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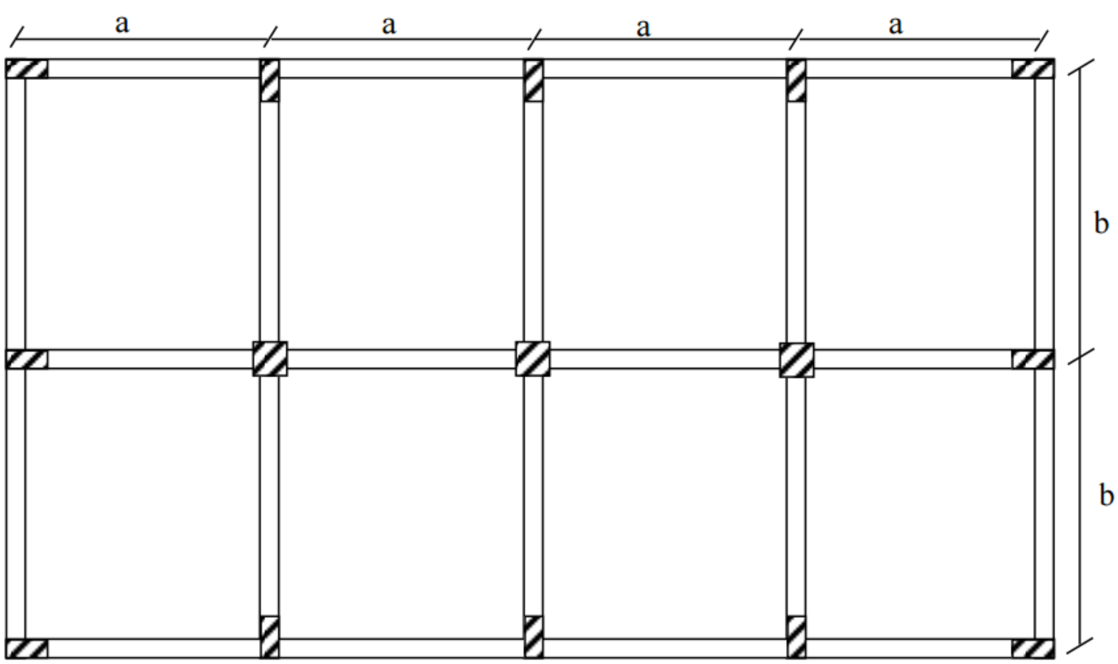
Introduction

This report is prepared for the solutions of the assigned problems in Homework 4. A reinforced concrete building frame is given below with following properties.

- Story height is 3 meters.
- All floors have the same the architectural and structural plans.
- Building is R/C frame, with $E_c = 25 \times 10^6$ kN/m^2.
- Building is used as residence.
- Foundation has sufficient strength.
- Floor slabs are rigid diaphragms in their own plane.
- Beams are 25x45 cm, square columns are 40x40 cm and slab thickness is 15 cm.



Id Number	Last Name	First Name	a (m)	b (m)	CD (cmxcm)	N
1872621	ÇANDIR	ESAT	5	4	25x50	7

According to given properties and dimensions, dynamic mass calculation is made with respect to Turkish Earthquake Code (2007) below;

$$w_i = g_i + n * q_i$$

$$where\ n = 0.3\ for\ residential\ buildings$$

$$m_{slab} = \rho * 4a * 2b * t = 4 * 4 * 5 * 2 * 4 * 0.15 = 60\ tons$$

$$m_{beam} = \rho * 0.25 * (0.45 - 0.15) * (2 * 5b + 4 * 3a)$$

$$m_{beam} = 2.5 * 0.25 * 0.3 * (2 * 5 * 4 + 4 * 3 * 5) = 18.75\ tons$$

$$m_{rectangular-column} = 3 * 0.25 * 0.5 * 12 * 2.5 = 11.25\ tons$$

$$m_{square-column} = 3 * 0.4 * 0.4 * 3 * 2.5 = 3.6\ tons$$

$$g_i = 60 + 18.75 + 11.25 + 3.6 = 93.6\ tons\ for\ each\ middle\ storey$$

$$g_i = 60 + 18.75 + \frac{11.25}{2} + \frac{3.6}{2} = 86.175\ tons\ for\ thelast\ storey$$

$$q_i = 0.2 * 4a * 2b = 0.2 * 4 * 5 * 2 * 4 = 32\ tons$$

$$\boldsymbol{w_i = g_i + n * q_i = 93.6 + 0.3 * 32 = 103.2\ tons}$$

Table 1: Dynamic Mass Calculation

Story #	Columns (tons)	Beams (tons)	Slabs (tons)	Dead (tons)	Live (tons)	DL+0.3LL (tons)	I_{mass} (tons.m^2)
1	14.85	18.75	60	93.60	32	103.2	3990.4
2	14.85	18.75	60	93.60	32	103.2	3990.4
3	14.85	18.75	60	93.60	32	103.2	3990.4
4	14.85	18.75	60	93.60	32	103.2	3990.4
5	14.85	18.75	60	93.60	32	103.2	3990.4
6	14.85	18.75	60	93.60	32	103.2	3990.4
7	9.225	18.75	60	87.98	32	97.58	3772.9
						$\sum$ 716.775	

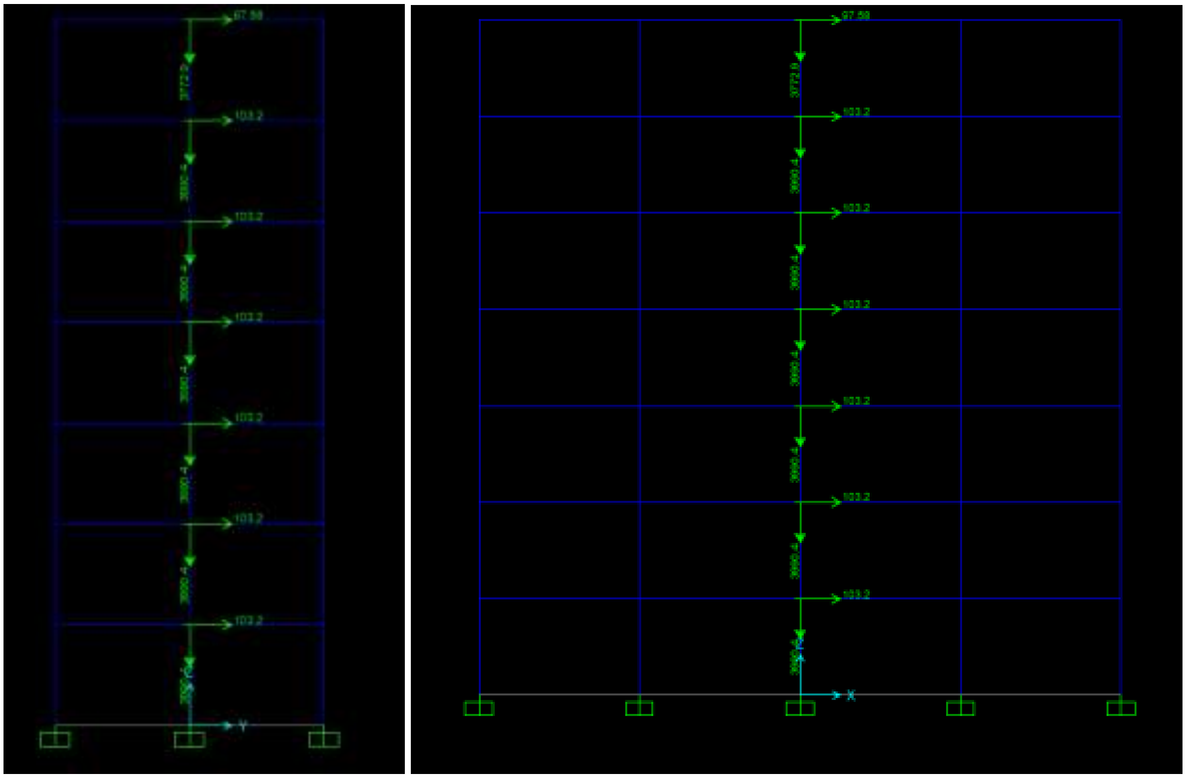


Figure 1: Dynamic Mass insertion

Table 2: Modal Periods and Frequencies

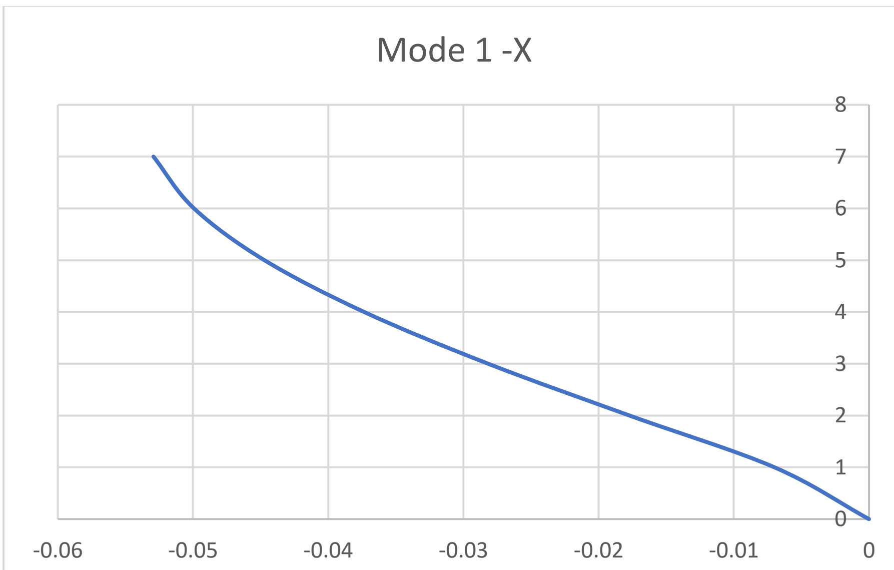
Mode	Period (sec)	Frequency	CircFrequency	Eigenvalue
1	1.01	0.99	6.21	38.51
2	0.99	1.01	6.34	40.19
3	0.87	1.15	7.20	51.91
4	0.33	3.06	19.22	369.24
5	0.32	3.13	19.67	387.10
6	0.29	3.50	22.01	484.49

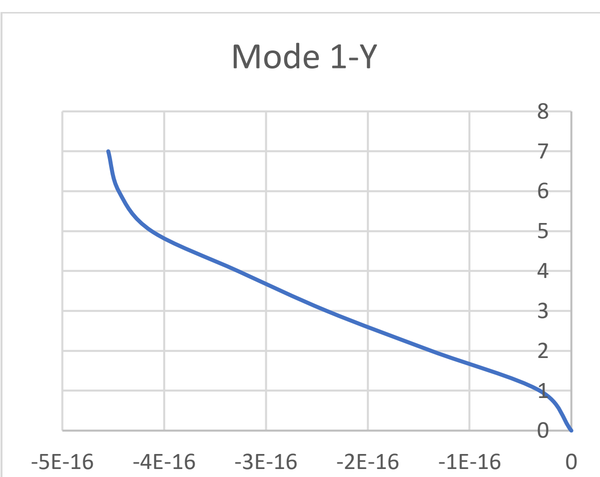
Part 1

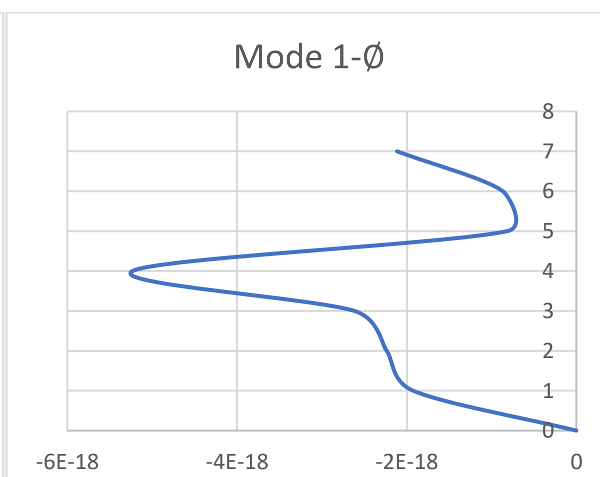
Mode Shapes

Period (sec)	Frequency (Cyc/sec)	Joint	OutputCase	CaseType	StepType	StepNum	U1	U2	U3	R1	R2	R3	Floor
		Text	Text	Text	Text	Unitless	m	m	m	Radians	Radians	Radians	#
1.012462	0.987691114						0	0	0	0	0	0	0
		58	MODAL	LinModal	Mode	1	-0.00699	-3.104E-17	0	1.377E-17	-0.002087	-1.924E-18	1
		12	MODAL	LinModal	Mode	1	-0.017713	-1.377E-16	-1.95E-20	2.131E-17	-0.002299	-2.236E-18	2
CircFreqy (rad/sec)	Eigenvalue (rad2/sec2)	31	MODAL	LinModal	Mode	1	-0.028161	-2.403E-16	-1.505E-20	1.871E-17	-0.002105	-2.616E-18	3
6.2058463	38.51252827	52	MODAL	LinModal	Mode	1	-0.03734	-3.276E-16	-1.14E-20	1.748E-17	-0.001771	-5.231E-18	4
		71	MODAL	LinModal	Mode	1	-0.044715	-4.123E-16	-3.476E-20	1.216E-17	-0.00134	-8.132E-19	5
		92	MODAL	LinModal	Mode	1	-0.049925	-4.446E-16	-5.8E-20	5.014E-18	-0.000869	-8.674E-19	6
		111	MODAL	LinModal	Mode	1	-0.052921	-4.549E-16	-7.711E-20	2.602E-18	-0.00038	-2.114E-18	7

