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

By

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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.

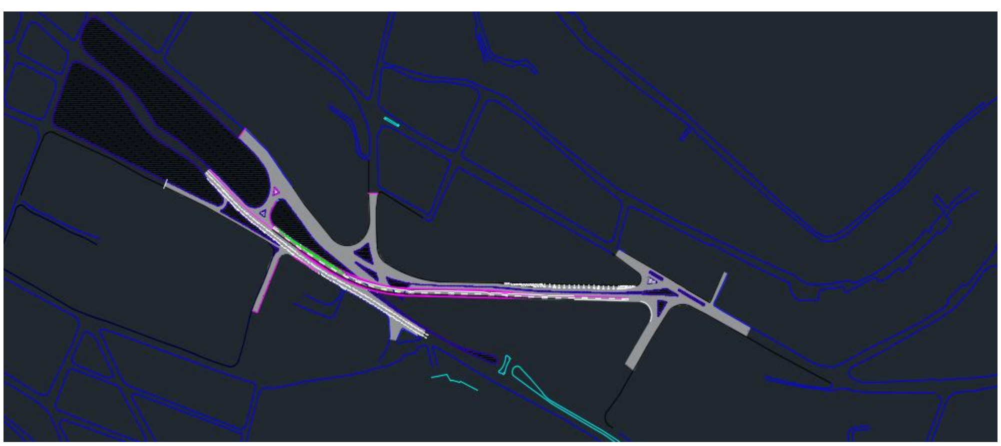


Figure 6.2: Auto cad layout.

6.2 Vertical scale of bridge:

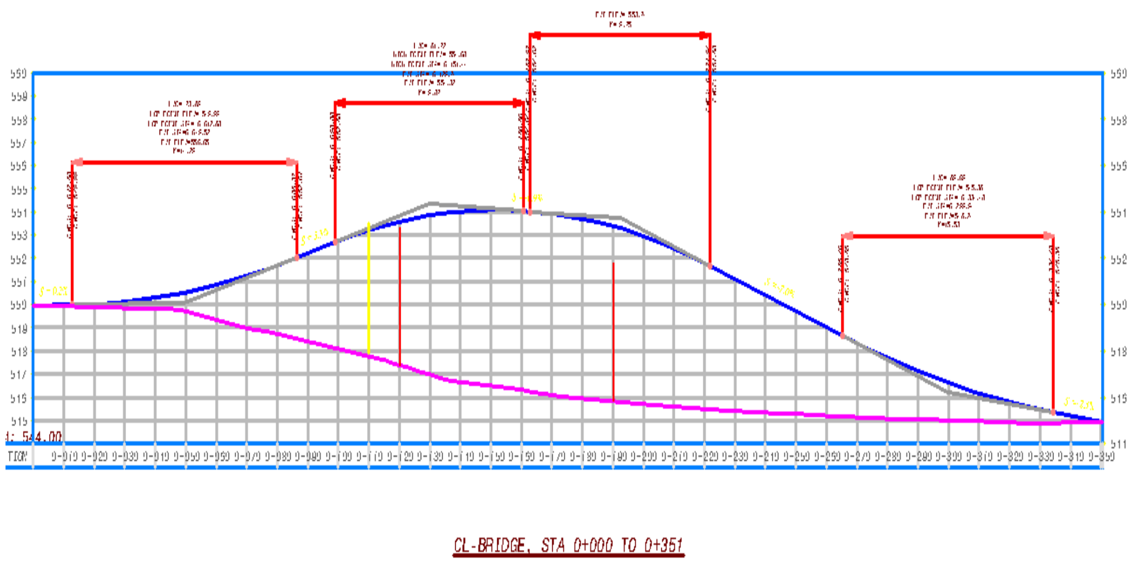


Figure 6.3: Vertical Cross-section layout.

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.

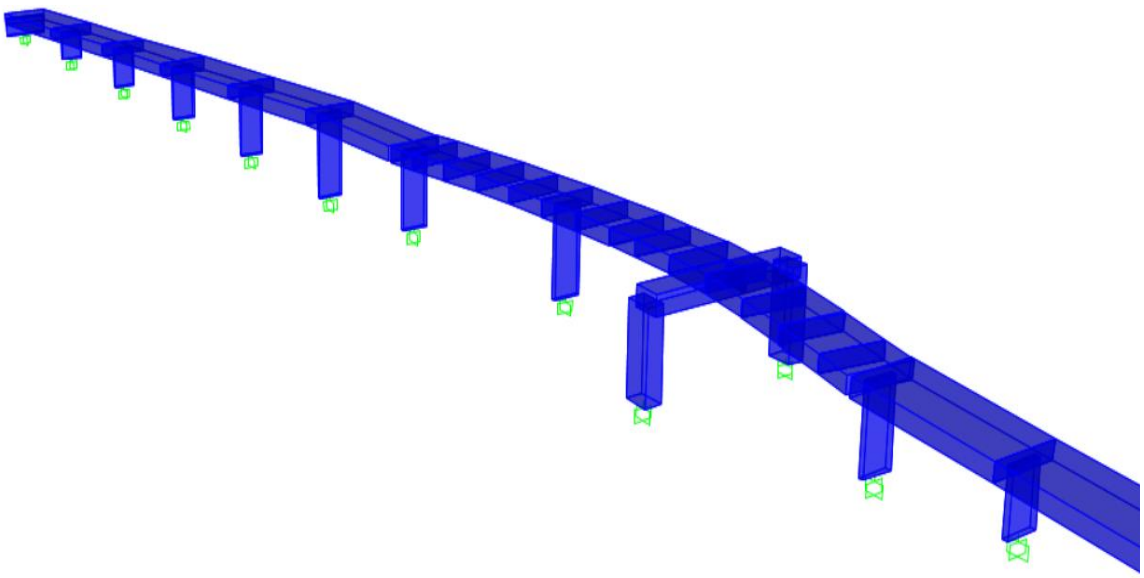


Figure 6.8: Bridge model 1.

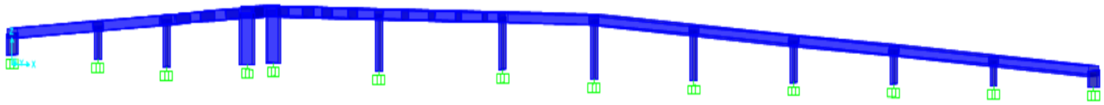


Figure 6.9: Bridge model 2.

The material used for the bridge:

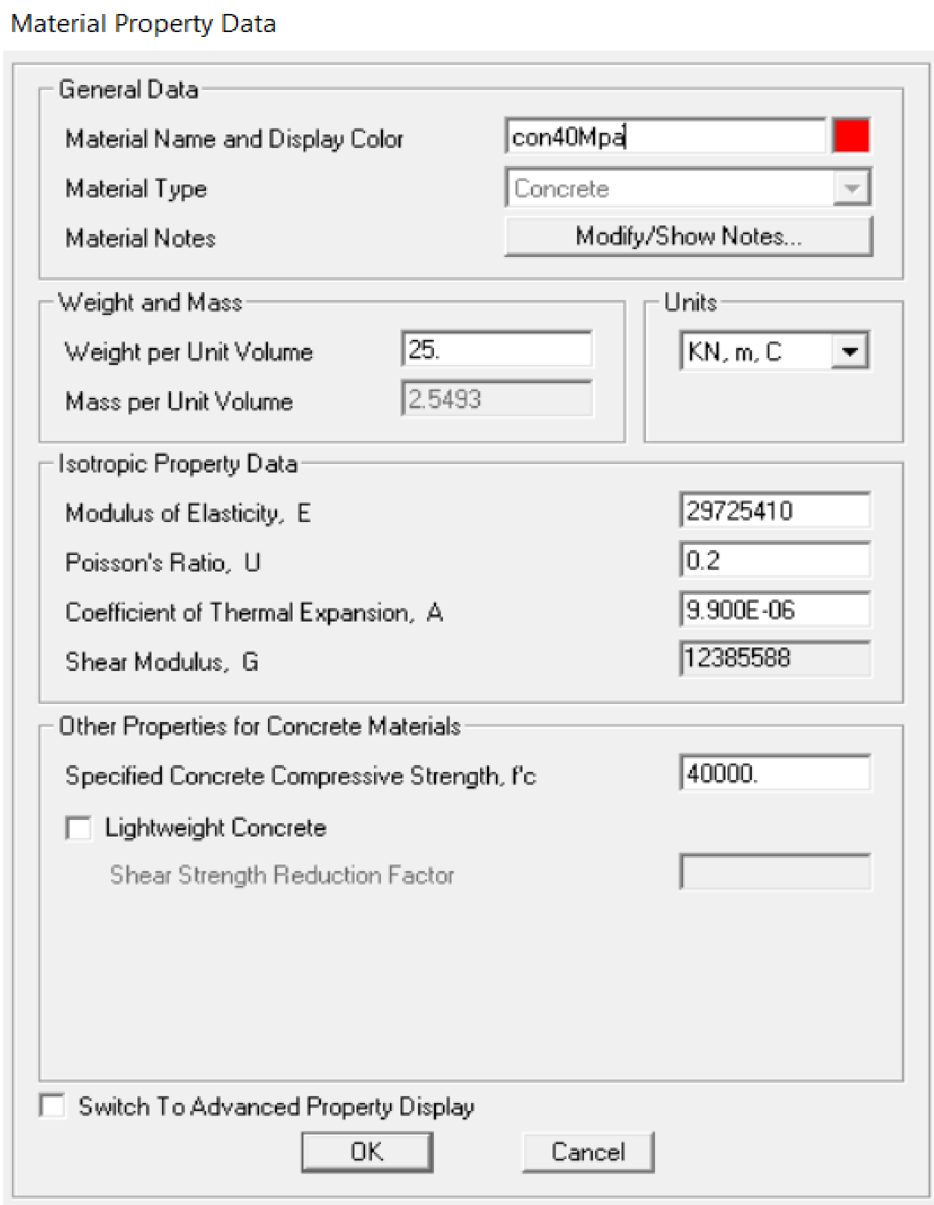


Figure 6.10: Material Property Data.

Sections:

1. **external shear wall:**

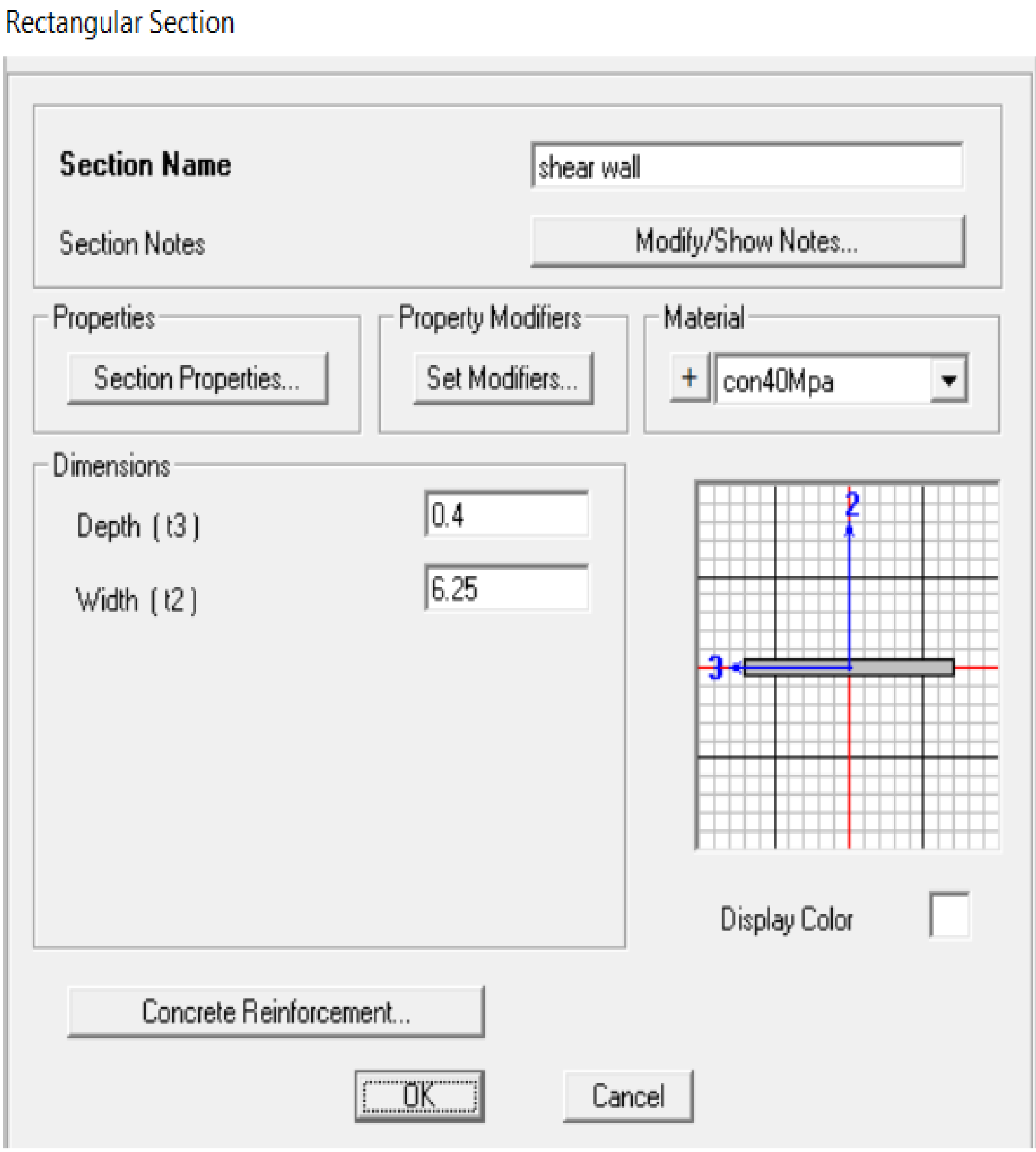


Figure 6.11: External shear wall.

