**Learning Outcome Assessment III (Senior Design Project)**
**Spring 2019 Final Presentation**

# Design of RCC Multi Story Parking at PMU


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Group 4

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# Outline

- Introduction
- Objective
- Car Park Regulation
- Structural Elements
- Steel Reinforcements
- Geotechnical
- Constraints
- Cost Estimation
- References

# Introduction

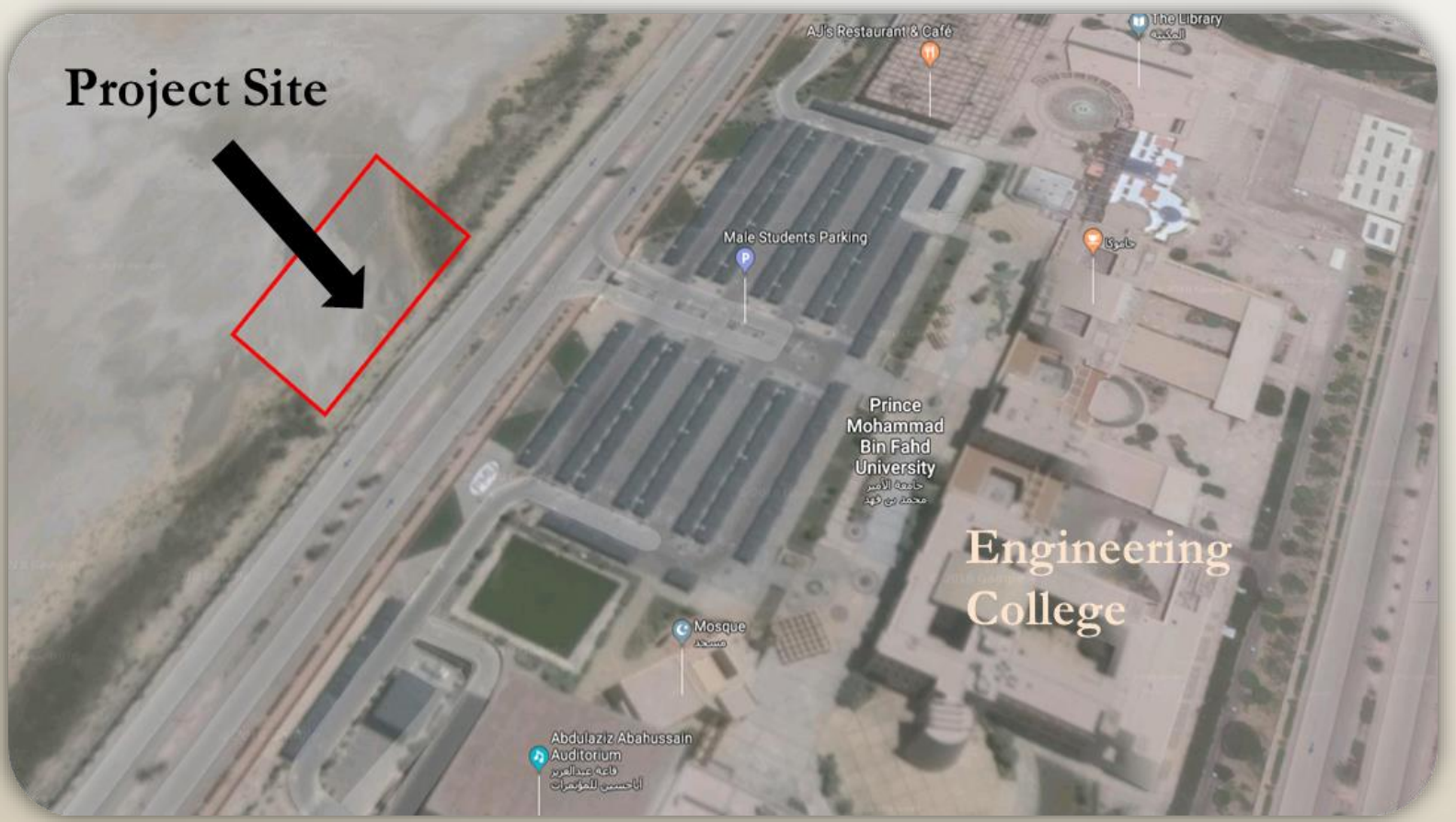
- Shortage in Car Parks
- Expected Increase of Population
- Problem will Propagate.
- Concrete Multi-Story Car Park
- Structural and Geotechnical Design
- Cost Estimation

# Objective

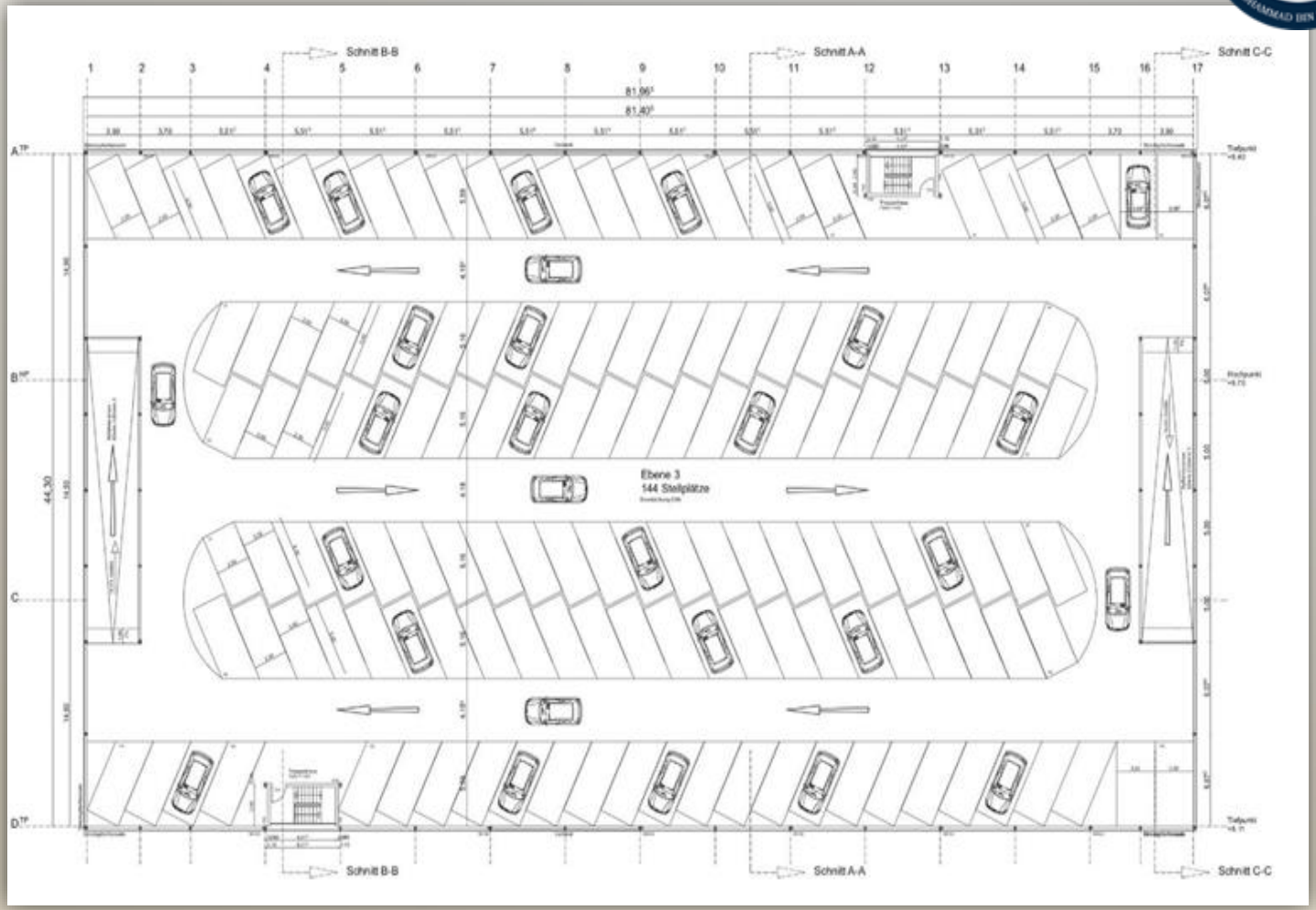
**Design a multi-story car park:**

- To provide safe and easily accessible area for car parking.
- Modeling using ETABS for structural design.
- Geotechnical design of the foundation system.
- To estimate the total cost for construction.

# Location

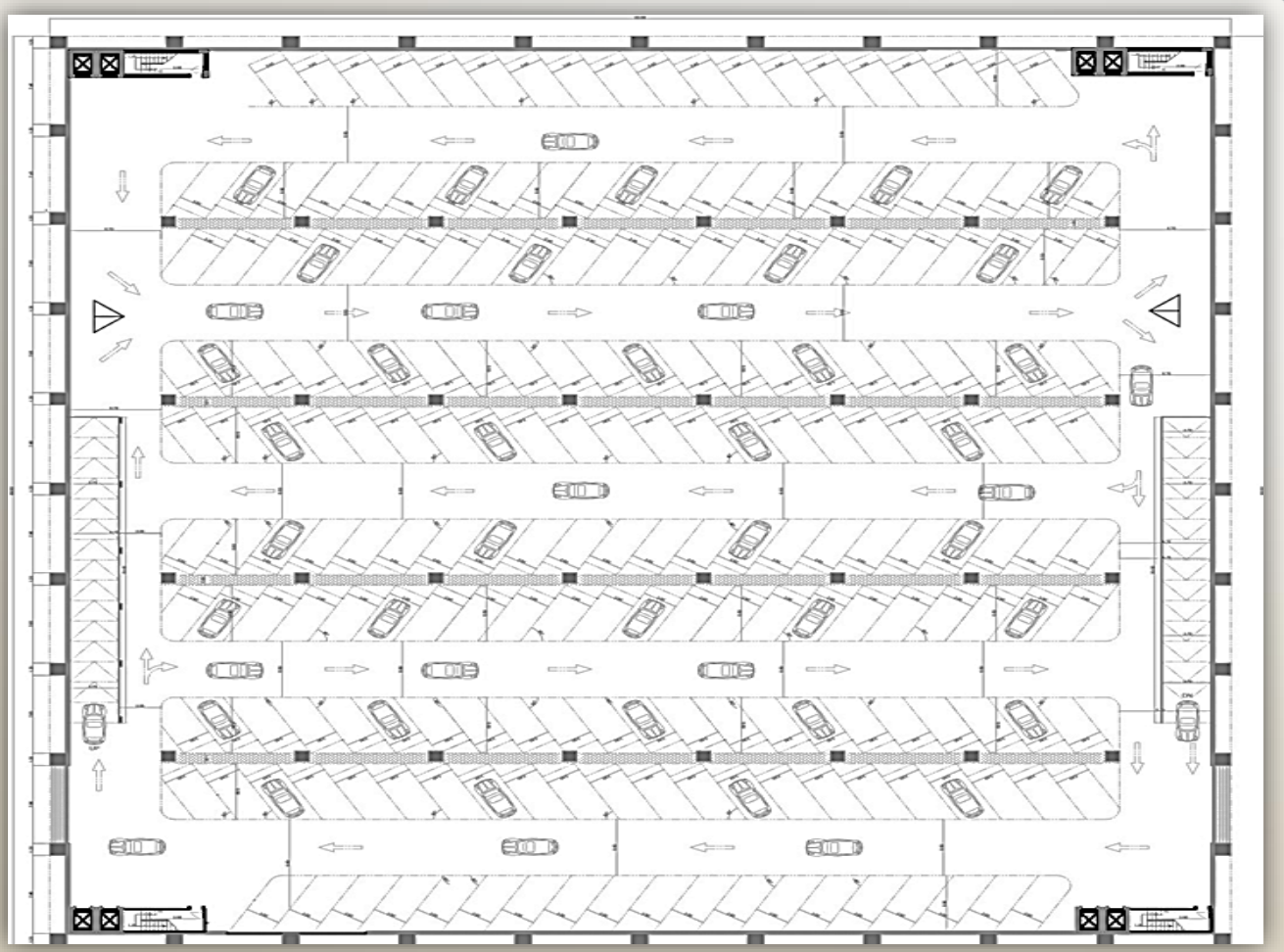

Project Site
AJ's Restaurant & Café
The Library
Male Students Parking
Prince Mohammad Bin Fahd University
Engineering College
Mosque
Abdulaziz Abahussain Auditorium