Figure 2: Mode 1

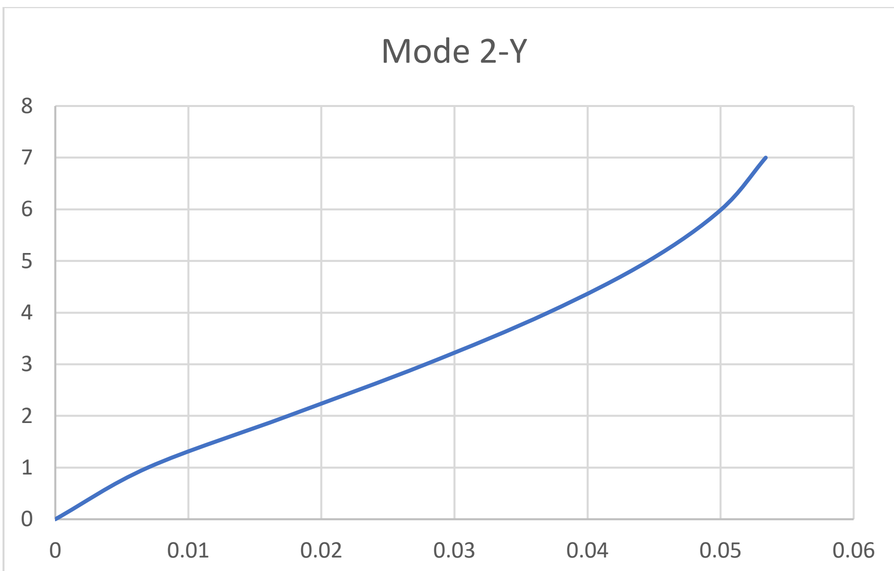


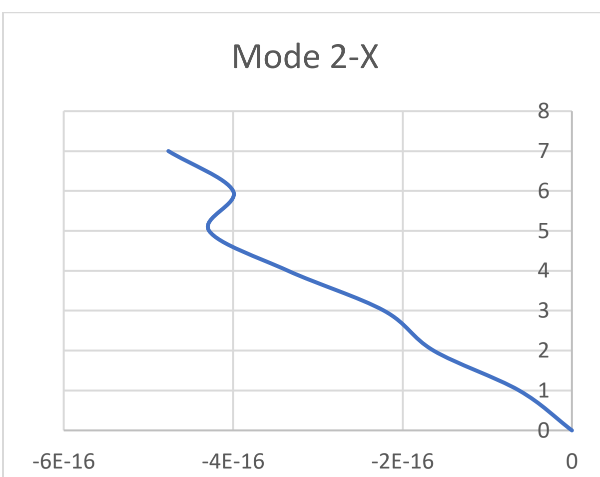


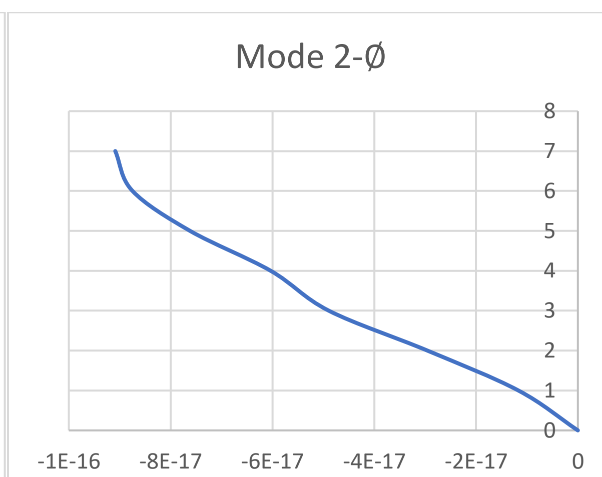


Period (sec)	Frequency (Cyc/sec)	Joint	OutputCase	CaseType	StepType	StepNum	U1	U2	U3	R1	R2	R3	Floor
		Text	Text	Text	Text	Unitless	m	m	m	Radians	Radians	Radians	#
0.991126	1.008953285						0	0	0	0	0	0	0
		58	MODAL	LinModal	Mode	2	-6.24E-17	0.006959	0	-0.001813	-1.99E-17	-1.169E-17	1
		12	MODAL	LinModal	Mode	2	-1.63E-16	0.017494	3.107E-20	-0.002075	-1.69E-17	-2.956E-17	2
CircFreqy (rad/sec)	Eigenvalue (rad2/sec2)	31	MODAL	LinModal	Mode	2	-2.22E-16	0.027835	5.257E-20	-0.001946	-1.74E-17	-4.894E-17	3
6.33944045	40.18850527	52	MODAL	LinModal	Mode	2	-3.35E-16	0.037039	4.767E-20	-0.001695	-2.47E-17	-6.035E-17	4
		71	MODAL	LinModal	Mode	2	-4.28E-16	0.044575	2.914E-20	-0.001348	-5.25E-18	-7.619E-17	5
		92	MODAL	LinModal	Mode	2	-4E-16	0.050064	0	-0.000958	-3.86E-18	-8.749E-17	6
		111	MODAL	LinModal	Mode	2	-4.76E-16	0.053391	-2.077E-20	-0.000537	-1.35E-17	-9.088E-17	7

Figure 3: Mode 2

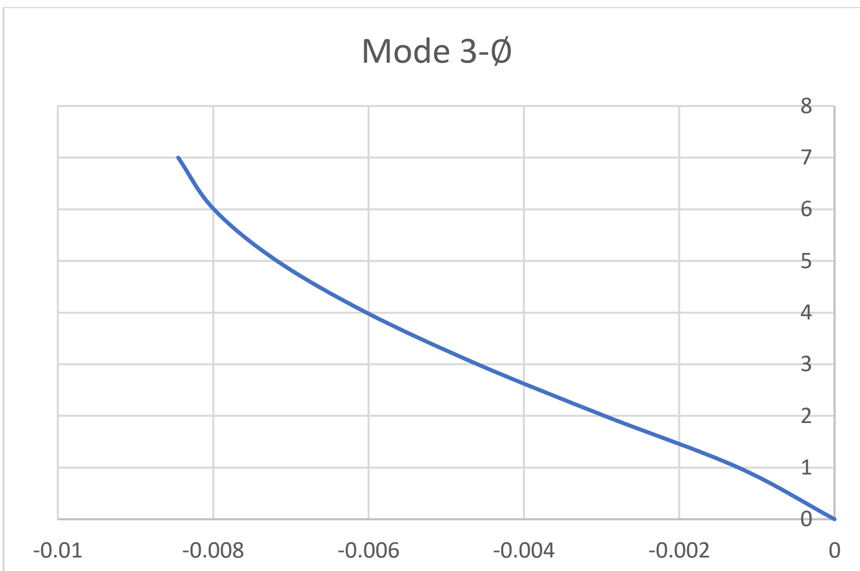


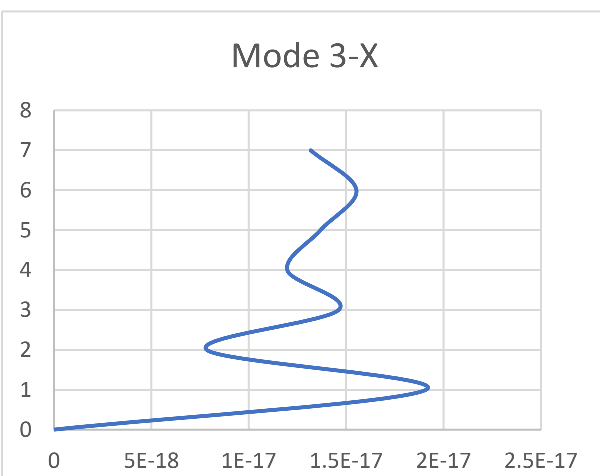


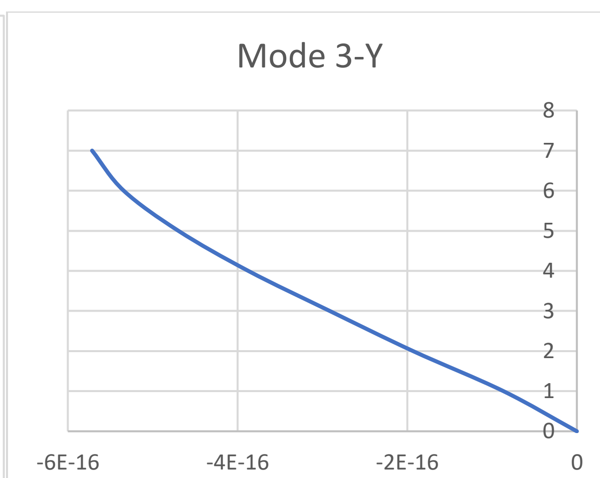


Period (sec)	Frequency (Cyc/sec)	**Joint**	**OutputCase**	**CaseType**	**StepType**	**StepNum**	**U1**	**U2**	**U3**	**R1**	**R2**	**R3**	**Floor**
		Text	Text	Text	Text	Unitless	m	m	m	Radians	Radians	Radians	#
0.872103	**1.146654144**						0	0	0	0	0	0	0
		58	MODAL	LinModal	Mode	3	1.911E-17	-8.647E-17	-1.189E-20	2.027E-17	1.171E-18	-0.001238	1
		12	MODAL	LinModal	Mode	3	7.84E-18	-1.931E-16	-2.343E-20	2.038E-17	-8.62E-19	-0.00296	2
CircFreqy (rad/sec)	Eigenvalue (rad2/sec2)	31	MODAL	LinModal	Mode	3	1.462E-17	-2.912E-16	-3.631E-20	1.93E-17	9.8E-19	-0.004596	3
7.20464047	**51.90684431**	52	MODAL	LinModal	Mode	3	1.198E-17	-3.873E-16	-4.695E-20	1.782E-17	-2.19E-19	-0.006026	4
		71	MODAL	LinModal	Mode	3	1.369E-17	-4.697E-16	-5.381E-20	1.529E-17	1.468E-19	-0.007177	5
		92	MODAL	LinModal	Mode	3	1.553E-17	-5.341E-16	-5.964E-20	1.112E-17	5.421E-20	-0.00799	6
		111	MODAL	LinModal	Mode	3	1.318E-17	-5.714E-16	-6.184E-20	5.672E-18	-8.47E-19	-0.00845	7

Figure 4: Mode 3

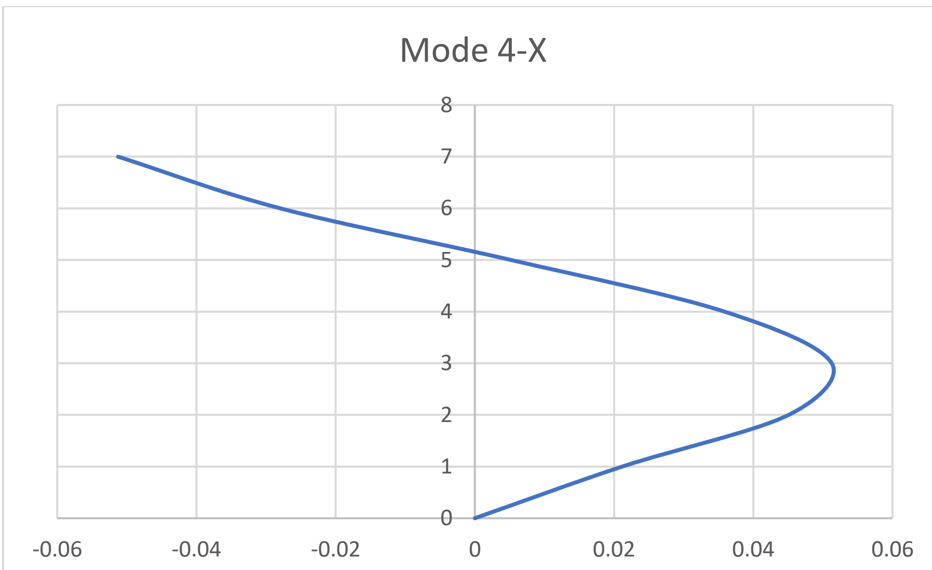


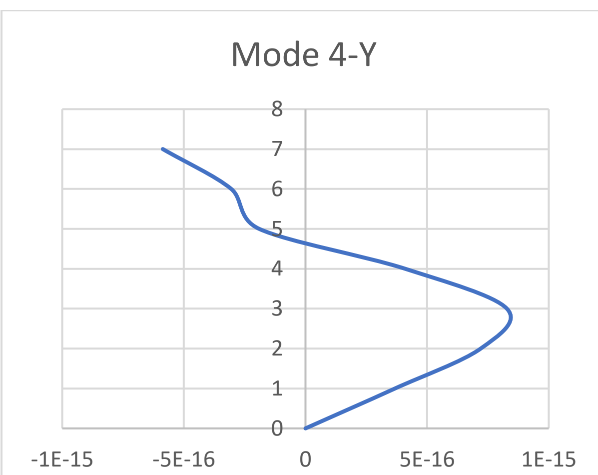


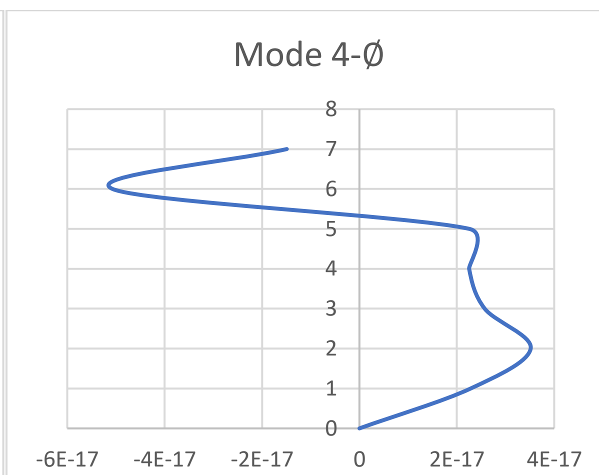


Period (sec)	Frequency (Cyc/sec)	Joint	OutputCase	CaseType	StepType	StepNum	U1	U2	U3	R1	R2	R3	Floor
		Text	Text	Text	Text	Unitless	m	m	m	Radians	Radians	Radians	#
0.326982	**3.0582734**						0	0	0	0	0	0	0
		58	MODAL	LinModal	Mode	4	0.021171	3.681E-16	5.033E-20	-7.439E-17	0.005642	2.286E-17	1
		12	MODAL	LinModal	Mode	4	0.045079	7.203E-16	1.239E-19	-4.682E-17	0.003463	3.517E-17	2
CircFreqy (rad/sec)	Eigenvalue (rad2/sec2)	31	MODAL	LinModal	Mode	4	0.051273	8.28E-16	8.801E-20	3.4E-17	-0.001004	2.573E-17	3
19.2156985	**369.2430686**	52	MODAL	LinModal	Mode	4	0.03587	4.098E-16	1.125E-19	1.1E-16	-0.005129	2.253E-17	4
		71	MODAL	LinModal	Mode	4	0.005184	-1.903E-16	1.103E-19	7.179E-17	-0.007091	2.257E-17	5
		92	MODAL	LinModal	Mode	4	-0.027968	-3.05E-16	7.728E-20	3.487E-17	-0.006228	-5.07E-17	6
		111	MODAL	LinModal	Mode	4	-0.051264	-5.865E-16	6.292E-20	3.964E-17	-0.003157	-1.491E-17	7

