

An-Najah National University

**Faculty of Engineering and
Information Technology**



**جامعة النجاح الوطنية
كلية الهندسة و تكنولوجيا
المعلومات**

Graduation Project Report II

Foundation Design For Al-Hurrieh Bridge

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**Submitted in partial fulfillment of the requirements for
Bachelor degree in Civil Engineering**

Summer-2020

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Chapter Six

Bridge Design

6.1 Bridge Drawings and site plans:

These are photos made to show the layout out and the location of the bridge:



Figure 6.1: Bridge Layout.

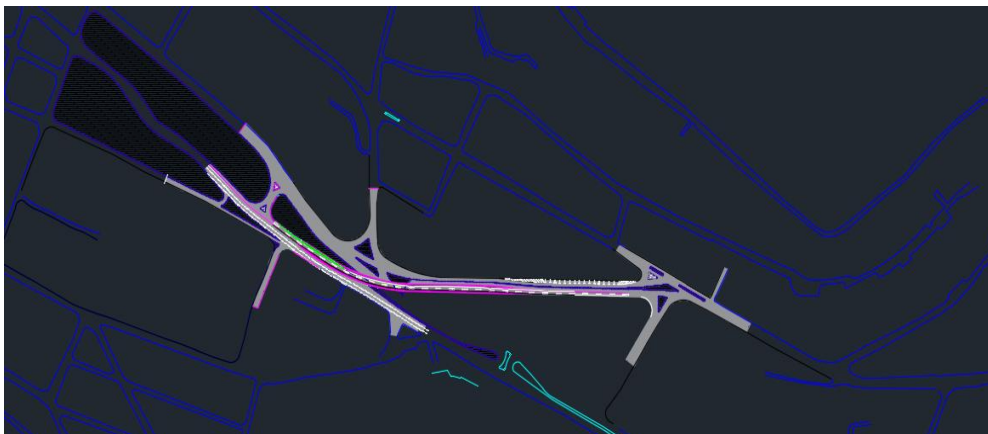


Figure 6.2: Auto cad layout.

6.2 Vertical scale of bridge:

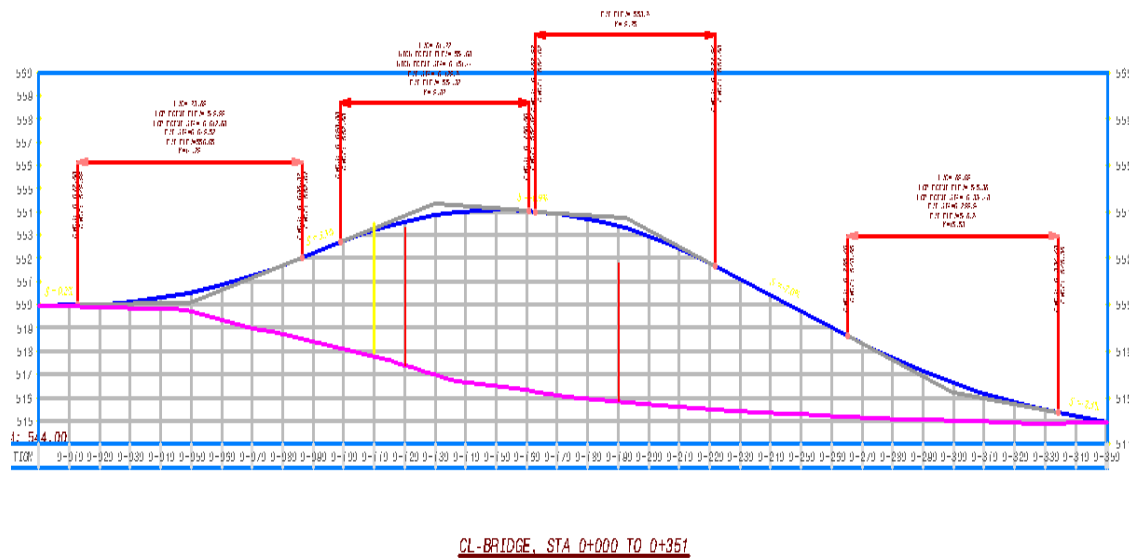


Figure 6.3: Vertical Cross-section layout.

Y-axis: shows the elevations.

X-axis: shows the distance.

Blue Color: shows the bridge level.

Pink Color: shows the street level.

6.3 Bridge Structure:

Our bridge classification goes under these types:

1. **Girder Bridge:** It is a bridge that use girders as the means of supporting its deck, the most common types of girders are plate and box.



Figure 6.4: Girder bridge

2. **Solid Slab Bridge:** It is the simplest form of reinforced concrete bridge deck. It cost less than other types, has a smaller thickness of deck, more simple arrangement of reinforcement and no stirrups or web reinforcement are required in this type.



Figure 6.5: solid slab bridge

3. **Voided Slab Bridge:** Voided slabs are a precast pre-stressed concrete slab mostly used for bridges deck. Voided slabs are available in various thickness and the slabs have a very popular design because of its rapid construction and cost saving.



Figure 6.6: voided slab bridge

4. **Box girder bridges:** A box girder bridge is a bridge that the main beams comprise girders in the shape of a hollow box.



Figure 6.7: box girder bridges.

6.4 Sap Modeling:

The sap model for the bridge: These pictures show the model in 3D.

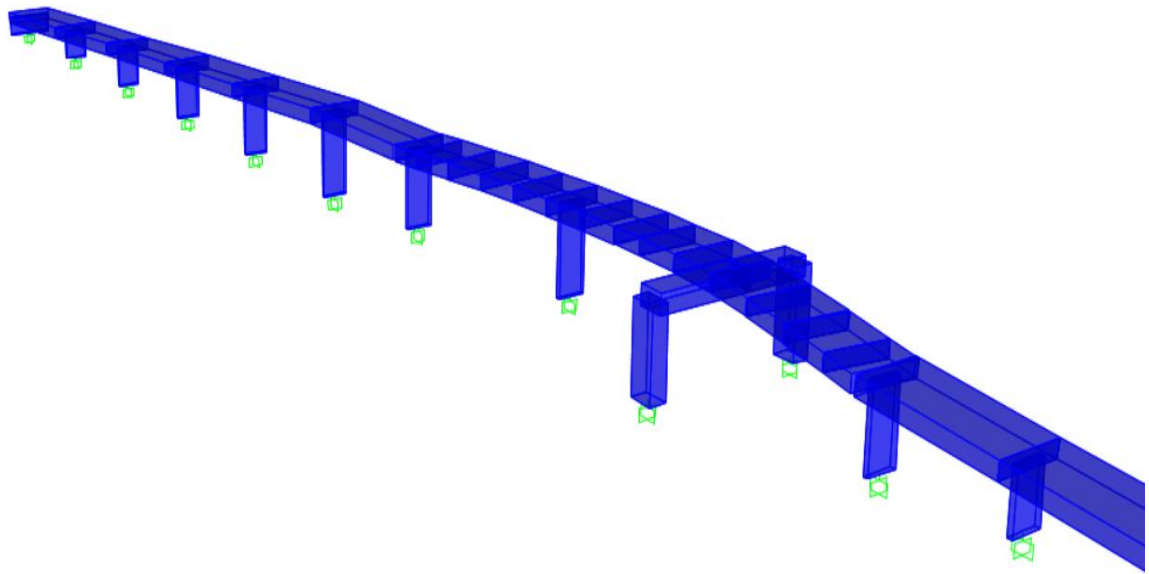


Figure 6.8: Bridge model 1.

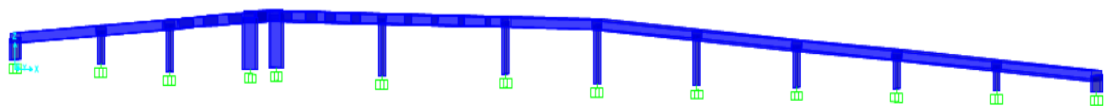
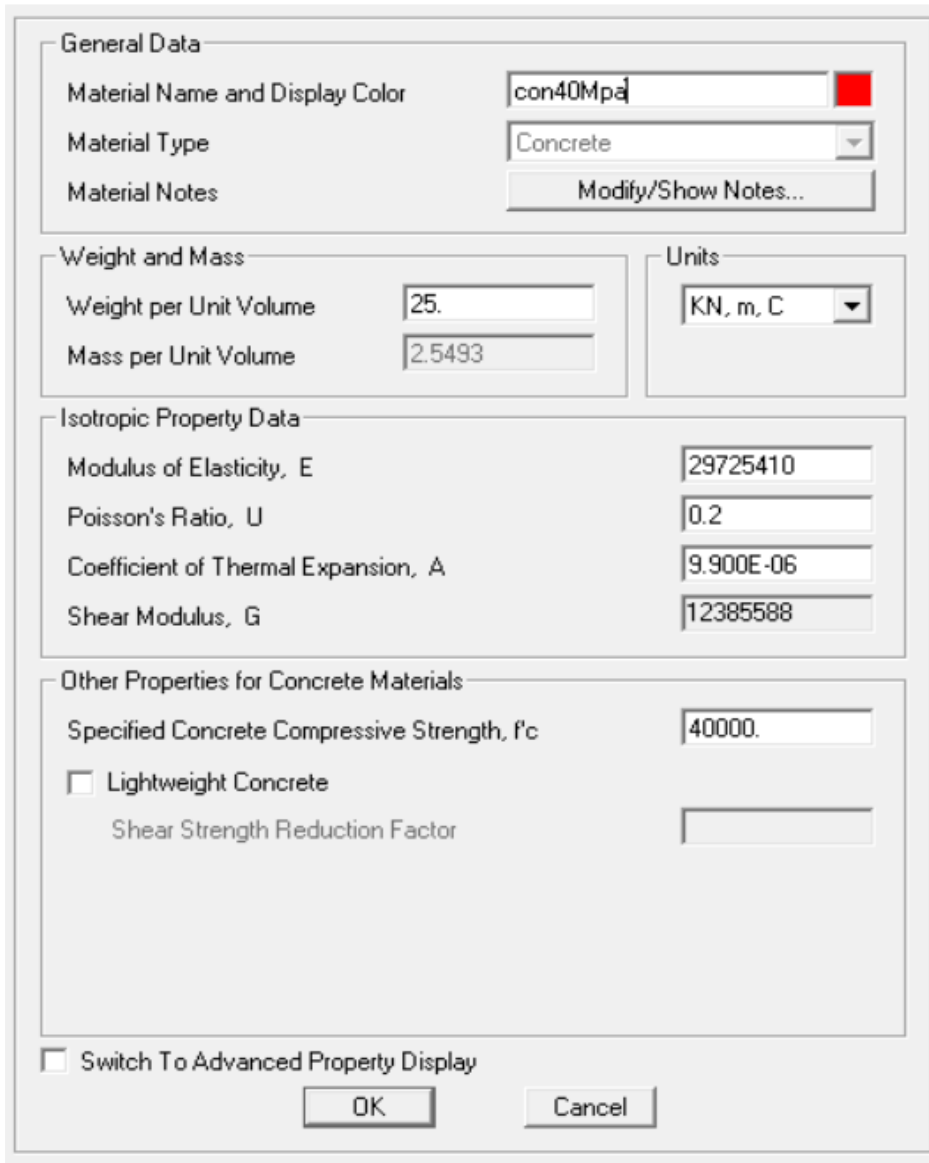


Figure 6.9: Bridge model 2.

