طرح نگهداشت و افزایش تولید 27 مخزن

CALCULATION NOTE FOR CCTV CONTROL ROOM-BINAK GCS

نگهداشت و افزایش تولید میدان نفتی بینک

D03	OCT. 2024	AFD	R.Berlouie	M.Fakharian	M.Sadeghian	
D02	FEB. 2024	AFD	R.Berlouie	M.Fakharian	S.Faramarzpour	
D01	JAN. 2024	IFA	R.Berlouie	M.Fakharian	S.Faramarzpour	
D00	SEP. 2023	IFC	R.Berlouie	M.Fakharian	A.M.Mohseni	
Rev.	**Date**	**Purpose of Issue/Status**	**Prepared by:**	**Checked by:**	**Approved by:**	**CLIENT Approval**

Class:2 **CLIENT Doc. Number: F0Z-709399**

Status:

IDC: Inter-Discipline Check
IFC: Issued For Comment
IFA: Issued For Approval
AFD: Approved For Design
AFC: Approved For Construction
AFP: Approved For Purchase
AFQ: Approved For Quotation
IFI: Issued For Information
AB-R: As-Built for CLIENT Review
AB-A: As-Built –Approved

REVISION RECORD SHEET

PAGE	D00	D01	D02	D03	D04
1	X	X	X	X	
2	X	X	X	X	
3	X				
4	X				
5	X				
6	X				
7	X				
8	X				
9	X				
10	X				
11	X				
12	X				
13	X				
14	X				
15	X	X			
16	X				
17	X				
18	X				
19	X				
20	X				
21	X				
22	X				
23	X				
24	X				
25	X				
26	X				
27	X				
28	X				
29	X				
30	X				
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
41					
42					
43					
44					
45					
46					
47					
48					
49					
50					
51					
52					
53					
54					
55					
56					
57					
58					
59					
60					
61					
62					
63					
64					
65					

PAGE	D00	D01	D02	D03	D04
66					
67					
68					
69					
70					
71					
72					
73					
74					
75					
76					
77					
78					
79					
80					
81					
82					
83					
84					
85					
86					
87					
88					
89					
90					
91					
92					
93					
94					
95					
96					
97					
98					
99					
100					
101					
102					
103					
104					
105					
106					
107					
108					
109					
110					
111					
112					
113					
114					
115					
116					
117					
118					
119					
120					
121					
122					
123					
124					
125					
126					
127					
128					
129					
130					

CONTENTS

1.0 INTRODUCTION 4
2.0 SCOPE 4
3.0 NORMATIVE REFERENCE 4
4.0 MATERIAL PROPERTIES 5
5.0 COMPUTER SOFTWARE 5
6.0 DESIGN INFORMATION 6
7.0 MATERIAL PROPERTIES 8
8.0 DESIGN LOADS 9
9.0 DEAD LOAD 9
10.0 LIVE LOAD 12
11.0 SNOW LOAD 13
12.0 SEISMIC LOAD 13
13.0 REDUNDANCY FACTOR ρ 16
14.0 LOADING TABLE 16
15.0 LOAD COMBINATIONS 17
16.0 STRUCTURE ANALYSIS AND DESIGN 20
17.0 STRUCTURAL DESIGN RESULTS 21
18.0 DRIFT CONTROL 22
19.0 JOIST SHEAR CAPACITY RATIO CONTROL 22
20.0 STRONG COLUMN-WEAK BEAM REQUIREMENTS IN SPECIAL CONCRETE MOMENT FRAME 23
21.0 FOUNDATION DESIGN AND RESULTS 24

1.0 INTRODUCTION

Binak oilfield in Bushehr province is a part of the southern oilfields of Iran, is located 20 km northwest of Genaveh city.

With the aim of increasing production of oil from Binak oilfield, an EPC/EPD Project has been defined by NIOC/NISOC and awarded to Petro Iran Development Company (PEDCO). Also PEDCO (as General Contractor) has assigned the EPC-packages of the Project to "Hirgan Energy - Design and Inspection" JV.

As a part of the Project, construction of well location, access road, wellhead facilities (with electric power supply) for W007S shall be done. In addition, construction of new flowline from aforementioned well location to Binak B/C unit (with extension of relevant manifold) are in the Project scope of work

2.0 SCOPE

This report covers designing of structure & foundation calculations of the “CCTV Control Room-Binak GCS”. The structure calculation is performed by “ETABS” & calculation of foundation is performed by “SAFE” software’s.

3.0 NORMATIVE REFERENCE

3.1 Local Codes and Standards

- INBC Part 6 “Iranian National Building Code
- INBC Part 7 “Iranian National Building Code
- INBC Part 9 “Iranian National Building Code
- INBC Part 10 “Iranian National Building Code
- Iranian Seismic Design Code for Petroleum Facilities(3rd edition)

3.2 International Codes and Standards

- ASCE 7-10 “Minimum Design Loads and Associated Criteria for Buildings and Other Structures-American Society of Civil Engineers”.
- ACI 318. “Building Code Requirements for Reinforced Concrete”, American Concrete Institute.
- AISC 358 “Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications.” American Institute of Steel Construction, Inc.
- AISC 360 - “Specification for Structural Steel Buildings”. American Institute of Steel Construction, Inc.

3.3 The Project Documents

- BK-GNRAL-PEDCO-000-ST-SP-0001 SPECIFICATION FOR CONCRETE WORK
- BK-GNRAL-PEDCO-000-ST-DC-0001 Structural Design Criteria
- BK-GNRAL-PEDCO-000-CV-SP-0004 Specification For Earth Work
- BK-GCS-PEDCO-120-GT-RT-0001 Geotechnical Investigation Report for Compressor Station
- BK-GCS-PEDCO-120-AR-DW-0008 Architectural Drawing For CCTV Control Room- Binak GCS

4.0 MATERIAL PROPERTIES

Material properties are delivered in the following table.

Material properties	
Structure and Foundation concrete	F'c=300kg/cm²(28 days cylindrical sample)
Long. Reinforcement	Fy=4000 kg/cm² (AIII)
Trans. Reinforcement	Fy=4000 kg/cm² (AIII)

5.0 COMPUTER SOFTWARE

Computer's Software, which is used in structure and foundation analysis and design, are defined in the following table.

Computer software	
analysis and design of structure	ETABS 16.2.1
analysis and design of foundation	SAFE 16.0.2

6.0 DESIGN INFORMATION

○ STRUCTURE LOCATION

The CCTV control room is located in Binak oilfield.

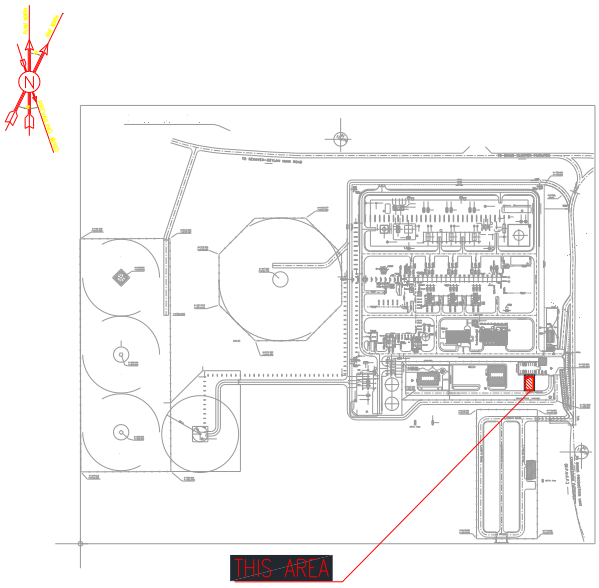


Figure 1: Project Location

○ ARCHITECTURAL PLANS

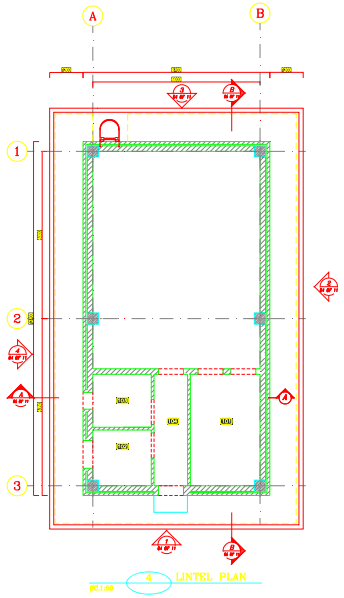


Figure 2: Plan of CCTV control room

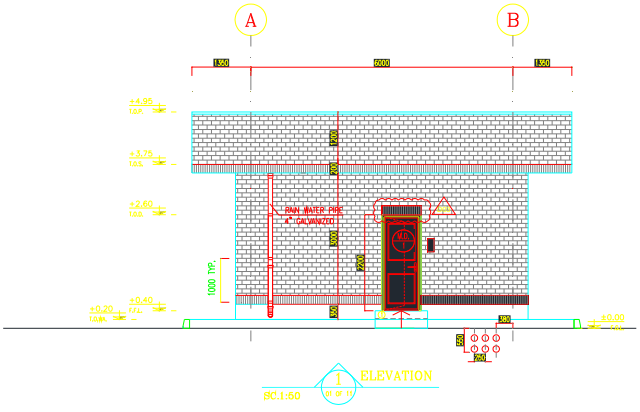


Figure 3: Elevation 1

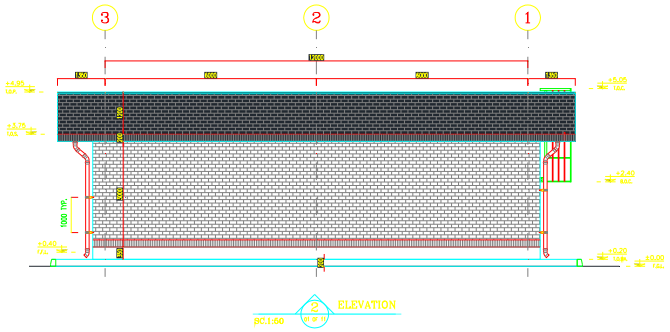


Figure 4: Elevation 2

7.0 MATERIAL PROPERTIES

○ REINFORCED CONCRETE

Concrete shall generally conform to the specification for Concrete Work, Document No:

BK-GNRAL-PEDCO-000-ST-SP-0001. The following properties of concrete are used.

