



University of Global Village (UGV), Barishal

SAFE (Foundation Design)

Content of Laboratory Course



Prepared By

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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	6 th Semester



SAFE (Foundation Design)

COURSE CODE: CE 0732-2104

CREDIT:01

TOTAL MARKS:50

CIE MARKS: 30

SEE MARKS: 20

Semester End Exam Hours 2

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 TRAINING (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

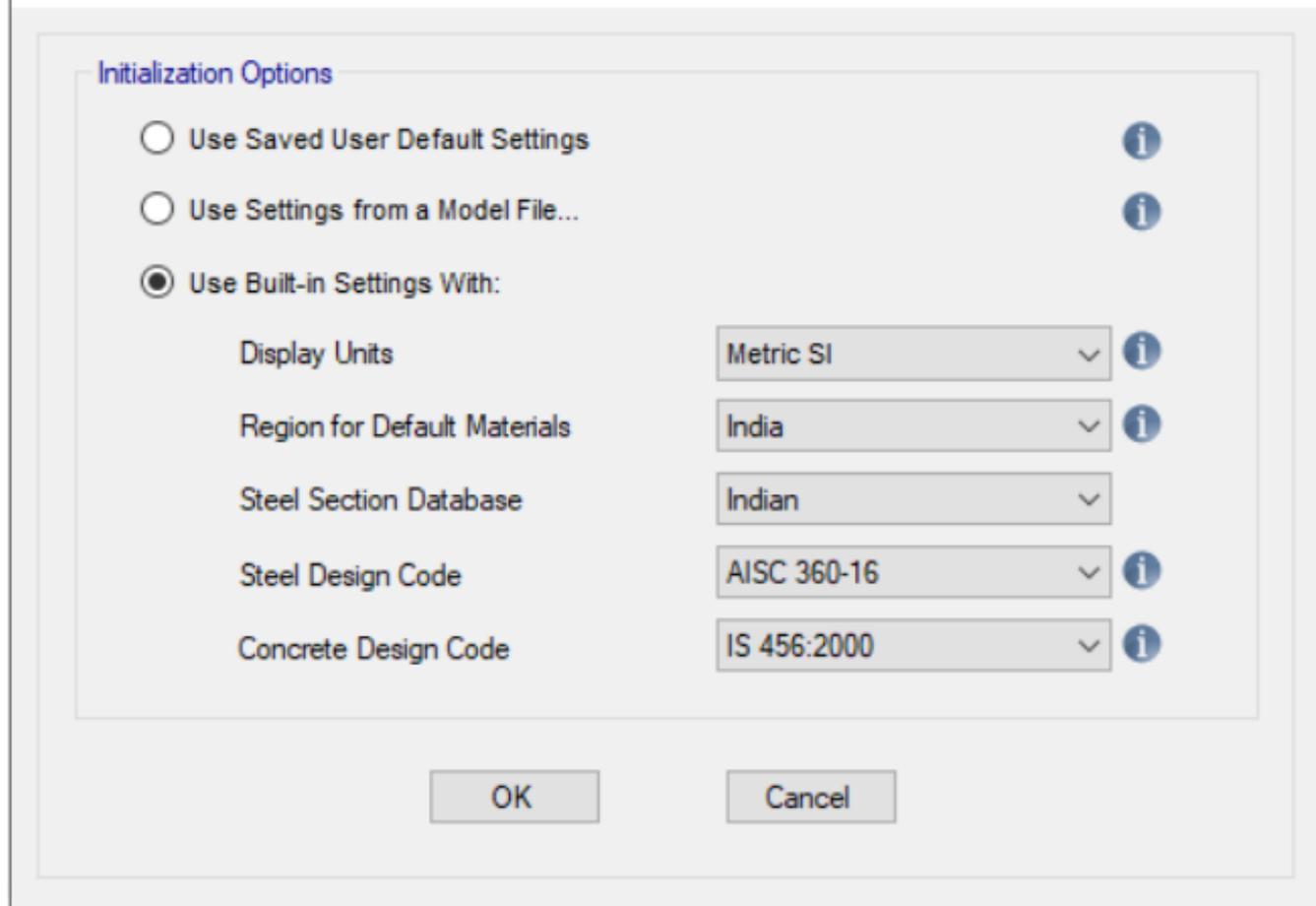
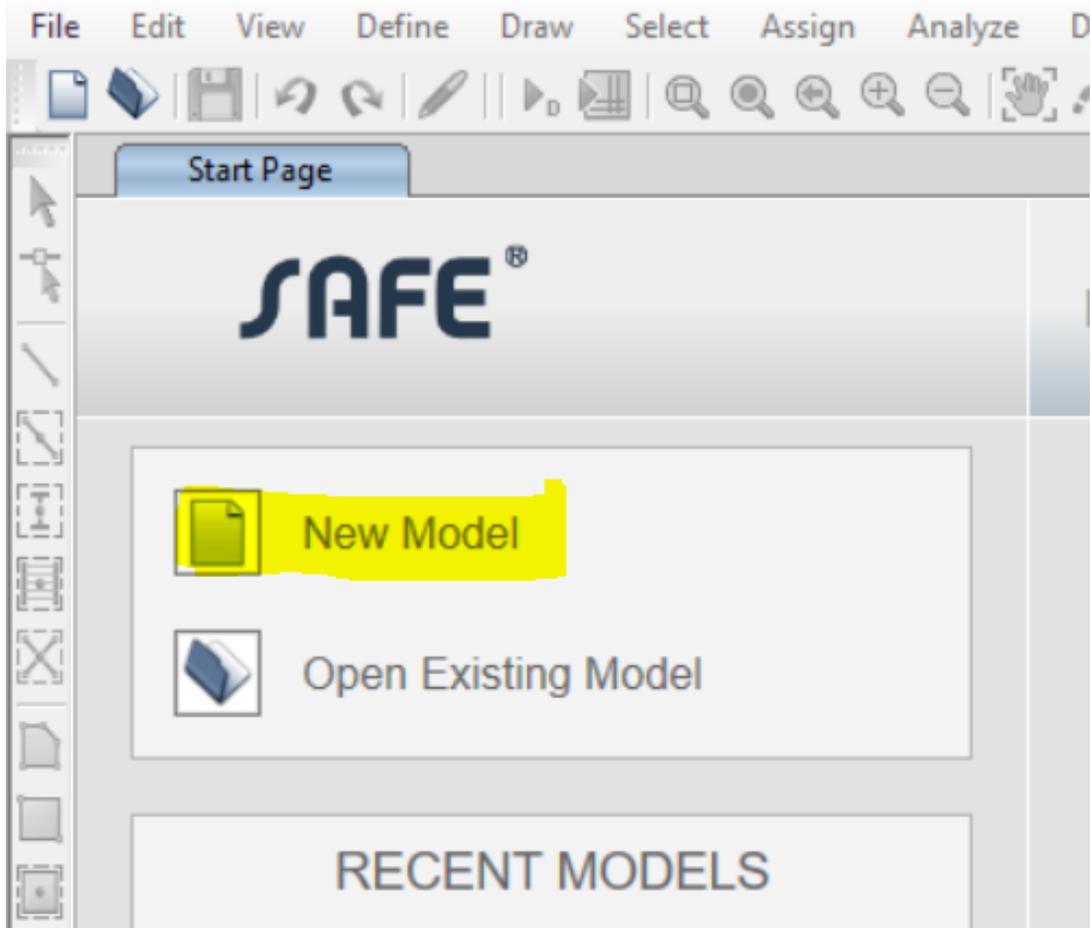
This software is used for the design of slab and foundation of a structure.



Introduction to all Shortcuts and Editing Command

Week 2

Pages 13-16



Grid Dimensions (Plan)

Uniform Grid Spacing ?

Number of Grid Lines in X Direction

Number of Grid Lines in Y Direction

Spacing of Grids in X Direction

 m

Spacing of Grids in Y Direction

 m

Specify Grid Labeling Options

Custom Grid Spacing ?

Story Dimensions

Model Datum

 m

Story Height Above

 m

Story Height Below

 m

Model Datum Name

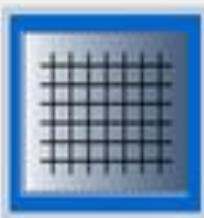
Name of Story Above

Name of Story Below

Add Structural Objects



Blank



Grid Only



Steel Deck



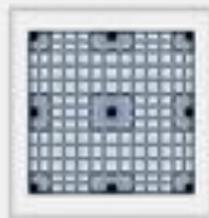
Flat Slab



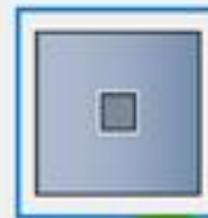
Flat Slab with
Perimeter Beams



Two Way or
Ribbed Slab



Waffle Slab



Single Footing



Combined Footing



Base Mat

Single Footing

Overhangs

Along X Direction

Left Edge Distance m

Right Edge Distance m

Along Y Direction

Top Edge Distance m

Bottom Edge Distance m

Structural System Properties

Footing Slab Thickness mm

Subgrade Modulus kN/m/m²

Load

Dead Load Pattern

Vertical Load, P (Dead) kN

Moment, M_x (Dead) kN-m

Moment, M_y (Dead) kN-m

Live Load Pattern

Vertical Load, P (Live) kN

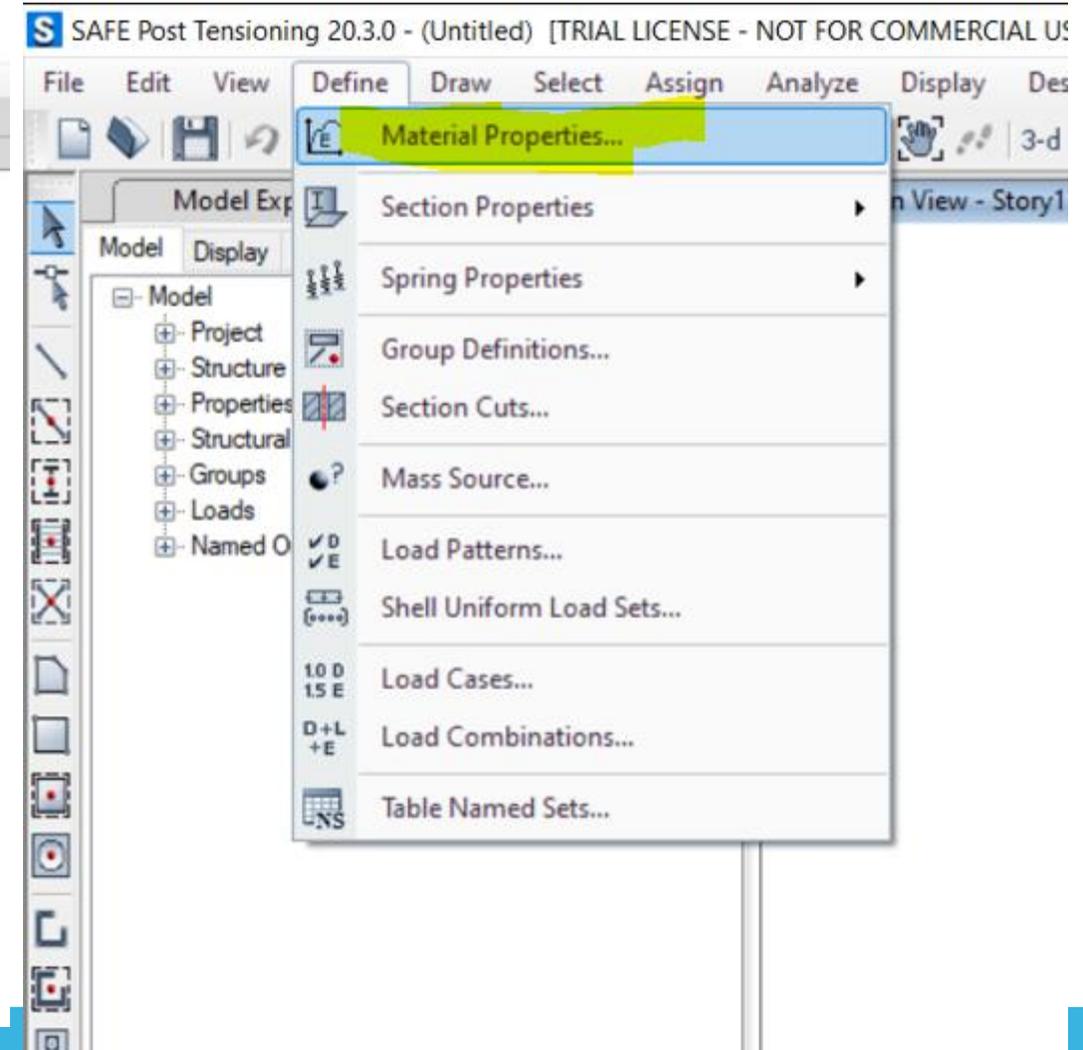
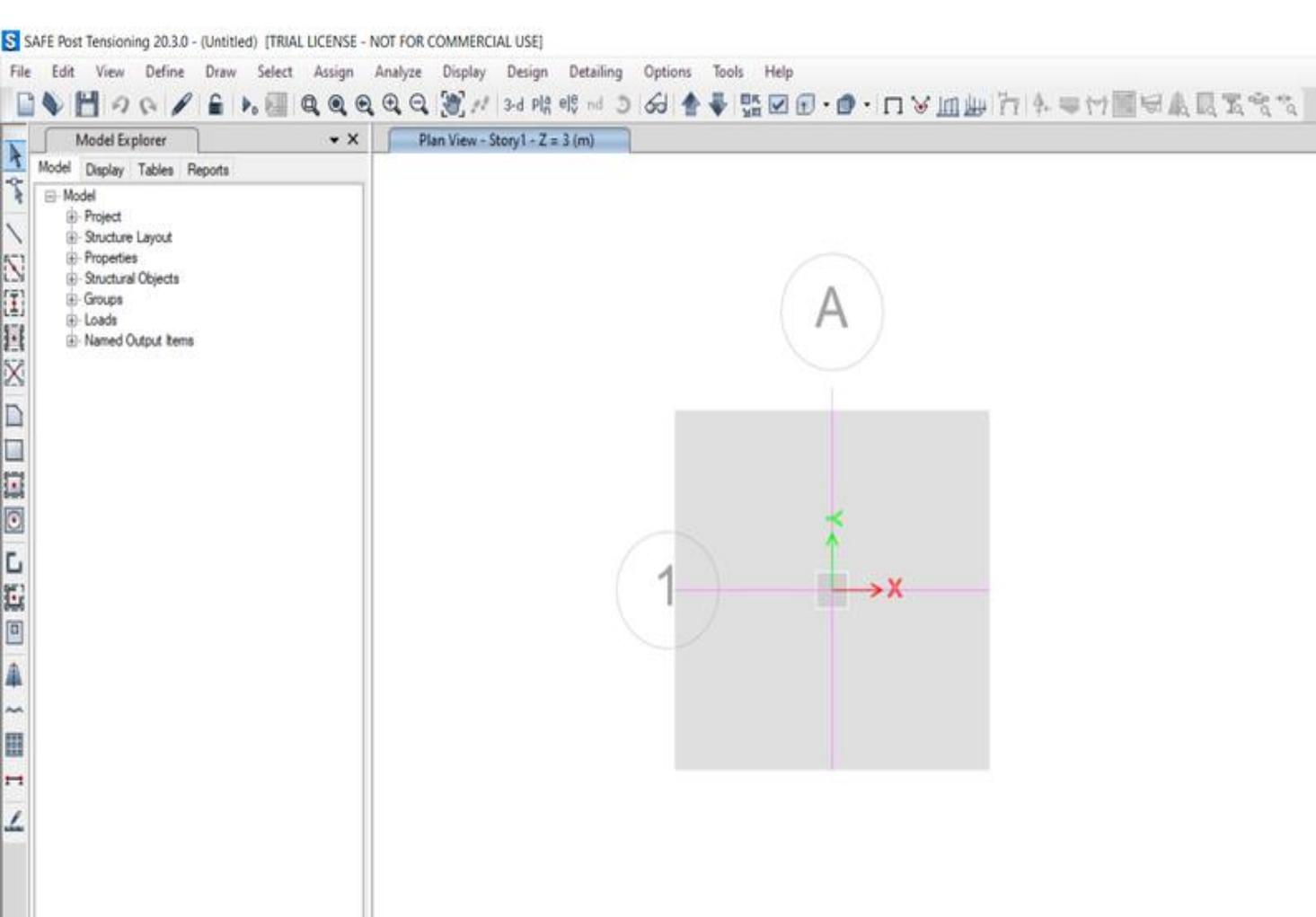
Moment, M_x (Live) kN-m

Moment, M_y (Live) kN-m

Load Size (square) mm

OK

Cancel

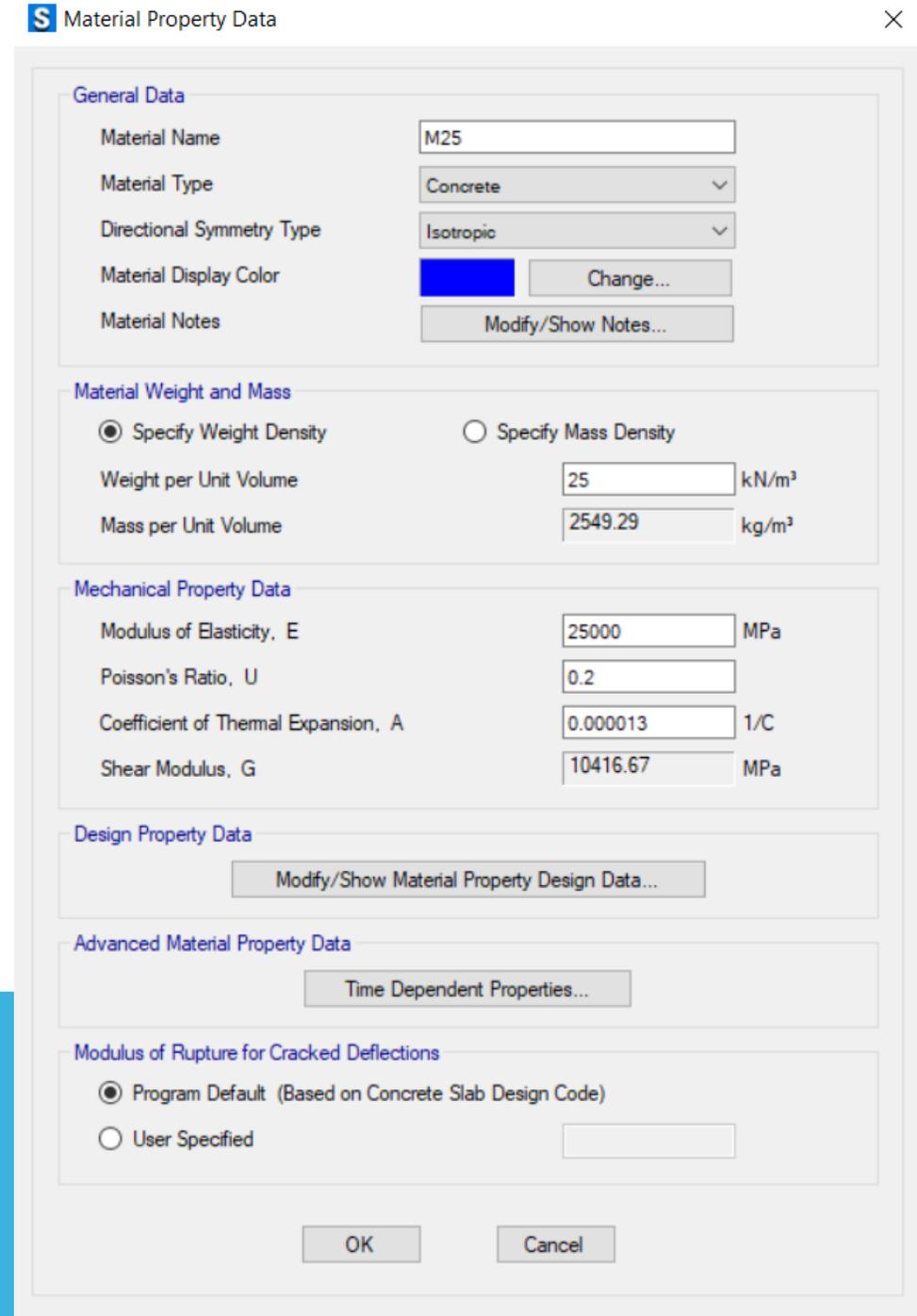
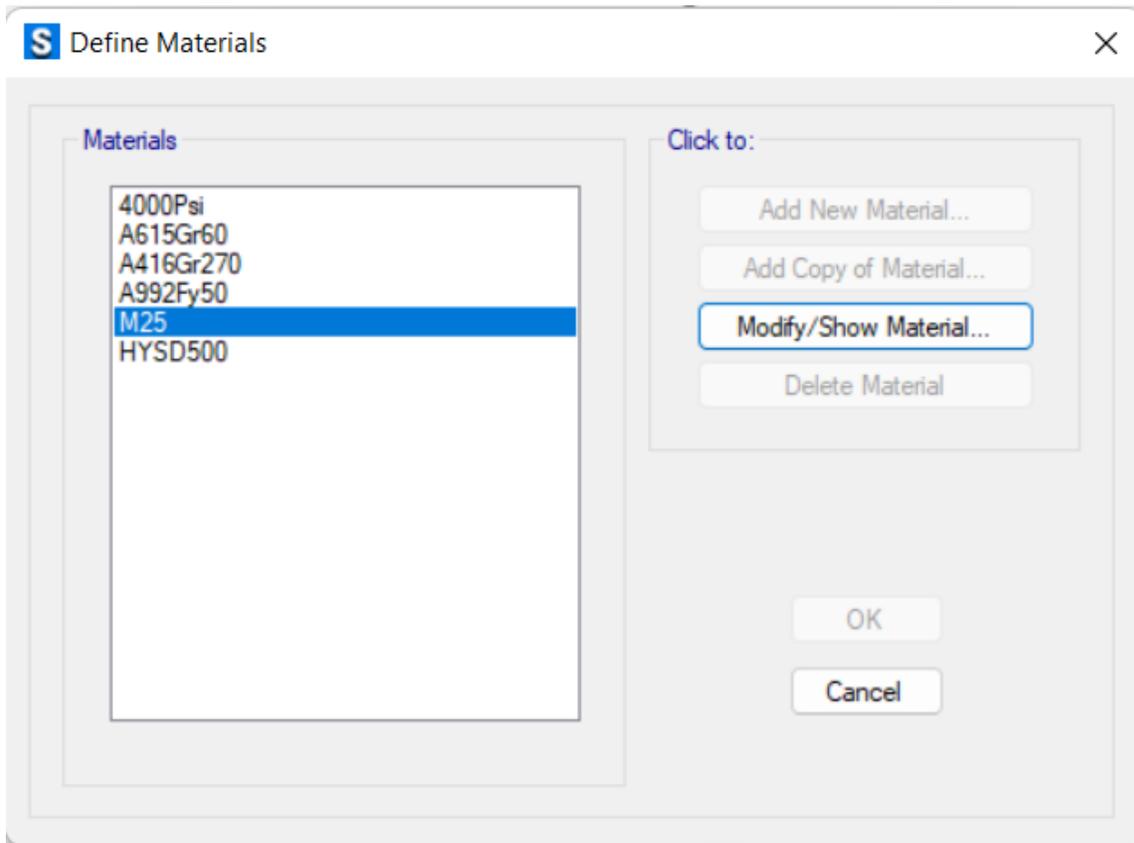




Introduction to all Shortcuts and Editing Command

Week 3

Pages 17-23



S Material Property Data



General Data

Material Name:

Material Type:

Directional Symmetry Type:

Material Display Color:

Material Notes:

Material Weight and Mass

Specify Weight Density Specify Mass Density

Weight per Unit Volume: kN/m³

Mass per Unit Volume: kg/m³

Mechanical Property Data

Modulus of Elasticity, E: MPa

Coefficient of Thermal Expansion, A: 1/C

Design Property Data

Advanced Material Property Data

S Material Property Design Data



Material Name and Type

Material Name:

Material Type:

Grade:

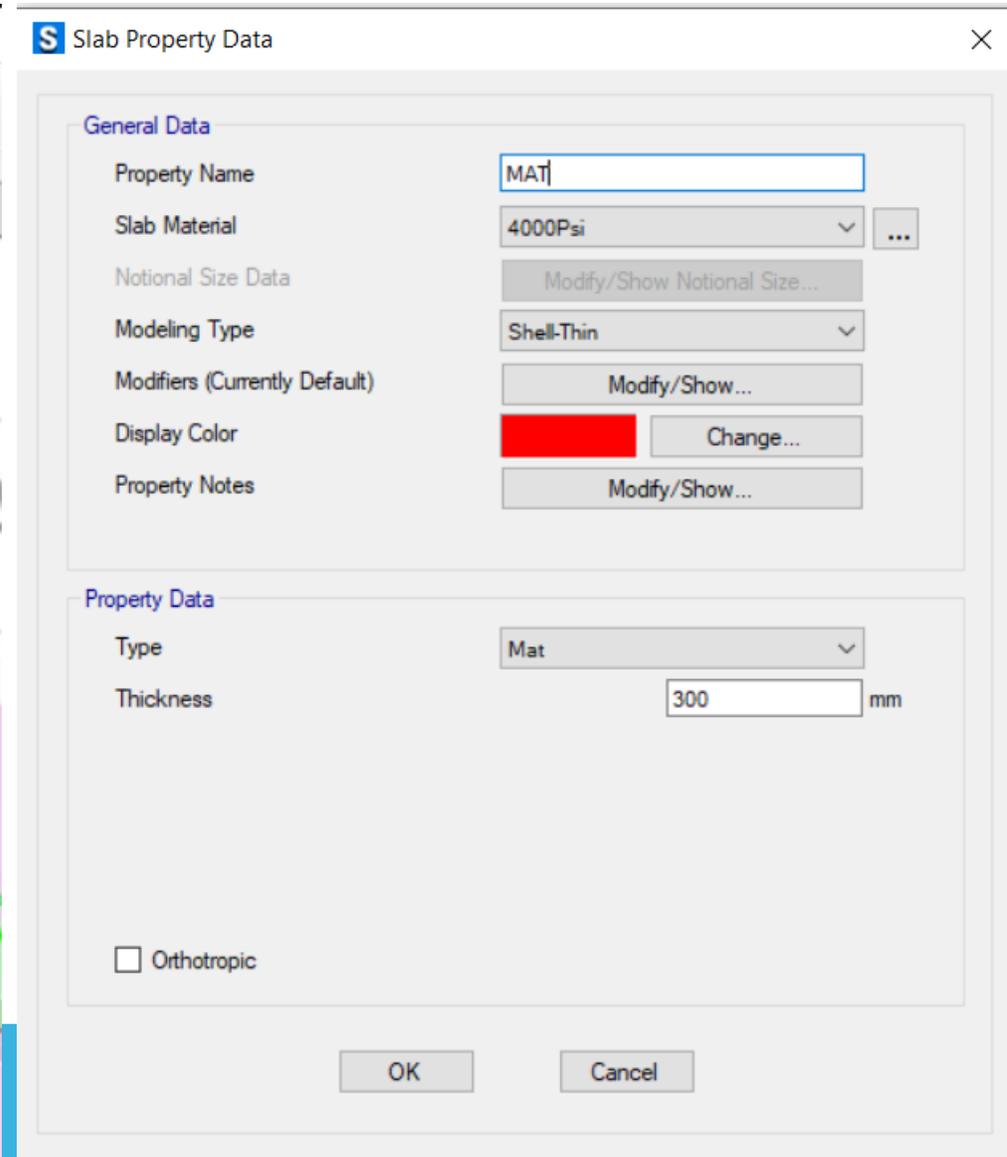
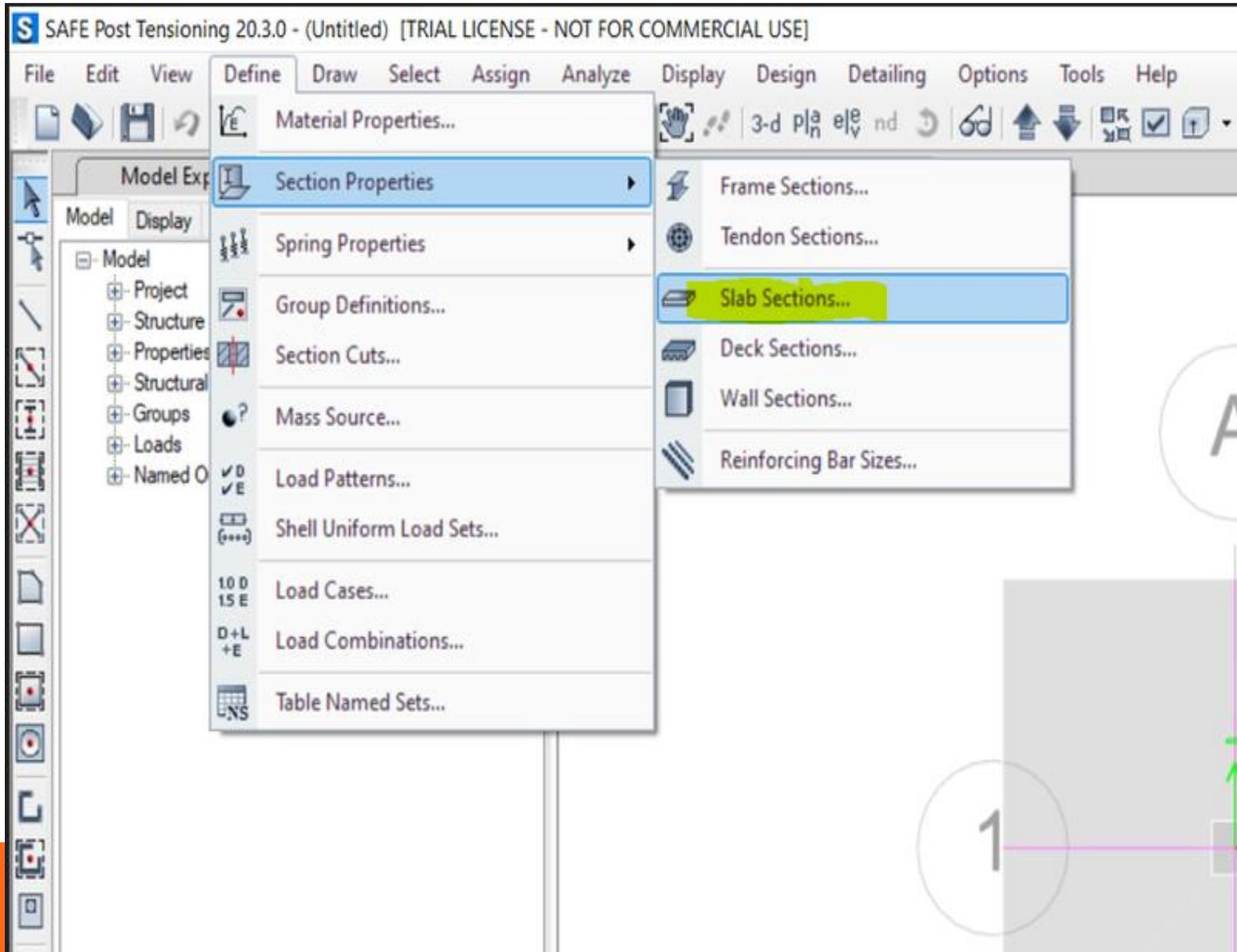
Design Properties for Rebar Materials

