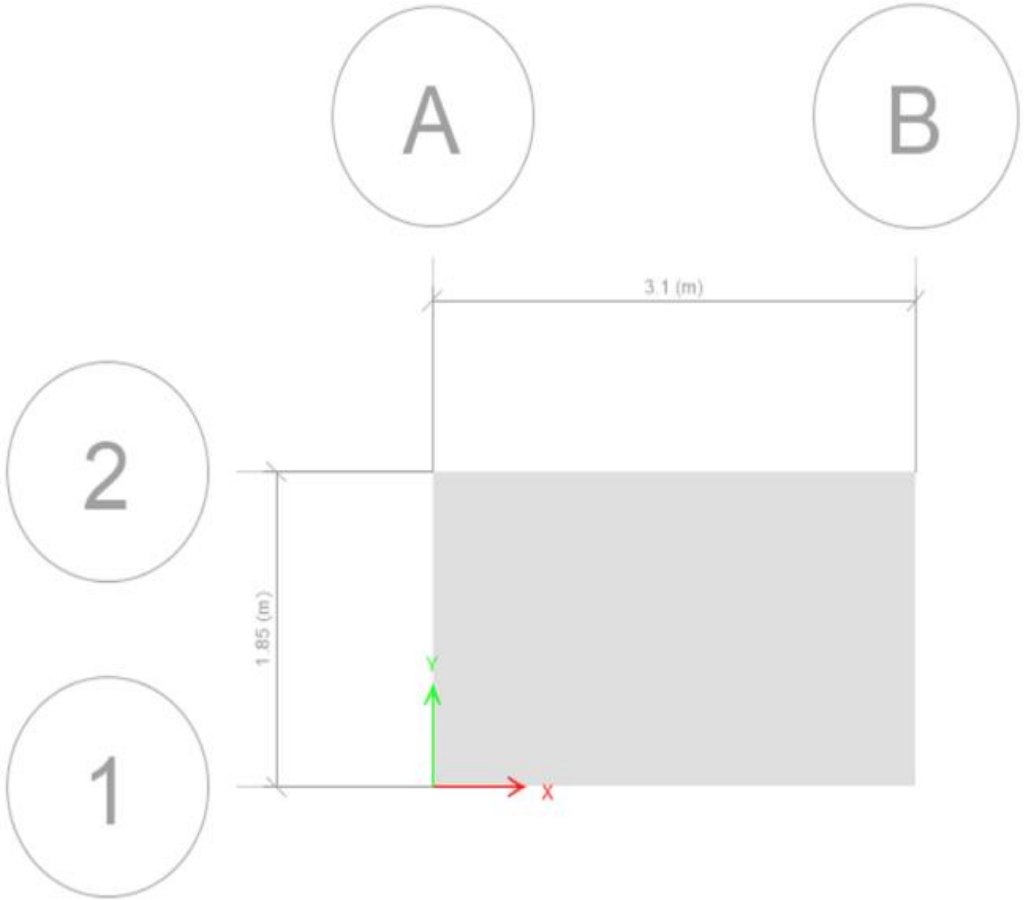

Material Property Data
General Data
Material Name
M25
Material Type
Concrete
Directional Symmetry Type
Isotropic
Material Display Color
Change...
Material Notes
Modify/Show Notes...
Material Weight and Mass
Specify Weight Density
Specify Mass Density
Weight per Unit Volume
24.9926
kN/m³
Mass per Unit Volume
2548.538
kg/m³
Mechanical Property Data
Modulus of Elasticity, E
25000
MPa
Poisson's Ratio, U
0.2
Coefficient of Thermal Expansion, A
0.000013
1/C
Shear Modulus, G
10416.67
MPa
Design Property Data
Modify/Show Material Property Design Data...
Advanced Material Property Data
Time Dependent Properties...
Modulus of Rupture for Cracked Deflections
Program Default (Based on Concrete Slab Design Code)
User Specified

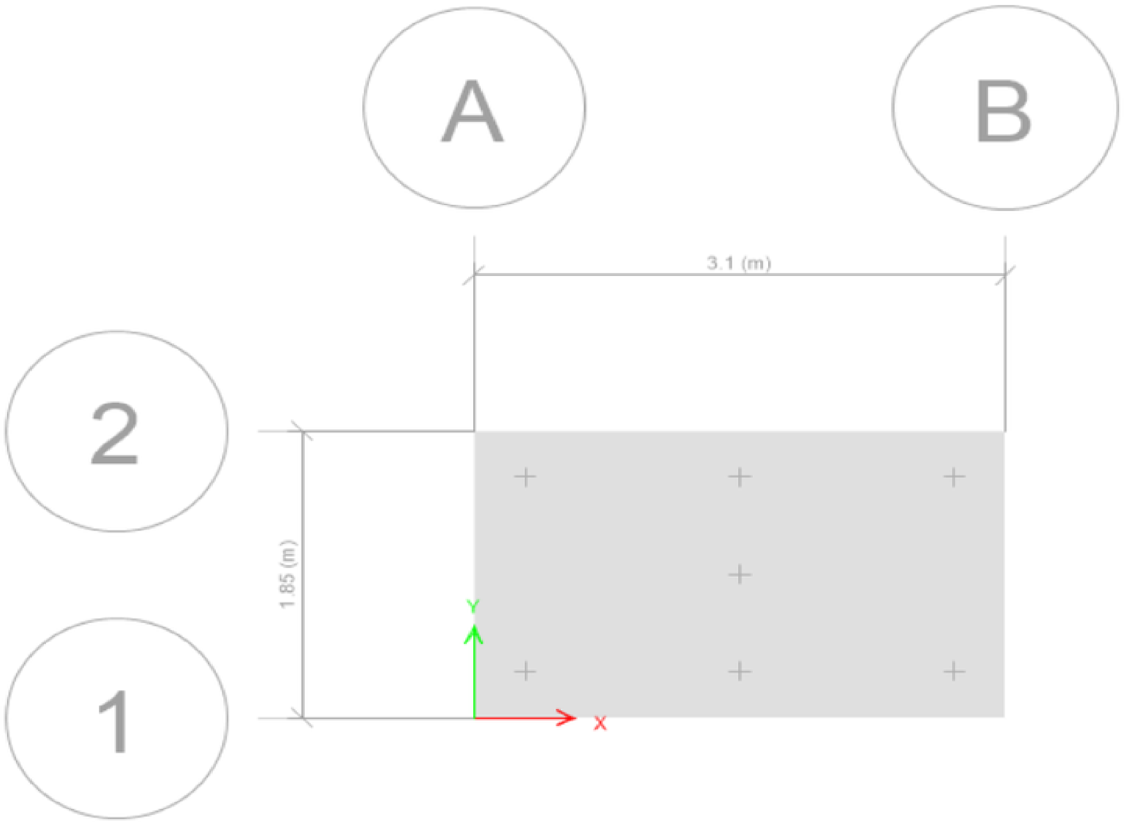

Add New Material Property
Region
India
Material Type
Rebar
Standard
Indian
Grade
HYSD Grade 500
OK
Cancel

