Graduation Project
Structural Design of Nablus Club

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Introduction:

*Nablus Club is a sport club located in Nablus in Al-Aghwar.

*It has an area of 2310 m2.

*The general plan is shown in the following figure:

The building is separated by two expansion joints into three parts.

Materials properties :

- Concrete with a unit weight =25 $KN\backslash m^3$
- Compressive strength of concrete f'c=28 MPA.
- Yielding stress (strength) Fy= 420 MPA.
- Other non structural materials as shown in table:

Material	Unit weight KN/m3
Blocks	12
Plastering	23
Mortar	23
Marble	26.5
Filling material	20
Insulation	0.4

Loads:

* For super imposed load S.I.D=5 $Kn\backslash m^2$.

* For live load L.L=5 $KN\backslash M^2$ (from code tables).

Soil properties:

Angle of friction $\phi = 12^{o}$ (assumed) .

Cohesion C = 22 $KN\backslash m^2$ (assumed).

Unit weight for soil =18 $KN\backslash m^3$ (assumed).

General bearing capacity equation used to calculate the bearing capacity of the soil and found to be: $q_{all} = 170\ KN/m^2$

Seismic properties:

*The seismic zone factor, Z=0.20.

*Design parameters of equivalent lateral force method -IBC2009:

- The mapped spectral accelerations for a 1- second period: S_1= 0.25.

- The mapped spectral accelerations for short period:

Ss= 0.5.

-Site classified as "C" according to Table 1613.5.2

$S_{MS} = F_a S_s = 0.6$

$S_{M1} = F_v S_1 = 0.3875$

- Occupancy category of structure: III

- The response modification factor R=3.5.

- Risk category of structure: III

-Important factors by risk category of structure: $I_e = 1.25$-

-Cs: The seismic response coefficient.-

$C_s = \frac{S_{DS}}{R/I_e}$,Cs = 0.10

Base shear = Cs*W

W: source of mass that participate in resisting earthquake loads.

Design codes and design methods :

1-ACI 318-08 code (American Concrete Institute) used for design concrete members.

2- IBC 2009 (International Building Code) for seismic loads calculations.

3-AISC 360-05 Code in steel design.

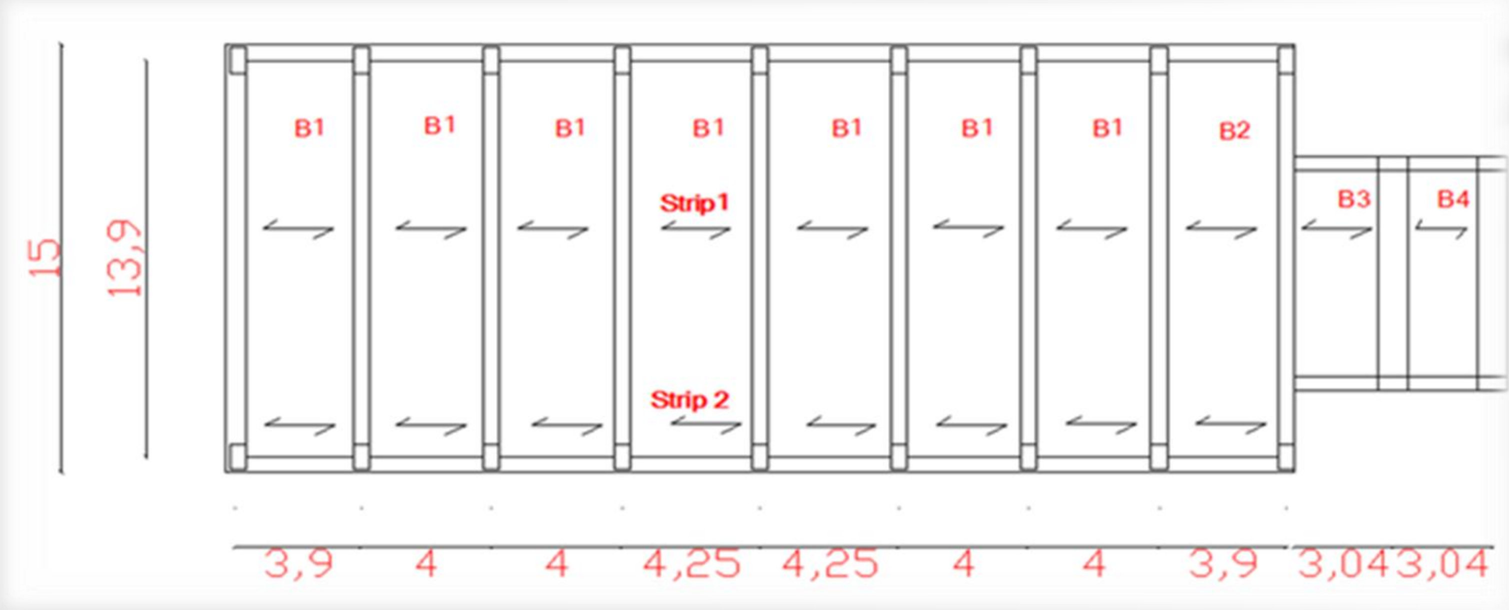
* Ultimate strength method of design for concrete.