Lean concrete: f'_c =150 kg/cm^2

Cast in place concrete: f'_c =300 kg/cm^2

Where f'_c is the minimum compressive characteristic strength of a cylinder specimen at 28 days.

Young Modulus of concrete: $E_c = 15100\sqrt{f'_c}$ kg/cm^2 =261540 kg/cm^2

Poisson's Ratio: v = 0.2

Unit weight of reinforced concrete: 2500 kg/m^3

Reinforcing Steel: f_y = 4000 kg/cm^3 (Minimum yield stress)

- **STIFFNESS MODIFICATION**

For analysis of concrete structure, the following modifications for flexural stiffness of elements are considered.

Columns……..0.7Ig

Beams…….0.35Ig

8.0 DESIGN LOADS

- **GENERAL**

Structural elements stability and stress checking have been performed considering the following load conditions.

- Dead Load
- Live Load
- Seismic Load
- Snow Load

9.0 DEAD LOAD

- **FOR CCTV CONTROL ROOM**

Dead Load is considered as the weight of materials forming a permanent part of the structure plant. The weight of materials of construction incorporated into the building, including but not limited to walls, floors, roofs, ceilings, stairways, built-in partitions, finishes, cladding and other similarly incorporated architectural and structural items, and the weight of fixed service equipment, such as plumbing stacks and risers, electrical feeders, heating, ventilating and air-conditioning systems.

Specific weight of materials which will be used is based on Iranian National Building Code, Part 6, where applicable. Other weights are in accordance with the specifications and/or drawings of vendors and manufacturers.

As it mentioned above the self-weight of structural elements (introduced Dead Load in software) is automatically considered by ETABS program with the specific weights below:

Reinforced Concrete: 2500 kg/m³

Structural Steel and Bars: 7850 kg/m³

Here is the calculation of design dead load for floors and walls.

- dead load for parapet wall(for 120cm height) :

(Pressed brick = 20cm × 1700 = 340→340 × 1.2 = 408 kg/m) + (Travertine stone= 2500 × 2cm = 50→50 × 1.2 = 60 kg/m) + (mortar = 1cm × 2100 = 21 → 21× 1.2 = 25.2 kg/m) + (Terrazzo tile (30*30*2.5)= 2500 × 2cm = 50→50 × 0.3 = 15 kg/m) + (mortar = 1cm × 2100 = 21 → 21× 0.3 = 6.3 kg/m) + (cement = 3cm × 2100 = 63→63 × 1 = 63 kg/m) + (Waterproofing (Isolation or Similar = 15 kg/m² × 30cm =4.5 kg/m) → totally ≈ 585 kg/m

- dead load for wall (for supper dead load(wall)) :

$(\text{Face Brick} = 5\text{cm} \times 1700 = 85) + (\text{Pressed brick} = 20\text{cm} \times 1700 = 340) + (\text{plaster and soil mortar} = 3\text{cm} \times 1600 = 48) \rightarrow \text{totally} \approx 475\ \text{kg/m}^2$

- dead load for roof :

$(\text{mosaic} = 2.5\text{cm} \times 2250 = 56.5) + (\text{mortar} = 2.5\text{cm} \times 2100 = 52.5) + +(\text{pumice} = 9\text{cm} \times 600 = 54) + (\text{clay block} = 8 \times 10 = 80) + (\text{facilities} = 20) + (\text{waterproofing} = 15) \rightarrow \text{totally} \approx 300\ \text{kg/m}^2$