Figure 5: Mode 4

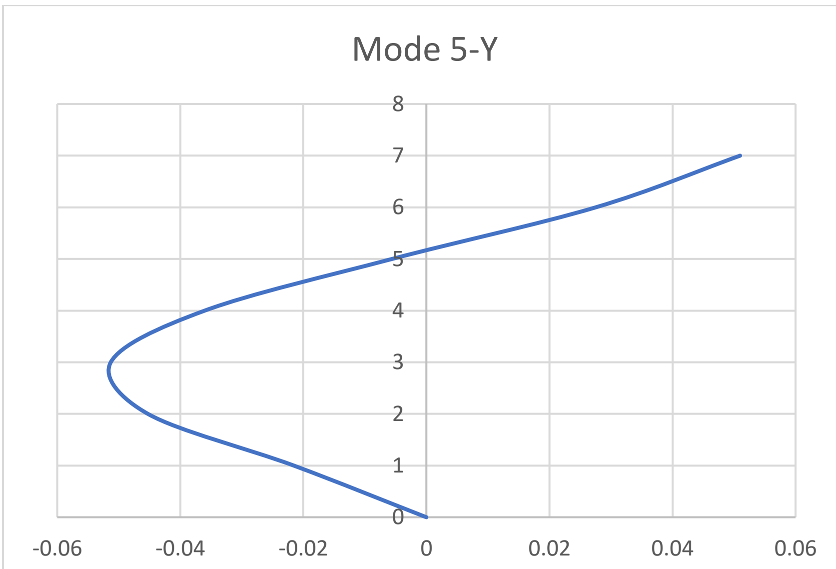


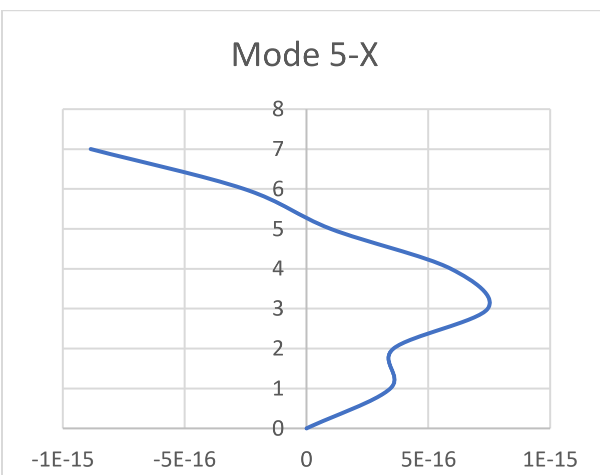


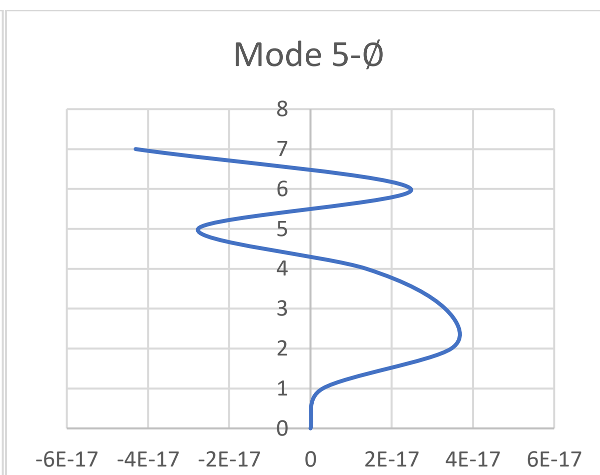


Period (sec)	Frequency (Cyc/sec)	Joint	OutputCase	CaseType	StepType	StepNum	U1	U2	U3	R1	R2	R3	Floor
		Text	Text	Text	Text	Unitless	m	m	m	Radians	Radians	Radians	#
0.319351	**3.131355079**						0	0	0	0	0	0	0
		58	MODAL	LinModal	Mode	5	3.441E-16	-0.021545	5.984E-20	0.004757	4.032E-17	3.033E-18	1
		12	MODAL	LinModal	Mode	5	3.572E-16	-0.045248	6.415E-20	0.002884	4.333E-17	3.466E-17	2
CircFreqy (rad/sec)	Eigenvalue (rad2/sec2)	31	MODAL	LinModal	Mode	5	7.439E-16	-0.051301	1.79E-19	-0.001087	3.93E-17	3.317E-17	3
		52	MODAL	LinModal	Mode	5	5.924E-16	-0.03603	2.229E-19	-0.004735	-8.12E-17	1.375E-17	4
19.6748842	**387.1010693**	71	MODAL	LinModal	Mode	5	9.951E-17	-0.00559	2.36E-19	-0.006515	-8.95E-17	-2.766E-17	5
		92	MODAL	LinModal	Mode	5	-2.56E-16	0.027542	2.445E-19	-0.005908	-1.06E-16	2.47E-17	6
		111	MODAL	LinModal	Mode	5	-8.86E-16	0.050992	2.196E-19	-0.003077	-9.46E-17	-4.306E-17	7

Figure 6: Mode 5

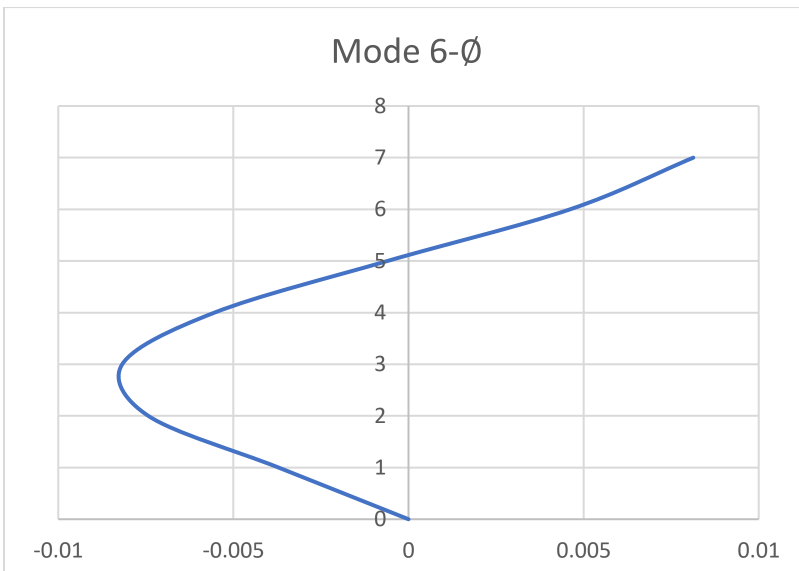


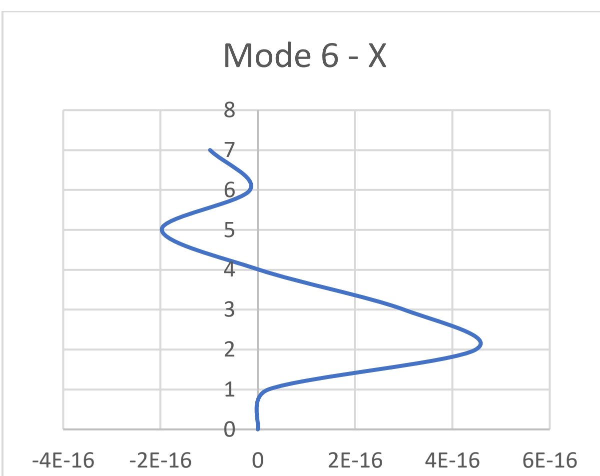


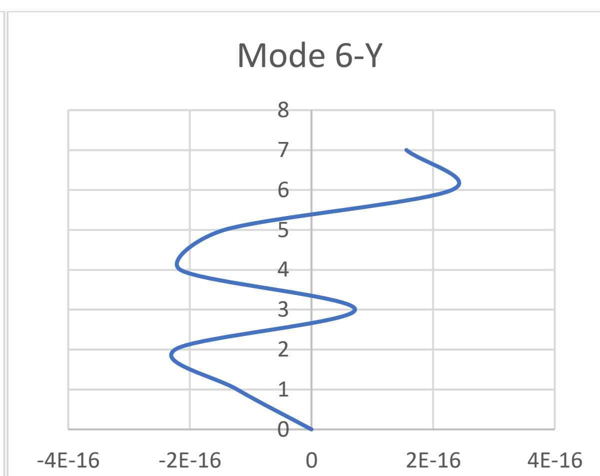


Period (sec)	Frequency (Cyc/sec)	Joint	OutputCase	CaseType	StepType	StepNum	U1	U2	U3	R1	R2	R3	Floor
		Text	Text	Text	Text	Unitless	m	m	m	Radians	Radians	Radians	#
0.285455	**3.503184916**						0	0	0	0	0	0	0
		58	MODAL	LinModal	Mode	6	2.175E-17	-1.222E-16	1.982E-20	2.832E-17	5.426E-17	-0.003708	1
		12	MODAL	LinModal	Mode	6	4.477E-16	-2.242E-16	2.967E-20	-2.725E-17	3.625E-17	-0.007427	2
CircFreqy (rad/sec)	Eigenvalue (rad2/sec2)	31	MODAL	LinModal	Mode	6	3.004E-16	7.165E-17	8.776E-20	-1.055E-18	-5.54E-17	-0.008174	3
22.01116	**484.4911643**	52	MODAL	LinModal	Mode	6	2.992E-18	-2.157E-16	1.118E-19	2.917E-17	-5.87E-17	-0.005541	4
		71	MODAL	LinModal	Mode	6	-1.98E-16	-1.431E-16	1.226E-19	-5.267E-17	2.673E-18	-0.0006	5
		92	MODAL	LinModal	Mode	6	-1.62E-17	2.309E-16	1.581E-19	-2.966E-17	1.639E-17	0.004615	6
		111	MODAL	LinModal	Mode	6	-9.82E-17	1.562E-16	1.454E-19	8.235E-18	-2.14E-17	0.008131	7

Figure 7: Mode 6







Modal Masses

$$M_n = \emptyset_n{}^T * \ m * \ \emptyset_n \qquad \textit{Modal Mass}$$

$$L_{ni} = \ \emptyset_n{}^T * m * l_i \quad \textit{Modal Excitation Factor}$$

$$M_{ni}{}^* = \frac{L_{ni}{}^2}{M_n} \qquad \textit{EffectiveModal Mass}$$

```
%This script is written for CE490- Introduction to Earthquake
Engineering course Homework-4
clear all
clc
mass_matrix=diag([103.2 103.2 3990.4 103.2 103.2 3990.4 103.2
103.2 3990.4 103.2 103.2 3990.4 103.2 103.2 3990.4 103.2 103.2
3990.4 103.2 103.2 3990.4 ]); %mass matrix

phi1=load('FirstMode.txt'); %Mode Shape 1st
phi2=load('SecondMode.txt'); %Mode Shape 2nd
phi3=load('ThirdMode.txt'); %Mode Shape 3rd
phi1Trans=transpose(phi1);
phi2Trans=transpose(phi2);
phi3Trans=transpose(phi3);
LengthFactorX=load('LengthFactor-X.txt');%(1 0 0 1 0 0 1 0 0 ..)
LengthFactorY=load('LengthFactor-Y.txt');%(0 1 0 0 1 0 0 1 0 ..)
ModalMass1=phi1Trans*mass_matrix*phi1; %Modal Mass 1st
ModalMass2=phi2Trans*mass_matrix*phi2; %Modal Mass 2nd
ModalMass3=phi3Trans*mass_matrix*phi3; %Modal Mass 3rd
ModalExcitationFactor1=phi1Trans*mass_matrix*LengthFactorX;
ModalExcitationFactor2=phi2Trans*mass_matrix*LengthFactorY;
ModalExcitationFactor3=phi3Trans*mass_matrix*LengthFactorY;
EffectiveModalMass1=ModalExcitationFactor1*ModalExcitationFactor
1/ModalMass1;
EffectiveModalMass2=ModalExcitationFactor2*ModalExcitationFactor
2/ModalMass2;
EffectiveModalMass3=ModalExcitationFactor3*ModalExcitationFactor
3/ModalMass3;

Force1=(ModalExcitationFactor1/ModalMass1)*mass_matrix*phi1;
Force2=(ModalExcitationFactor2/ModalMass2)*mass_matrix*phi2;
Force3=(ModalExcitationFactor3/ModalMass3)*mass_matrix*phi3;
```

	Modal Mass	Modal Excitation Factor	Effective Modal Mass
Mode 1	1.0157	-24.5373	592.7482
Mode 2	1.0160	24.4952	590.5609
Mode 3	1.0155	0.0000	0.0000

ModalExcitationFactor3 =-2.6143e-13 ≈ **0**

EffectiveModalMass3 = 6.7305e-26 ≈ **0**

Modal Forces

$$F_n = \left(\frac{L_{ni}}{M_n}\right) * m * \emptyset_n * Sa_n \qquad \textit{Modal Force}$$

	Story	F1(x)/Sa	F2(y)/Sa	F3(Ø)/Sa	
	1	17.43	0.00	0.00	
	2	44.16	0.00	0.00	
	3	70.21	0.00	0.00	
Mode1	4	93.09	0.00	0.00	=592.75
	5	111.47	0.00	0.00	
	6	124.46	0.00	0.00	
	7	131.93	0.00	0.00	
	1	0.00	17.31	0.00	
	2	0.00	43.53	0.00	
	3	0.00	69.26	0.00	
Mode 2	4	0.00	92.16	0.00	=590.56
	5	0.00	110.91	0.00	
	6	0.00	124.56	0.00	
	7	0.00	132.84	0.00	
	1	0.00	0.00	0.00	
	2	0.00	0.00	0.00	
	3	0.00	0.00	0.00	
Mode 3	4	0.00	0.00	0.00	=0.00
	5	0.00	0.00	0.00	
	6	0.00	0.00	0.00	
	7	0.00	0.00	0.00	

Modal forces are calculated via MATLAB matrix operations.