# Original Layout




Arch Daily (2009)

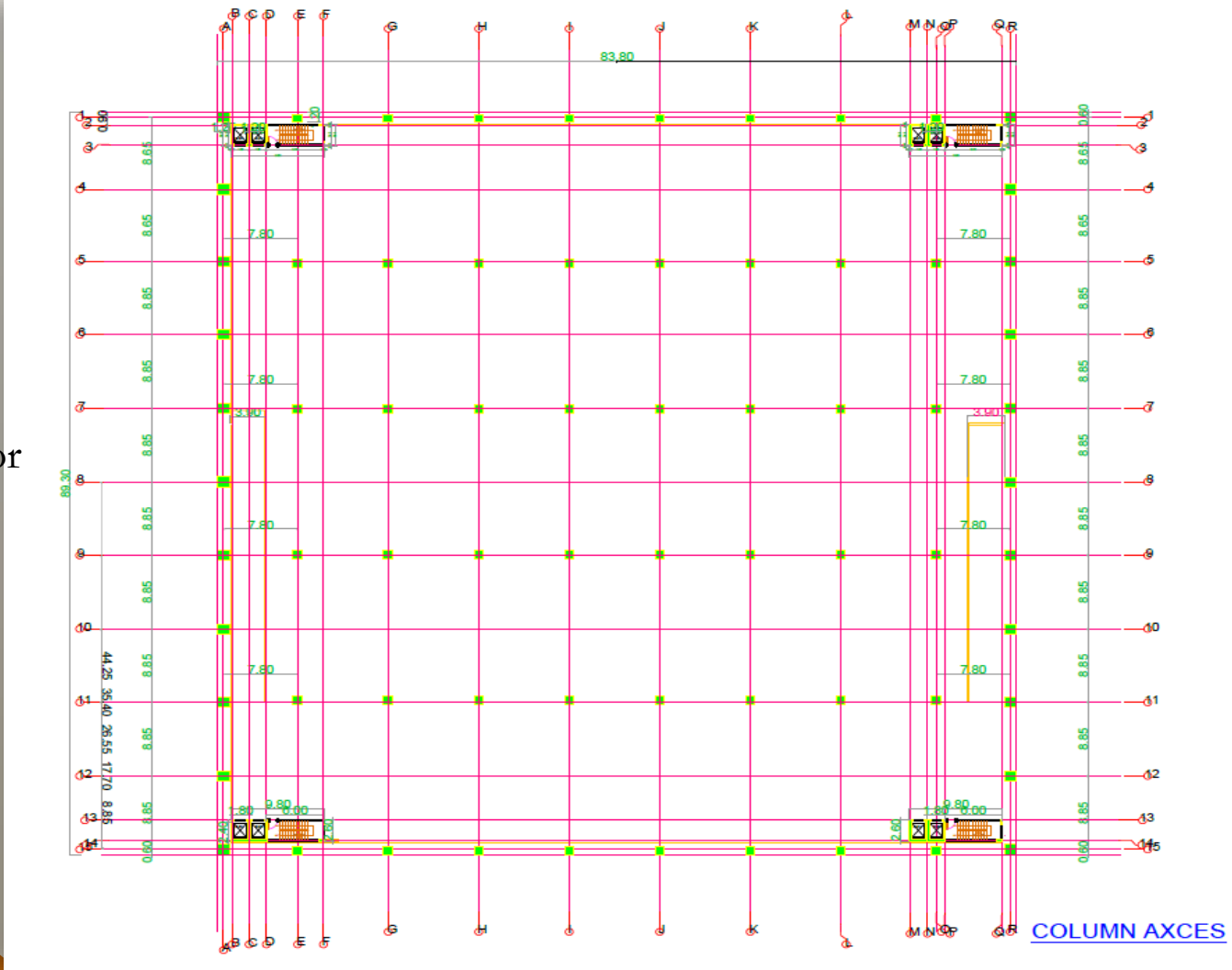
# Modified Layout



90m

84 m

# Grid Line




Elevation:

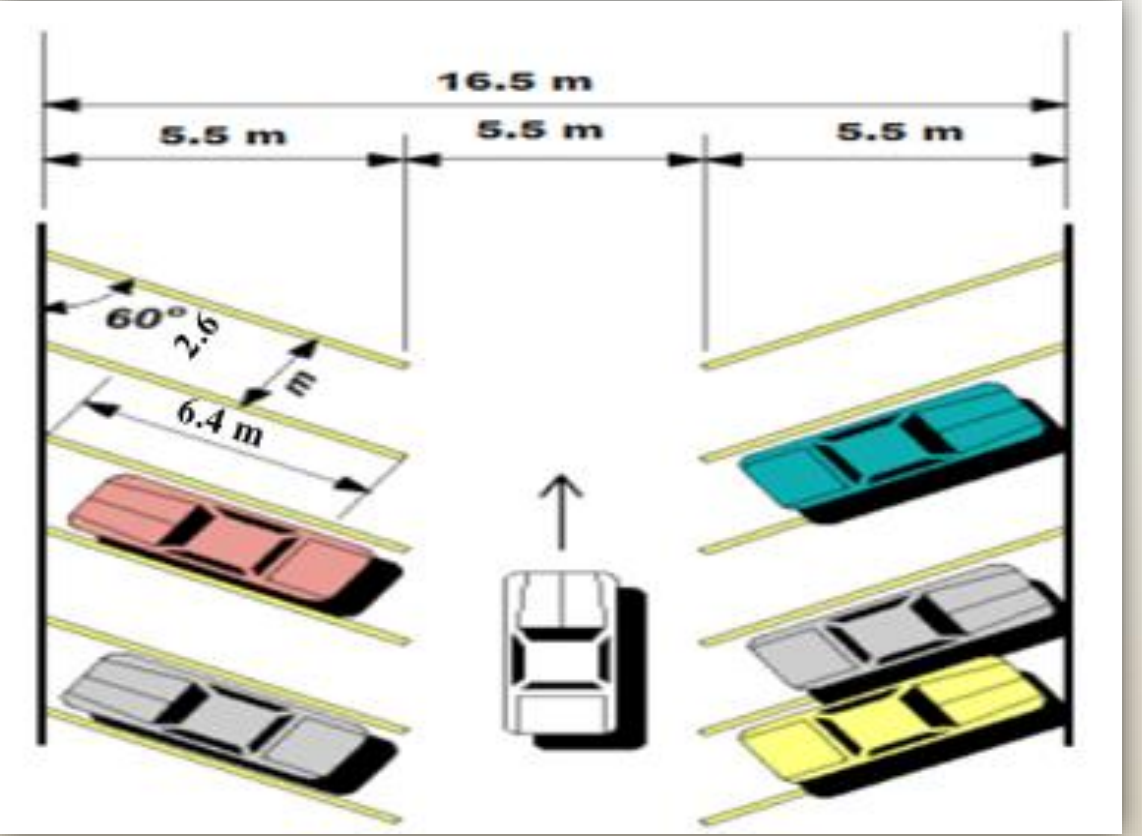
- 3.5 m/floor

Total Height:

- 14 m

# Parking Dimensions

- Width
- Length
- Drive Way
- Ramp
- Min. Clearance
- No. of Exits




(Edited): (Shakri., Khairuddin, 2015)

# Ramp

| Description | Dimensions |
|---|---|
| Ramp slope | 11% * |
| Angle of departure | 11% |
| Angle of approaches | 11% |
| Ramp Live load | 5 $KN/m^2$ |
| Ramp length | 35 m |
| Ramp width | 3.9 m |

* Ramp slope 11% = each 1 m increase the height by 11 cm

According to MOMRA Codes and SBC (301)

# Slab Design

- Flat Slab ⟶ No Beams
- $Ratio = \frac{Longer\ span}{shorter\ span} = {}^{17.7}/_{9.5} = 1.86 < 2$
- Ratio <2 ⟶ Two way slab
- $Slab\ thickness = \frac{L}{33} = \frac{17.7}{33} = 0.53\ m \approx 0.55\ m$ (SBC 304)

# Loads

- Live Load = 2 KN/m$^2$
- Dead Load = $\gamma t = 24\ x\ 0.55 = 13.2\ KN/m^2$
- Mechanical Load = 0.5 KN/m$^2$

(all loads from SBC 301)

# Central Columns

$$Pu = \emptyset r(0.85f'c(Ag - Ast) + fyAst)$$ (Wight, 2016)

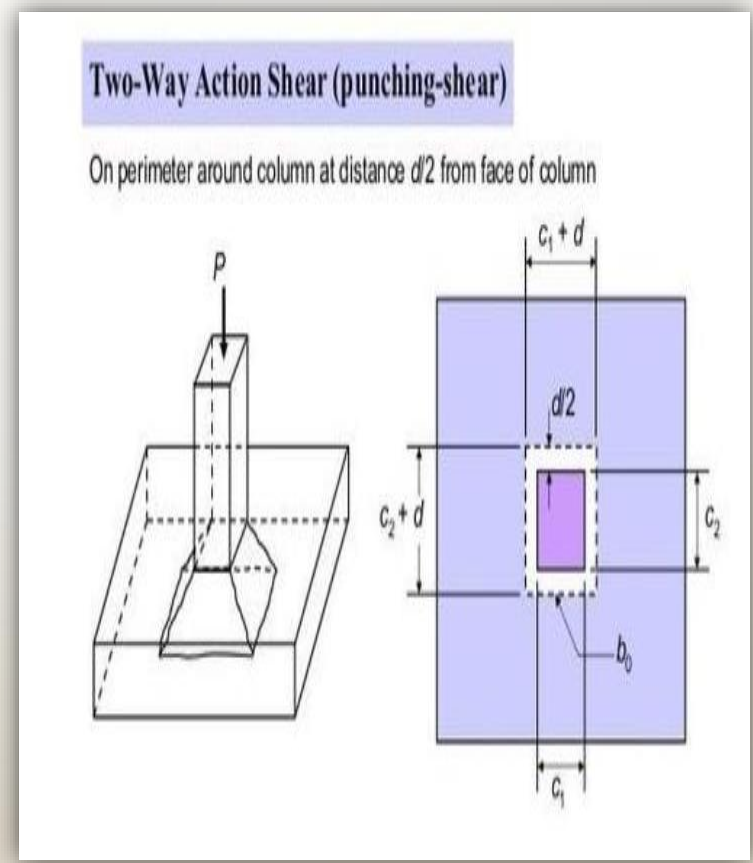
| Center Columns | |
|---|---|
| **Floor** | Columns Dimensions |
| **G** | 900 mm X 900 mm |
| **1** | 800 mm X 800 mm |
| **2** | 650 mm X 650 mm |
| **3** | 450 mm X 450 mm |

# Edge Columns

| Edge Columns | |
|---|---|
| **Floor** | Columns Dimensions |
| **G** | 650 mm X 650 mm |
| **1** | 550 mm X 550 mm |
| **2** | 450 mm X 450 mm |
| **3** | 350 mm X 350 mm |

# Punching Shear

- To pass Ø Vc ≥ Vu.
- $Vu = Wu\,(A_{tr} - A'_c)$
- $Vc = 4\sqrt{fc'}b * d$




(Rahul, 2016)