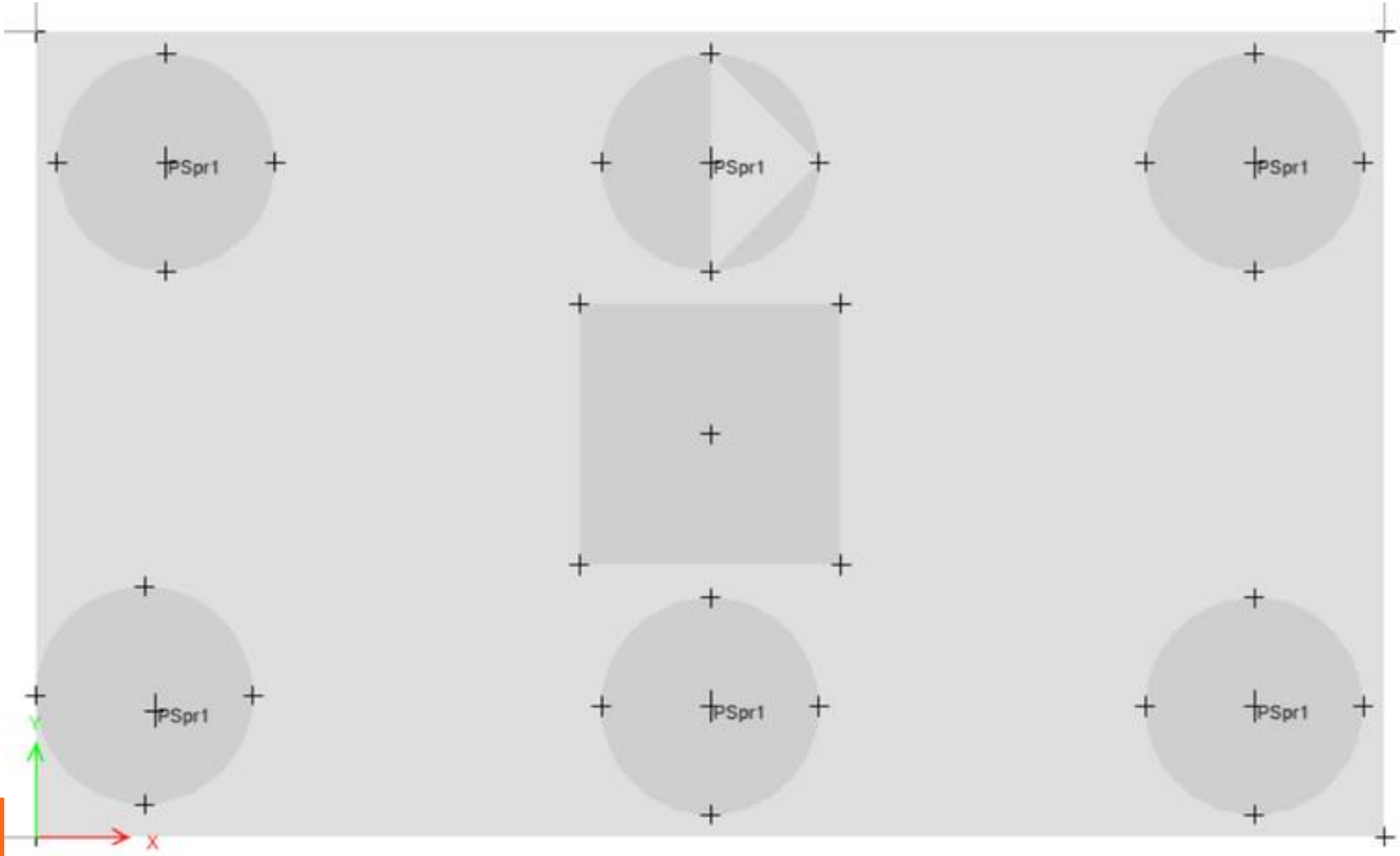

Material Property Data
General Data
Material Name
HYSD500
Material Type
Rebar
Directional Symmetry Type
Uniaxial
Material Display Color
Change...
Material Notes
Modify/Show Notes...
Material Weight and Mass
Specify Weight Density
Specify Mass Density
Weight per Unit Volume
76.9729
kN/m³
Mass per Unit Volume
7849.047
kg/m³
Mechanical Property Data
Modulus of Elasticity, E
200000
MPa
Coefficient of Thermal Expansion, A
0.0000117
1/C
Design Property Data
Modify/Show Material Property Design Data...
Advanced Material Property Data
Time Dependent Properties...

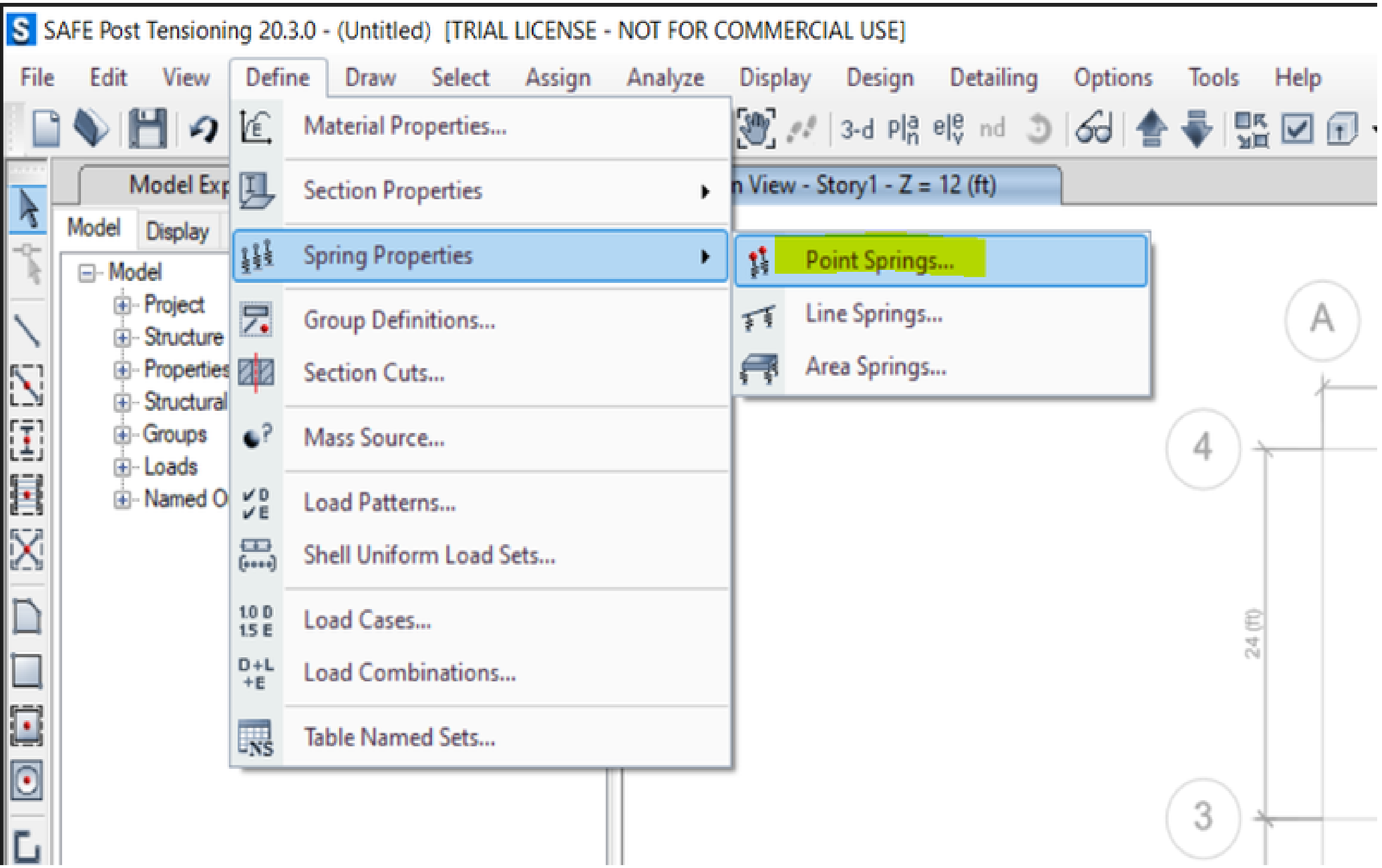

SAFE Post Tensioning 20.3.0 - (Untitled) [TRIAL LICENSE - NOT FOR COMMERCIAL USE]
File Edit View Define Draw Select Assign Analyze Display Design Detailing Options Tools
Material Properties...
Section Properties
Spring Properties
Group Definitions...
Section Cuts...
Mass Source...
Load Patterns...
Shell Uniform Load Sets...
Load Cases...
Load Combinations...
Table Named Sets...
Frame Sections...
Tendon Sections...
Slab Sections...
Deck Sections...
Wall Sections...
Reinforcing Bar Sizes...
Model Exp
Model Display
Model
Project
Structure
Properties
Structural
Groups
Loads
Named O