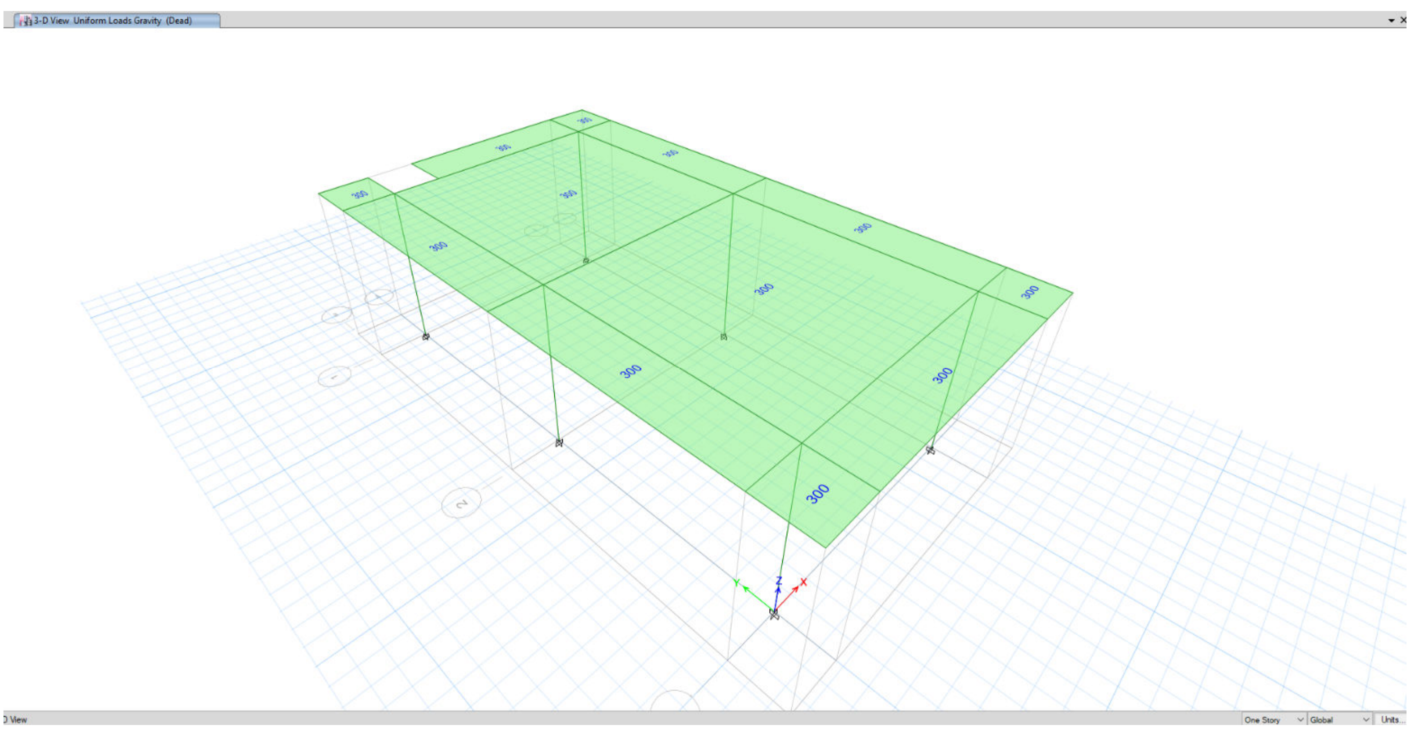


Figure 5: Dead load on roof

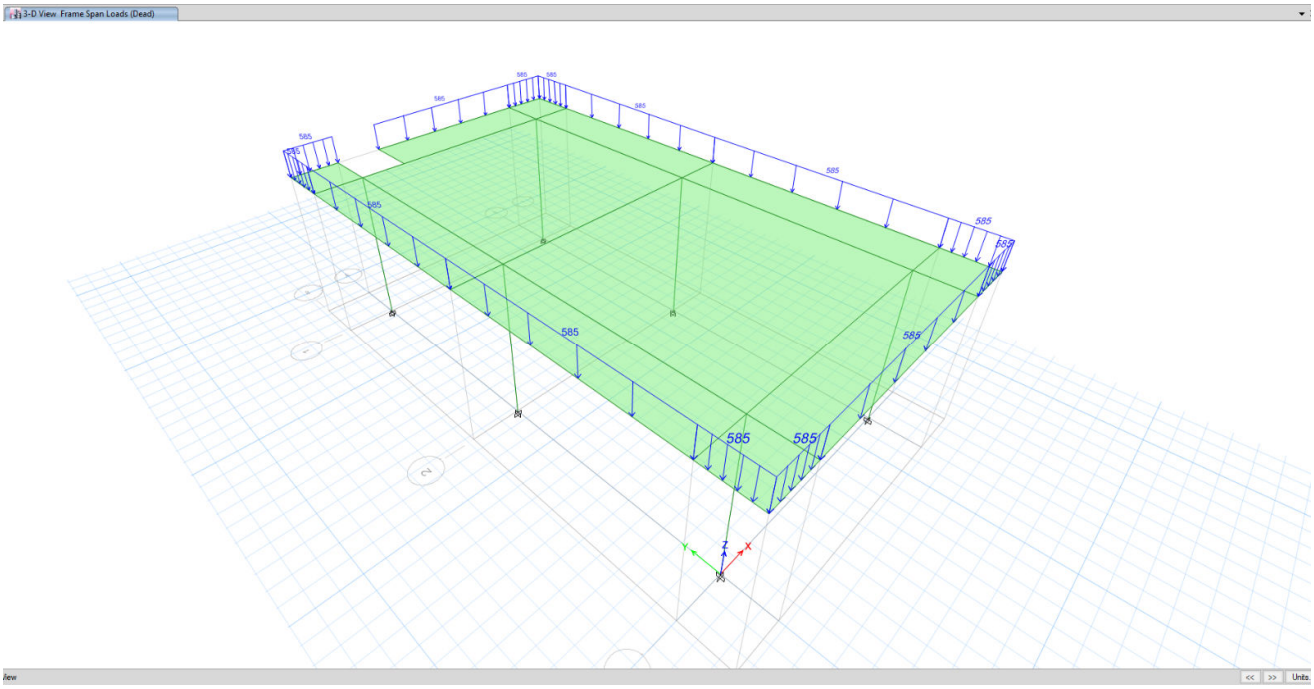


Figure 6: Parapet dead load

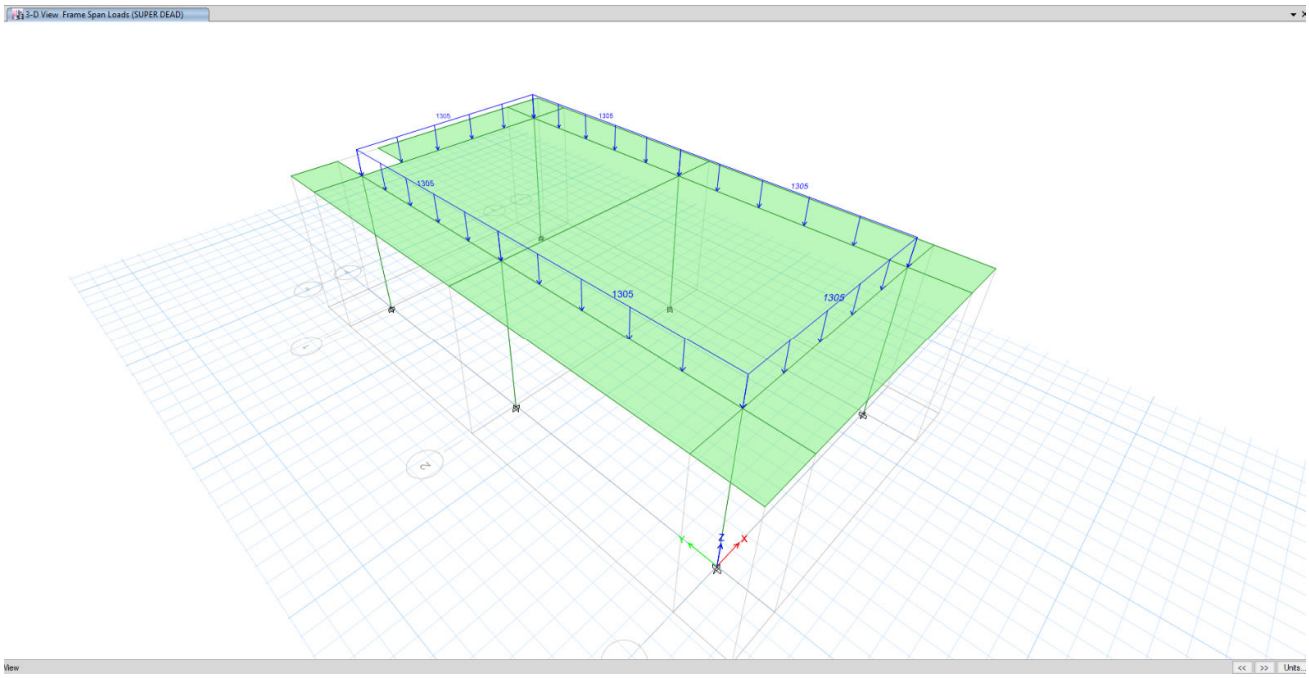


Figure 7: Dead load for wall

10.0 LIVE LOAD

Live Load is defined as the weight of all movable loads, including partition walls, personnel, tools, miscellaneous equipment and temporarily stored materials.

Generally where applicable, the live loads shall be in accordance with Iranian National Building Code, Part 6. The Live Loads is generally considered as uniformly distributed over the horizontal projection of the loaded areas, except for the loads with a concentrated nature.

The live load has been considered according to the following table.

- **Table 1- Live Load**

NO.	Level	kg/m^2
1	Roof	150

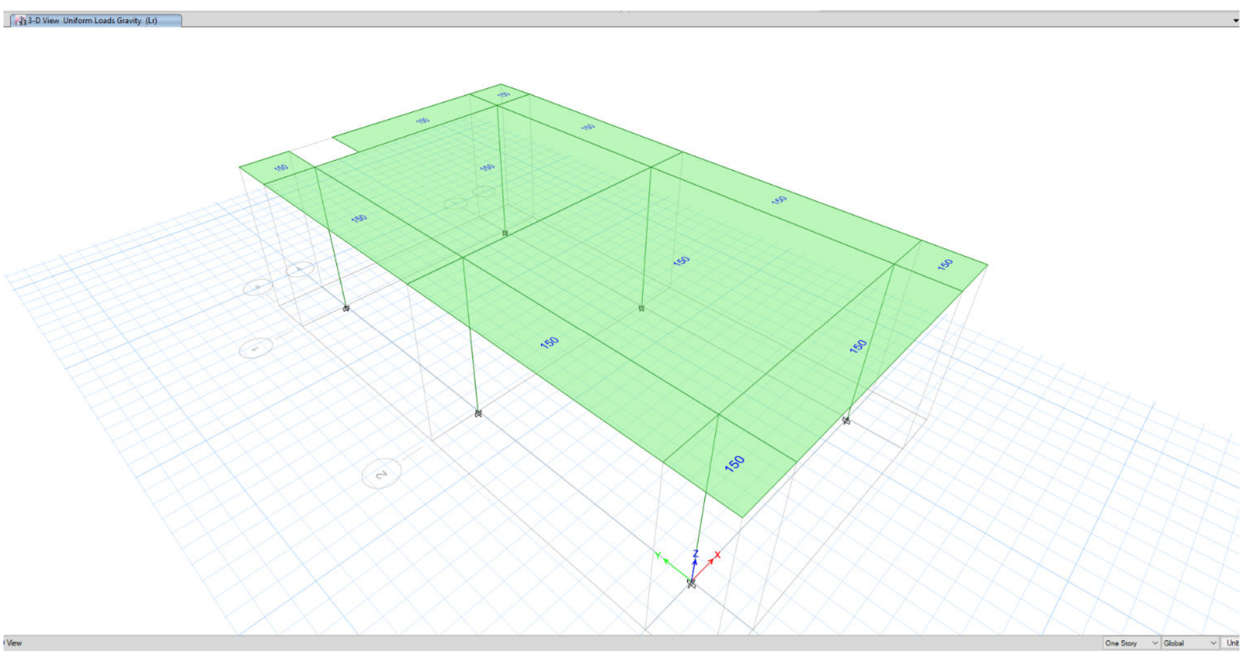


Figure 7: Live load on roof

11.0 SNOW LOAD

- **FOR CCTV CONTROL ROOM**

Snow load of this structure is calculated in accordance with Iranian National Building Code No.6 Latest edition. Parameters which are used in calculation of snow force is presented in below:

$P_r=I_s.C_n.C_h.C_s.P_s$ $\quad$ Ps=25 kg/m^2

Is=1, Cn= 1, Ch= 1, Cs= 1 → Pr=Ps = 25 kg/m^2

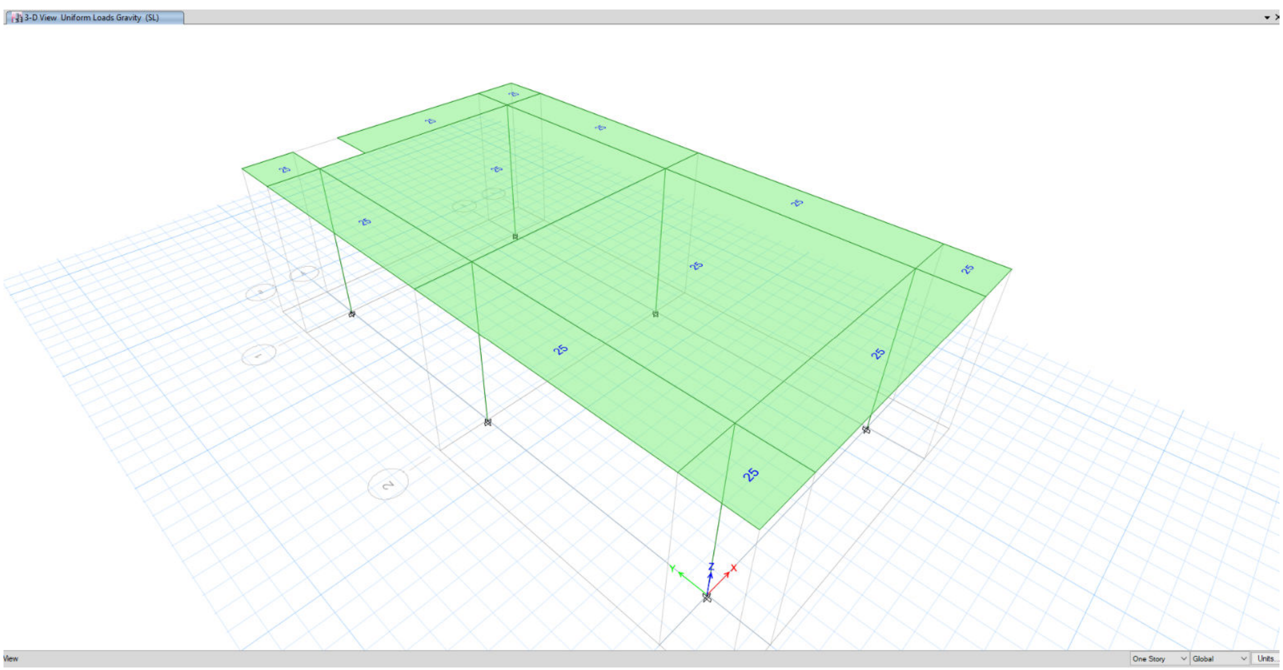


Figure 8: Snow load on roof

12.0 SEISMIC LOAD

- **HORIZONTAL SEISMIC LOAD**

According to Iranian Seismic Design Code for Petroleum Facilities (Pub.038-3rd edition) the structure shall be designed for earthquake load in two orthogonal directions.