* Load combinations used from ACI code (sec. 9.2.1)

Preliminary design of slabs and beams:

The structure composed of three parts, each part analyzed and designed individually.

Part A:



The structural system to be used in this part is One way solid slab with main dropped beams in y _ direction.

Depending on deflection criteria:

h= 0.18m , d=0.14m (cover =40mm)

$W_u = 20\ KN/m^2$.

* Check shear $\Phi V_c = 99.2\ Kn > V_u = 38.13\ Kn$.

Flexural design:

Positive moment :

M_{u1}=22.4 KN.m

$$\rho = \frac{0.85f'c}{fy}\left(1-\sqrt{1-\frac{2.61Mu*10^6}{bd^2f'c}}\right) = 0.00269$$

$$As = \rho bd = 0.00269 * 1000 * 150 = 403.5\ mm^2$$

,use4φ12mm/m.

Negative moment:

M_{u2} =22.19 KN.m

As=401 mm^2,use 4φ12 mm/m.

Design of beams:

*Beam 1:

h=900mm , b_f =3500mm.

*Beam 2:

h=900mm , b_f = 3500mm.

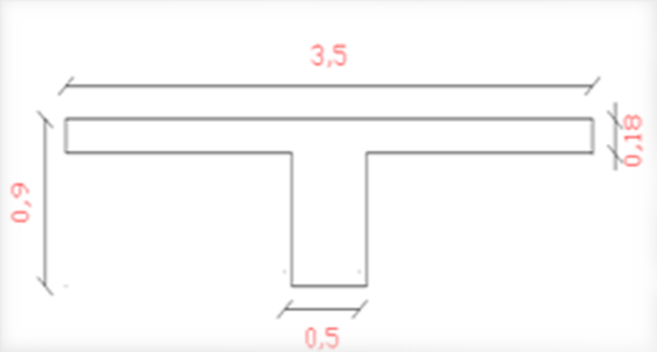
*Beam 3:

h=500mm , b_f = 2000mm.

*Beam 4:

h=500mm , b_f = 1100mm.

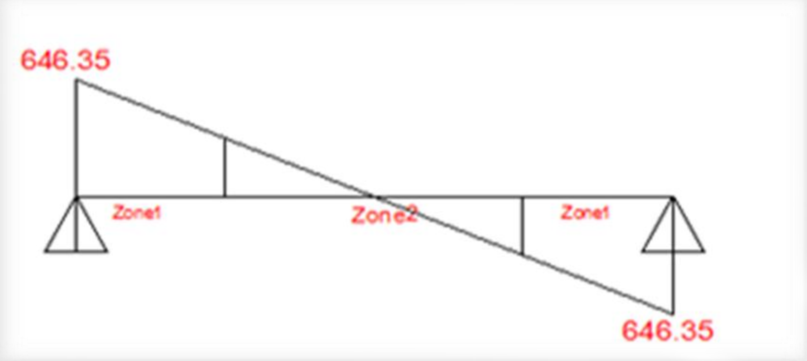
(Beams depths calculated based on deflection criteria ACI code , widths based on code equations)