# Results of Punching Shear

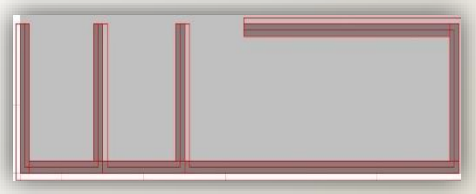
| Center Columns | | |
|---|---|---|
| **Floor** | Columns Dimensions | Punching Shear |
| **G** | 900 mm x 900 mm | Pass |
| **1** | 800 mm x 800 mm | Pass |
| **2** | 650 mm x 650 mm | Fail |
| **3** | 450 mm x 450 mm | Fail |

# New Dimensions

| Center Columns | |
|---|---|
| **Floor** | Columns Dimensions |
| **G** | 900 mm x 900 mm |
| **1** | 900 mm x 900 mm |
| **2** | 750 mm x 750 mm |
| **3** | 750 mm x 750 mm |

# Shear Wall

- Total length of all the shear wall sides = 24.7 m
- Effective area = 39.4m$^2$
- Ag = 18333501 mm$^2$ ( from excel sheet )



- The thickness obtained is $\frac{Ag}{toal\ length} = \frac{18333501\ mm^2}{24700\ mm} =$

$$7.4\ mm \quad < \quad 150\ mm$$

# Modeling

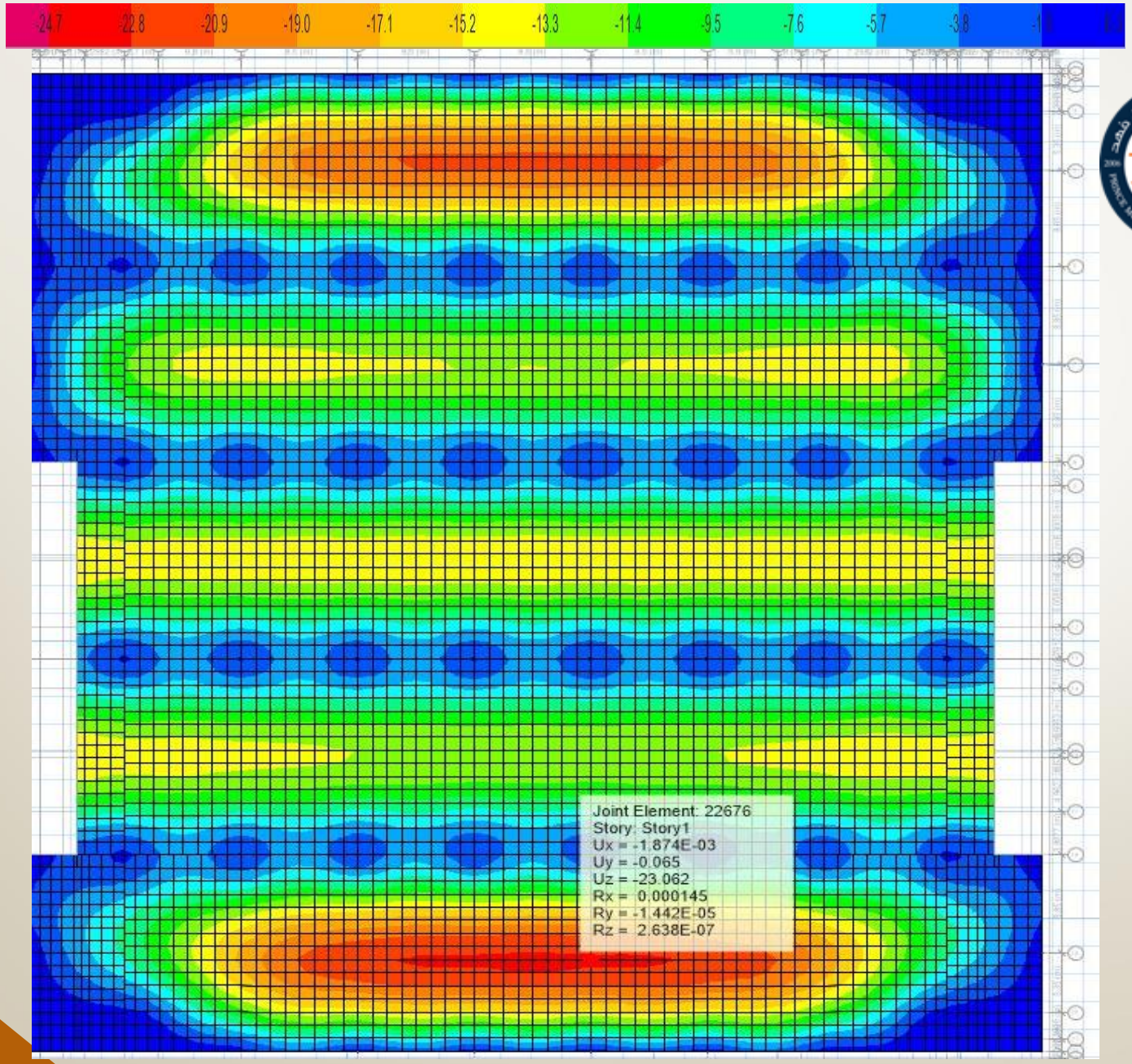
- Stress
- Member Failure
- Deflection Check

# New Edge Columns

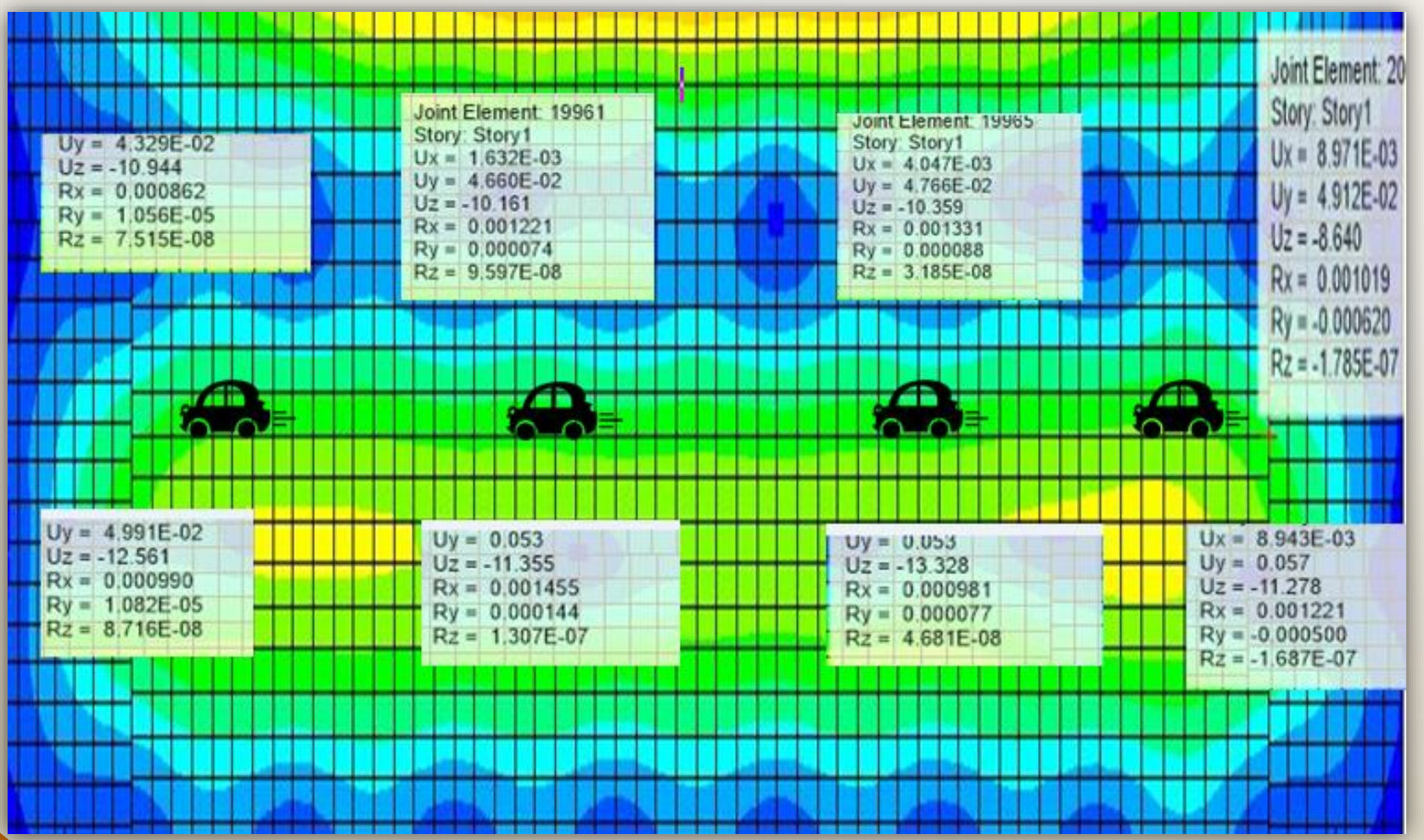
| Edge Columns | |
|---|---|
| **Floor** | Columns Dimensions |
| **G** | 650 mm X 650 mm |
| **1** | 650 mm X 650 mm |
| **2** | 600 mm X 600 mm |
| **3** | 600 mm X 600 mm |

# Deflection

- $\partial = \frac{l}{240}$ = 17.7/240= 73.75 mm. Use 25mm
- $\Delta = \frac{5wl^4}{384\,E\,I}$ = 23.72 mm < 25mm (pass)
- From ETABS: 23.13 mm < 25mm (pass)

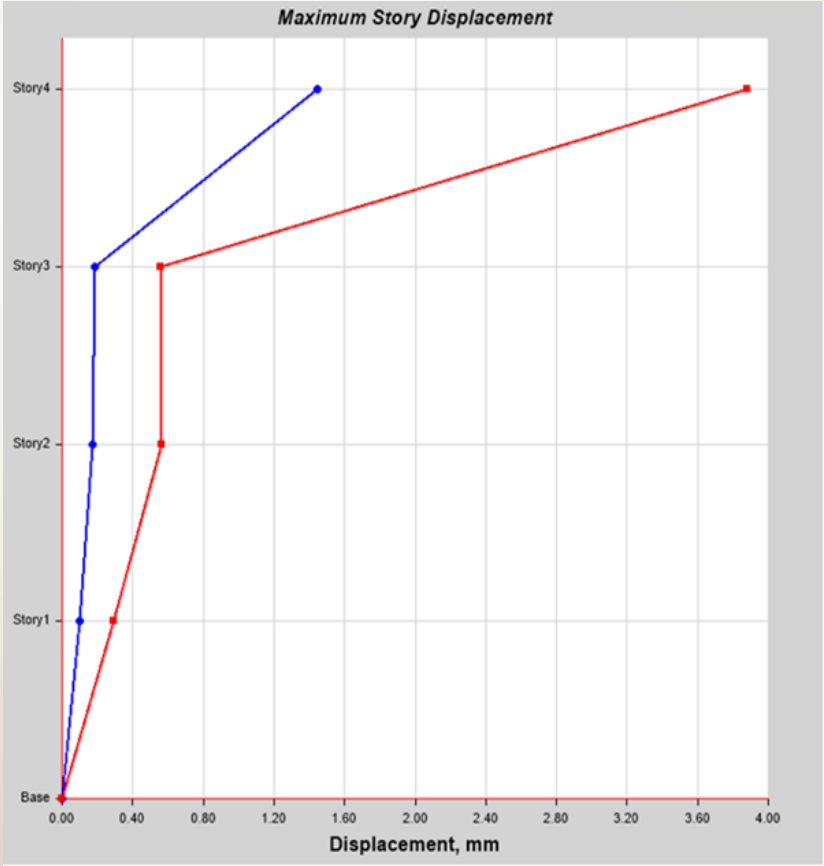

-24.7
-22.8
-20.9
-19.0
-17.1
-15.2
-13.3
-11.4
-9.5
-7.6
-5.7
-3.8
Joint Element: 22676
Story: Story1
Ux = -1.874E-03
Uy = -0.065
Uz = -23.062
Rx = 0.000145
Ry = -1.442E-05
Rz = 2.638E-07