The material used for the bridge:

Material Property Data



The image shows a software dialog box titled "Material Property Data". It is organized into several sections with expandable/collapsible headers. The "General Data" section is expanded, showing fields for "Material Name and Display Color" (set to "con40Mpa" with a red color swatch), "Material Type" (set to "Concrete" in a dropdown), and "Material Notes" (with a "Modify/Show Notes..." button). The "Weight and Mass" section is also expanded, showing "Weight per Unit Volume" (25) and "Mass per Unit Volume" (2.5493). To the right of these is a "Units" dropdown set to "KN, m, C". The "Isotropic Property Data" section is expanded, showing "Modulus of Elasticity, E" (29725410), "Poisson's Ratio, U" (0.2), "Coefficient of Thermal Expansion, A" (9.900E-06), and "Shear Modulus, G" (12385588). The "Other Properties for Concrete Materials" section is expanded, showing "Specified Concrete Compressive Strength, f'c" (40000), a checkbox for "Lightweight Concrete" (unchecked), and a "Shear Strength Reduction Factor" field. At the bottom, there is a checkbox for "Switch To Advanced Property Display" (unchecked) and "OK" and "Cancel" buttons.

General Data	
Material Name and Display Color	con40Mpa ■
Material Type	Concrete
Material Notes	<button>Modify/Show Notes...</button>

Weight and Mass	
Weight per Unit Volume	25
Mass per Unit Volume	2.5493

Units	
	KN, m, C

Isotropic Property Data	
Modulus of Elasticity, E	29725410
Poisson's Ratio, U	0.2
Coefficient of Thermal Expansion, A	9.900E-06
Shear Modulus, G	12385588

Other Properties for Concrete Materials	
Specified Concrete Compressive Strength, f'c	40000
<input type="checkbox"/> Lightweight Concrete	
Shear Strength Reduction Factor	

☐ Switch To Advanced Property Display

OK Cancel

Figure 6.10: Material Property Data.

Sections:

1. external shear wall:

Rectangular Section

The image shows a software dialog box titled "Rectangular Section" for defining an external shear wall. The dialog is organized into several sections:

- Section Name:** A text field containing "shear wall".
- Section Notes:** A text area with a "Modify/Show Notes..." button.
- Properties:** A button labeled "Section Properties...".
- Property Modifiers:** A button labeled "Set Modifiers...".
- Material:** A dropdown menu showing "con40Mpa" with a "+" icon to the left and a downward arrow to the right.
- Dimensions:** Two input fields: "Depth (t3)" with the value "0.4" and "Width (t2)" with the value "6.25".
- Grid Diagram:** A 10x10 grid with a horizontal red line and a vertical blue line intersecting at the center. A gray rectangular section is drawn on the grid, centered on the intersection. The width of the section is marked with a blue arrow and the number "3", and its depth is marked with a blue arrow and the number "2".
- Display Color:** A checkbox labeled "Display Color" which is currently unchecked.
- Buttons:** At the bottom, there are three buttons: "Concrete Reinforcement...", "OK", and "Cancel".

Figure 6.11: External shear wall.

2. internal shear wall:

Rectangular Section

The image shows a software dialog box for defining a rectangular section. The 'Section Name' field contains 'int.shear wall'. The 'Section Notes' field is empty, with a 'Modify/Show Notes...' button. The 'Properties' section has a 'Section Properties...' button. The 'Property Modifiers' section has a 'Set Modifiers...' button. The 'Material' section has a dropdown menu showing 'con40Mpa'. The 'Dimensions' section has 'Depth (t3)' set to '0.5' and 'Width (t2)' set to '3.'. To the right is a grid diagram with a gray rectangle representing the section, with blue arrows indicating dimensions '2' (vertical) and '3' (horizontal). Below the grid is a 'Display Color' checkbox. At the bottom are buttons for 'Concrete Reinforcement...', 'OK', and 'Cancel'.

Section Name int.shear wall

Section Notes

Properties

Property Modifiers

Material + con40Mpa ▼

Dimensions

Depth (t3) 0.5

Width (t2) 3.

☐ Display Color

Figure 6.12: internal shear wall.

3. Bridge Section:

The section of the bridge is a hollow section, but for ease of reinforcement the Sections are defined as solid slabs, and modification the modifiers the section.

Rectangular Section

The image shows a software dialog box for defining a bridge section. It has a title bar and a main content area with several sections:

- Section Name:** A text field containing "BRIDGE-SECTION-1".
- Section Notes:** A text area with a "Modify/Show Notes..." button.
- Properties:** A button labeled "Section Properties...".
- Property Modifiers:** A button labeled "Set Modifiers...".
- Material:** A dropdown menu showing "con40Mpa" with a "+" icon to the left and a downward arrow to the right.
- Dimensions:** Two text fields: "Depth (t3)" with the value "1.3" and "Width (t2)" with the value "6.5".
- Diagram:** A grid-based diagram showing a rectangular section. A blue arrow labeled "2" points upwards from the top edge, and a blue arrow labeled "3" points to the left from the left edge. Red lines extend from the right and bottom edges.
- Display Color:** A checkbox that is currently unchecked.
- Buttons:** At the bottom, there are three buttons: "Concrete Reinforcement...", "OK", and "Cancel".

Figure 6.13: Bridge Section 1.

Section Name

Section Notes

Frame Property/Stiffness Modification Factors

Property/Stiffness Modifiers for Analysis

Cross-section (axial) Area	<input type="text" value="0.8"/>
Shear Area in 2 direction	<input type="text" value="0.8"/>
Shear Area in 3 direction	<input type="text" value="0.8"/>
Torsional Constant	<input type="text" value="0.0001"/>
Moment of Inertia about 2 axis	<input type="text" value="0.8"/>
Moment of Inertia about 3 axis	<input type="text" value="0.8"/>
Mass	<input type="text" value="0.55"/>
Weight	<input type="text" value="0.55"/>

Figure 6.14: Bridge Section 2.

4. Column:

There are two column designs in the middle of the bridge to avoid obstructing the road.

Rectangular Section

The image shows a 'Column Design' dialog box with the following components:

- Section Name:** A text field containing 'COULMN'.
- Section Notes:** A text area with a 'Modify/Show Notes...' button.
- Properties:** A button labeled 'Section Properties...'.
- Property Modifiers:** A button labeled 'Set Modifiers...'.
- Material:** A dropdown menu showing 'con40Mpa' with a '+' icon to the left and a downward arrow to the right.
- Dimensions:** Two input fields: 'Depth (t3)' with the value '1.7' and 'Width (t2)' with the value '2.5'.
- Diagram:** A grid-based diagram showing a rectangular column section. The rectangle is outlined in red with a dashed border. Blue arrows labeled '2' and '3' indicate the depth and width dimensions respectively.
- Display Color:** A checkbox that is currently unchecked.
- Buttons:** 'Concrete Reinforcement...', 'OK', and 'Cancel' buttons at the bottom.

Figure 6.15: Column Design.

5. Beam:

To reduce the distance between the shear walls and help with carrying the bridge.

Rectangular Section

The image shows a software dialog box for beam design. At the top, the 'Section Name' is 'B-1500X2500'. Below it is a 'Section Notes' field and a 'Modify/Show Notes...' button. The dialog is divided into three main sections: 'Properties' with a 'Section Properties...' button, 'Property Modifiers' with a 'Set Modifiers...' button, and 'Material' with a dropdown menu showing 'con40Mpa'. The 'Dimensions' section has input fields for 'Depth (t3)' set to 1.5 and 'Width (t2)' set to 2.5. To the right is a grid-based diagram of a rectangular section with blue dimension lines labeled '2' and '3'. Below the grid is a 'Display Color' checkbox with a blue square. At the bottom are buttons for 'Concrete Reinforcement...', 'OK', and 'Cancel'.

Figure 6.16: Beam Design.

6.5 Load Analysis on Bridge:

There are several loads acting on the bridge.

1. Defining load patterns:

Define Load Patterns

Load Pattern Name	Type	Self Weight Multiplier	Auto Lateral Load Pattern
DEAD	DEAD	1	
DEAD	DEAD	1	
Vehicle load	VEHICLE LIVE	0	
EQ.x	QUAKE	0	IBC 2012
EQ.y	QUAKE	0	IBC 2012
BR	OTHER	0	

Click To:

Add New Load Pattern

Modify Load Pattern

Show Lateral Load Pattern...

Delete Load Pattern

Show Load Pattern Notes...

OK

Cancel

Figure 6.17: Load Patterns.

2. Vehicle load:

To consider loads scenarios load paths are defined by using SAP2000 program.

Path Data

Path Name: PATH1 Display Color: [Red]

Frame	Centerline Offset
23	1.6
23	1.6
61	1.6
169	1.6
163	1.6
164	1.6
165	1.6
166	1.6

Add

Insert

Modify

Delete

Reverse Order

Reverse Sign

Move Path...

Discretization

Maximum Discretization Length: 3.048

☒ Discretization Length Not Greater Than 1/ 10. of Path Length

OK

Cancel

Figure 6.18: Path Data 1.

Path Data

Path Name
Display Color
☐

Frame	Centerline Offset
23	-1.6
23	-1.6
61	-1.6
169	-1.6
163	-1.6
164	-1.6
165	-1.6
166	-1.6

Add
Insert
Modify
Delete

Reverse Order
Reverse Sign
Move Path...

Discretization
Maximum Discretization Length
☒ Discretization Length Not Greater Than 1/ of Path Length

OK
Cancel

Figure 6.19: Path Data 2.

Vehicle Data

Vehicle name
Units

Load Elevation

Load Length Type	Minimum Distance	Maximum Distance	Uniform Load	Axle Load
Fixed Length	1.		9.2	35.
Fixed Length	1.		9.2	35.
Fixed Length	4.2		9.2	142.
Fixed Length	4.2		9.2	142.

Add
Insert
Modify
Delete

☐ Vehicle Remains Fully In Path

OK
Cancel

Figure 6.20: Path Data 3.

3. Seismic load:

According to the seismicity of the site report and area classification in the seismic map issued by the Center for Earth Sciences and Seismic Engineering at An-Najah National University, Seismic load was found in the X-axis and Y-axis Directions.

IBC 2012 Seismic Load Pattern

Load Direction and Diaphragm Eccentricity

☒ Global X Direction
☐ Global Y Direction

Ecc. Ratio (All Diaph.)

Override Diaph. Eccen.

Time Period

☐ Approx. Period Ct (ft), x =
☐ Program Calc Ct (ft), x =
☒ User Defined T =

Lateral Load Elevation Range

☒ Program Calculated
☐ User Specified

Max Z
Min Z

Factors

Response Modification, R
System Overstrength, Omega
Deflection Amplification, Cd
Occupancy Importance, I

Seismic Coefficients

☐ Ss and S1 from USGS - by Lat./Long.
☐ Ss and S1 from USGS - by Zip Code
☒ Ss and S1 User Specified

Site Latitude (degrees) ?
Site Longitude (degrees) ?
Site Zip Code (5-Digits) ?

0.2 Sec Spectral Accel, Ss
1 Sec Spectral Accel, S1
Long-Period Transition Period

Site Class

Site Coefficient, Fa
Site Coefficient, Fv

Calculated Coefficients

SDS = (2/3) * Fa * Ss
SD1 = (2/3) * Fv * S1

Figure 6.21: Seismic Load Pattern.

4. **Moment at serves load:**

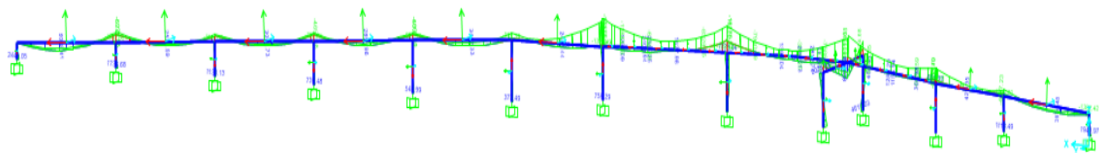


Figure 6.22: Moment at serves load.