2. **internal shear wall:**

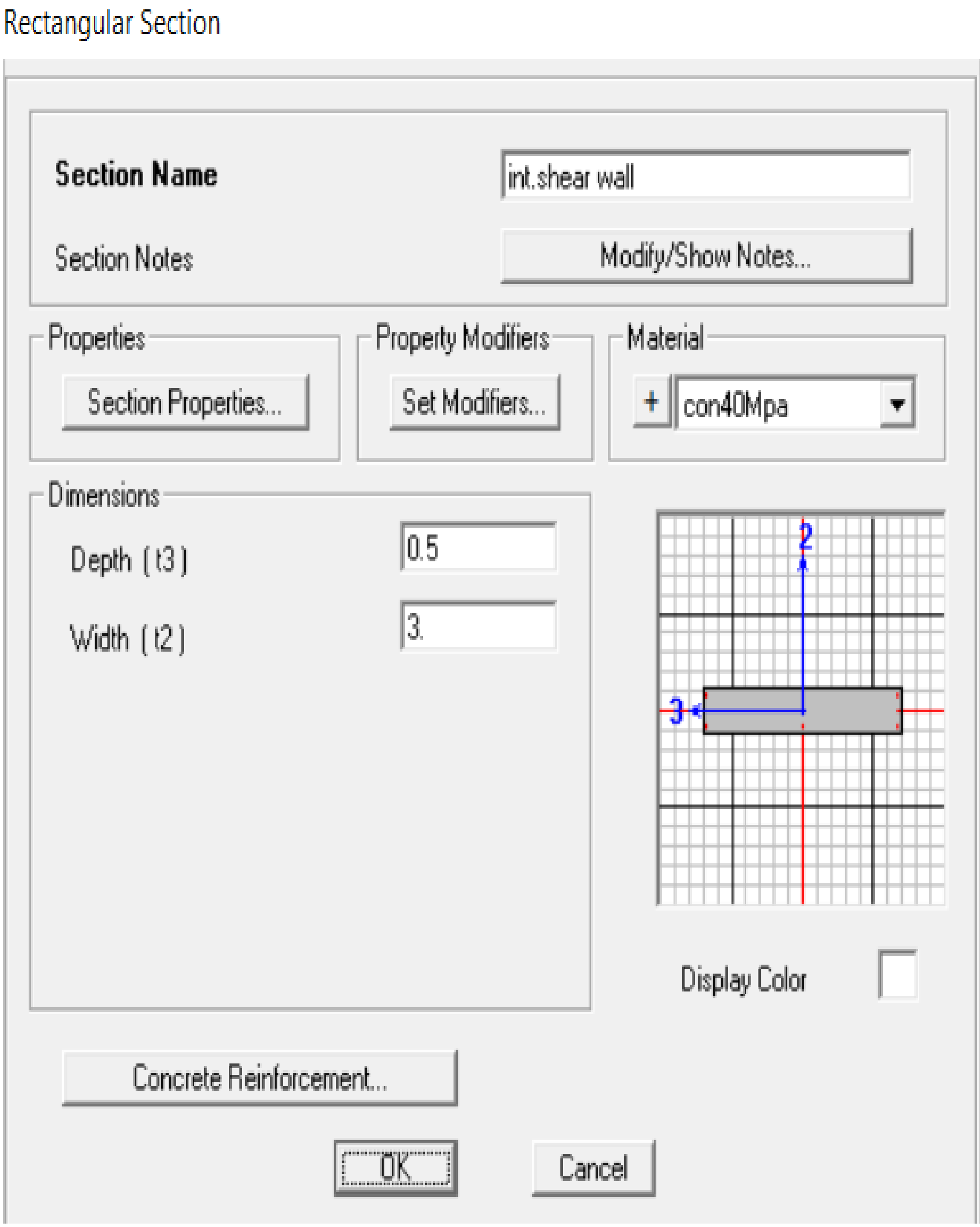


Figure 6.12: internal shear wall.

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.

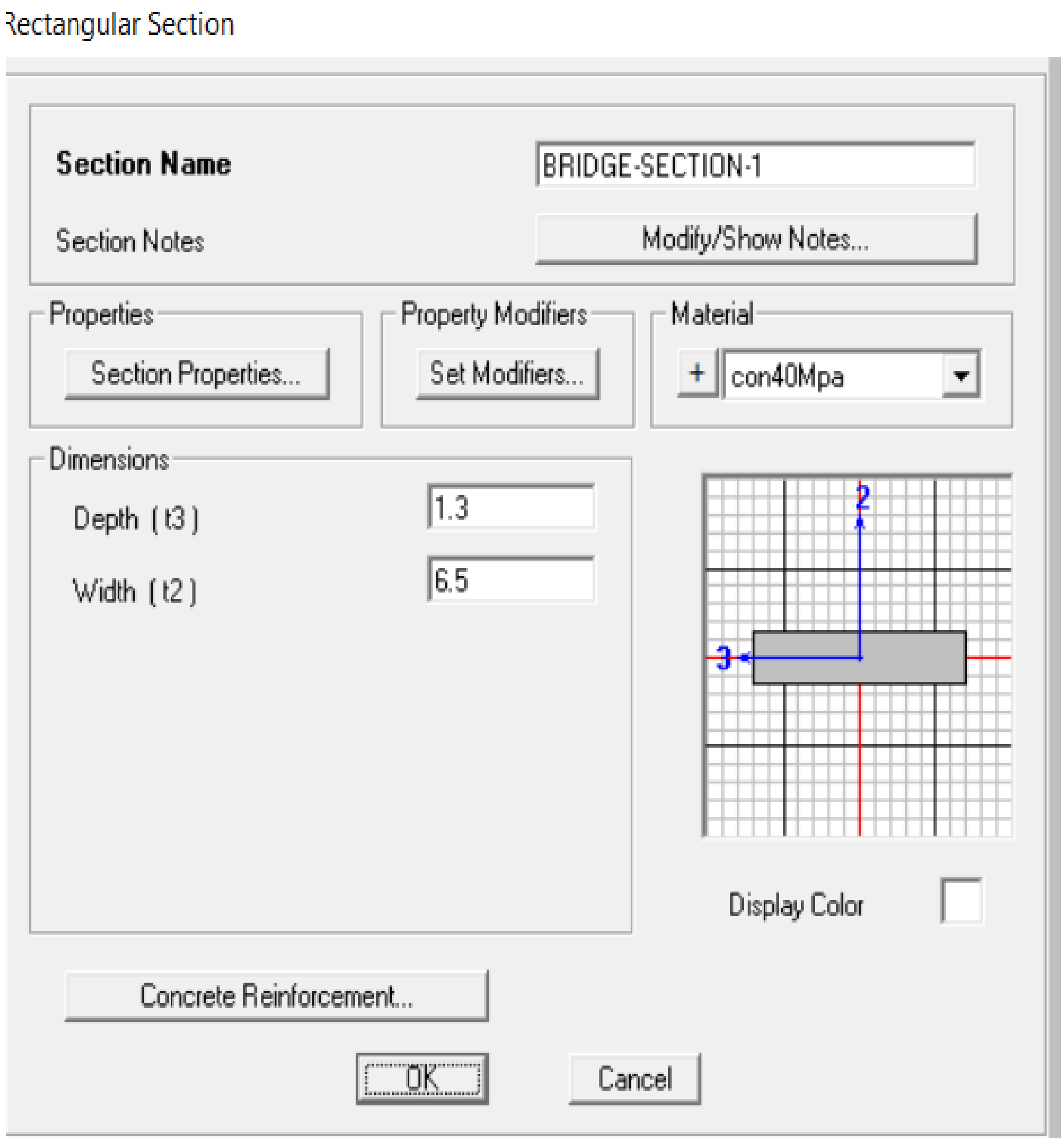


Figure 6.13: Bridge Section 1.

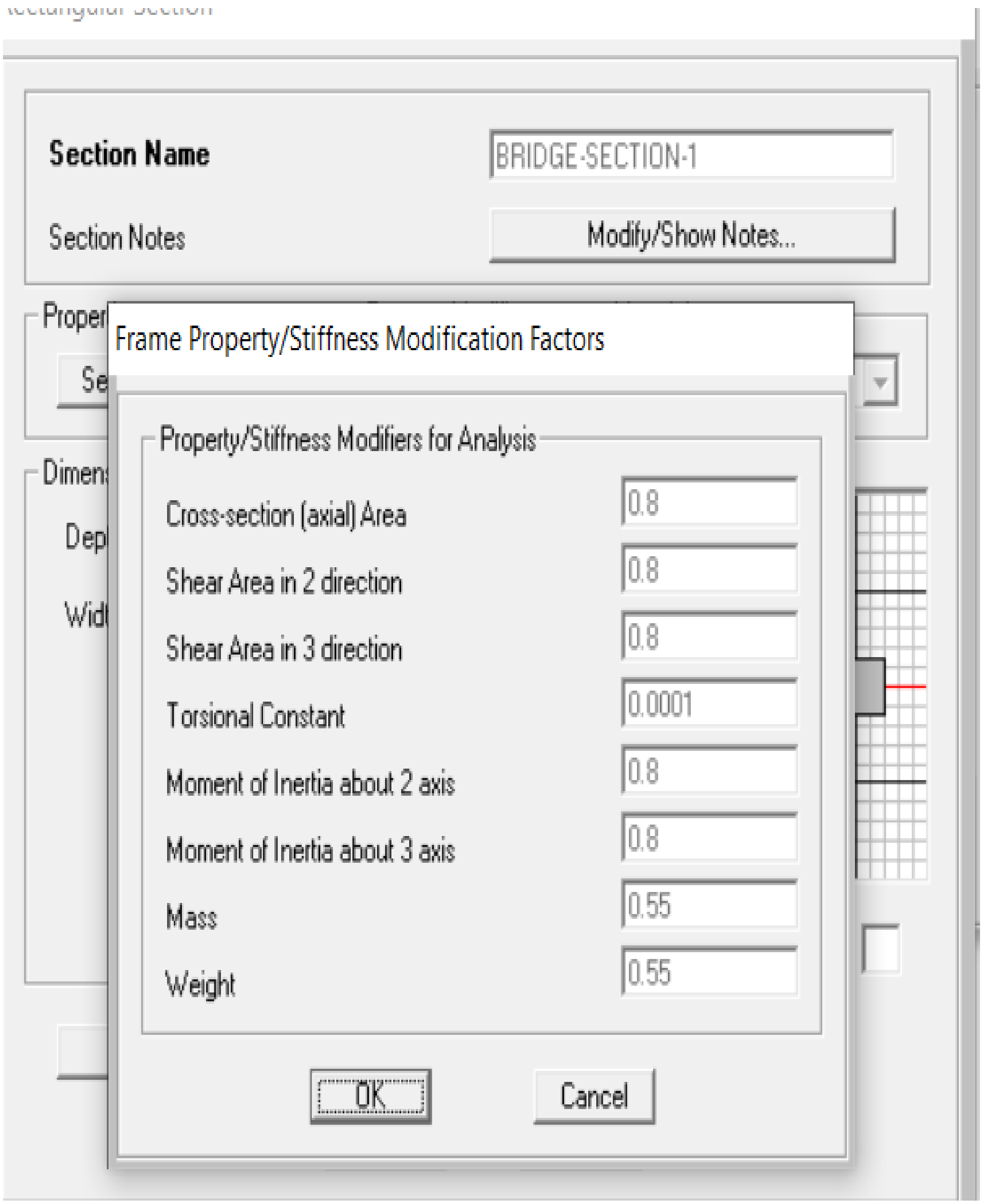


Figure 6.14: Bridge Section 2.

4. **Column:**

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

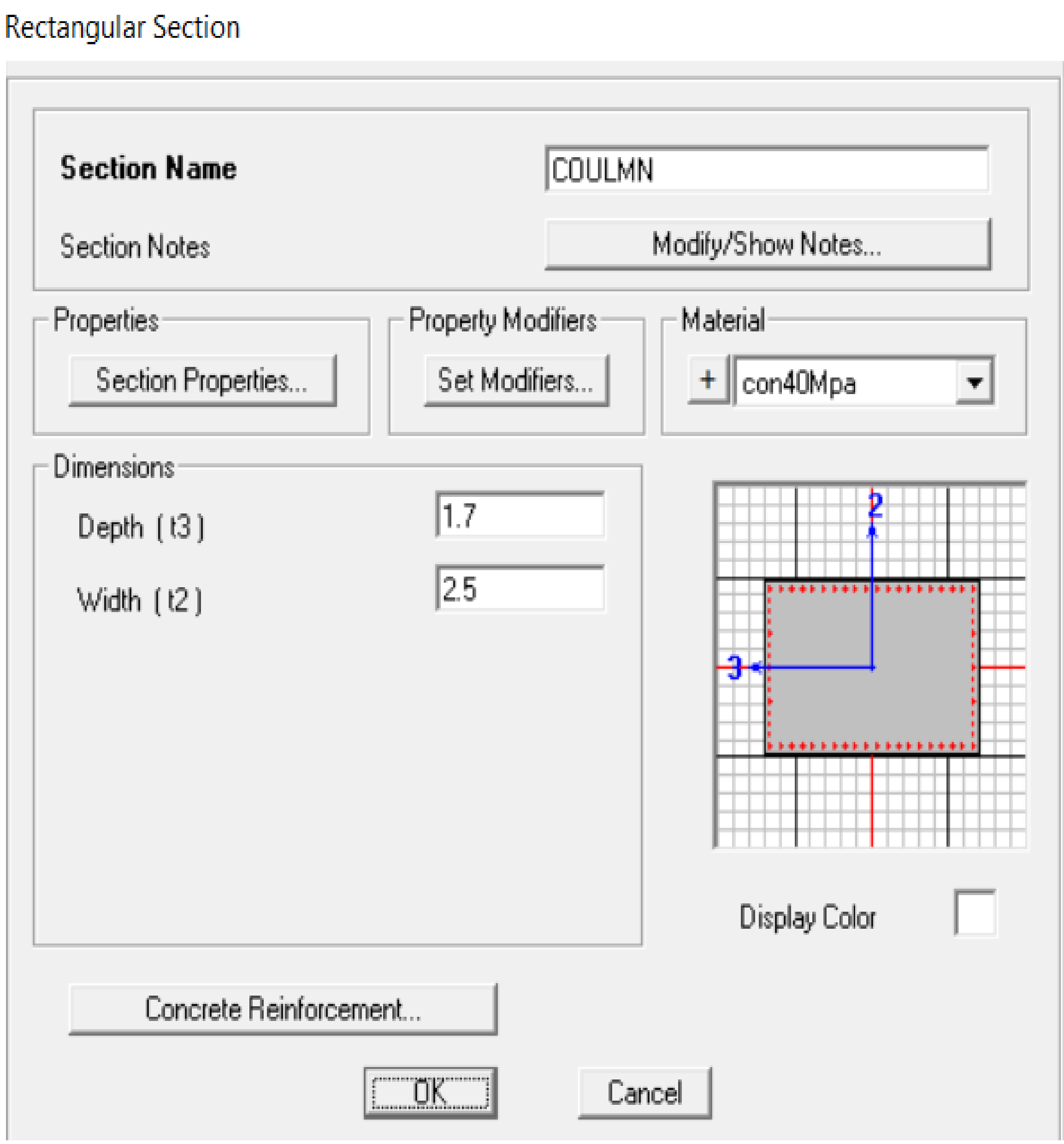


Figure 6.15: Column Design.