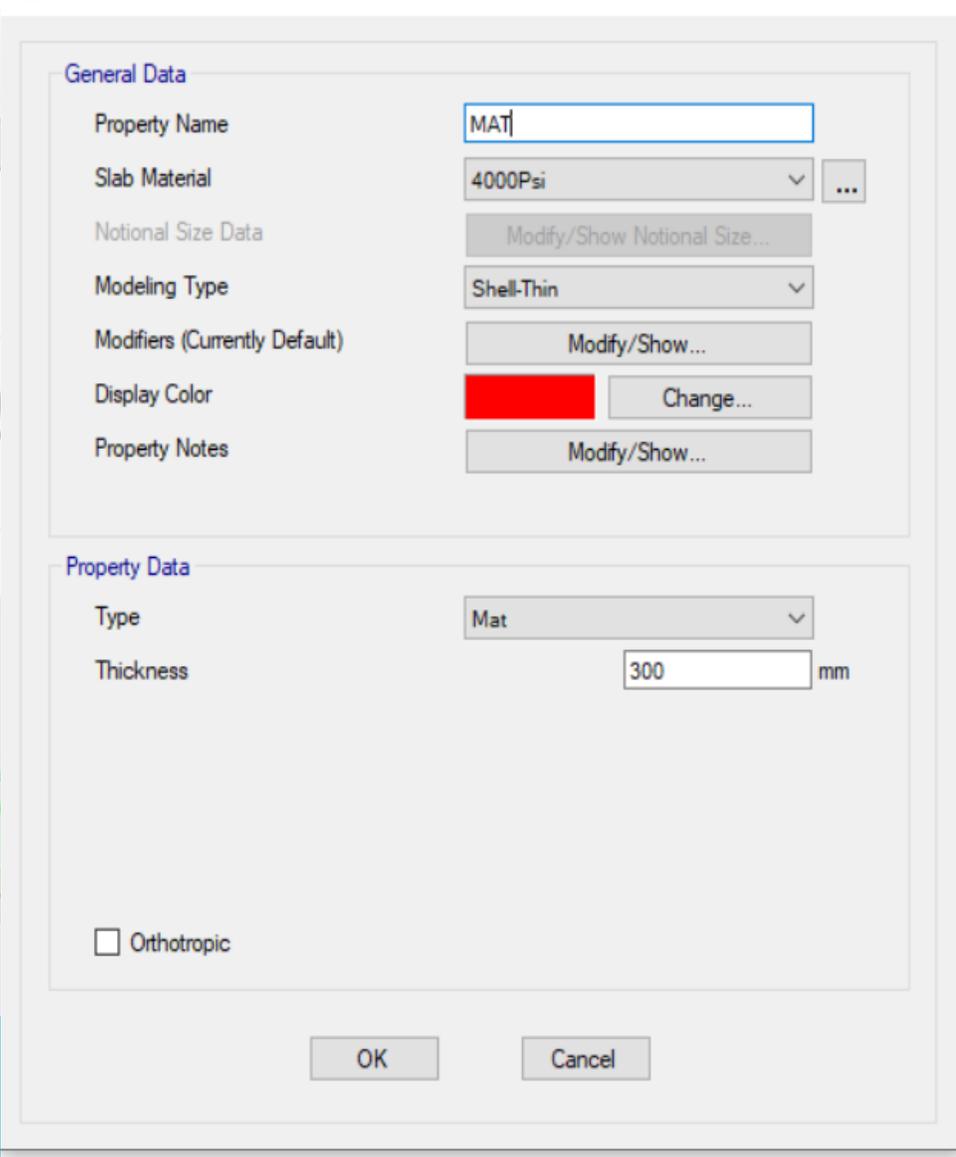
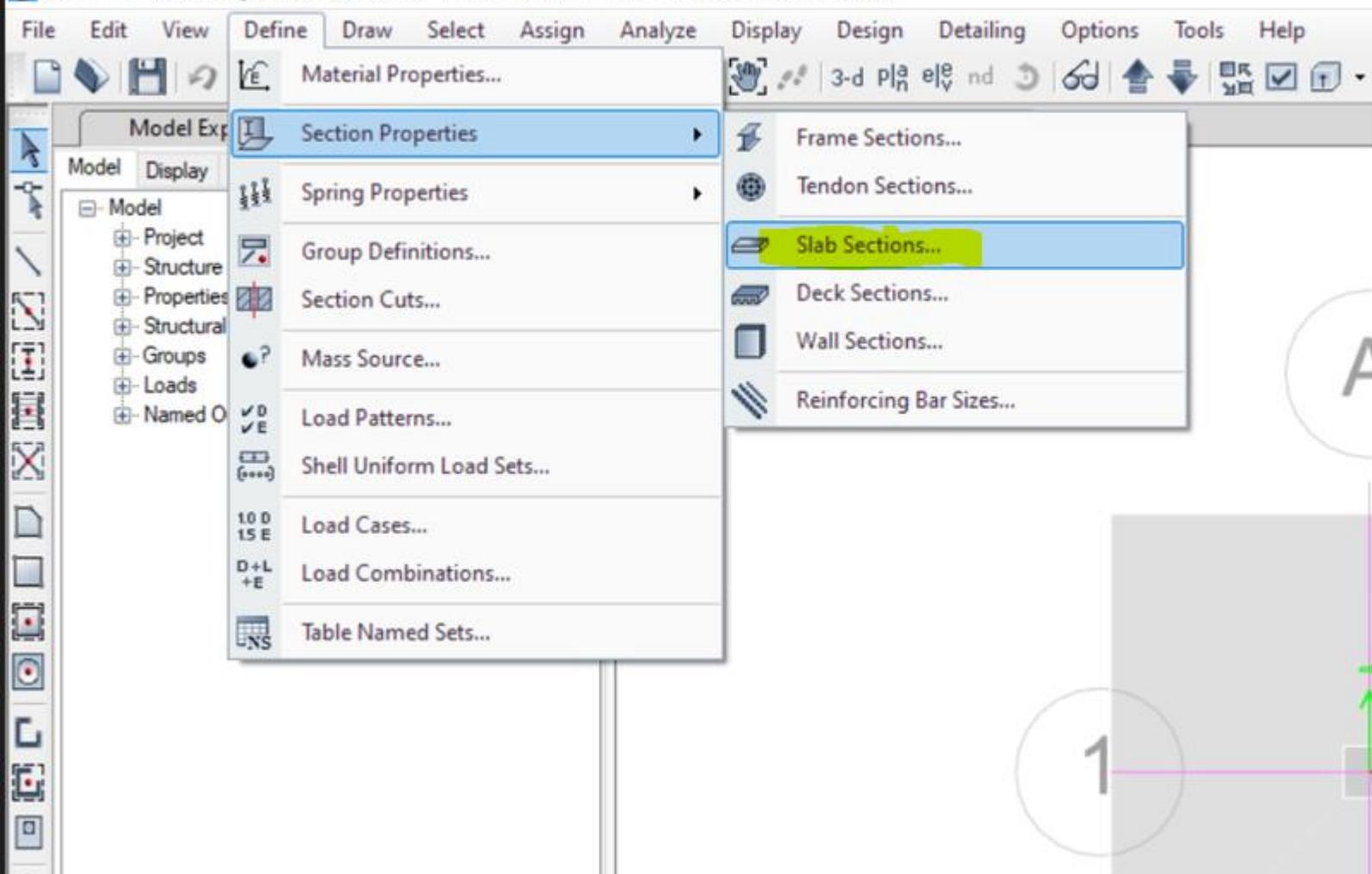
Minimum Yield Strength, F_y: MPa

Minimum Tensile Strength, F_u: MPa

Expected Yield Strength, F_{ye}: MPa

Expected Tensile Strength, F_{ue}: MPa





S Slab Property Data



General Data

Property Name

Slab Material ...

Notional Size Data

Modeling Type

Modifiers (Currently Default)

Display Color

Property Notes

Property Data

Type

Thickness mm

Orthotropic

OK

Cancel

S Slab Properties



Slab Property

MAT

Stiff1

Click to:

Add New Property...

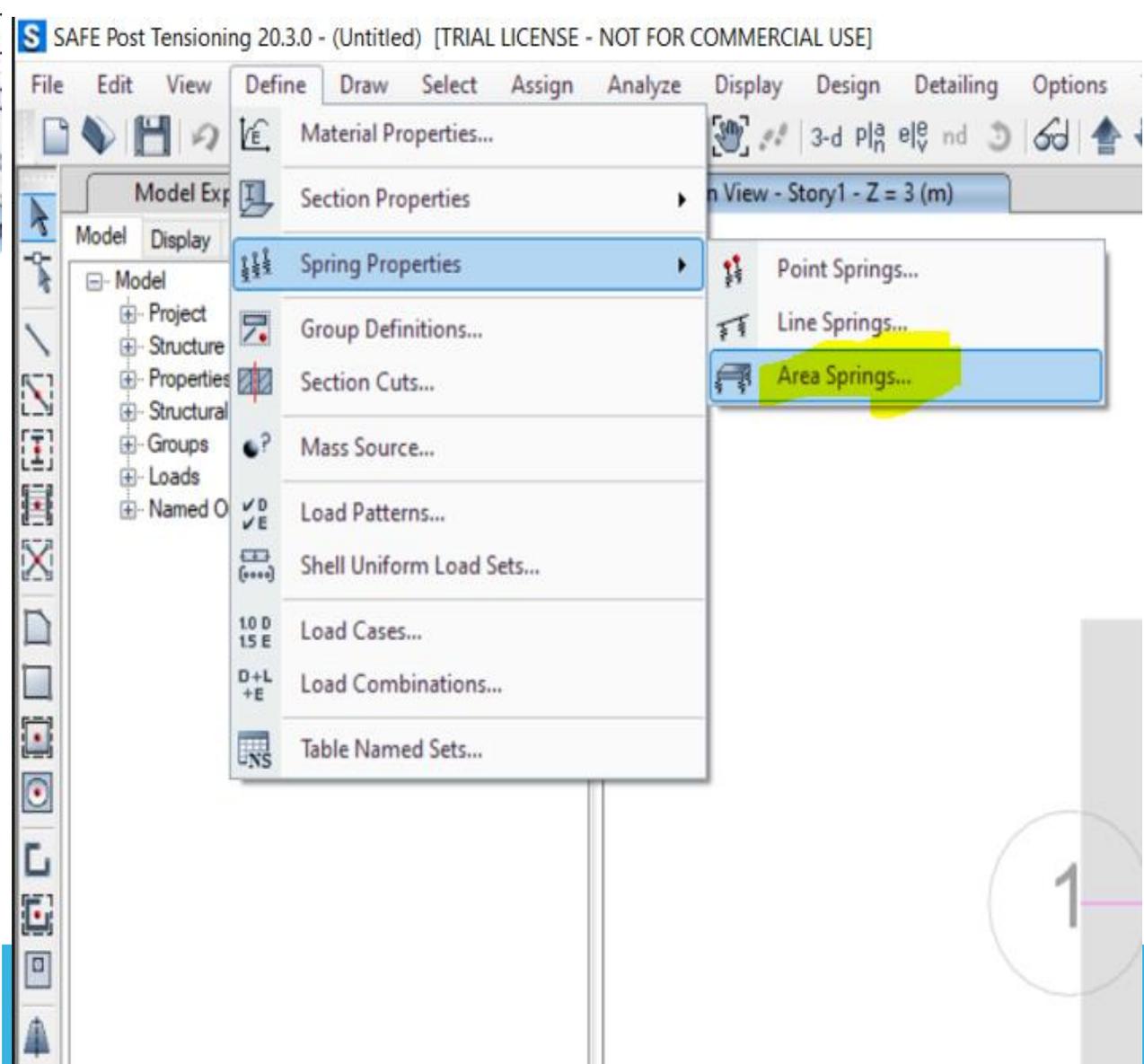
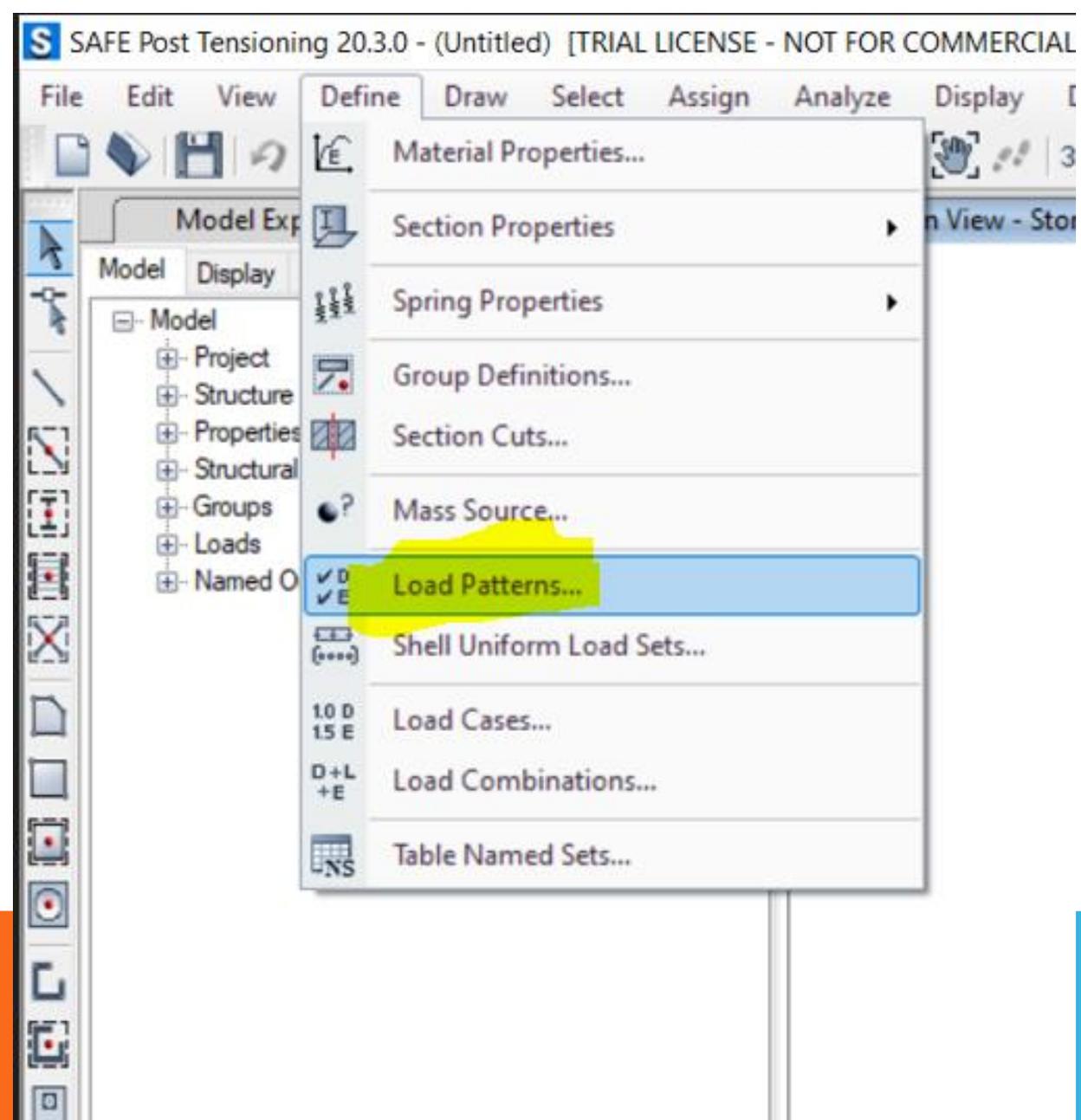
Add Copy of Property...

Modify/Show Property...

Delete Property

OK

Cancel



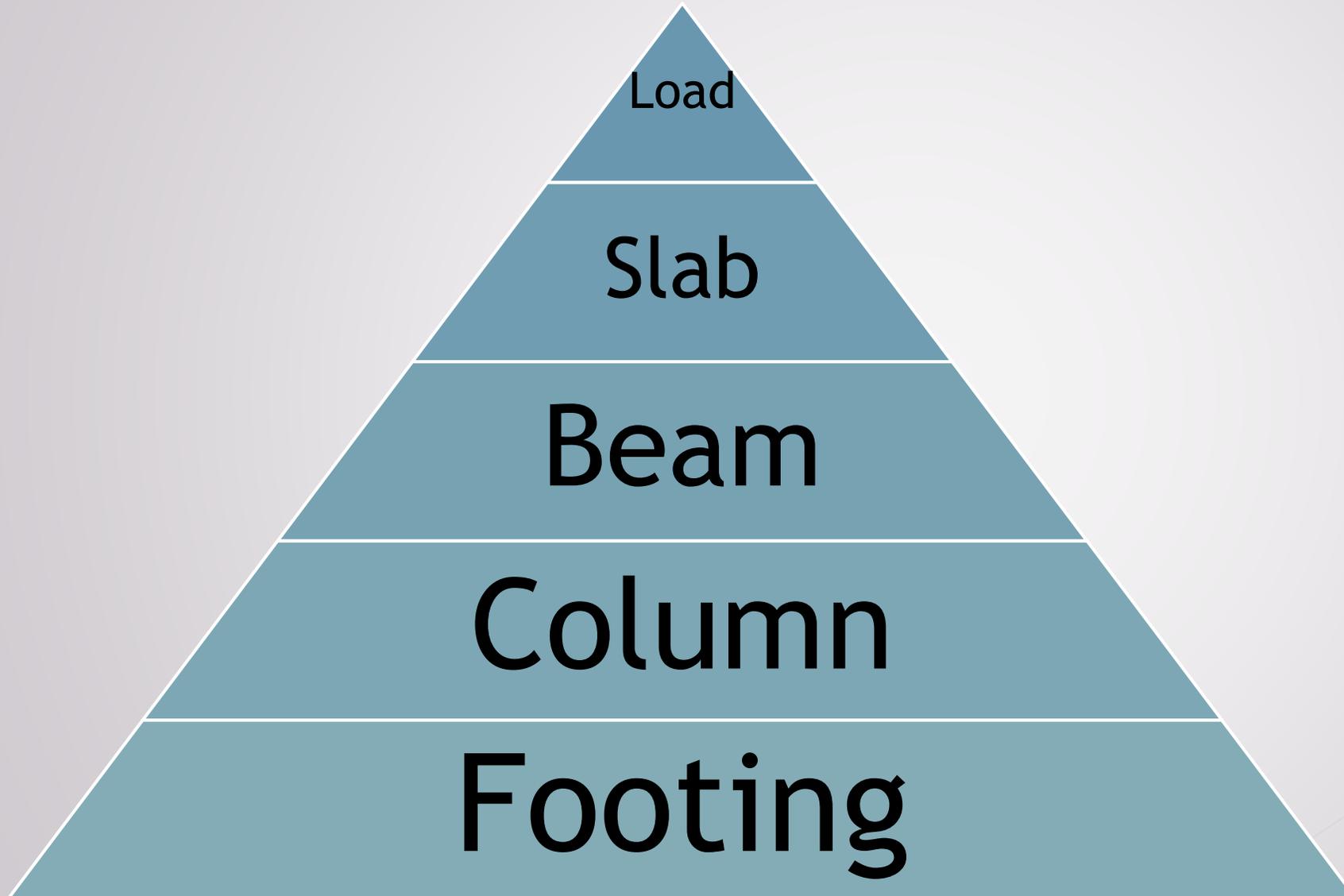


Load Transferring Mechanism

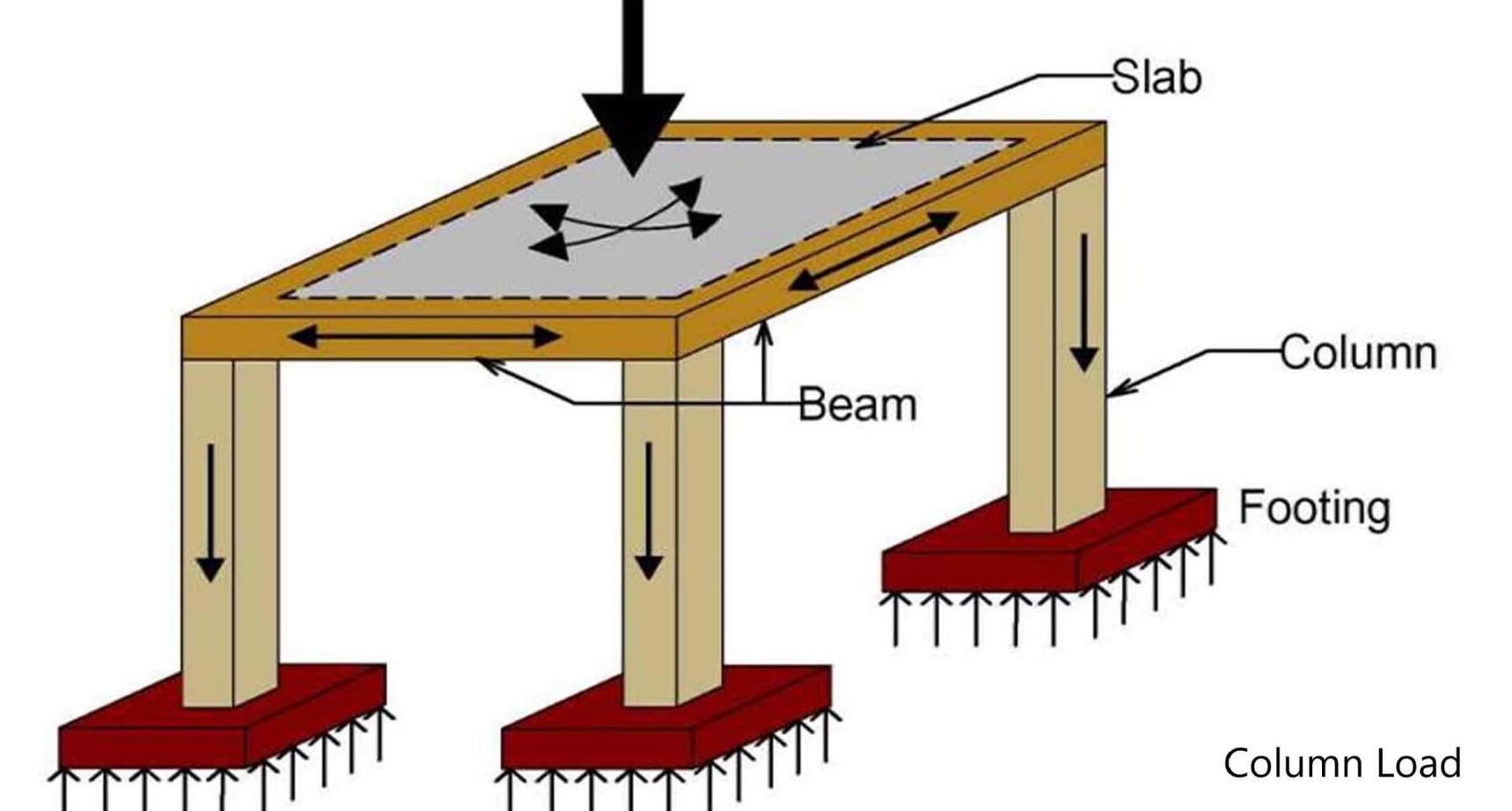
Week 4

Pages 24-31

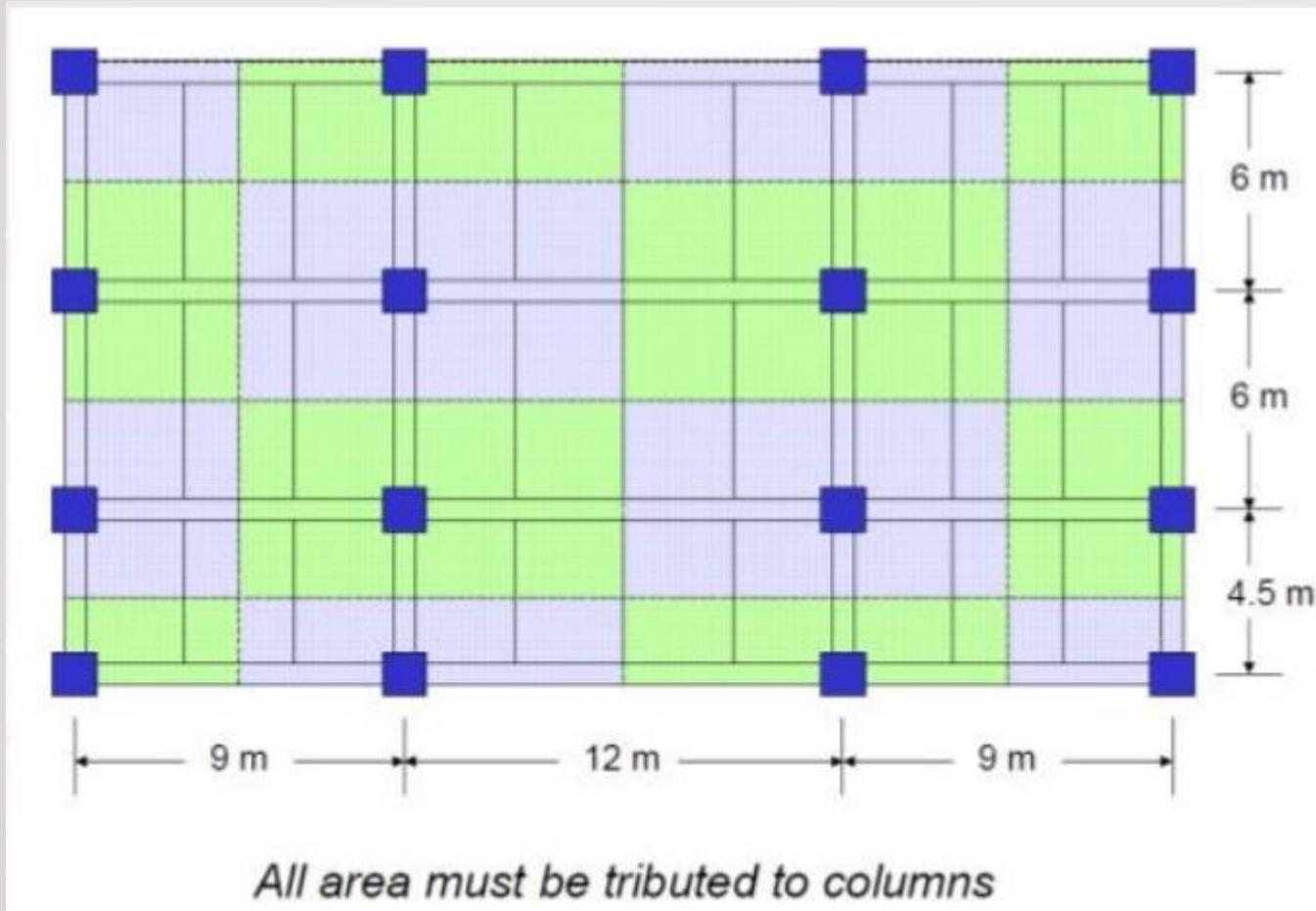
Load Transferring Mechanism of Building Structure



Continue...



Tributary Area of Column



File Edit View Define Draw Select Assign Analyze

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...

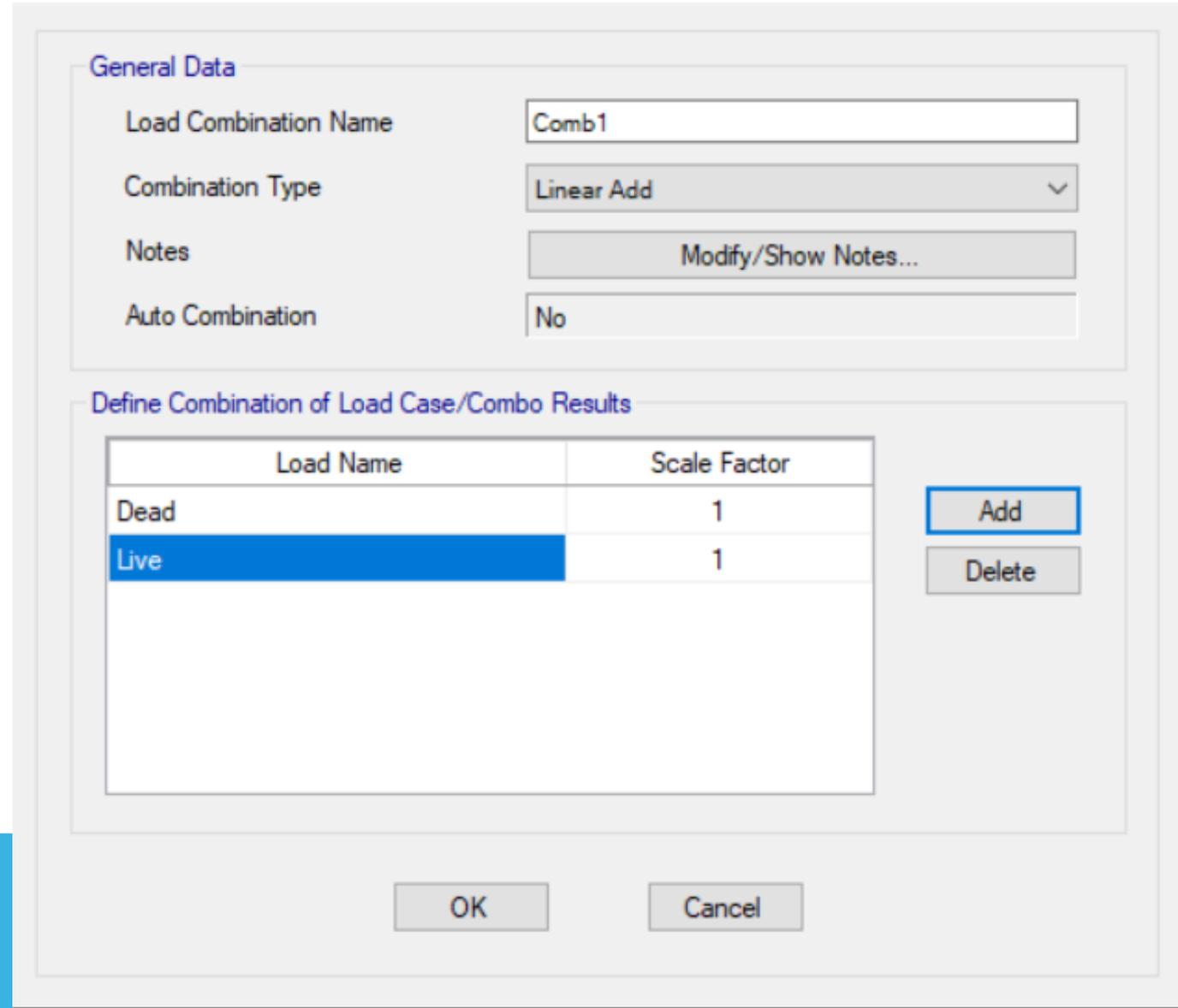
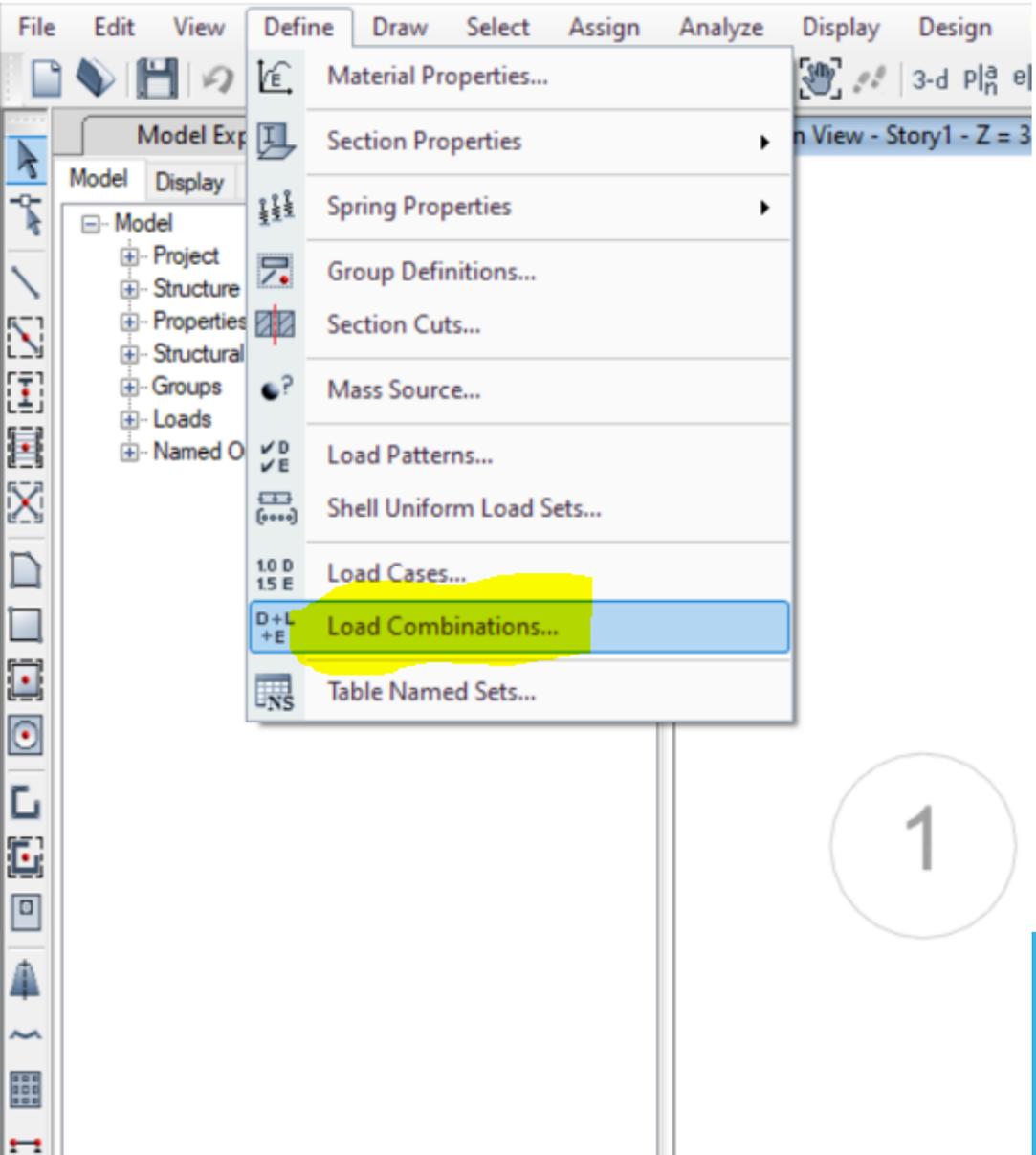
Define Load Patterns

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



General Data

Load Combination Name:

Combination Type:

Notes:

Auto Combination:

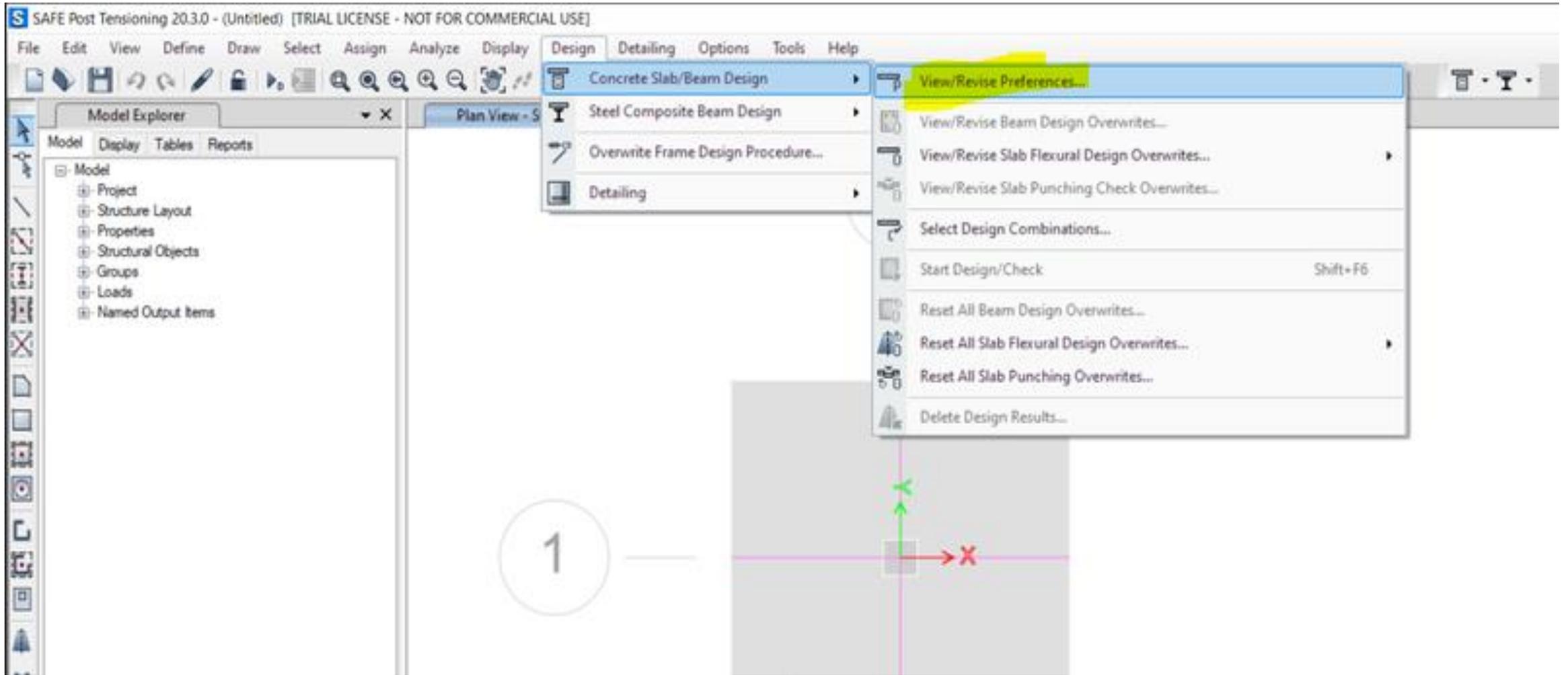
Define Combination of Load Case/Combo Results

Load Name	Scale Factor
Dead	1.5
Live	1.5

Combinations

- Comb1
- Comb2

Click to:



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

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

Design Code IS 456:2000

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

Single Column Footing

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

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


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

One-way Shear

The factored shearing force at the critical section

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

Where,

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

The allowable shear force

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

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 (ϕV_c) of concrete.