Total Mass was 716. 775 tons from the dynamic mass calculation. Modal mass participation situation;

EffectiveModalMass1/Total Mass = 0.826

EffectiveModalMass2/Total Mass = 0.823

Table 3: Mass Participation Ratios from SAP2000

Output Case	Step Type	StepNum	Period (sec)	UX	UY	UZ	Sum UX	Sum UY	Sum UZ
MODAL	Mode	1	1.012462	**0.81973**	0	0	0.81973	0	0
MODAL	Mode	2	0.991126	0	**0.81672**	0	0.81973	0.81672	0
MODAL	Mode	3	0.872103	0	0	0	0.81973	0.81672	0
MODAL	Mode	4	0.326982	0.10024	0	0	0.91997	0.81672	0
MODAL	Mode	5	0.319351	0	0.10473	0	0.91997	0.92145	0
MODAL	Mode	6	0.285455	0	0	0	0.91997	0.92145	0

According to both hand calculations and SAP2000 analysis results, mass participation ratios for the first three modes in x and y directions are about 82 %.

$$x\ direction:\ \sum_{n=1}^{N_{min}} M_n^* = \sum_{n=1}^{N_{min}} \frac{L_{xn}^2}{M_n} \geq 0.90 \sum_{i=1}^{N} m_i$$

$$y\ direction:\ \sum_{1}^{N_{min}} M_n^* = \sum_{n=1}^{N_{min}} \frac{L_{yn}^2}{M_n} \geq 0.90 \sum_{1}^{N} m_i$$

Figure 8:TEC 2007

In Turkish Earthquake Code 2007, it is specified that mass participation ratio should be equal or greater than 90 %. In this part of the homework, SAP2000 model is analyzed in three modes. In order to achieve 90 % mass participation, Structural model should be analyzed with higher modes. According to SAP2000 analysis results, 6 modes analysis is sufficient for minimum 90 % mass participation.

Part 2

- E is defined for Earthquake Region 1 and soil type Z3.
- TEC 2007 design spectrum.

A_0 = 0.4 for the Earthquake Region 1

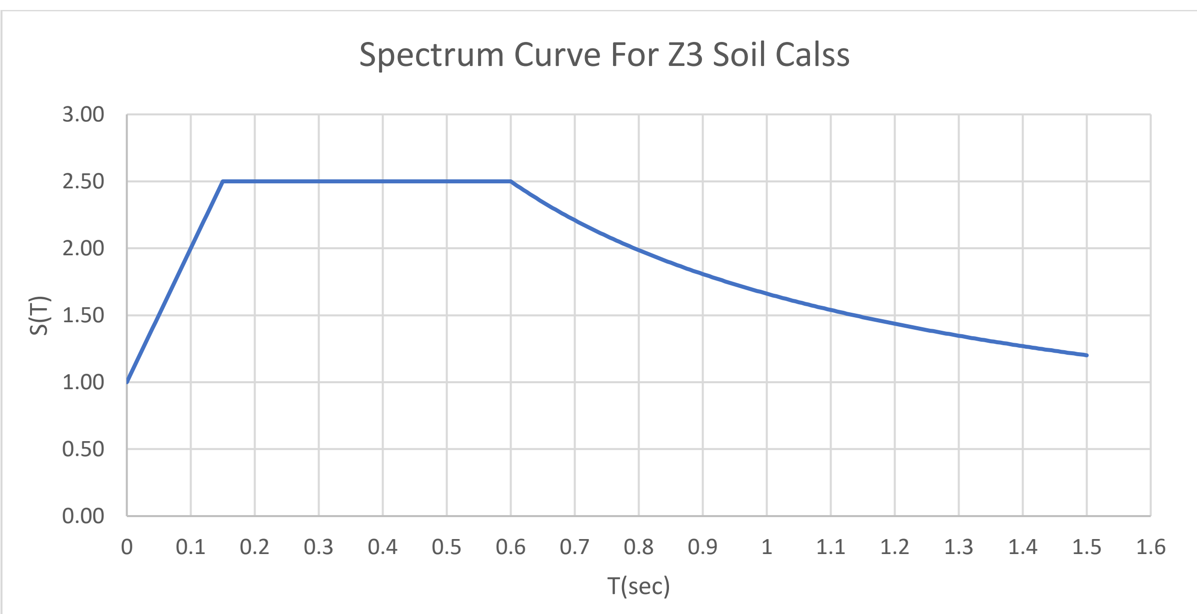
I = 1 for residence buildings

T_A = 0.15 and $_{TB}$ = 0.6 for Z3 soil type

Turkish Earthquake Code is used in order to obtain design spectrum for the structural system and following formulas are taken into consideration.

$$A(T) = A_o\, I\, S(T)$$
$$S_{ae}(T) = A(T)\, g$$

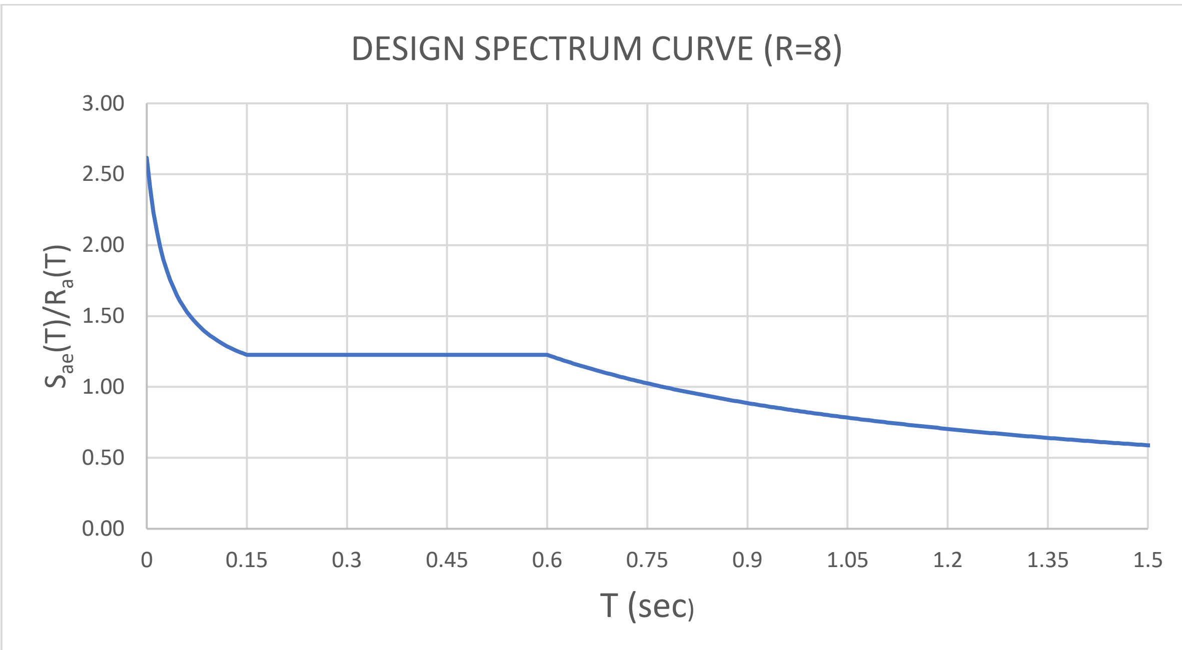
$$S(T) = 1 + 1.5\,\frac{T}{T_A} \qquad (0 \le T \le T_A)$$
$$S(T) = 2.5 \qquad (T_A < T \le T_B)$$
$$S(T) = 2.5\left(\frac{T_B}{T}\right)^{0.8} \qquad (T_B < T)$$



- TEC 2007, reduced spectrum. Enhanced ductility level is used for the system.

$$S_{aR}(T_n) = \frac{S_{ae}(T_n)}{R_a(T_n)}$$

$$R_a(T) = 1.5 + (R-1.5)\,\frac{T}{T_A} \qquad (0 \le T \le T_A)$$
$$R_a(T) = R \qquad (T_A < T)$$



- Modal spectrum analysis

In order to make response spectrum analysis, design spectrum data is imported to SAP2000 and a function is created. By using **1G + 1Q ± 1E** combination and trapezoidal load distribution from slabs to the beams, response spectrum analysis is applied.

From first part of the homework, in dynamic mass calculation section, dead load per story is calculated as 936 kN and live load is calculated as 320 kN for each story.

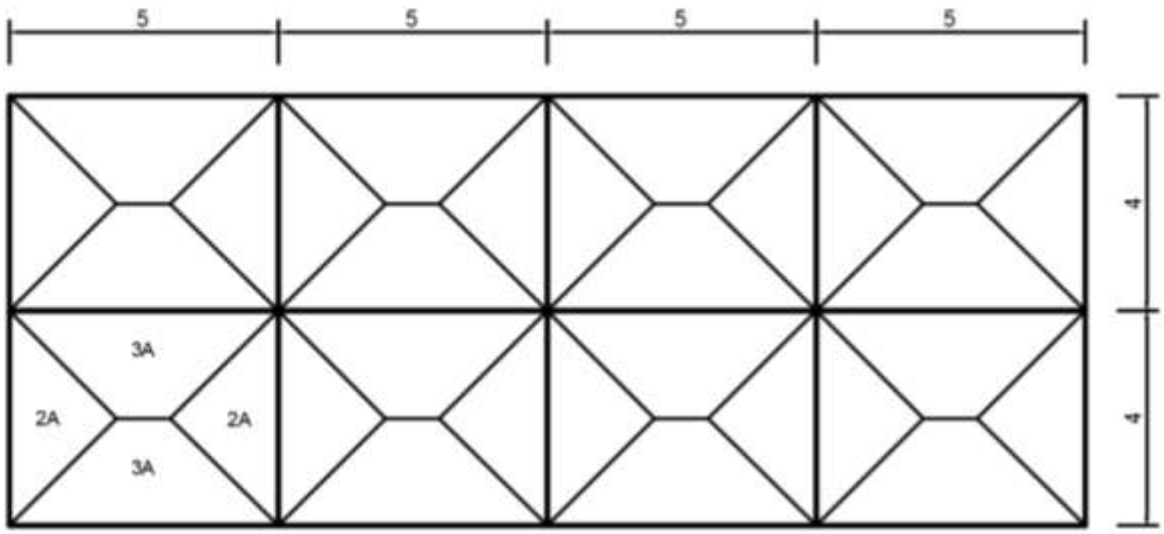


Figure 9: Load distribution from slabs to beams

For outer 5m beams the distributed load is;
G = 11.7 kN/m (trapezoidal section)   Q = 4 kN/m (triangular section)

For inner 5m beams the distributed load is;
G = 23.4 kN/m (trapezoidal section)   Q = 8 kN/m (triangular section)

For outer 4m beams the distributed load is;
G = 5.85 kN/m (triangular section)   Q = 4 kN/m (triangular section)

For inner 4m beams the distributed load is;
G = 11.7 kN/m (triangular section)   Q = 8 kN/m (triangular section)