5. **Beam:**

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

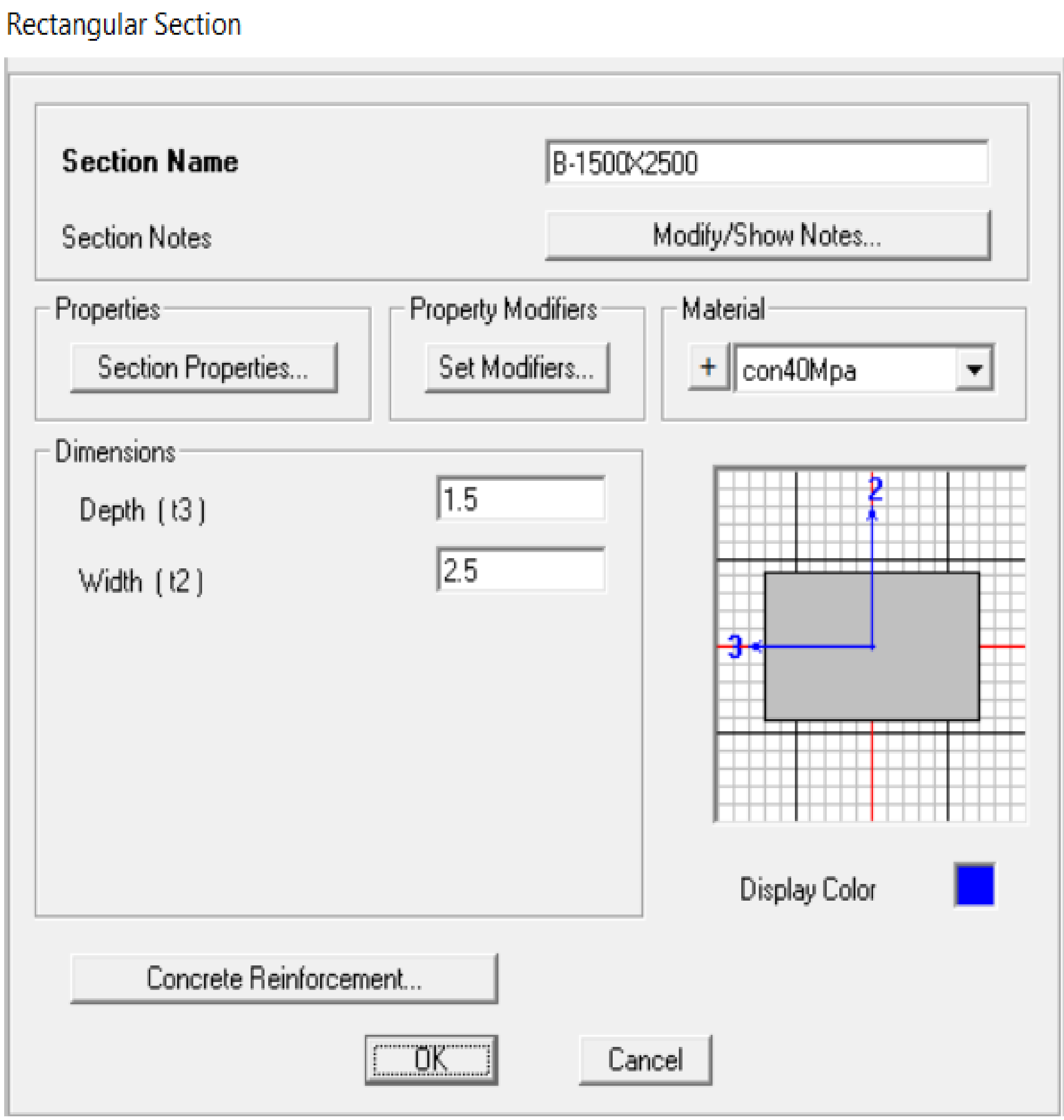


Figure 6.16: Beam Design.

6.5 Load Analysis on Bridge:

There are several loads acting on the bridge.

1. **Defining load patterns:**

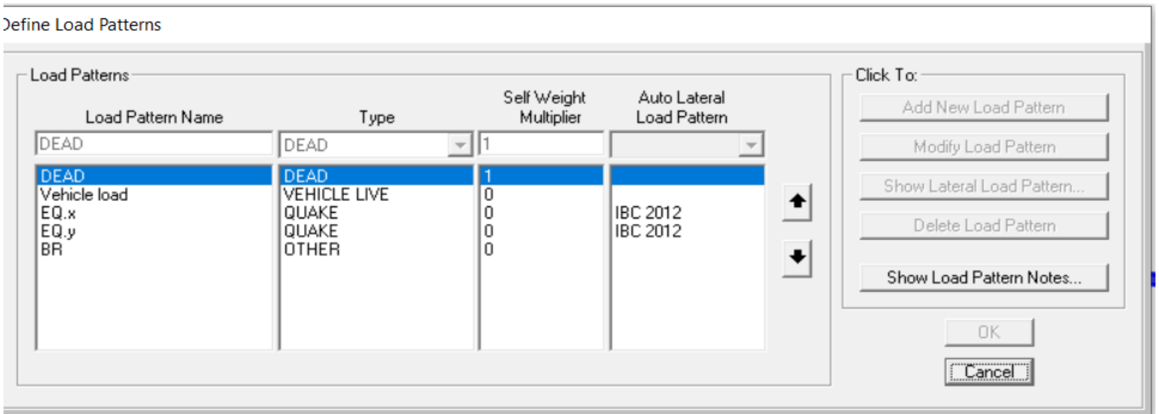


Figure 6.17: Load Patterns.

2. **Vehicle load:**

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

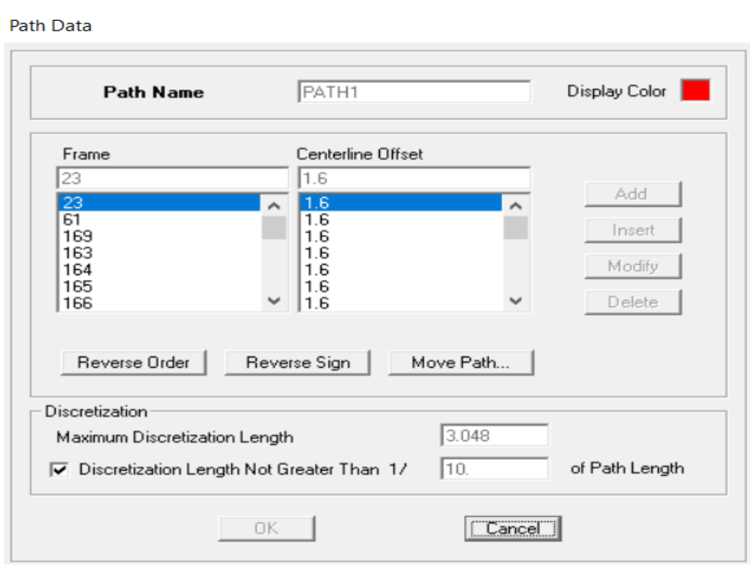


Figure 6.18: Path Data 1.

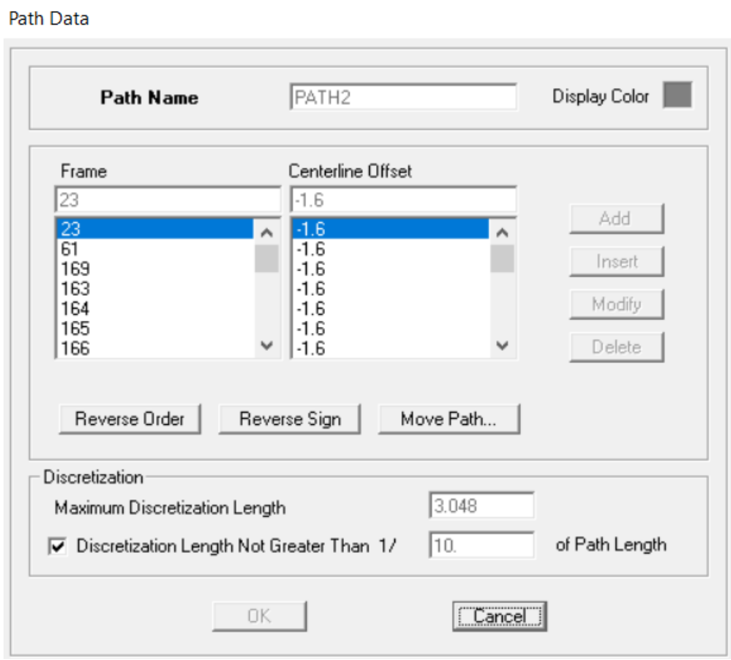


Figure 6.19: Path Data 2.

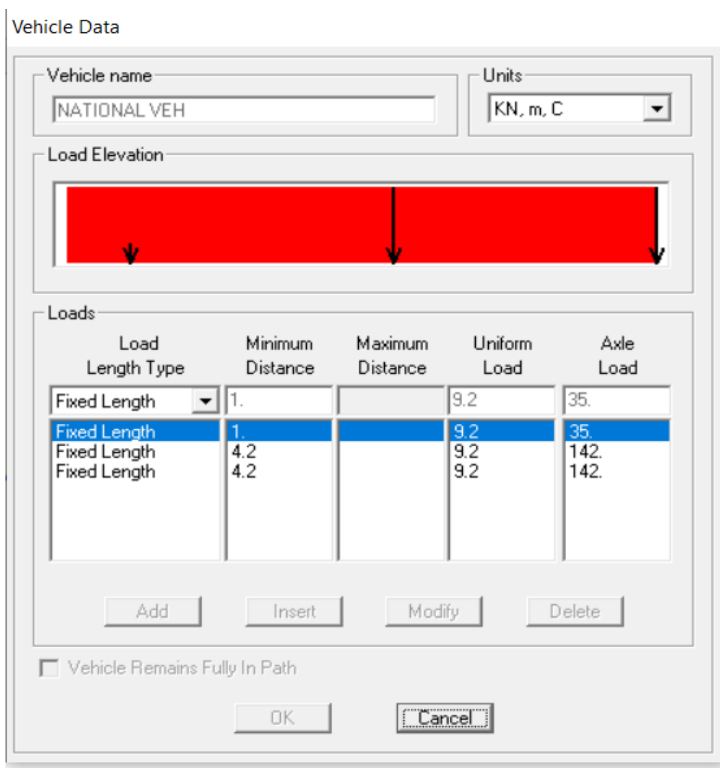


Figure 6.20: Path Data 3.

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.

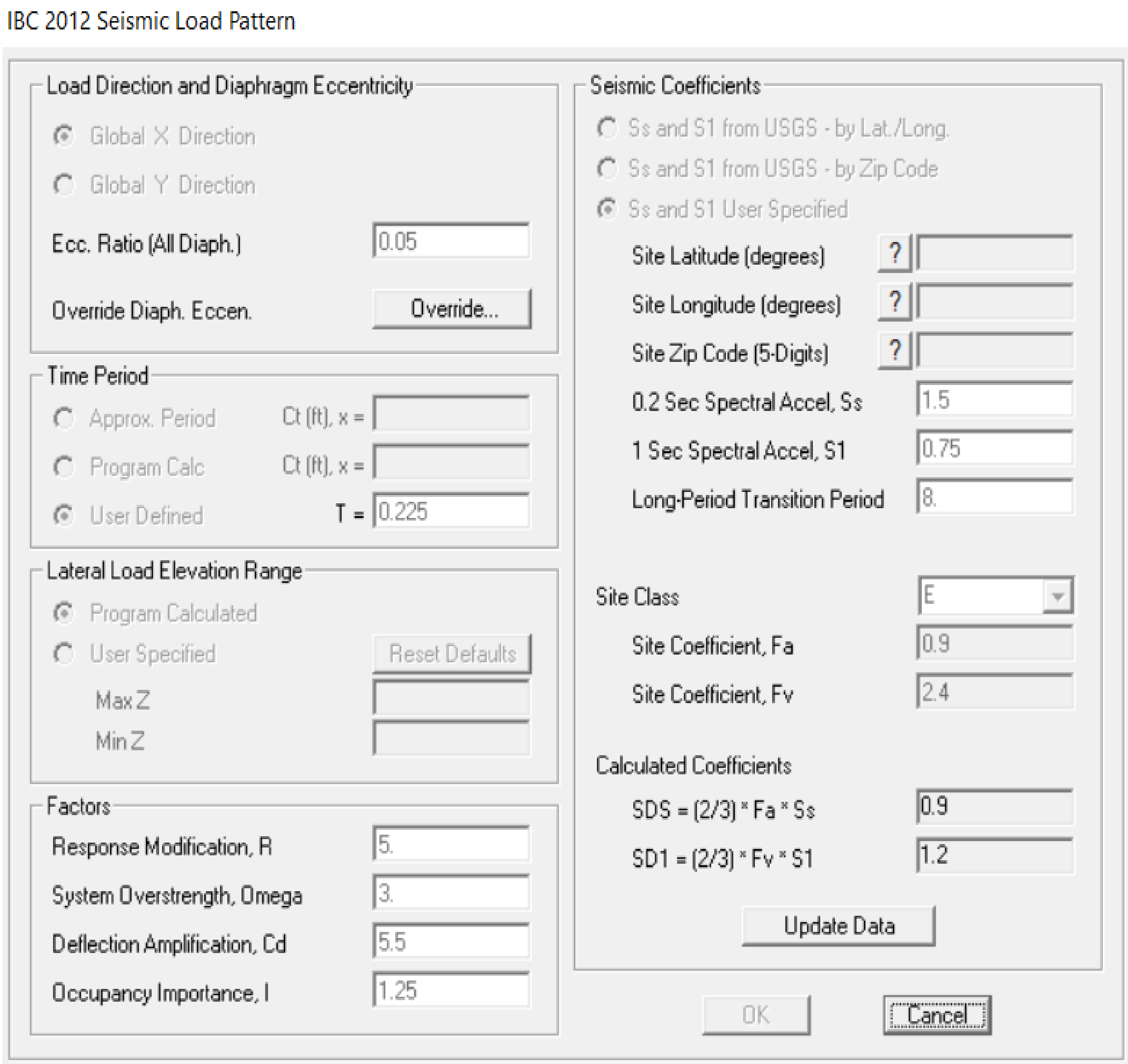


Figure 6.21: Seismic Load Pattern.

4. **Moment at serves load:**

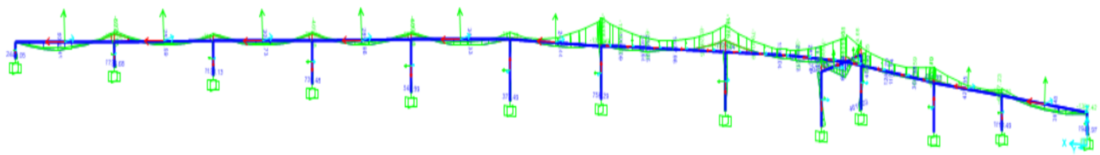


Figure 6.22: Moment at serves load.