B1 preliminary design:

Shear design:

Vu_1=646.35- 93*.84=568.23 KN



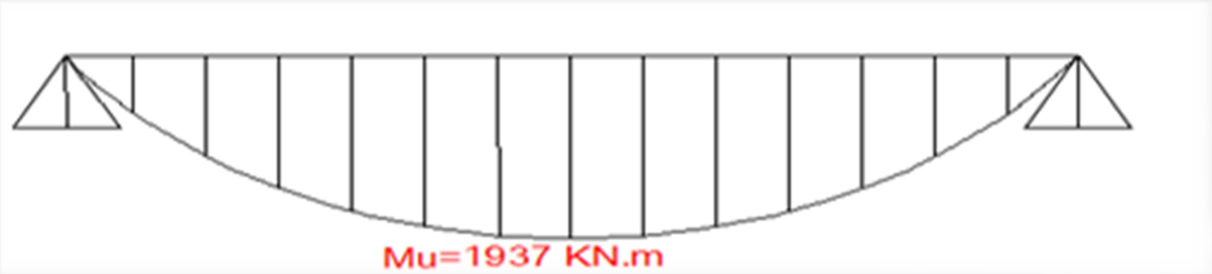
$$V_c = \frac{1}{6}\sqrt{f'_c}bd = \frac{\frac{1}{6}\sqrt{28}(500)(840)}{1000} = 370.4\ KN$$

$$Vn = \frac{Vu}{0.75} = 757.64KN$$

$$\frac{Av}{s} = \frac{Vs}{fy\,d} = \frac{387.24 * 10^3}{420 * 840} = 1.1\ mm^2/mm$$

Use 1φ10mm /150 mm C/C

Longitudinal steel :