5. **Joint Reactions:**

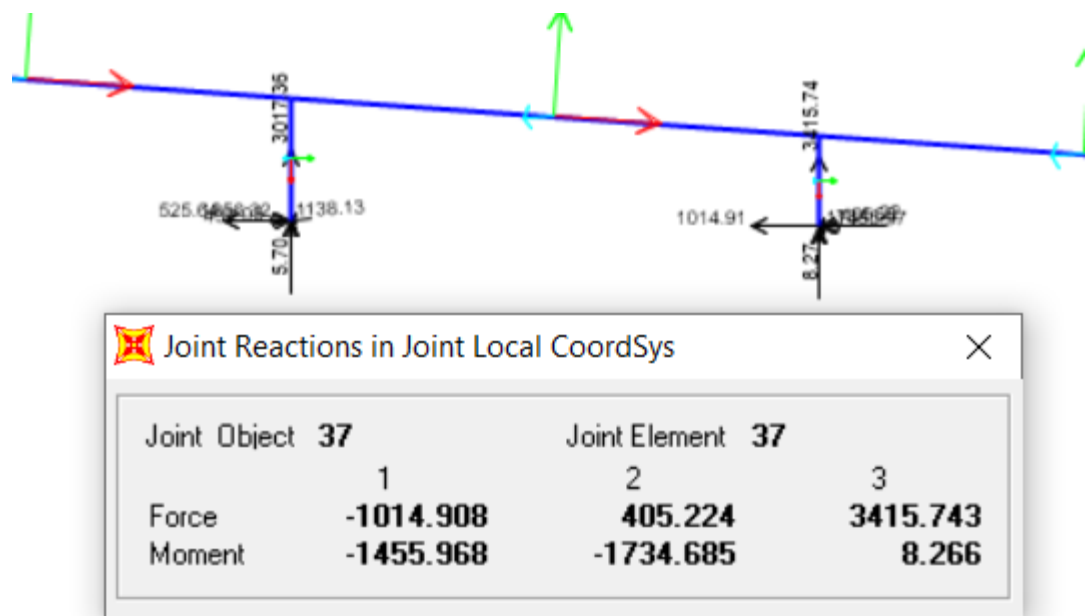


Figure 6.23: Joint reactions.

6. Check design the Bridge:

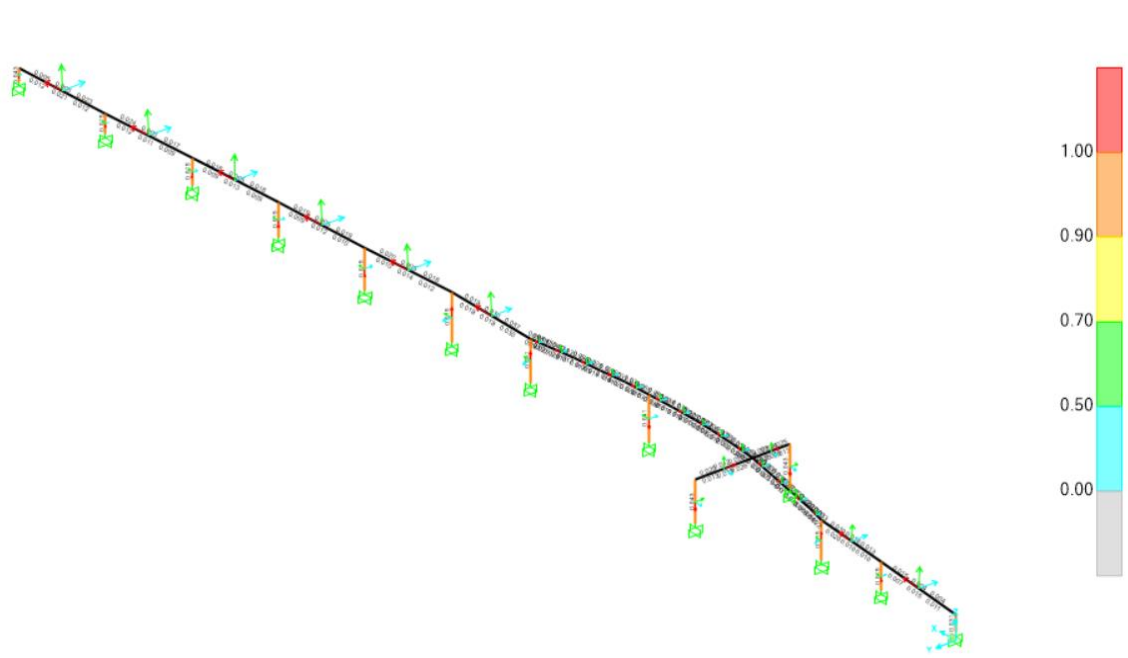


Figure 6.24: Check design the Bridge.

Chapter Seven

Foundation Design and Reinforcement

7.1 Piles Introduction:

Introduction:

Piles are columnar elements in a foundation which have the function of transferring load from the superstructure through weak compressible strata or through water, onto stiffer or more compact and less compressible soils or onto rock. They may be required to carry uplift loads when used to support tall structures subjected to overturning forces from winds or waves. Piles used in marine structures are subjected to lateral loads from the impact of berthing ships and from waves. Combinations of vertical and horizontal loads are carried where piles are used to support retaining walls, bridge piers and abutments, and machinery foundations.

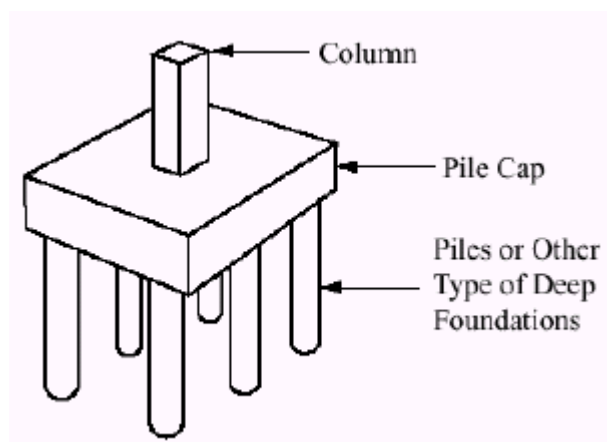


Figure 7.1: Piles image 1.

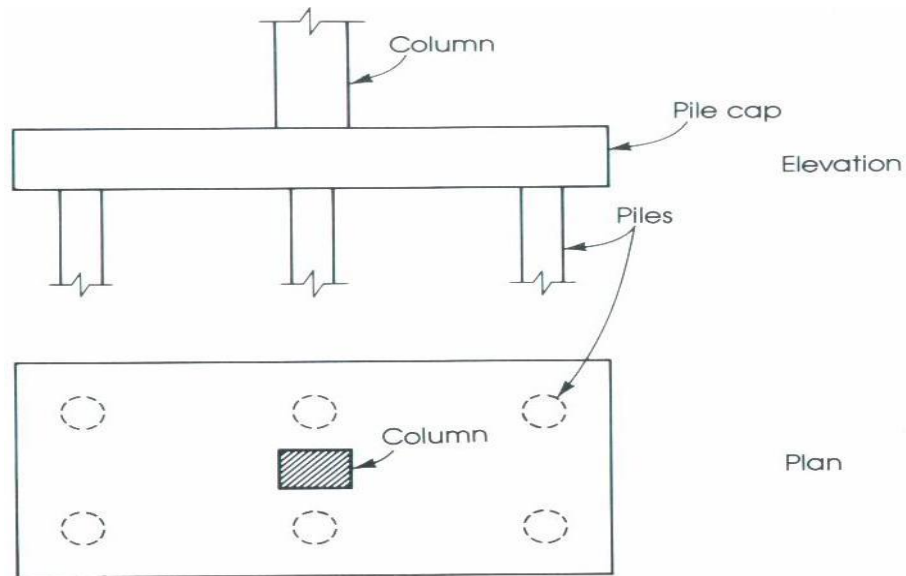


Figure 7.2: Piles image 2.

Main reasons for using piles:

1. In case of the top layers are so weak that they could not bear the structure, the piles transfer loads to a good layer at reasonable depth.
2. In order to resist uplift pressure.
3. In case of structure in water.
4. In order to densify the soil as in case of short stone piles.

Types of piles:

1. With respect to the method of transform loads:
 - A. End Bearing piles.
 - B. Friction piles.
 - C. End Bearing + Friction piles.

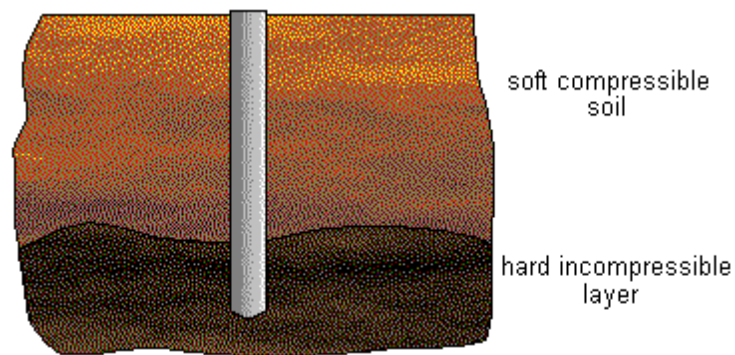


Figure 7.3: End Bearing Piles.

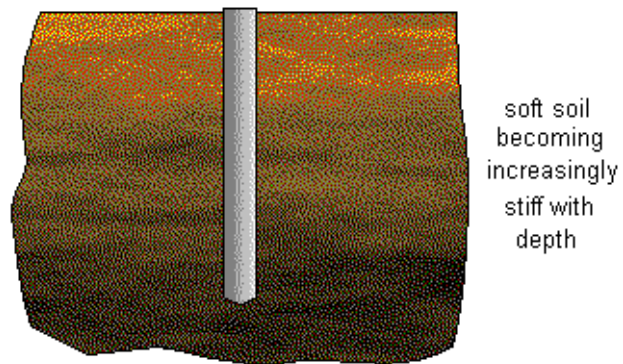


Figure 7.4: Friction Piles.

2. With respect to material:

The main types of materials used for piles are wood, steel and concrete.

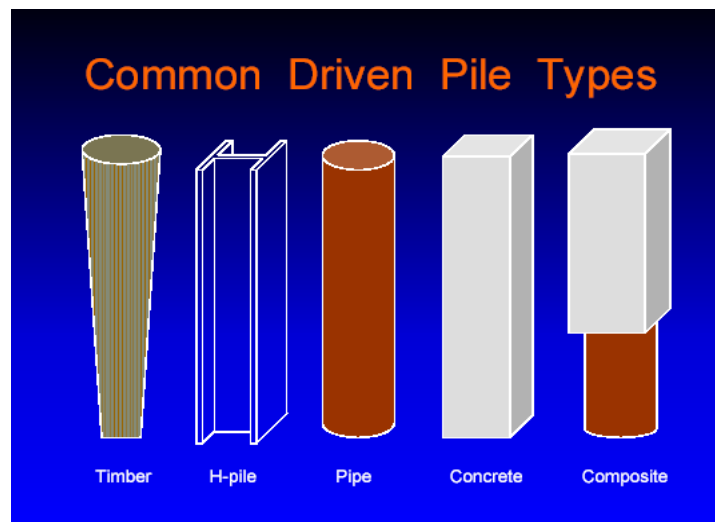


Figure 7.5: Types of Materials.

Materials used for piles:

1. Timber Piles:

Timber piles are used in temporary works. Length: 9 → 15 m, Max load: 45 Ton.



Figure 7.6: Timber Piles.

2. Steel Piles:

Steel piles are used when the pile crosses hard layers. Length: 12 → 50 m, Max load: 35 → 100 Ton.



Figure 7.7: Steel Piles.