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

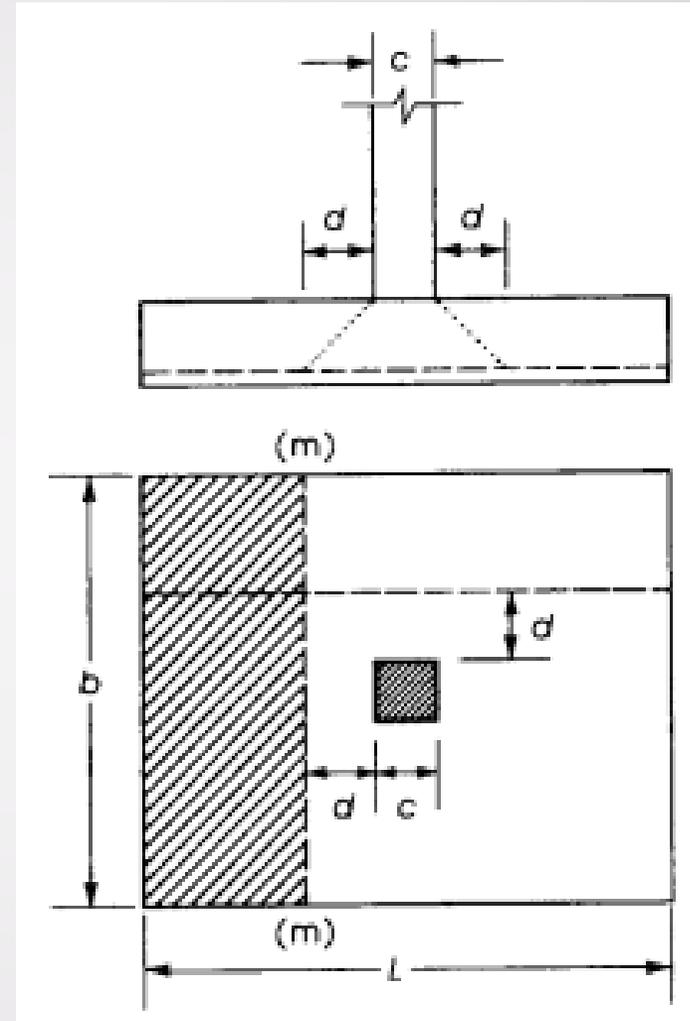


Fig.: One-way Shear

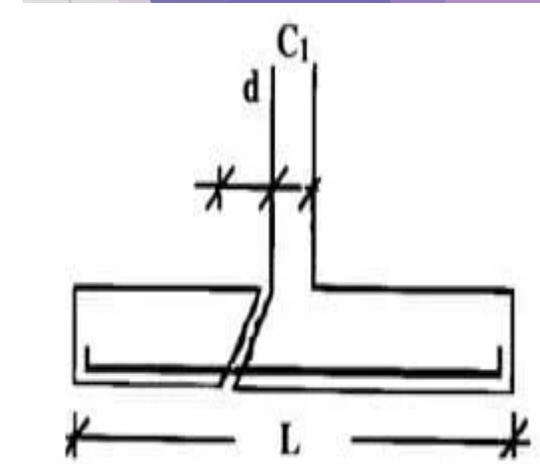


Fig.: One-way Shear Failure

Two-way Shear

The factored shearing force at the critical section

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

$$V_u = P_u - q_u(c_1 + d)(c_2 + d) \text{ for rectangular column}$$

Where,

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

The allowable shear force

$$\phi V_c = 4\phi\lambda\sqrt{f'_c}b_0d$$

Where,

$$b_0 = \text{perimeter of critical section}$$

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

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 (ϕV_c) of concrete.

$$\text{i.e., } \phi V_c \geq V_u$$

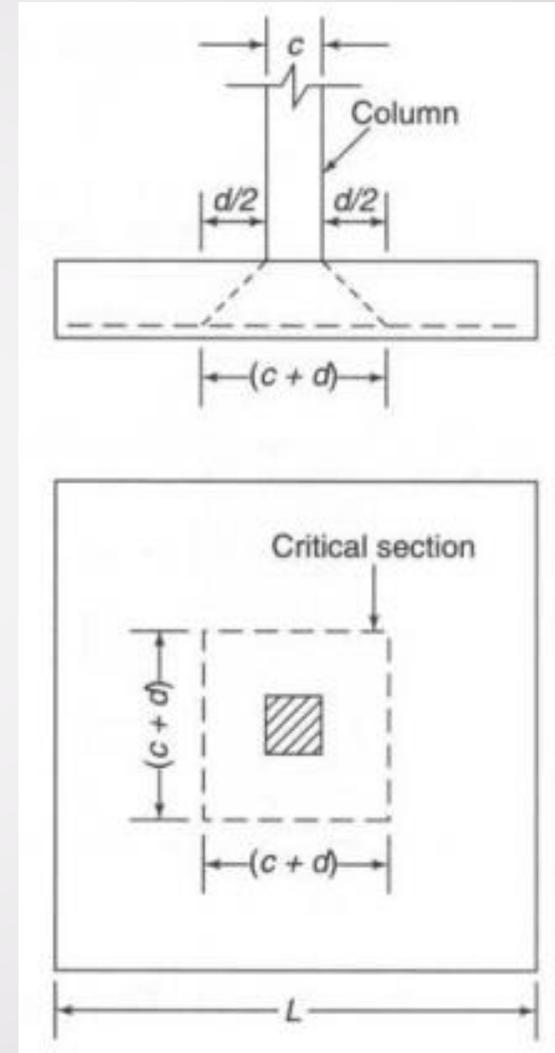


Fig.: Two-way Shear

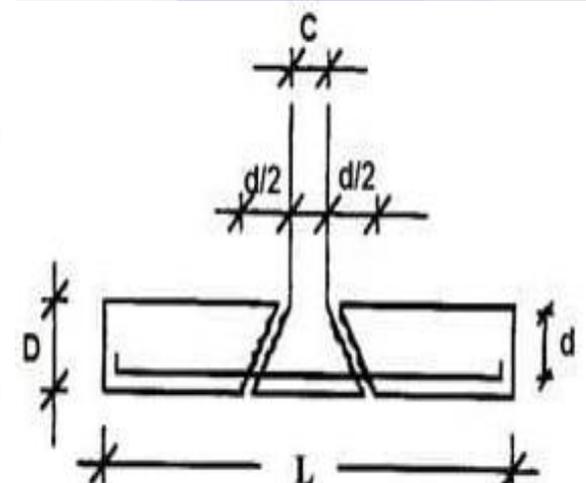


Fig.: Two-way Shear Failure

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,

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

For design,

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

Where,

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

From this equation calculate the required area of reinforcement.

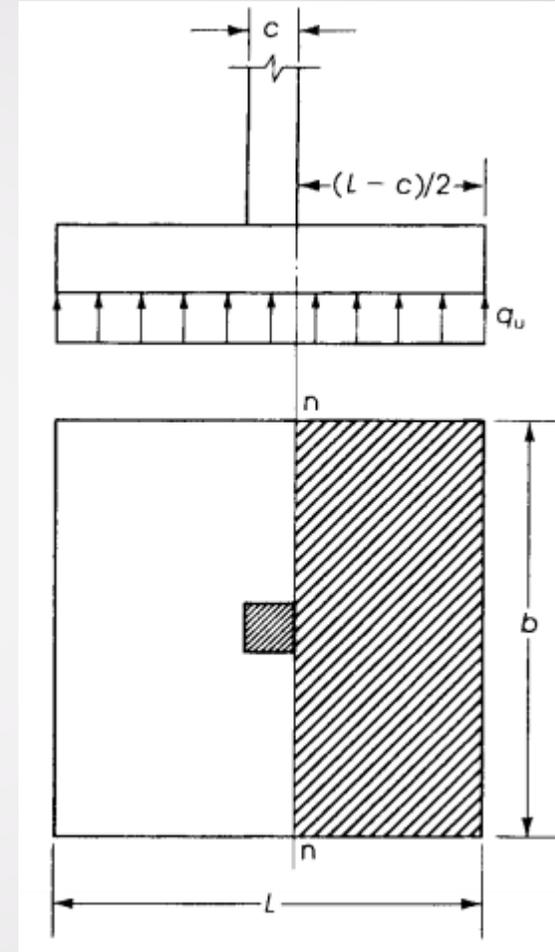


Fig.: Critical Section of Bending

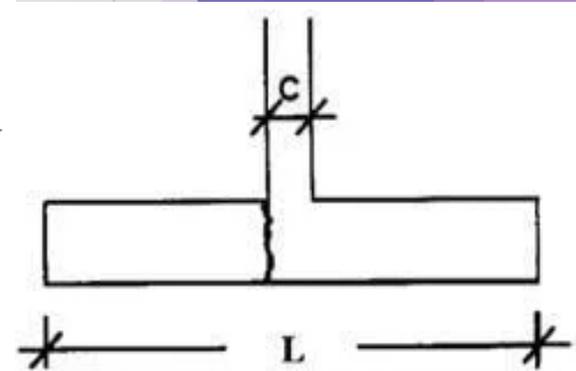
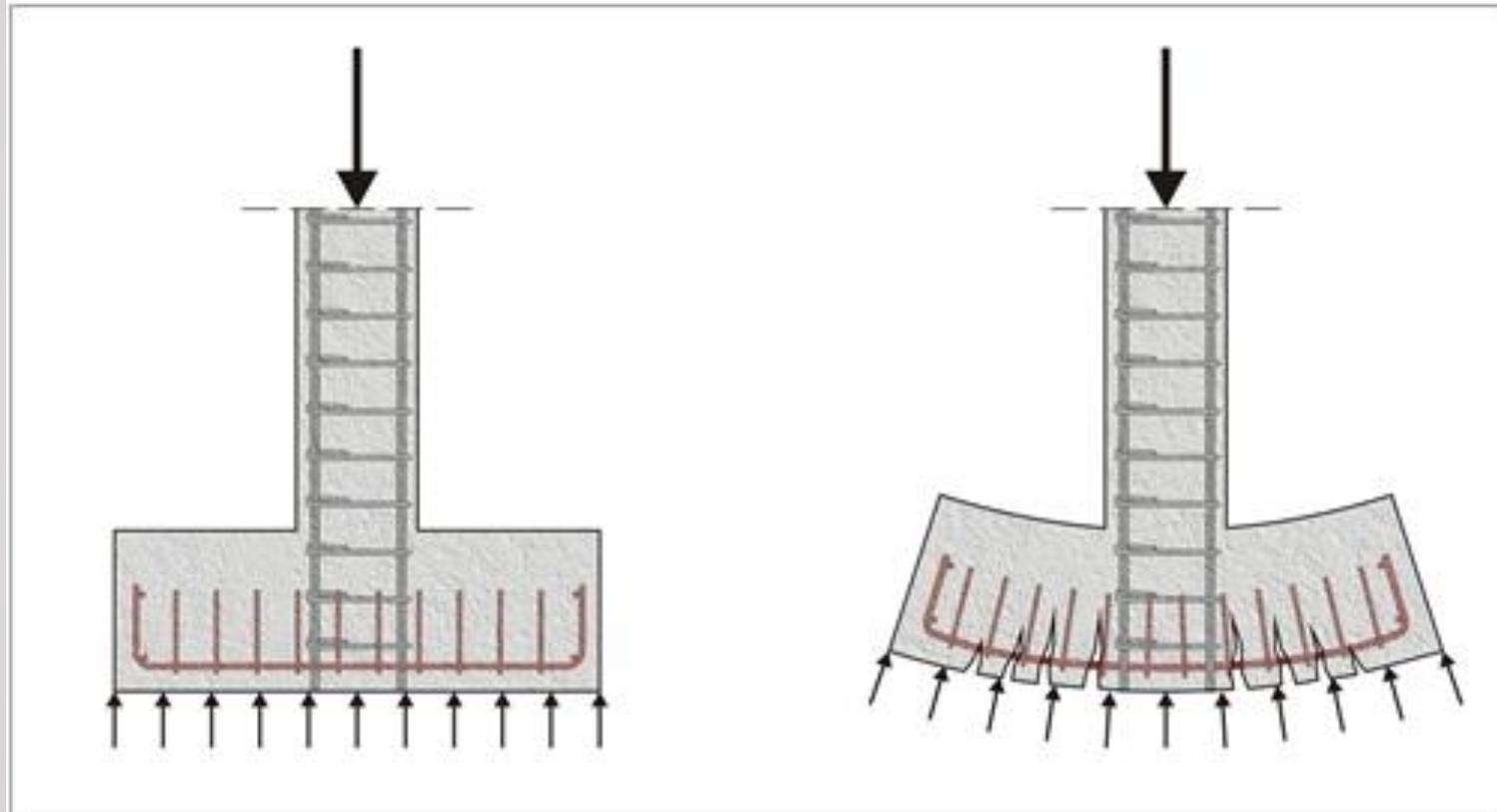
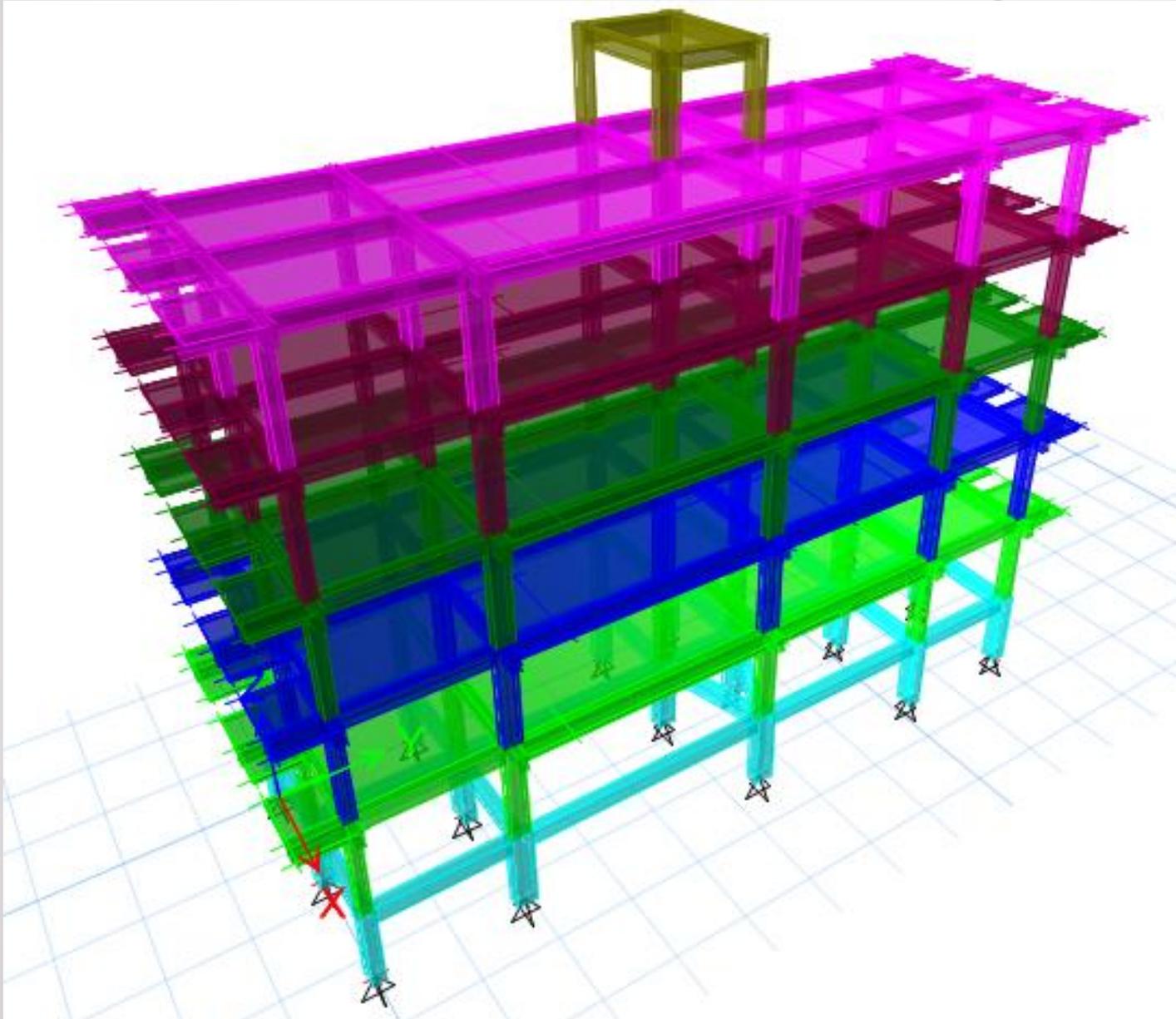


Fig.: Bending Failure

Single Column Footing Under Loading Condition



ETABS Model of a Building



Reaction Load of Footing From ETABS Model

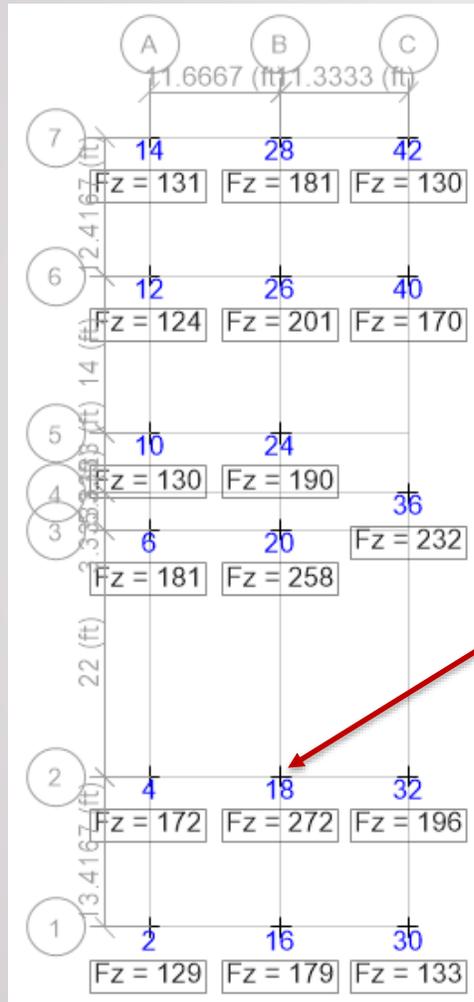


Fig.: Reaction for Service Load (DL+LL)

$P=272$ 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:

$$\begin{aligned} \text{Area of Footing} &= \frac{\text{Total Service Load}}{\text{Allowable Soil Pressure}} \\ &= \frac{272}{3.0} = 90.67 \text{ ft}^2 \end{aligned}$$

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

$$\text{Size of Footing} = 10'-0'' \times 10'-0''$$

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

Continue...

One-way Punching:

The factored shearing force at the critical section

$$\begin{aligned}V_u &= q_u b \left(\frac{L}{2} - \frac{c}{2} - d \right) \\ &= q_u b \left(\frac{L}{2} - \frac{c}{2} - d \right) \\ &= 3.47 \times 10 \times \left(\frac{10}{2} - \frac{15}{2 \times 12} - \frac{15}{12} \right) \\ &= 108.44 \text{ kips}\end{aligned}$$

The allowable shear force

$$\begin{aligned}\phi V_c &= 2\phi\lambda\sqrt{f'_c}bd \\ &= 2 \times 0.75 \times 1 \times \sqrt{3500} \times (10 \times 12) \times 15 \\ &= 159734 \text{ lb} \\ &= 159.734 \text{ kips}\end{aligned}$$

Here, $\phi V_c > V_u$

So, $d=15''$ is **Ok**.

$$\begin{aligned}q_u &= \frac{Pu (1.2DL + 1.6LL)}{\text{Area of footing}} \\ &= \frac{347}{100} \\ &= 3.47 \text{ ksf} > 3.0 \text{ ksf}\end{aligned}$$

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

$$\begin{aligned}V_u &= P_u - q_u(c + d)^2 \text{ for square column} \\ &= 347 - 3.47 \times \left(\frac{15}{12} + \frac{15}{12}\right)^2 \\ &= 325.31 \text{ kips}\end{aligned}$$

The allowable shear force

$$\begin{aligned}\phi V_c &= 4\phi\lambda\sqrt{f'_c}b_0d \\ &= 4 \times 0.75 \times 1 \times \sqrt{3500} \times 120 \times 15 \\ &= 319468 \text{ lb} \\ &= 319.468 \text{ kips}\end{aligned}$$

Here, $\phi V_c < V_u$

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

$$\begin{aligned}q_u &= \frac{P_u (1.2DL + 1.6LL)}{\text{Area of footing}} \\ &= \frac{347}{100} \\ &= 3.47 \text{ ksf} > 3.0 \text{ ksf}\end{aligned}$$

$$b=10 \text{ ft}$$

$$L=10 \text{ ft}$$

$$\text{Column Size} = 15'' \times 15''$$

$$c=15''$$

$$\text{Let, } d = 15''$$

$$b_0 = 4 \times (15+15) = 120''$$

Continue...

Two-way Punching:

The factored shearing force at the critical section

$$\begin{aligned}V_u &= P_u - q_u(c + d)^2 \text{ for square column} \\ &= 347 - 3.47 \times \left(\frac{15}{12} + \frac{17}{12}\right)^2 \\ &= 322.32 \text{ kips}\end{aligned}$$

The allowable shear force

$$\begin{aligned}\phi V_c &= 4\phi\lambda\sqrt{f'_c}b_0d \\ &= 4 \times 0.75 \times 1 \times \sqrt{3500} \times 128 \times 17 \\ &= 386201 \text{ lb} \\ &= 386.201 \text{ kips}\end{aligned}$$

Here, $\phi V_c > V_u$

So, $d=17''$ is **Ok**.

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

Now, Footing Dimension = $10'-0'' \times 10'-0'' \times 1'-8''$

$$\begin{aligned}q_u &= \frac{Pu (1.2DL + 1.6LL)}{\text{Area of footing}} \\ &= \frac{347}{100} \\ &= 3.47 \text{ ksf} > 3.0 \text{ ksf}\end{aligned}$$

$b=10 \text{ ft}$

$L=10 \text{ ft}$

Column Size= $15'' \times 15''$

$c=15''$

Let, $d = 17''$

$b_0 = 4 \times (15+17) = 128''$

Continue...

Reinforcement Design:

The bending moment at the critical section

$$\begin{aligned}M_u &= \frac{1}{2} q_u b \left(\frac{L}{2} - \frac{c}{2} \right)^2 \\&= \frac{1}{2} \times 3.47 \times 10 \times \left(\frac{10}{2} - \frac{15}{2 \times 12} \right)^2 \\&= 332.09 \text{ kip} - \text{ft} \\&= 3985 \text{ kip} - \text{inch}\end{aligned}$$

Now,

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

$$\begin{aligned}\text{Or, } A_s &= \frac{M_u}{\phi f_y \left(d - \frac{a}{2} \right)} \\&= \frac{3985}{0.9 \times 60 \times \left(17 - \frac{1}{2} \right)} \quad (\text{Say } a=1) \\&= 4.47 \text{ in}^2\end{aligned}$$

$$\begin{aligned}q_u &= \frac{Pu (1.2DL + 1.6LL)}{\text{Area of footing}} \\&= \frac{347}{100} \\&= 3.47 \text{ ksf} > 3.0 \text{ ksf}\end{aligned}$$

$$b=10 \text{ ft}$$

$$L=10 \text{ ft}$$

$$\text{Column Size} = 15'' \times 15''$$

$$c=15''$$

$$d=17''$$

Continue...

$$\begin{aligned}\text{Check } a &= \frac{A_s f_y}{0.85 f'_c b} \\ &= \frac{4.47 \times 60}{0.85 \times 3.5 \times (10 \times 12)} \\ &= 0.693 < a\end{aligned}$$

So do it again considering $a = 0.69$

$$\begin{aligned}A_s &= \frac{M_u}{\phi f_y \left(d - \frac{a}{2} \right)} \\ &= \frac{3985}{0.9 \times 60 \times \left(17 - \frac{0.69}{2} \right)} \quad (\text{Say } a = 0.69) \\ &= 4.43 \text{ in}^2\end{aligned}$$

$$\begin{aligned}\text{Check } a &= \frac{A_s f_y}{0.85 f'_c b} \\ &= \frac{4.43 \times 60}{0.85 \times 3.5 \times (10 \times 12)} \\ &= 0.687 \approx a\end{aligned}$$

So, $A_s = 4.43 \text{ in}^2$

$$\begin{aligned}q_u &= \frac{Pu (1.2DL + 1.6LL)}{\text{Area of footing}} \\ &= \frac{347}{100} \\ &= 3.47 \text{ ksf} > 3.0 \text{ ksf}\end{aligned}$$

$b = 10 \text{ ft}$

$L = 10 \text{ ft}$

Column Size = 15" X 15"

$c = 15''$

$d = 17''$

Continue...

Minimum Area of Reinforcement:

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

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

So, Required area of reinforcement, $A_s = 7.992 \text{ in}^2$

$$\begin{aligned}\text{Spacing of reinforcement} &= \frac{ba_s}{A_s} \\ &= \frac{10 \times 12 \times 0.31}{7.992} \\ &= 4.65 \text{ in}\end{aligned}$$

Provide 16mmØ @ 4.5 inch c/c.

$$\begin{aligned}q_u &= \frac{Pu(1.2DL + 1.6LL)}{\text{Area of footing}} \\ &= \frac{347}{100} \\ &= 3.47 \text{ ksf} > 3.0 \text{ ksf}\end{aligned}$$

b=10 ft

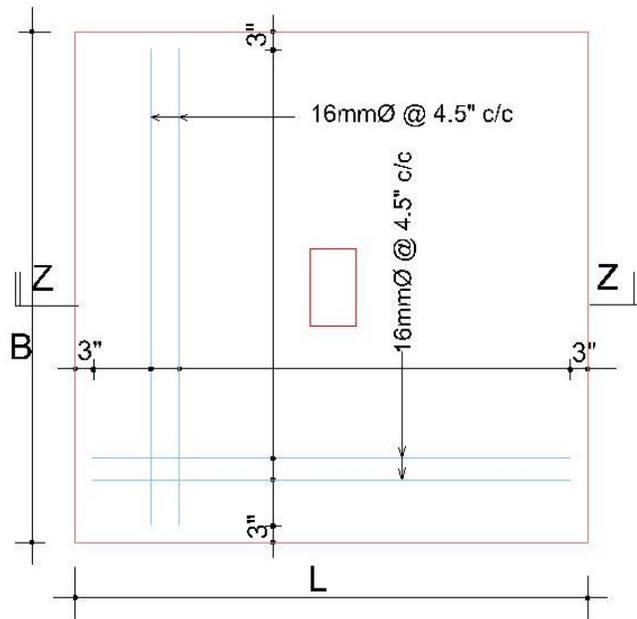
L=10 ft

Column Size= 15" X 15"

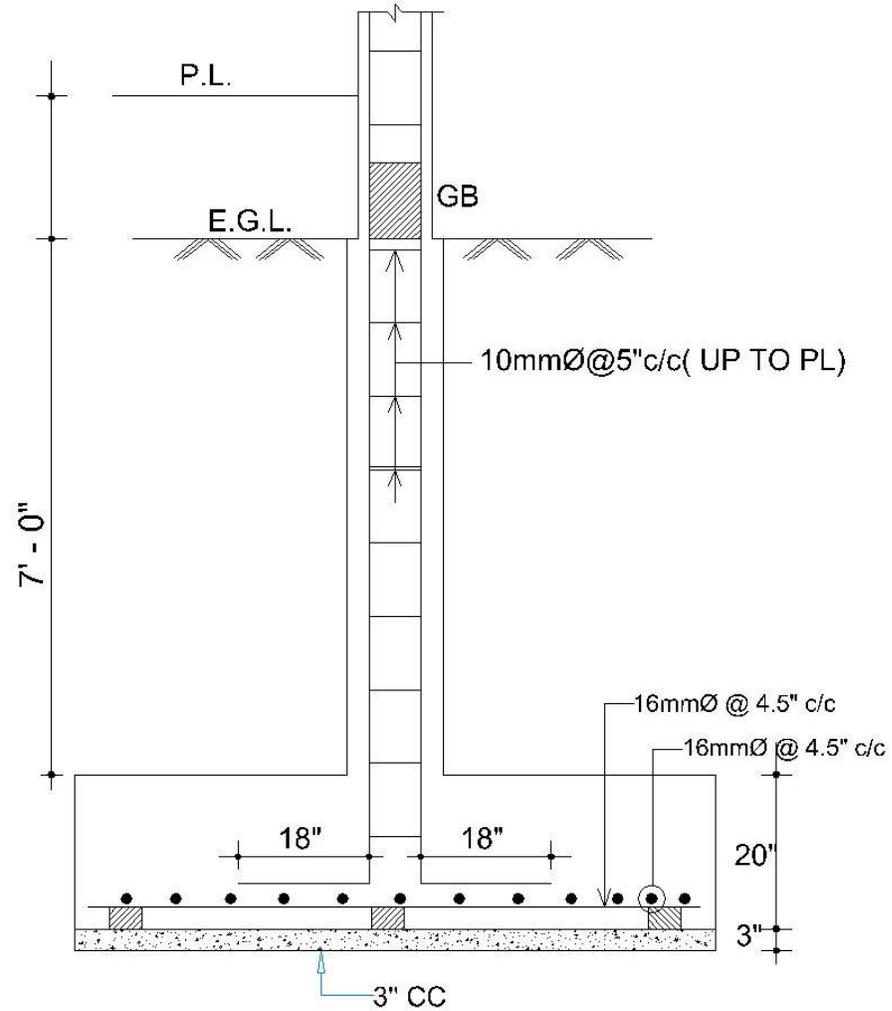
c=15"

d=17"