# Moving Load


Uy = 4.329E-02
Uz = -10.944
Rx = 0.000862
Ry = 1.056E-05
Rz = 7.515E-08
Joint Element: 19961
Story: Story1
Ux = 1.632E-03
Uy = 4.660E-02
Uz = -10.161
Rx = 0.001221
Ry = 0.000074
Rz = 9.597E-08
Joint Element: 19965
Story: Story1
Ux = 4.047E-03
Uy = 4.766E-02
Uz = -10.359
Rx = 0.001331
Ry = 0.000088
Rz = 3.185E-08
Joint Element: 20
Story: Story1
Ux = 8.971E-03
Uy = 4.912E-02
Uz = -8.640
Rx = 0.001019
Ry = -0.000620
Rz = -1.785E-07
Uy = 4.991E-02
Uz = -12.561
Rx = 0.000990
Ry = 1.082E-05
Rz = 8.716E-08
Uy = 0.053
Uz = -11.355
Rx = 0.001455
Ry = 0.000144
Rz = 1.307E-07
Uz = -13.328
Rx = 0.000981
Ry = 0.000077
Rz = 4.681E-08
Ux = 8.943E-03
Uy = 0.057
Uz = -11.278
Rx = 0.001221
Ry = -0.000500
Rz = -1.687E-07

# Wind

- Max allowable drift is 0.02h
- h = 14m ⟶ max drift = 0.28m.
- 3.4 mm on shorter face
- 3.88mm on longer face



# Earthquake

- Max allowable drift = 0.28m

**Story Response Values: (Shorter Face)**

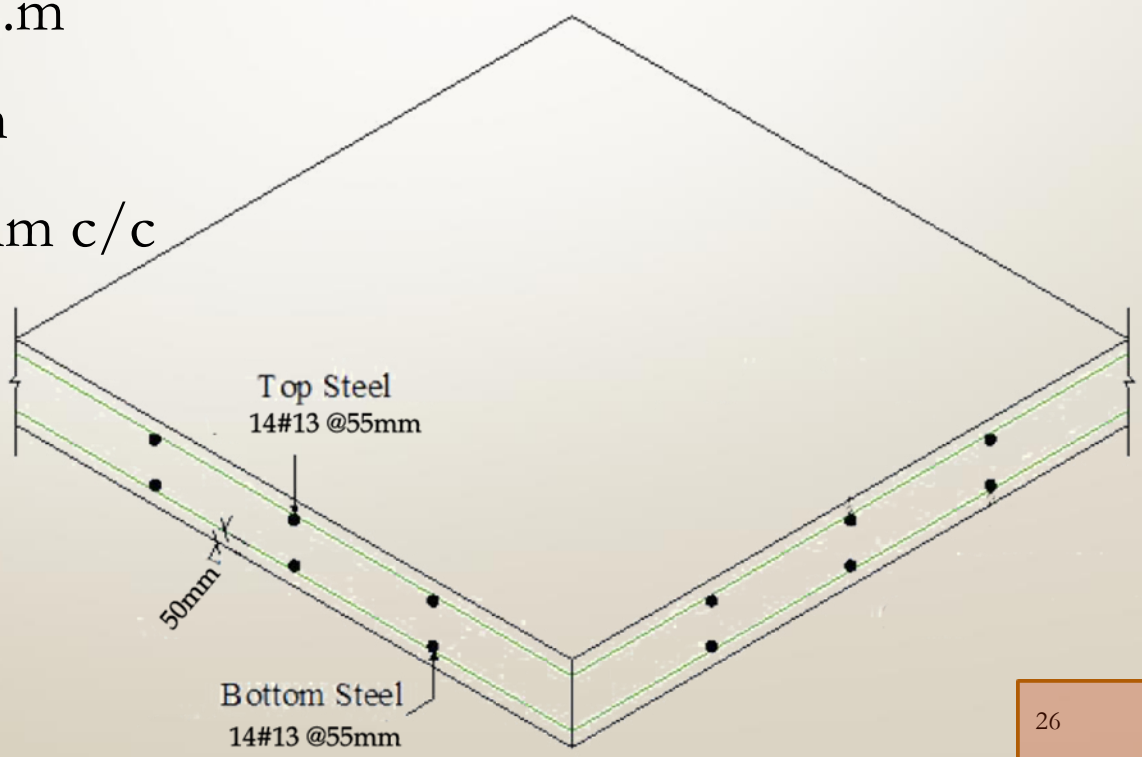
| Story | Elevation | Location | X-Dir | Y-Dir |
|---|---|---|---|---|
| | m | | mm | mm |
| Story4 | 14 | Top | 5.796 | 3.673 |
| Story3 | 10.5 | Top | 3.81 | 0.532 |
| Story2 | 7 | Top | 2.482 | 0.35 |
| Story1 | 3.5 | Top | 1.28 | 0.234 |
| Base | 0 | Top | 0 | 0 |

**Story Response Values: (Longer Face)**

| Story | Elevation | Location | X-Dir | Y-Dir |
|---|---|---|---|---|
| | m | | mm | mm |
| Story4 | 14 | Top | 1.598 | 12.158 |
| Story3 | 10.5 | Top | 0.469 | 7.038 |
| Story2 | 7 | Top | 0.411 | 4.928 |
| Story1 | 3.5 | Top | 0.318 | 2.487 |
| Base | 0 | Top | 0 | 0 |

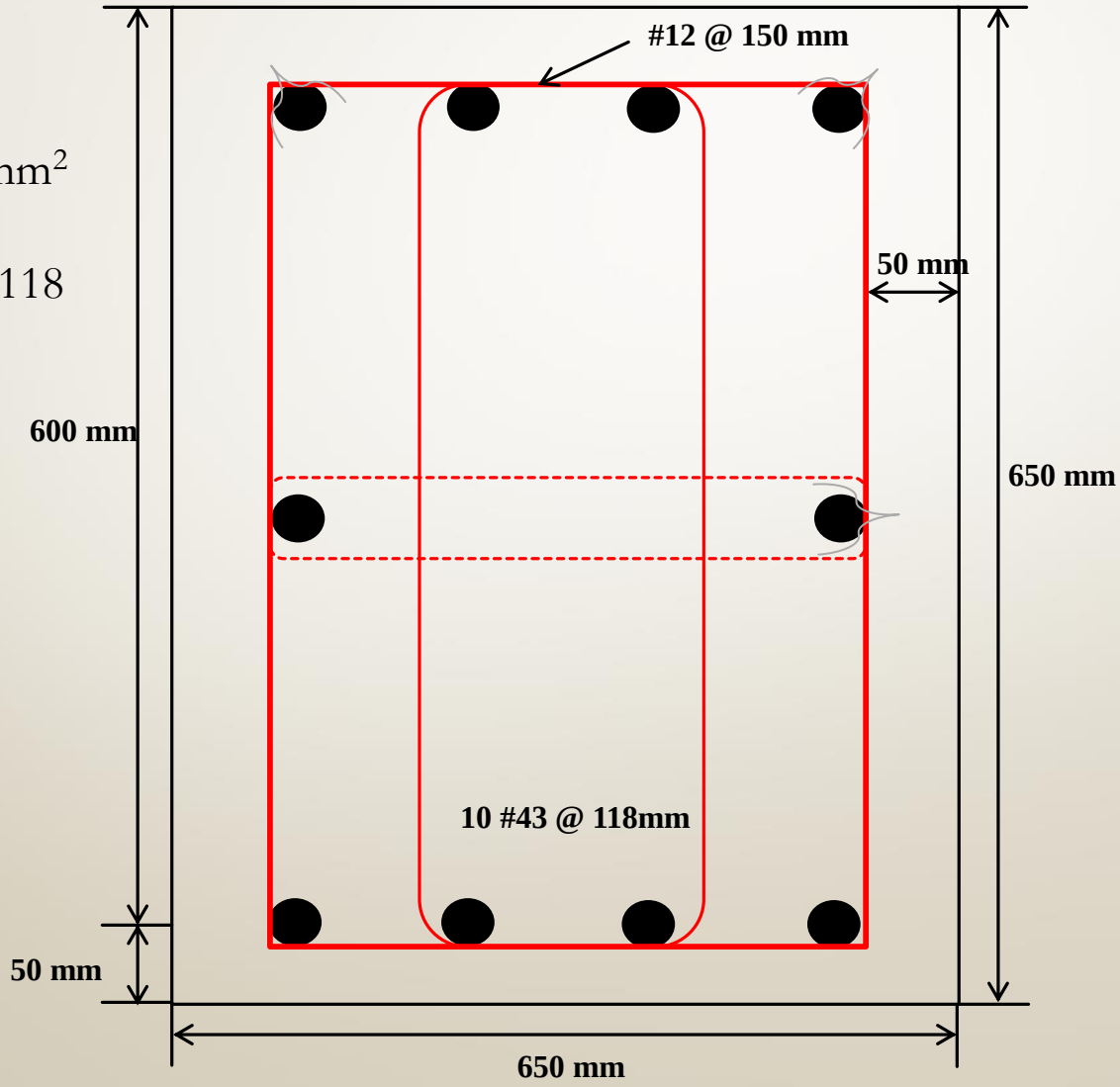
# Slab Reinforcement

- Slab thickness = 0.55 m
- Moment = 330 KN.m
- As = 1800 $mm^2$ /m
- Use 14# 13 @ 55mm c/c