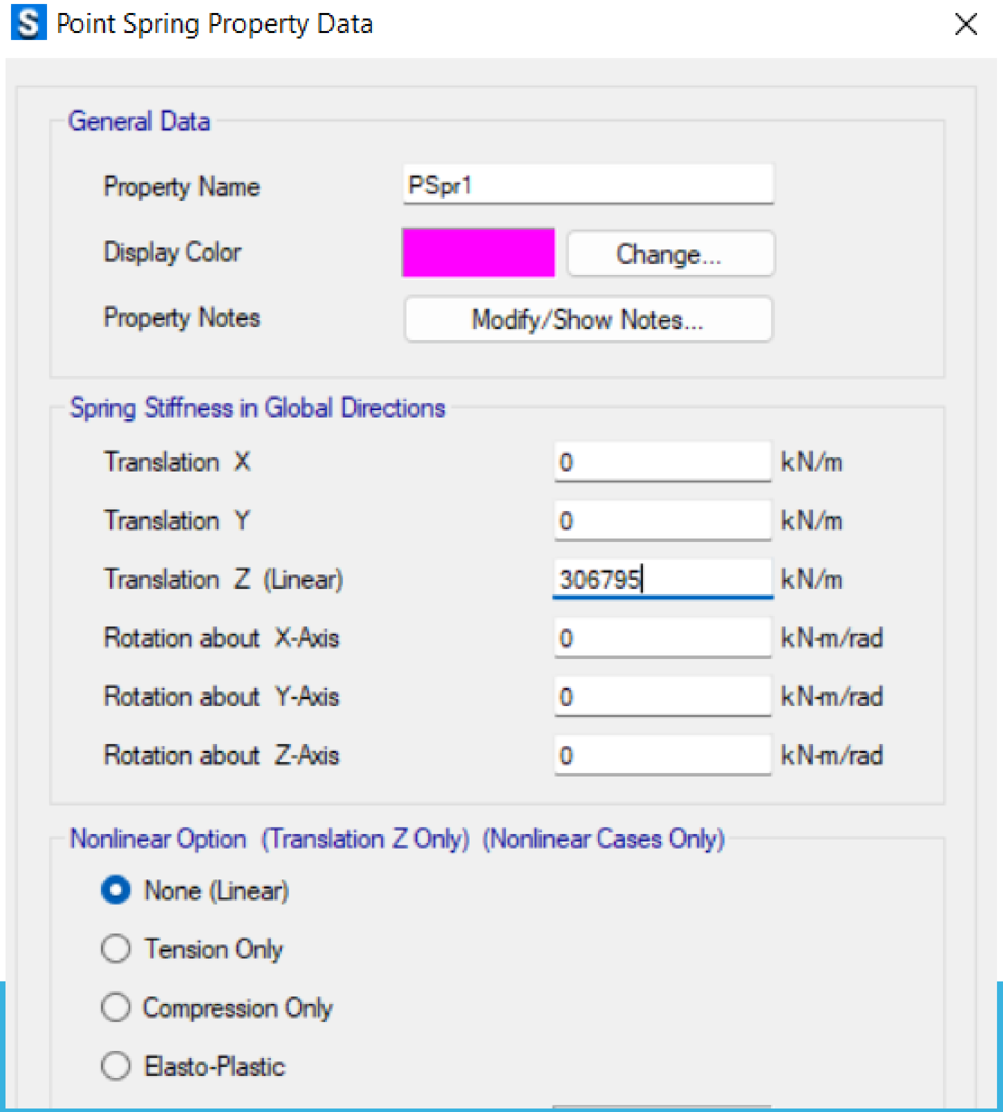

Slab Properties
Slab Property
Column
Footing
Pile Cap
Click to:
Add New Property...
Add Copy of Property...
Modify/Show Property...
Delete Property
OK
Cancel