5. **Joint Reactions:**

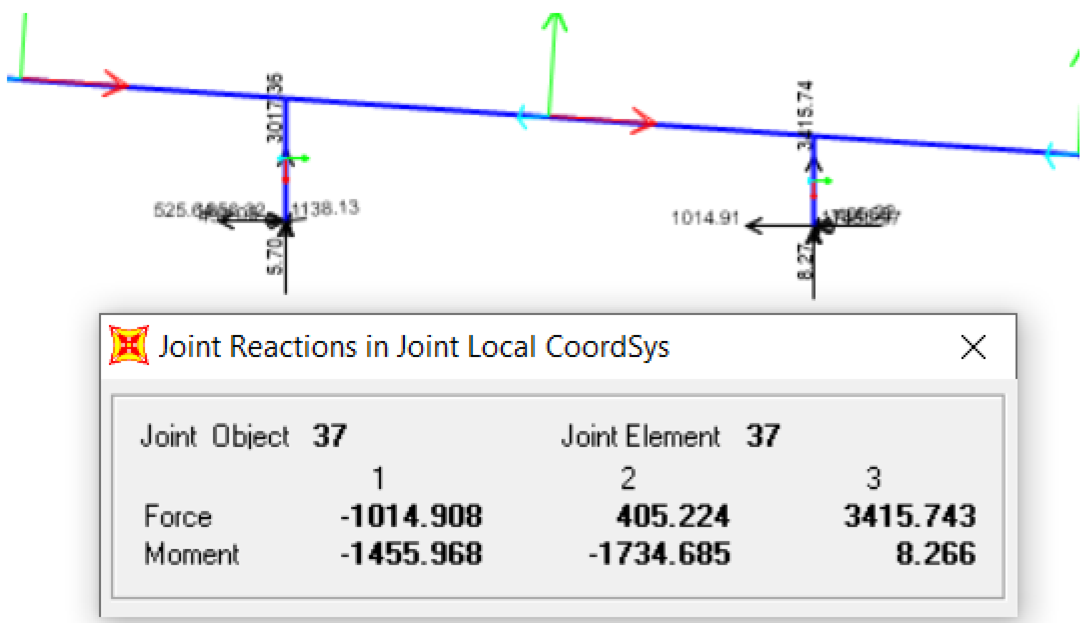


Figure 6.23: Joint reactions.

6. **Check design the Bridge:**

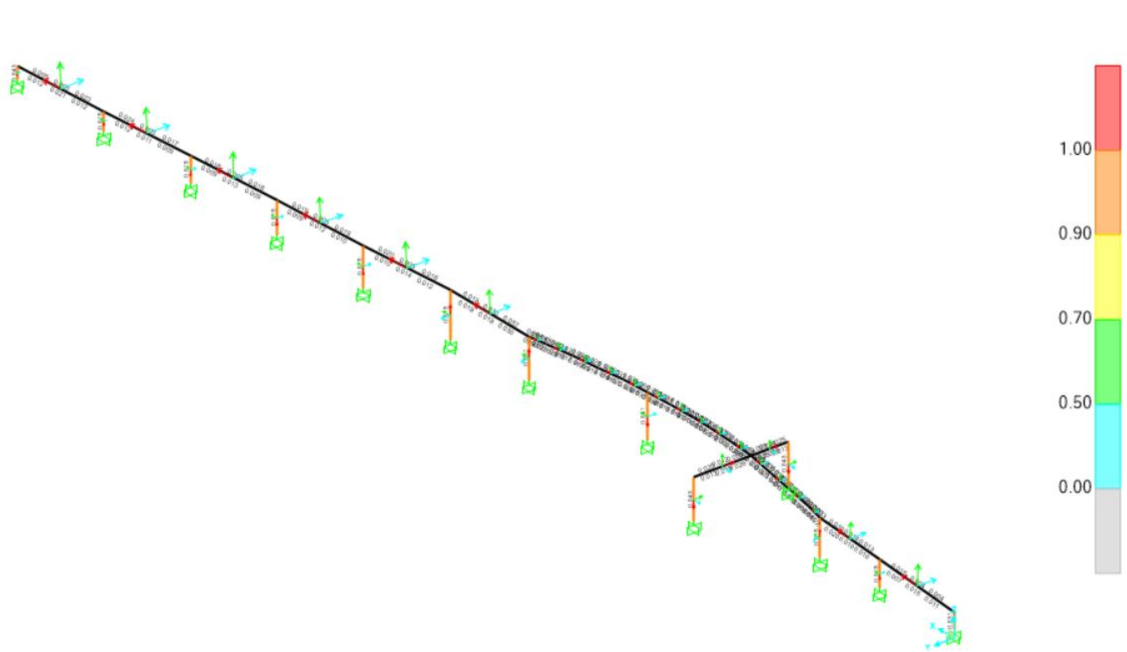


Figure 6.24: Check design the Bridge.

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.

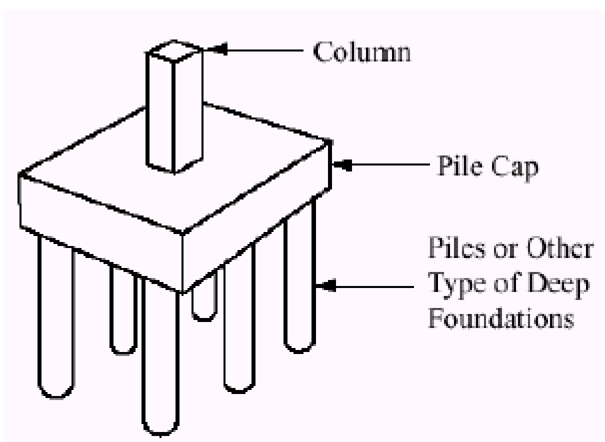


Figure 7.1: Piles image 1.

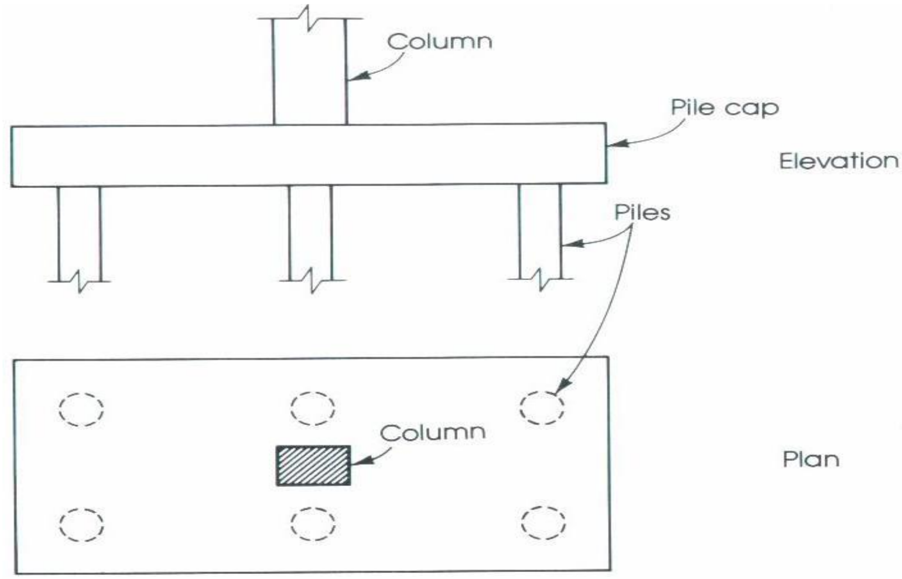


Figure 7.2: Piles image 2.

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.

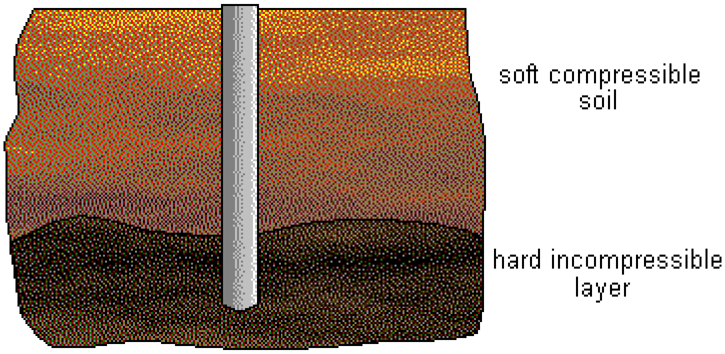


Figure 7.3: End Bearing Piles.

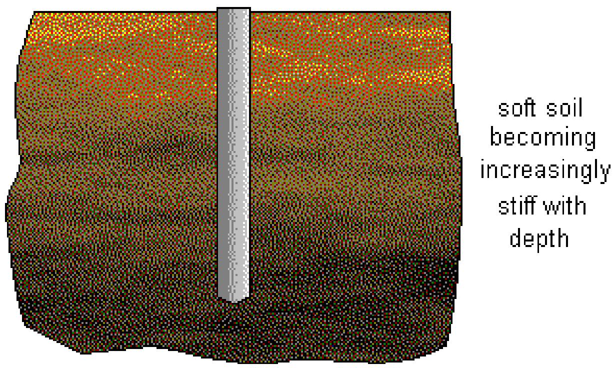


Figure 7.4: Friction Piles.

2. With respect to material:

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

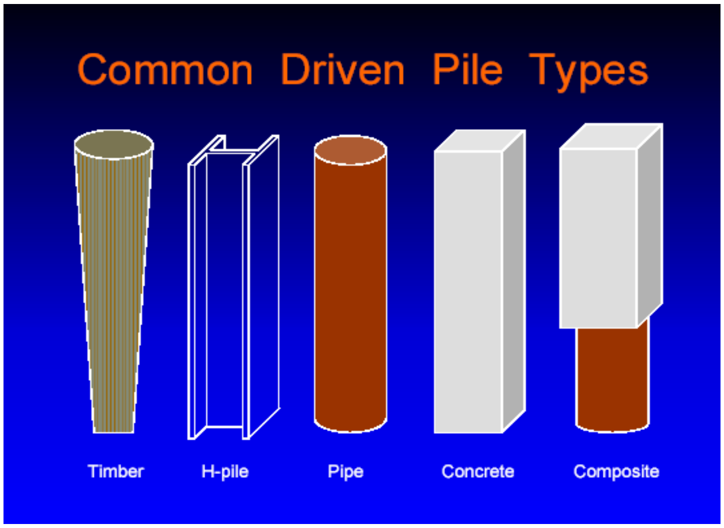


Figure 7.5: Types of Materials.

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):**

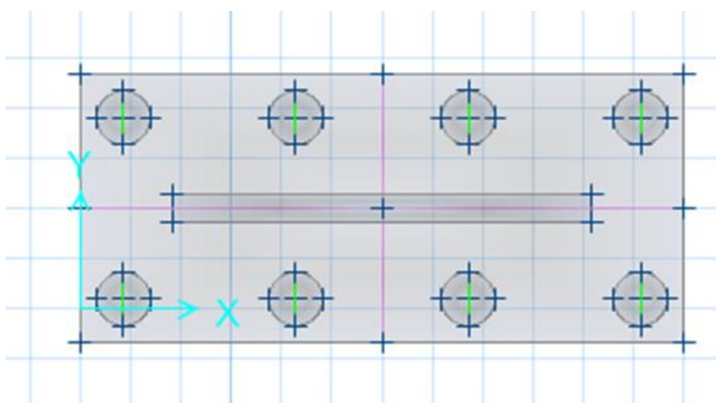


Figure 7.10: Footing 1a.

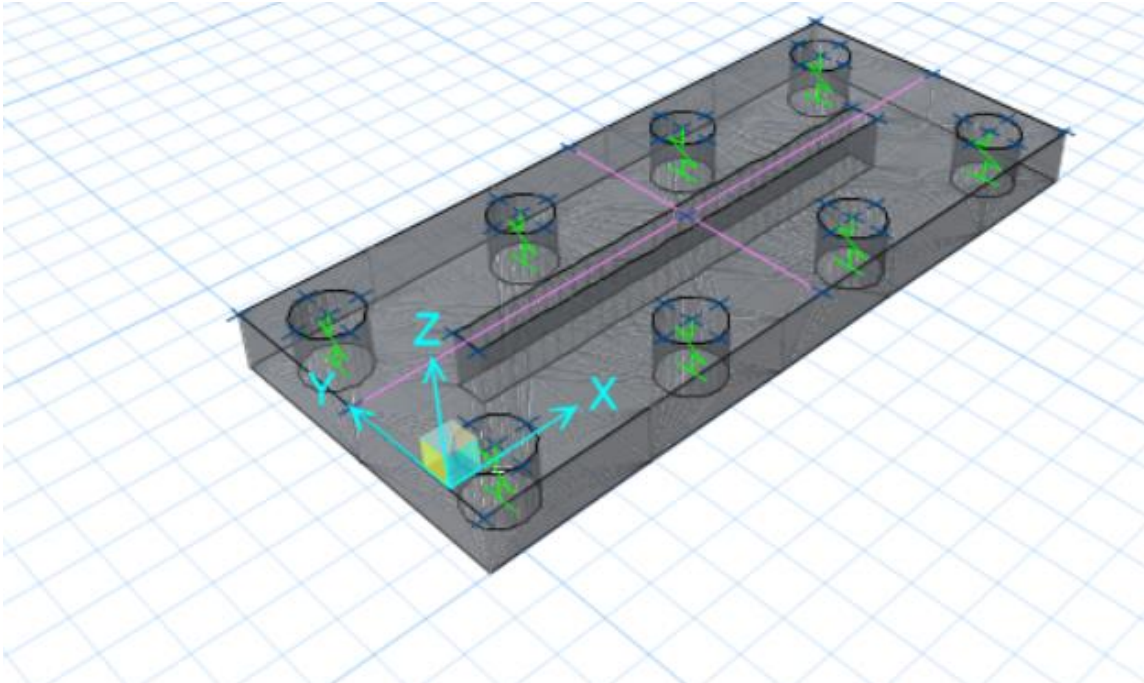


Figure 7.11: Footing 1b.

1. The Cap.

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

Assume h = 70cm.

Define Cap section by SAFE as shown in the figure:

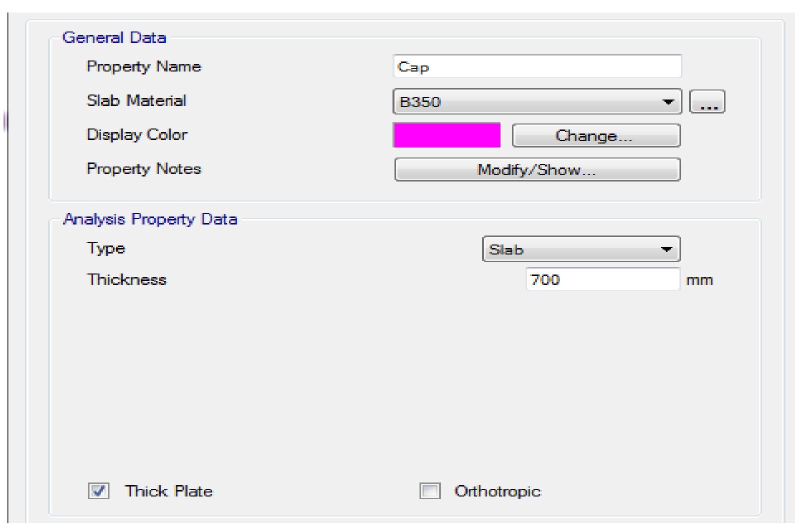


Figure 7.12: Cap-section define by SAFE.