Base level is defined as the level below which the structure does not move relative to the ground during an earthquake.

Basic parameters which are used in calculation of earthquake forces are presented below.

Following formula is used for calculations according to Iranian Seismic Design Code for Petroleum Facilities (Pub.038-3rd edition)

$$V_u = \frac{S_a}{R_u/I} W$$

In which:

V_u: Basic Shear

S_a: Mapped Spectral Response Acceleration Parameter (g)

I: Importance Factor of Structure

R_u: Structural System Factor

W= Effective Seismic Weight of the structure, including dead loads and other loads, calculated from base level.

- **Table 6- B Table 6- Basic Parameters Used for Earthquake Loads**

Height of the structure from the base level (m)	4.35
Importance factor, I	1.25
Structural System	Special Moment Frame at Both Direction
Soil type	II
Ru	8
C_t (Based on table (4-6) Pub.038)	0.047
X (Based on table (4-6) Pub.038)	0.9
$T_{x\&Y\ (calculation)} = C_t . H^x$	0.176
Based on part (4-8-3) Pub.038 : $T_{x\&Y\ (calculation)}$	= 0.176*1.4 = 0.247
T_y (analysis) – mode 1	0.59
T_x (analysis) – mode 2	0.58
$T_{x\ (select\ for\ design)}$	0.247
$T_{Y\ (select\ for\ design)}$	0.247
Sa_x	0.75

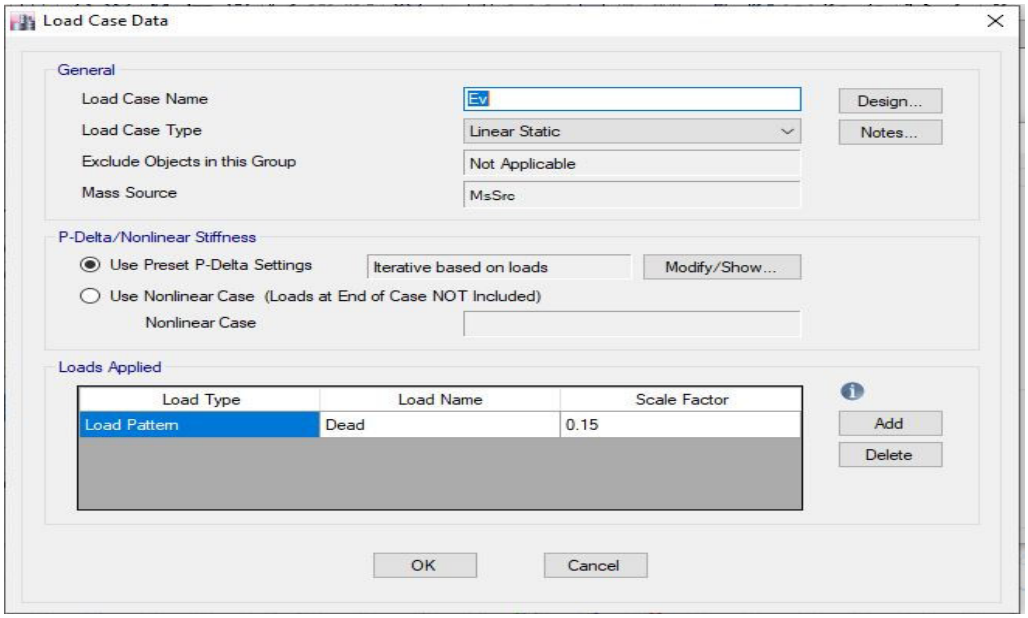
Sa_y	0.75
$C_{min} = 0.044 S_{DS} I$	0.04125
$C_x = \frac{S_{a_x}}{R_u/I}$	0.136
$C_y = \frac{S_{a_y}}{R_u/I}$	0.136

SD1	Sa	T0	TS
0.41	0.75	0.1	0.5

- **VERTICAL SEISMIC LOAD**

Ev : Vertical seismic load applied at model according to section 2-2-3-2 (code 038)

$E_v = \alpha S_{DS} D = 0.2 * 0.75D = 0.15D$



13.0 REDUNDANCY FACTOR ρ

According to Iranian Seismic Design Code for Petroleum Facilities (Pub.038-3rd edition Paragraph 4-6) - ρ =1.0

14.0 LOADING TABLE

Loading for structure and foundation for CCTV control room is defined as below table.

TABLE

Load Pat	Design Type	Self Wt Mult	Auto Load	Not Base Pat	Not Ratio	Not Dir.
DL	Dead	1				
Lr	Roof Live	0				
EX	Quake	0	USER COEFF			
EY	Quake	0	USER COEFF			
SL	Snow	0				
SUPERDEAD	Dead	0				
T	Temperature	0				
Ev	Quake	0	None			
NotionalX(DL)	Notional	0		DL	0.002	Global X
NotionalY(DL)	Notional	0		DL	0.002	Global Y
NotionalX(Lr)	Notional	0		Lr	0.002	Global X
NotionalY(Lr)	Notional	0		Lr	0.002	Global Y
NotionalX (SUPERDEAD)	Notional	0		SUPERDEAD	0.002	Global X
NotionalY (SUPERDEAD)	Notional	0		SUPERDEAD	0.002	Global Y
Soil	Other	0				

Notional loads must be added with the same coefficient in all combinations of loads that have gravity loads. Although this type is not necessary for concrete building, it has been considered.

15.0 LOAD COMBINATIONS

For foundations, structures and members of structures, according to structural design criteria & Iranian National Building Code Part 6, the following load combinations have been considered:

1) 1.4D

2) 1.2D + 1.6L + 0.5 (Lr or S)

3) 1.2D + 1.6 (Lr or S) + (L or 0.5(1.6W))

4) 1.2D +1.6 W + L + 0.5 (Lr or S)

5) 1.2D+(Eh + Ev)+ L + 0.2S

6) 0.9D + 1.6W

7) 0.9D + (Eh – Ev)

Load listed herein shall be considered to act in the following combinations; whichever produces the most unfavourable effect considering soil reactions.

Allowable Stress Design:

Category		Load Combination
Category A	Operation Without Wind	1.0(DL+ DLempty + LLop)
		1.0(DL+ DLempty + LLop + LL + TL ± TLst ± FR)
		1.0(DL+ DLempty + LLop + TL ± TLst ± FR) + 0.75LL + 0.75S
	Operation With Wind	1.0(DL+ DLempty + LLop + TL ± FR) ± WL
		1.0(DL+ DLempty + LLop + TL ± FR) + 0.75LL ± 0.75WL
		1.0(DL+ DLempty + LLop + TL ± FR) + 0.75LL ± 0.75WL + 0.75S
		0.6(DL+ DLempty + LLop+TL + FR) ± WL
Category B	Test	1.0(DL+ DLempty + Test) ± 0.25WL
		1.0(DL+ DLempty + Test) + 0.75LL ± 0.25WL + 0.75S
		0.6(DL+ DLempty + Test) ± 0.25WL
Category C	Erection	1.0(DL+ DLempty + ER ± WL)
		1.0(DL+ DLempty + ER) + 0.75LL ± 0.75WL
		0.6(DL+ DLempty + ER) ± WL
Category D	Earthquake	1.0(DL+ DLempty + LLop + TL) ± 0.7EQ
		1.0(DL+ DLempty + LLop + TL) ± 0.525EQ + 0.75LL + 0.75S
		0.6(DL+ DLempty + LLop+ TL) ± 0.7EQ
Category E	Maintenance	1.0(DL+ DLempty + ML)
		1.0(DL+ DLempty+ ML) + 0.75LL ± 0.25WL
		0.6(DL+ DLempty+ ML) ± 0.25WL

Strength Design:

Category		Load Combination
Category A	Operation Without Wind	1.4(DL+ DLempty + LLop)
		1.2(DL+ DLempty + LLop ± FR + TL ± TLst) +1.6LL
		1.2(DL+ DLempty + LLop ± FR + TL ± TLst) +1.6LL + 0.5S
	Operation With Wind	1.2(DL+ DLempty + LLop ± FR + TL) + 1.0LL ± 1.6WL + 0.5S
		1.2(DL+ DLempty + LLop ± FR + TL) ± 0.8WL + 1.6S
		0.9(DL+ DLempty + LLop ± FR + TL) ± 1.6WL
Category B	Test	1.2(DL+ DLempty + Test) + 1.0LL ± 1.6(0.25WL) + 0.5S
		1.2(DL+ DLempty + Test) + 1.6LL + 0.5S
		0.9(DL+ DLempty + Test) ± 1.6(0.25WL)
Category C	Erection	1.2(DL+ DLempty + ER) + 1.6LL
		1.2(DL+ DLempty + ER) + 1.0LL ± 0.8WL
		0.9(DL+ DLempty + ER) ± 1.6WL
Category D	Earthquake	1.2(DL+ DLempty + LLop + TL) + 1.0LL ± 1.0EQ + 0.2S
		0.9(DL+ DLempty + LLop+ TL) ± 1.0EQ
Category E	Maintenance	1.2(DL+ DLempty + ML) + 1.0LL ± 1.6(0.25WL)
		1.2(DL+ DLempty + ML) + 1.6(LL)
		0.9(DL+ DLempty+ ML) ± 1.6(0.25WL)

16.0 STRUCTURE ANALYSIS AND DESIGN

The steel structure is checked in accordance with LRFD method. Frame analysis and structural checks are based on the 3D model that covers all the Load Combinations.