3. Concrete piles:

Concrete piles are divided into two types:

A. Pre cast: Driven:

Precast concrete units placed in drilled hole.

B. Cast in place: Driven (poured)

Fresh concrete poured in hole.



Figure 7.8: Pre cast piles.



Figure 7.9: Piles drilling.

7.2 Design and reinforcement of Foundation:

7.2.1 Footings design:

1. Define material:

Table 7.1: Define materials

Type of frame or shells	Compressive strength of Concrete “f _c ”.
Cap	28
Column	28
Pile	28

2. Define shells:

- **Footing (1):**

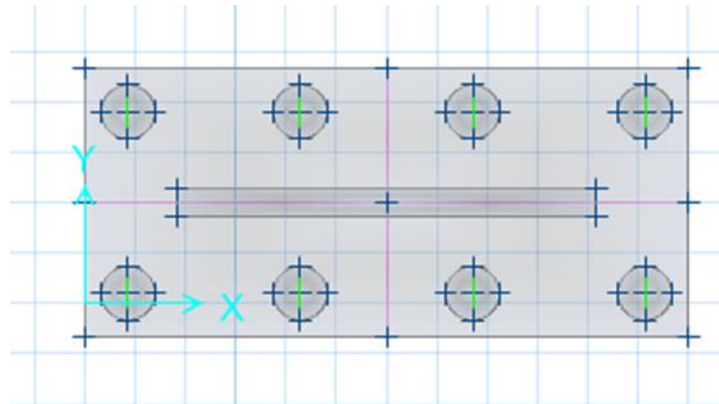


Figure 7.10: Footing 1a.

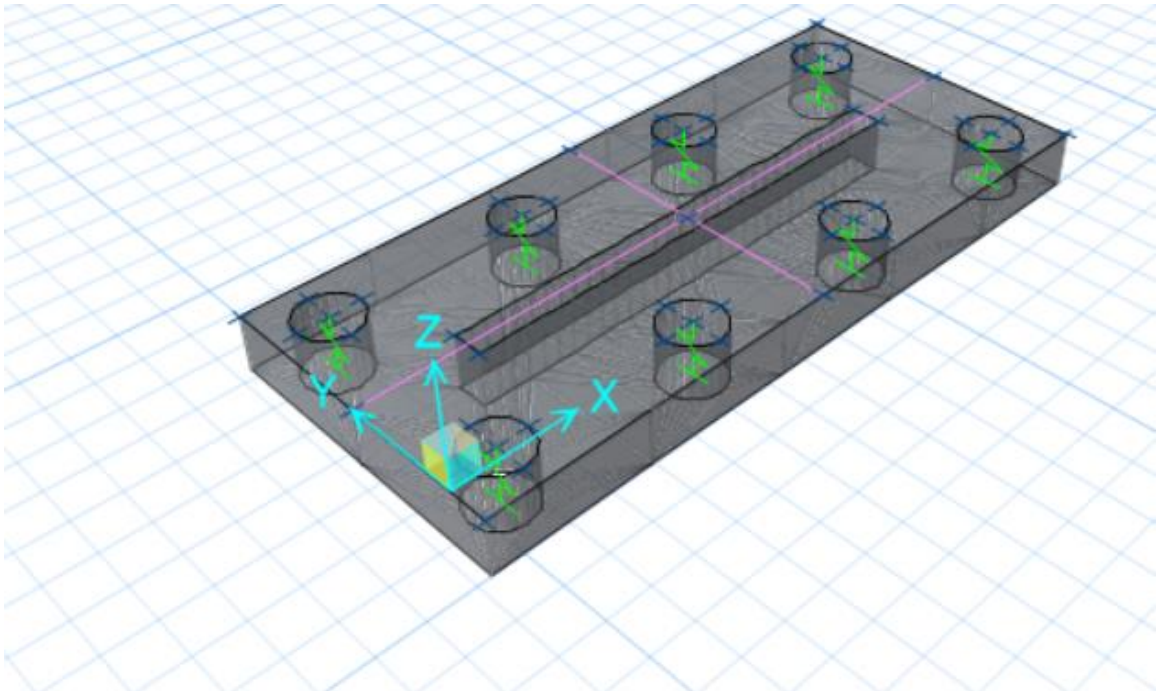


Figure 7.11: Footing 1b.

1. The Cap.

According to ACI318, the approximate depth of the Cap controlled by Punching Shear.

Assume $h = 70\text{cm}$.

Define Cap section by SAFE as shown in the figure:

General Data

Property Name: Cap

Slab Material: B350

Display Color: Change...

Property Notes: Modify/Show...

Analysis Property Data

Type: Slab

Thickness: 700 mm

☒ Thick Plate ☐ Orthotropic

Figure 7.12: Cap-section define by SAFE.

2. Shear walls and piles:

Table 7.2: Shear walls and piles (F.1)

Member type	Dimensions
Piles	Diameter = 80cm.
Shear walls	6.25m*0.4m

Define piles and shear wall sections by SAFE as shown in the figure:

The screenshot shows the SAFE software interface for defining a property. The 'General Data' section includes fields for 'Property Name' (Stiff), 'Slab Material' (B350), 'Display Color' (a pink color swatch), and 'Property Notes'. The 'Analysis Property Data' section includes a 'Type' dropdown (Stiff) and a 'Thickness' field (700 mm). At the bottom, there are checkboxes for 'Thick Plate' (checked) and 'Orthotropic' (unchecked).

Figure 7.13: Footing (1) Stiff-section defines by SAFE.

Stiff property data gives a realistic deflection, and realistic moments.

3. Define point spring (Spring Stiffness):

A point spring added under all piles to demonstrate the allowable piles settlement which given from soil reports which equal 10mm.

From foundation equations:

Minimum number of piles = 8piles.

$$Q_{\text{All comp}} = 950\text{KN.}$$

$$Q_{\text{All tens}} = 750\text{KN.}$$

Spring Stiffness = $950/10 = 95\text{KN/mm}$.

The screenshot displays the 'Define Spring' dialog box in the SAFE software. It is divided into three main sections:

- General Data:** Contains fields for 'Property Name' (set to 'pile'), 'Display Color' (a blue square), and 'Property Notes' (with a 'Modify/Show Notes...' button).
- Spring Stiffness in Global Directions:** A table of stiffness values:

Direction	Stiffness (kN/mm)
Translation X	0
Translation Y	0
Translation Z (Compression Only)	95
Rotation about X-Axis	0
Rotation about Y-Axis	0
Rotation about Z-Axis	0
- Nonlinear Option (Translation Z Only) (Nonlinear Cases Only):** A group of radio buttons with 'Compression Only' selected.

Figure 7.14: Footing (1) point spring define by SAFE.

4. Define of load patterns and load combination:

All load patterns defined by SAP, only dead load defined by SAFE. Services load taken by SAP and added as a dead load by SAFE. Ultimate and service combinations added by SAFE.

Load Patterns

Load Patterns

Load	Type	Self Weight Multiplier
DEAD	DEAD	0.0000

General Data

Load Combination Name: Service
Combination Type: Linear Add
Notes: [Modify/Show Notes...](#)
Auto Combination: No

Define Combination of Load Case/Combo Results

	Load Name	Scale Factor
▶	DEAD	1.0000
*		

Design Selection

☐ Strength (Ultimate)
☒ Service - Normal
☐ Service - Initial
☐ Service - Long Term

General Data

Load Combination Name: Ultimate
Combination Type: Linear Add
Notes: [Modify/Show Notes...](#)
Auto Combination: No

Define Combination of Load Case/Combo Results

	Load Name	Scale Factor
▶	DEAD	1.3000
*		

Design Selection

☒ Strength (Ultimate)
☐ Service - Normal
☐ Service - Initial
☐ Service - Long Term

Figure 7.15: load patterns and load combination defined by SAFE.

5. Assign load on model:

A point Load added as a dead load on the center of shear wall.

Table 7.3: Assign load on model (F.1)

Type of load	Direction	Magnitude
Vertical load	Z-direction	2070KN.
Moments	X-direction	570KN.m
	Y-direction	1855KN.m

Load Pattern	DEAD
Point Loads	
Force in Gravity Dir (-Global Z) (kN)	2070
Moment about Global X Axis (kN-m)	-570
Moment about Global Y Axis (kN-m)	1855
Load Size X Dimension (mm)	6250
Load Size Y Dimension (mm)	400

Figure 7.16: loads of footing.

6. Analysis the model and checks:

The following checks are important to be taken in consideration:

- Compatibility:

To make sure that all the structural elements are compatible with each other. This can be achieved and approved by noticing and analyzing the deformed shape animation of the model by SAFE.

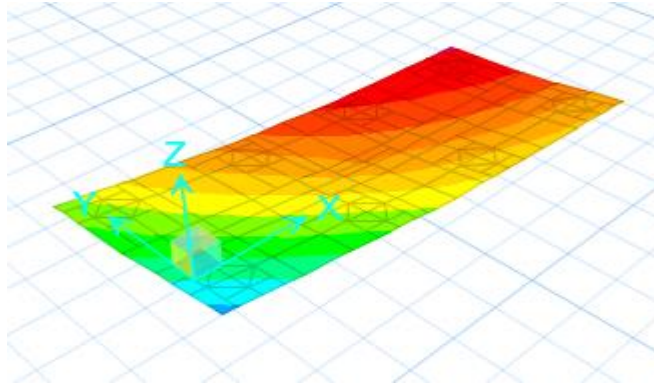


Figure 7.17: Compatibility.

- Dimensions check based on soil failure:

$$R_{\max} \leq q_{\text{all comp}}$$

$$R_{\max} = P/N + (M_x * Y_{\text{com}} / \Sigma y^2) + (M_y * X_{\text{comp}} / \Sigma X^2)$$

$$= 2070/8 + (570 * 1.35 / 8 * 1.35^2) + (1855 * 3.85 / (4 * 3.85^2 + 4 * 1.28^2))$$

$$= 421 \text{ kN} < Q_{\text{all comp}}$$

$$R_{\min} \leq q_{\text{all tens}}$$

$$R_{\min} = P/N - (M_x * Y_{\text{com}} / \Sigma y^2) - (M_y * X_{\text{comp}} / \Sigma X^2)$$

$$= 2070/8 - (570 * 1.35 / 8 * 1.35^2) - (1855 * 3.85 / (4 * 3.85^2 + 4 * 1.28^2))$$

$$= 97 \text{ kN} < Q_{\text{all tens}}$$

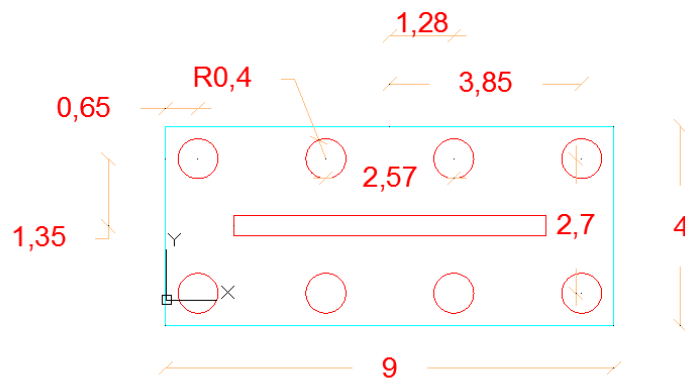


Figure 7.18: Footing (1) dimensions.

Space between piles should be $> 3 \cdot d_{\text{pile}} = 3 \cdot 0.8 = 2.4\text{m}$.