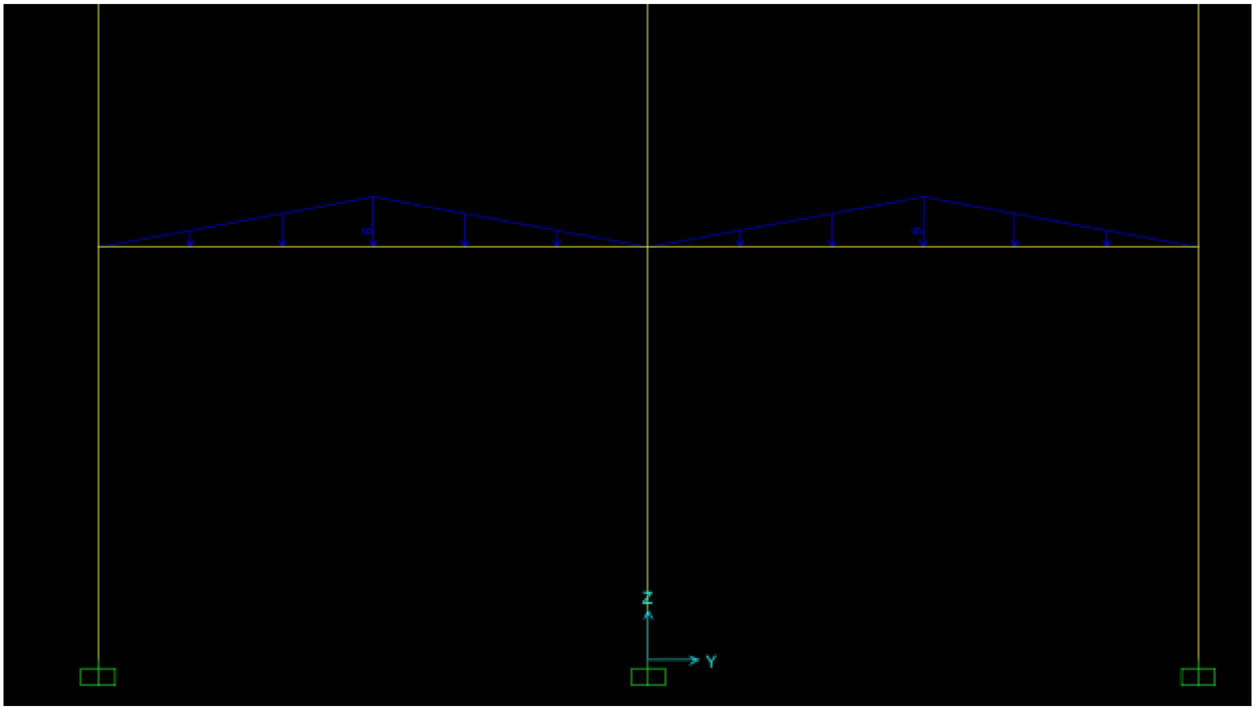


Figure 10: Inner 4m beam live load arrangement

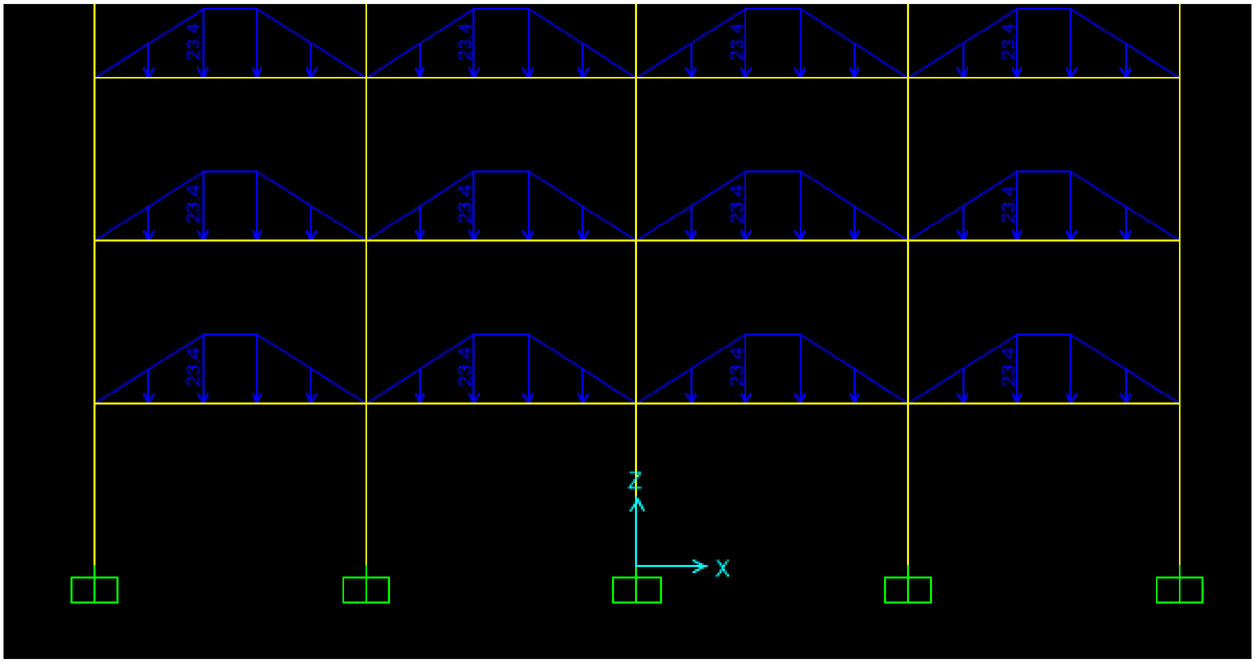


Figure 11: Inner 5m Beams dead load arrangement

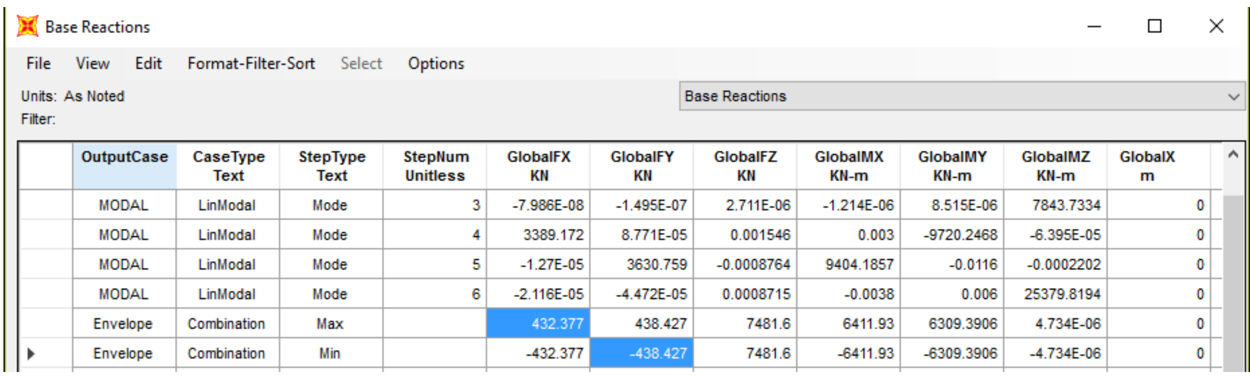
From the first part of the homework, period of the building is calculated as 1.01 sec. For this period value, Sae(T)/Ra(T)= 0.81 is obtained from reduced response spectrum. A(T)=0.66 and total mass of the building is calculated as 716.775 tons in the first part of the homework.

$$V_t = \frac{WA(T_1)}{R_a(T_1)} \geq 0.10\, A_o\, I\, W$$

V_t = 716.775*9.81*0.66/8 > 0.1*0.4*1*716.775*9.81

V_t = 580.1>281.3

After doing modal spectrum analysis, base shear force from x-direction is 432.4 kN and from y-direction 438.4 kN. By implementing SRSS,



OutputCase	CaseType Text	StepType Text	StepNum Unitless	GlobalFX KN	GlobalFY KN	GlobalFZ KN	GlobalMX KN-m	GlobalMY KN-m	GlobalMZ KN-m	GlobalX m
MODAL	LinModal	Mode	3	-7.986E-08	-1.495E-07	2.711E-06	-1.214E-06	8.515E-06	7843.7334	0
MODAL	LinModal	Mode	4	3389.172	8.771E-05	0.001546	0.003	-9720.2468	-6.395E-05	0
MODAL	LinModal	Mode	5	-1.27E-05	3630.759	-0.0008764	9404.1857	-0.0116	-0.0002202	0
MODAL	LinModal	Mode	6	-2.116E-05	-4.472E-05	0.0008715	-0.0038	0.006	25379.8194	0
Envelope	Combination	Max		432.377	438.427	7481.6	6411.93	6309.3906	4.734E-06	0
Envelope	Combination	Min		-432.377	-438.427	7481.6	-6411.93	-6309.3906	-4.734E-06	0

Figure 12: Base Reactions

V_1 = 432.4 kN

V_2 = 438.4 kN

V_{tB} = $(432.4^2+438.4^2)^{0.5}$ = 615.8 kN

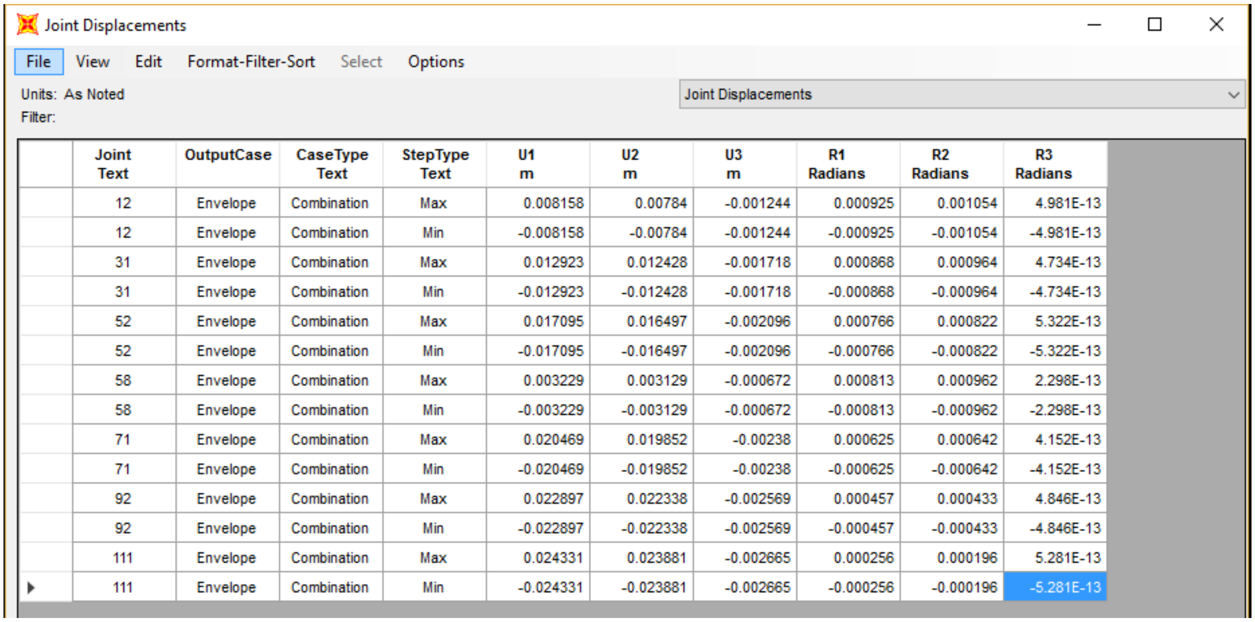
Modification check;

V_{tB} = 615.8 > 0.9*V_t = 0.8*580.1= 464.08 kN, hence, no modification is needed.

- <u>Drift Check</u>

$$\frac{(\delta_i)_{max}}{h_i} \leq 0.02$$

where h=3 m



Joint Displacements

File View Edit Format-Filter-Sort Select Options

Units: As Noted

Filter:

Joint Displacements

Joint Text	OutputCase	CaseType Text	StepType Text	U1 m	U2 m	U3 m	R1 Radians	R2 Radians	R3 Radians
12	Envelope	Combination	Max	0.008158	0.00784	-0.001244	0.000925	0.001054	4.981E-13
12	Envelope	Combination	Min	-0.008158	-0.00784	-0.001244	-0.000925	-0.001054	-4.981E-13
31	Envelope	Combination	Max	0.012923	0.012428	-0.001718	0.000868	0.000964	4.734E-13
31	Envelope	Combination	Min	-0.012923	-0.012428	-0.001718	-0.000868	-0.000964	-4.734E-13
52	Envelope	Combination	Max	0.017095	0.016497	-0.002096	0.000766	0.000822	5.322E-13
52	Envelope	Combination	Min	-0.017095	-0.016497	-0.002096	-0.000766	-0.000822	-5.322E-13
58	Envelope	Combination	Max	0.003229	0.003129	-0.000672	0.000813	0.000962	2.298E-13
58	Envelope	Combination	Min	-0.003229	-0.003129	-0.000672	-0.000813	-0.000962	-2.298E-13
71	Envelope	Combination	Max	0.020469	0.019852	-0.00238	0.000625	0.000642	4.152E-13
71	Envelope	Combination	Min	-0.020469	-0.019852	-0.00238	-0.000625	-0.000642	-4.152E-13
92	Envelope	Combination	Max	0.022897	0.022338	-0.002569	0.000457	0.000433	4.846E-13
92	Envelope	Combination	Min	-0.022897	-0.022338	-0.002569	-0.000457	-0.000433	-4.846E-13
111	Envelope	Combination	Max	0.024331	0.023881	-0.002665	0.000256	0.000196	5.281E-13
111	Envelope	Combination	Min	-0.024331	-0.023881	-0.002665	-0.000256	-0.000196	-5.281E-13

Figure 13: Joint Displacements

$$\delta_i = R\,\Delta_i \qquad \text{where} \qquad \Delta_i = d_i - d_{i-1}$$

Table 4: Drift Check

	U1(x) (m)	U2(y) (m)	$(R^*\Delta_i/h_i)x$	Status (if<0.02)	$(R^*\Delta_i/h_i)y$	Status(if<0.02)
1st Story	0.00323	0.00313	0.00861	**OK**	0.00834	**OK**
2nd Story	0.00816	0.00784	0.01314	**OK**	0.01256	**OK**
3rd Story	0.01292	0.01243	0.01271	**OK**	0.01223	**OK**
4th Story	0.01710	0.01650	0.01113	**OK**	0.01085	**OK**
5th Story	0.02047	0.01985	0.00900	**OK**	0.00895	**OK**
6th Story	0.02290	0.02234	0.00647	**OK**	0.00663	**OK**
7th Story	0.02433	0.02388	0.00382	**OK**	0.00411	**OK**

According to drift check requirements, each story drifts within given intervals, i.e. there is no story drift problem. Since there is no drifting problem, no shear wall is needed in the structural system.