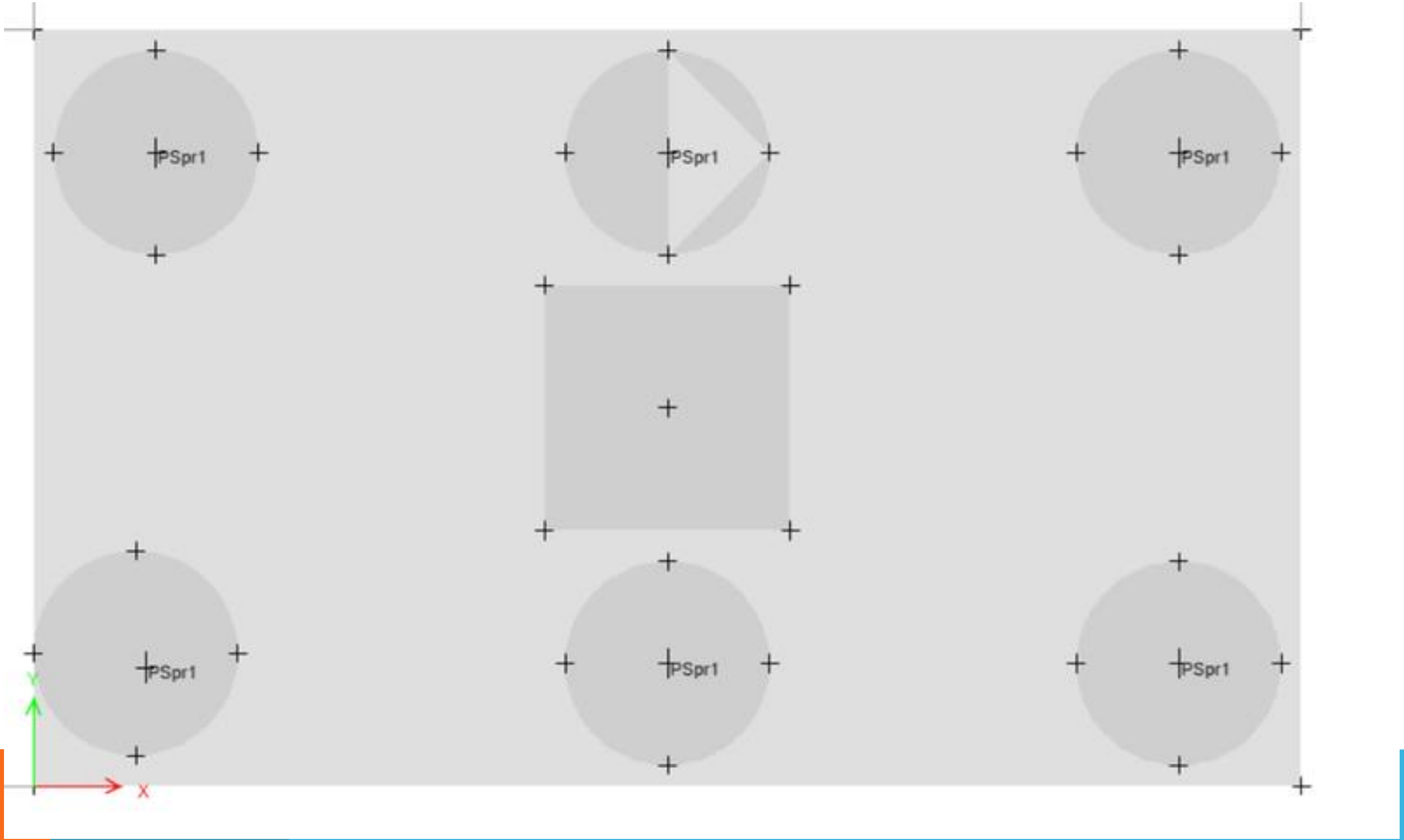

A
B
3.1 (m)
2
1
1.85 (m)
Y
X

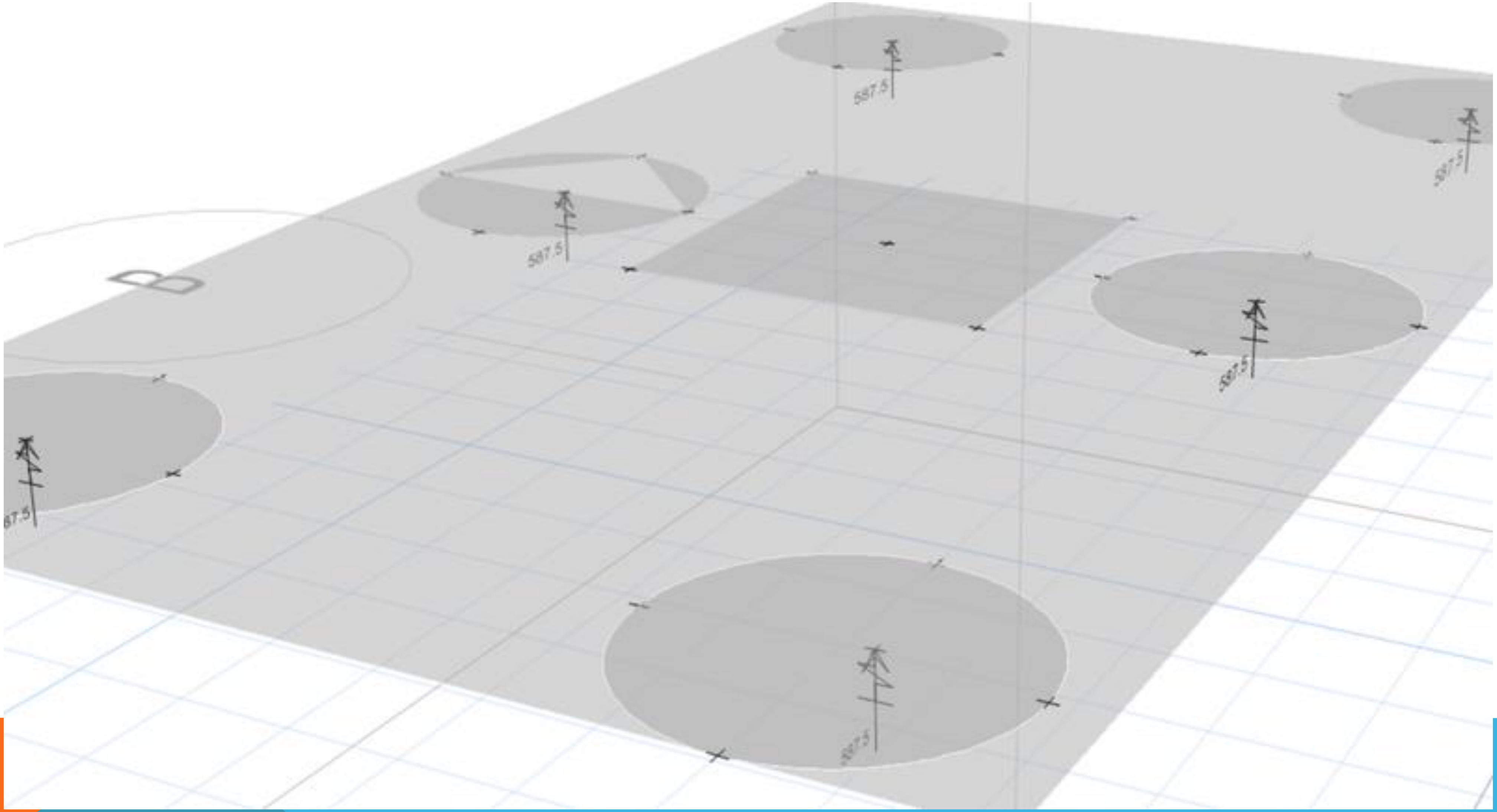

A
B
3.1 (m)
2
1
1.85 (m)
Y
X

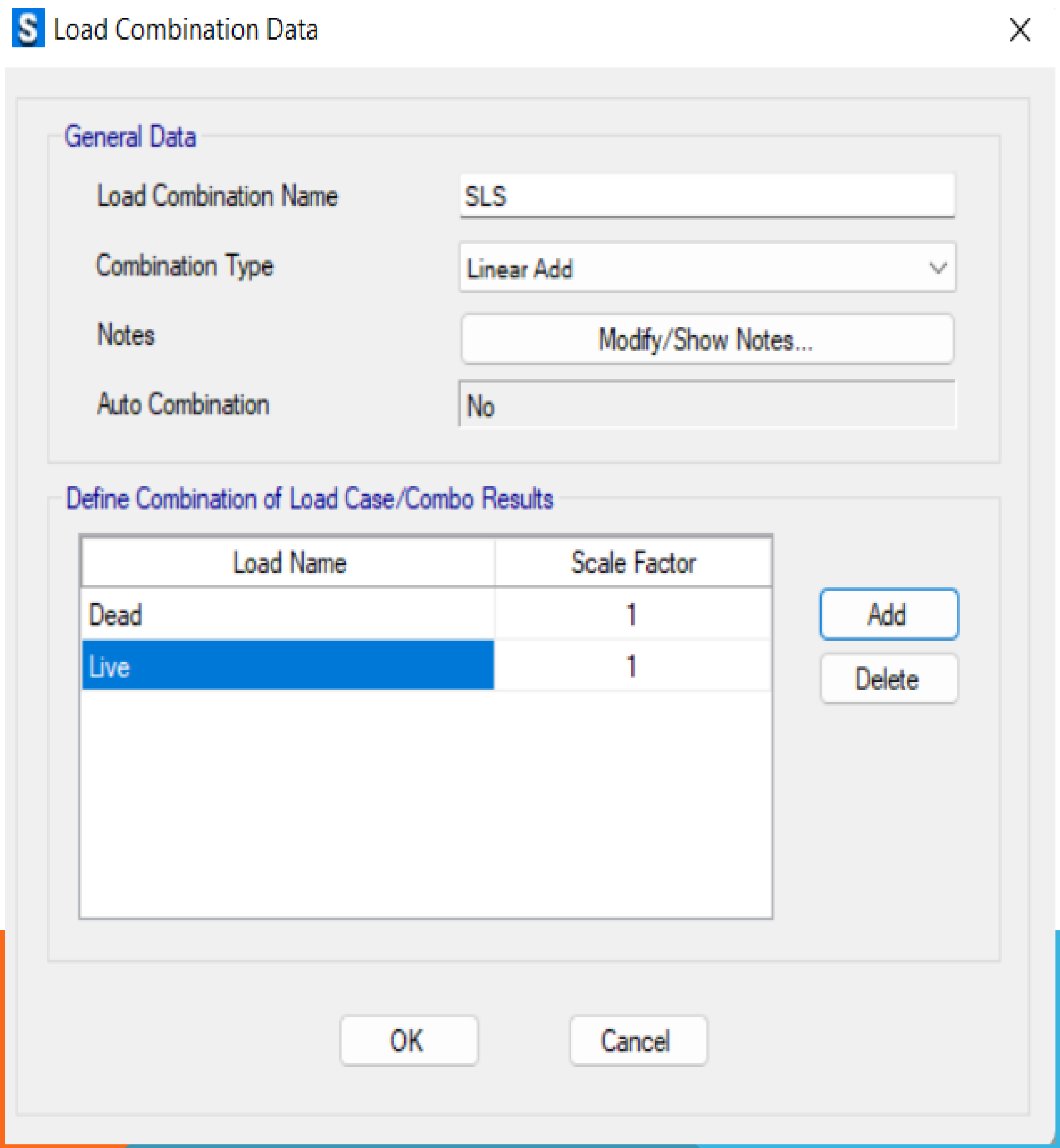

PSpr1
PSpr1
PSpr1
PSpr1
PSpr1
PSpr1
Y
X

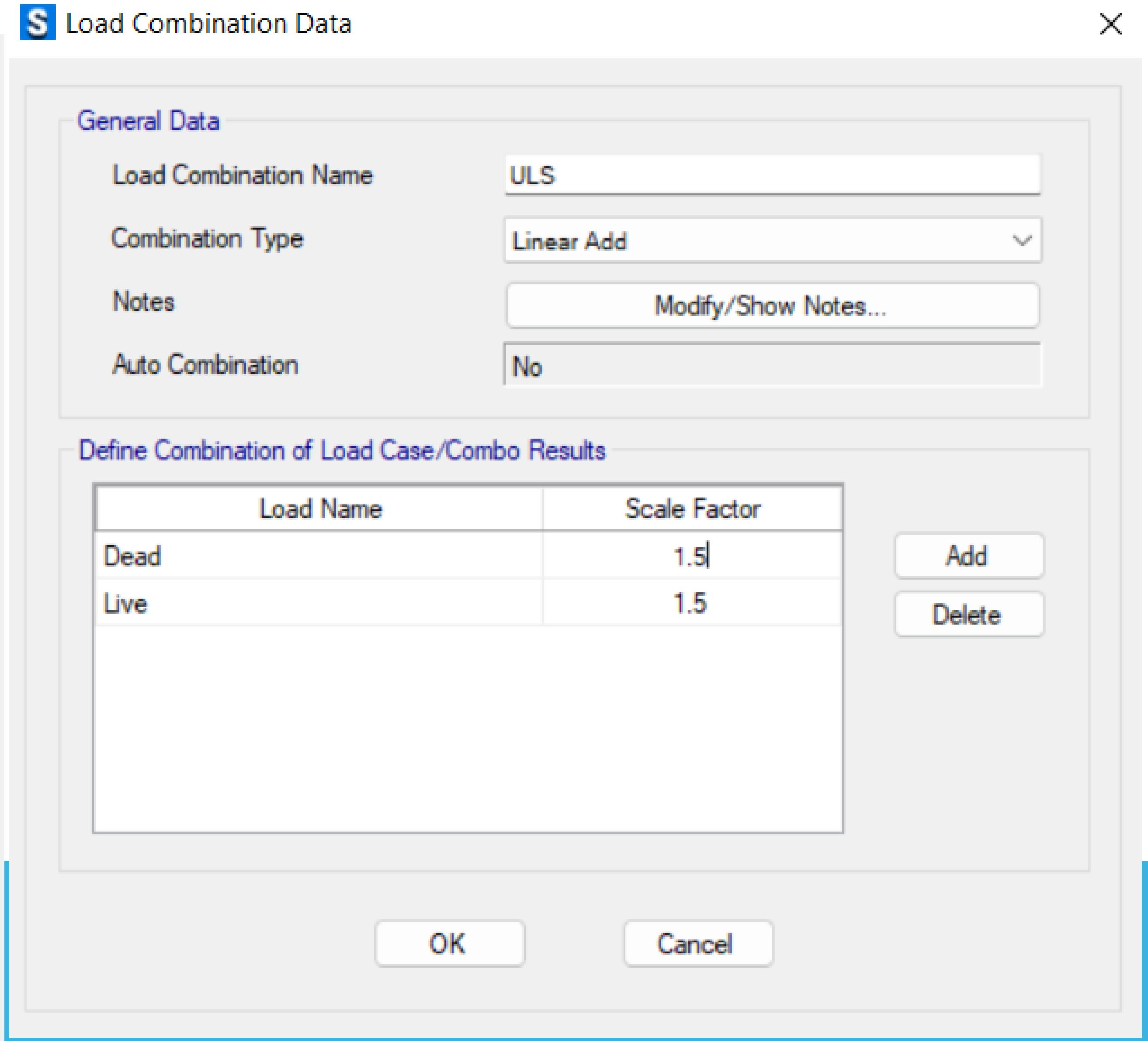

SAFE Post Tensioning 20.3.0 - (Untitled) [TRIAL LICENSE - NOT FOR COMMERCIAL USE]
File Edit View Define Draw Select Assign Analyze Display Design Detailing Options Tools Help
Material Properties...
Section Properties
Spring Properties
Point Springs...
Line Springs...
Area Springs...
Group Definitions...
Section Cuts...
Mass Source...
Load Patterns...
Shell Uniform Load Sets...