- Displacement check:

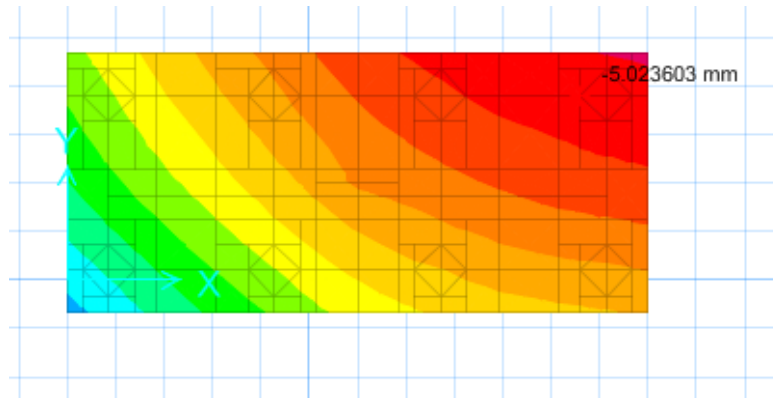


Figure 7.19: Footing (1) displacement.

The displacement under footing should be $< 10\text{mm}$.

- Punching Shear check:

Punching Shear ratio = max shear applied / max shear capacity.

a) If punching shear ratio > 1 , the design is not ok.

b) If punching shear ratio < 1 , the design is ok.

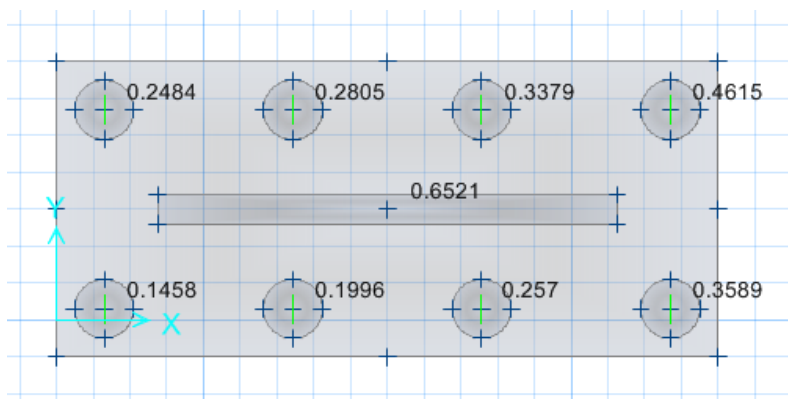


Figure 7.20: Footing (1) punching shear ratio given by SAFE.

From the figure punching check is ok.

7. Footing Reinforcement:

First of all, $A_{s \min}$ should be calculated.

$$A_{s \min} = A_s \text{ shrinking} = 0.0018 * b * h$$

Footing thickness $= h = 700 \text{ mm}$

$$A_{s \min} = 0.0018 * 1000 * 700 = 1260 \text{ mm}^2/\text{m}.$$

So use $7 \phi 16/\text{m}$ if footing needs minimum reinforcing.

The following figures give the bottom and top reinforcement in all directions.

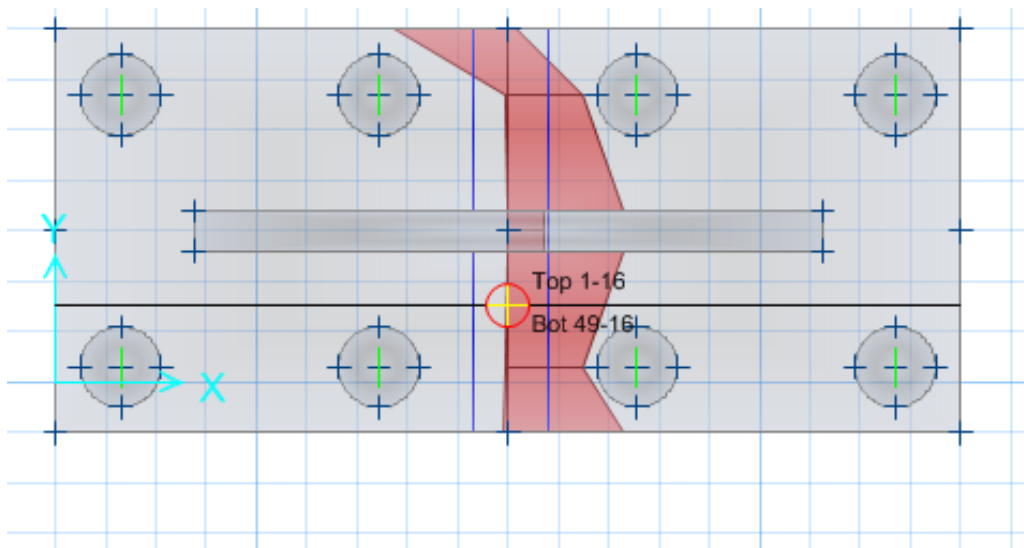


Figure 7.21: Total bottom number of bars in Y(short) direction.

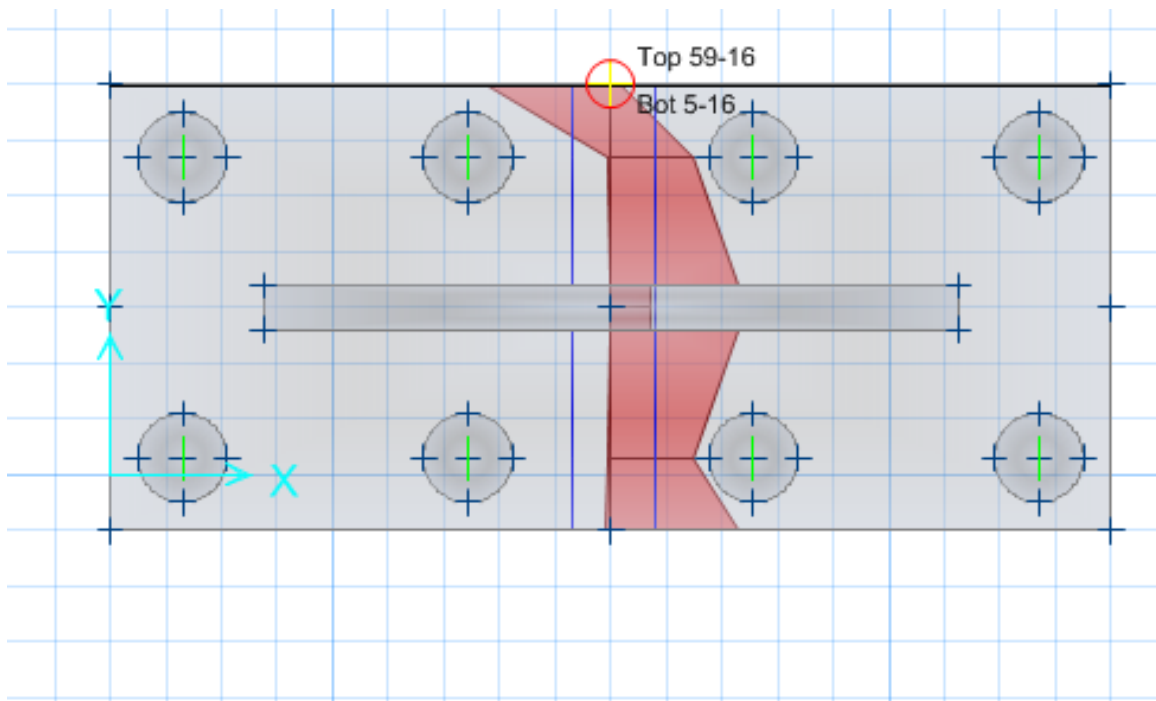


Figure7.22: Total Top number of bars in Y(short) direction.

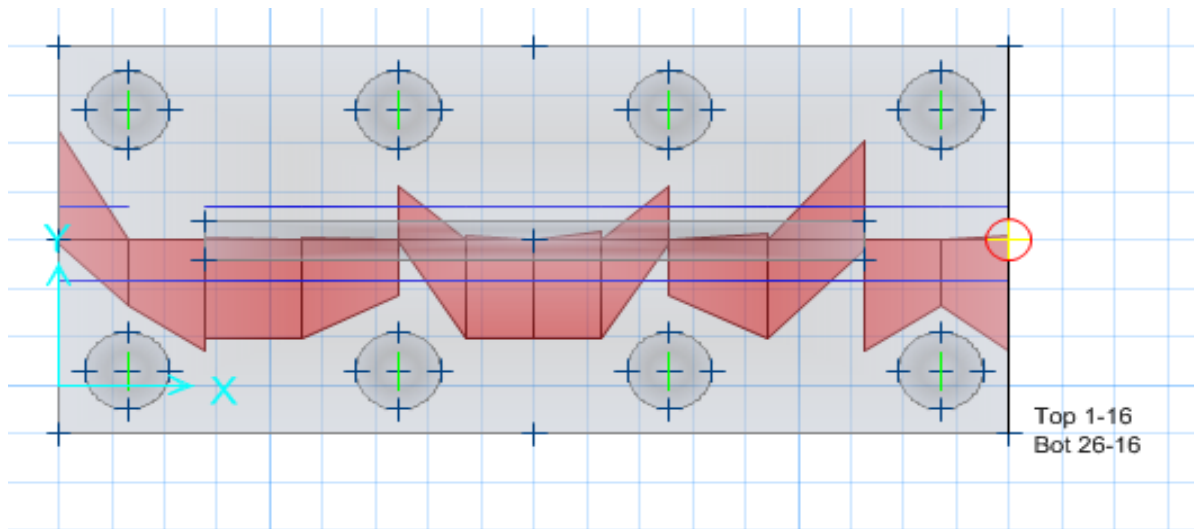


Figure 7.23: Total bottom number of bars in X(Long) direction.

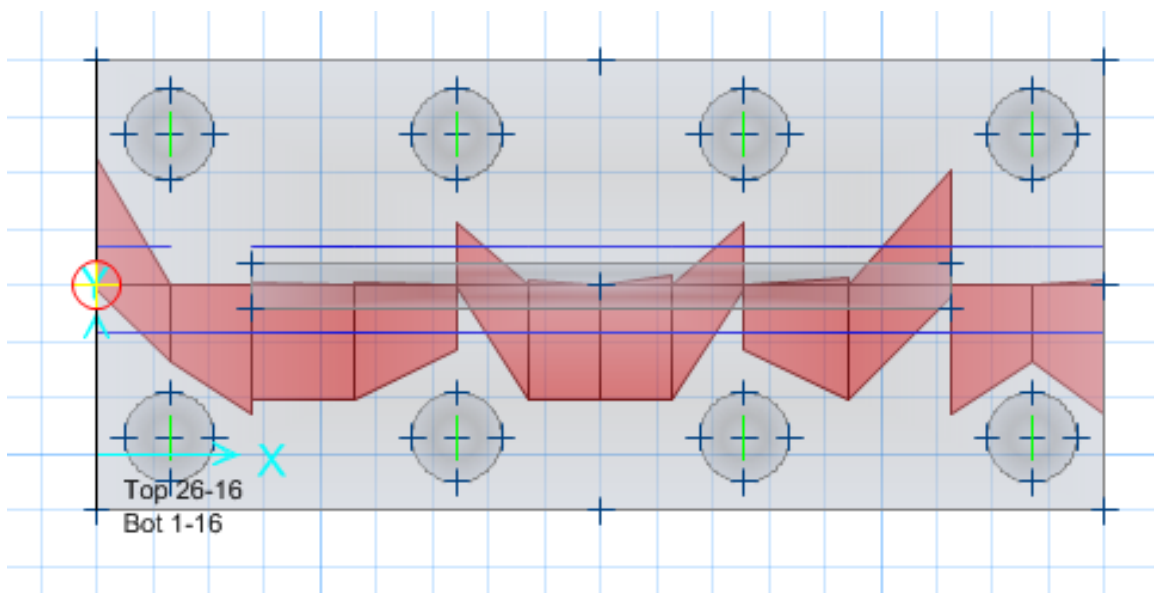


Figure 7.24: Total Top number of bars in X(Long) direction.