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:

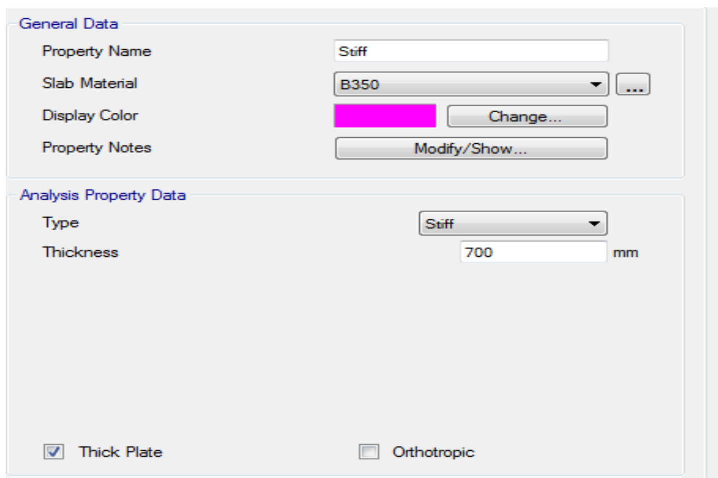


Figure 7.13: Footing (1) Stiff-section defines by SAFE.

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.

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

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

Spring Stiffness = 950/10 = 95KN/mm.

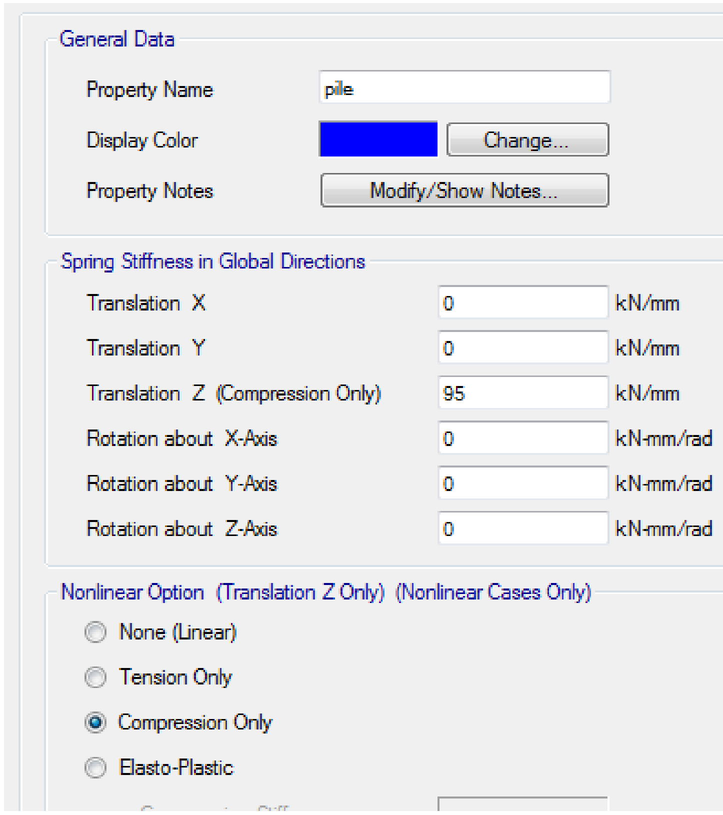


Figure 7.14: Footing (1) point spring define by SAFE.

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.

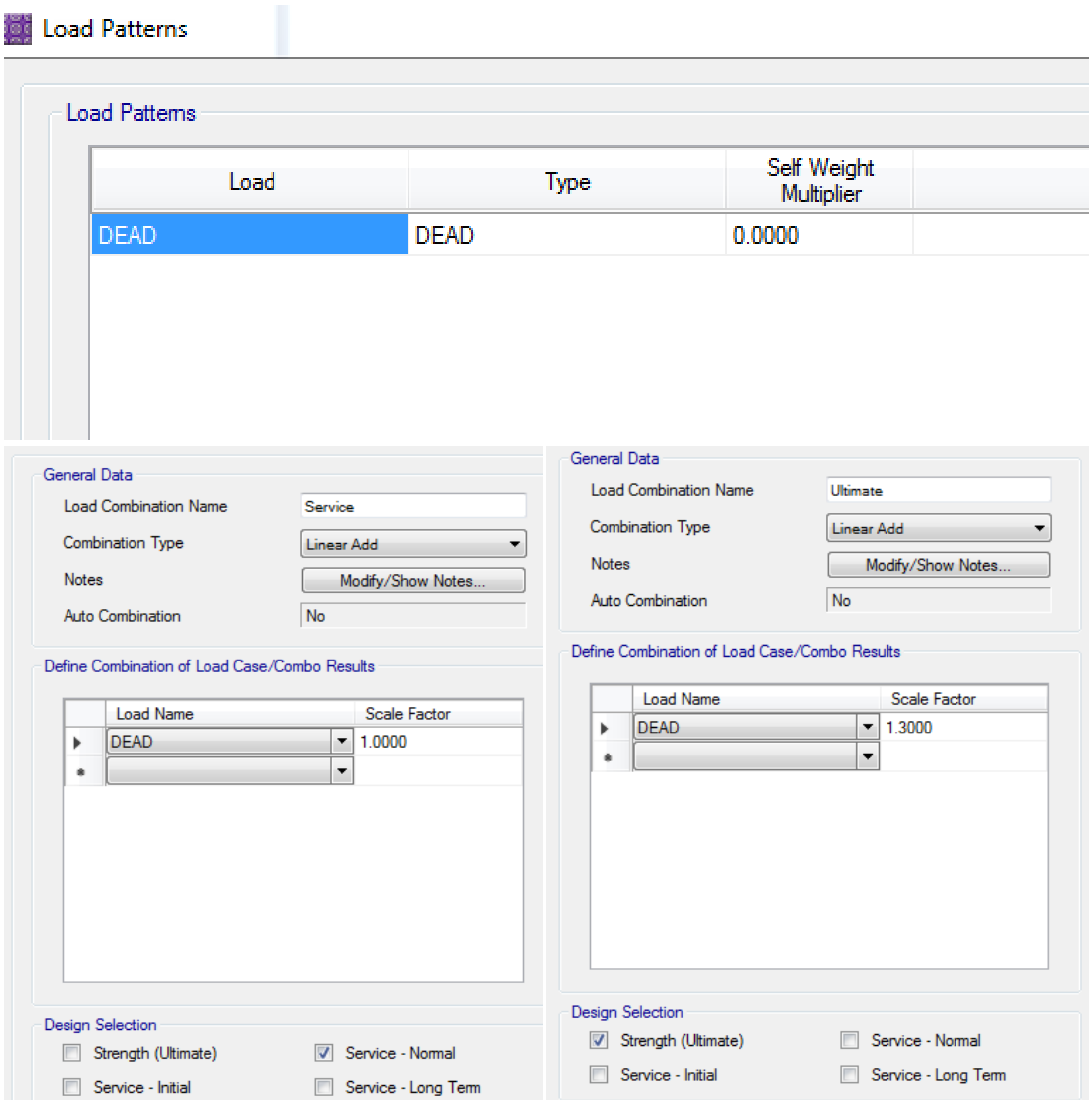


Figure 7.15: load patterns and load combination defined by SAFE.

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.

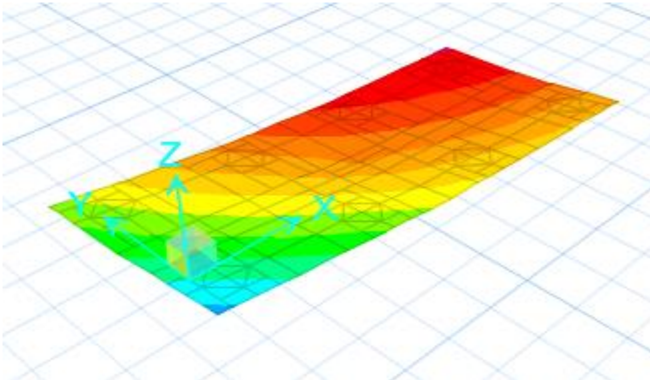


Figure 7.17: Compatibility.

- Dimensions check based on soil failure:

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

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

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

=421KN< Qall comp

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

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

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

=97KN< Qall tens

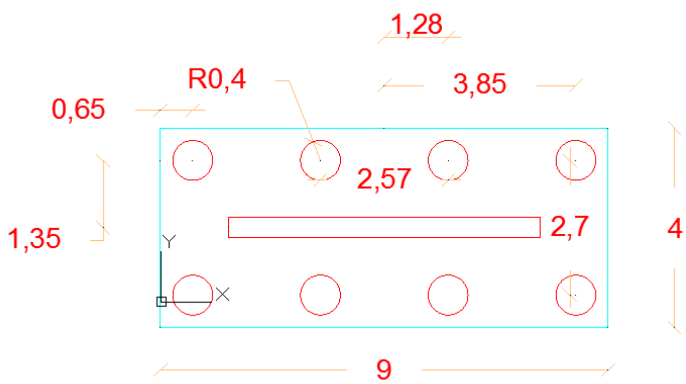


Figure 7.18: Footing (1) dimensions.

Space between piles should be > 3*dpile = 3*0.8=2.4m.

- Displacement check:

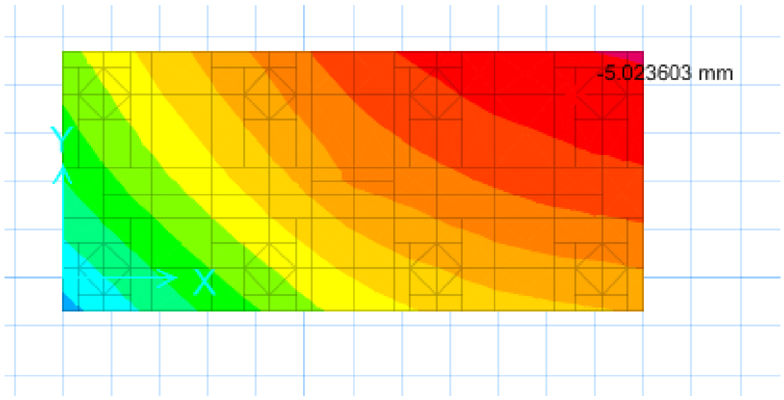


Figure 7.19: Footing (1) displacement.

The displacement under footing should be < 10mm.

- 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.

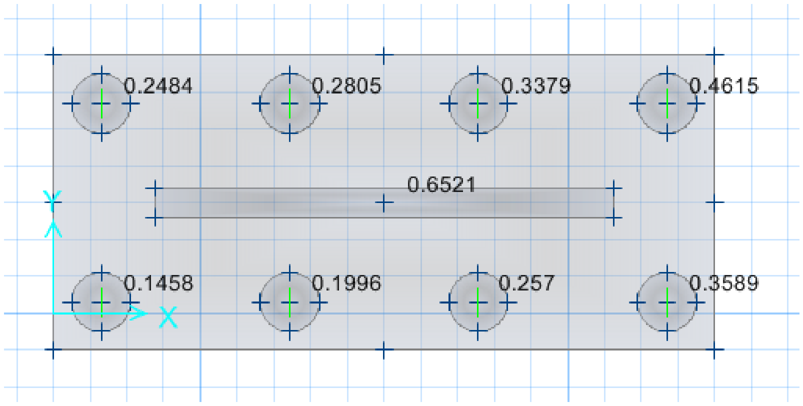


Figure 7.20: Footing (1) punching shear ratio given by SAFE.

From the figure punching check is ok.

7. Footing Reinforcement:

First of all, as min should be calculated.

As min = AS shrinking= 0.0018 *b *h

Footing thickness =h =700mm

As min = 0.0018*1000*700 =1260mm2/m.

So use 7 ϕ 16/m if footing needs minimum reinforcing.

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

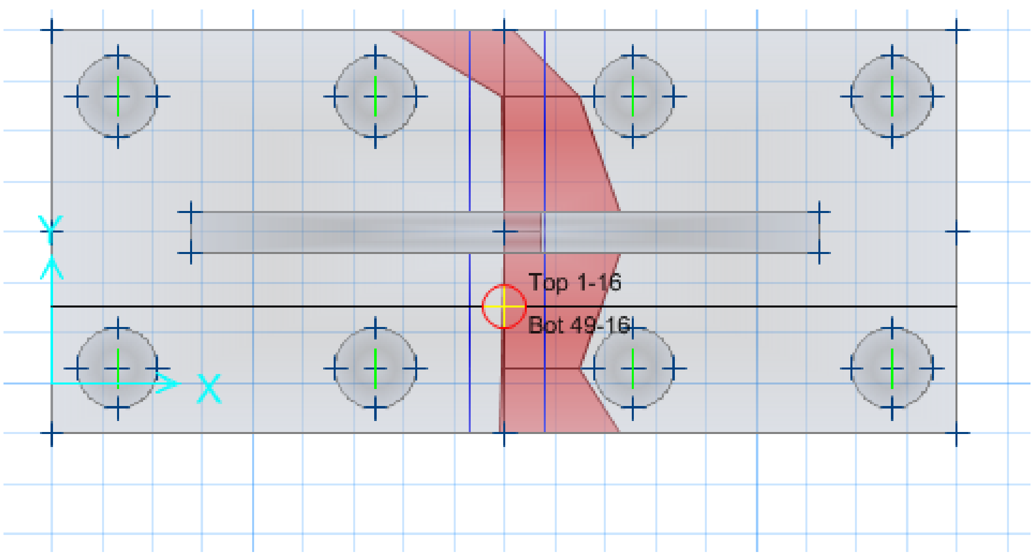


Figure 7.21: Total bottom number of bars in Y(short) direction.

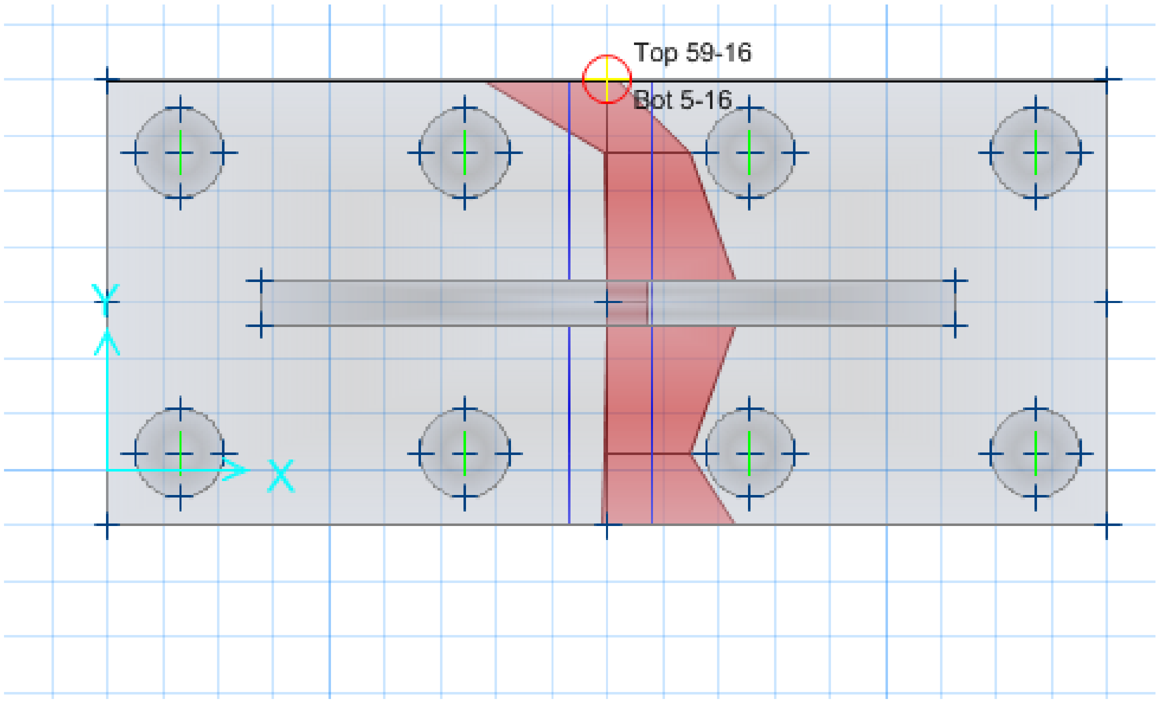


Figure7.22: Total Top number of bars in Y(short) direction.