Detailing of Single Column Footing



PLAN OF FOOTING



Section Z-Z

Reaction Load of Footing From ETABS Model

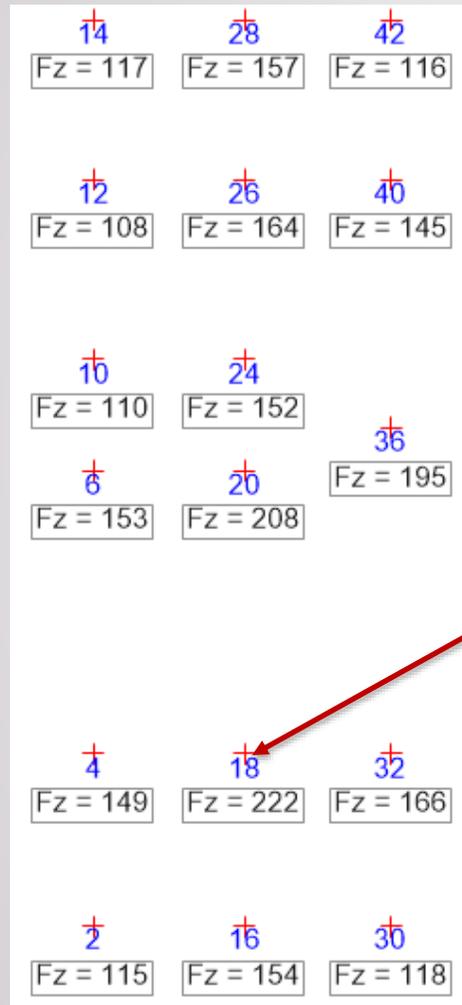


Fig.: Reaction for Dead Load (DL)

$P_{DL} = 222$ kips
 $P_{LL} = 50$ kips

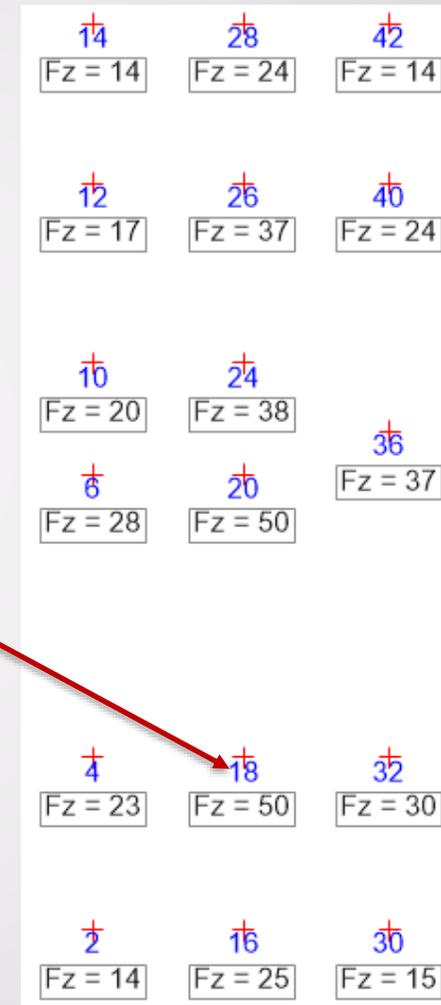
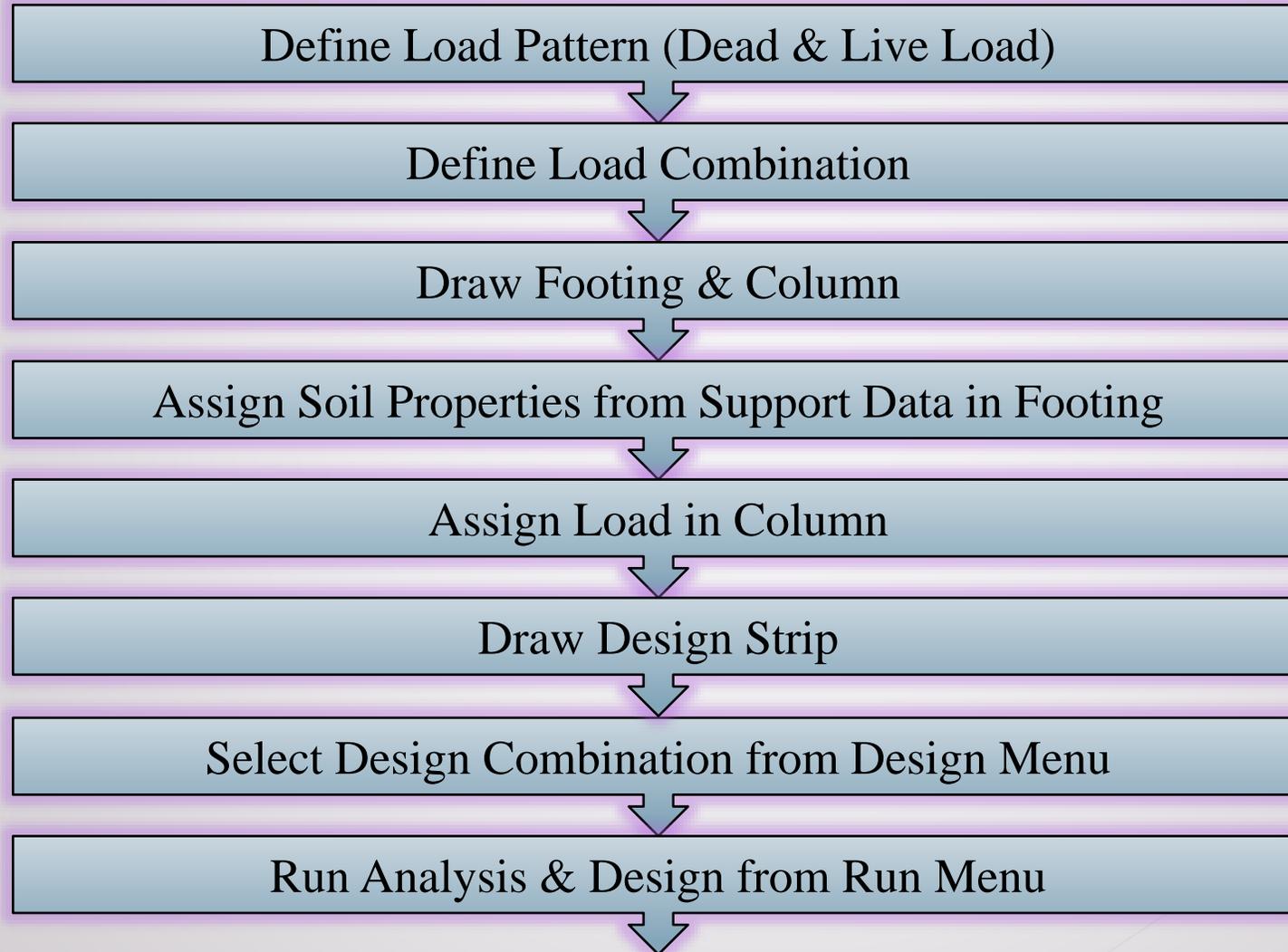


Fig.: Reaction for Live Load (LL)

Single Column Footing Design With SAFE Software



Continue...



Continue...

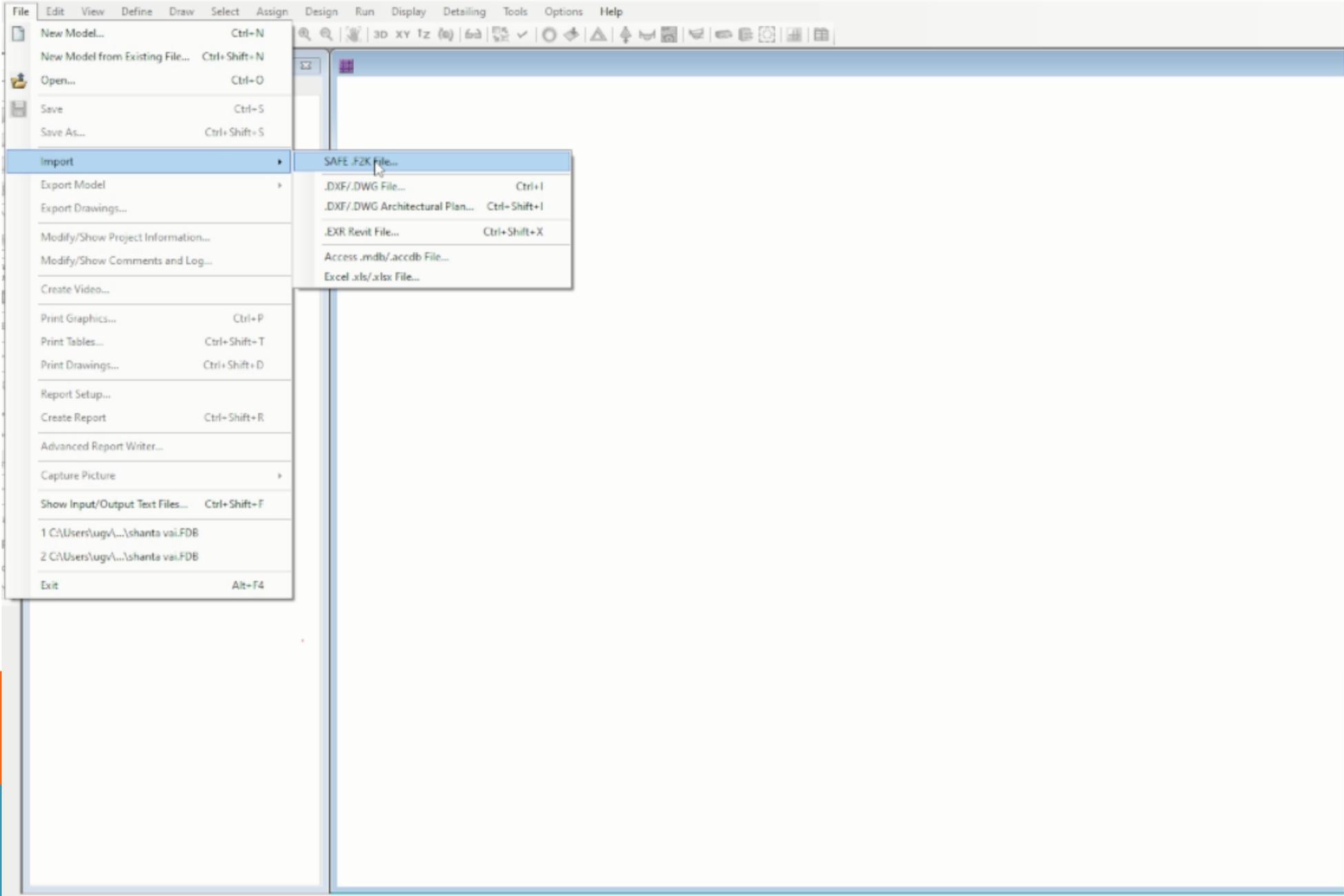




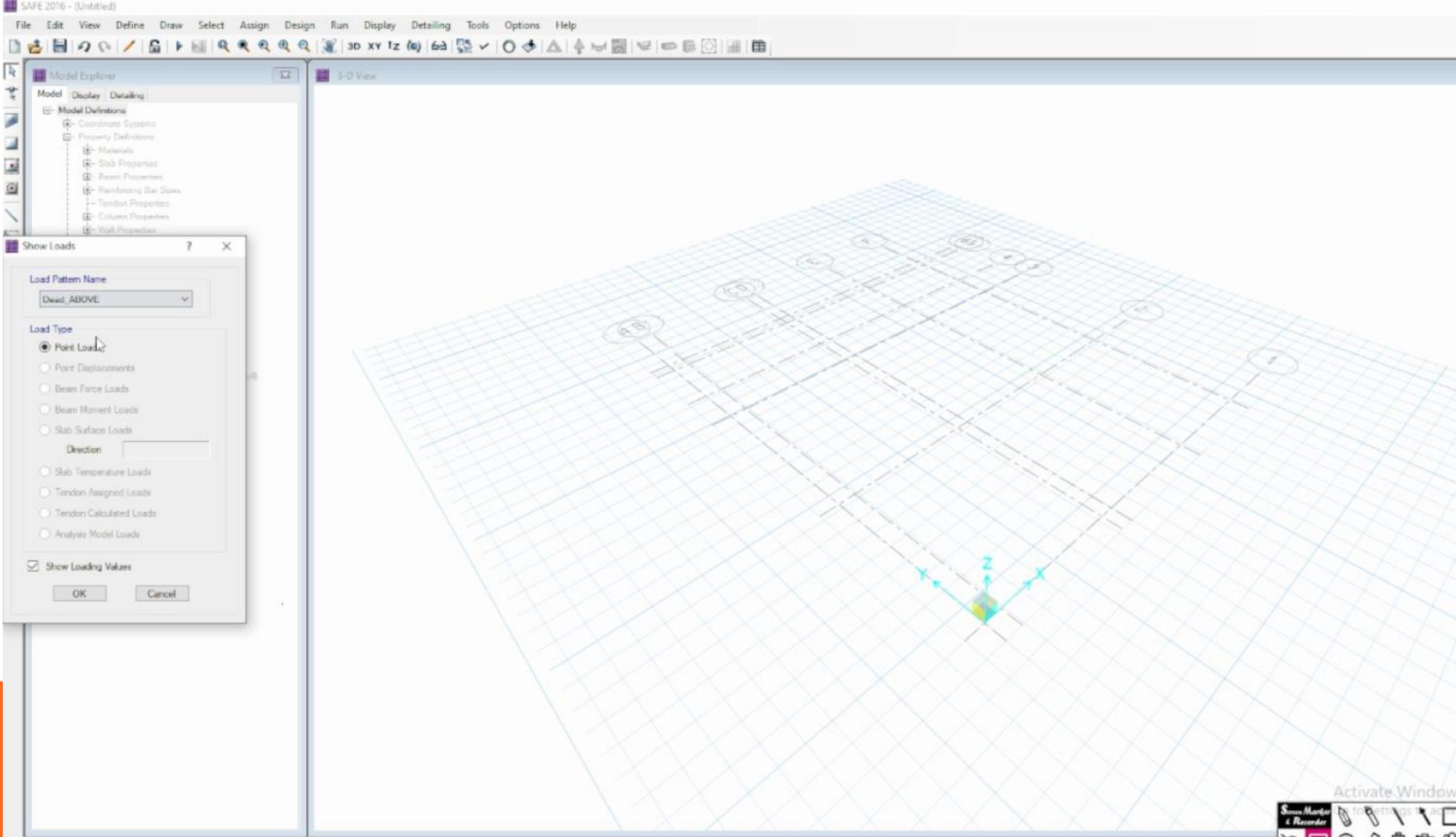
Design of Single Column Footing-II

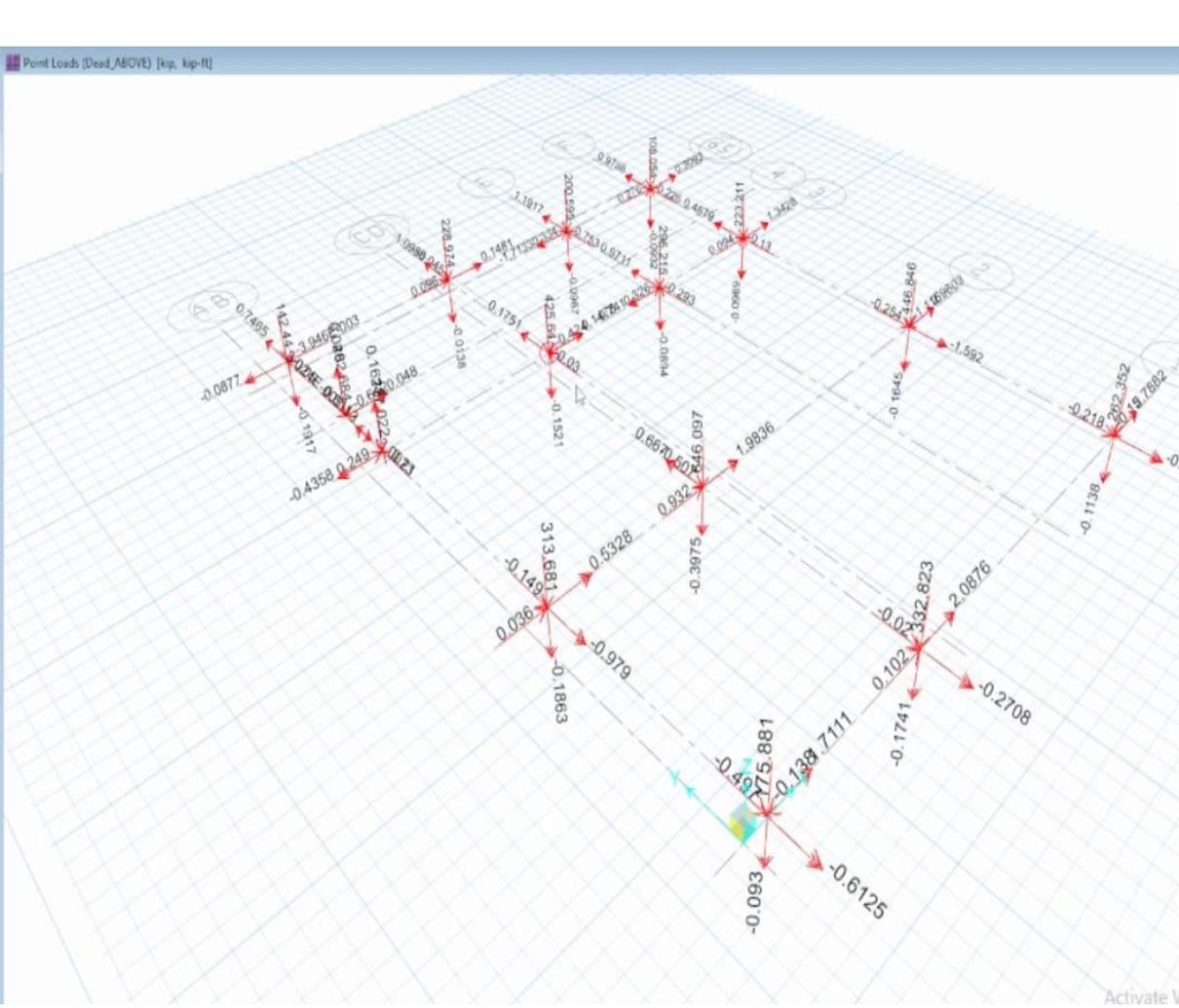
Week 7

Pages 58-66



Use File Menu to Create or Open Model





Model Explorers

Model Display Detailing

- Model Definitions
 - Coordinate Systems
 - Property Definitions
 - Materials
 - Slab Properties
 - Beam Properties
 - Reinforcing Bar Sizes
 - Tendon Properties
 - Column Properties
 - Wall Properties
 - Soil Subgrade Properties
 - Point Spring Properties
 - Line Spring Properties
 - Load Definitions
 - Load Patterns
 - Load Cases
 - Load Combinations
 - Groups
 - Objects
 - Area Objects (Slabs)
 - Line Objects (Beams)
 - Tendon Objects
 - Slab Rebar Objects
 - Design Time Objects
 - Point Objects

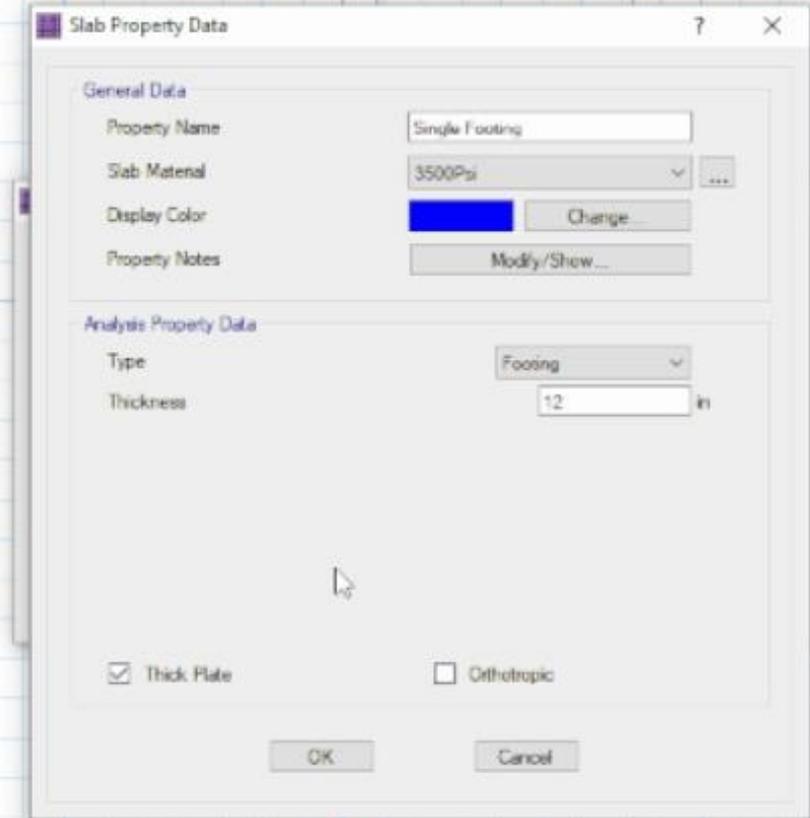
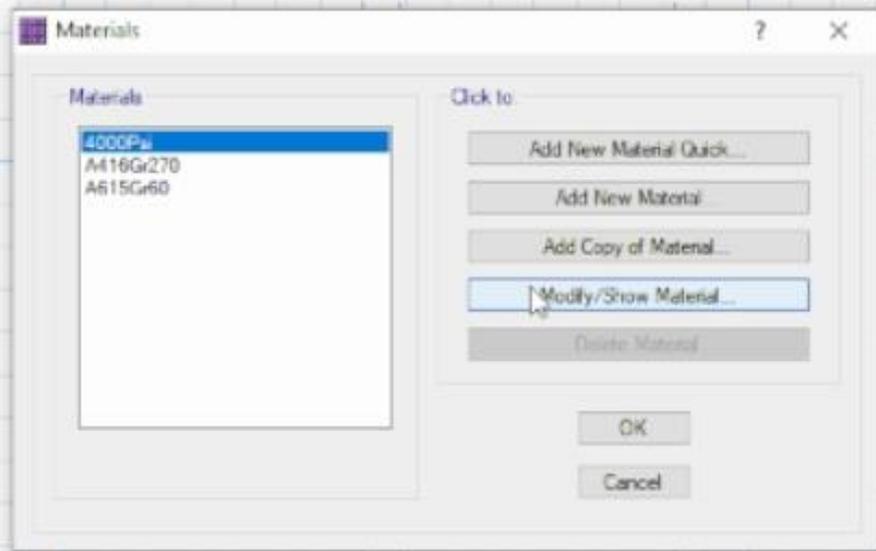
Plan View

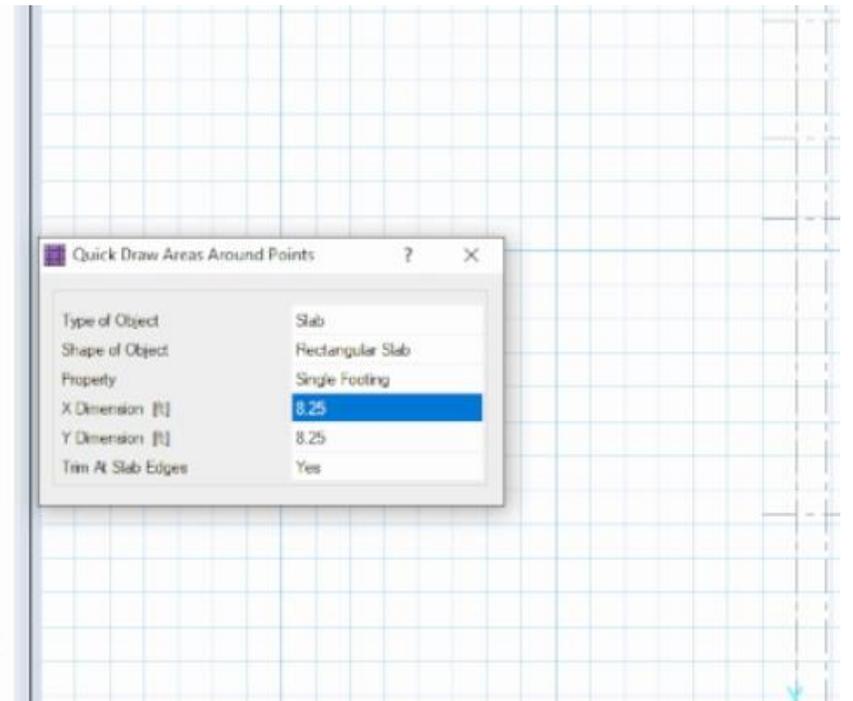
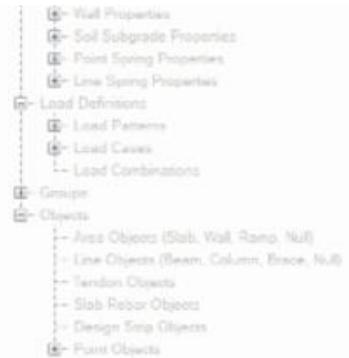
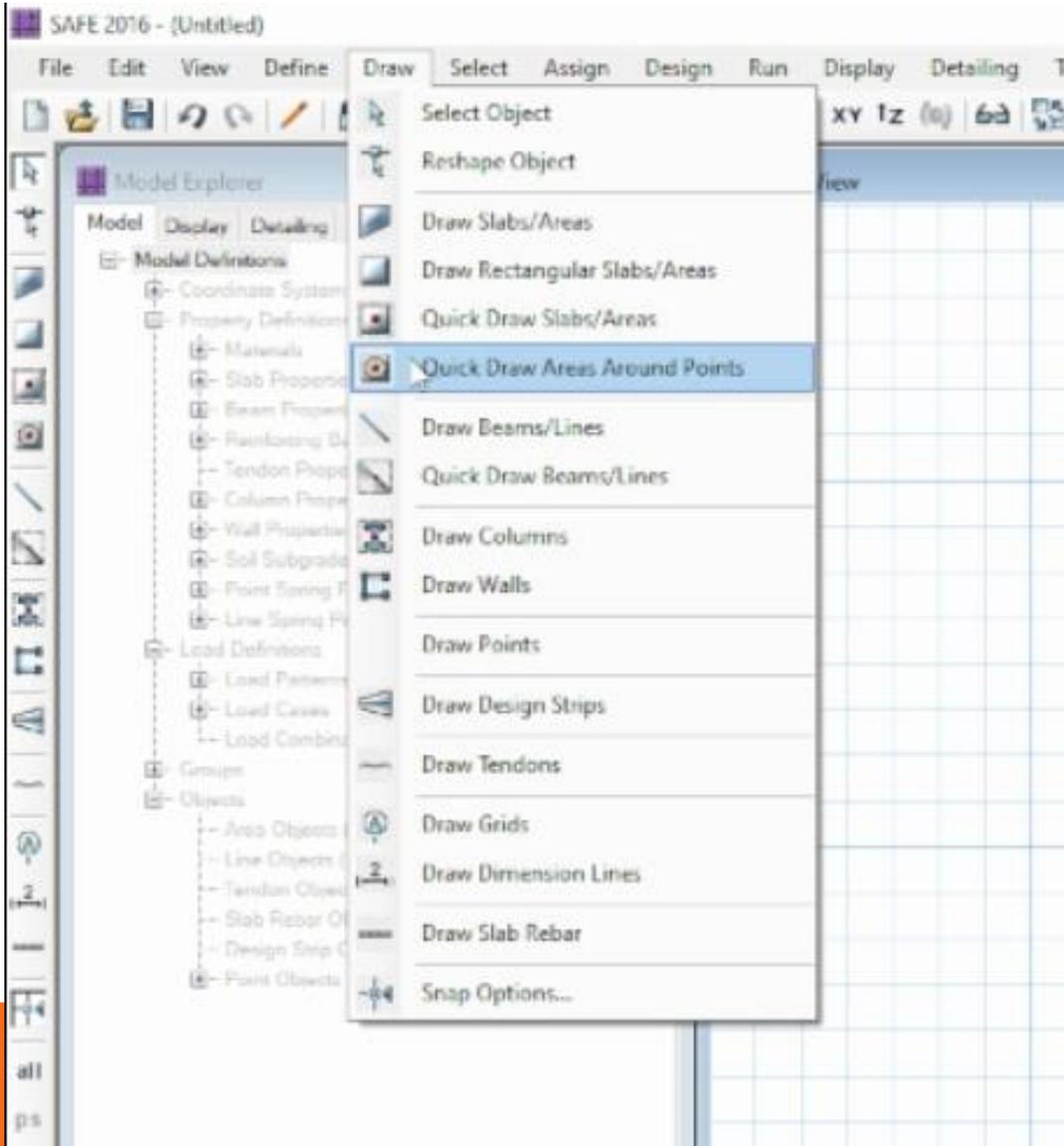
Point Object Information

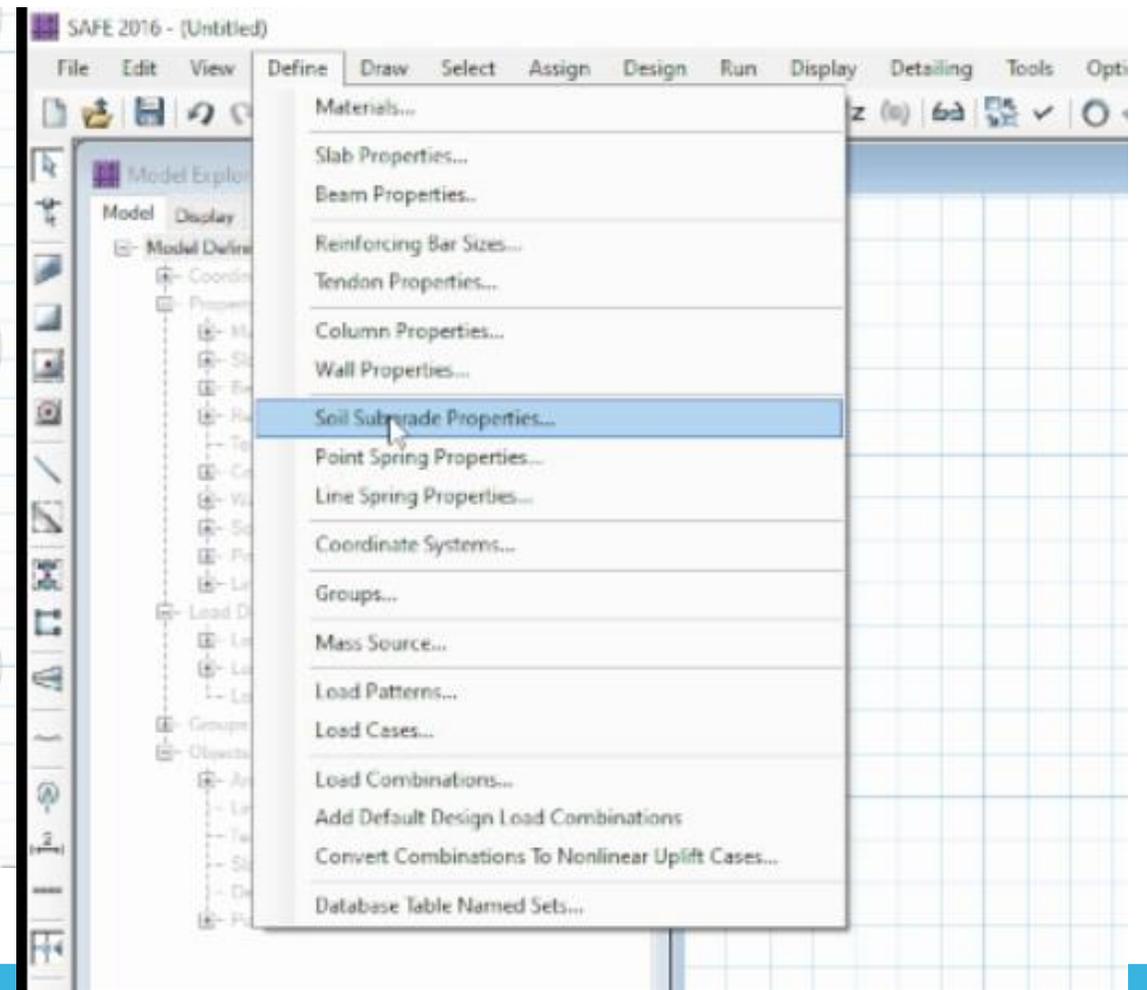
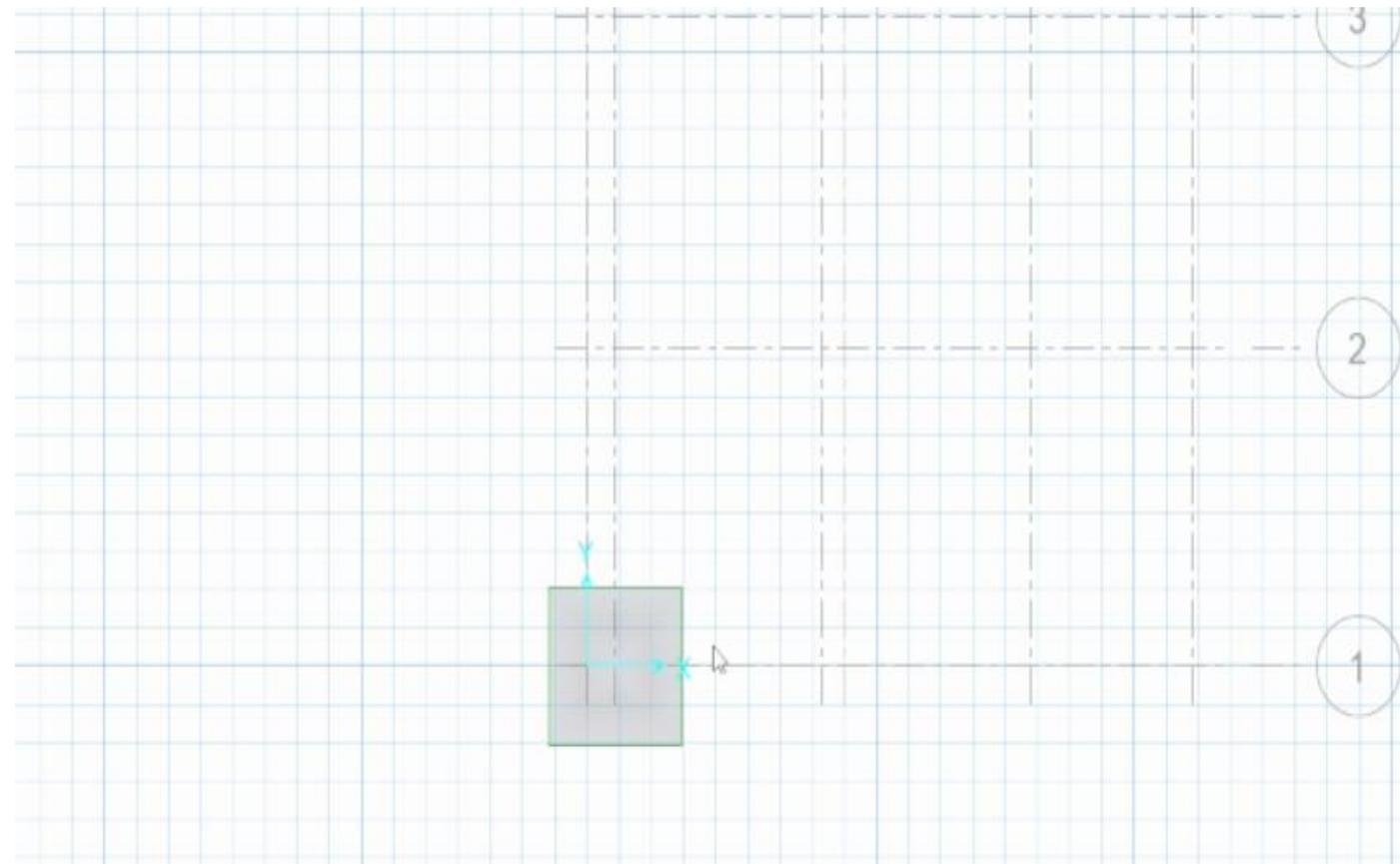
Point Object Name: 11