Table 7.4: Bottom and top reinforcement (F.1)

Reinforcement	Long direction	Short direction
Top	7 Φ 16/m	7 Φ 16/m
Bottom	7 Φ 16/m	7 Φ 16/m

- **Footing (2):**

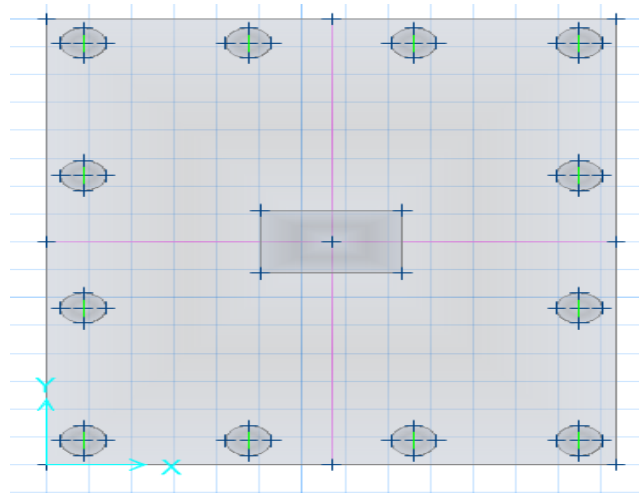


Figure 7.25: Footing 2.

1. The Cap:

According to ACI318, the approximate depth of the Cap controlled by Punching Shear.

Assume $h = 110\text{cm}$.

Define Cap section by SAFE as shown in the figure:

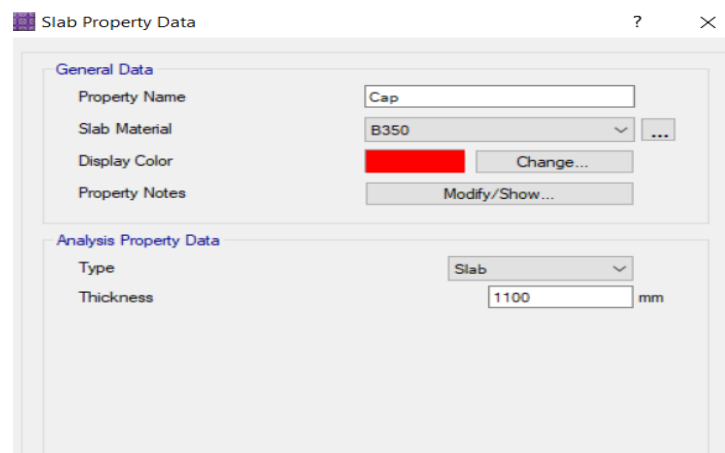


Figure 7.26: Cap-section define by SAFE.

2. Column and piles:

Table 7.5: Column and piles (F.2)

Member type	Dimensions
Piles	Diameter = 80cm.
column	1.7m*2.5m

Define piles and shear wall sections by SAFE as shown in the figure:

The screenshot displays the SAFE software interface for defining a Stiff-section. It is divided into two main sections: 'General Data' and 'Analysis Property Data'.
In the 'General Data' section:
- 'Property Name' is set to 'Stiff'.
- 'Slab Material' is set to 'B350' with a dropdown arrow and an ellipsis button.
- 'Display Color' is set to a red color swatch with a 'Change...' button.
- 'Property Notes' has a 'Modify/Show...' button.
In the 'Analysis Property Data' section:
- 'Type' is set to 'Stiff' with a dropdown arrow.
- 'Thickness' is set to '1100' with a unit of 'mm'.

Figure 7.27: Footing (2) Stiff-section defines by SAFE.

3. Define point spring (Spring Stiffness):

A point spring added under all piles to demonstrate the allowable piles settlement which given from soil reports which equal 10mm.

From foundation equations:

Minimum number of piles = 8piles.

$$Q_{\text{All comp}} = 950\text{KN.}$$

$$Q_{\text{All tens}} = 750\text{KN.}$$

$$\text{Spring Stiffness} = 950/10 = 95\text{KN/mm.}$$

4. Define of load patterns and load combination:

All load patterns defined by SAP , only dead load defined by SAFE.

Services load taken by SAP and added as a dead load by SAFE .

Ultimate and service combinations added by SAFE.

The screenshot displays the SAFE software interface for defining load patterns and combinations. The top section, titled 'Load Patterns', shows a table with columns 'Load', 'Type', and 'Self Weight Multiplier'. A single row is defined with 'DEAD' as the load, 'DEAD' as the type, and '0.0000' as the multiplier. Below this, two panels show the configuration for 'Service' and 'Ultimate' load combinations. Both panels have 'Load Combination Name' set to 'Service' and 'Ultimate' respectively, with 'Combination Type' set to 'Linear Add' and 'Auto Combination' set to 'No'. The 'Define Combination of Load Case/Combo Results' section for both shows a table with 'Load Name' and 'Scale Factor'. For the 'Service' combination, the scale factor for 'DEAD' is '1.0000'. For the 'Ultimate' combination, the scale factor for 'DEAD' is '1.3000'. The 'Design Selection' section at the bottom of each panel shows 'Strength (Ultimate)' selected for both, with 'Service - Normal' and 'Service - Long Term' also selected for the 'Service' combination, and 'Service - Initial' selected for the 'Ultimate' combination.

Load	Type	Self Weight Multiplier
DEAD	DEAD	0.0000

Service Load Combination

General Data

Load Combination Name: Service

Combination Type: Linear Add

Notes: Modify/Show Notes...

Auto Combination: No

Define Combination of Load Case/Combo Results

Load Name	Scale Factor
DEAD	1.0000

Design Selection

☐ Strength (Ultimate) ☒ Service - Normal

☐ Service - Initial ☐ Service - Long Term

Ultimate Load Combination

General Data

Load Combination Name: Ultimate

Combination Type: Linear Add

Notes: Modify/Show Notes...

Auto Combination: No

Define Combination of Load Case/Combo Results

Load Name	Scale Factor
DEAD	1.3000

Design Selection

☒ Strength (Ultimate) ☐ Service - Normal

☐ Service - Initial ☐ Service - Long Term

Figure 7.28: load patterns and load combination defined by SAFE.

5. Assign load on model:

A point Load added as a dead load on the center of shear wall.

Table 7.6: Assign load on model (F.2)

Type of load	Direction	Magnitude
Vertical load	Z-direction	6971KN.
	X-direction	4612KN.m

Moments	Y-direction	9063KN.m
---------	-------------	----------

Load Pattern	DEAD
Point Loads	
Force in Gravity Dir (-Global Z) (kN)	6971
Moment about Global X Axis (kN-m)	-4612
Moment about Global Y Axis (kN-m)	-9063
Load Size X Dimension (mm)	2500
Load Size Y Dimension (mm)	1700

Figure 7.29: loads of footing

6. Analysis the model and checks:

The following checks are important to be taken in consideration:

- Compatibility:

To make sure that all the structural elements are compatible with each other. This can be achieved and approved by noticing and analyzing the deformed shape animation of the model by SAFE.

- Dimensions check based on soil failure:

$$R_{\max} \leq q_{\text{all comp}}$$

$$R_{\max} = P/N + (M_x * Y_{\text{com}} / \Sigma y^2) + (M_y * X_{\text{comp}} / \Sigma X^2) = 6971/12 + (4612 * 5.35 / (8 * 5.35^2) + (4 * 1.78^2)) + (9063 * 4.35 / (8 * 4.35^2 + 4 * 1.45^2)) = 930 < Q_{\text{all comp}}$$

$$R_{\min} \leq q_{\text{all tens}}$$

$$R_{\min} = 581 - 103 - 246 = 232 \text{ KN} < Q_{\text{all tens}}$$

- Displacement check:

The displacement under footing should be $< 10 \text{ mm}$.

- Punching Shear check:

Punching Shear ratio = max shear applied / max shear capacity

a) If punching shear ratio > 1 , the design is not ok

b) If punching shear ratio < 1 , the design is ok

Punching check is ok.

7. Footing Reinforcement:

Table 7.7: Bottom and top reinforcement (F.2)

Reinforcement	Long direction	Short direction
Top	10 Φ 16/m	10 Φ 16/m
Bottom	10 Φ 25/m	7 Φ 25/m

• Footing (3):

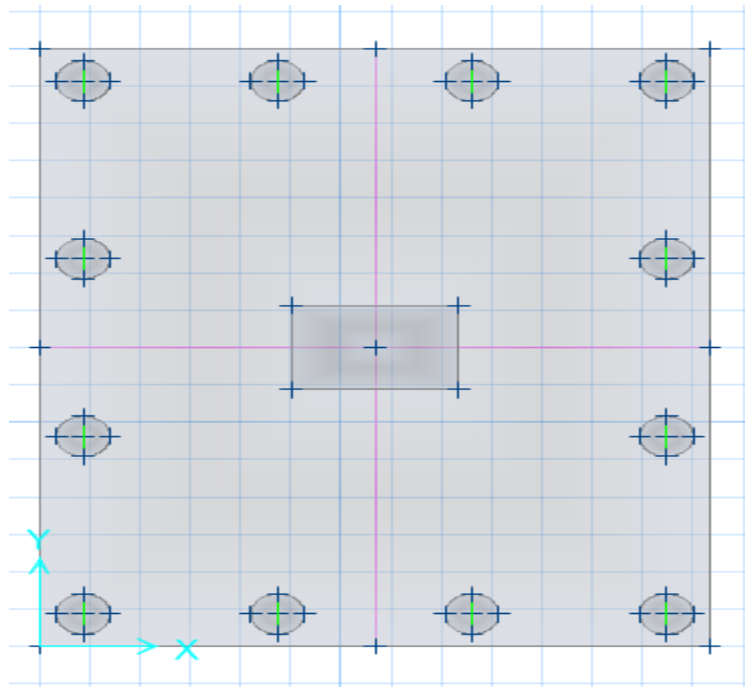


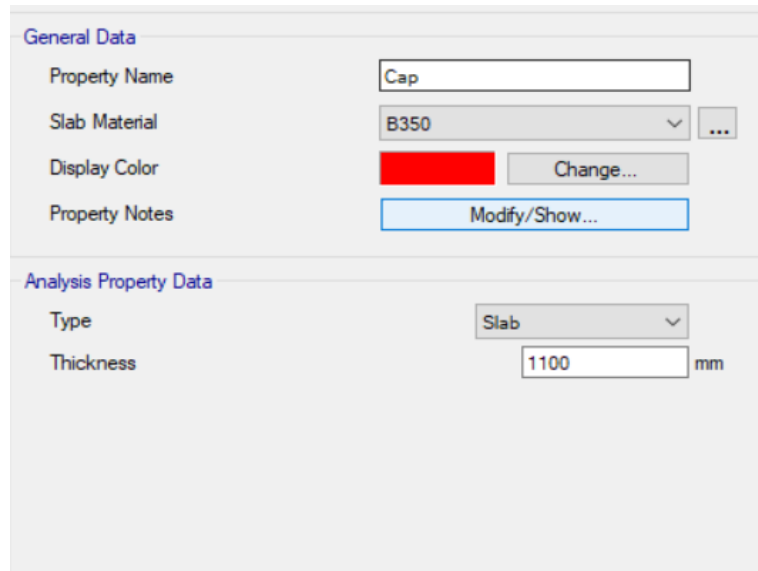
Figure7.30: Footing 3.

1. The Cap.

According to ACI318, the approximate depth of the Cap controlled by Punching Shear.

Assume $h = 110\text{cm}$.