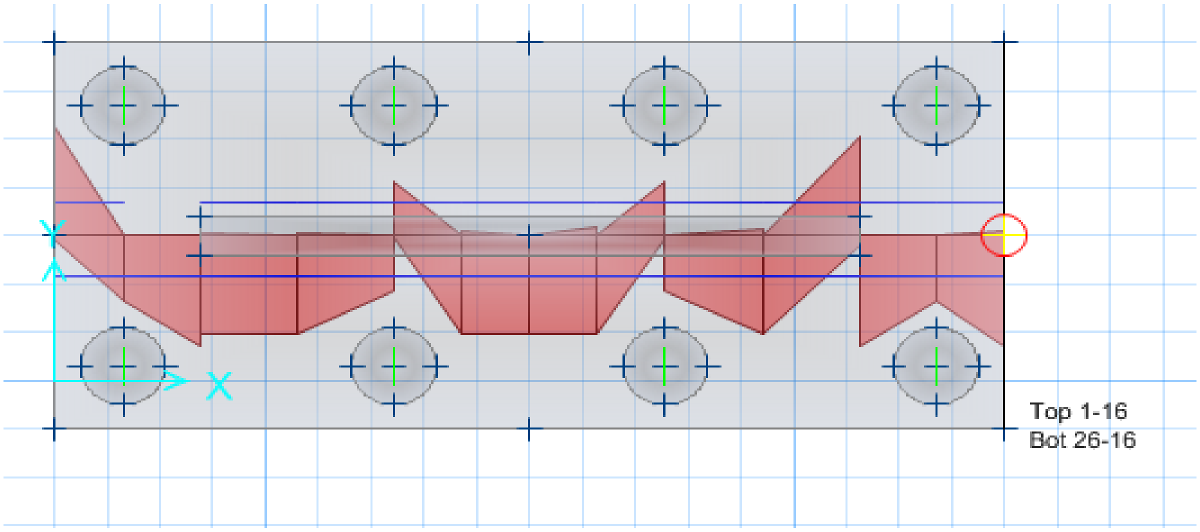


Figure 7.23: Total bottom number of bars in X(Long) direction.

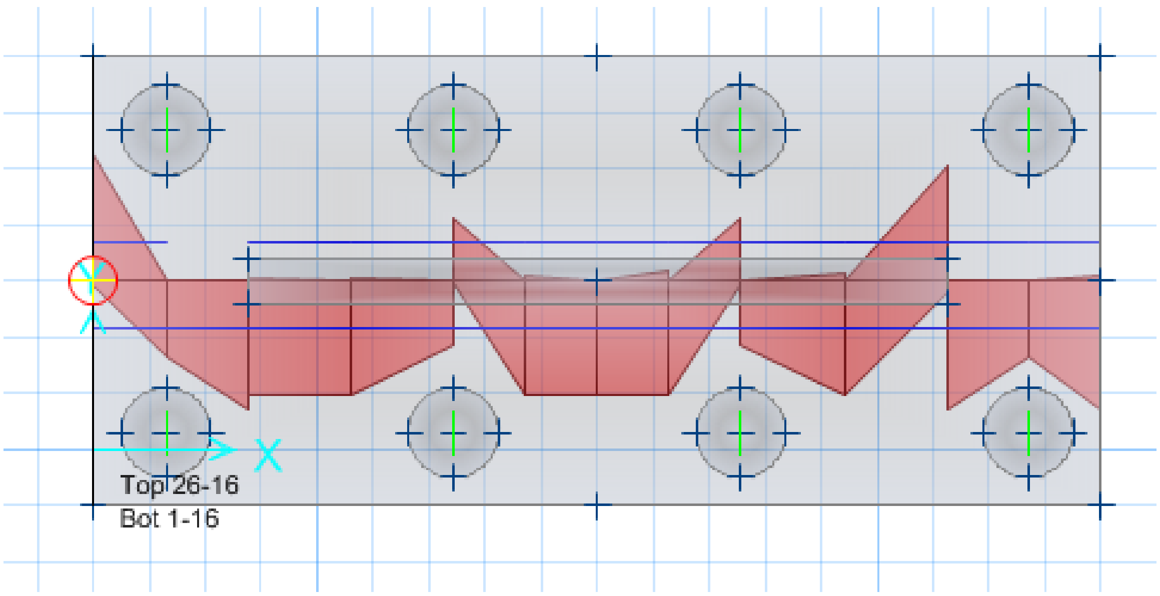


Figure 7.24: Total Top number of bars in X(Long) direction.

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

Reinforcement	Long direction	Short direction
Top	7Φ16/m	7Φ16/m
Bottom	7Φ16/m	7Φ16/m

- **Footing (2):**

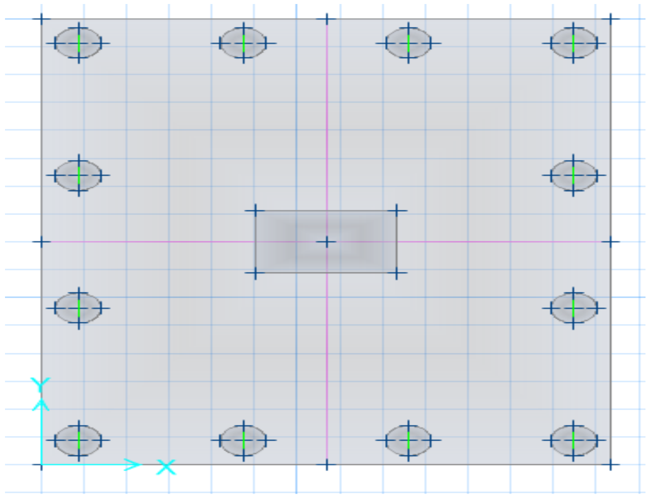


Figure 7.25: Footing 2.

1. The Cap:

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

Assume h = 110cm.

Define Cap section by SAFE as shown in the figure:

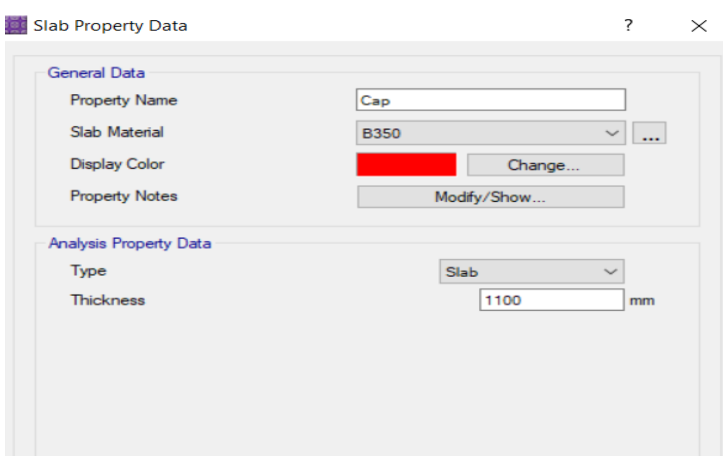


Figure 7.26: Cap-section define by SAFE.

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:

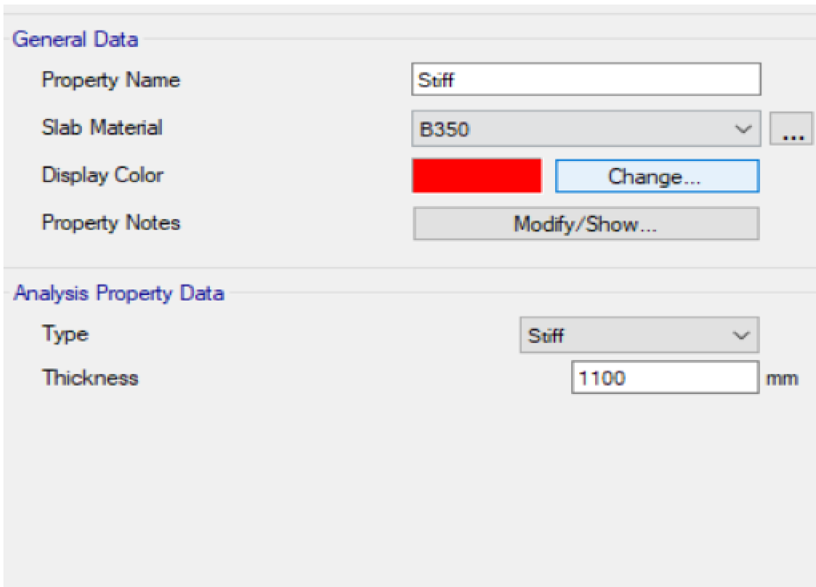


Figure 7.27: Footing (2) Stiff-section defines by SAFE.

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.

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

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

   Spring Stiffness = 950/10 = 95KN/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.

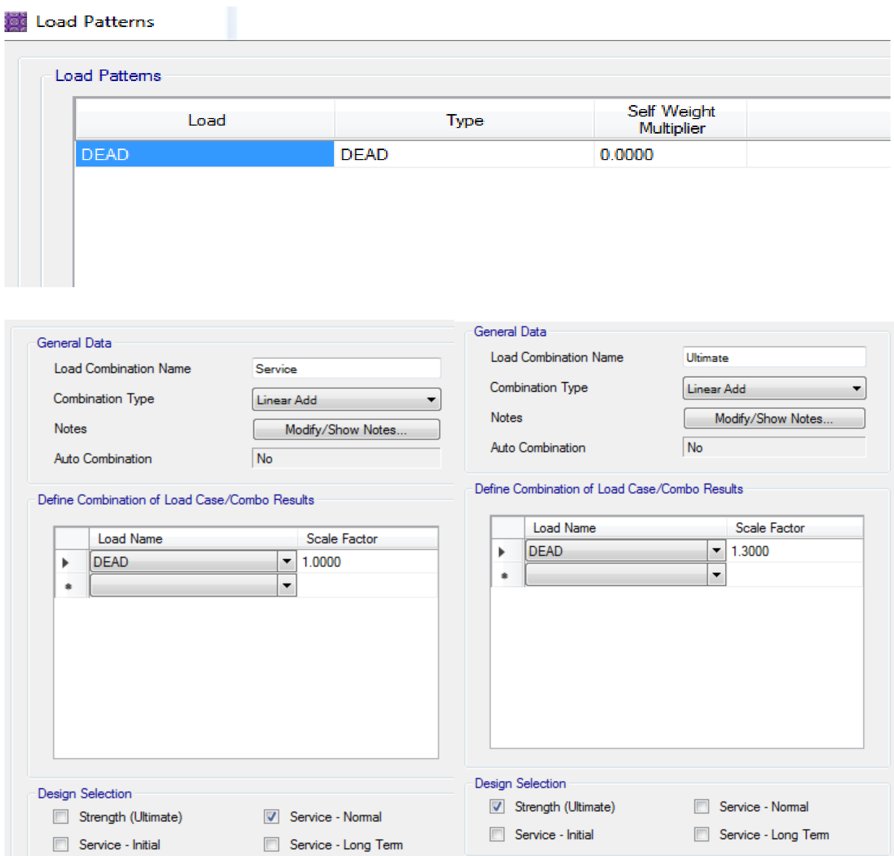


Figure 7.28: load patterns and load combination defined by SAFE.

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:

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

$R_{max} = P/N + (M_x * Y_{com}/\Sigma y^2) + (M_y * X_{comp}/\Sigma X^2) = 6971/12+$

$(4612*5.35/(8*5.35^2)+(4*1.78^2))+(9063*4.35/(8*4.35^2+4*1.45^2)$

=930< Qall comp

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

$R_{min} = 581-103-246$

=232KN< Qall tens

- Displacement check:

The displacement under footing should be < 10mm.

- 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	10Φ16/m	10Φ16/m
Bottom	10Φ25/m	7Φ25/m

- **Footing (3):**

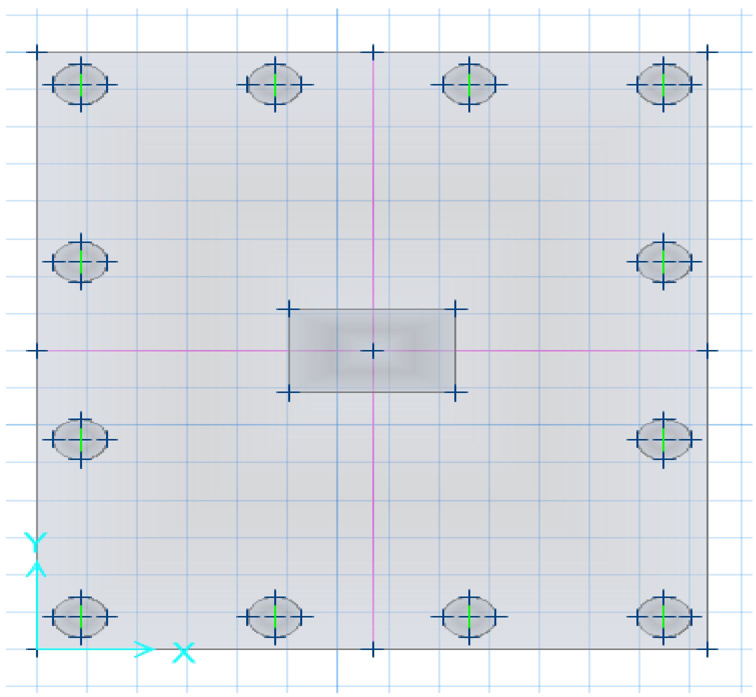


Figure7.30: Footing 3.

1. The Cap.

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

Assume h = 110cm.