Design Procedure

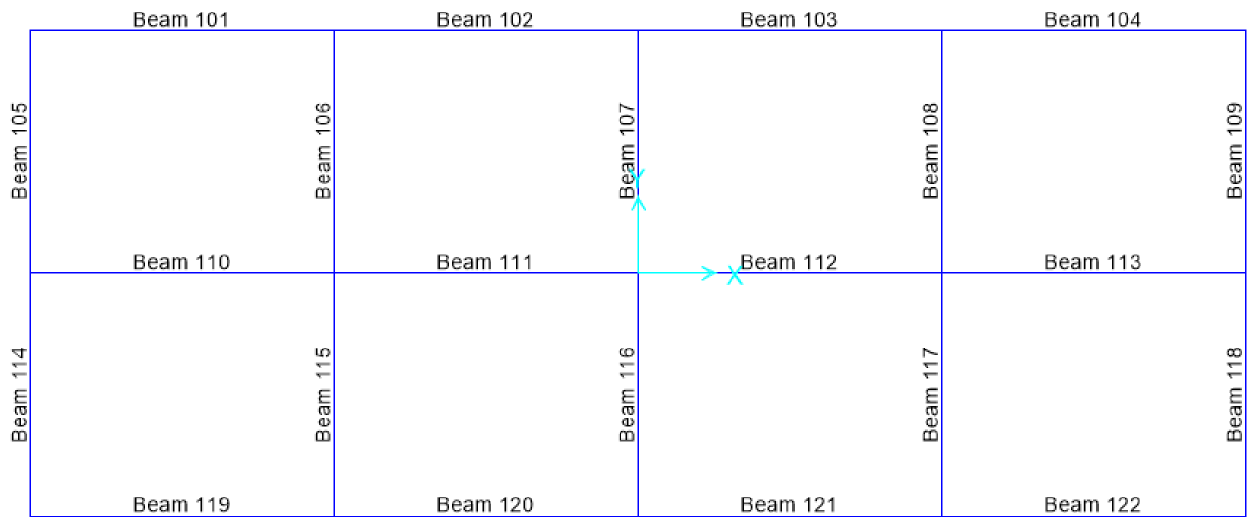


Figure 14: 1st story beam labels

By doing analysis in SAP2000 with prespecified load combinations, shear forces and moments on the beam elements are found as follows;

TABLE: Element Forces - Frames

Frame	Station	OutputCase	CaseType	StepType	P	V2	V3	T	M2	M3	FrameElem	ElemStation
Text	m	Text	Text	Text	KN	KN	KN	KN-m	KN-m	KN-m	Text	m
Beam 116	0	1.0G+1.0Q+1.0EY	Combination	Max	0	13.049	0	1.891E-08	0	54.5371	Beam 116-1	0
Beam 116	0	1.0G+1.0Q-1.0EY	Combination	Max	0	13.049	0	1.891E-08	0	54.5371	Beam 116-1	0
Beam 116	0	Envelope	Combination	Max	0	13.049	1.555E-16	1.6045	0	54.5371	Beam 116-1	0
Beam 107	4	1.0G+1.0Q+1.0EY	Combination	Max	0	53.121	0	6.926E-10	0	54.5371	Beam 107-1	4
Beam 107	4	1.0G+1.0Q-1.0EY	Combination	Max	0	53.121	0	6.926E-10	0	54.5371	Beam 107-1	4
Beam 107	4	Envelope	Combination	Max	0	53.121	1.555E-16	1.6045	6.221E-16	54.5371	Beam 107-1	4
Beam 117	0	1.0G+1.0Q+1.0EY	Combination	Max	0	12.874	0	0.0523	0	54.1948	Beam 117-1	0
Beam 117	0	1.0G+1.0Q-1.0EY	Combination	Max	0	12.874	0	0.0523	0	54.1948	Beam 117-1	0
Beam 117	0	Envelope	Combination	Max	0	12.874	1.555E-16	2.0637	0	54.1948	Beam 117-1	0
Beam 115	0	1.0G+1.0Q+1.0EY	Combination	Max	0	12.874	0	-0.0149	0	54.1948	Beam 115-1	0
Beam 115	0	1.0G+1.0Q-1.0EY	Combination	Max	0	12.874	0	-0.0149	0	54.1948	Beam 115-1	0
Beam 115	0	Envelope	Combination	Max	0	12.874	1.555E-16	1.9966	0	54.1948	Beam 115-1	0
Beam 108	4	1.0G+1.0Q+1.0EY	Combination	Max	0	53.029	0	-0.0149	0	54.1948	Beam 108-1	4
Beam 108	4	1.0G+1.0Q-1.0EY	Combination	Max	0	53.029	0	-0.0149	0	54.1948	Beam 108-1	4
Beam 108	4	Envelope	Combination	Max	0	53.029	1.555E-16	1.9966	6.221E-16	54.1948	Beam 108-1	4
Beam 106	4	1.0G+1.0Q+1.0EY	Combination	Max	0	53.029	0	0.0523	0	54.1948	Beam 106-1	4
Beam 106	4	1.0G+1.0Q-1.0EY	Combination	Max	0	53.029	0	0.0523	0	54.1948	Beam 106-1	4

It is observed that middle elements take more forces than outer elements. Also, there are two critical elements in each case due to symmetry in each direction.

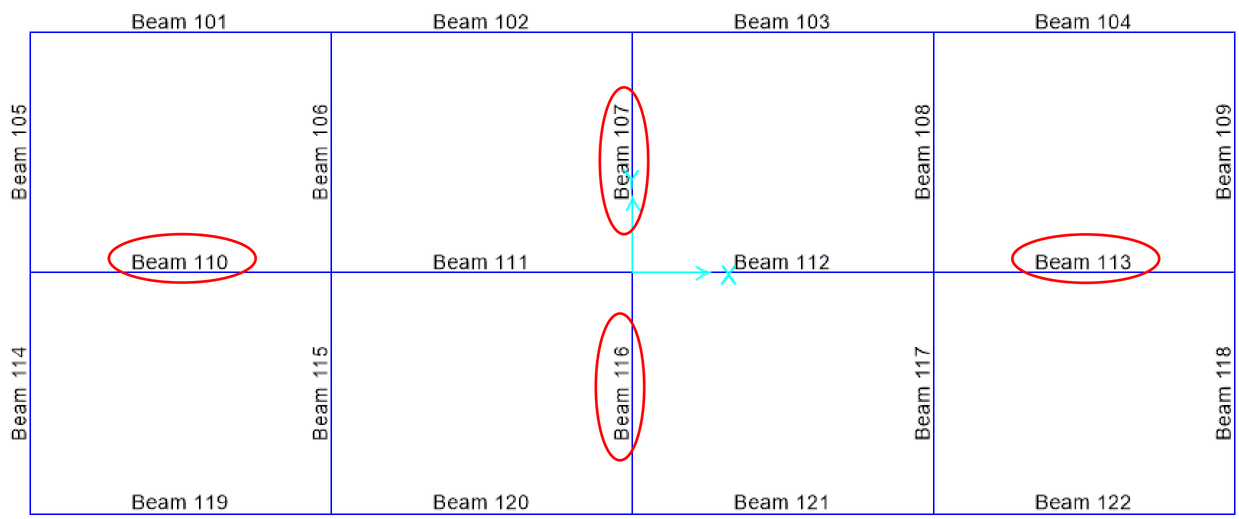


Figure 15: Most critical beams on the first floor

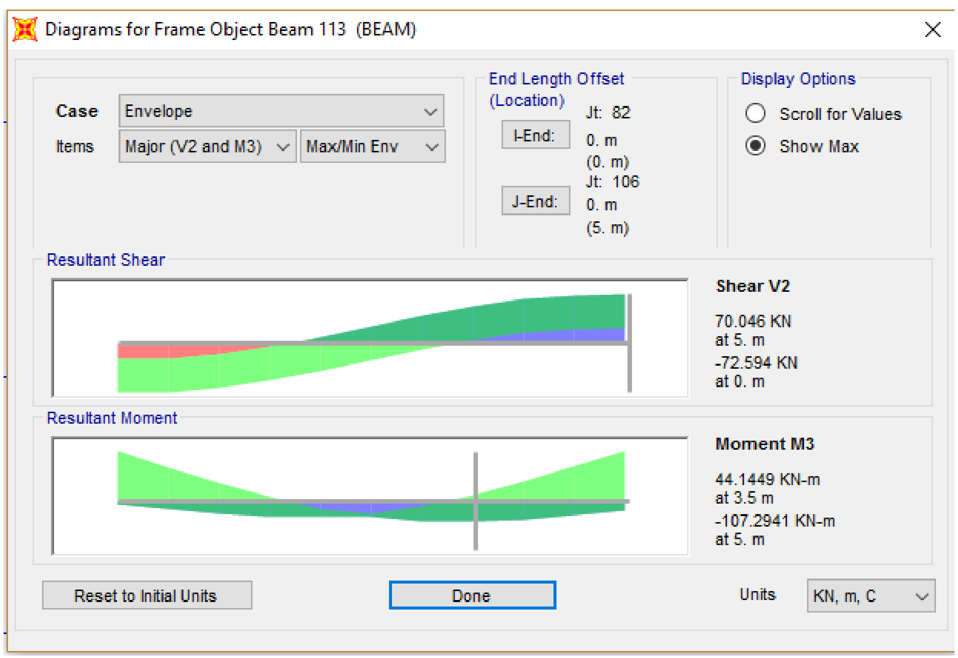


Figure 16: Most critical beam in x-direction

End Moments are -107.3 kN-m and 44.1 kN-m and span moment is 34.1 kN-m

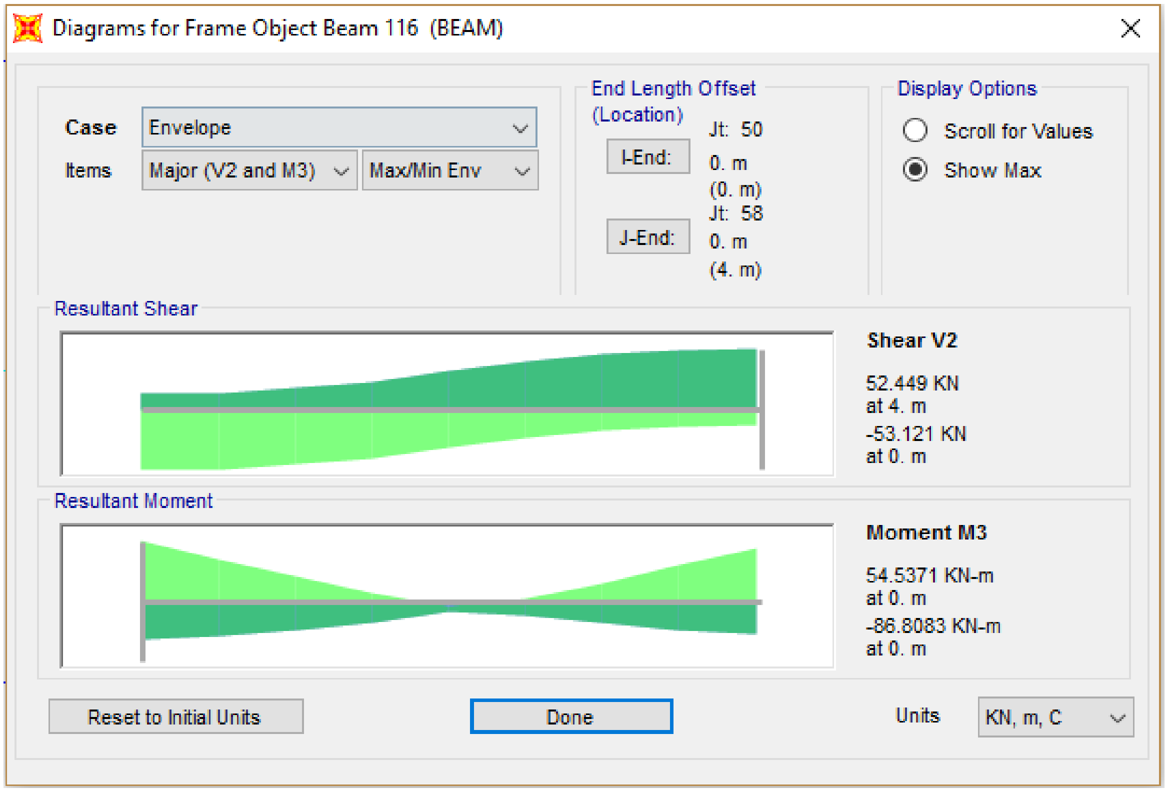


Figure 17: Most critical beam in y-direction

End Moments are -86.8 kN-m and 54.5 kN-m and span moment is 20.7 kN-m

Since all material properties are not given, some of them are needed to be assumed certain values so as to continue the design procedure. Concrete type is assumed as C25 since it is widely used and easily accessible. Steel reinforcement is selected as S420 and clear cover is assumed as 4 cm. d=410 mm, b_w=250 mm.

Hence, $f_{cd} = 25/1.5 = 16.67$ Mpa , $f_{yd} = 420/1.15 = 365$ Mpa

Minimum required steel area is $(A_s)_{min} = b_w d*(0.8 f_{ctd}/f_{yd}) = 250*410*0.8*1.17/365 = 262.85\ mm^2$

<u>Beam design in x-direction;</u>

Since the most critical beams in x-direction are Beam 110 and Beam 113, all the beams in x-direction are going to be designed according to those beams. End Moments are -107.3 kN-m and 44.1 kN-m and span moment is 34.1 kN-m

Negative moment at support; M_d = -107.3 kN-m K=250*410*410/107.3/1000 = 391.7 mm^2/kN and Kl value for C25 type of concrete is 380 mm^2/kN. Hence K>Kl there is no need for compression steel.

A_s = 107.3*10^3/0.365/0.86/410 = 833.7 mm^2 6Ø14 = 923.6 mm^2 Hence **6Ø14 bars at the support top**

Positive moment at support; M_d = 44.1 kN-m K=250*410*410/44.1/1000 = 952.9 mm^2/kN and Kl value for C25 type of concrete is 380 mm^2/kN. Hence K>Kl there is no need for compression steel.

A_s = 44.1*10^3/0.365/0.86/410 = 342.66 mm^2 3Ø14 = 461.8 mm^2 Hence **3Ø14 bars at the support bottom**

Since span moment is smaller than the support bottom moment, by continuing to use the same reinforcement in the support bottom, required reinforcement at the span is satisfied. **3Ø14 bars at the span bottom**

<u>Beam design in y-direction;</u>

Since the most critical beams in y-direction are Beam 107 and Beam 116, all the beams in x-direction are going to be designed according to those beams. End Moments are -86.8 kN-m and 54.5 kN-m and span moment is 20.7 kN-m

Negative moment at support; M_d = -86.8 kN-m K=250*410*410/86.8/1000 = 484.16 mm^2/kN and Kl value for C25 type of concrete is 380 mm^2/kN. Hence K>Kl there is no need for compression steel.