Define Cap section by SAFE as shown in the figure:



The screenshot shows the SAFE software interface for defining a Cap section. It is divided into two main sections: 'General Data' and 'Analysis Property Data'. In the 'General Data' section, the 'Property Name' is set to 'Cap', 'Slab Material' is 'B350', 'Display Color' is a red square, and 'Property Notes' has a 'Modify/Show...' button. In the 'Analysis Property Data' section, the 'Type' is 'Slab' and 'Thickness' is '1100 mm'.

Figure 7.31: Cap-section define by SAFE.

2. Column and piles:

Table 7.8: Column and piles (F.3)

Member type	Dimensions
Piles	Diameter = 80cm.
Column	1.7m*2.5m

Define piles and shear wall sections by SAFE as shown in the figure:

The screenshot displays the SAFE software interface for defining a footing. It is divided into two main sections: 'General Data' and 'Analysis Property Data'.

General Data:

- Property Name:** A text box containing the word 'Stiff'.
- Slab Material:** A dropdown menu showing 'B350' with a small '...' button to its right.
- Display Color:** A red color swatch next to a 'Change...' button.
- Property Notes:** A button labeled 'Modify/Show...'.

Analysis Property Data:

- Type:** A dropdown menu showing 'Stiff'.
- Thickness:** A text box containing '1100' followed by a unit label 'mm'.

Figure 7.32: Footing (3) Stiff-section defines by SAFE.

3. Define point spring (Spring Stiffness):

A point spring added under all piles to demonstrate the allowable piles settlement which given from soil reports which equal 10mm.

From foundation equations:

Minimum number of piles = 8piles.

$$Q_{\text{All comp}} = 950\text{KN.}$$

$$Q_{\text{All tens}} = 750\text{KN.}$$

$$\text{Spring Stiffness} = 950/10 = 95\text{KN/mm.}$$

4. Define of load patterns and load combination:

All load patterns defined by SAP, only dead load defined by SAFE.

Services load taken by SAP and added as a dead load by SAFE.

Ultimate and service combinations added by SAFE.

The screenshot displays the SAFE software interface for defining load patterns and combinations. The top section, titled 'Load Patterns', contains a table with the following data:

Load	Type	Self Weight Multiplier
DEAD	DEAD	0.0000

Below this, the 'Load Combination' settings are shown in two panels. The left panel, 'General Data', has the following fields:

- Load Combination Name: Service
- Combination Type: Linear Add
- Notes: Modify/Show Notes...
- Auto Combination: No

The right panel, 'General Data', has the following fields:

- Load Combination Name: Ultimate
- Combination Type: Linear Add
- Notes: Modify/Show Notes...
- Auto Combination: No

Below these, the 'Define Combination of Load Case/Combo Results' section contains two tables. The left table, for the 'Service' combination, has the following data:

Load Name	Scale Factor
DEAD	1.0000

The right table, for the 'Ultimate' combination, has the following data:

Load Name	Scale Factor
DEAD	1.3000

At the bottom, the 'Design Selection' section contains checkboxes for various design types:

- ☐ Strength (Ultimate)
- ☒ Service - Normal
- ☐ Service - Initial
- ☐ Service - Long Term

Figure 7.33: load patterns and load combination defined by SAFE.

5. Assign load on model:

A point Load added as a dead load on the center of shear wall.

Table 7.9: Assign load on model (F.3)

Type of load	Direction	c
Vertical load	Z-direction	6138KN.
Moments	X-direction	6899KN.m
	Y-direction	6535KN.m

Load Pattern	DEAD
Point Loads	
Force in Gravity Dir (-Global Z) (kN)	6138
Moment about Global X Axis (kN-m)	6899
Moment about Global Y Axis (kN-m)	-6535
Load Size X Dimension (mm)	2500
Load Size Y Dimension (mm)	1700

Figure 7.34: loads of footing

6. Analysis the model and checks:

The following checks are important to be taken in consideration:

- Compatibility:

To make sure that all the structural elements are compatible with each other. This can be achieved and approved by noticing and analyzing the deformed shape animation of the model by SAFE.

- Dimensions check based on soil failure:

$$R_{\max} \leq q_{\text{all comp}}$$

$$R_{\max} = P/N + (M_x * Y_{\text{com}} / \Sigma y^2) + (M_y * X_{\text{comp}} / \Sigma X^2)$$

$$= 6138/12$$

$$+ (6899 * 5.35 / (8 * 5.35^2)) + (4 * 1.78^2) + (6535 * 4.35 / (8 * 4.35^2 + 4 * 1.45^2))$$

$$= 844 < q_{\text{all comp}}$$

$$R_{\min} \leq q_{\text{all tens}}$$

$$R_{\min} = 512 - 154 - 178$$

$$= 180 \text{ KN} < q_{\text{all tens.}}$$

- Displacement check:

The displacement under footing should be $< 10 \text{ mm}$.

- Punching Shear check:

Punching Shear ratio = max shear applied / max shear capacity

a) If punching shear ratio > 1 , the design is not ok

b) If punching shear ratio < 1 , the design is ok

Punching check is ok.

7. Footing Reinforcement:

Table 7.10: Bottom and top reinforcement (F.3)

Reinforcement	Long direction	Short direction
Top	9Φ16/m	8Φ16/m

Bottom	10 Φ 25/m	6 Φ 25/m
--------	----------------	---------------

- **Footing (4):**

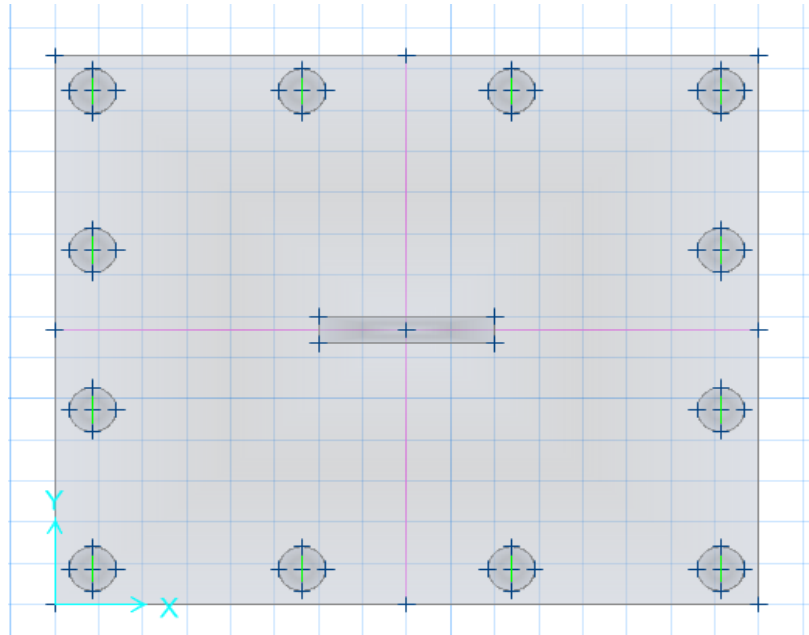


Figure 7.35: Footing 4.

1. The Cap:

According to ACI318, the approximate depth of the Cap controlled by Punching Shear.

Assume $h = 1.5\text{m}$.

The image shows a software window for defining a 'Cap' section. It is divided into two main sections: 'General Data' and 'Analysis Property Data'.
 In the 'General Data' section:
 - 'Property Name' is set to 'Cap'.
 - 'Slab Material' is set to 'B350'.
 - 'Display Color' is set to a red color swatch, with a 'Change...' button next to it.
 - 'Property Notes' has a 'Modify/Show...' button.
 In the 'Analysis Property Data' section:
 - 'Type' is set to 'Slab'.
 - 'Thickness' is set to '1500' mm.

Figure 7.36: Cap-section define by SAFE.

2. Shear walls and piles:

Table 7.11: Shear walls and piles (F.4)

Member type	Dimensions
Piles	Diameter = 80cm.
Shear walls	3m*0.5m

Define piles and shear wall sections by SAFE as shown in the figure:

The screenshot displays the SAFE software interface for defining a footing section. It is divided into two main sections: 'General Data' and 'Analysis Property Data'.

General Data:

- Property Name:** A text box containing the word 'Stiff'.
- Slab Material:** A dropdown menu showing 'B350' with a small '...' button to its right.
- Display Color:** A red color swatch next to a 'Change...' button.
- Property Notes:** A 'Modify/Show...' button.

Analysis Property Data:

- Type:** A dropdown menu showing 'Stiff'.
- Thickness:** A text box containing '1500' followed by a unit label 'mm'.

Figure 7.37: Footing (4) Stiff-section defines by SAFE.

3. Define point spring (Spring Stiffness):

A point spring added under all piles to demonstrate the allowable piles settlement which given from soil reports which equal 10mm.

From foundation equations:

Minimum number of piles = 8piles.

$$Q_{\text{All comp}} = 950\text{KN.}$$

$$Q_{\text{All tens}} = 750\text{KN.}$$


$$\text{Spring Stiffness} = 950/10 = 95\text{KN/mm.}$$

4. Define of load patterns and load combination:

All load patterns defined by SAP, only dead load defined by SAFE.

Services load taken by SAP and added as a dead load by SAFE.

Ultimate and service combinations added by SAFE.


Load Patterns

Load Patterns

Load	Type	Self Weight Multiplier
DEAD	DEAD	0.0000

General Data

Load Combination Name

Service

Combination Type

Linear Add

Notes

Modify/Show Notes...

Auto Combination

No

Define Combination of Load Case/Combo Results

	Load Name	Scale Factor
▶	DEAD	1.0000
*		

Design Selection

☐ Strength (Ultimate)
 ☒ Service - Normal

☐ Service - Initial
 ☐ Service - Long Term

General Data

Load Combination Name

Ultimate

Combination Type

Linear Add

Notes

Modify/Show Notes...

Auto Combination

No

Define Combination of Load Case/Combo Results

	Load Name	Scale Factor
▶	DEAD	1.3000
*		

Design Selection

☒ Strength (Ultimate)
 ☐ Service - Normal

☐ Service - Initial
 ☐ Service - Long Term

Figure 7.38: load patterns and load combination defined by SAFE.

5. Assign load on model:

A point Load added As a dead load on the center of shear wall.

Table 7.12: Assign load on model (F.4)

Type of load	Direction	Magnitude
Vertical load	Z-direction	8709KN.
Moments	X-direction	6424N.m
	Y-direction	740KN.m

Load Pattern	DEAD
Point Loads	
Force in Gravity Dir (-Global Z) (kN)	8709
Moment about Global X Axis (kN-m)	6424
Moment about Global Y Axis (kN-m)	-740
Load Size X Dimension (mm)	3000
Load Size Y Dimension (mm)	500

Figure 7.39: loads of footing

6. Analysis the model and checks:

The following checks are important to be taken in consideration:

- Compatibility:

To make sure that all the structural elements are compatible with each other. This can be achieved and approved by noticing and analyzing the deformed shape animation of the model by SAFE.

- Dimensions check based on soil failure:

$$R_{max} < q_{all \text{ comp}}$$

$$R_{max} = P/N + (M_x * Y_{com} / \Sigma y^2) + (M_y * X_{comp} / \Sigma X^2)$$

$$= 8709/12$$

$$+ (6424 * 4.35 / (8 * 4.35^2) + (4 * 1.45^2)) + (740 * 5.35 / (8 * 5.35^2 + 4 * 1.78^2))$$

$$= 918 < Q_{all \text{ comp}}.$$

$$R_{min} < q_{all \text{ tens.}}$$

$$R_{min} = 726 - 175 - 17$$

$$= 534 \text{ KN} < Q_{all \text{ tens.}}$$

- Displacement check:

The displacement under footing should be $< 10 \text{ mm}$.

- Punching Shear check:

Punching Shear ratio = max shear applied /max shear capacity

a) If punching shear ratio > 1 , the design is not ok

b) If punching shear ratio < 1 , the design is ok

punching check is ok.