Define Cap section by SAFE as shown in the figure:

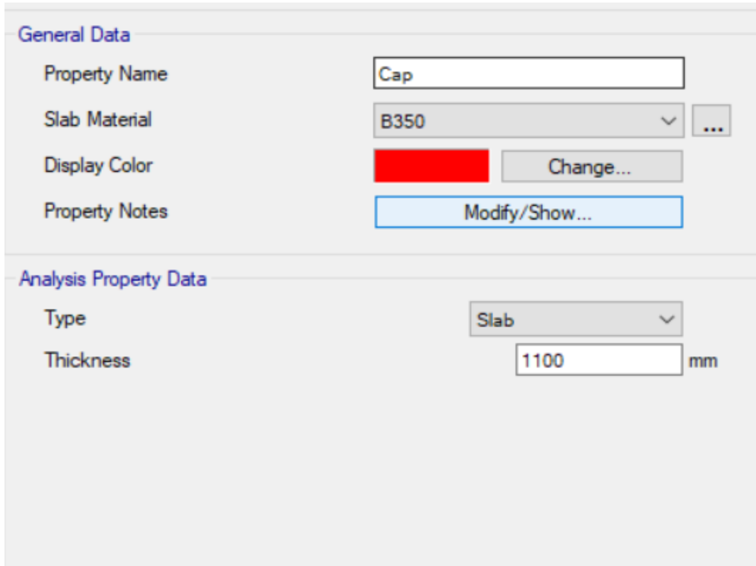


Figure 7.31: Cap-section define by SAFE.

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:

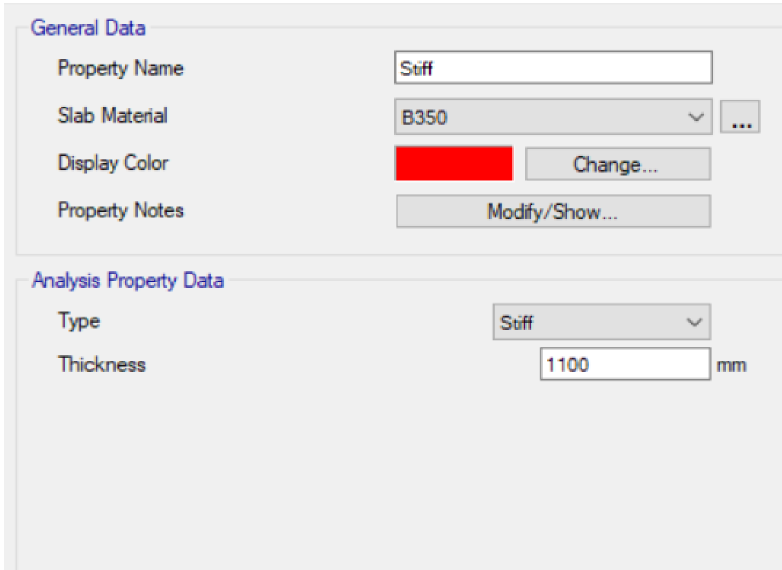


Figure 7.32: Footing (3) Stiff-section defines by SAFE.

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.

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

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

Spring Stiffness = 950/10 = 95KN/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.

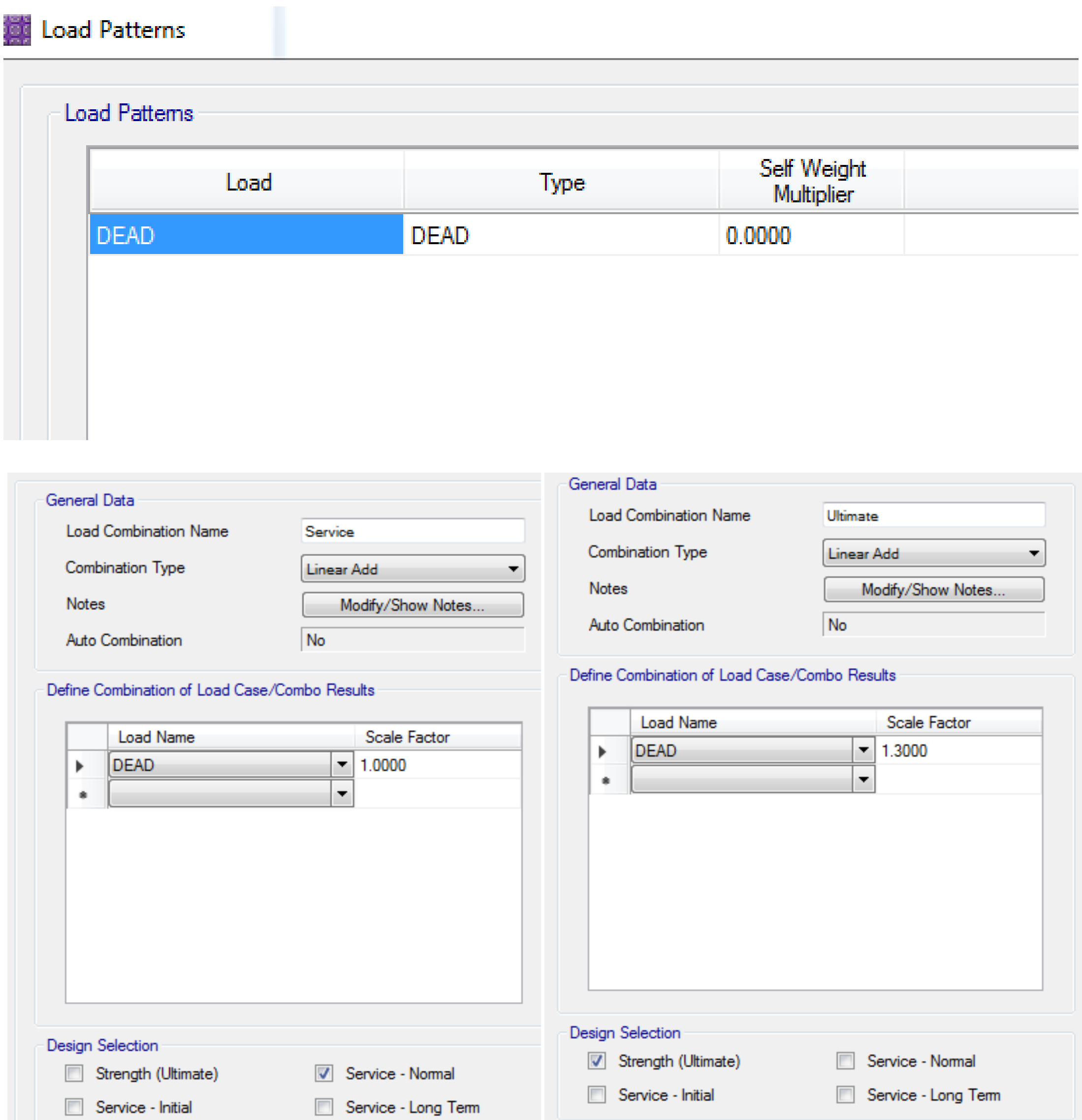


Figure 7.33: load patterns and load combination defined by SAFE.

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:

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

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

$= 6138/12 + (6899*5.35/(8*5.35^2)+(4*1.78^2)) + (6535*4.35/(8*4.35^2+4*1.45^2))$

=844< Qall comp

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

R_{min} = 512-154-178

=180KN< Qall tens.

- Displacement check:

The displacement under footing should be < 10mm.

- 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	10Φ25/m	6Φ25/m

- **Footing (4):**

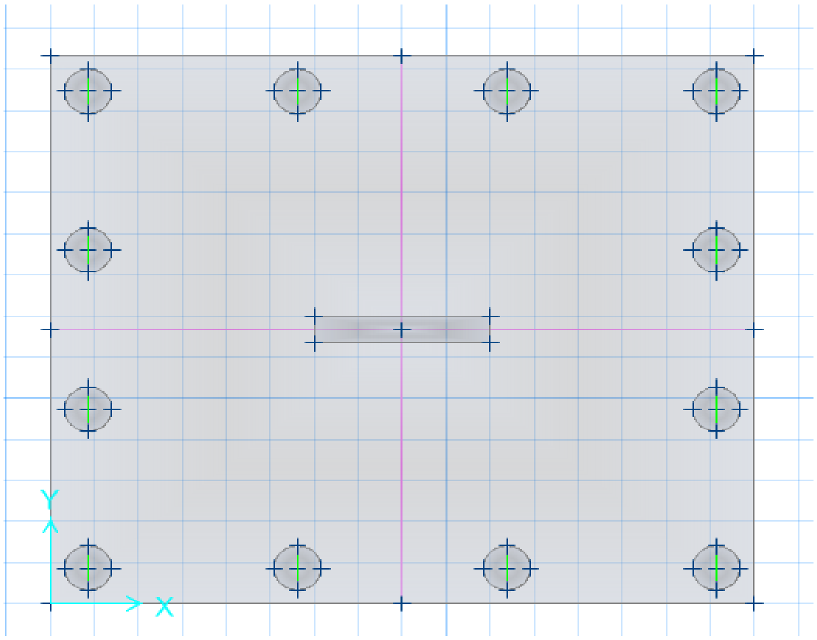


Figure 7.35: Footing 4.

1. The Cap:

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

Assume h = 1.5m.

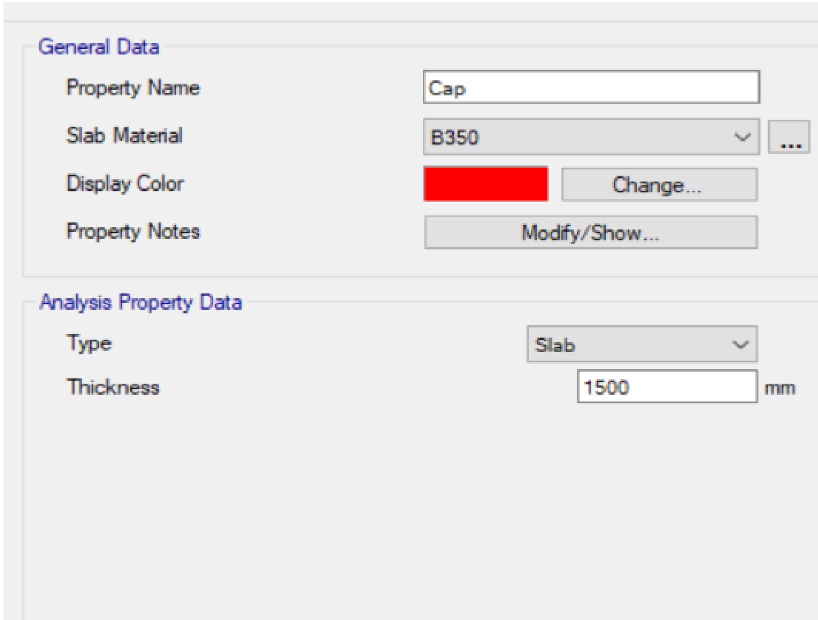


Figure 7.36: Cap-section define by SAFE.

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:

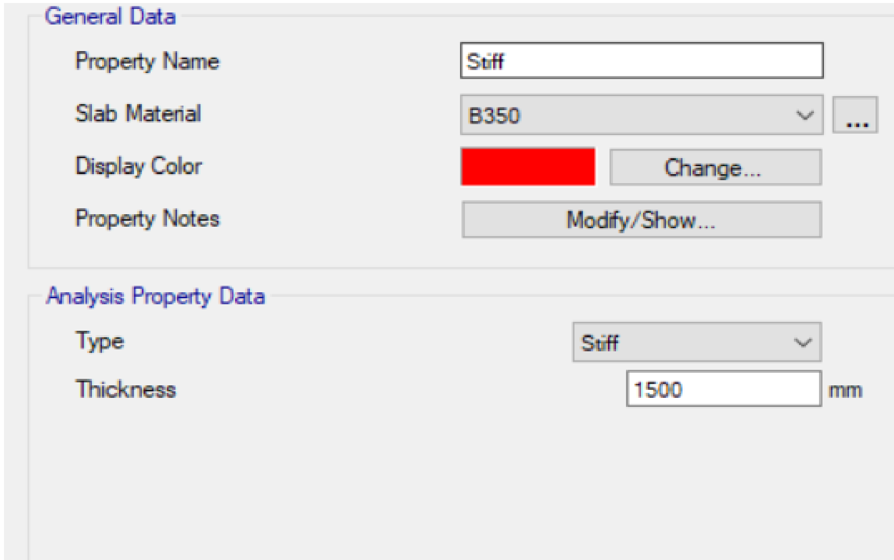


Figure 7.37: Footing (4) Stiff-section defines by SAFE.

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.

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

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

Spring Stiffness = 950/10 = 95KN/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.

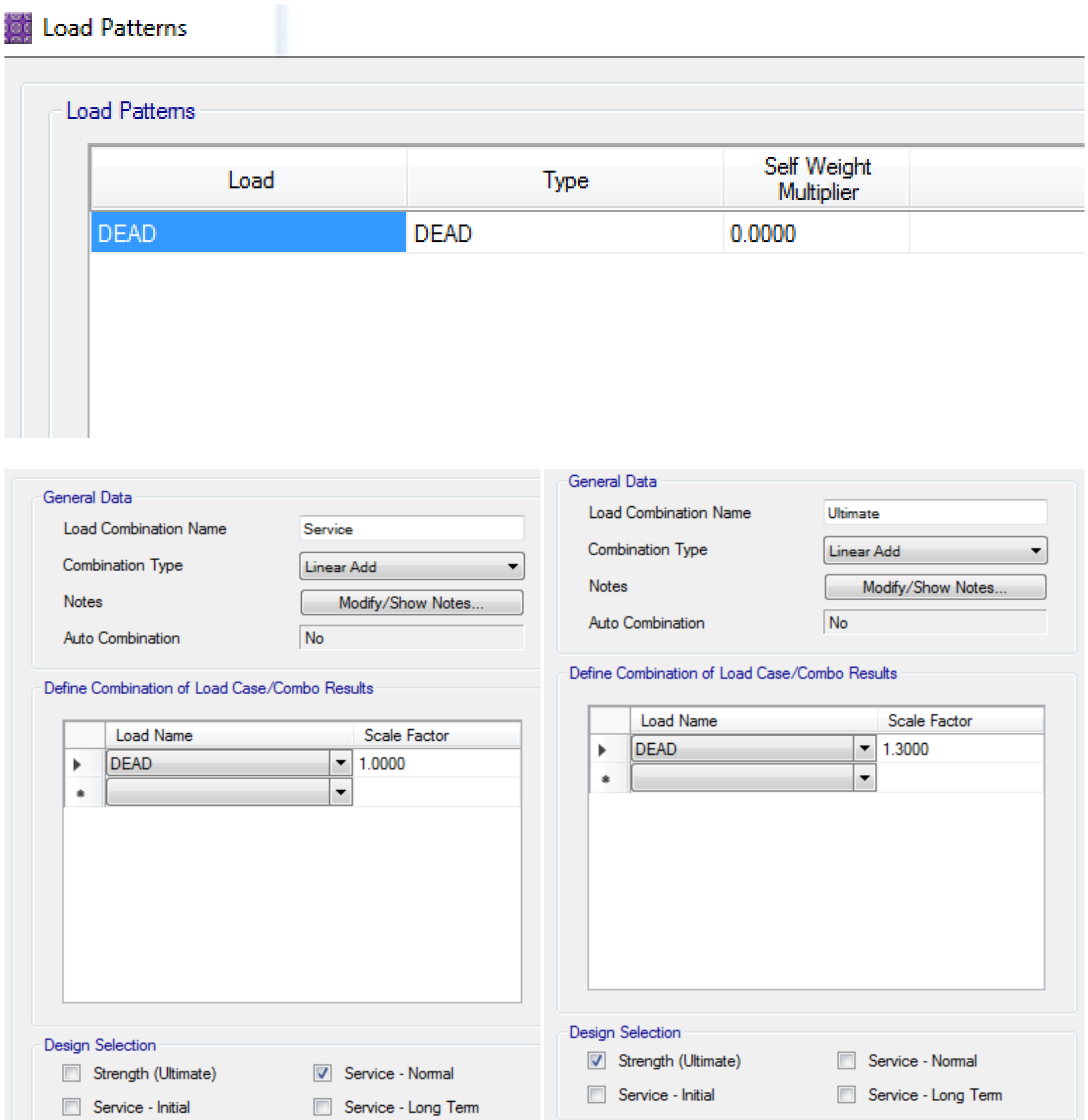


Figure 7.38: load patterns and load combination defined by SAFE.