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	

Buttons: Assign Load, Reset All, OK, Cancel







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

Compression Stiffness:

Compression Strength:

Tension Stiffness:

Tension Strength:

OK Cancel

$q_u = 3 \times 3.75$

Δ

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

Model Explorer

Model Display Detailing

- Model Definitions
 - Coordinate Systems
 - Property Definitions
 - Materials
 - Slab Properties
 - Beam Properties
 - Reinforcing Bar Sizes
 - Tendon Properties
 - Column Properties
 - Wall Properties
 - Soil Subgrade Properties

Slab Strip Design - Layer A - Bottom Reinforcement Intensity (Enveloping Flexural) [In2/Ft]

Slab Design

Choose Display Type

Design Basis:

Display Type:

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:

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

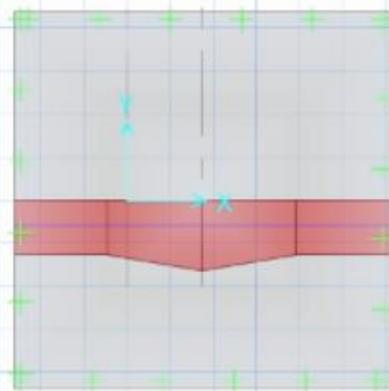
Define by Bar Area and Bar Spacing

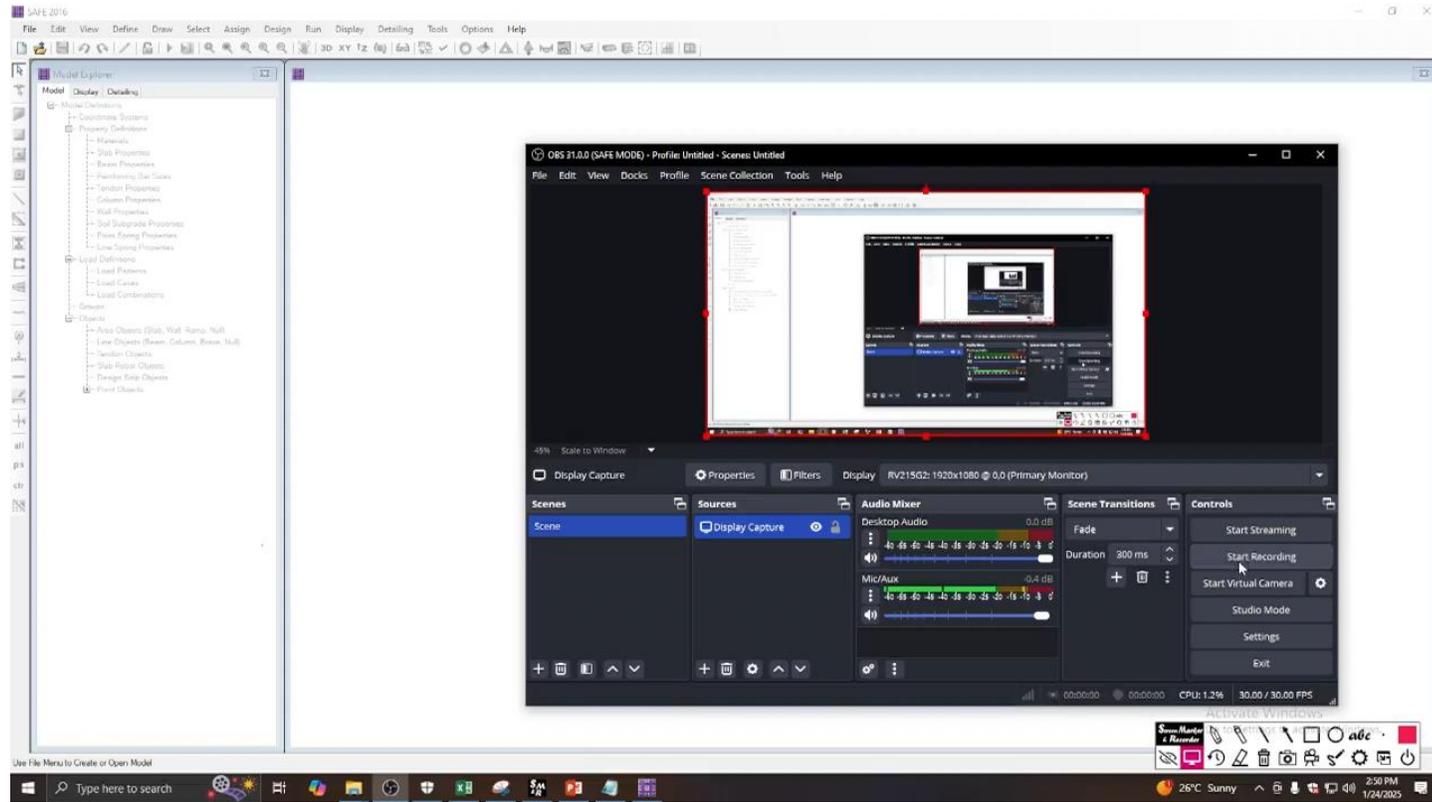
Bar Size Spacing (in)

Top:

Bottom:

Apply Close





Design of Single Column Footing (video)



Design of Combined Footing-I

Week 8-9

Pages 68-75

Skill Details:

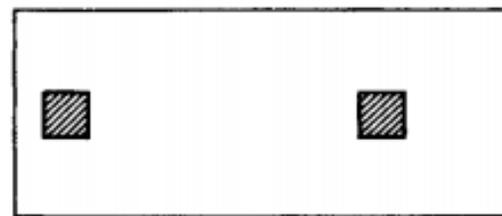
- Understanding the design procedure of combined column footing (hand calculation)
- Assigning the loads/structural frame
- Assigning area of footing according to soil test report
- Assigning grade of concrete and steel
- Run the model
- Checking the accuracy of results
- Detecting the problems and solving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

Combined Footing

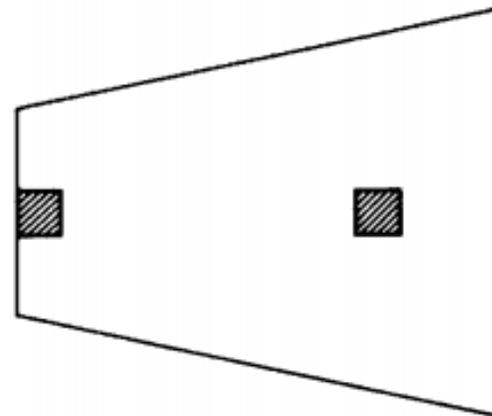
Definition: *A combined footing is a type of shallow foundation where a common base is provided for two closely spaced columns.*

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.



Rectangular



Trapezoidal

Figure Combined footings.

Design Consideration

Same as individual Column Footing

Size of Footing

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


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

One-way and Two-way Shear

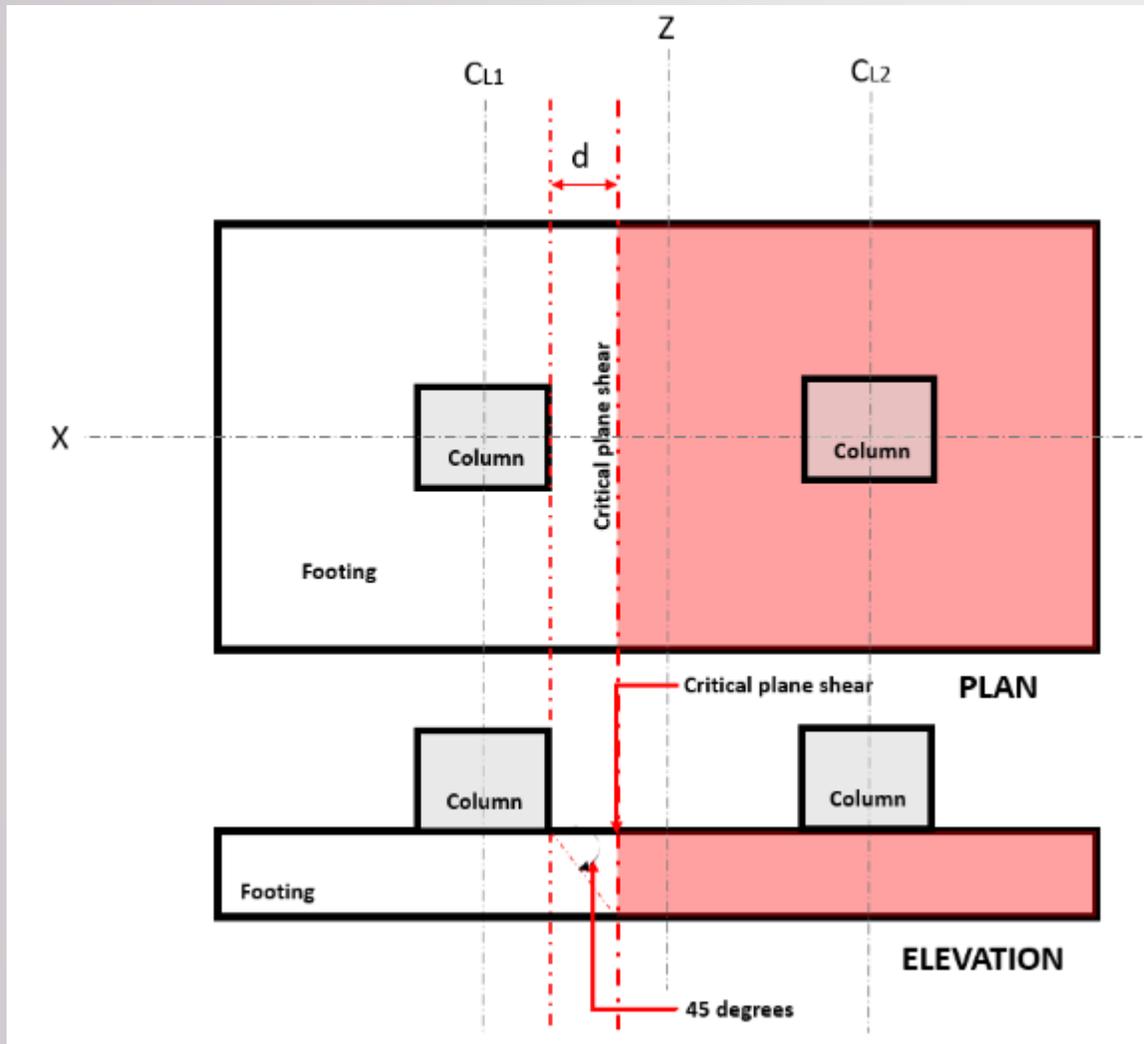


Fig.: One-way Shear

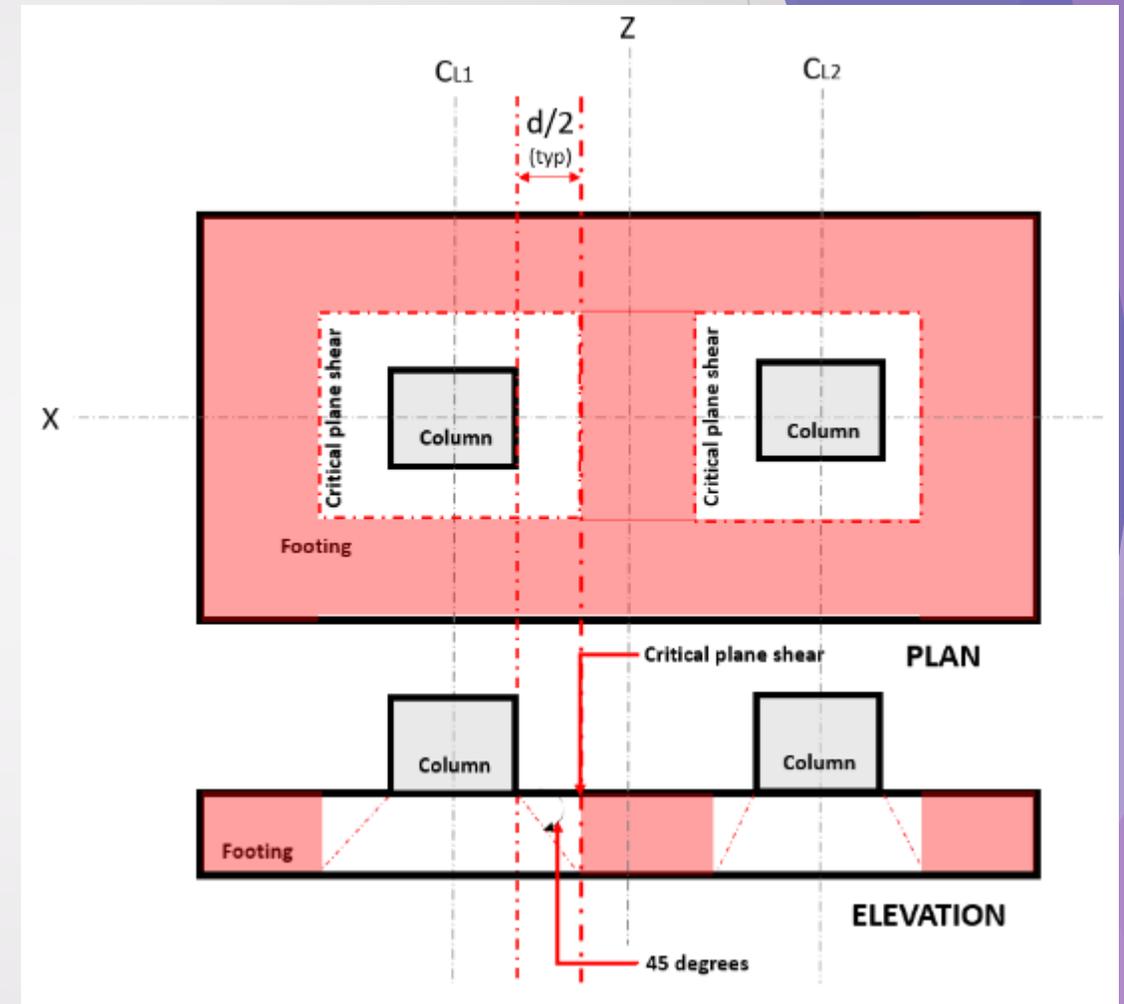


Fig.: Two-way Shear

Flexural Strength and Footing Reinforcement

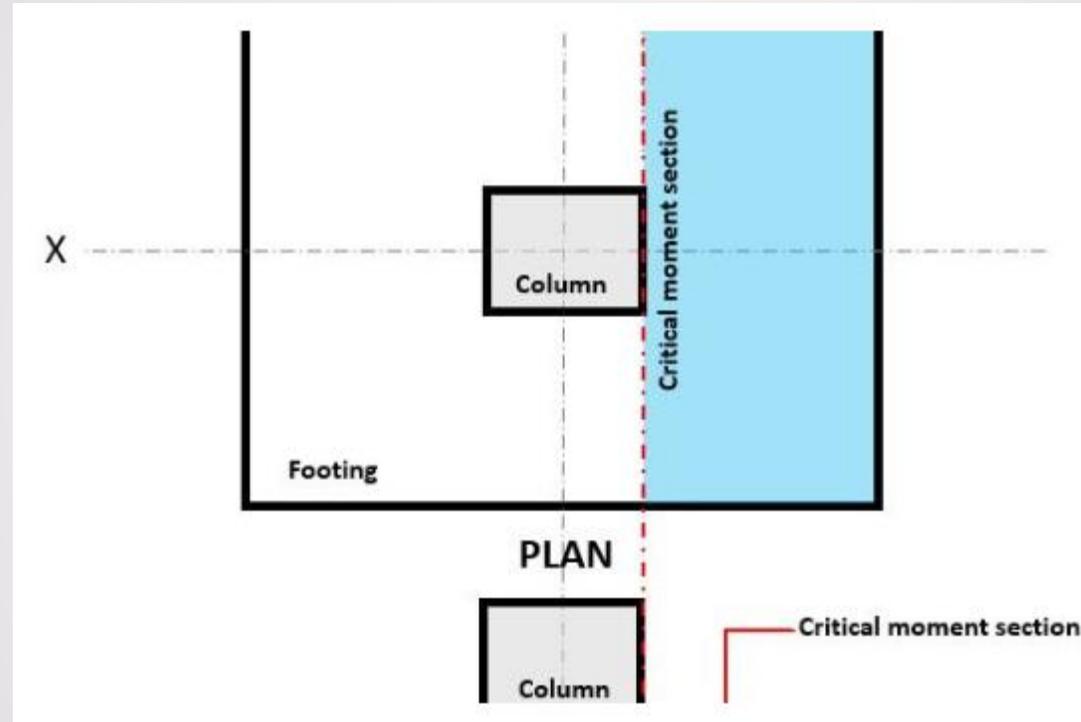
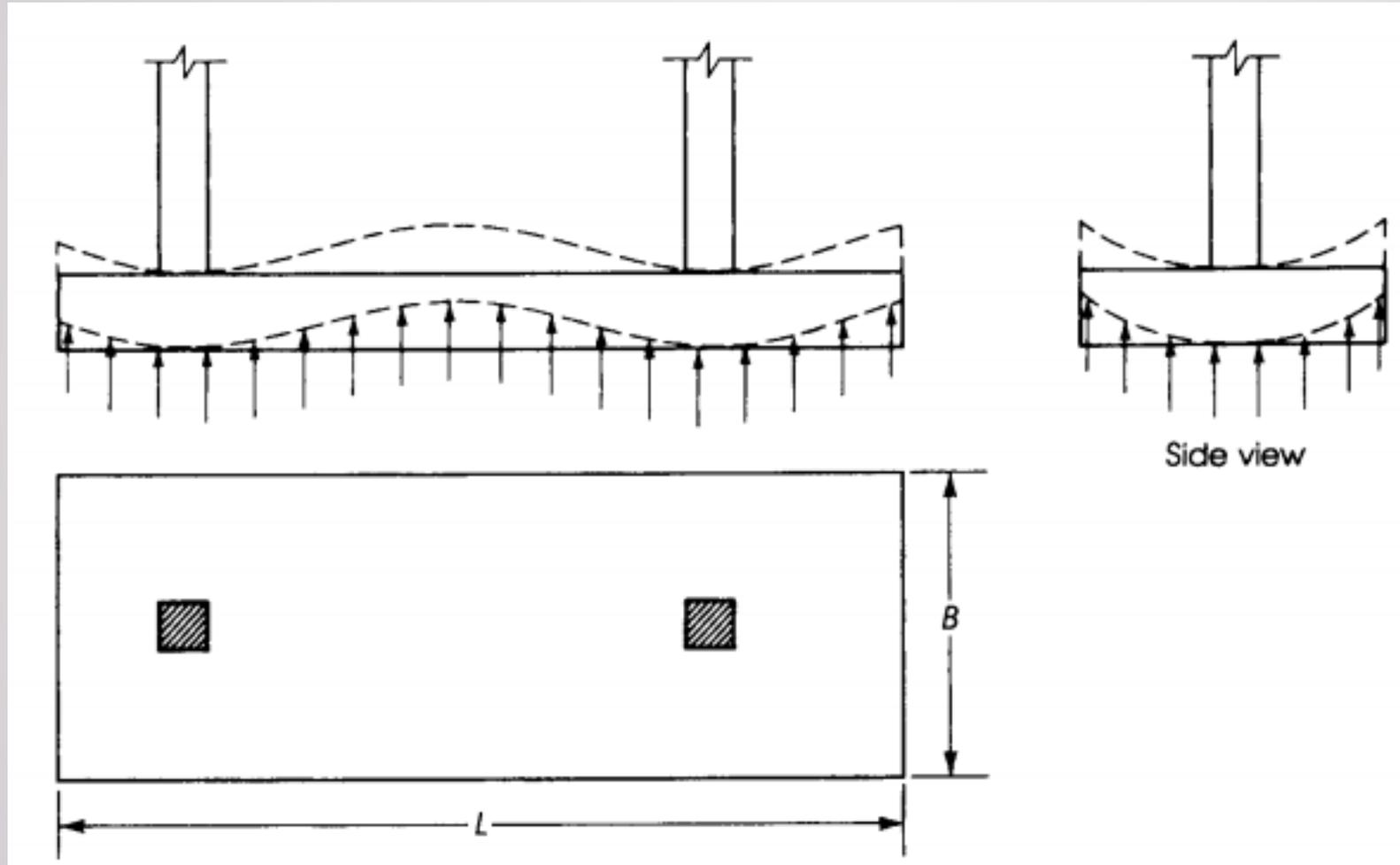
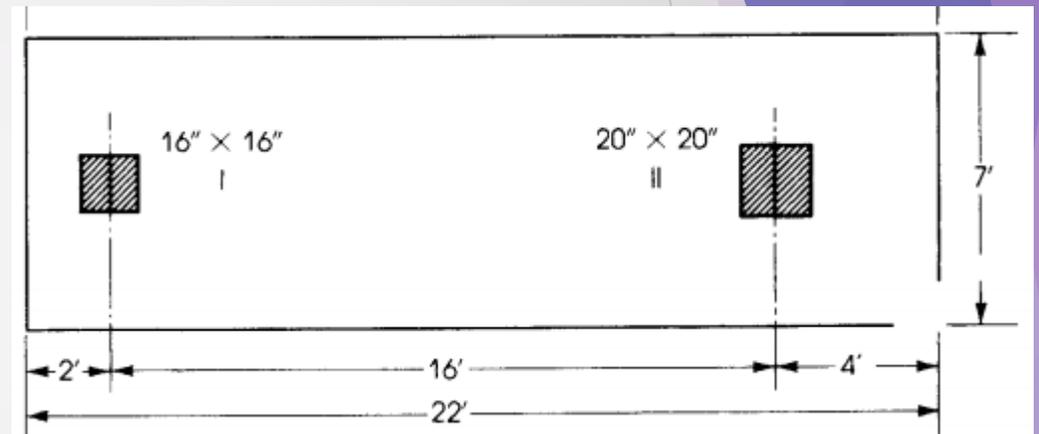
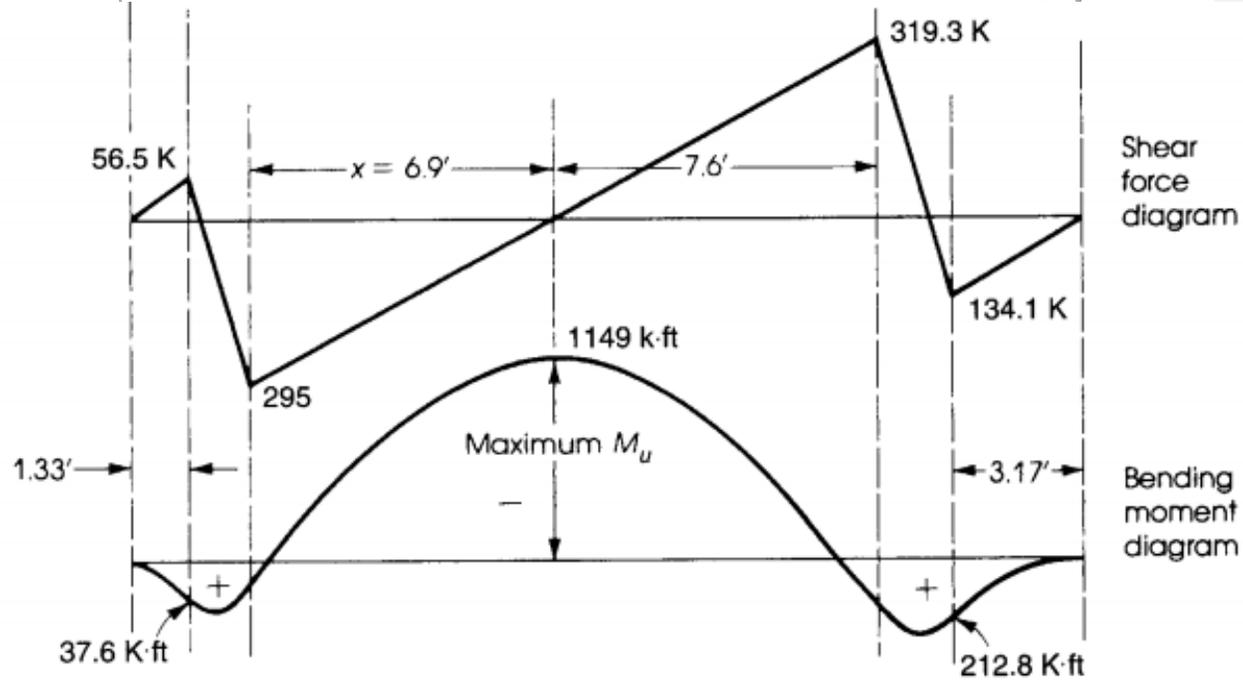
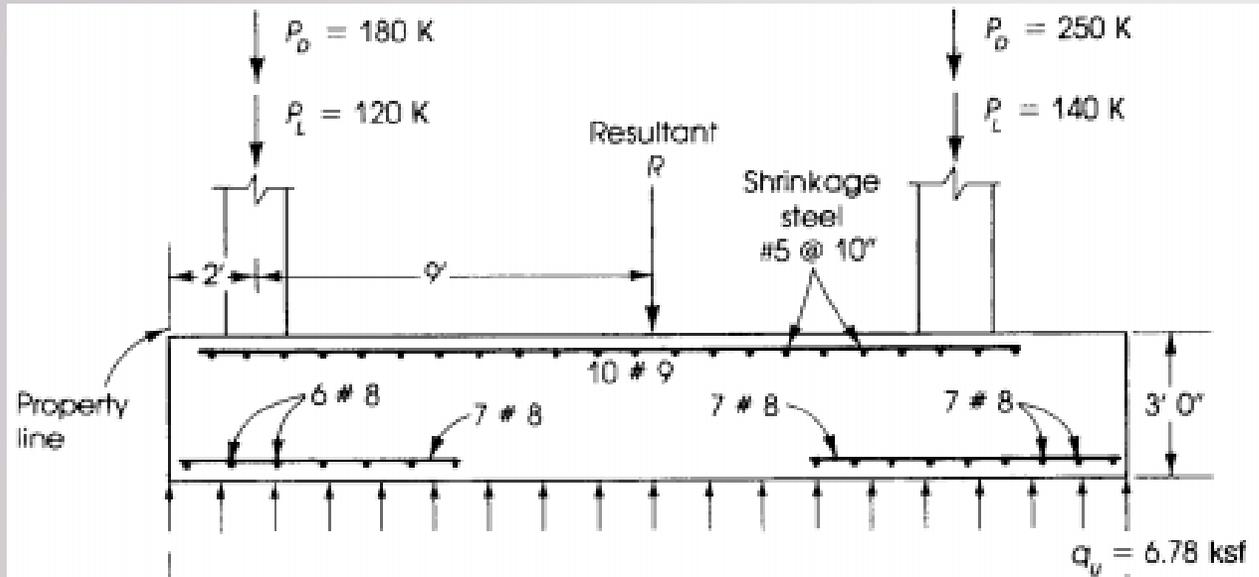


Fig.: Critical Section of Bending

Combined Footing Under Loading Condition



Continue...