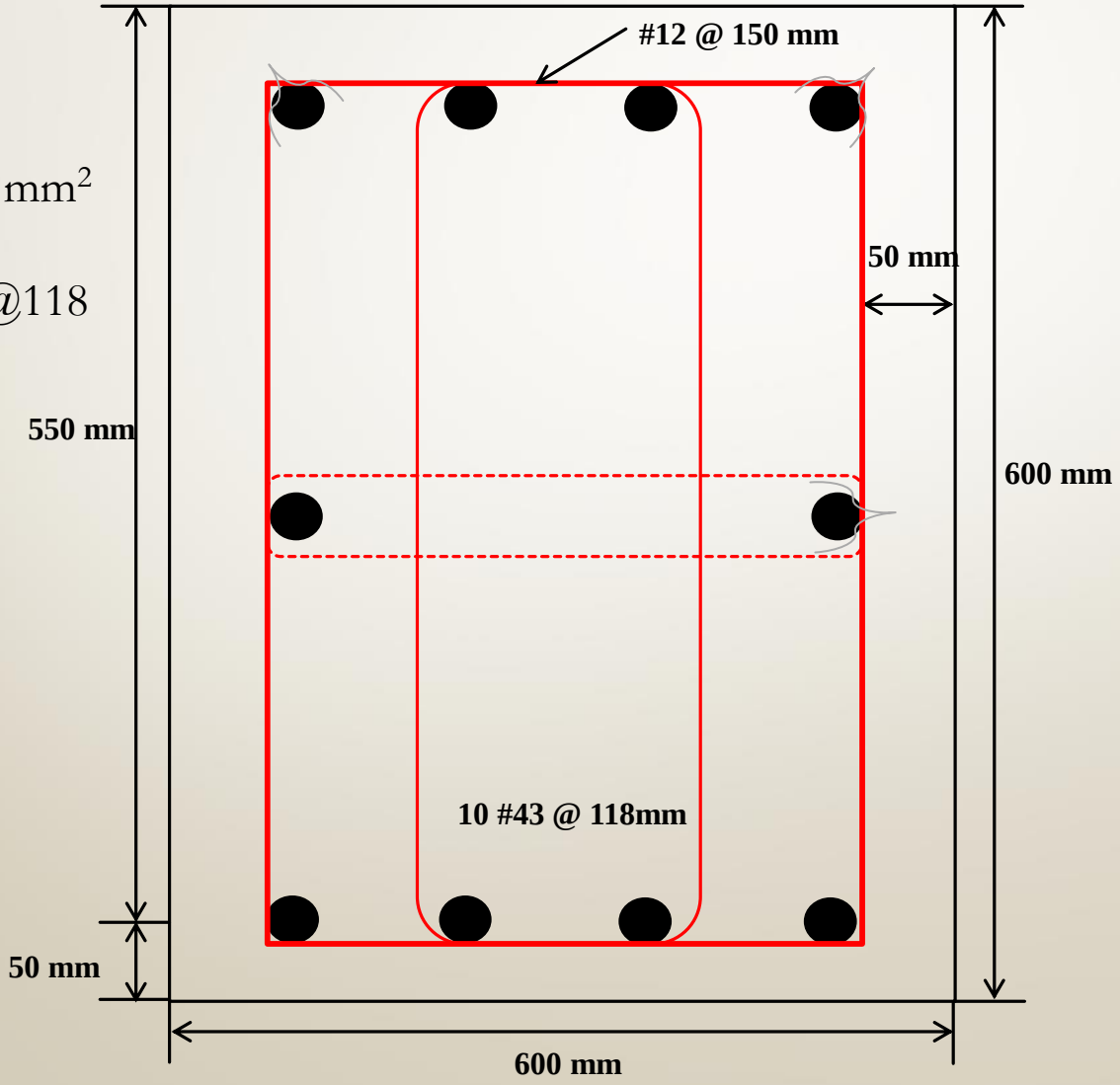
# Ground & First Edge Columns

- As = 13865 $mm^2$
- Use 10#43 @118 mm c/c



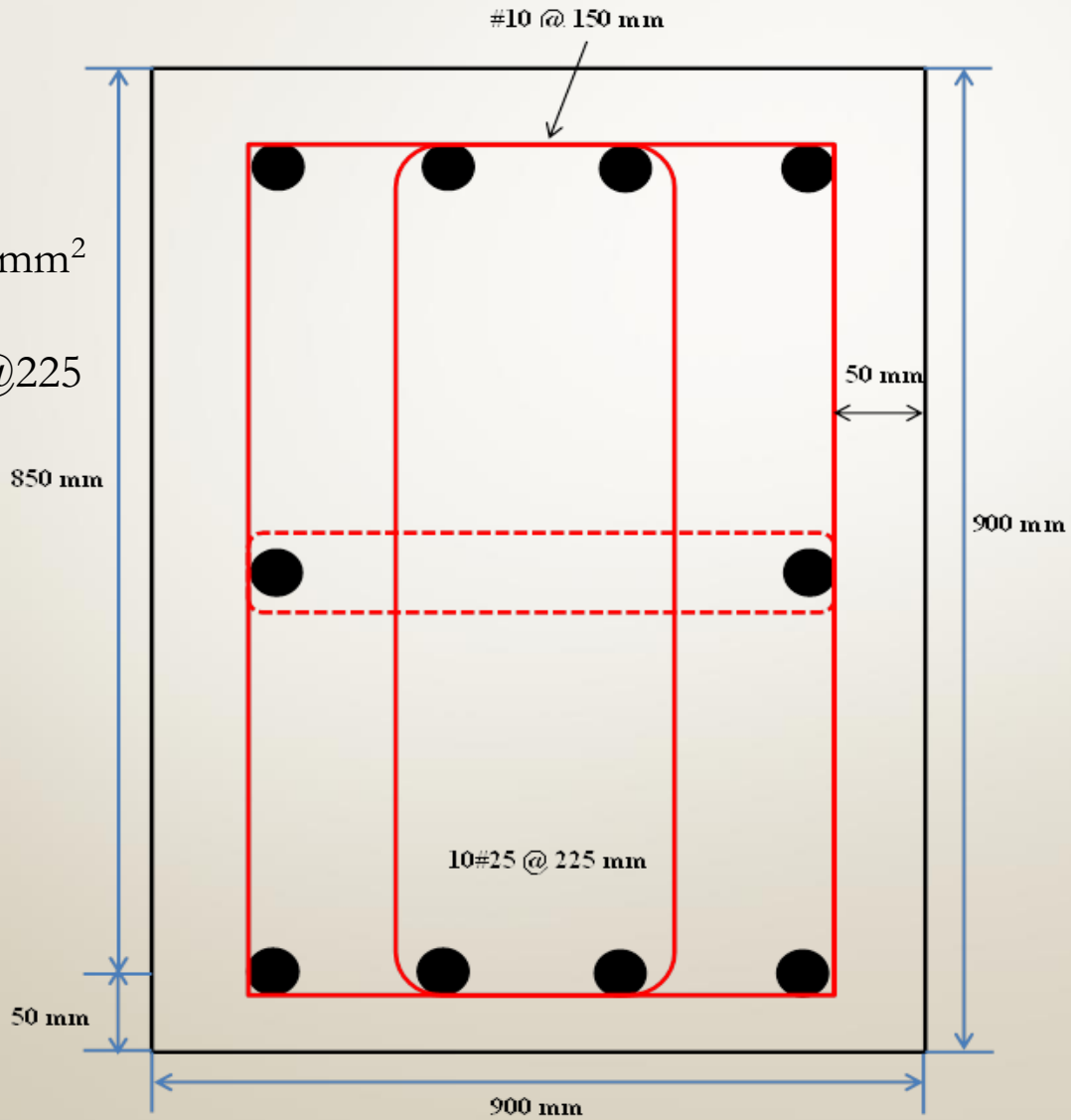
# Second & Third Edge Columns

- As = 13349 $mm^2$
- Use 10#43 @118 mm c/c



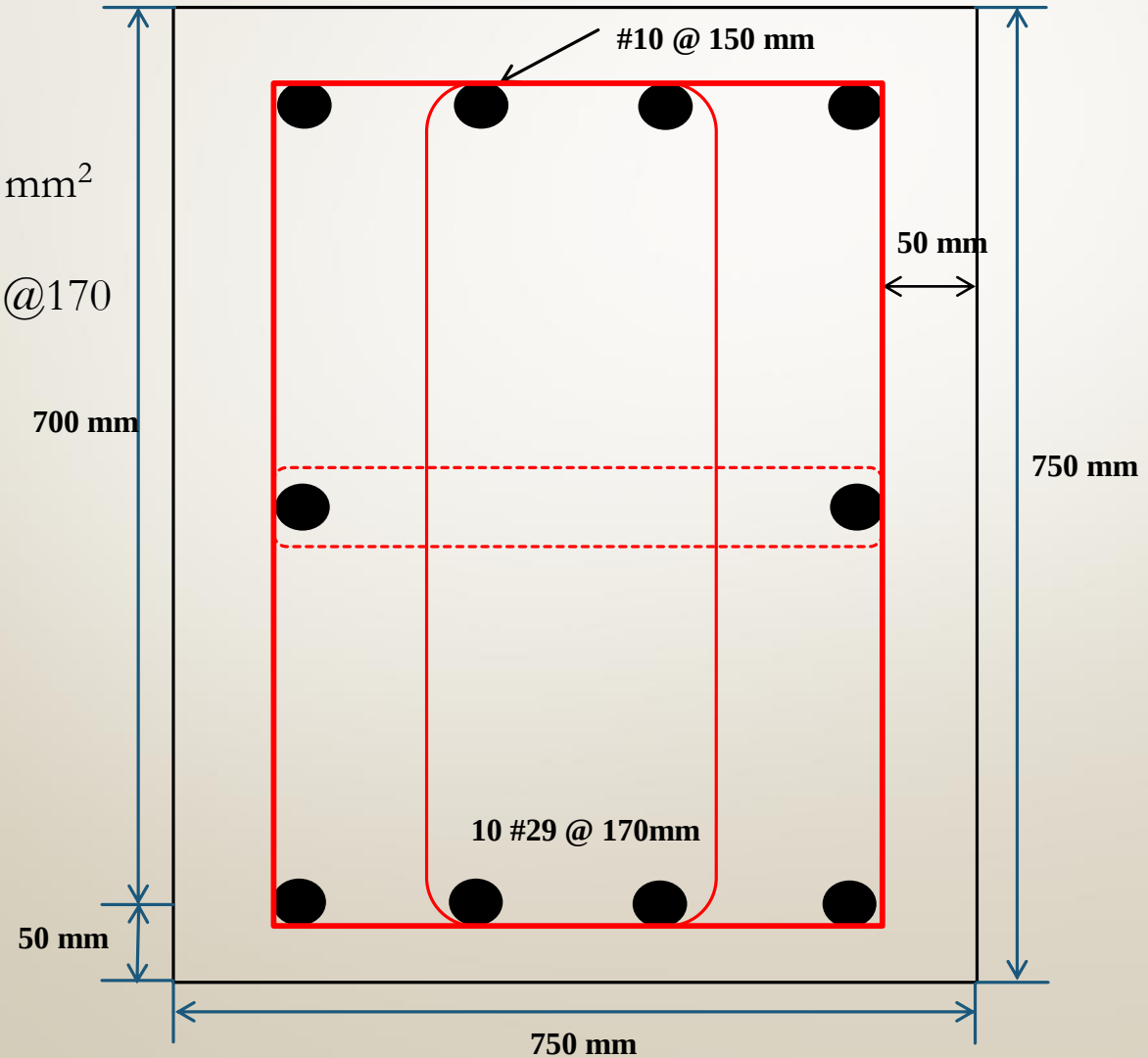
# Ground & First Center Columns

- As = 21495 $mm^2$
- Use 10#25 @225 mm c/c



# Second & Third Center Columns

- As = 5625 $mm^2$
- Use 10#29 @170 mm c/c

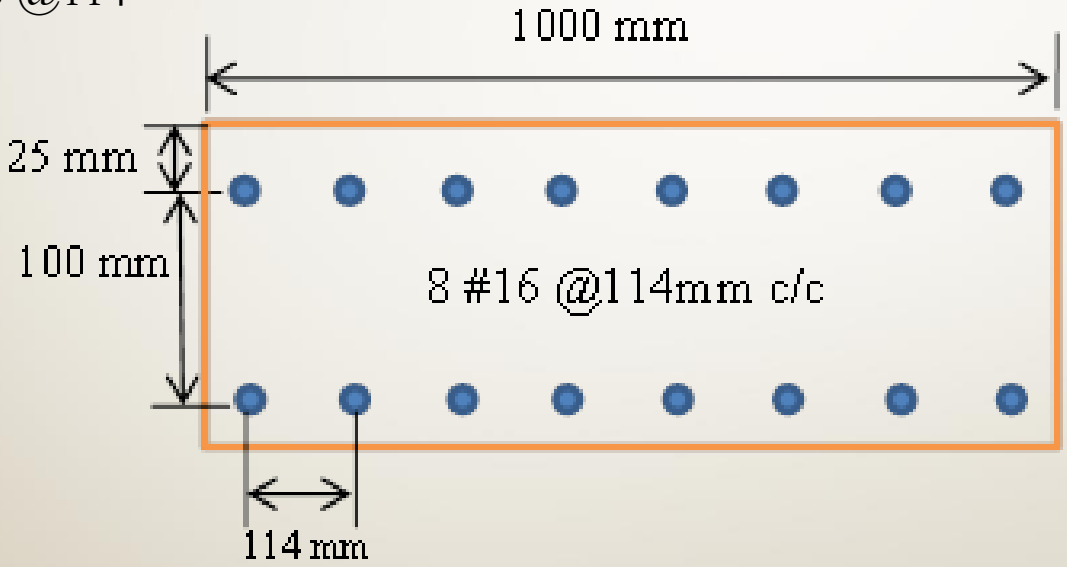


# Shear Wall


| Shape | Length |
|---|---|
| 1 | 2.5m |
| 2 | 2m |
| 3 | 6m |
| 4 | 4.7m |
| Total | 24.7m |