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:

Rmax < qall comp

Rmax = P/N+ (Mx*Ycom/Σy2)+(My*Xcomp/ ΣX2)

= 8709/12
+(6424*4.35/(8*4.352)+(4*1.452))+(740*5.35/(8*5.352+4*1.782)

=918< Qall comp.

Rmin < qall tens.

Rmin = 726-175-17

=534KN< Qall tens.

- Displacement check:

The displacement under footing should be < 10mm.

- 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	7Φ16/m	8Φ16/m
Bottom	6Φ25/m	9Φ25/m

- **Footing (5):**

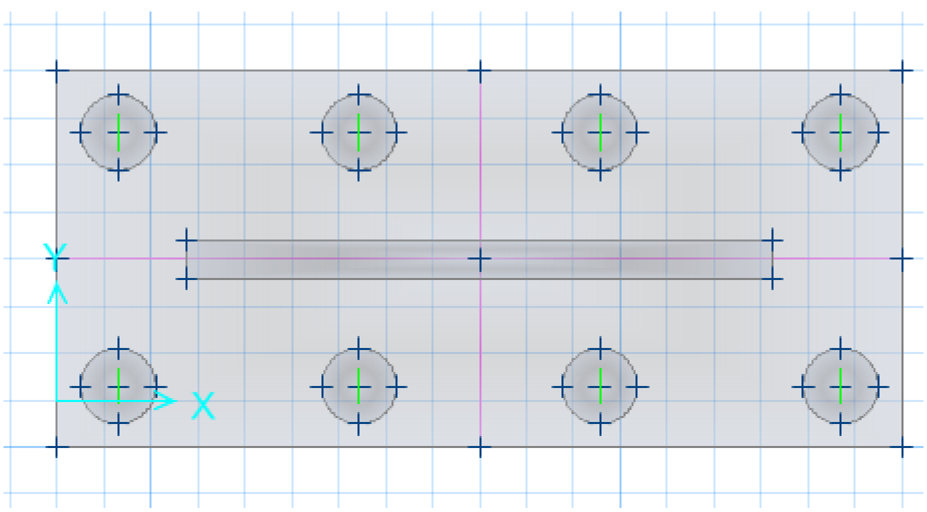


Figure 7.40: Footing 5.

1. The Cap:

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

Assume h = 70cm.

Define Cap section by SAFE as shown in the figure:

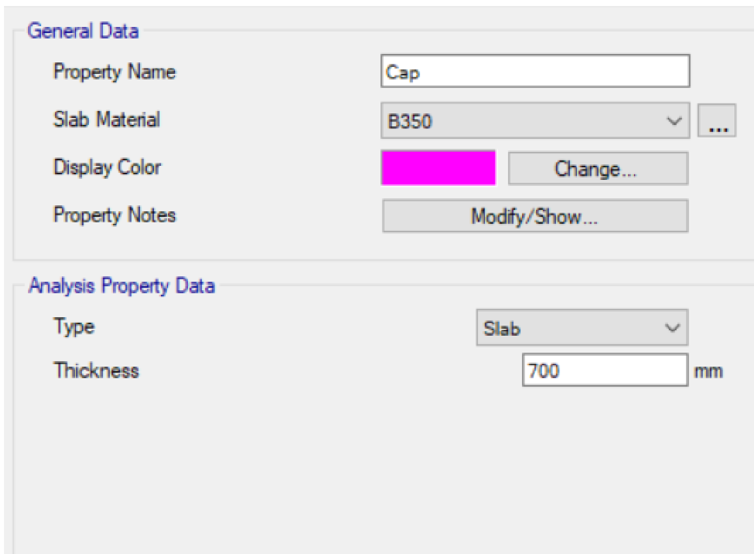


Figure 7.41: Cap-section define by SAFE.

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:

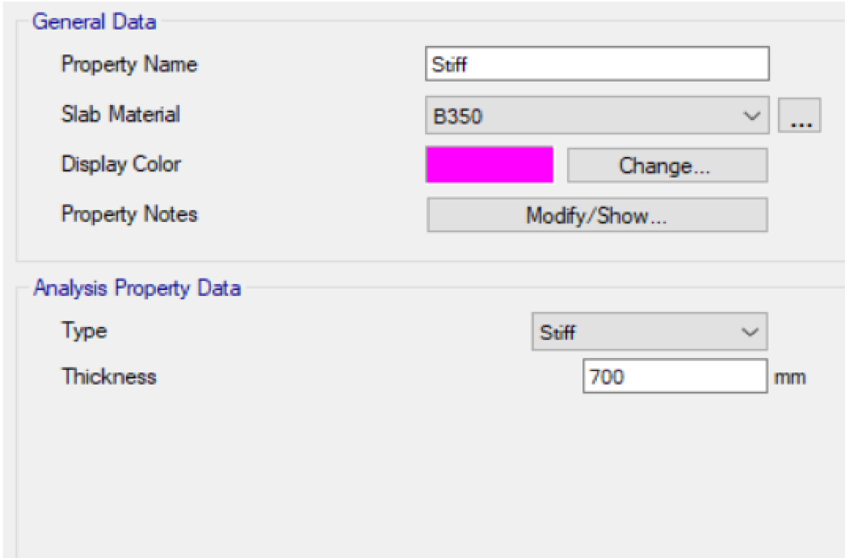


Figure 7.42: Footing (5) Stiff-section defines by SAFE.

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.

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

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

Spring Stiffness = 950/10 = 95KN/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.

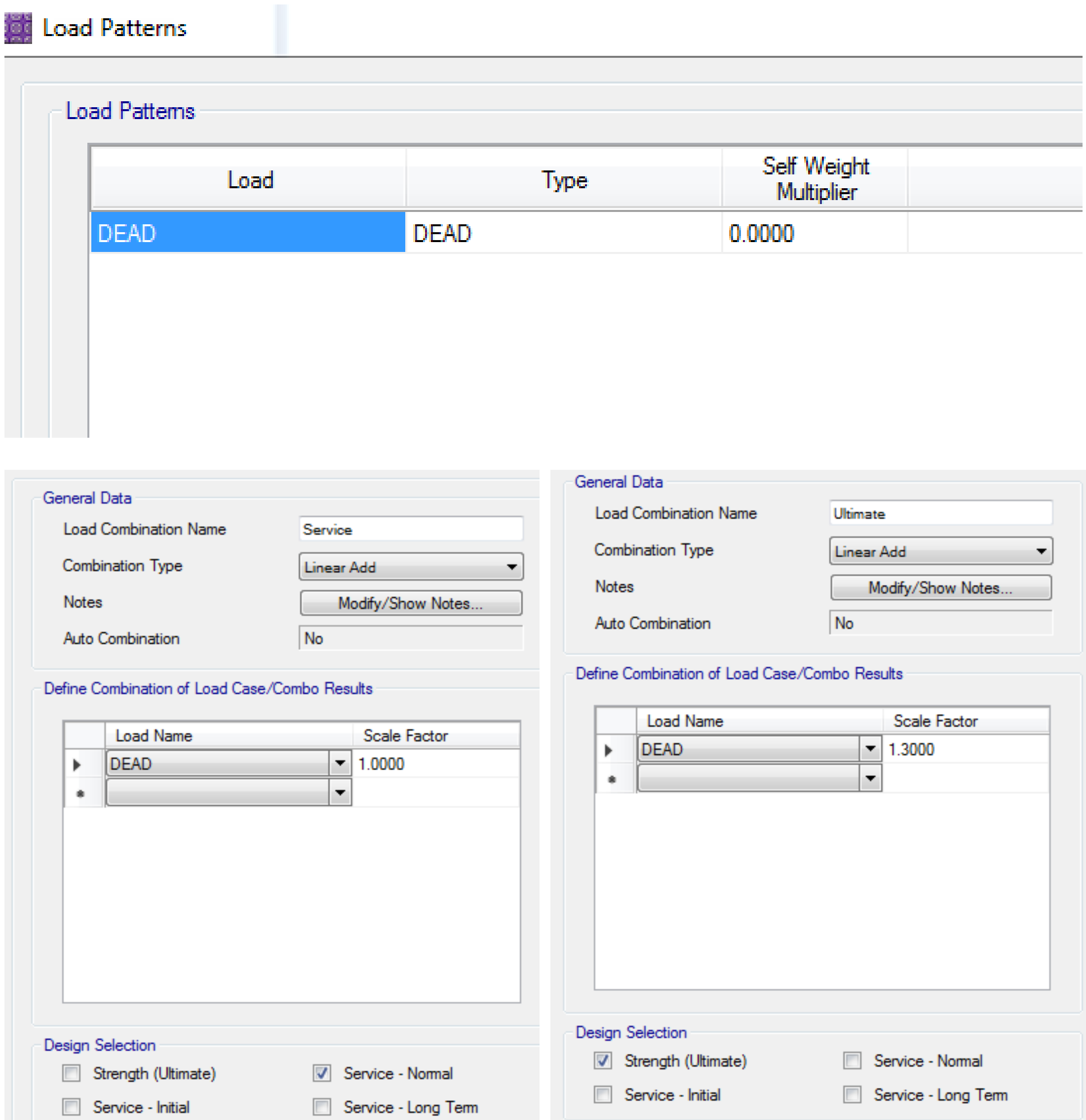


Figure 7.43: load patterns and load combination defined by SAFE.

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:

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

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

$= 2110/8 + (875*1.35/(8*1.35^2) + (2354*3.85/(4*3.85^2+4*1.28^2)$

=483KN< Qall comp

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

$R_{min} = 264-81-138$

= 45KN < Qall tens.

- Displacement check:

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

- 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	7Φ16/m	4Φ16/m
Bottom	7Φ16/m	7Φ16/m

7.2.2 Reinforcement of piles:

Pu = 1330

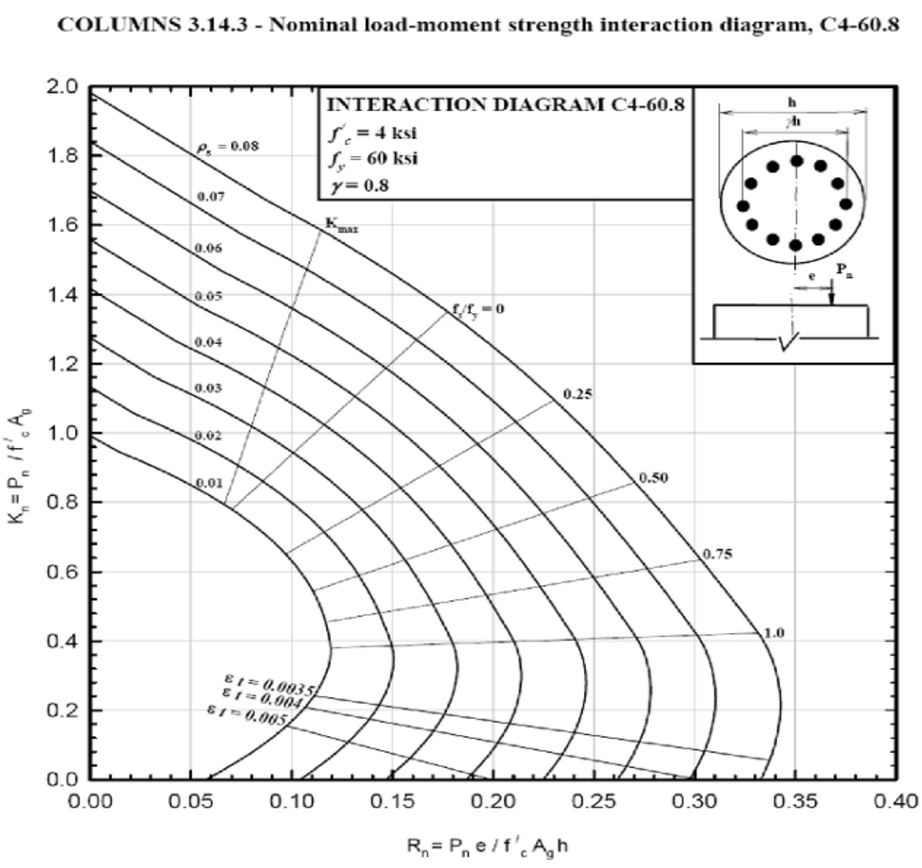
Ag = 800^2*3.14/4=502400

Kn = 1330*10^3/28 * (502400) *7 = 0.0135

e = 0.015+0.03h = 0.039

Rn = 1330*10^3*0.039/28*7 * 800 * 502400 = 6.5 * 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.

ρ =0.01

Cover=60

As=3629.84mm2

Use 15ϕ18

- Shear check of piles:

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

Vs = Vu-Vc

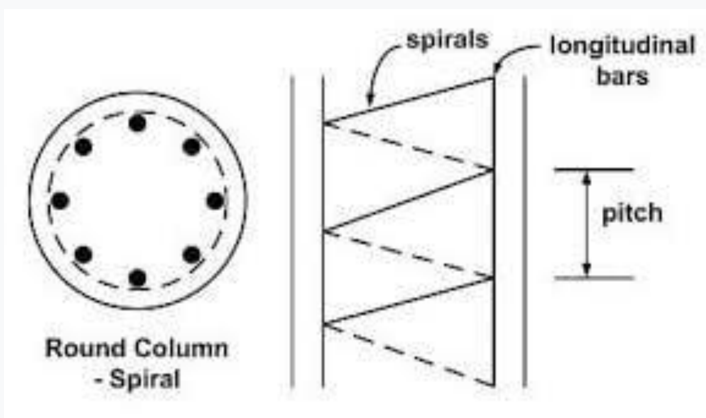
$\frac{Av}{S} = \frac{vs}{fy \times d}$

All pile have Vu < Vc then:

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

Use Ø =8

S = 150 mm (spiral stirrups)



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- AASHTO LRFD Code.
- ACI-318 Code.
- ASCE 7-10 Code.
- SAP 2000, version 20.0 Program
- Auto Cad, version 2017 Program.
- Safe, version 2016 program.