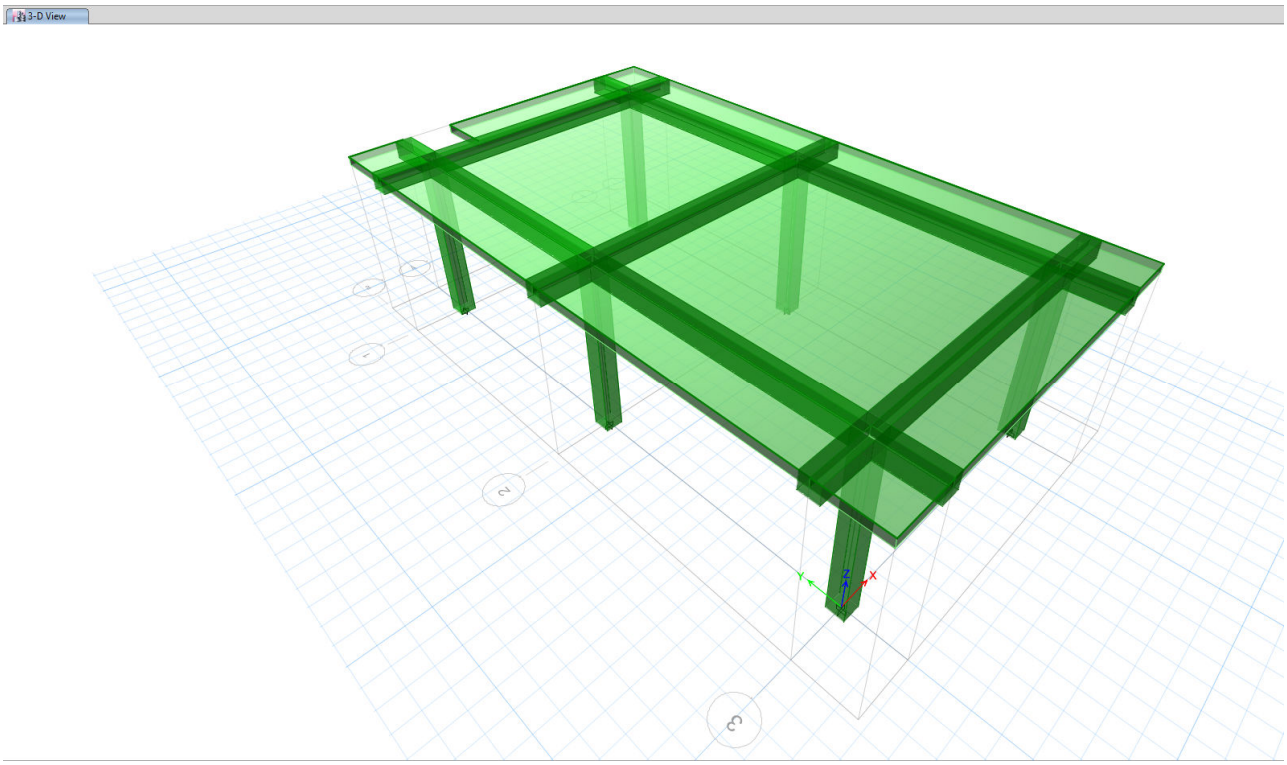


Figure 9: 3D model of ETABS

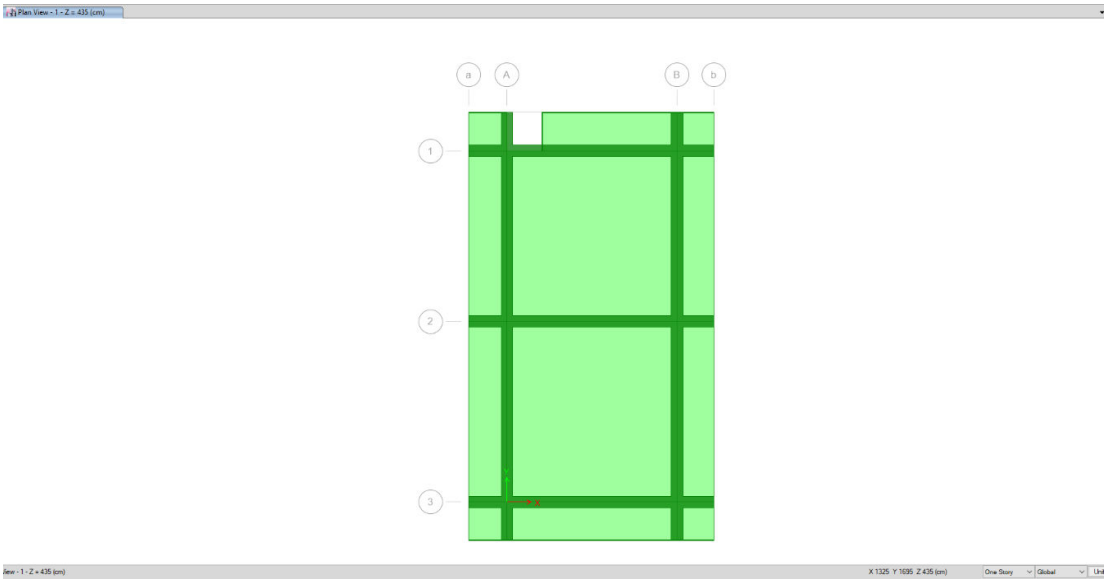


Figure 10: Plan View

17.0 STRUCTURAL DESIGN RESULTS

The design of these elements is done by software facilities according to Code ACI-318-14. Summary of the results for columns and beams design is shown in the following figures.

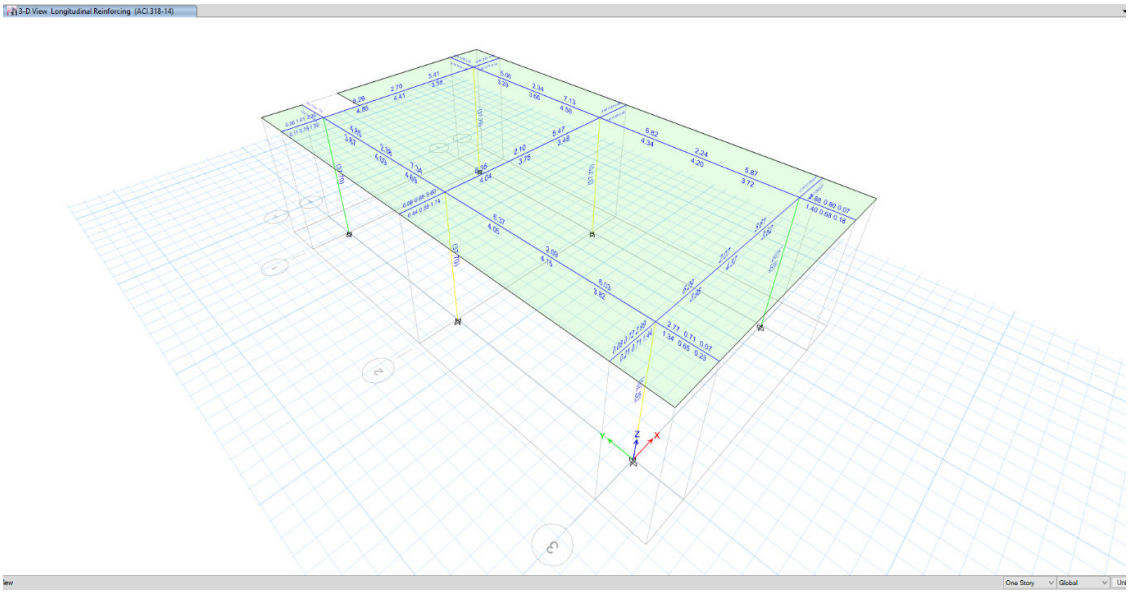


Figure 11: Ratio Check

For all elements D/C ratio shall be ≤ 1, according to above output all elements are ok.

18.0 DRIFT CONTROL

According to "Iranian Seismic Design Code for Petroleum Facilities (Pub.038-3rd edition)" Table 4-8, drift shall not exceed 0.02.

انواع سازه‌ها	گروه کاربری و خطرزایی		
	I و II	III	IV
سازه‌های چهار طبقه و کمتر با تیغه‌بندی‌ها، سقف‌ها، دیوارهای داخلی و سیستم دیوارهای جانبی پیرامونی بدون دیوار برشی بنایی که در برابر جابجایی نسبی طبقه طراحی شده‌اند.	۰٫۰۲۵	۰٫۰۲۰	۰٫۰۱۵
سازه‌های با دیوار برشی بنایی طره‌ای	۰٫۰۱۰	۰٫۰۱۰	۰٫۰۱۰
دیگر سازه‌های با دیوار برشی بنایی	۰٫۰۰۷	۰٫۰۰۷	۰٫۰۰۷
دیگر سازه‌ها	۰٫۰۲۰	۰٫۰۱۵	۰٫۰۱۰

The deflection at level X (δ_x) (in. or mm) used to compute the design story drift, Δ, shall be determined in accordance with the following equation:

Equation 4-22 (Pub.038-3rd edition, part 4-14-1):

δ_{xe} =Maximum displacement in x direction due to earthquake: 11.9 mm

$$\delta_x = \frac{C_d \delta_{xe}}{I} = \frac{5.5 \times 1.19}{1.25} = 5.23\ cm \rightarrow \quad \Delta x = \frac{5.23}{435} = 0.012 < 0.02\ \ ok$$

Also

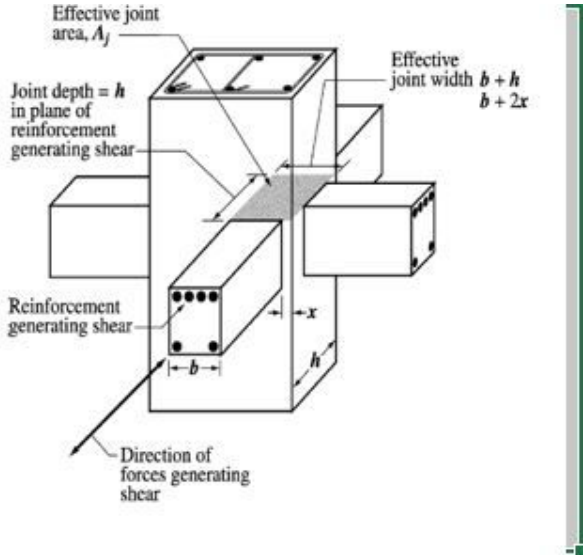
δ_{ye} =Maximum displacement in y direction due to earthquake: 11.6mm

$$\delta_y = \frac{C_d \delta_{ye}}{I} = \frac{5.5 \times 1.16}{1.25} = 5.10\ cm\ , \quad \Delta y = \frac{5.10}{435} = 0.011 < 0.02\ \ ok$$