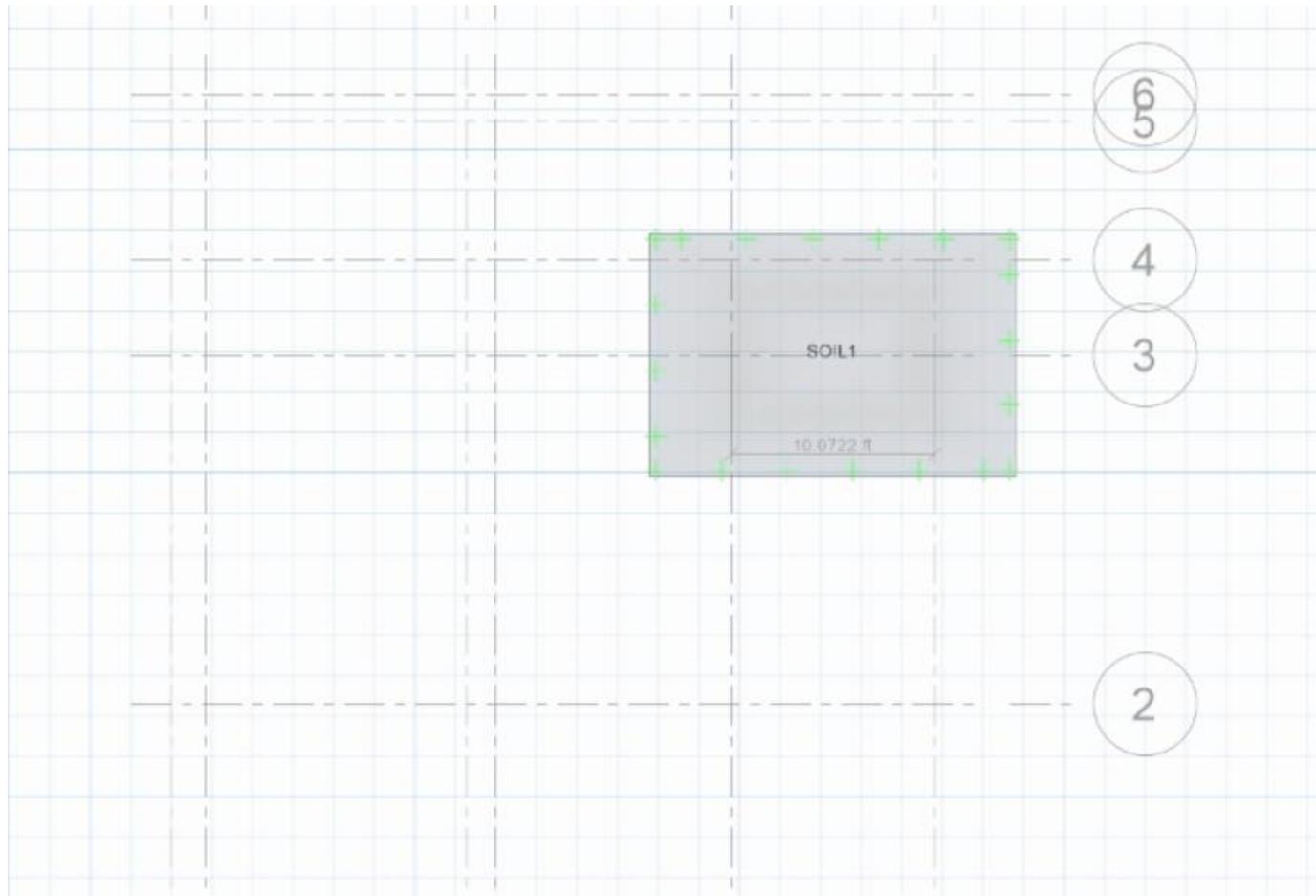




Design of Combined Footing-II

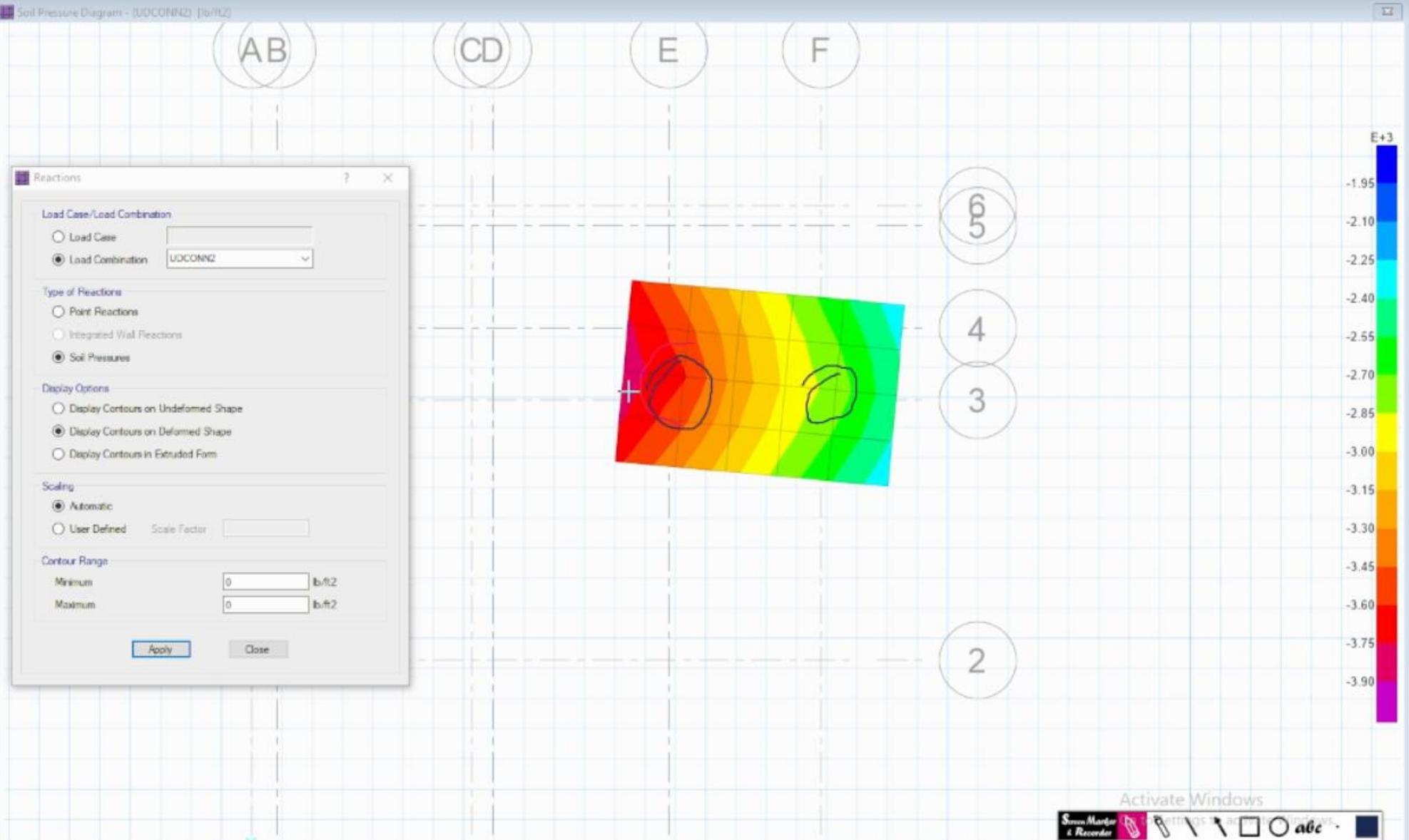
Week 10

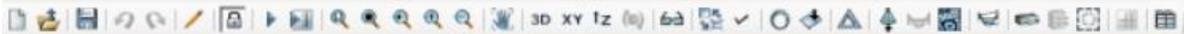
Pages 77-81



Model Explorer

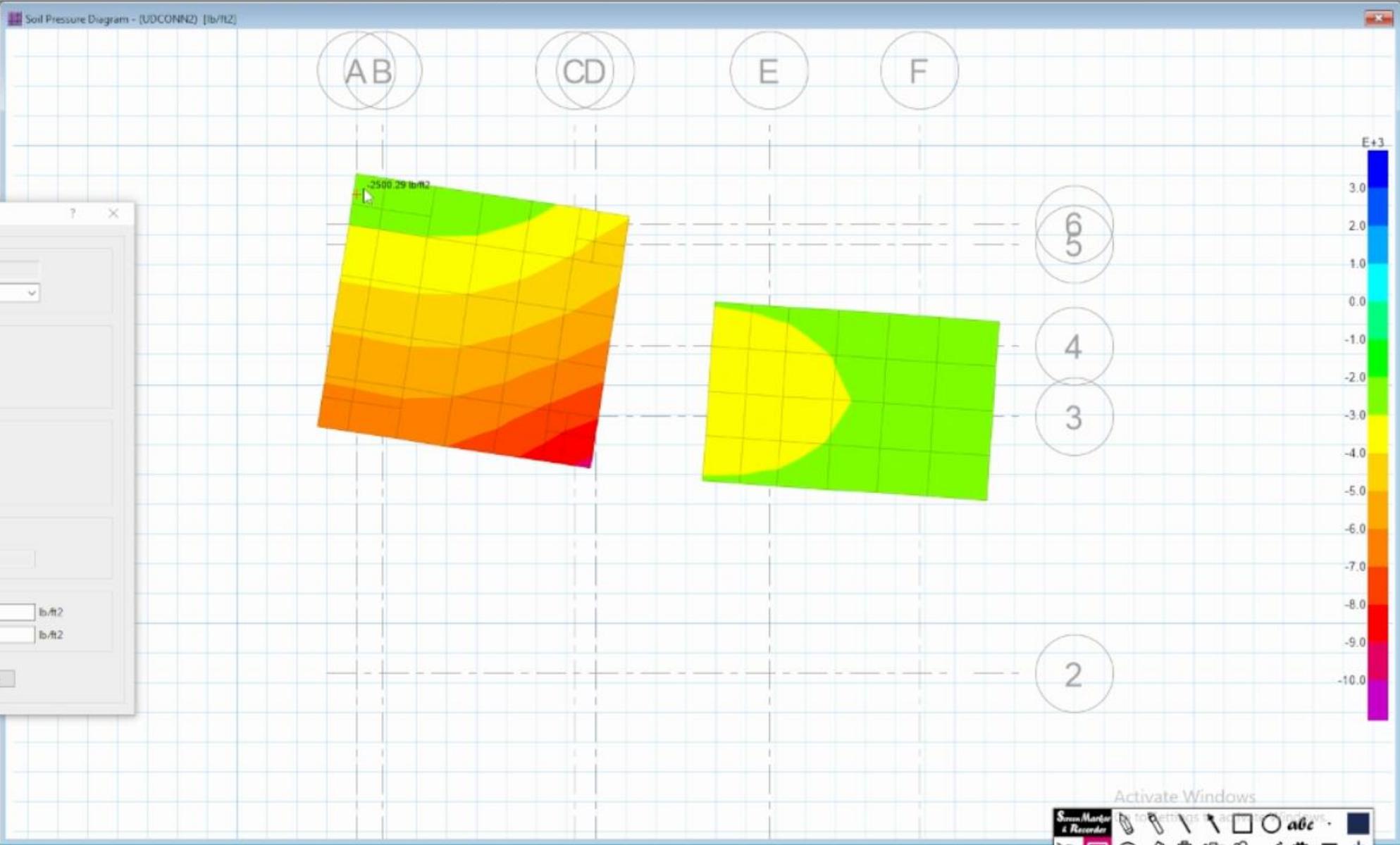
- Model
- Display
- Detailing
- Model Definitions
 - Coordinate Systems
 - Property Definitions
 - Materials
 - Slab Properties
 - Beam Properties
 - Reinforcing Bar Sizes
 - Tendon Properties
 - Column Properties
 - Wall Properties
 - Soil Subgrade Properties
 - Plane Spring Properties
 - Line Spring Properties
 - Load Definitions
 - Load Patterns
 - Load Cases
 - Load Combinations
 - Groups
 - Objects
 - Area Objects (Slab, Wall, Ramp, Wall)
 - Line Objects (Beam, Column, Erase, Null)
 - Tendon Objects
 - Slab Rebar Objects
 - Design Strip Objects
 - Point Objects





Model Explorer

- Model
- Display
- Detailing
- Model Definitions
 - Coordinate Systems
 - Property Definitions
 - Materials
 - Slab Properties
 - Beam Properties
 - Reinforcing Bar Sizes
 - Tendon Properties
 - Column Properties
 - Wall Properties
 - Soil/Groundwater Properties



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

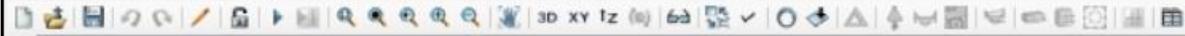
Apply Close

Value = -2500.29 lb/ft²

X 0, Y 48.752, Z 0 (ft)

Activate Windows

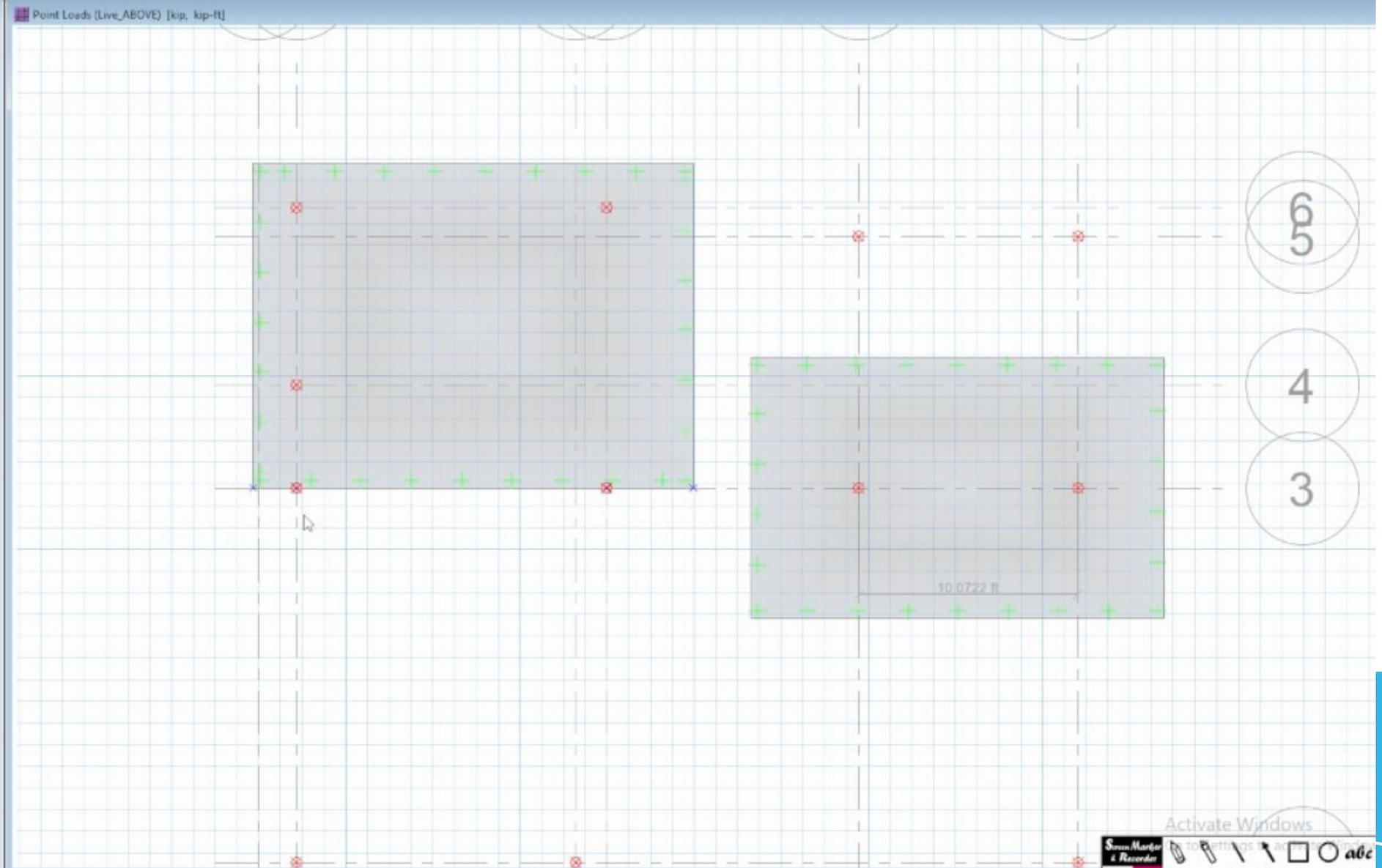
Screen Recorder & Recorder



Model Explorer

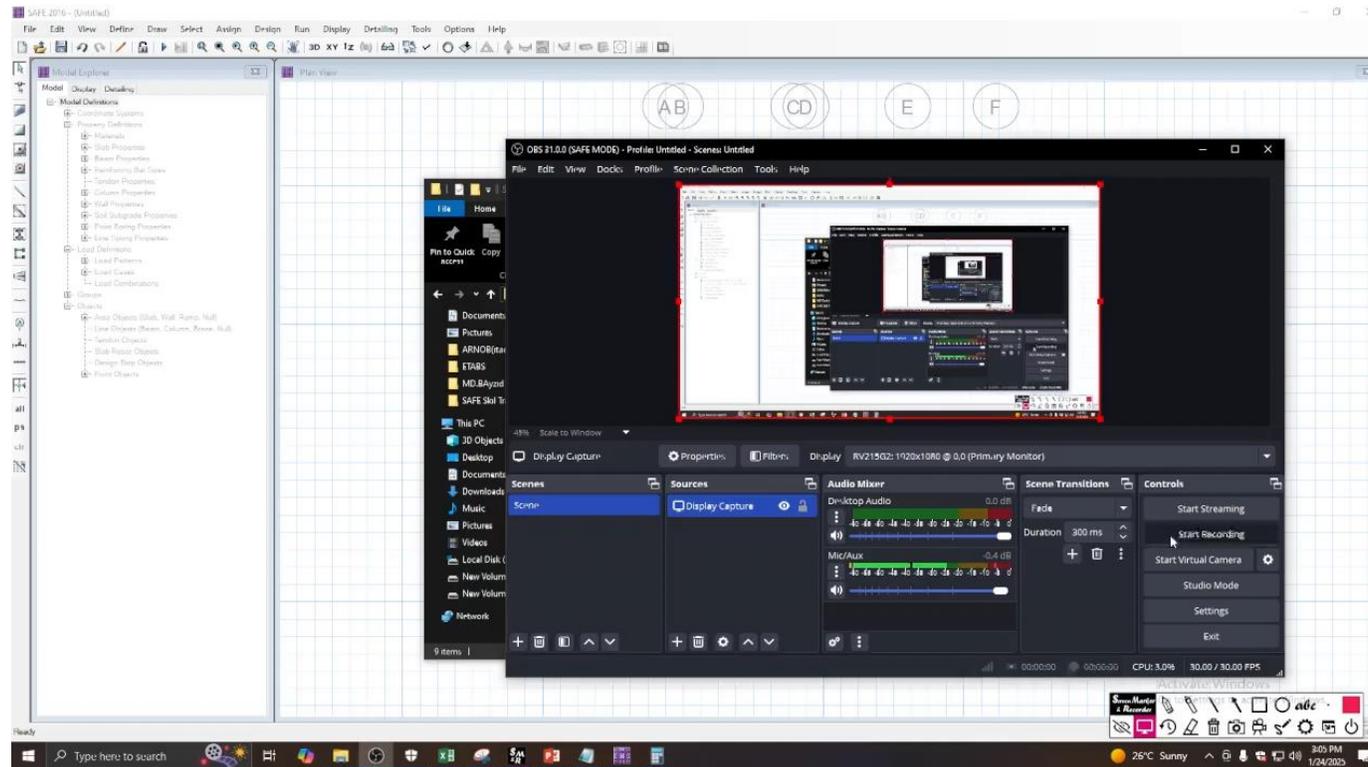
Model Display Detailing

- Model Definitions
 - Coordinate Systems
 - Property Definitions
 - Materials
 - Slab Properties
 - Beam Properties
 - Reinforcing Bar Sizes
 - Tendon Properties
 - Column Properties
 - Wall Properties
 - Soil Subgrade Properties
 - Point Spring Properties
 - Line Spring Properties
 - Load Definitions
 - Load Patterns
 - Load Cases
 - Load Combinations
 - Groups
 - Area Objects (Slab, Wall, Rump, Null)
 - Line Objects (Beam, Column, Brace, Null)
 - Tendon Objects
 - Slab Rebar Objects
 - Design Strip Objects
 - Point Objects



Activate Windows





Design of Combined Footing and Mat Foundation (Video)



Design of Mat foundation

Week 11-12

Pages 82-90

Mat Foundation

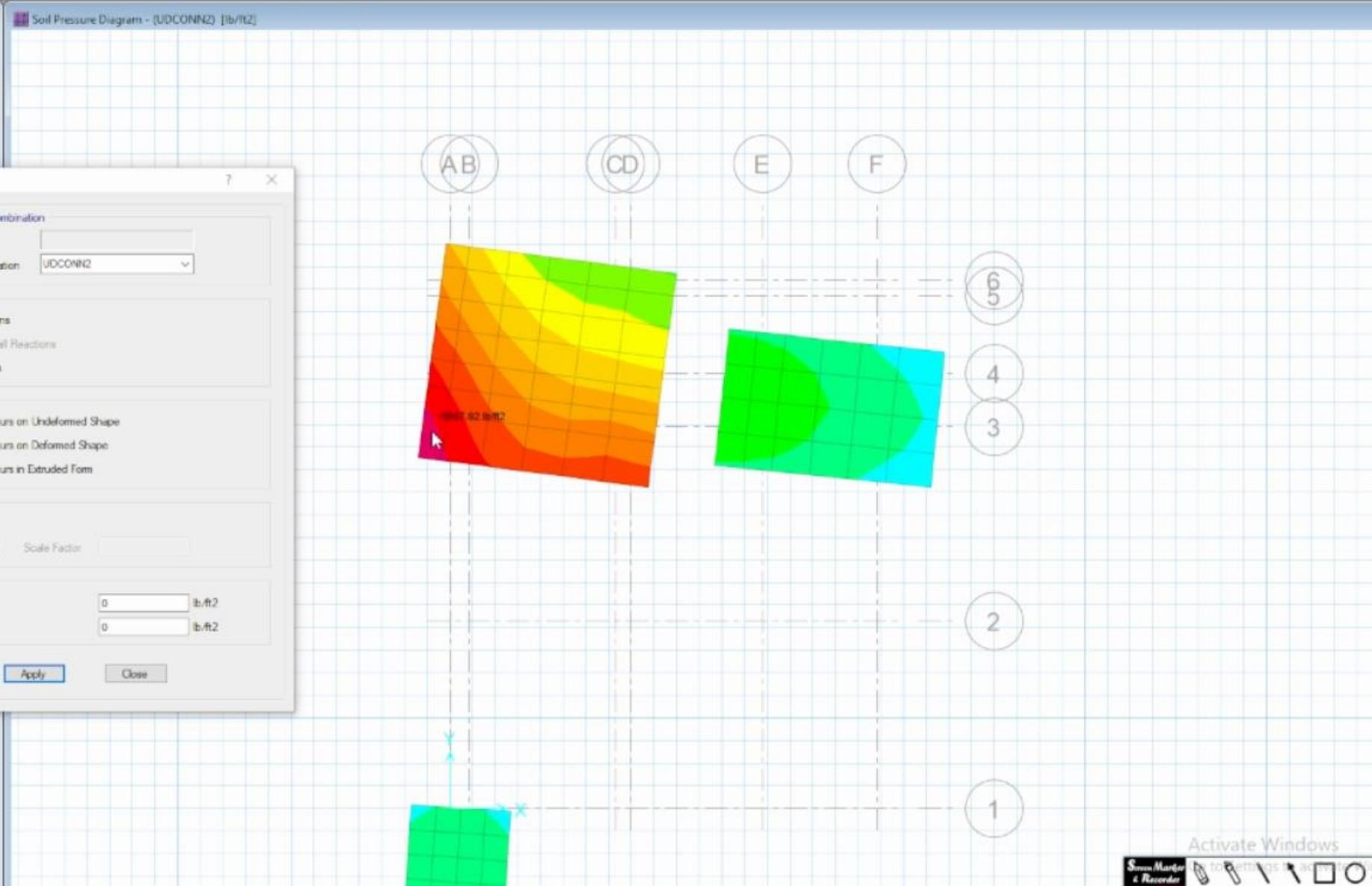
Skill Details:

- 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

Model Explorer

Model Display Detailing

- Model Definitions
 - Coordinate Systems
 - Property Definitions
 - Materials
 - Slab Properties
 - Beam Properties
 - Reinforcing Bar Sizes
 - Tendon Properties
 - Column Properties
 - Wall Properties
 - Soil Subgrade Properties
 - Point Spring Properties
 - Line Spring Properties
 - Load Definitions
 - Load Patterns
 - Load Cases
 - Load Combinations
 - Groups
 - Objects
 - Area Objects (Slab, Wall)
 - Line Objects (Beam, Col)
 - Tendon Objects
 - Slab Rebar Objects
 - Design Smp Objects
 - Point Objects



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

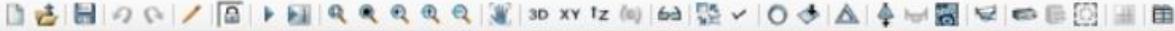
- Automatic
- User Defined: Scale Factor

Contour Range

Minimum: 0 lb/ft²

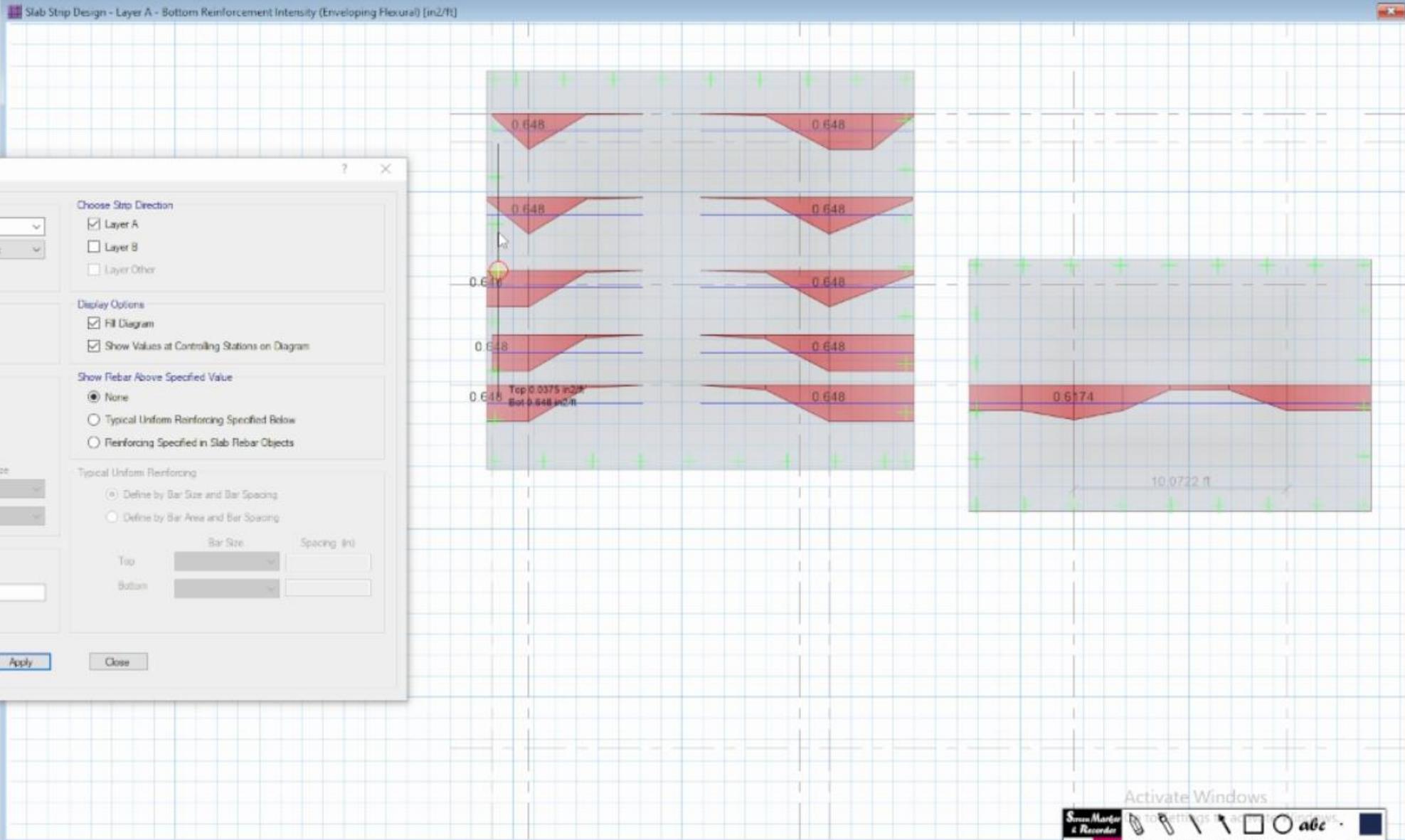
Maximum: 0 lb/ft²

Apply Close



Model Explorer

- Model
- Display
- Detailing
- Model Definitions
 - Coordinate Systems
 - Property Definitions
 - Materials
 - Slab Properties
 - Beam Properties
 - Reinforcing Bar Sizes
 - Tendon Properties



Slab Design

Choose Display Type

Design Basis:

Display Type:

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:

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

Top:

Bottom:

Spacing (ft)

Top:

Bottom:

Apply Close



Model Explorer

- Model
- Display
- Detailing
- Model Definitions
 - Coordinate Systems
 - Property Definitions
 - Materials
 - Slab Properties
 - Beam Properties
 - Reinforcing Bar Sizes
 - Tendon Properties

Slab Strip Design - Layer A - Bottom Reinforcement Intensity (Enveloping Flexural) [in2/ft]

Slab Design

Choose Display Type

Design Basis:

Display Type:

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:

Top: Bar Size

Bottom: Bar Size

Reinforcing Diagram

Show Reinforcing Envelope Diagram

Scale Factor:

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

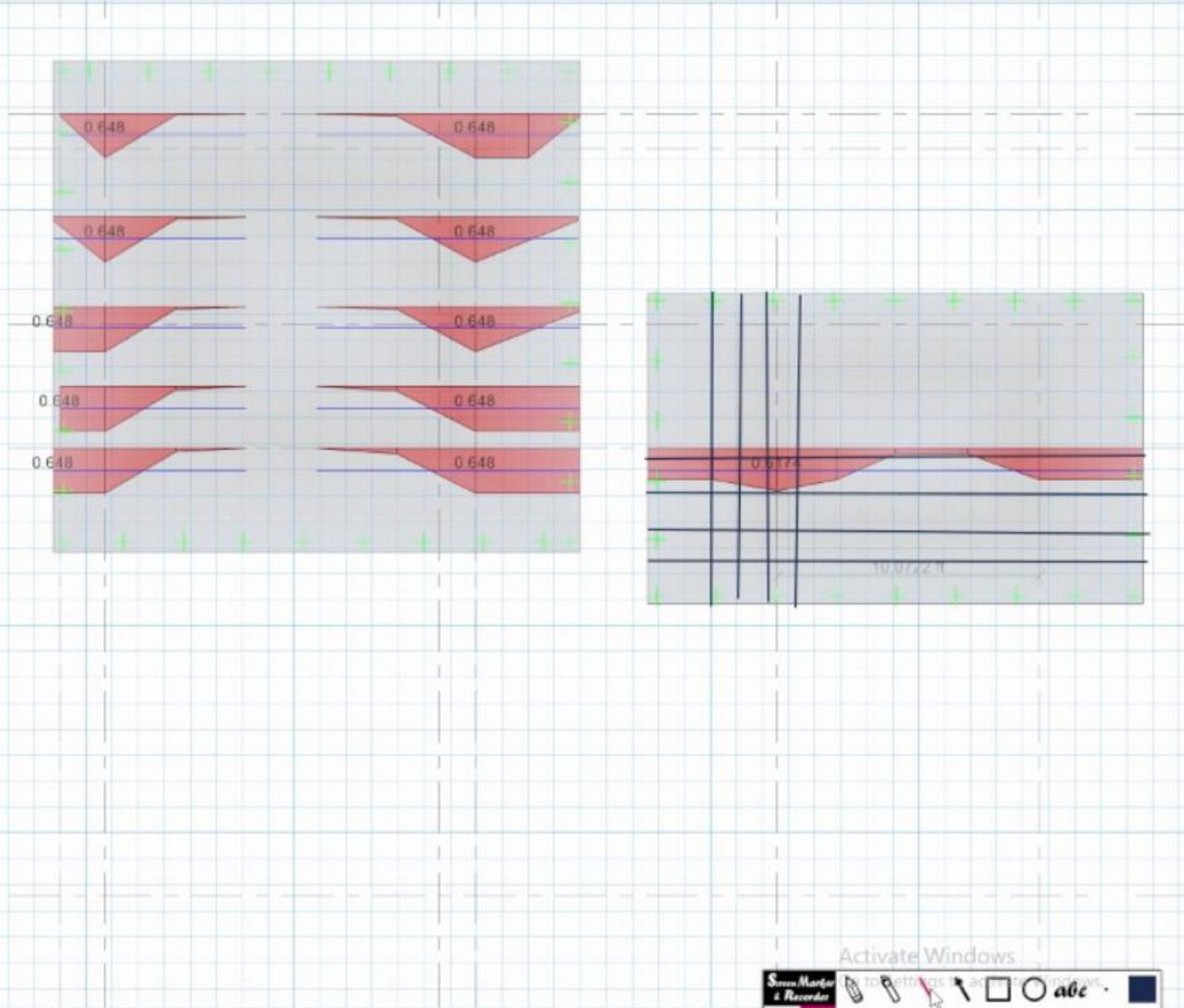
Define by Bar Size and Bar Spacing

Define by Bar Area and Bar Spacing

Top: Bar Size Spacing (in)

Bottom: Bar Size Spacing (in)

Apply Close



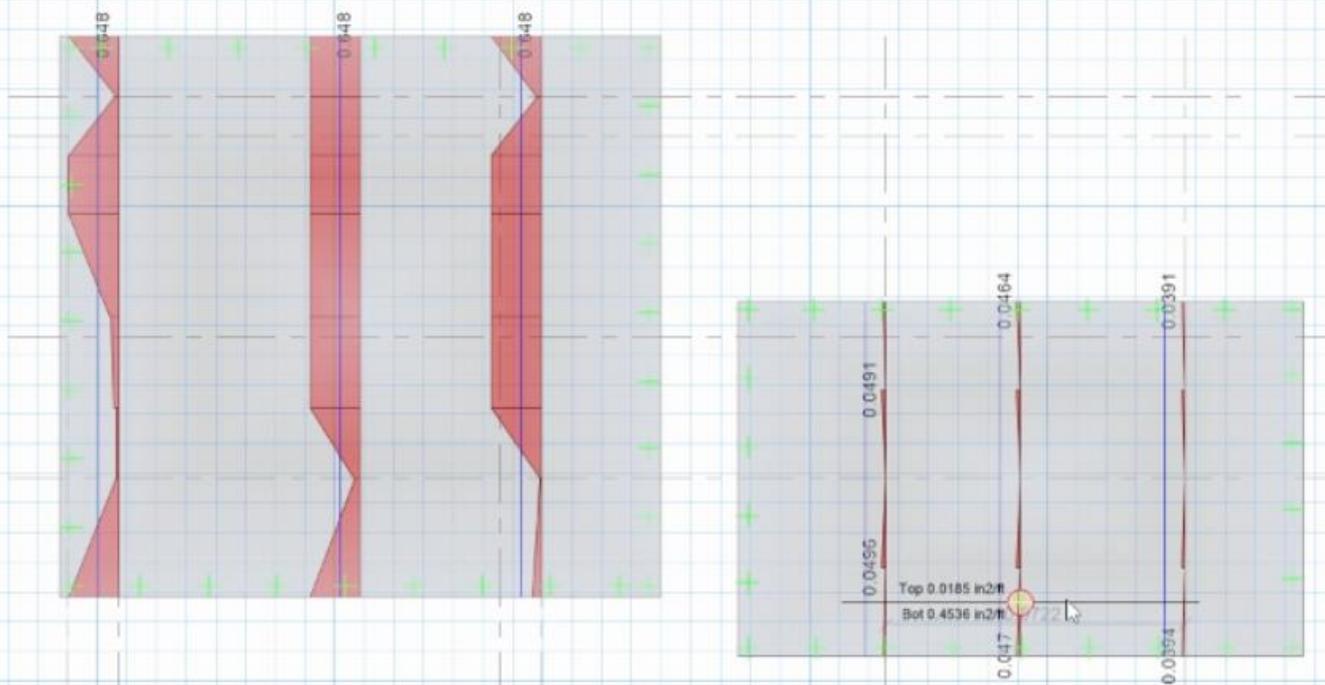
Activate Windows

Go to Settings to activate Windows.