Load Cases...
Load Combinations...
Table Named Sets...
Model
Display
Project
Structure
Loads
Groups
n View - Story1 - Z = 12 (ft)
A
4
3

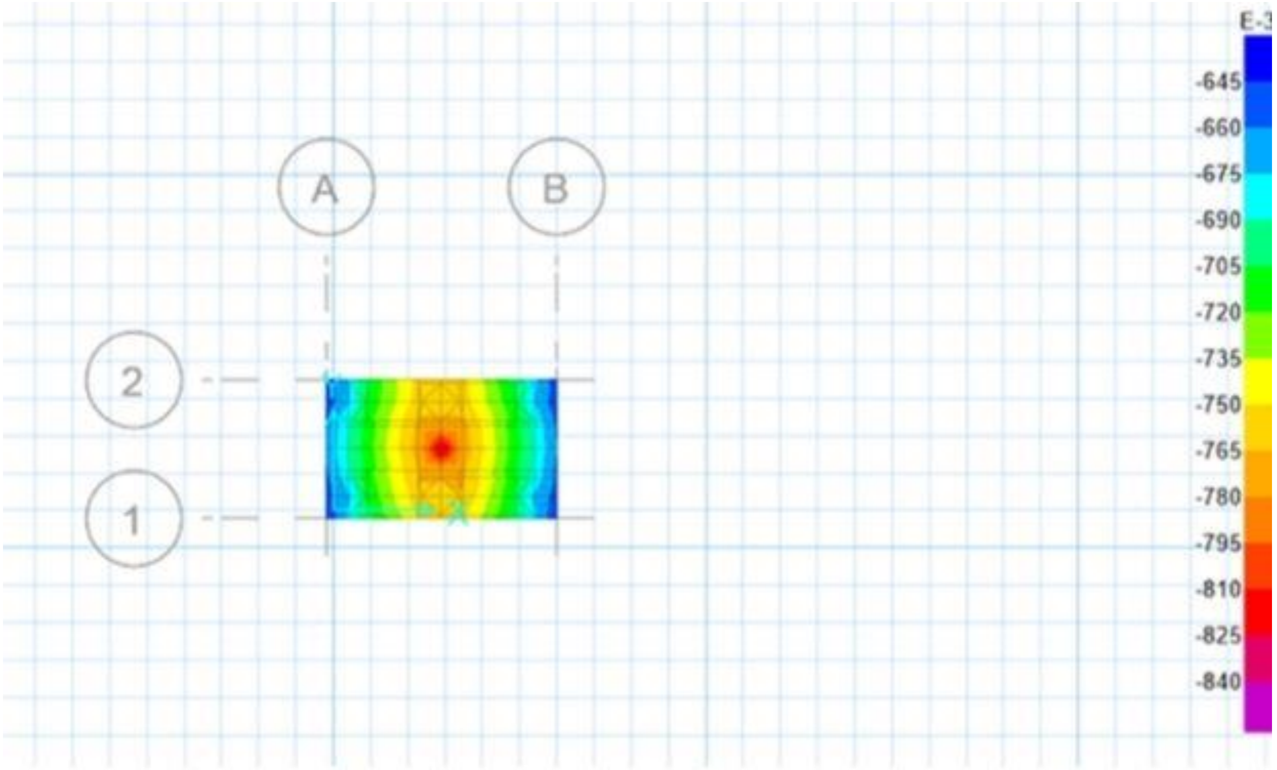

Point Spring Property Data
General Data
Property Name
PSpr1
Display Color
Change...
Property Notes
Modify/Show Notes...
Spring Stiffness in Global Directions
Translation X 0 kN/m
Translation Y 0 kN/m
Translation Z (Linear) 306795 kN/m
Rotation about X-Axis 0 kN-m/rad
Rotation about Y-Axis 0 kN-m/rad
Rotation about Z-Axis 0 kN-m/rad
Nonlinear Option (Translation Z Only) (Nonlinear Cases Only)
None (Linear)
Tension Only
Compression Only
Elasto-Plastic