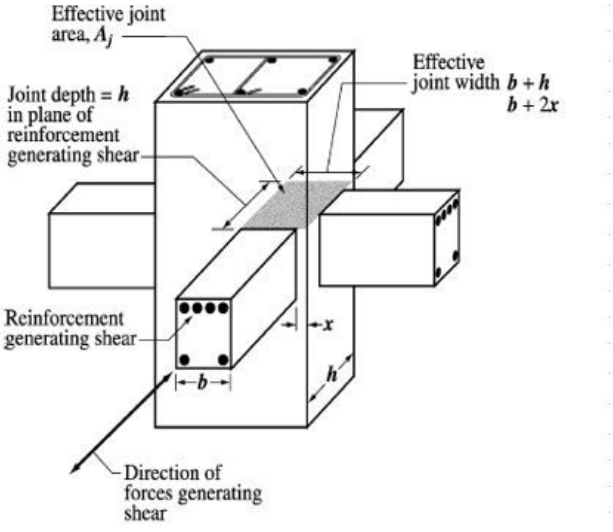
19.0 JOIST SHEAR CAPACITY RATIO CONTROL

According to ACI 318-14 part 18-8-4, shear strength of connection has been controlled and for two columns (Axis 4C & D1) as a sample have been shown below.

Location:	At the Intersection of Axes 4&C	
fy=	4000.00	kg/cm^2
f'c=	300.00	kg/cm^2
h=	45.00	cm
B=	45.00	cm
As_1=	10.160	cm^2
As_2=	10.160	cm^2
As=	As_1+As_2	cm^2
As=	20.32	cm^2
b=	45.00	cm
x=	0.00	cm
Ø=	0.75	
Aj=	h(min (b+h),(b+2x)	cm^2
Aj=	2025	cm^2
Vn=	$5.3ØAj(f'c)^{0.5}$	
Vn=	139.4	ton
Vu=	1.25fyAs	
Vu=	101.6	ton
Ratio=	Vu / Vn	
Ratio=	0.73	OK



Location:	At the Intersection of Axes D1	
fy=	4000.00	kg/cm^2
f'c=	300.00	kg/cm^2
h=	45.00	cm
B=	45.00	cm
As_1=	7.620	cm^2
As_2=	7.620	cm^2
As=	As_1+As_2	cm^2
As=	15.24	cm^2
b=	45.00	cm
x=	0.00	cm
Ø=	0.75	
Aj=	h(min (b+h),(b+2x)	cm^2
Aj=	2025	cm^2
Vn=	$3.2ØAj(f'c)^{0.5}$	
Vn=	139.4	ton
Vu=	1.25fyAs	
Vu=	76.2	ton
Ratio=	Vu / Vn	
Ratio=	0.55	OK



20.0 STRONG COLUMN-WEAK BEAM REQUIREMENTS IN SPECIAL CONCRETE MOMENT FRAME

According to INBC Part 9 (section: 9-20-60-4), the flexural strength of columns shall satisfy:

$\Sigma M_{nc} \geq 1.2\ \Sigma M_{nb}$

Based on Etabs report, maximum force due to seismic load combination is equal to 48.6 ton which

is smaller than $0.1A_g f'_c$, so according to section 9-20-6-4-5 could be ignored above equation for one story building.

21.0 FOUNDATION DESIGN AND RESULTS

○ FOUNDATION MODEL

Foundation model, analyse and design has been done by SAFE2016 software.

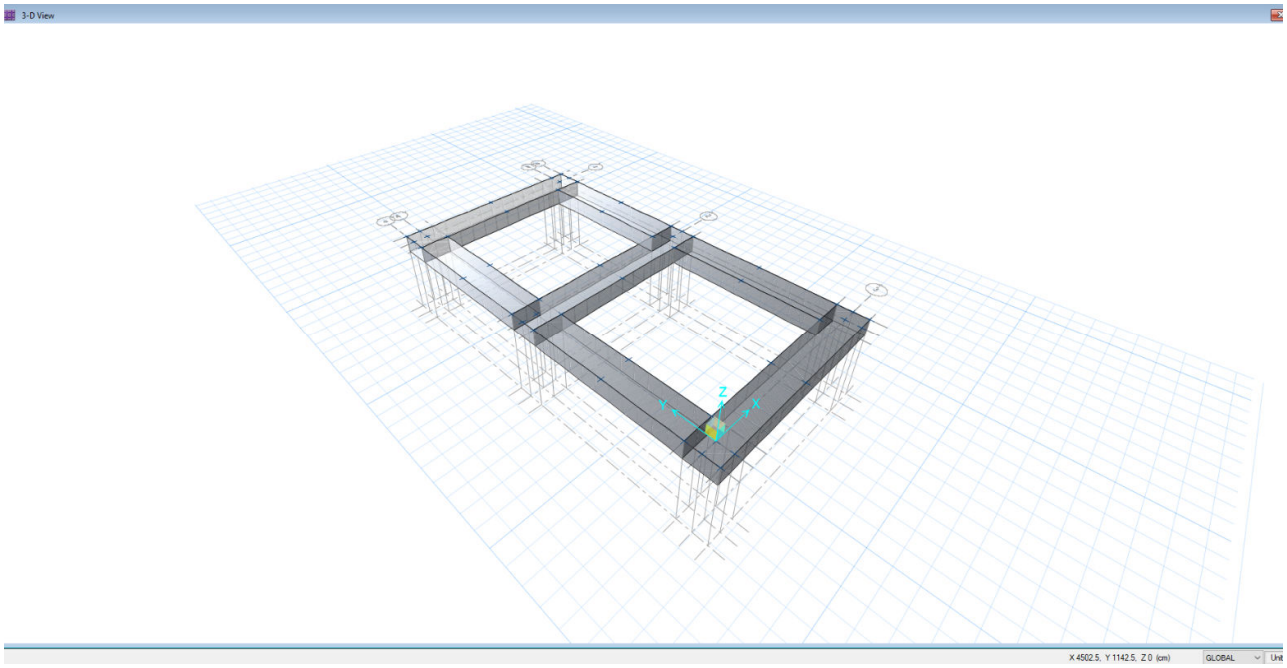


Figure 11: Foundation 3D plan in SAFE

○ SOIL CHARACTERISTIC

Based on Geotechnical Report (Attachment 4, 5):

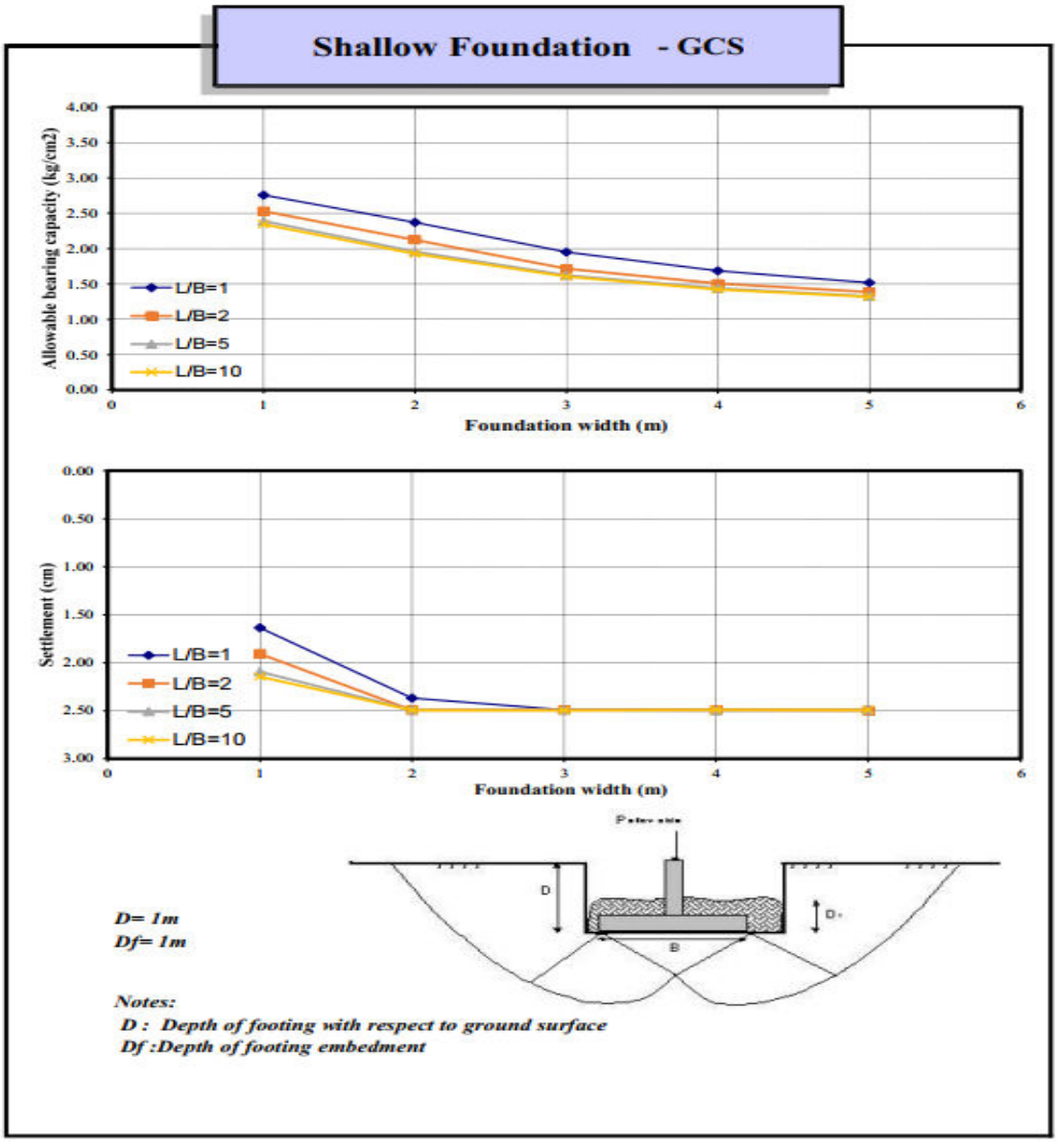
q allowable = 1.75 kg/cm^2 (Allowable Soil Bearing Capacity)