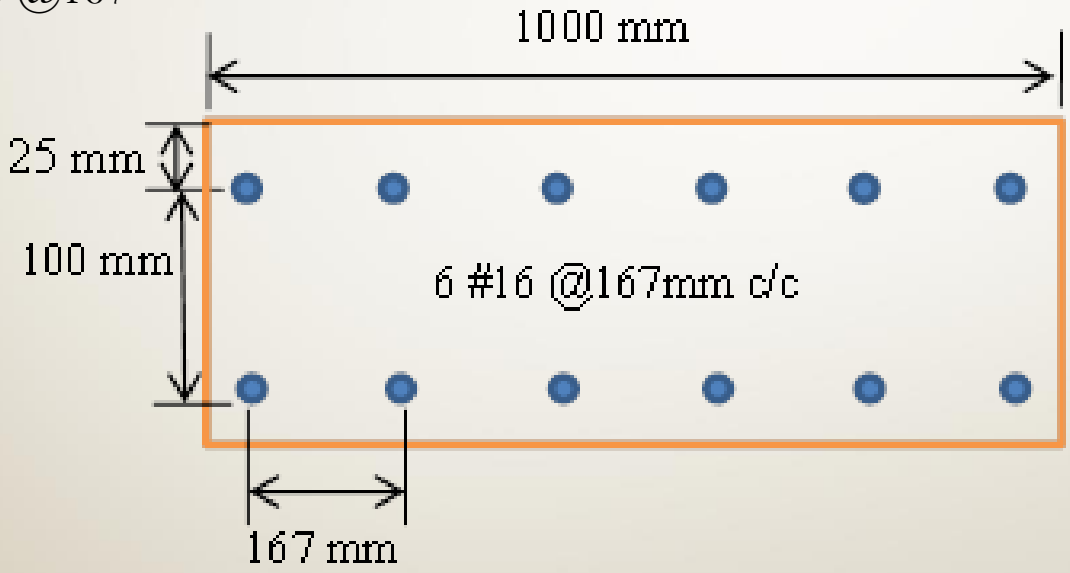
# Section 1:

- As = 1500 $mm^2$
- Use 8#16 @114 mm c/c



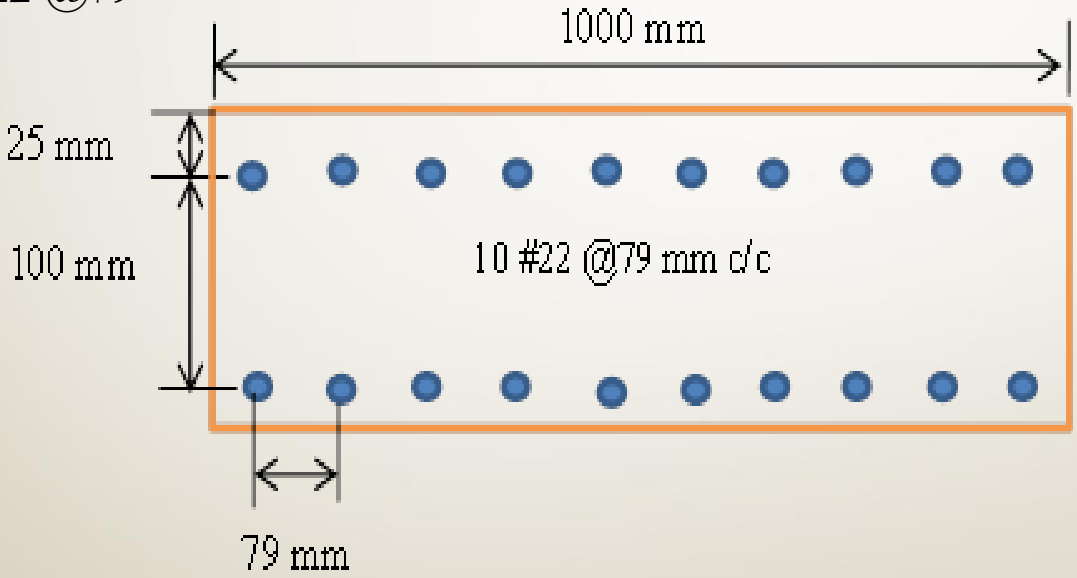
# Section 2:

- As = 1125 $mm^2$
- Use 6#16 @167 mm c/c



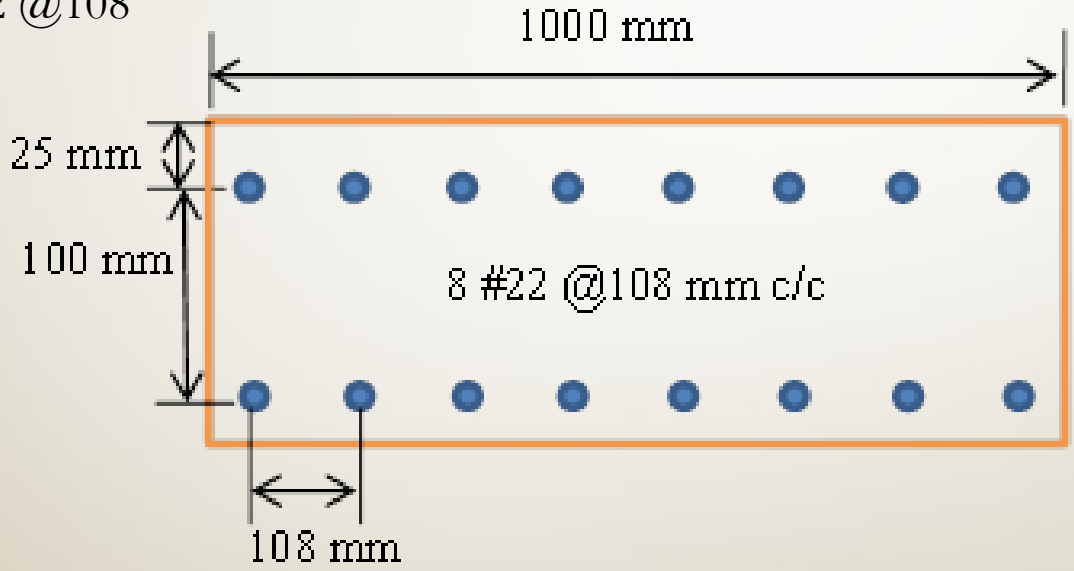
# Section 3:

- As = 3750 $mm^2$
- Use 10#22 @79 mm c/c



# Section 4:

- As = 2940 $mm^2$
- Use 8#22 @108 mm c/c

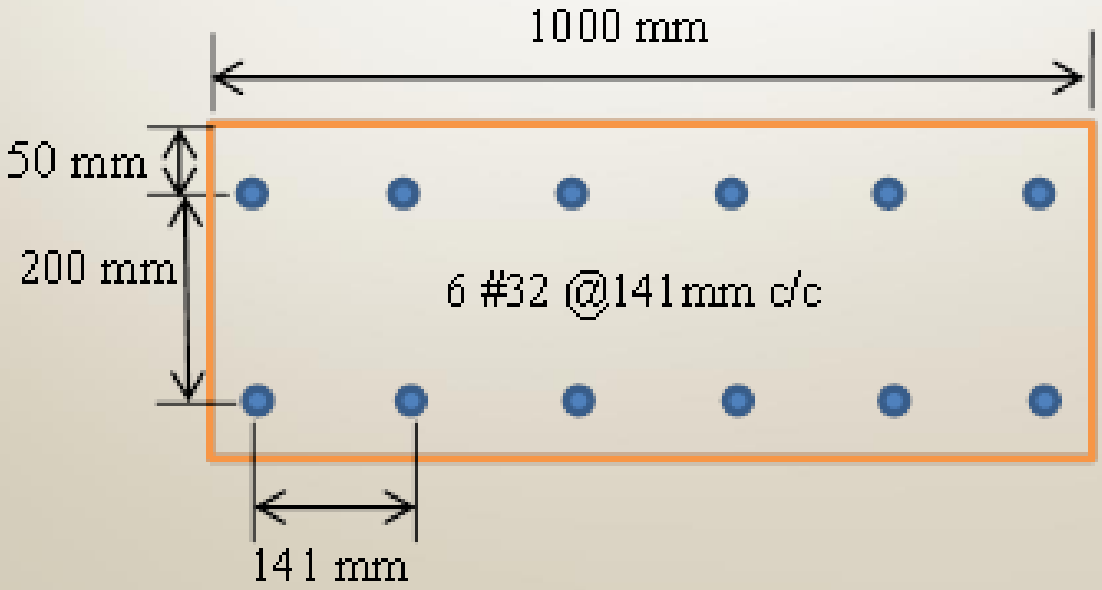


# Shear Wall Summary

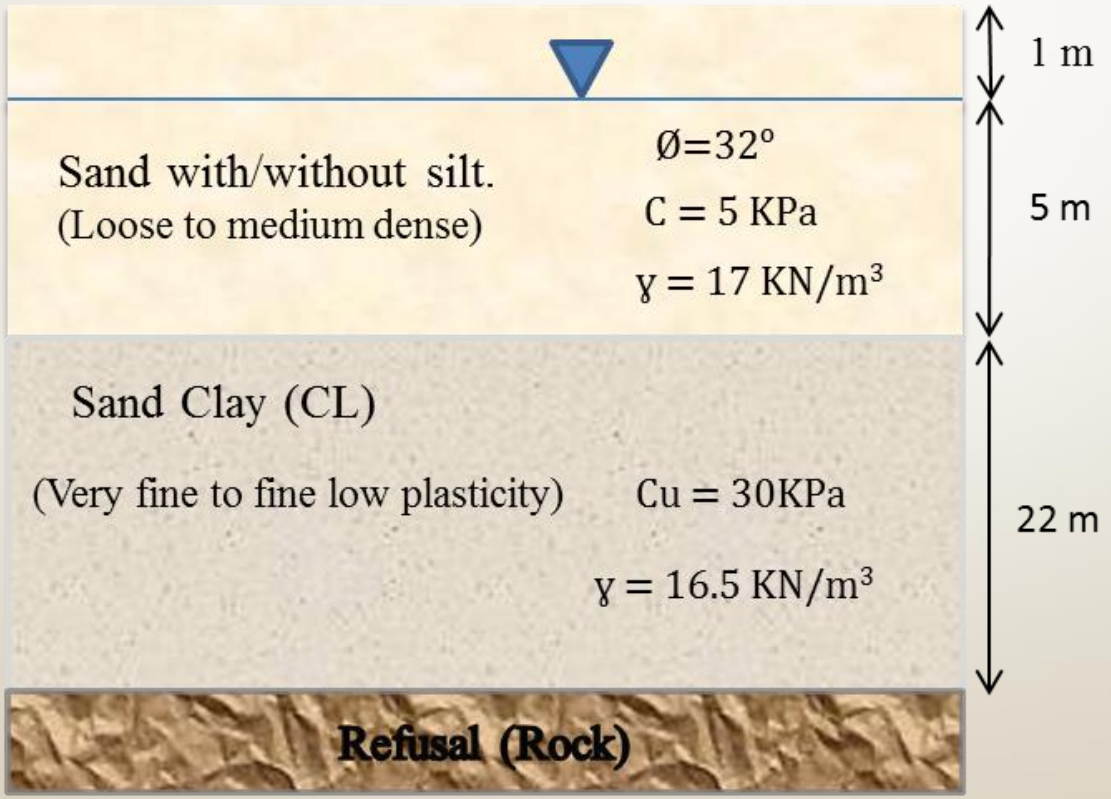
| Shear Wall | | | | |
|---|---|---|---|---|
| Total length | 24.7 m | | | |
| Thickness | 150 mm | | | |
| Shear Wall Section | 1 | 2 | 3 | 4 |
| $A_{st}$ (req.) | 1500 $mm^2$ | 1125 $mm^2$ | 3750 $mm^2$ | 2940 $mm^2$ |
| Reinforcement (Each Side) | 8#16 | 6#16 | 10#22 | 8#22 |
| $A_{st}$ (act.) | 1592 $mm^2$ | 1194 $mm^2$ | 3870 $mm^2$ | 3096 $mm^2$ |