$$M_u = \frac{Wul_n^2}{8} = \frac{93 * 13.9^2}{8} = 2246.1\ KN.m$$

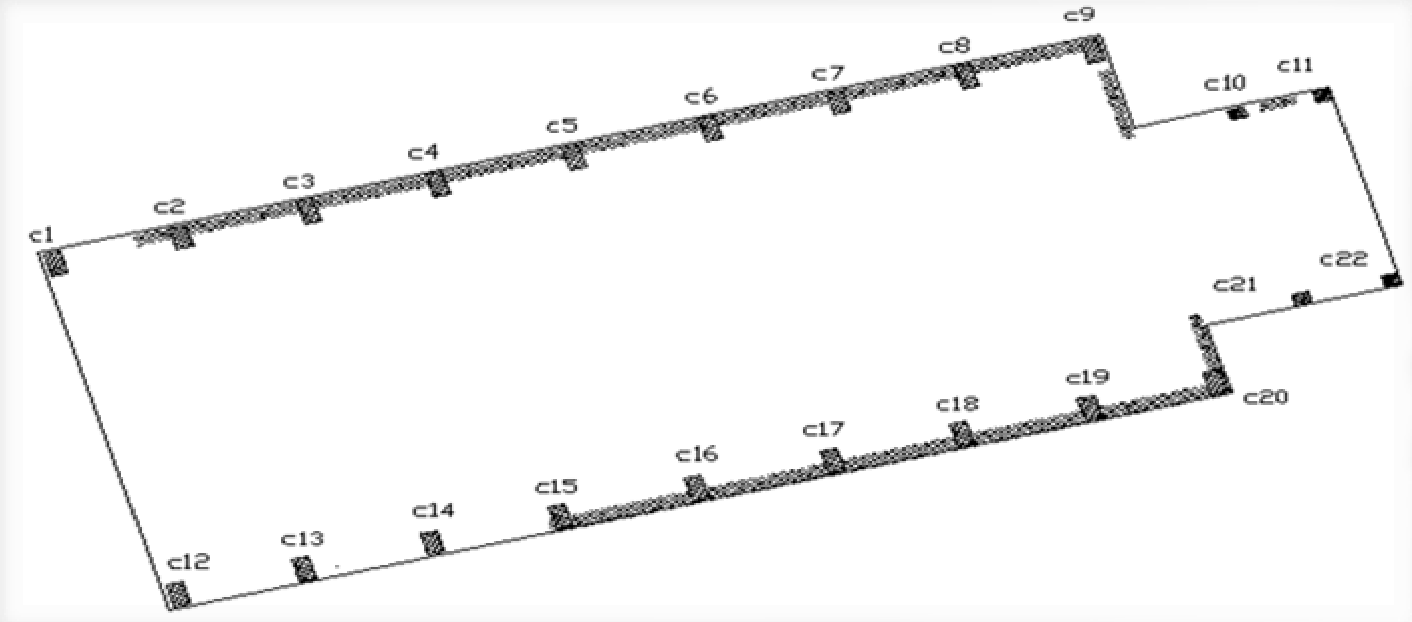
b=3500, d=840

$$\rho = 0.00246$$

As=7232 mm^2 , use 9φ32 mm

Columns preliminary design:

Part A:

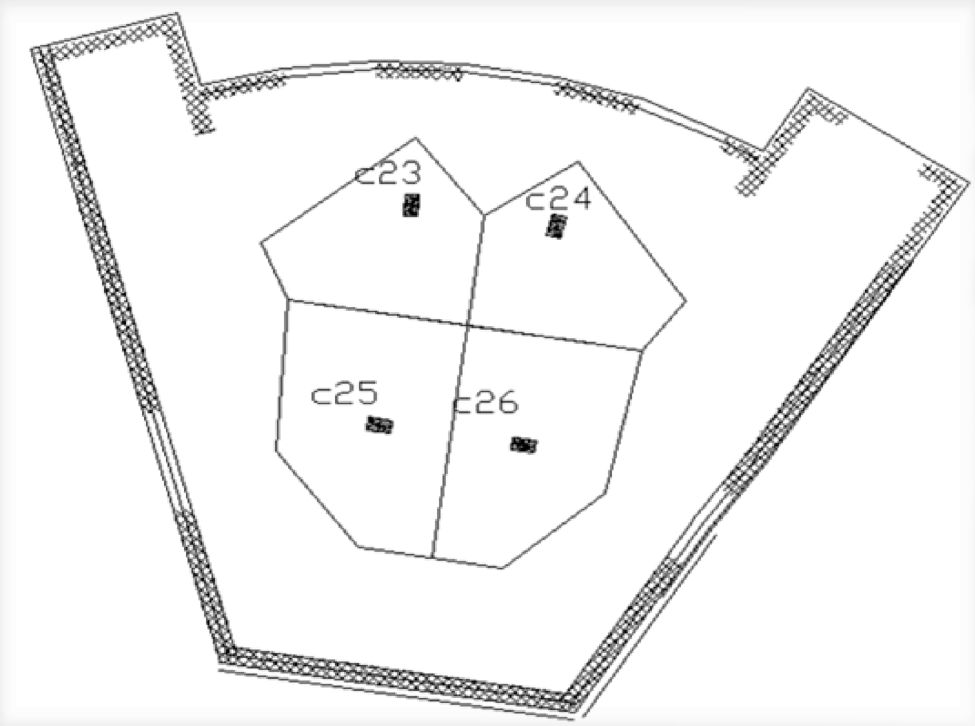


Analysis and design of columns (as a part of frame) using Sap2000:

Columns dimensions: 0.70 m*0.90 m

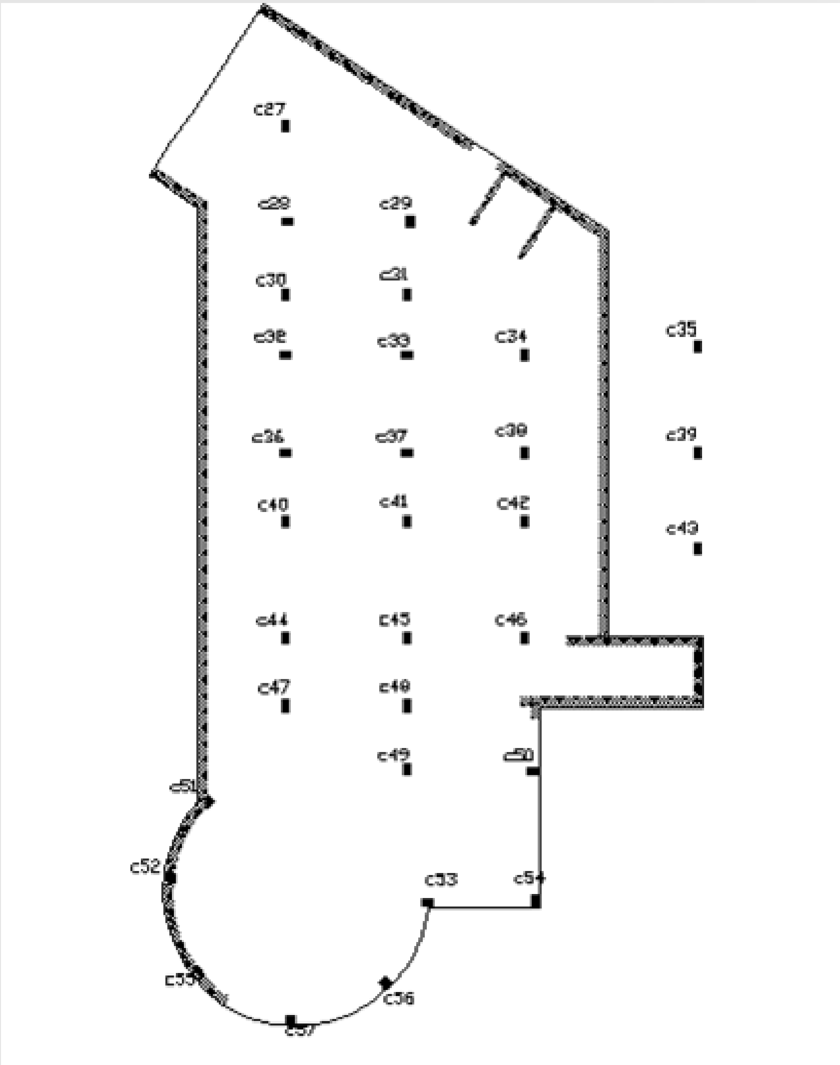
Parts B&C:

Use tributary area method to calculate the load on each column.



Part B

Part C :


c27
c28
c29
c30
c31
c32
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c35
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c41
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c55
c56
c57

Columns are sorted into many groups according to ultimate loads on each column.

Group 1: Columns 23,24,34,35,39,43 C50 and C52.
Pu=955 Kn

Pu=.8Φ[.85f'c(Ag-As)+Fy*As]=

Use column 300 *300 mm^2

As=.01*300*300=900 mm^2

Use6 Φ14mm

use 1Φ10 mm stirrup/200mm.

The final results for the preliminary design for columns can be summarized as shown in the following table:

Group	Load Pu	Dimension	Reinforcement	Stirrups
C23,C24,C34,C35,C39,C43, C50 and C52	955 KN	300*300 mm^2	6 Φ14mm	1Φ10 mm stirrup/200mm
C25,C26,C29,C30,C31,C37,C38,C42,C46,C47, C48,C49,C54,C55,C56 &C57	1477 KN	300 *400 mm^2	6 Φ16 mm	1Φ10 mm stirrup/250mm
C28, C36,C40,C41,C44 &C45	1964 KN	300 *500 mm^2	6 Φ18 mm	1Φ10 mm stirrup/250mm
C27,C32,C33,C51 &C53	2426 KN	300 *600 mm^2	6 Φ20 mm	1Φ10 mm stirrup/300m.

3D modeling in Sap2000 & Final Design:

Sap2000 program (ver.14) was used to analyze and design of structure and the following stages were followed:

1)Modeling:

*First a grid system was constructed for each part using a distances obtained from AUTOCAD plans.

*Define sections for beams , columns and slabs(obtained from preliminary design).

*Define used materials (concrete &reinforcing steel).

*Drawing columns , beams then slabs and walls.