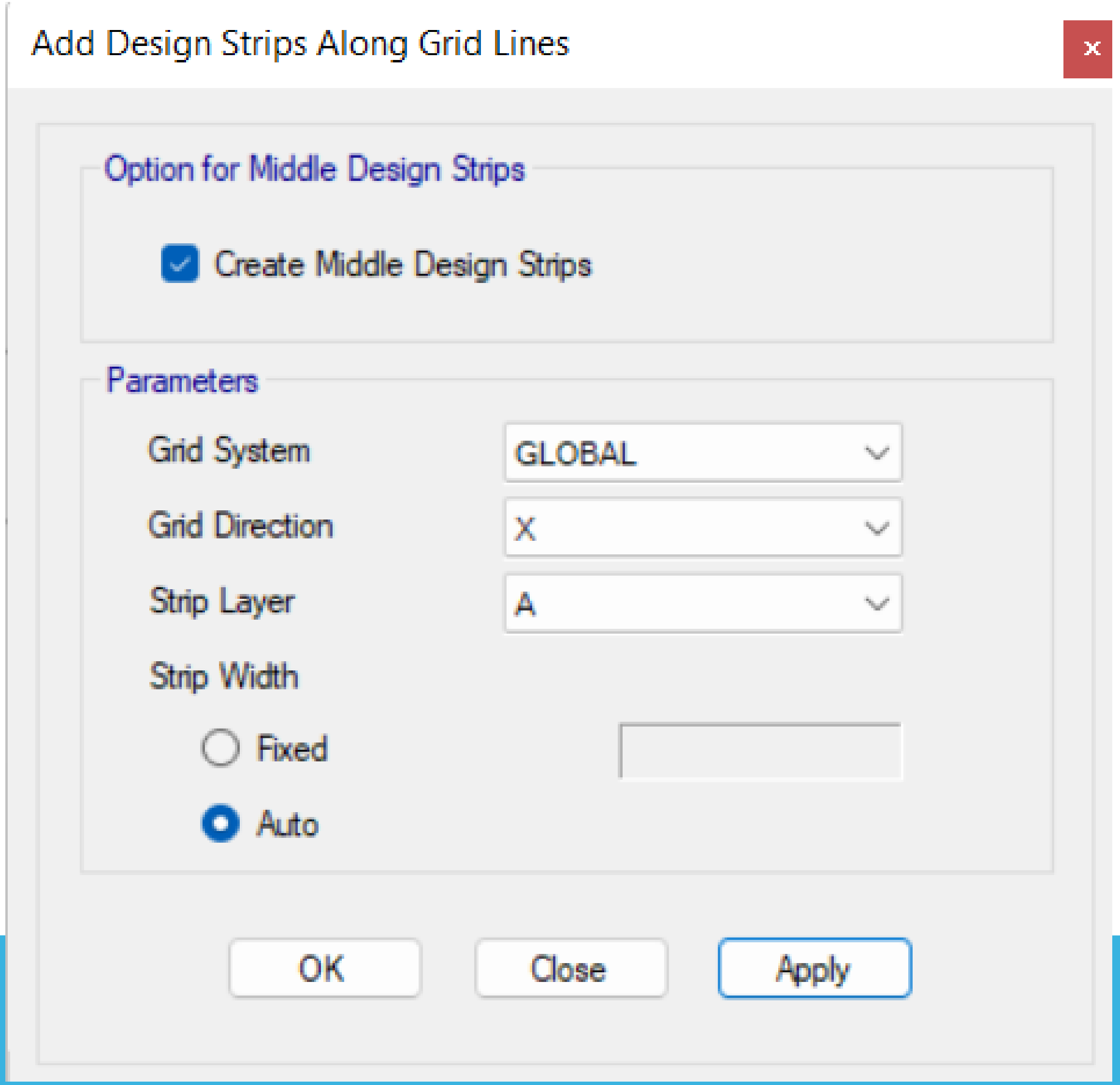

PSpr1
PSpr1
PSpr1
PSpr1
PSpr1
PSpr1
Y
X

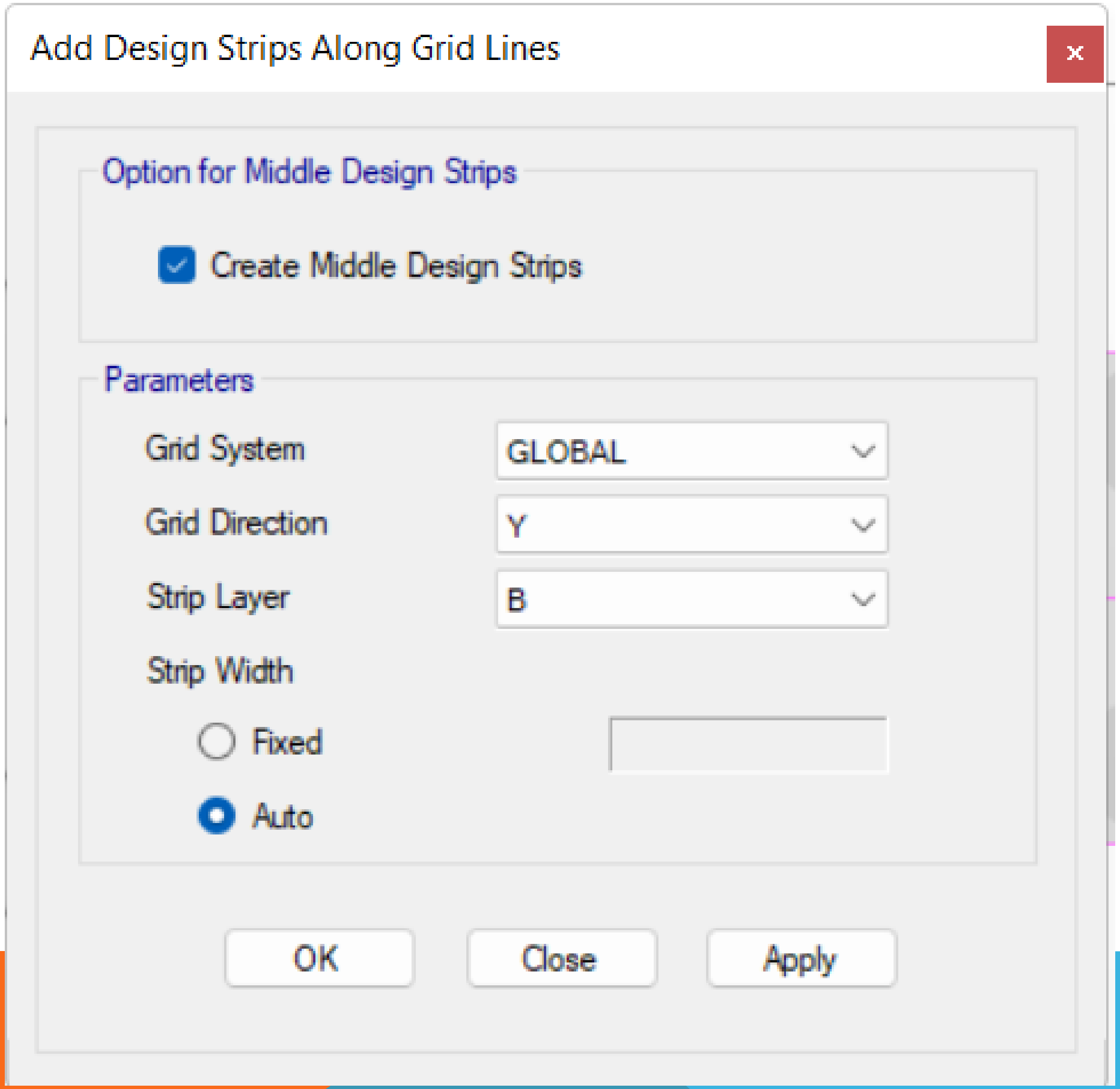

587.5
587.5
587.5
587.5
587.5

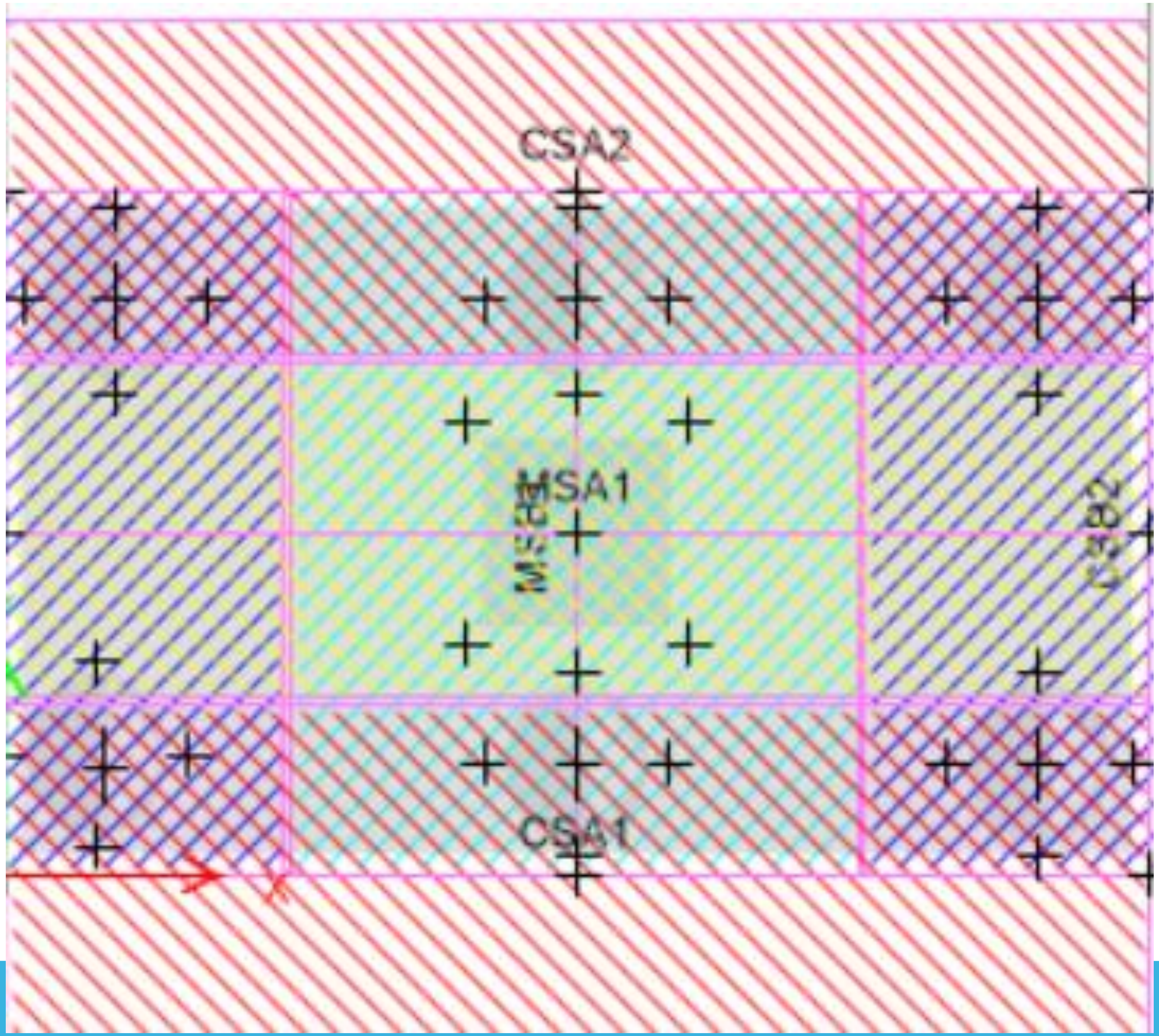

Load Combination Data
General Data
Load Combination Name
SLS
Combination Type
Linear Add
Notes
Modify/Show Notes...
Auto Combination
No
Define Combination of Load Case/Combo Results