δ allowable = 1.6 cm (Allowable Settlement)

Ks = 1.6 kg/cm^3 (Subgrade Modulus)

جدول 6-1. مدول عکس العمل بستر پی مربعی، مستطیلی و نواری برای عمق یک متر

B(m)	مدول عکس‌العمل بستر پی سطحی (kg/cm3)			
	L/B=1	L/B=2	L/B=5	L/B=10
1.0	1.69	1.33	1.14	1.09
2.0	1.00	0.85	0.78	0.77
3.0	0.78	0.69	0.65	0.64
4.0	0.68	0.60	0.57	0.57
5.0	0.61	0.55	0.53	0.53



- **LOADS**

The loads have been imported from ETABS analysis.

Reinforced concrete unit weight equals 2500 kg/m^3 and defined for SAFE, so the program calculated the foundation weight automatically.

Soil unit weight equals to 1900 kg/m^3. The soil height above foundation is 0.95 m, so distributed soil weight:

Ws = 0.95×1900 = 1805 kg/m^2

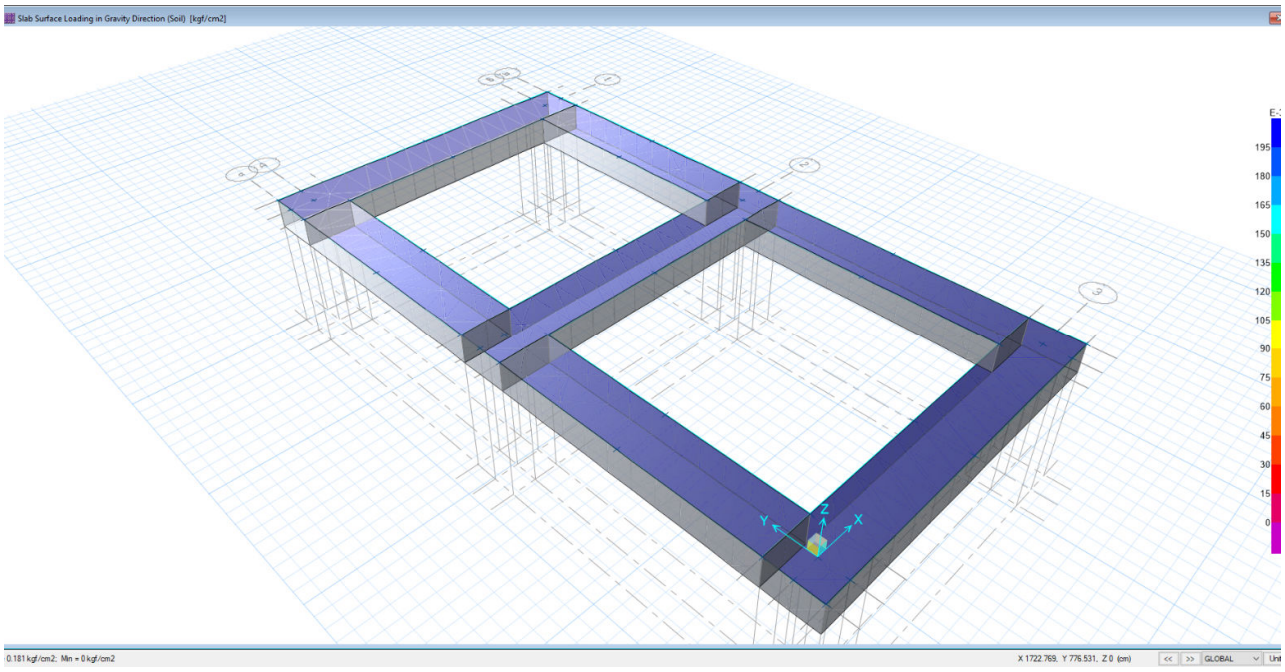


Figure 12: soil weight on foundation

○ SETTLEMENT CONTROL

Settlement in different service load combinations should be checked by allowable value.

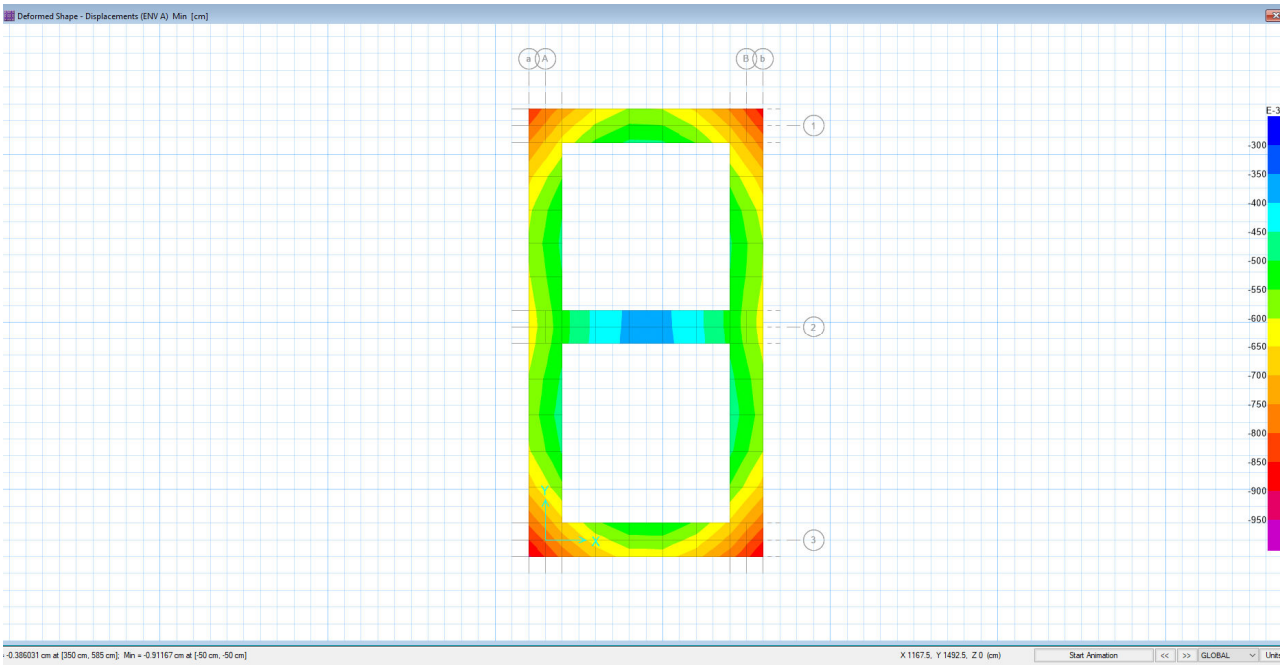
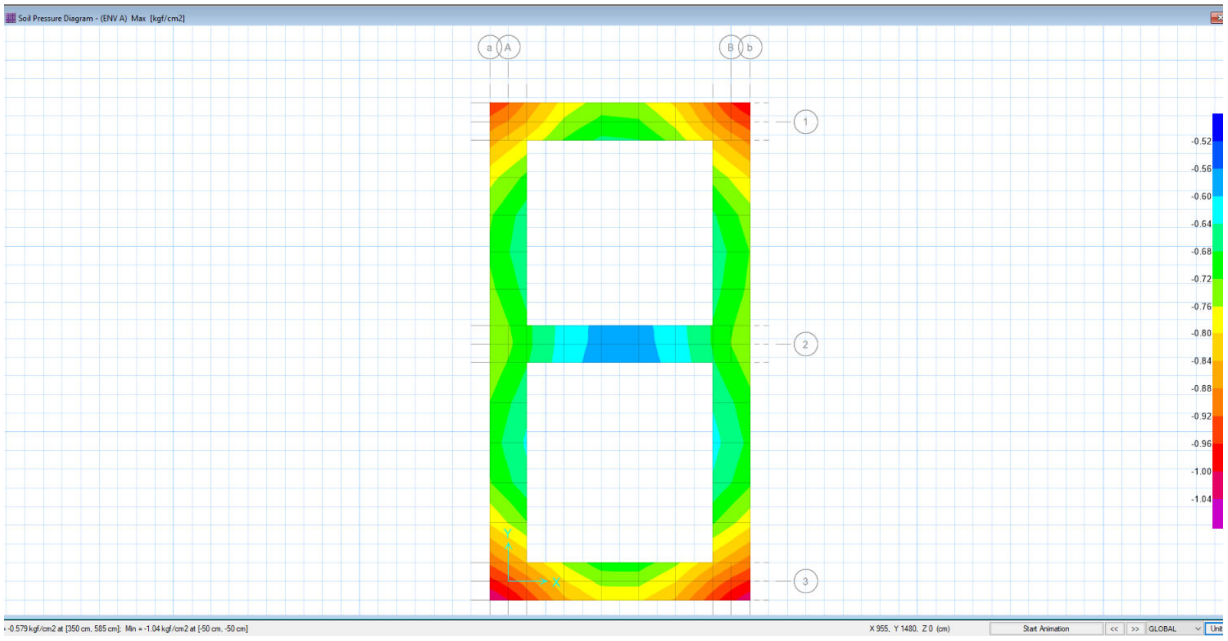


Figure 13: Foundation Settlement

Maximum settlement of foundation equals to 0.91 cm, which is less than allowable 1.6 cm.