Model Explorer

- Model
- Display
- Detailing
- Model Definitions
 - Coordinate Systems
 - Property Definitions
 - Materials
 - Slab Properties
 - Beam Properties
 - Reinforcing Bar Sizes
 - Tendon Properties

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

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

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: Top, Bottom

Spacing (in): Top, Bottom

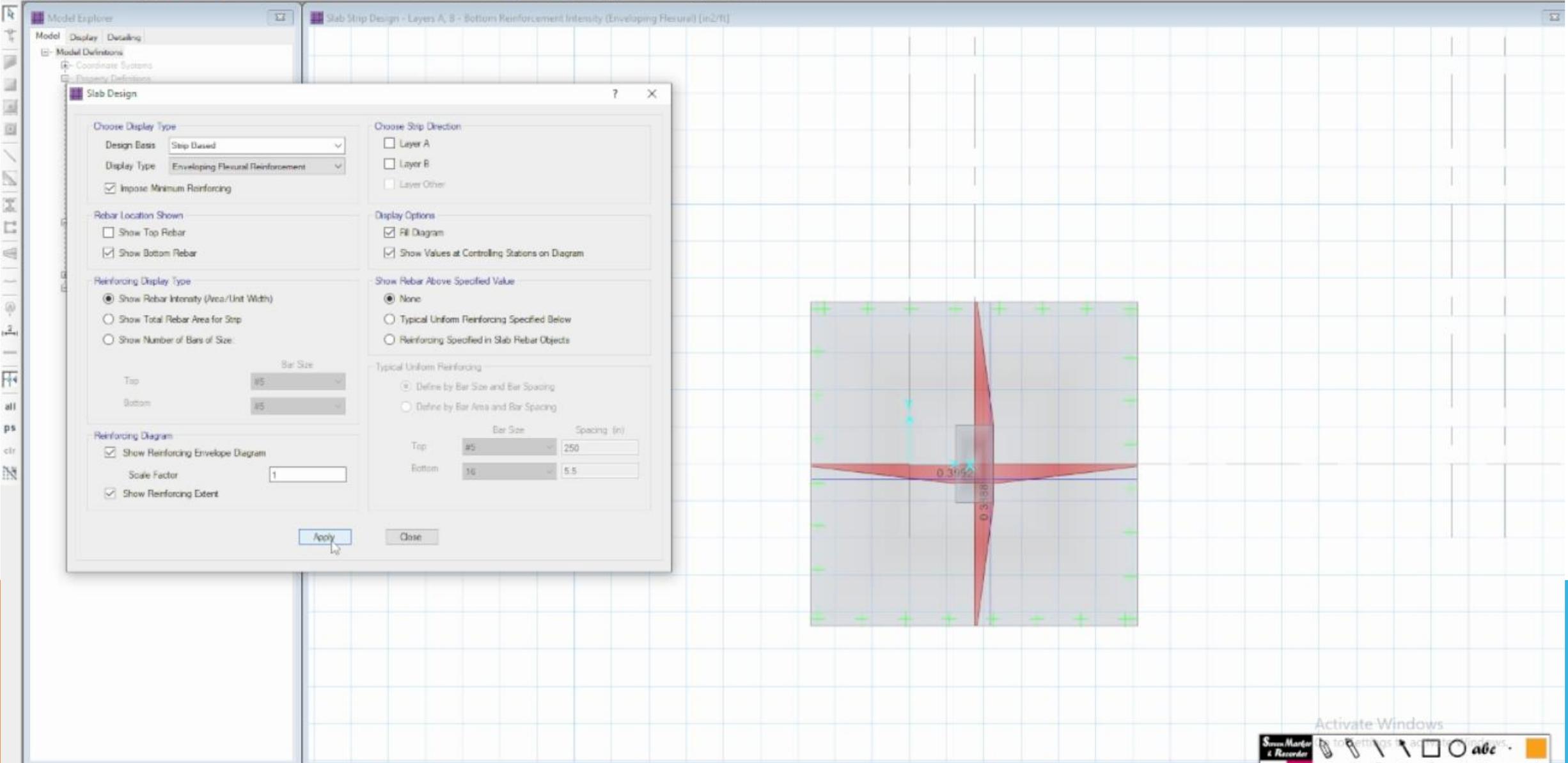
Reinforcing Diagram

Show Reinforcing Envelope Diagram

Scale Factor: 1

Show Reinforcing Extent

Apply Close





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

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

Point Spring Constant of Pile

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

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:

$$\begin{aligned} \text{Nos of Pile} &= \frac{\text{Total Service Load}}{\text{Allowable capacity of each pile}} \\ &= \frac{(467+137) \times 1.1}{200} \\ &= 3.32 \\ &\approx 4 \end{aligned}$$

$$\begin{aligned} \text{Point Spring Constant} &= \frac{EA}{L} \\ &= \frac{57000 \times \sqrt{3500} \times \frac{\pi \times 20^2}{4}}{90 \times 12} \\ &= 980.923 \text{ kip/inch} \end{aligned}$$

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:

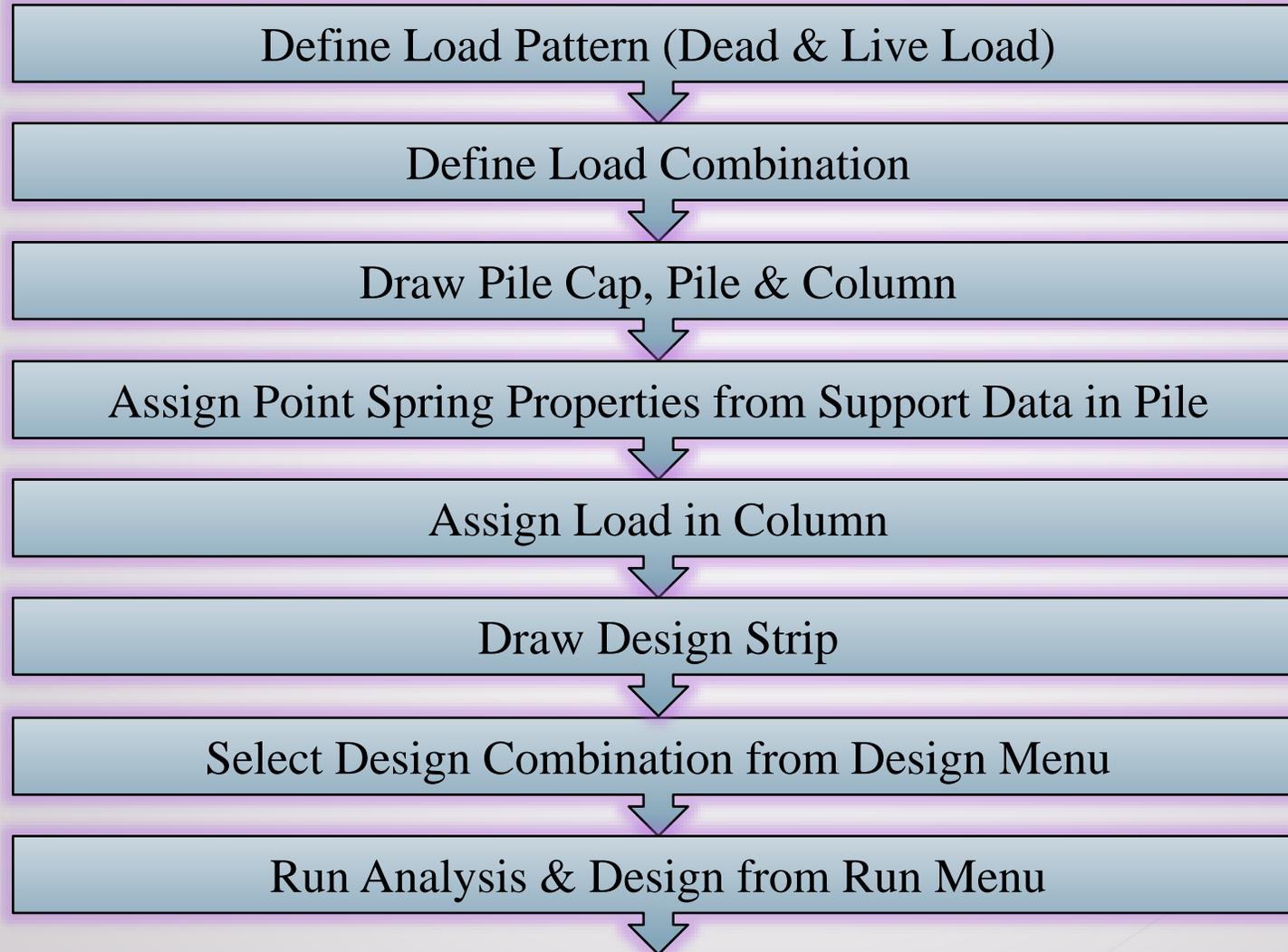
$$\begin{aligned} \text{Nos of Pile} &= \frac{\text{Total Service Load}}{\text{Allowable capacity of each pile}} \\ &= \frac{(327+138) \times 1.1}{200} \\ &= 2.55 \\ &\approx 3 \end{aligned}$$

$$\begin{aligned} \text{Point Spring Constant} &= \frac{EA}{L} \\ &= \frac{57000 \times \sqrt{3500} \times \frac{\pi \times 20^2}{4}}{90 \times 12} \\ &= 980.923 \text{ kip/inch} \end{aligned}$$

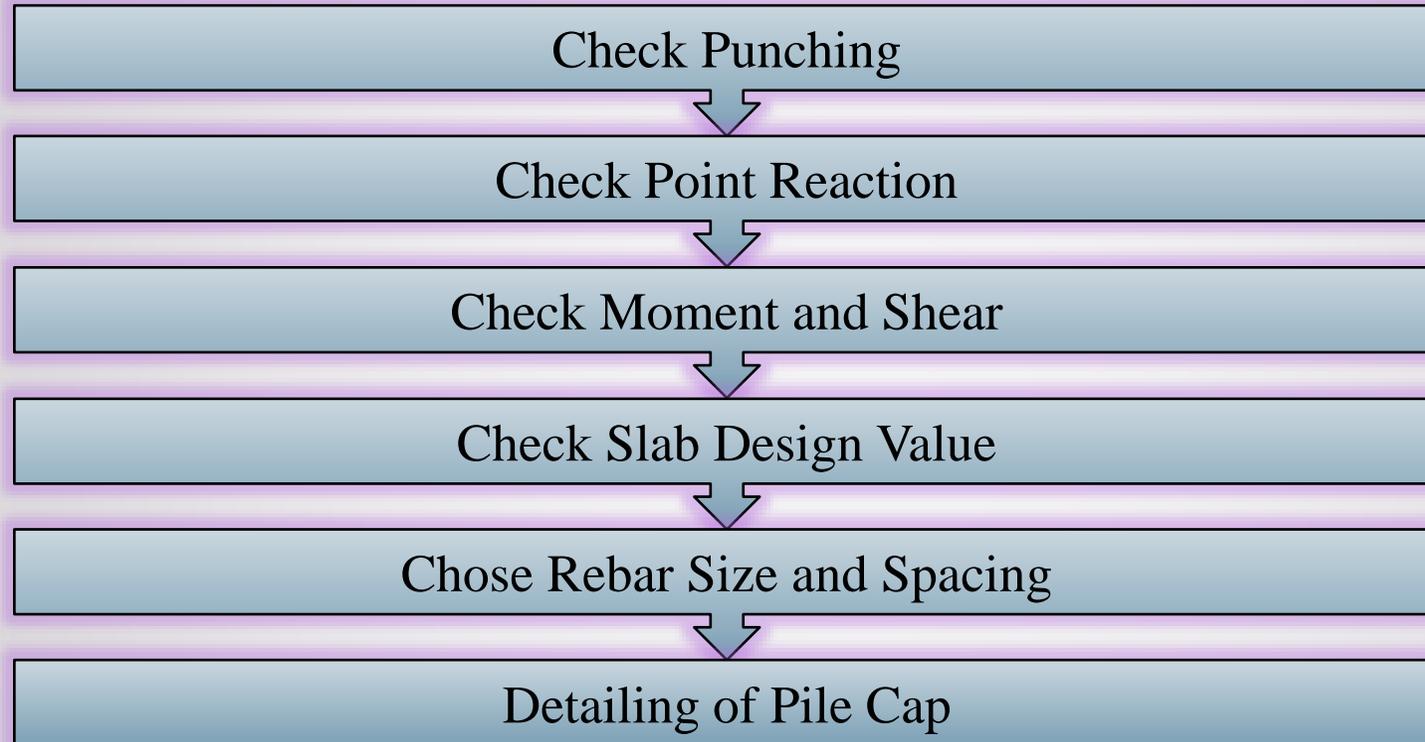
Pile Foundation Design With SAFE Software

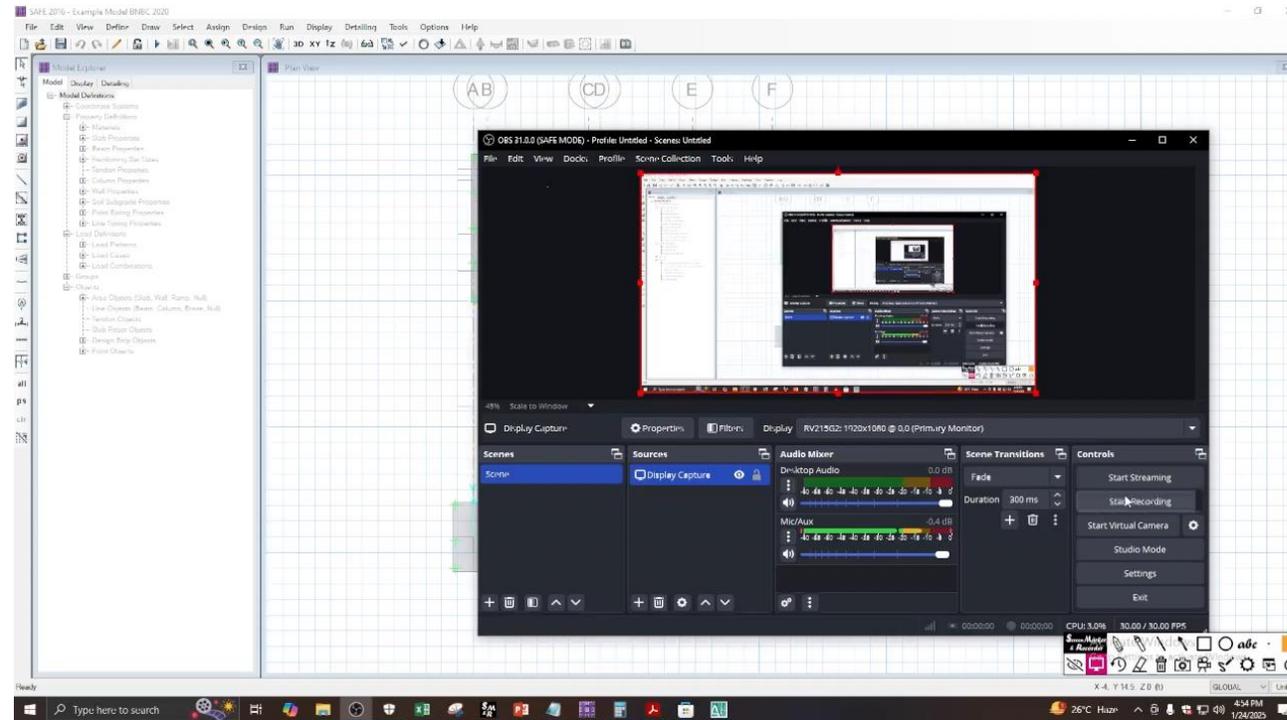


Continue...



Continue...





Design of pile foundation (Video)



Design of Group Pile

Week 15-16

Pages 106-122



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 

Region for Default Materials 

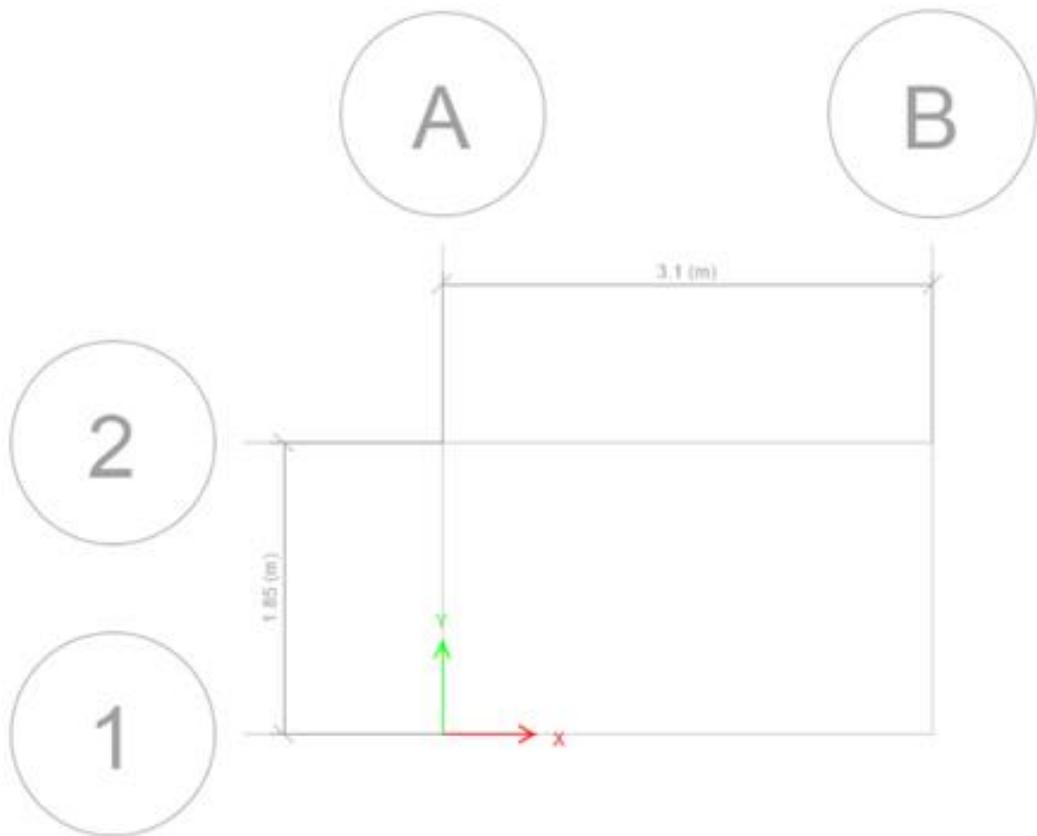
Steel Section Database 

Steel Design Code 

Concrete Design Code 

OK

Cancel



- Section Properties
- Spring Properties
- Group Definitions...
- Section Cuts...
- Mass Source...
- Load Patterns...
- Shell Uniform Load Sets...
- Load Cases...
- Load Combinations...
- Table Named Sets...



Materials

- 4000Psi
- A615Gr60
- A416Gr270
- A992Fy50

Click to:

Add New Material...

Add Copy of Material...

Modify/Show Material...

Delete Material

OK

Cancel



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

S Add New Material Property

Region

Material Type

Standard

Grade

OK

Cancel

S Material Property Data

General Data

Material Name

Material Type

Directional Symmetry Type

Material Display Color

Material Notes

Material Weight and Mass

Specify Weight Density Specify Mass Density

Weight per Unit Volume kN/m³

Mass per Unit Volume kg/m³

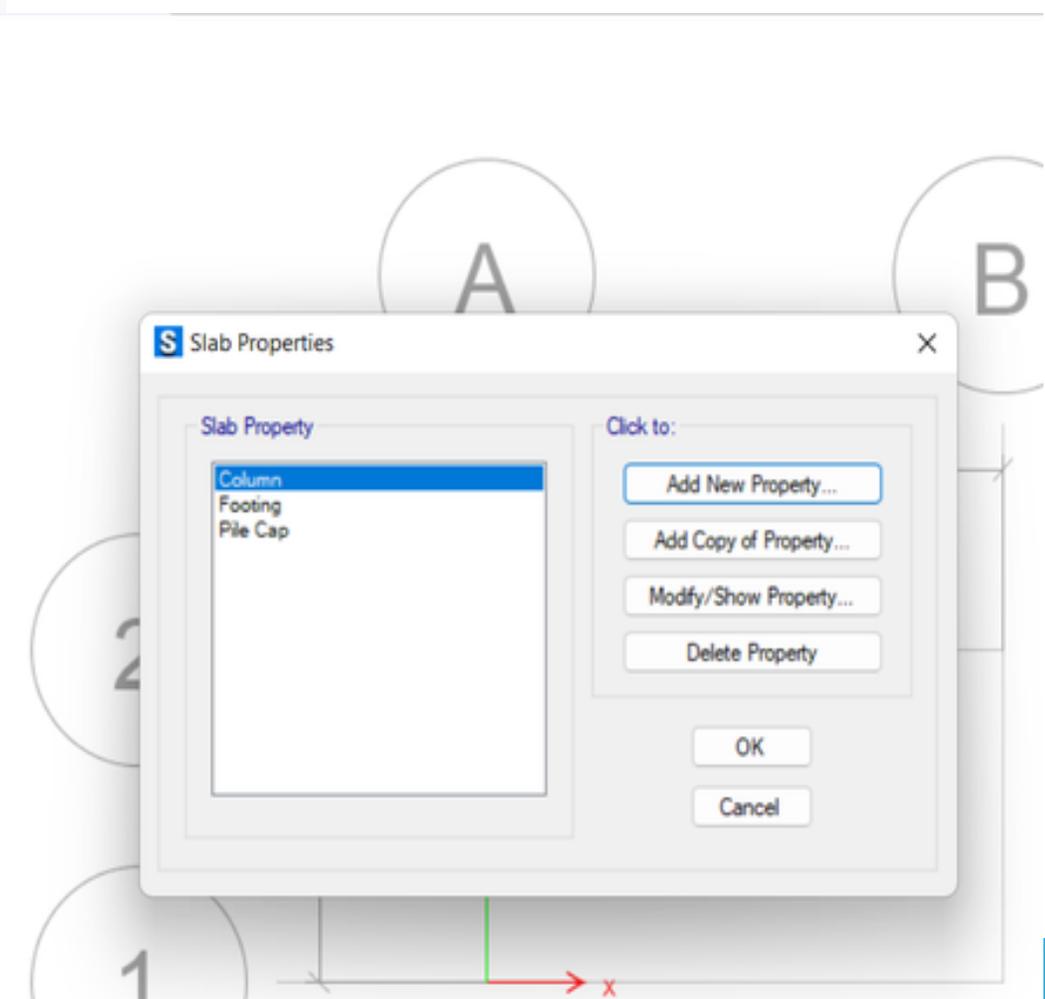
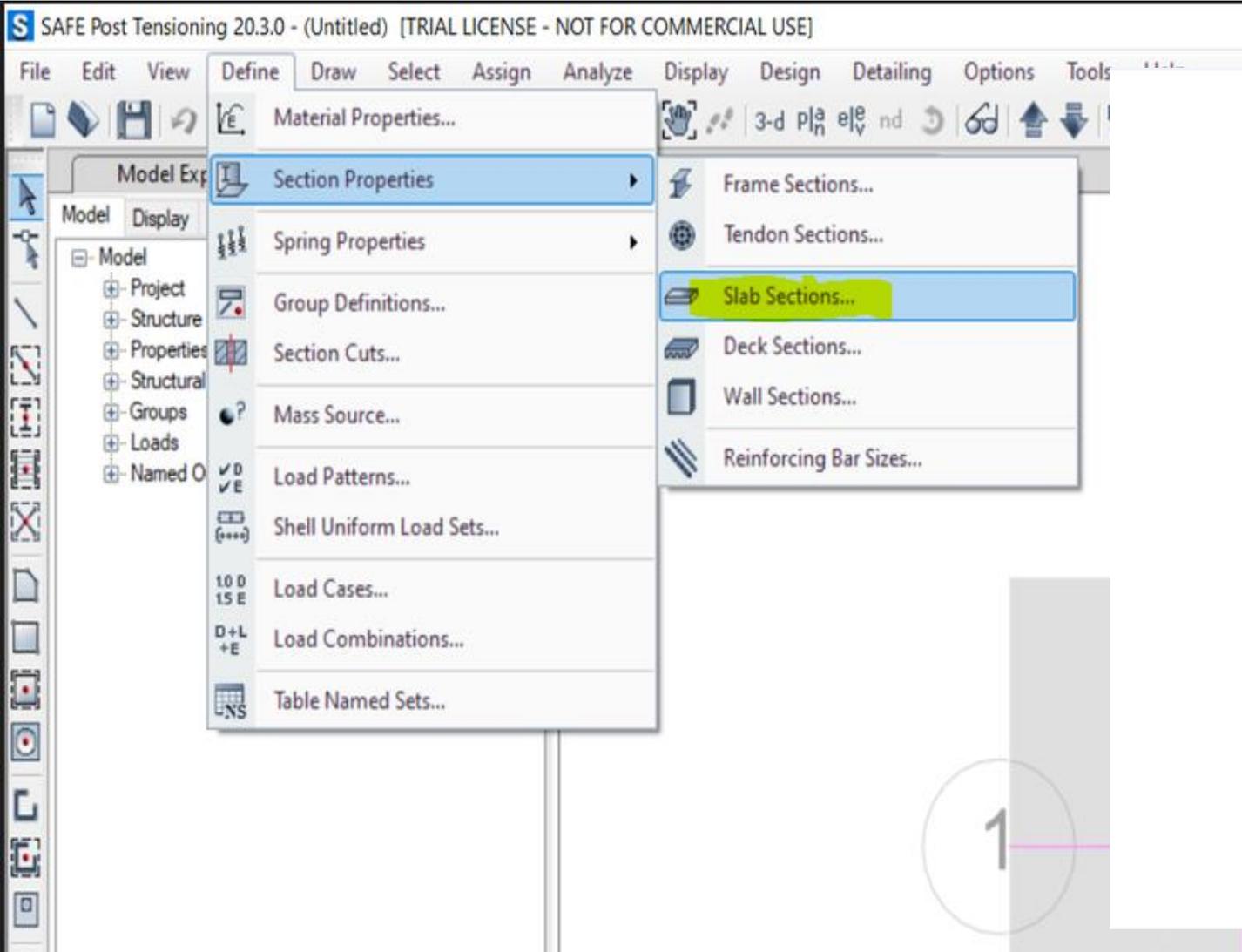
Mechanical Property Data

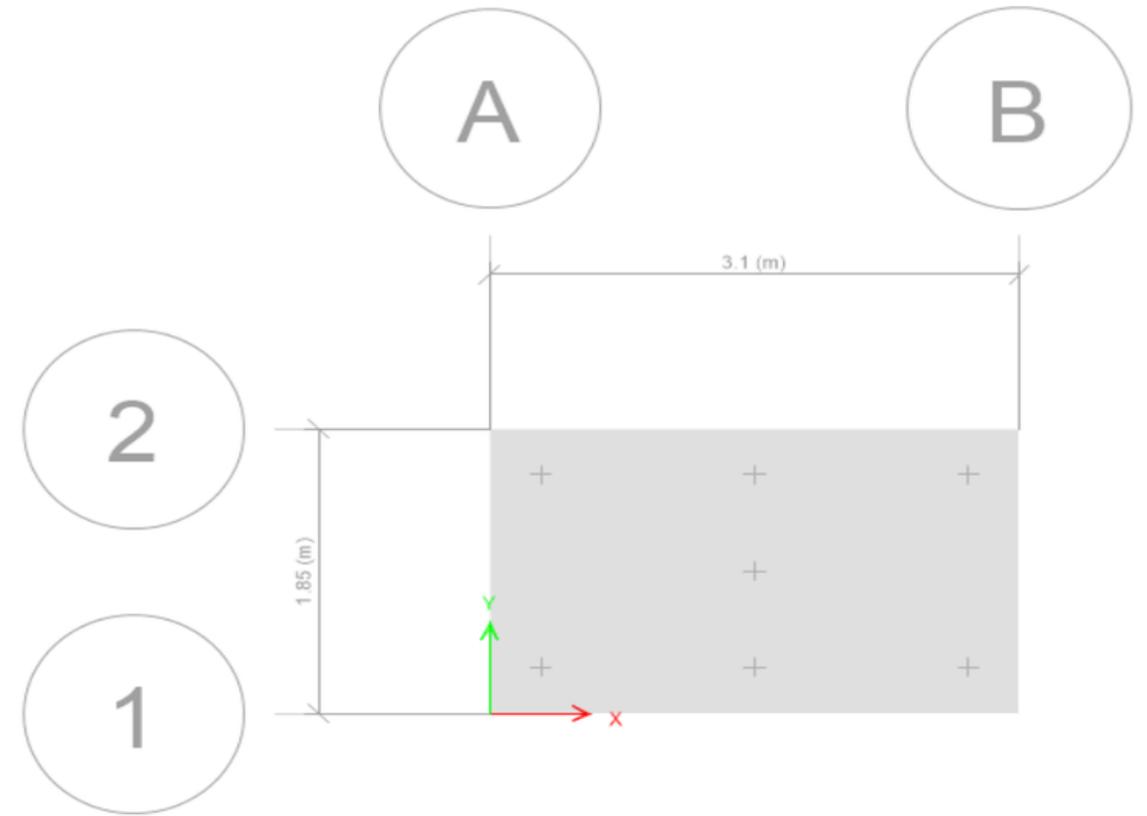
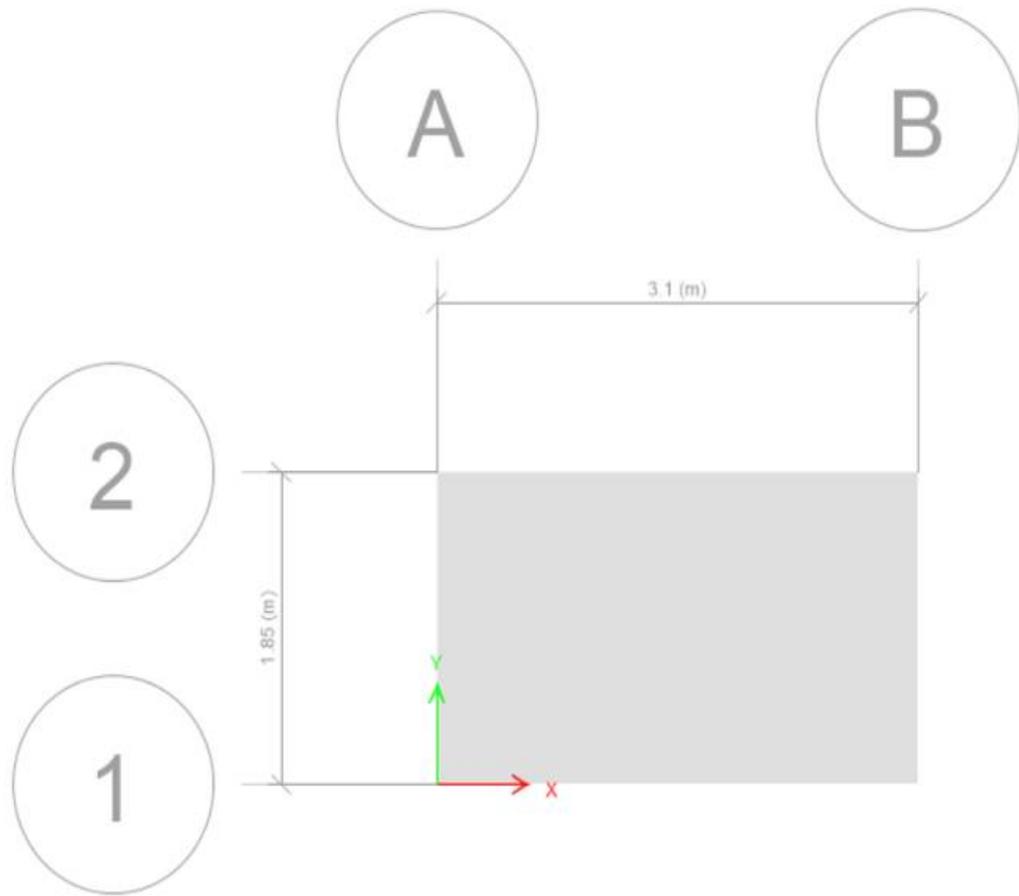
Modulus of Elasticity, E MPa