Load Name
Scale Factor
Dead
1
Live
1
Add
Delete
OK
Cancel

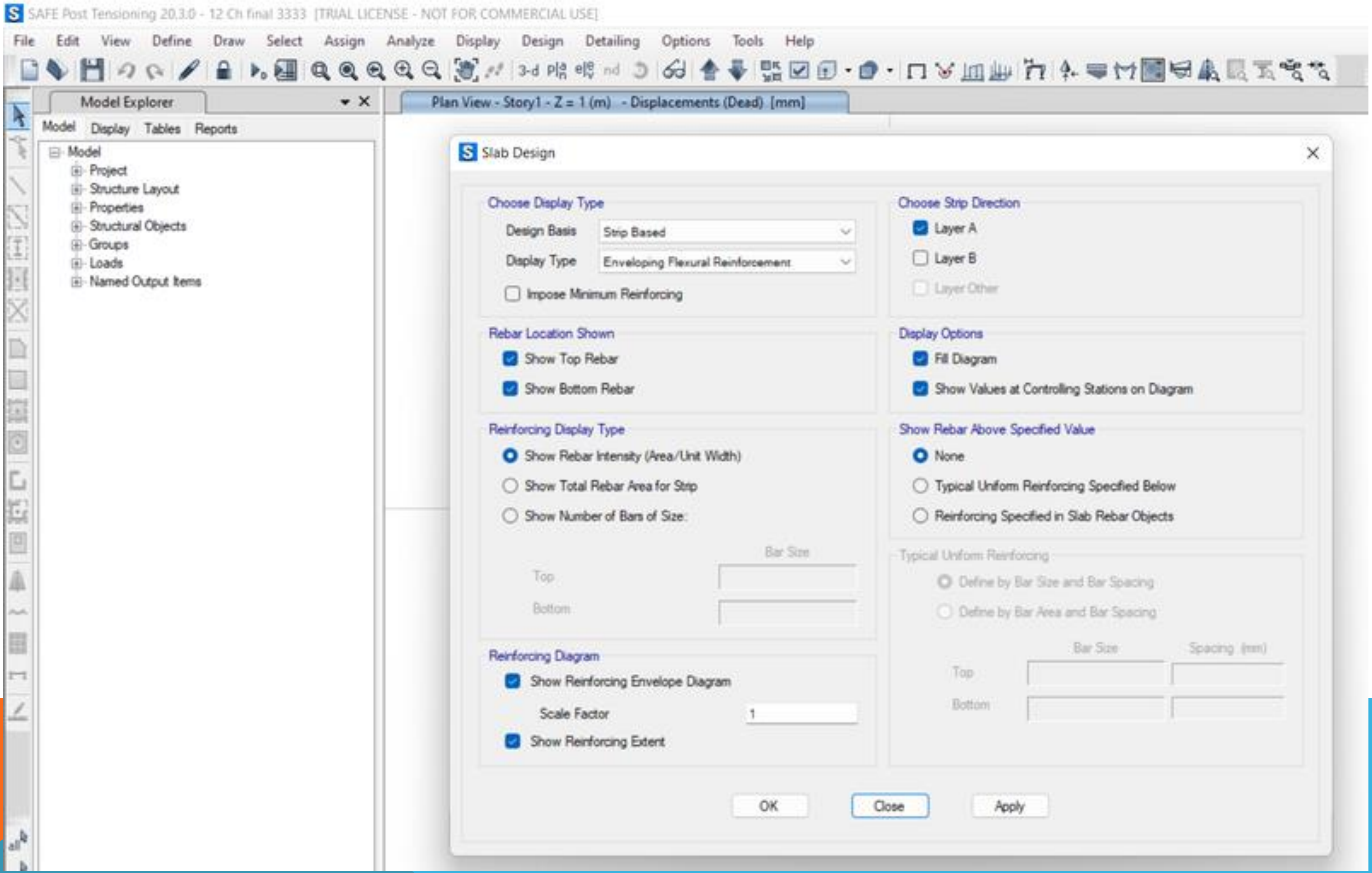

Load Combination Data
General Data
Load Combination Name
ULS
Combination Type
Linear Add
Notes
Modify/Show Notes...
Auto Combination
No
Define Combination of Load Case/Combo Results
Load Name
Scale Factor
Dead
1.5
Live
1.5
Add
Delete
OK
Cancel