7. Footing Reinforcement:

Table 7.13: Bottom and top reinforcement (F.4)

Reinforcement	Long direction	Short direction
Top	7 Φ 16/m	8 Φ 16/m
Bottom	6 Φ 25/m	9 Φ 25/m

- **Footing (5):**

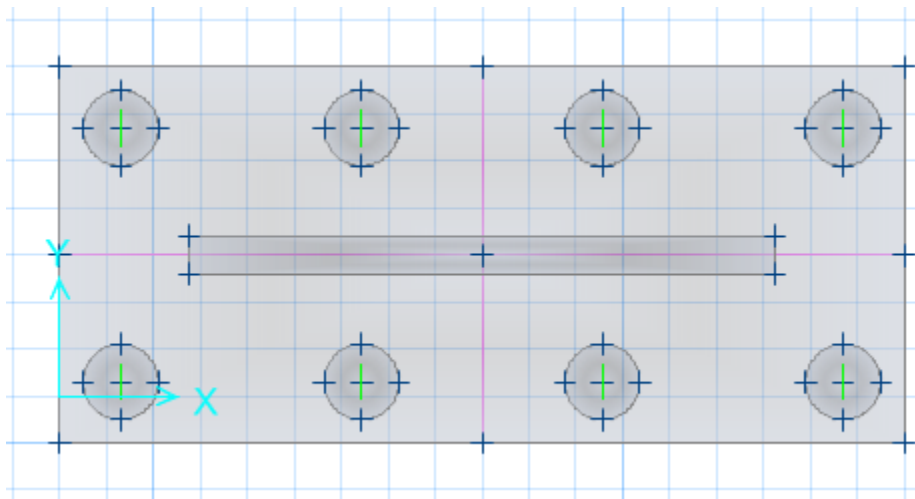


Figure 7.40: Footing 5.

1. The Cap:

According to ACI318, the approximate depth of the Cap controlled by Punching Shear.

Assume $h = 70\text{cm}$.

Define Cap section by SAFE as shown in the figure:

The screenshot shows the SAFE software interface for defining a 'Cap' section. It is divided into two main sections: 'General Data' and 'Analysis Property Data'.
In the 'General Data' section:
- 'Property Name' is set to 'Cap'.
- 'Slab Material' is set to 'B350'.
- 'Display Color' is set to a magenta color, with a 'Change...' button next to it.
- 'Property Notes' has a 'Modify/Show...' button.
In the 'Analysis Property Data' section:
- 'Type' is set to 'Slab'.
- 'Thickness' is set to '700' mm.

Figure 7.41: Cap-section define by SAFE.

2. Shear walls and piles:

Table 7.14: Shear walls and piles (F.5)

Member type	Dimensions
Piles	Diameter = 80cm.
Shear walls	6.25m*0.4m

Define piles and shear wall sections by SAFE as shown in the figure:

The screenshot shows the SAFE software interface for defining a property. The 'General Data' section includes fields for 'Property Name' (Stiff), 'Slab Material' (B350), 'Display Color' (a blue square), and 'Property Notes'. The 'Analysis Property Data' section includes a 'Type' dropdown (Stiff) and a 'Thickness' input field (700 mm).

Figure 7.42: Footing (5) Stiff-section defines by SAFE.

3. Define point spring (Spring Stiffness):

A point spring added under all piles to demonstrate the allowable piles settlement which given from soil reports which equal 10mm.

From foundation equations:

Minimum number of piles = 8piles.

$$Q_{\text{All comp}} = 950\text{KN}.$$

$$Q_{\text{All tens}} = 750\text{KN}.$$

$$\text{Spring Stiffness} = 950/10 = 95\text{KN/mm}.$$

4. Define of load patterns and load combination:

All load patterns defined by SAP, only dead load defined by SAFE.

Services load taken by SAP and added as a dead load by SAFE.

Ultimate and service combinations added by SAFE.

Load Patterns

Load Patterns

Load	Type	Self Weight Multiplier	
DEAD	DEAD	0.0000	

General Data

Load Combination Name

Service

Combination Type

Linear Add

Notes

Modify/Show Notes...

Auto Combination

No

Define Combination of Load Case/Combo Results

	Load Name	Scale Factor
▶	DEAD	1.0000
*		

Design Selection

☐ Strength (Ultimate)

☒ Service - Normal

☐ Service - Initial

☐ Service - Long Term

General Data

Load Combination Name

Ultimate

Combination Type

Linear Add

Notes

Modify/Show Notes...

Auto Combination

No

Define Combination of Load Case/Combo Results

	Load Name	Scale Factor
▶	DEAD	1.3000
*		

Design Selection

☒ Strength (Ultimate)

☐ Service - Normal

☐ Service - Initial

☐ Service - Long Term

Figure 7.43: load patterns and load combination defined by SAFE.

5. Assign load on model:

A point Load added as a dead load on the center of shear wall.

Table 7.15: Assign load on model (F.5)

Type of load	Direction	Magnitude
Vertical load	Z-direction	2110KN.
Moments	X-direction	875N.m
	Y-direction	2354KN.m

Load Pattern	DEAD
Point Loads	
Force in Gravity Dir (-Global Z) (kN)	2110
Moment about Global X Axis (kN-m)	875
Moment about Global Y Axis (kN-m)	-2354
Load Size X Dimension (mm)	6250
Load Size Y Dimension (mm)	400

Figure 7.44: loads of footing

6. Analysis the model and checks:

The following checks are important to be taken in consideration:

- Compatibility:

To make sure that all the structural elements are compatible with each other. This can be achieved and approved by noticing and analyzing the deformed shape animation of the model by SAFE.

- Dimensions check based on soil failure:

$$R_{\max} \leq q_{\text{all comp}}$$

$$\begin{aligned} R_{\max} &= P/N + (M_x * Y_{\text{com}} / \Sigma y^2) + (M_y * X_{\text{comp}} / \Sigma X^2) \\ &= 2110/8 + (875 * 1.35 / (8 * 1.35^2)) + (2354 * 3.85 / (4 * 3.85^2 + 4 * 1.28^2)) \\ &= 483 \text{KN} < Q_{\text{all comp}} \end{aligned}$$

$$R_{\min} \leq q_{\text{all tens}}$$

$$\begin{aligned} R_{\min} &= 264 - 81 - 138 \\ &= 45 \text{KN} < Q_{\text{all tens}}. \end{aligned}$$

- Displacement check:

The displacement under footing should be $\leq 10 \text{mm}$.

- Punching Shear check

Punching Shear ratio = max shear applied / max shear capacity

a) If punching shear ratio > 1 , the design is not ok

b) If punching shear ratio < 1 , the design is ok

Punching check is ok.

8. Footing Reinforcement:

Table 7.16: Bottom and top reinforcement (F.5)

Reinforcement	Long direction	Short direction
Top	7 Φ 16/m	4 Φ 16/m
Bottom	7 Φ 16/m	7 Φ 16/m

7.2.2 Reinforcement of piles:

$$P_u = 1330$$

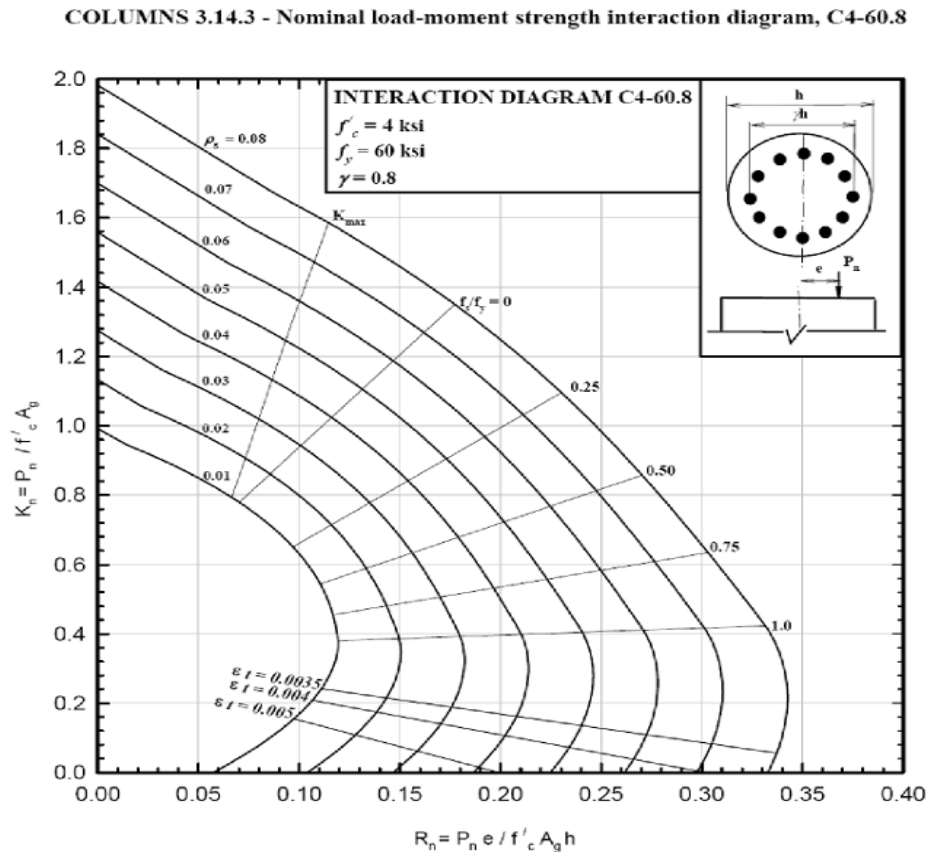
$$A_g = 800^2 \cdot \pi / 4 = 502400$$

$$K_n = 1330 \cdot 10^3 / 28 \cdot (502400) \cdot 7 = 0.0135$$

$$e = 0.015 + 0.03h = 0.039$$

$$R_n = 1330 \cdot 10^3 \cdot 0.039 / 28 \cdot 7 \cdot 800 \cdot 502400 = 6.5 \cdot 10^{-7}$$

And from the figure:



Graph 12 Column interaction diagrams for circular spiral columns.

Figure 7.45: Column interaction diagrams for circulars spiral columns.

$$\rho = 0.01$$

$$\text{Cover} = 60$$

$$A_s = 3629.84 \text{ mm}^2$$

Use $15\phi 18$

- Shear check of piles:

$$V_c = \frac{1}{6} \times \sqrt{28} \times \frac{\mu}{4} \times 800^2 = 433 \text{ Kn}$$

$$V_s = V_u - V_c$$

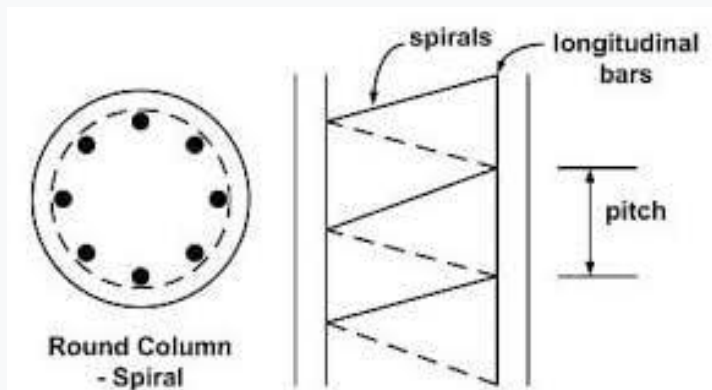
$$\frac{Av}{s} = \frac{vs}{f_y \times d}$$

All pile have $V_u < V_c$ then:

$$\frac{Av}{s} = 0.33$$

Use $\emptyset = 8$

$S = 150 \text{ mm}$ (spiral stirrups)



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