# Ramp Reinforcement

- Ramp Thickness = 300mm
- Area of steel = 4773 $mm^2$
- Use 6#32 @141 mm c/c

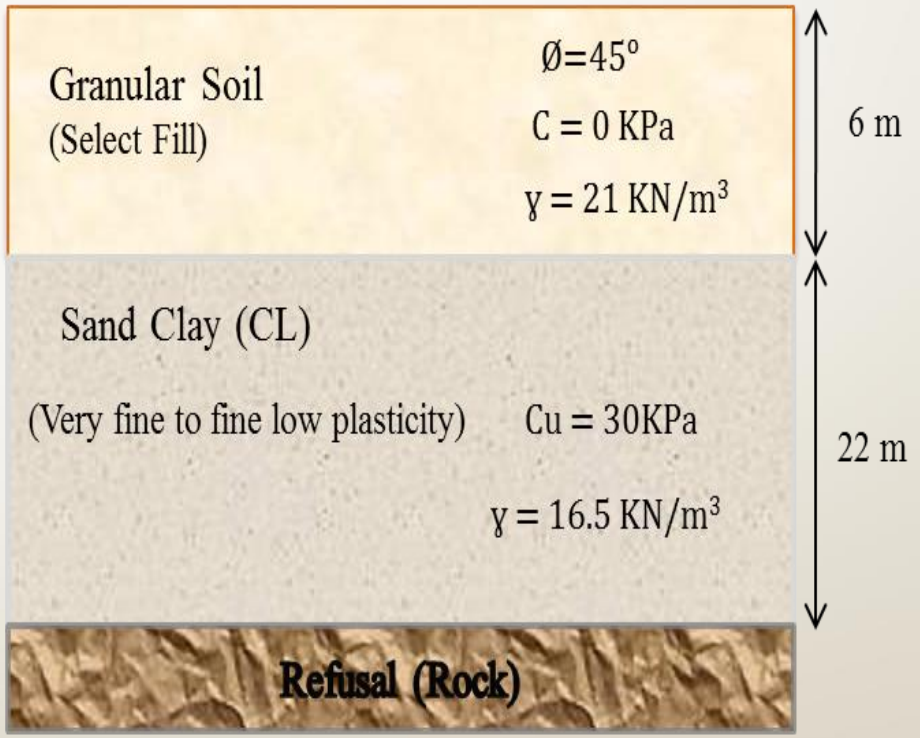


# Soil Profile

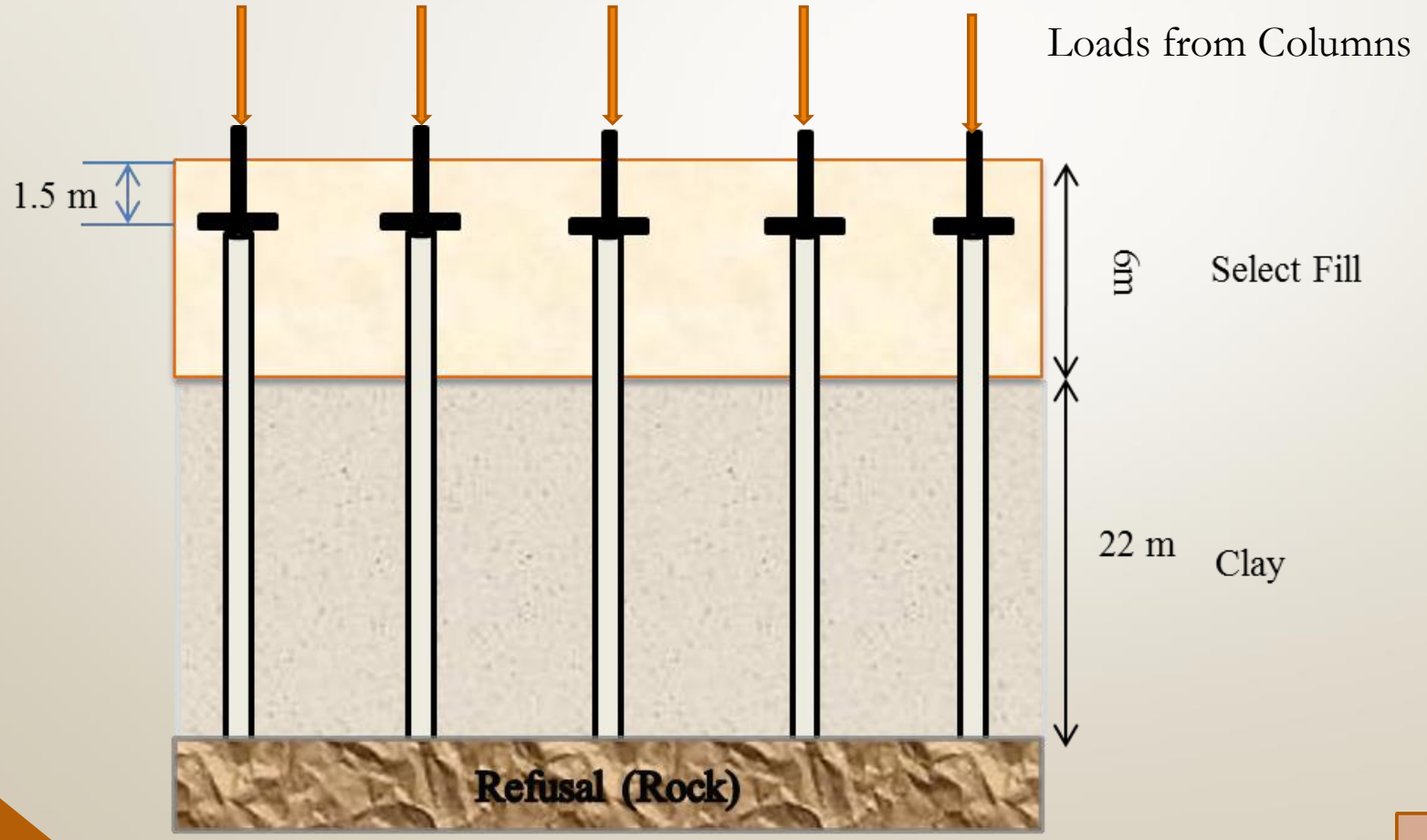


# Modified Soil Profile

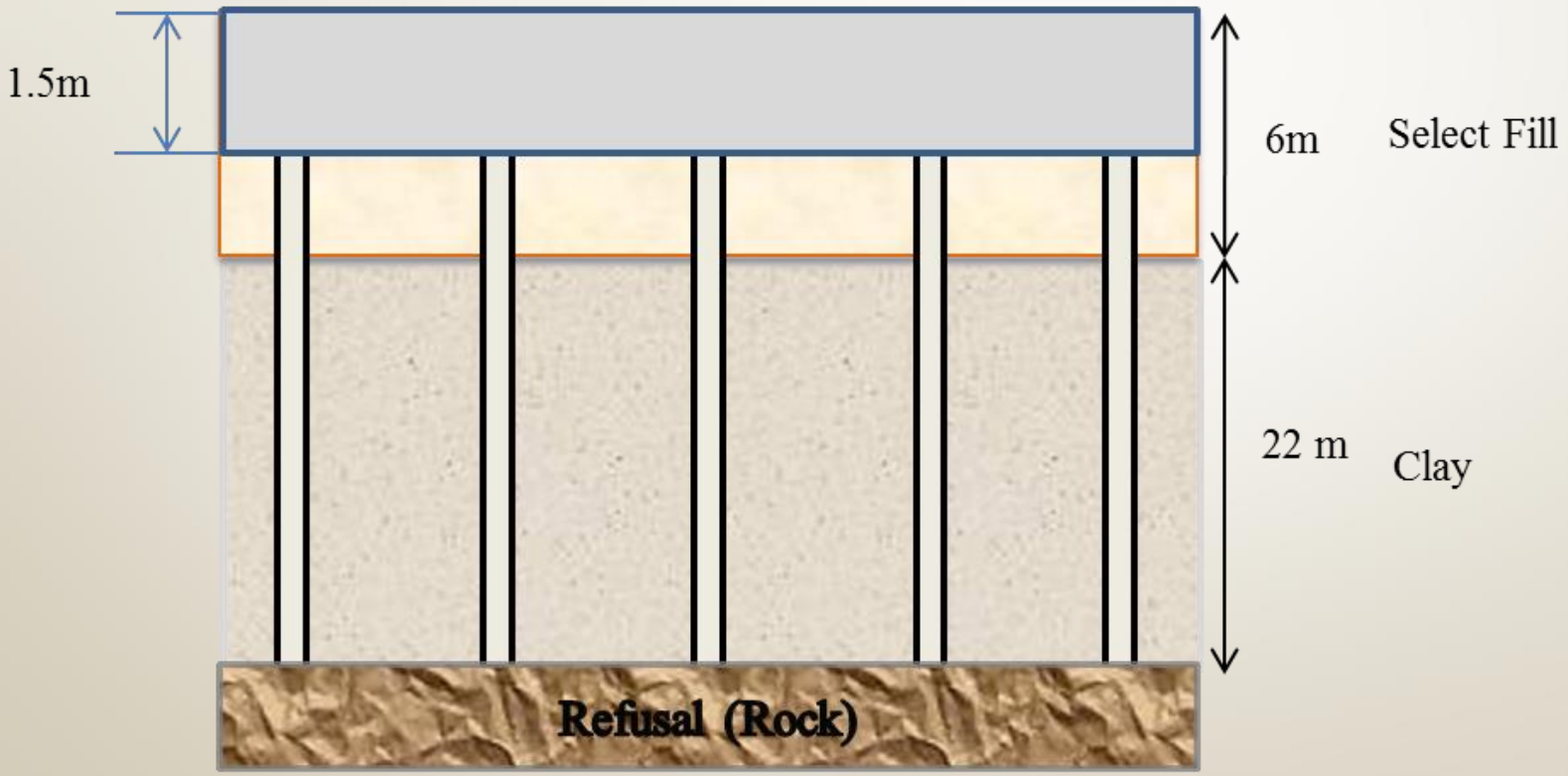
- Dewatering System
- Decrease Water Table
- Removal of Top Layer
- Replace with Granular Soil