A
B
2
1
-645
-660
-675
-690
-705
-720
-735
-750
-765
-780
-795
-810
-825
-840

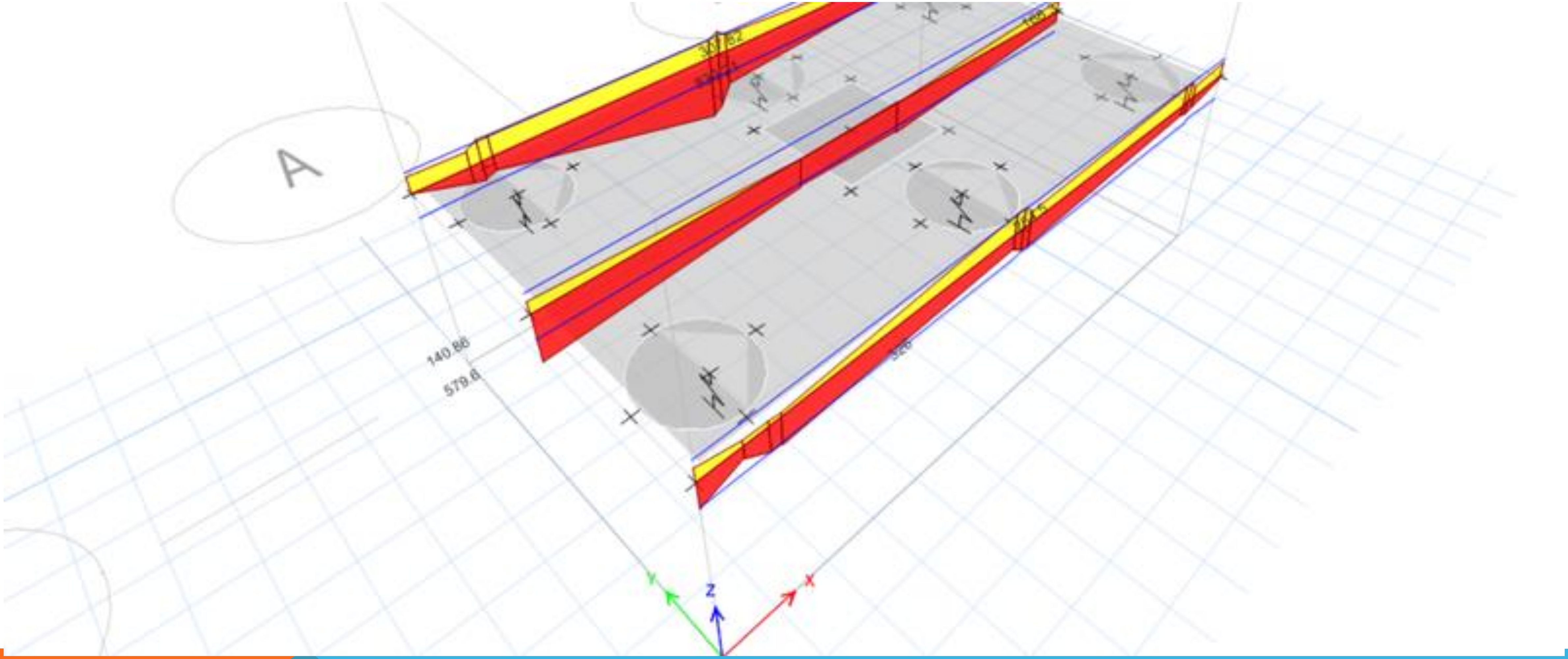

Add Design Strips Along Grid Lines
Option for Middle Design Strips
Create Middle Design Strips
Parameters
Grid System
GLOBAL
Grid Direction
X
Strip Layer
A
Strip Width
Fixed
Auto
OK
Close
Apply

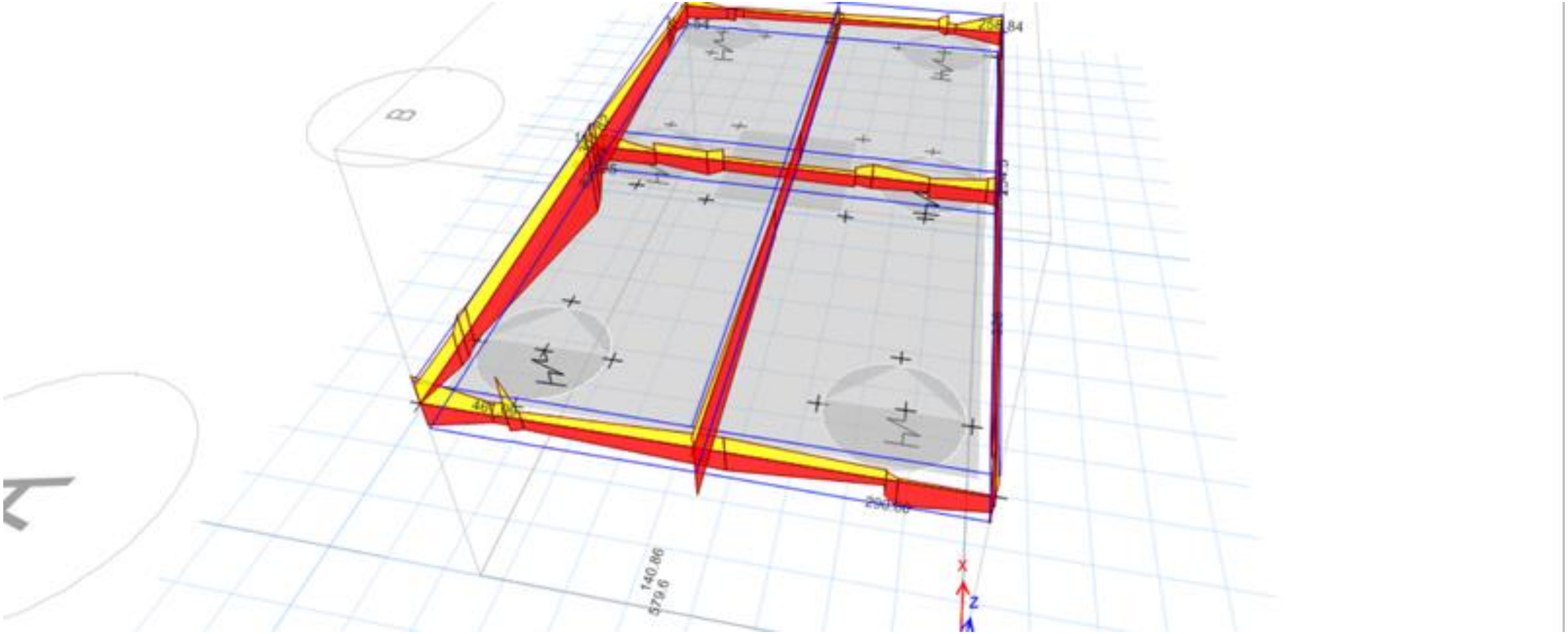

Add Design Strips Along Grid Lines
Option for Middle Design Strips
Create Middle Design Strips
Parameters
Grid System
GLOBAL
Grid Direction
Y
Strip Layer
B
Strip Width
Fixed
Auto
OK
Close
Apply


CSA2
MSA1
CSA1



SAFE Post Tensioning 20.3.0 - 12 Ch final 3333 [TRIAL LICENSE - NOT FOR COMMERCIAL USE]
File Edit View Define Draw Select Assign Analyze Display Design Detailing Options Tools Help
Model Explorer
Plan View - Story1 - Z = 1 (m) - Displacements (Dead) [mm]
Model Display Tables Reports
Model
Project
Structure Layout
Properties
Structural Objects
Groups
Loads
Named Output Items
Slab Design
Choose Display Type
Design Basis
Strip Based
Display Type
Enveloping Flexural Reinforcement
Impose Minimum Reinforcing
Choose Strip Direction
Layer A
Layer B
Layer Other
Rebar Location Shown
Show Top Rebar
Show Bottom Rebar
Display Options
Fill Diagram
Show Values at Controlling Stations on Diagram
Reinforcing Display Type
Show Rebar Intensity (Area/Unit Width)
Show Total Rebar Area for Strip
Show Number of Bars of Size:
Bar Size
Top
Bottom
Show Rebar Above Specified Value
None
Typical Uniform Reinforcing Specified Below
Reinforcing Specified in Slab Rebar Objects
Typical Uniform Reinforcing
Define by Bar Size and Bar Spacing
Define by Bar Area and Bar Spacing
Bar Size
Spacing (mm)
Top
Bottom
Reinforcing Diagram
Show Reinforcing Envelope Diagram
Scale Factor
1
Show Reinforcing Extent
OK
Close
Apply


A
140.88
579.6
Y
Z
X



258.84
290.66
140.86
579.6

RESULT:-

- Pile Cap is Designed for Square column of size 600mm x 600 mm
- We have to provide pile cap Size as 3.1m x 1.85m
- Bearing soil pressure is checked and found to be safe
- Punching shear ratio is check and found to be safe

Review and Problem solving class

Week 17

Questions?

Thank you