○ SOIL PRESSURE CONTROL

Soil pressures in different service load combinations should be checked by allowable value.



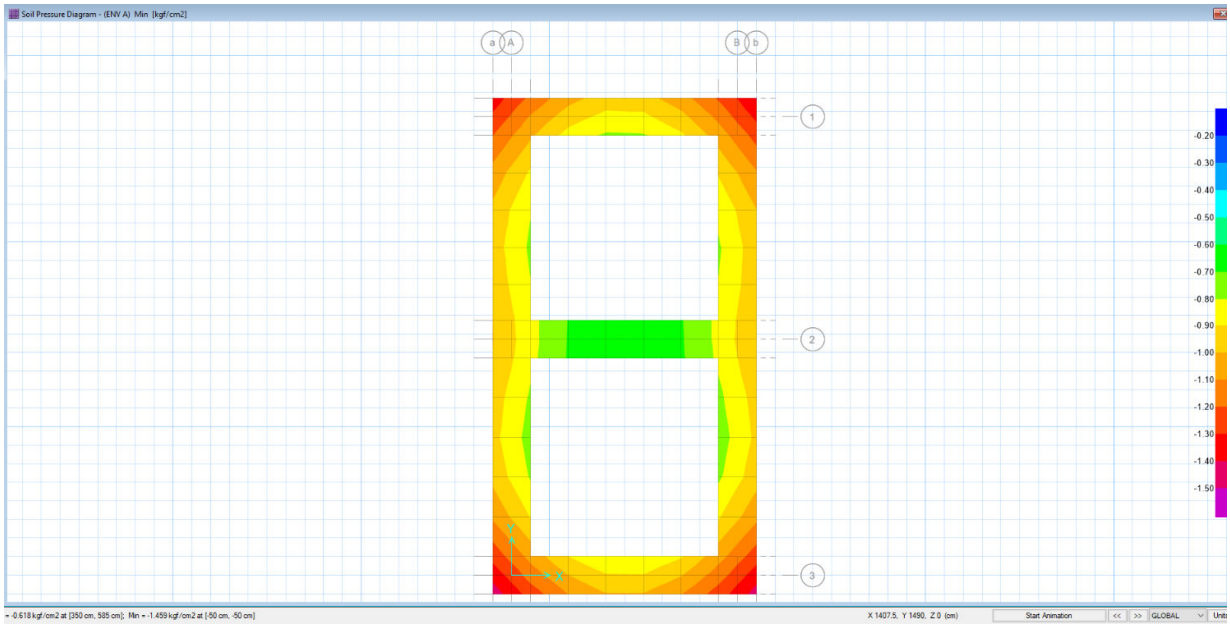


Figure 14: Soil Pressure under Foundation

Maximum soil pressure under foundation equals to 1.43 kg/cm^2, which is less than1.75 kg/cm^2.

- **PUNCHING SHEAR CONTROL**

The punching shear control ratio of foundation is shown below. As seen the punching shear ratio in all columns base which is calculated by software is less than allowable range (1.0), so the footing thickness is acceptable.

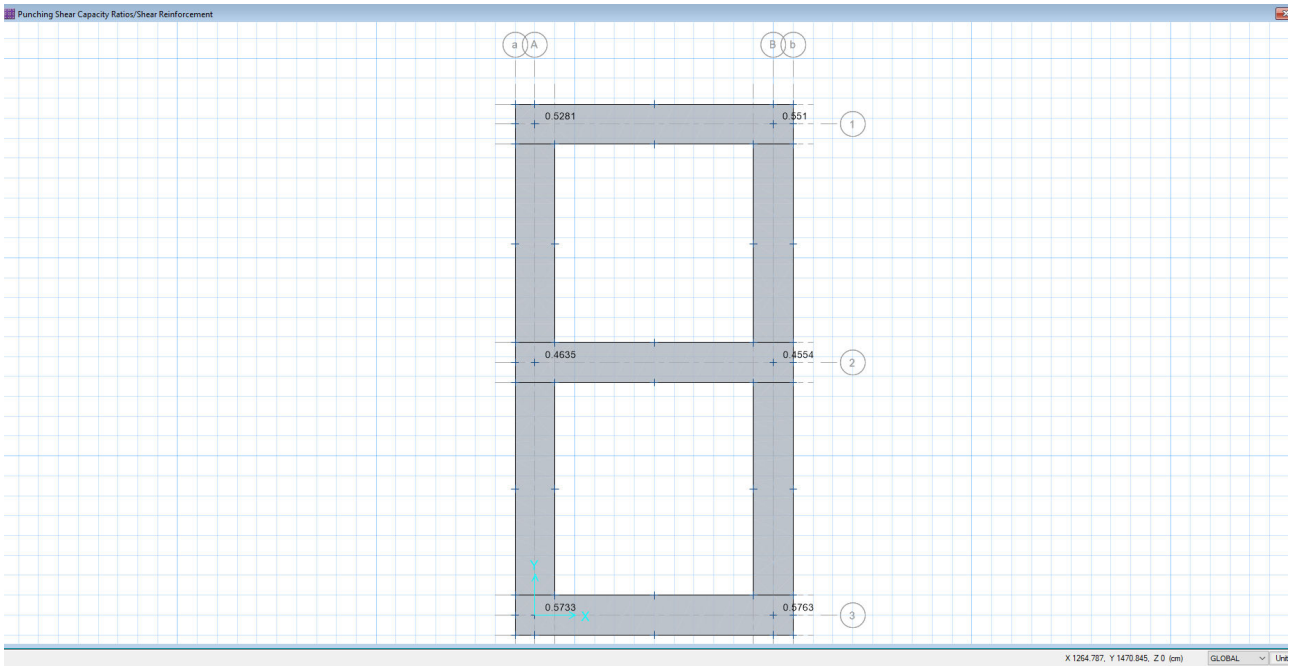


Figure 15: Punching Shear Capacity Ratios

- **FOUNDATION DESIGN**

Foundation reinforcement is calculated by software and add bars in X, Y direction are shown at below figure. Uniform Φ16@150 pattern is assigned for top and bottom of foundation in both directions and needed additional bars at some part that is presented in below pictures.

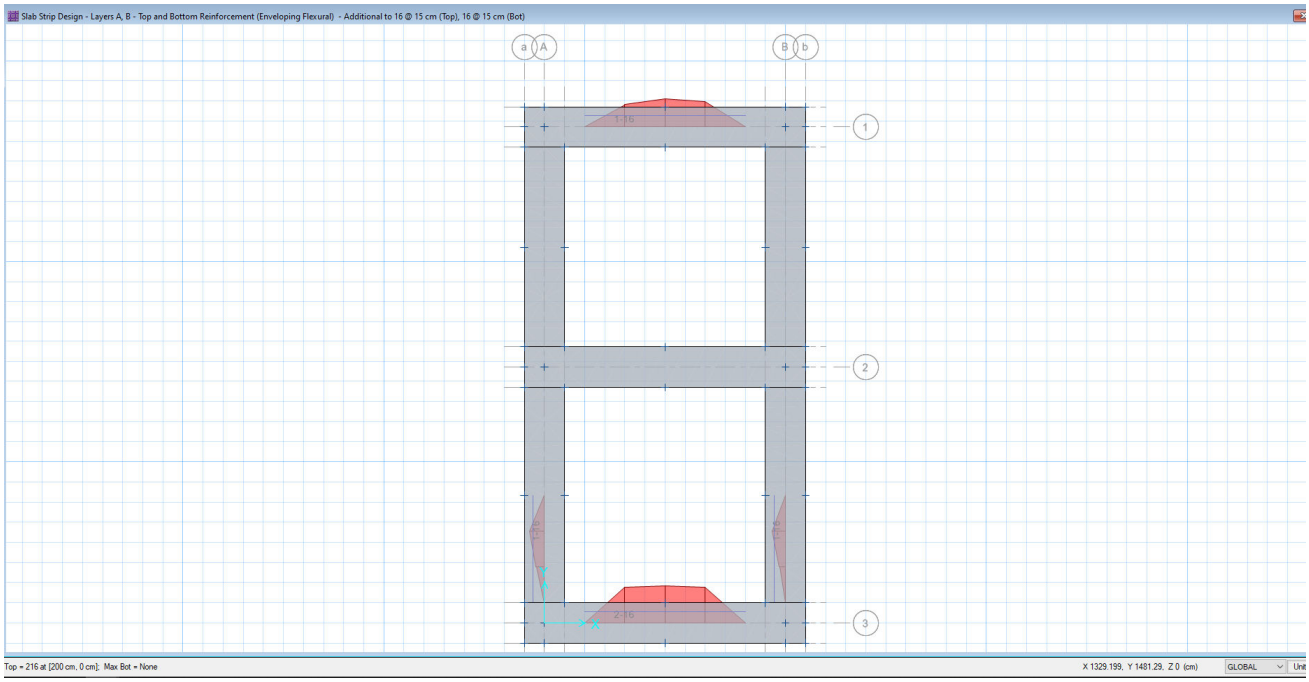


Figure 16: Reinforcement in X, Y Direction

In Both Directions:

Top Bar USE Φ16@150 mm

Bottom Bar USE Φ16@150 mm

Minimum rebar for strip foundation:

$$A_{smin} = 0.0018\,bh = 0.0018 \times 100 \times 60 = 10.8 \ \ cm^2/m$$

$$A_{s\,used} = Ø16@150 = 12.06\ cm^2$$