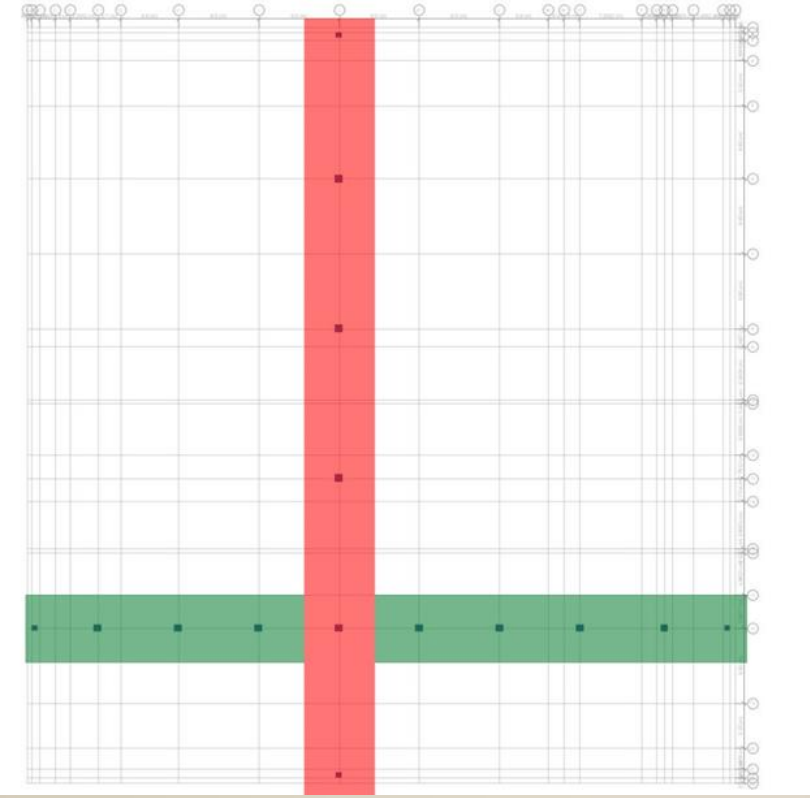
# Pile Foundation



# Mat Foundation



# Critical Strips



$$M_{min} = -20947\ KN * m \quad (y - strip)$$

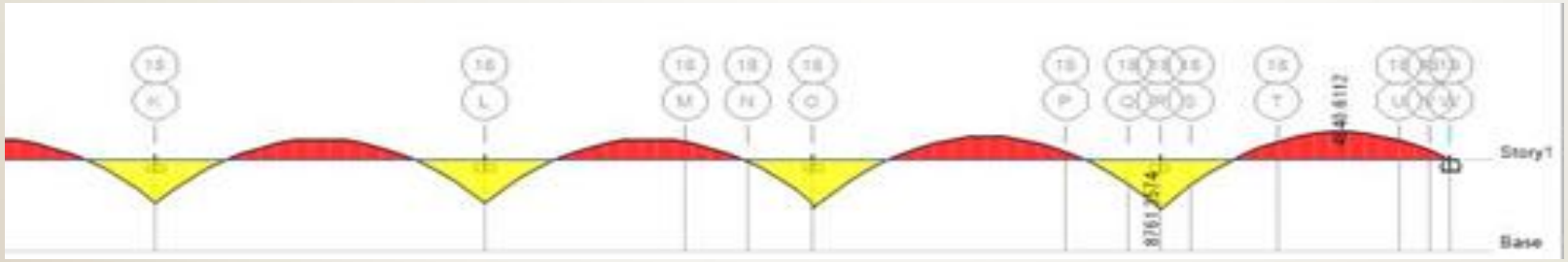
$$M_{max} = 8761\ KN * m \quad (x - strip)$$

$$M_{min} = -4940\ KN * m \quad (x - strip)$$

$$M_{max} = 37029\ KN * m \quad (y - strip)$$

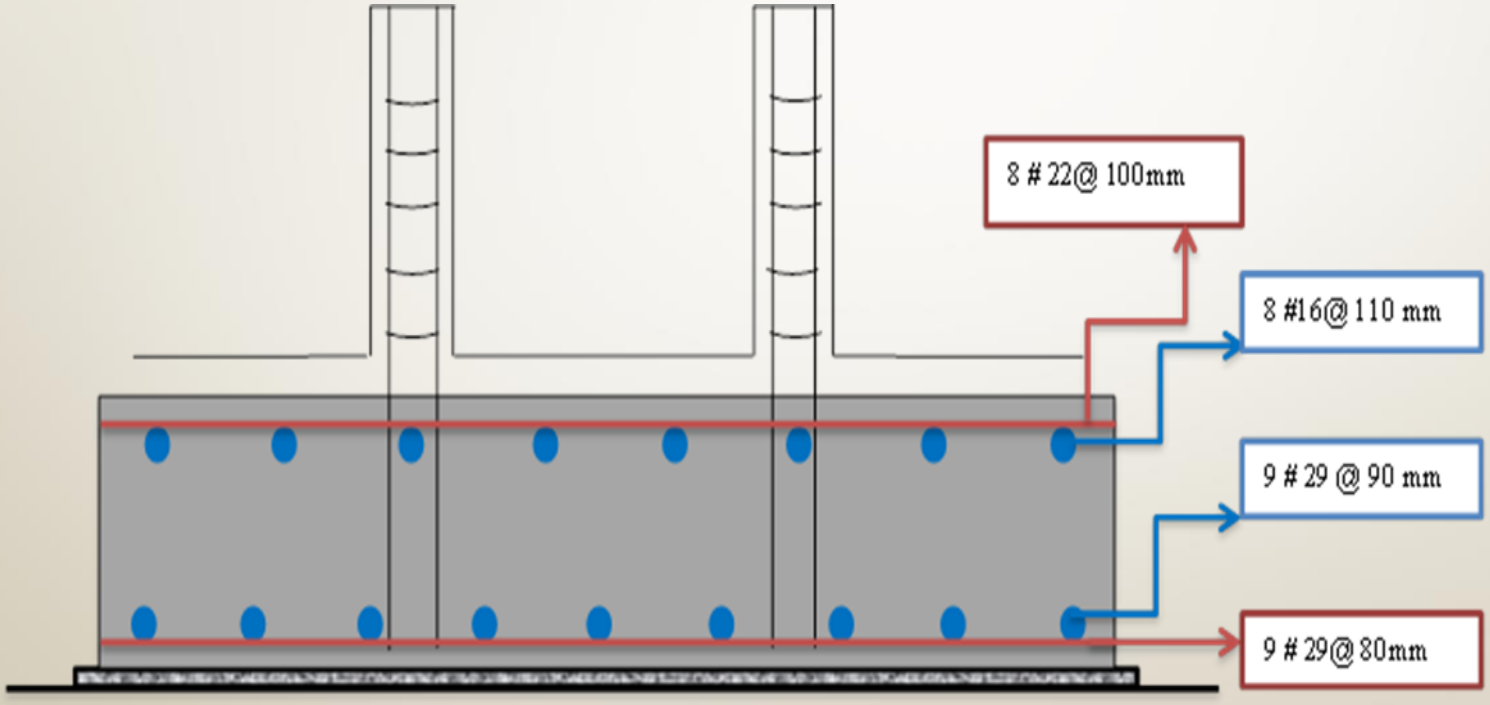
# Moment on the Strips

X-Strip:




Y-Strip:

# Mat Reinforcement



# Constraints

| Constraints | | Solution |
|---|---|---|
| Geotechnical | Water table at 1 m | Dewatering |
| | | Permanent drainage system |
| | Sabkha Soil | Excavation and Replacement |
| Material | Sulfates | Type 5 sulfate resistance Portland cement |
| | Chlorides | Coating the foundation |
| Environmental | Contaminated Water | Transporting the contaminated water to the right disposal place |
| | Contaminated Soil | Dispose the contaminated soil into hazardous landfill |
| Structural | Size of Structure | Min. 1000 car bays |
| | | Maximum 6 stories |
| Safety | Road Crossing | Pedestrian walkway |

# Cost Estimation

Unit Price Method:

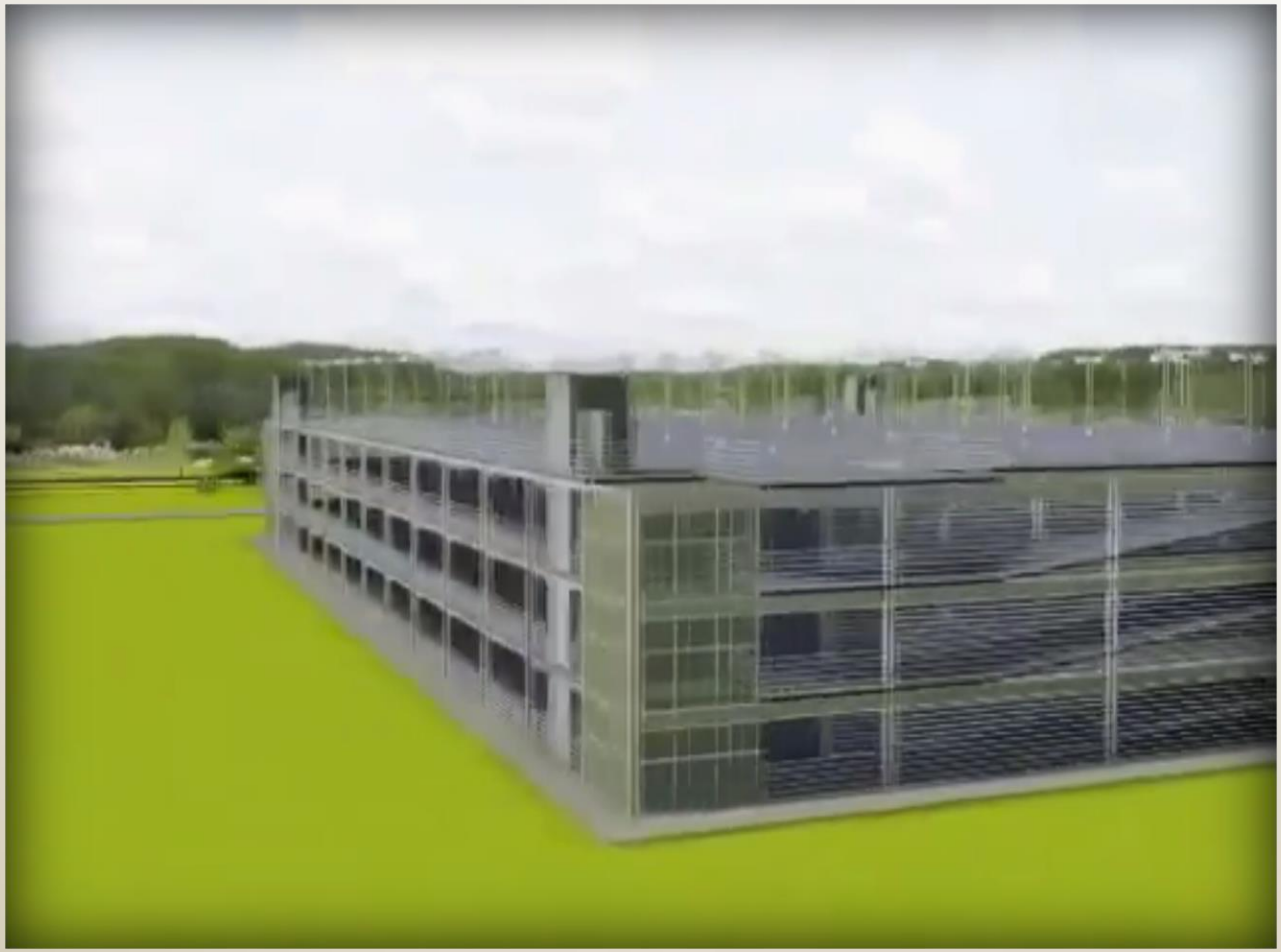
| Materials | Volume | Unit Price | Total Price (SAR) |
|---|---|---|---|
| **Concrete** | 29048 ($m^3$) | 199.5 (SAR/$m^3$) | 5,795,076 |
| **Reinforcement** | 4677.05 tons | 2300(SAR/ton) | 10,757,215 |
| **Finishing** | 38250 ($m^2$) | 64.91 (SAR/$m^2$) | 2,482,843.65 |
| **Total** | | | 19,035,134.35 |

# Cost Estimation

| Floors | Area ($m^2$) | Unit Price(SAR/$m^2$) | Total(SAR) |
|---|---|---|---|
| G - Floor | 7650 | 497.65 | 3,807,026.87 |
| 1st Floor | 7650 | 497.65 | 3,807,026.87 |
| 2nd Floor | 7650 | 497.65 | 3,807,026.87 |
| 3rd Floor | 7650 | 497.65 | 3,807,026.87 |
| 4th Floor | 7650 | 497.65 | 3,807,026.87 |
| | | Total | 19,035,134.35 |

# Conclusion

- 5 Floors
- 214 / floor
- One way traffic
- 60 degree parking
- Cost 19 million SR
- Recommendation:
  - Pathway to the campus
  - Entrance to 3rd floor



# References



arch
daily


وزارة الشـــؤون
البلدية و القروية


aci


كود البناء السعودي
Saudi Building Code

# Questions

# &

# Answers