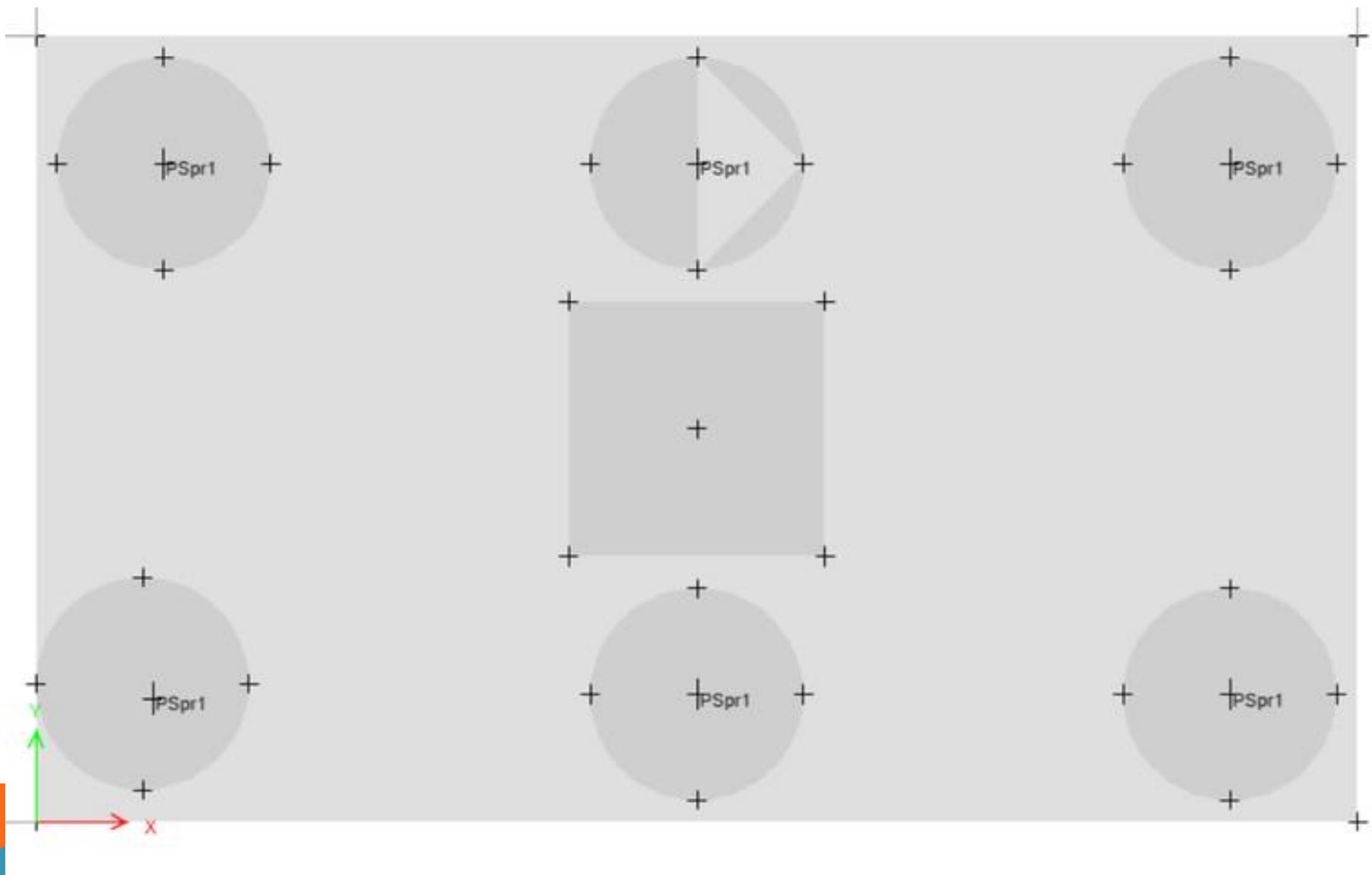
Coefficient of Thermal Expansion, A 1/C

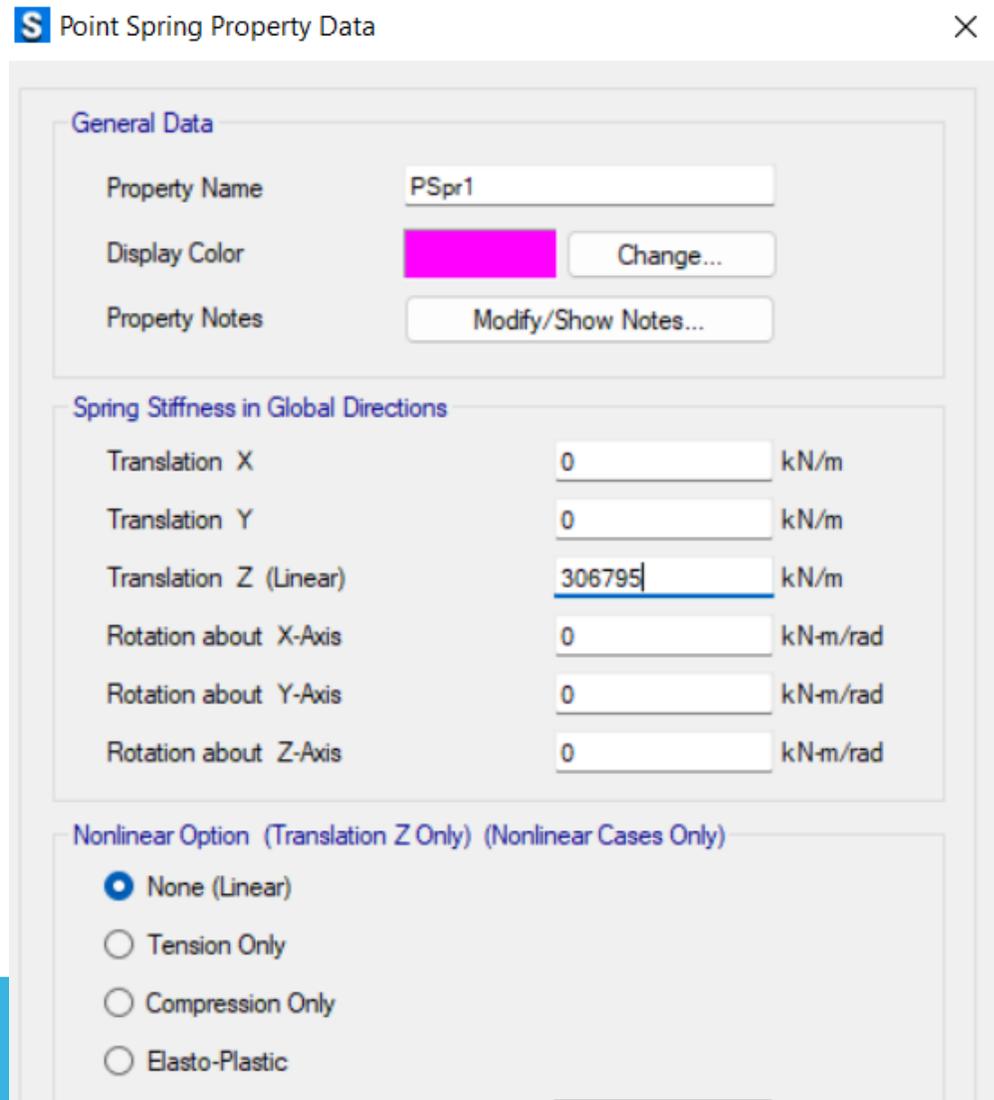
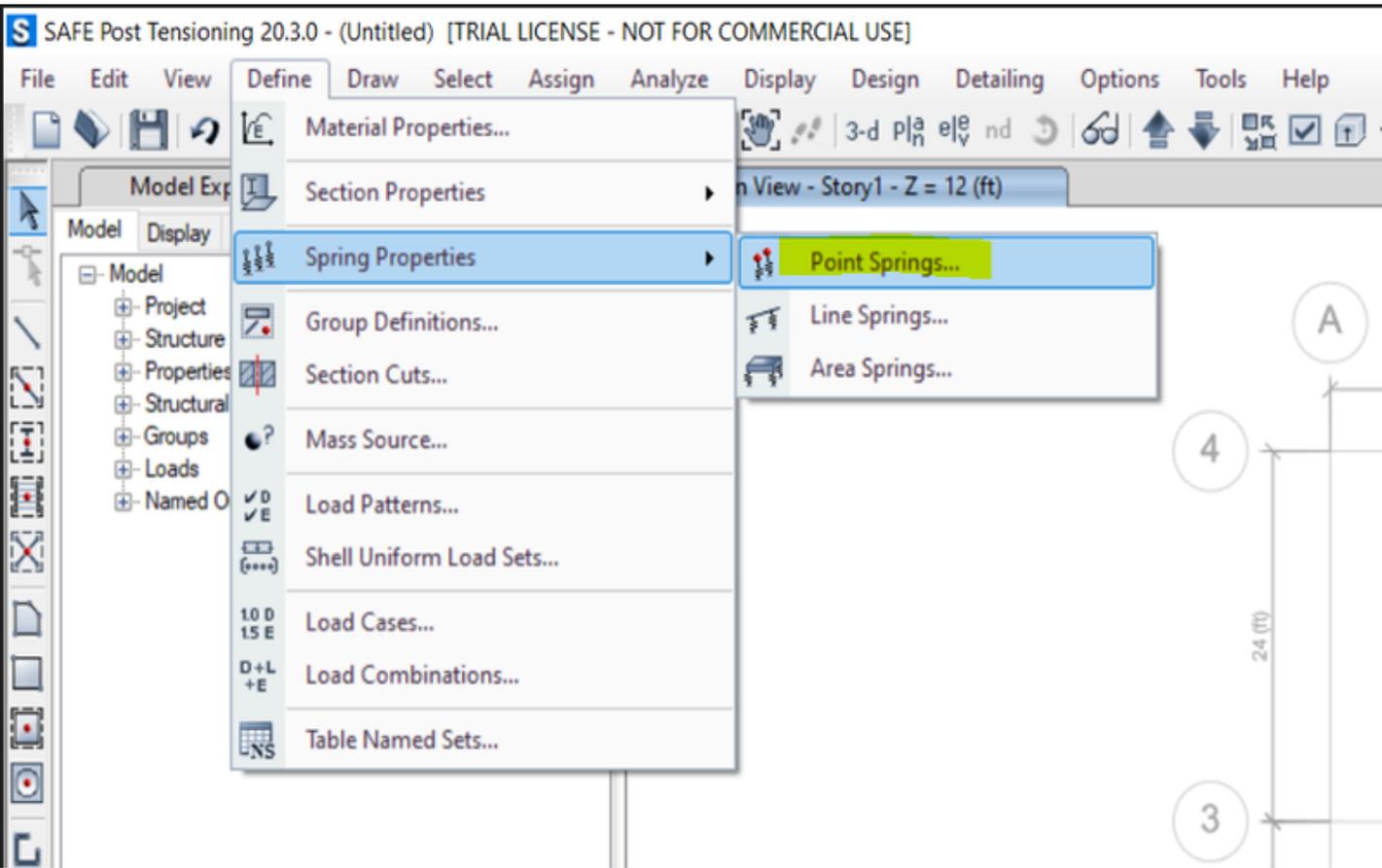
Design Property Data

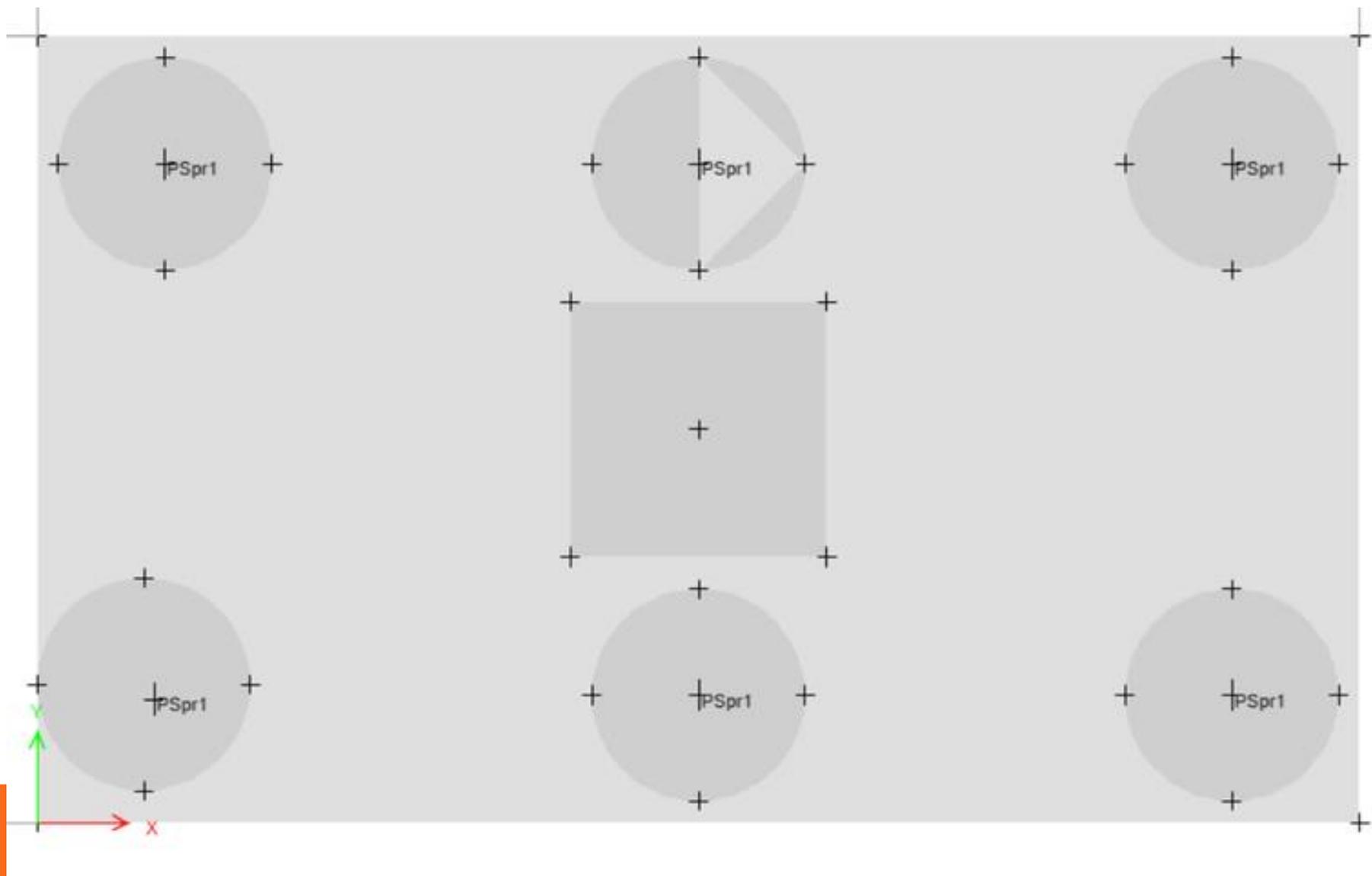
Advanced Material Property Data

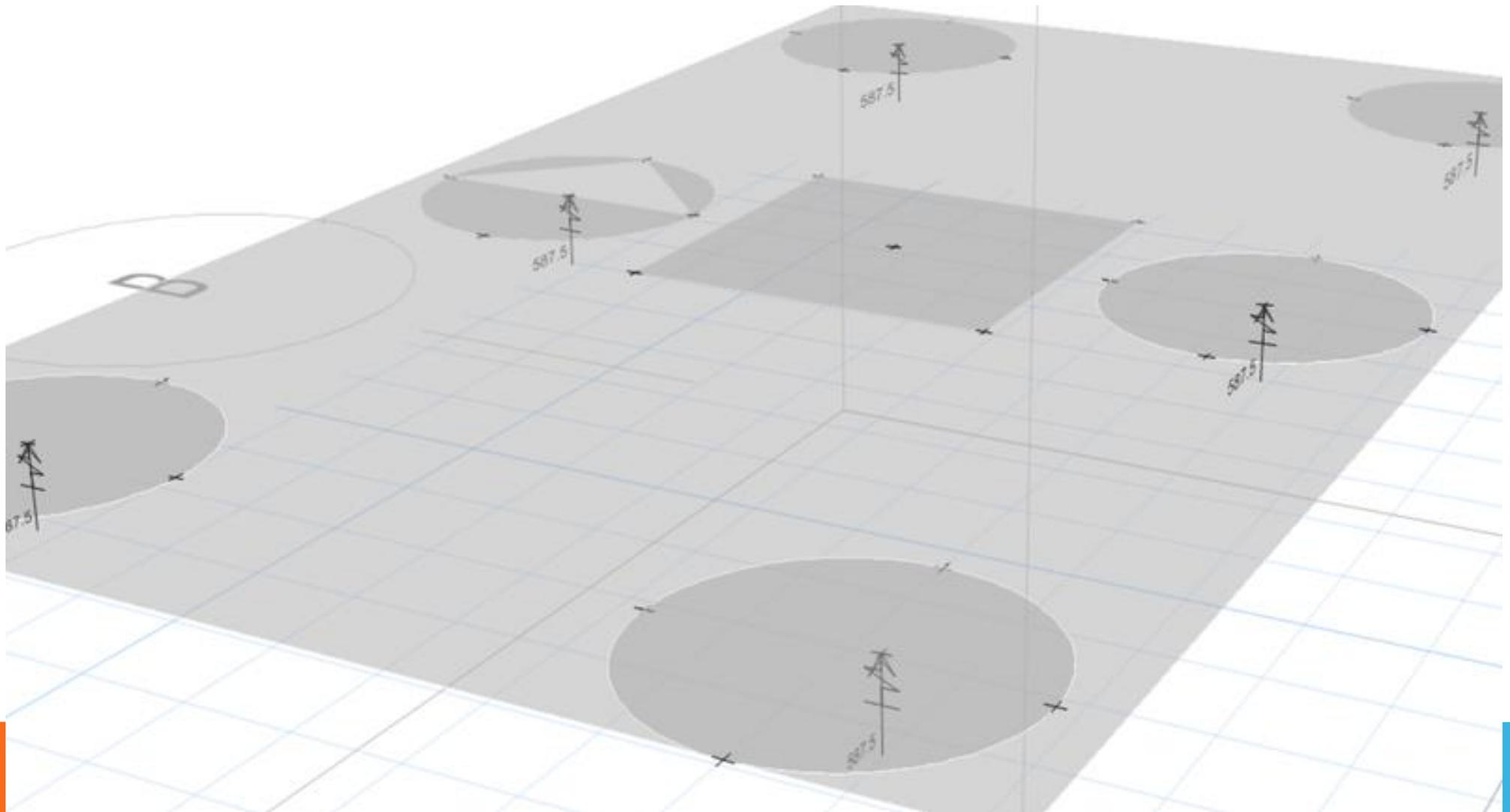














General Data

Load Combination Name:

Combination Type:

Notes:

Auto Combination:

Define Combination of Load Case/Combo Results

Load Name	Scale Factor
Dead	1
Live	1



General Data

Load Combination Name:

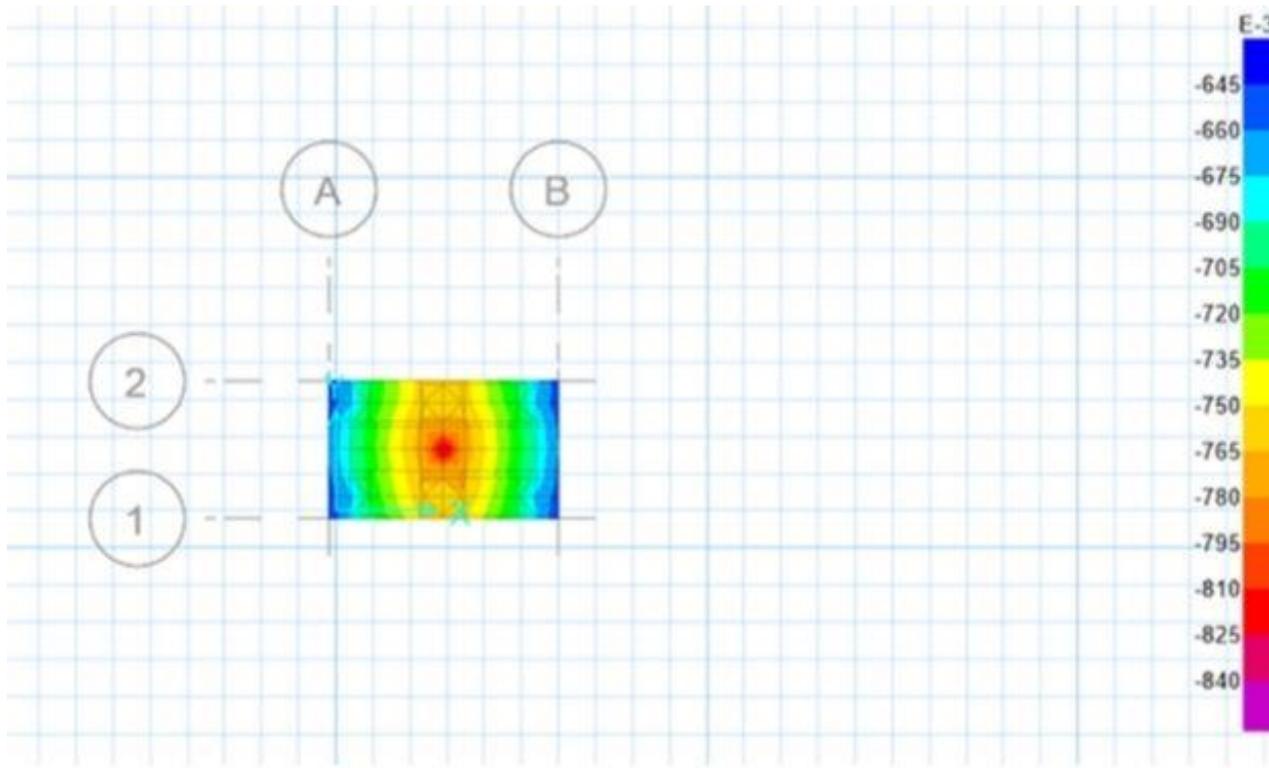
Combination Type:

Notes:

Auto Combination:

Define Combination of Load Case/Combo Results

Load Name	Scale Factor
Dead	1.5
Live	1.5



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

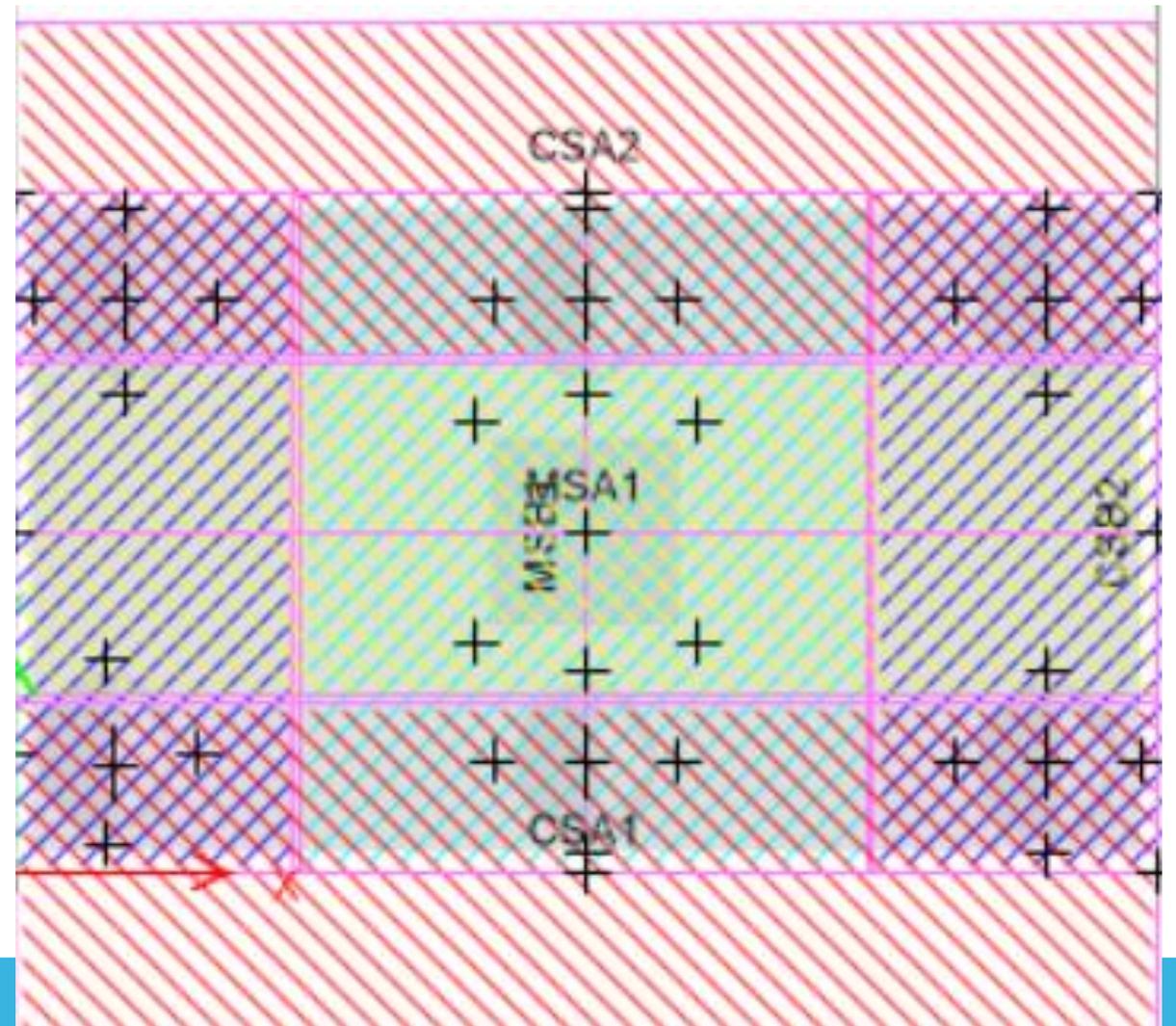
Fixed

Auto

OK

Close

Apply





Plan View - Story1 - Z = 1 (m) - Displacements (Dead) [mm]

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

Reinforcing Display Type

Show Rebar Intensity (Area/Unit Width)

Show Total Rebar Area for Strip

Show Number of Bars of Size:

Top: Bar Size

Bottom:

Reinforcing Diagram

Show Reinforcing Envelope Diagram

Scale Factor:

Show Reinforcing Extent

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

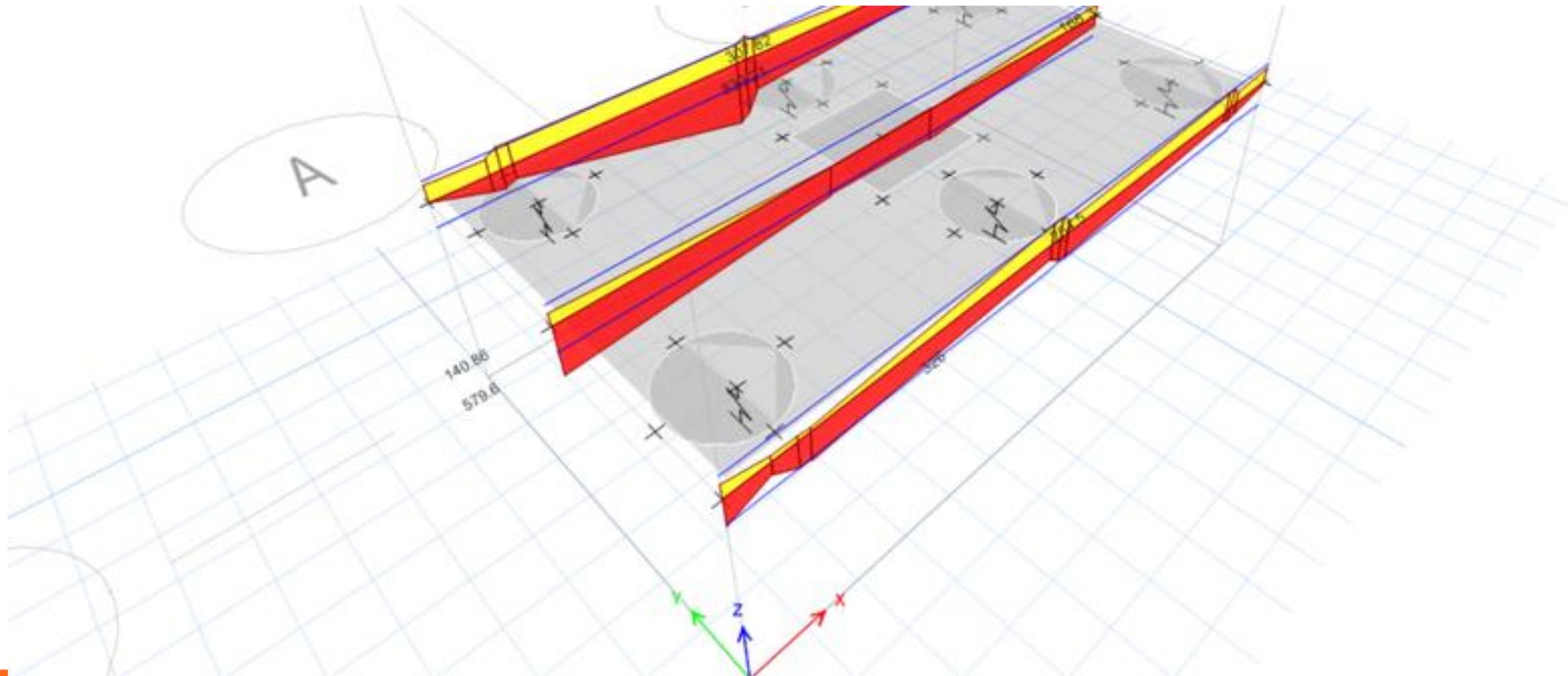
Define by Bar Size and Bar Spacing

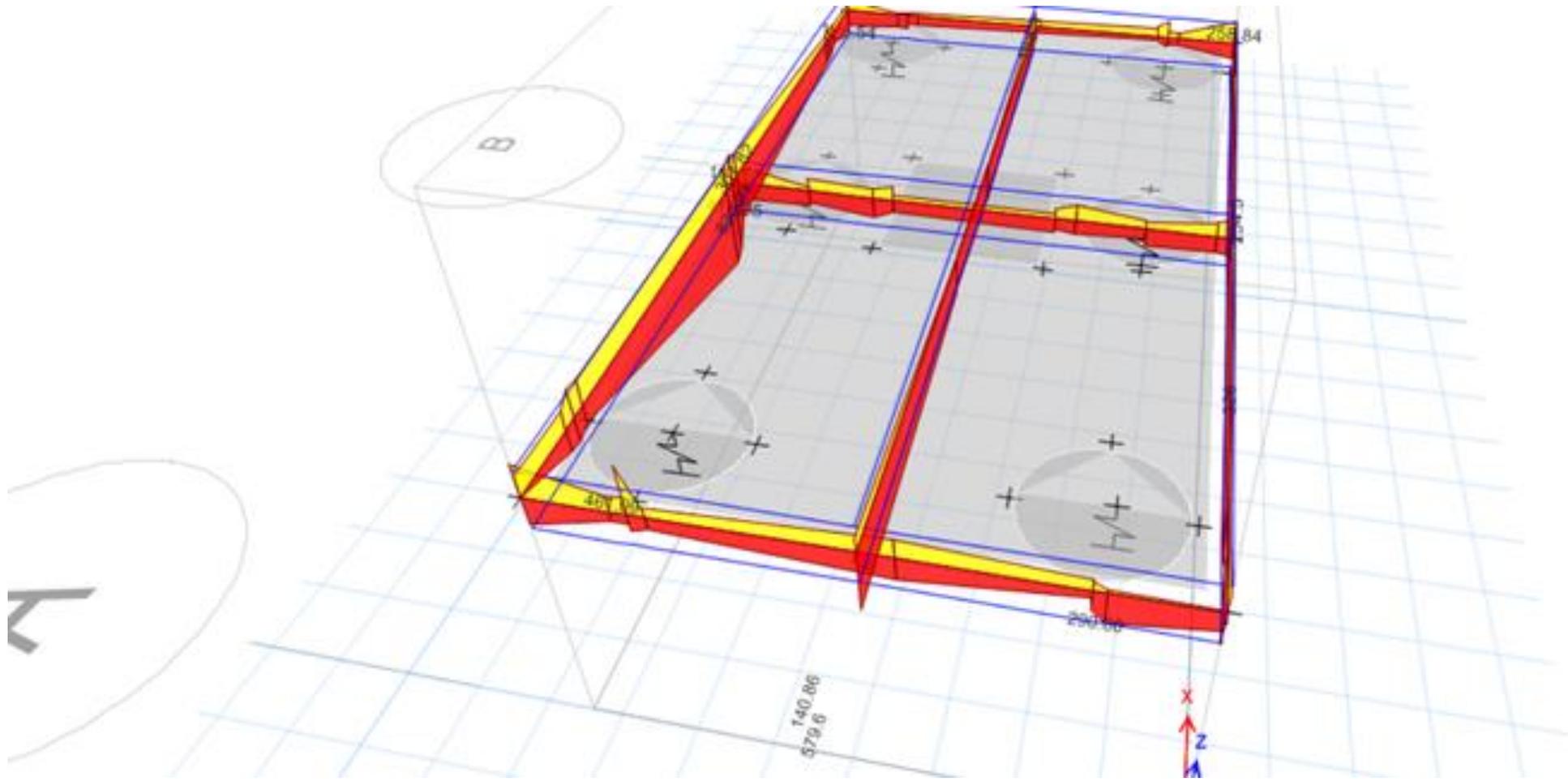
Define by Bar Area and Bar Spacing

Top: Bar Size Spacing (mm)

Bottom: Bar Size Spacing (mm)

OK Close Apply





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