A_s = 86.8*10^3/0.365/0.86/410 = 674.44 mm^2 5Ø14 = 769.7 mm^2 Hence **5Ø14 bars at the support top**

Positive moment at support; M_d = 54.51 kN-m K=250*410*410/54.5/1000 = 771.1 mm^2/kN and Kl value for C25 type of concrete is 380 mm^2/kN. Hence K>Kl there is no need for compression steel.

A_s = 54.5*10^3/0.365/0.86/410 = 423.5 mm^2 3Ø14 = 461.8 mm^2 Hence **3Ø14 bars at the support bottom**

Since span moment is smaller than the support bottom moment, by continuing to use the same reinforcement in the support bottom, required reinforcement at the span is satisfied. **3Ø14 bars at the span bottom**

Since there is not much differences between beams in x-direction and beams in y-direction, reinforcement detailing is chosen the same for all beams. That is; **6Ø14 bars at the support top** and **3Ø14 bars at the support bottom**

Plastic moment capacities of the beams at each end is calculated;

$$Mri,j \approx As * fyd * j * d \text{ where } j = 0.86$$

Mri = $(923.6*0.86*365*410)*10^{-6}$ = 118.87 kN.m for negative moment (at the support top)
Mri = $(461.8*0.86*365*410)*10^{-6}$ = 59.4 kN.m for positive moment (at the support bottom& span)
Since all reinforcement is symetrical;

Mrj = 118.87 kN.m negative moment

Mrj = 59.4 kN.m positive moment

Therefore;

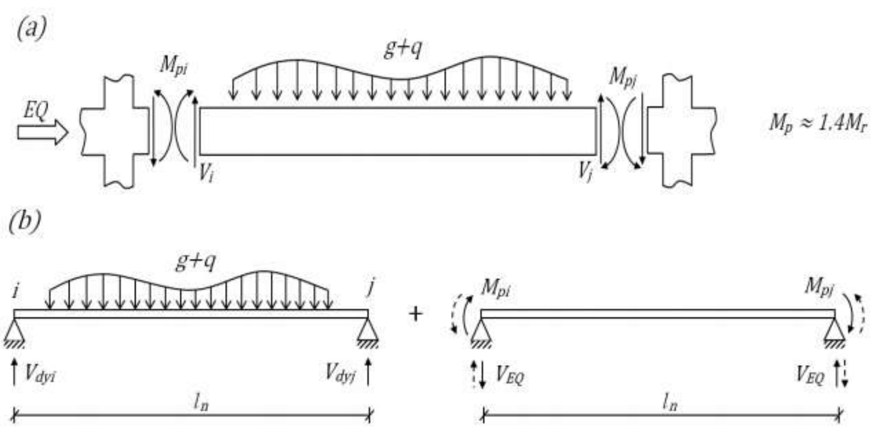
Mpi = Mri * 1.4 = 166.4 kN.m negative moment at one end

= 83.2 kN.m positive moment at one end

Mpj= Mrj * 1.4 = 166.4 kN.m negative moment at the other end

= 83.2 kN.m positive moment at the other end

Shear Design of Beams



$$V_{e\ i,j} = V_{dy\ i,j} \mp V_{EQ} \quad \text{where} \quad V_{EQ} = \frac{M_{pi} + M_{pj}}{l_n}$$

$$V_e < V_r \qquad\qquad V_e \leq 0.22\ b_w\ d\ f_{cd}$$

Figure 18: Shear design formulas

	Beams in x-direction	Beams in y-direction
Ln	5 m	4 m
$\mathbf{V_{EQ}}$ $(M_{pi}+ M_{pj})/Ln$	49.92 kN	62.4 kN
$\mathbf{V_{dy}}$ (g+q)	48.37 kN	20.062 kN
$\mathbf{V_e}$ $(V_{dy} \pm V_{EQ})$	98.29 kN	82.462 kN

$$\mathbf{V_e = 98.3\ kN}$$

$$V_c = 0.8*(0.65*f_{ctd}*b_w*d*\varphi),\quad \varphi=1 \text{ since } Nd=0$$

$$\mathbf{Vc= 62.18\ kN}$$

$$V_r = V_c + V_w \geq V_e$$

$$\frac{Asw}{s} = \frac{Ve - Vc}{fyd * d} = 0.241mm$$

If Ø8 ($Asw=2*50=100.5\ mm^2$) is used for stirrup reinforcement then s = 410 mm. Therefore Ø8/400 can be used in the spans. However, according to TS500, spacing at the span can not be smaller than 20 cm and also spacing near the supports can not be smaller than 10 cm. Consequently, stirrup spacing at the span is 20 cm and at the beam ends 10 cm.

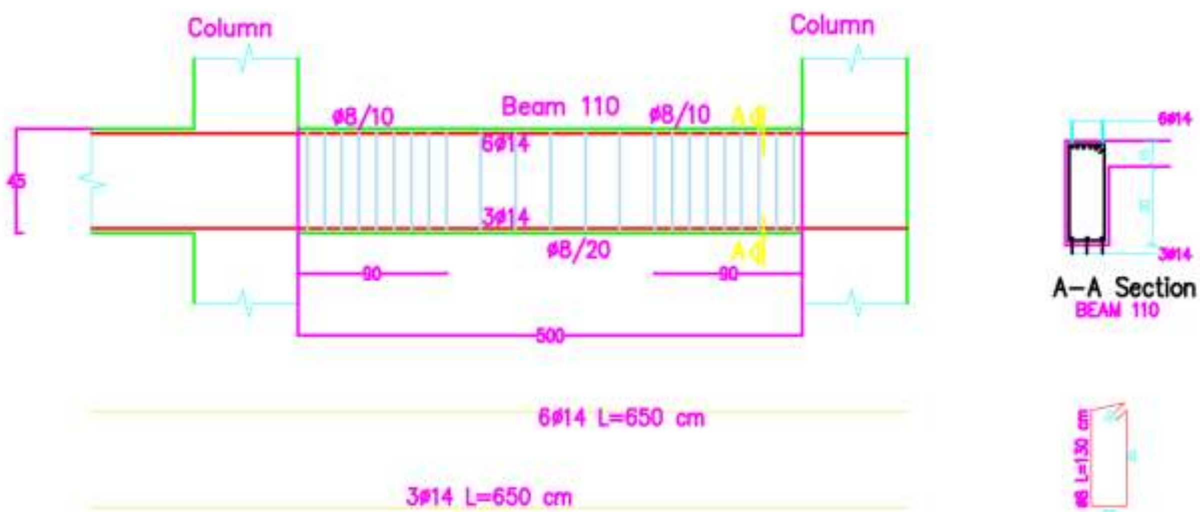


Figure 19: Beam reinforcement detailing

- <u>Column Design</u>

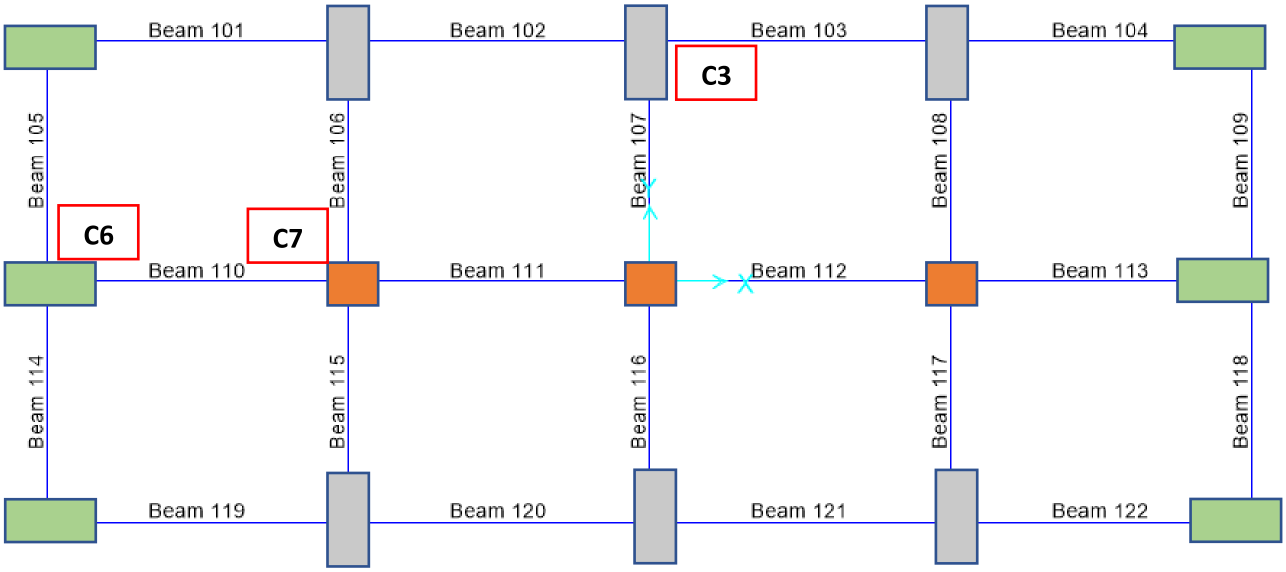


Figure 20: Column locations

Square Column 40x40 (Column 7 in SAP2000 Model);

$Md_{3\text{-}3} = 78.2$ kN-m, $Md_{2\text{-}2} = 79.3$ kN-m and Nd = 902.94 kN

DİKDÖRTGEN KOLON TASARIMI İÇİN HESAP TABLOSU

Tasarım Değerleri	
N_d (kN)	M_d $^{(*)}$ (kN.m)
902.0	79.3

Donatı Deseni Düzenlemesi		
d' (mm)	Donatı sırası (ds) $2 \le ds \le 6$	$\lambda^{(**)}$
40	3	0.25

Donatı Yerleşimi		
Donatı	Gerekli Donatı Alanı (A_{si}) (mm^2)	Kesit Merkezine Uzaklık (x_i) (mm)
1) Üst	600	160
2) Alt	600	-160
3)Ara 1	400	0
4) Ara 2	0	0
5) Ara 3	0	0
6) Ara 4	0	0

Malzeme - Beton	
f_{ck} (MPa)	γ_{mc}
25	1.50

Malzeme - Çelik	
f_{yk} (MPa)	γ_{ms}
420	1.15

Kesit Geometrisi	
Genişlik (b) (mm)	Yükseklik (h) (mm)
400	400

NOTLAR:
1. Bu sayfada yalnızca gri fon ile işareti bölümlere veri girişi yapılabilir.
2. Donatıların kesit merkezine olan uzaklıkları, kesit geometrisi ve donatı sırası tanımlandığında kendiliğinden belirlenir.

(*) Tasarım momenti ikinci mertebe etkileri içermelidir.
(**) Ara donatı oranı (Toplam ara donatı alanı / Toplam donatı alanı)

ρ_t = 0.010
N_d = 902.0 kN
M_r = 180.4 kN.m

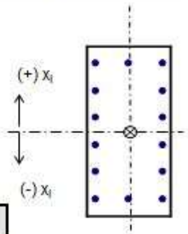
Formu Sil | Hesapla

D İ K D Ö R T G E N   K E S İ T   A N A L İ Z İ

BETON ve ÇELİK MODELLERİ				
f_{ck} (MPa)	γ_{mc}	f_{yk} (MPa)	γ_{ms}	E_s (MPa)
25	1.50	420	1.15	200,000

BU PROGRAMDA:
1) Betonun çekme dayanı ihmal edilmektedir.
2) Beton basınç dağılımı dikdörtgen alınmaktadır.
3) Çelik modelinde pekleşme ihmal edilmektedir.
4) Sargı etkisi göz önüne alınmamaktadır.

KESİT GEOMETRİSİ	
Genişlik (b) (mm)	Yükseklik (h) (mm)
400	400



DONATI DÜZENLEMESİ		
No.	Donatı Alanı (mm^2)	Kesit Merkezinden Uzaklık (x_i) (mm)
1	603	160
2	603	-160
3	402	0
4		
5		
6		

Tüm Formu Sil

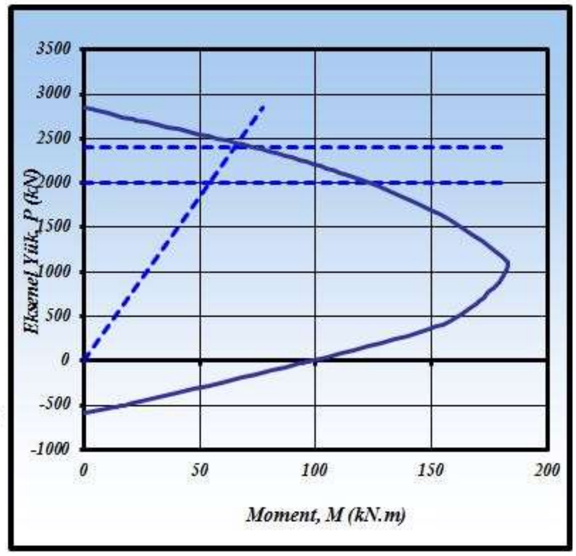
N-M Diyagramı Çiz

N (kN): 902.0

M (kN.m): 179.6

Yeni hesap değeri gir

Hesapla



Etkileşim diyagramında kesikli çizgiler ile TS500 ve Deprem Yönetmeliği eksenel yük sınırları ve TS500 minimum dışmerkezlik sınırı gösterilmektedir.

Rectangular Column 50x25 (Column 6 in SAP2000 Model);

$Md_{3\text{-}3}$ = 88.4 kN-m, $Md_{2\text{-}2}$ = 29.5 kN-m and Nd = 564.1 kN

DİKDÖRTGEN KOLON TASARIMI İÇİN HESAP TABLOSU

Tasarım Değerleri	
N_d (kN)	M_d (*) (kN.m)
564.0	88.4

Donatı Deseni Düzenlemesi		
d' (mm)	Donatı sırası (ds) $2 \le ds \le 6$	$\lambda^{(**)}$
40	3	0.25

Donatı Yerleşimi		
Donatı	Gerekli Donatı Alanı (A_{si}) (mm^2)	Kesit Merkezine Uzaklık (x_i) (mm)
1) Üst	469	210
2) Alt	469	-210
3)Ara 1	313	0
4) Ara 2	0	0
5) Ara 3	0	0
6) Ara 4	0	0

Malzeme - Beton	
f_{ck} (MPa)	γ_{mc}
25	1.50

Malzeme - Çelik	
f_{yk} (MPa)	γ_{ms}
420	1.15

Kesit Geometrisi	
Genişlik (b) (mm)	Yükseklik (h) (mm)
250	500

NOTLAR:
1. Bu sayfada yalnızca gri fon ile işaretli bölümlere veri girişi yapılabilir.
2. Donatıların kesit merkezine olan uzaklıkları, kesit geometrisi ve donatı sırası tanımlandığında kendiliğinden belirlenir.

(*) Tasarım momenti ikinci mertebe etkileri içermelidir.
(**) Ara donatı oranı (Toplam ara donatı alanı / Toplam donatı alanı)

ρ_t = 0.010
N_d = 564.0 kN
M_r = 176.5 kN.m

Formu Sil

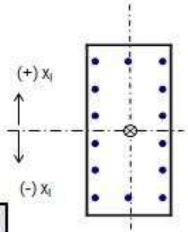
Hesapla

DİKDÖRTGEN KESİT ANALİZİ

BETON ve ÇELİK MODELLERİ				
f_{ck} (MPa)	γ_{mc}	f_{yk} (MPa)	γ_{ms}	E_s (MPa)
25	1.50	420	1.15	200,000

BU PROGRAMDA:
1) Betonun çekme dayanı ihmal edilmektedir.
2) Beton basınç dağılımı dikdörtgen alınmaktadır.
3) Çelik modelinde pekleşme ihmal edilmektedir.
4) Sargı etkisi göz önüne alınmamaktadır.

KESİT GEOMETRİSİ	
Genişlik (b) (mm)	Yükseklik (h) (mm)
250	500



DONATI DÜZENLEMESİ		
No.	Donatı Alanı (mm^2)	Kesit Merkezinden Uzaklık (x_i) (mm)
1	603	210
2	603	-210
3	402	0
4		
5		
6		

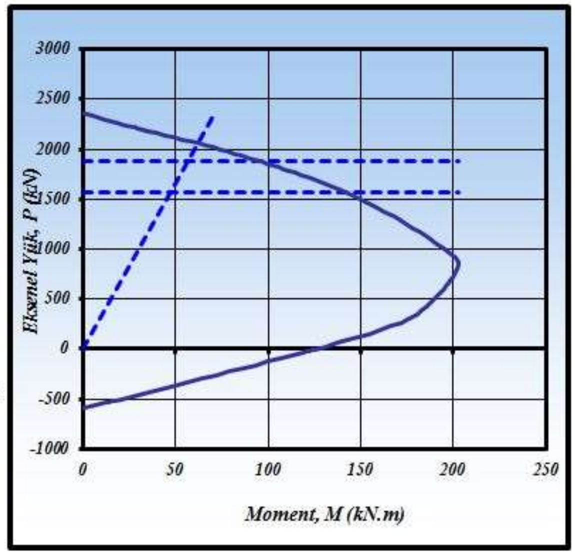
Tüm Formu Sil

N-M Diyagramı Çiz

N (kN): 564.0
M (kN.m): 193.0

Yeni hesap değeri gir | Hesapla

Etkileşim diyagramında kesikli çizgiler ile TS500 ve Deprem Yönetmeliği eksenel yük sınırları ve TS500 minimum dışmerkezlik sınırı gösterilmektedir.



Rectangular Column 25x50 (Column 3 in SAP2000 Model);

$Md_{3\text{-}3}$ = 28.5 kN-m, $Md_{2\text{-}2}$ = 76.7 kN-m and Nd = 658.3 kN

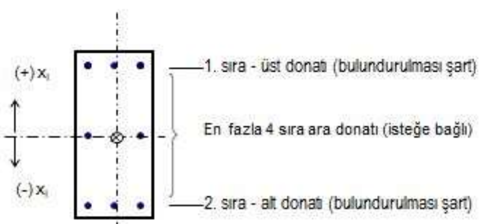
DIKDORTGEN KOLON TASARIMI IÇIN HESAP TABLOSU

Tasarım Değerleri	
N_d (kN)	M_d (*) (kN.m)
658.0	76.7

Donatı Deseni Düzenlemesi		
d' (mm)	Donatı sırası (ds) $2 \le ds \le 6$	λ (**)
40	3	0.25

Donatı Yerleşimi		
Donatı	Gerekli Donatı Alanı (A_{si}) (mm^2)	Kesit Merkezine Uzaklık (x_i) (mm)
1) Üst	469	210
2) Alt	469	-210
3)Ara 1	313	0
4) Ara 2	0	0
5) Ara 3	0	0
6) Ara 4	0	0

Malzeme - Beton	
f_{ck} (MPa)	γ_{mc}
25	1.50



Malzeme - Çelik	
f_{yk} (MPa)	γ_{ms}
420	1.15

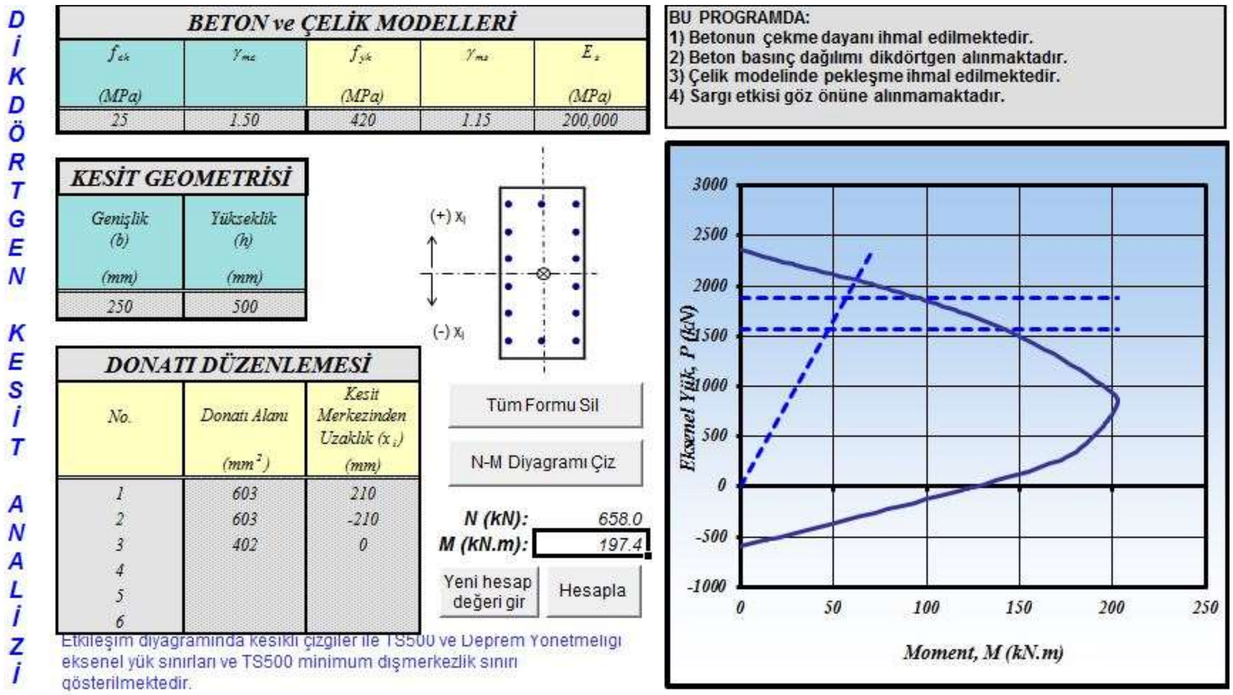
Kesit Geometrisi	
Genişlik (b) (mm)	Yükseklik (h) (mm)
250	500

NOTLAR:
1. Bu sayfada yalnızca gri fon ile işaretli bölümlere veri girişi yapılabilir.
2. Donatıların kesit merkezine olan uzaklıkları, kesit geometrisi ve donatı sırası tanımlandığında kendiliğinden belirlenir.

(*) Tasarım momenti ikinci mertebe etkileri içermelidir.
(**) Ara donatı oranı (Toplam ara donatı alanı / Toplam donatı alanı)

ρ_t = 0.010
N_d = 658.0 kN
M_r = 179.0 kN.m

Formu Sil | Hesapla



From the beam design part

$$(M_{ra} + M_{rü}) > 1.2*(M_{ri} + M_{rj}) = 1.2*(118.87 + 59.4) = 213.92$$

Table 5: Strong Column Weak Beam Principle Check

40*40 Column		Status	50*25 Column		Status	25*50 Column		Status
Mrj	59.4	OK	Mrj	59.4	OK	Mrj	59.4	OK
Mri	118.87		Mri	118.87		Mri	118.87	
Mra	179.6		Mra	193.0		Mra	197.4	
Mrü	179.6		Mrü	193.0		Mrü	197.4	

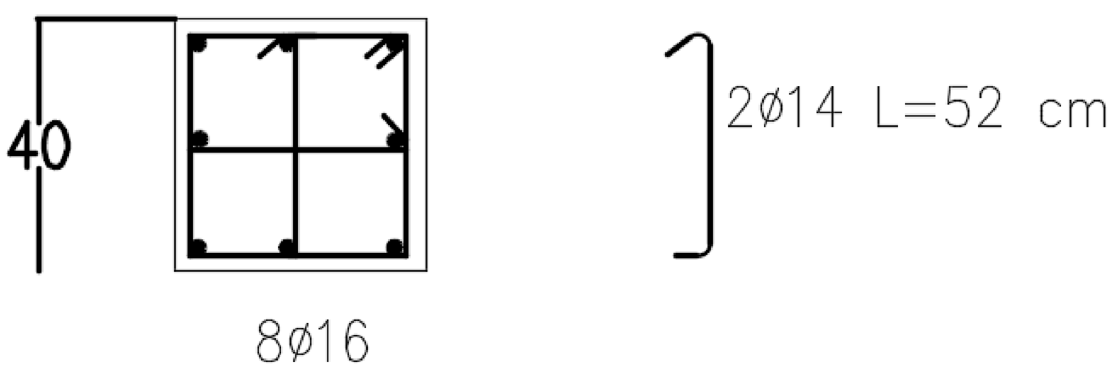


Figure 21: 40x40 Column C7 Reinforcement Detailing

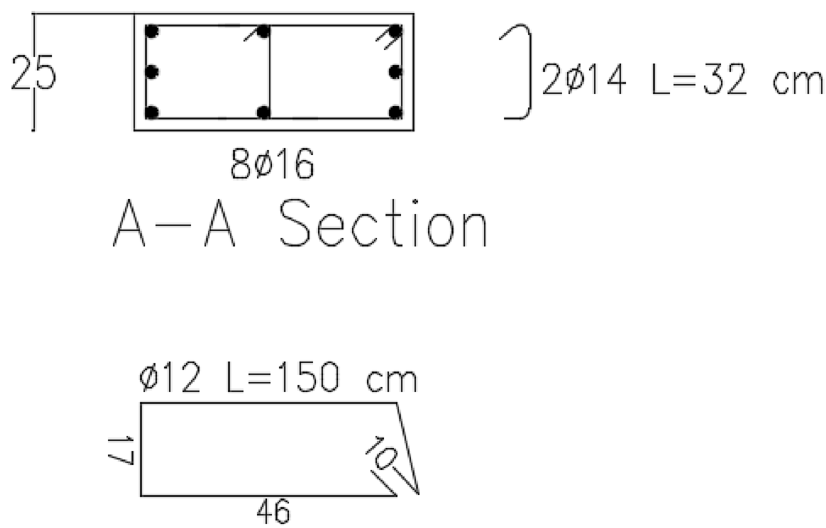


Figure 22: Column 50x25 Reinforcement Detailing

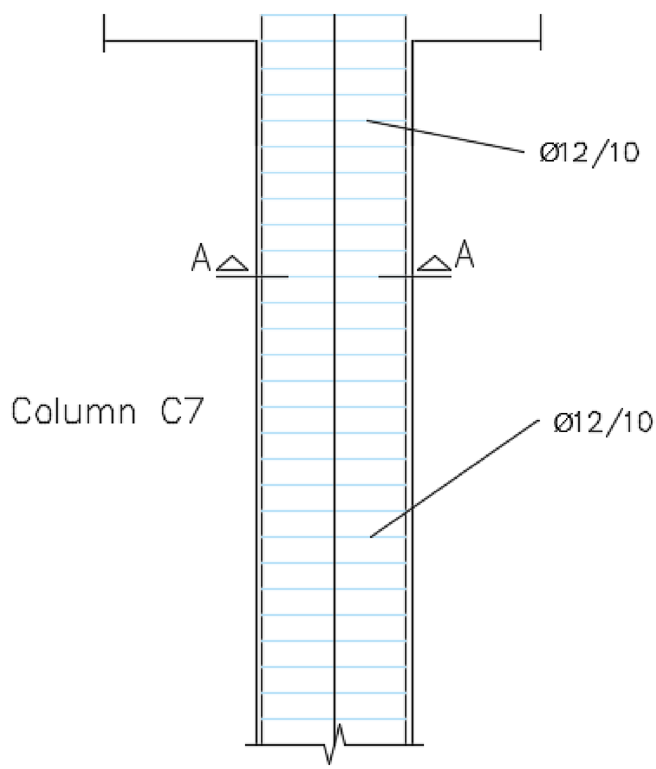


Figure 23:Column C7, C3 and C6 Shear Reinforcement Detailing

Conclusion

This assignment is based on modal analysis and software SAP2000 usage. For the earthquake situation, equivalent lateral load and response spectrum analysis is performed according to previously given information. While designing the frame elements, no dimension change or shear wall addition is required. Because, all checks according to TS500 are satisfied. Story drift ratios are checked and it is seen that ratios are smaller than the critical value. The 7-story building is located on Earthquake Region 1, that means ductility level of the structural system should be high. In the design process, enhanced ductility level is selected. After making analysis with enhanced ductility level (R=8), no dimension modification is required.