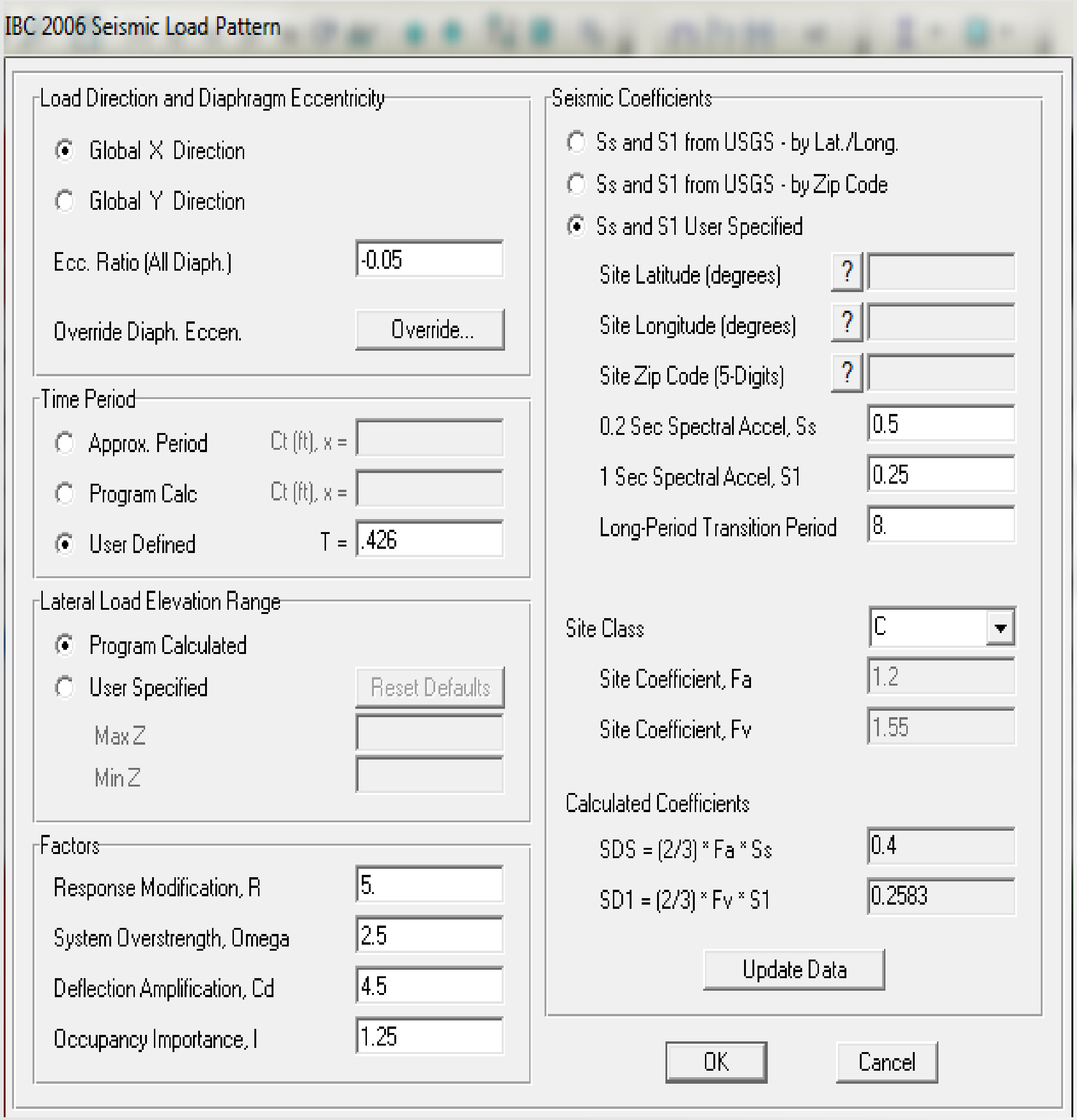
*Divide areas of slabs and walls(meshing) and edit joints.

*Assign supports , and define load patterns.

*Assign loads (live , super imposed dead & soil loads).

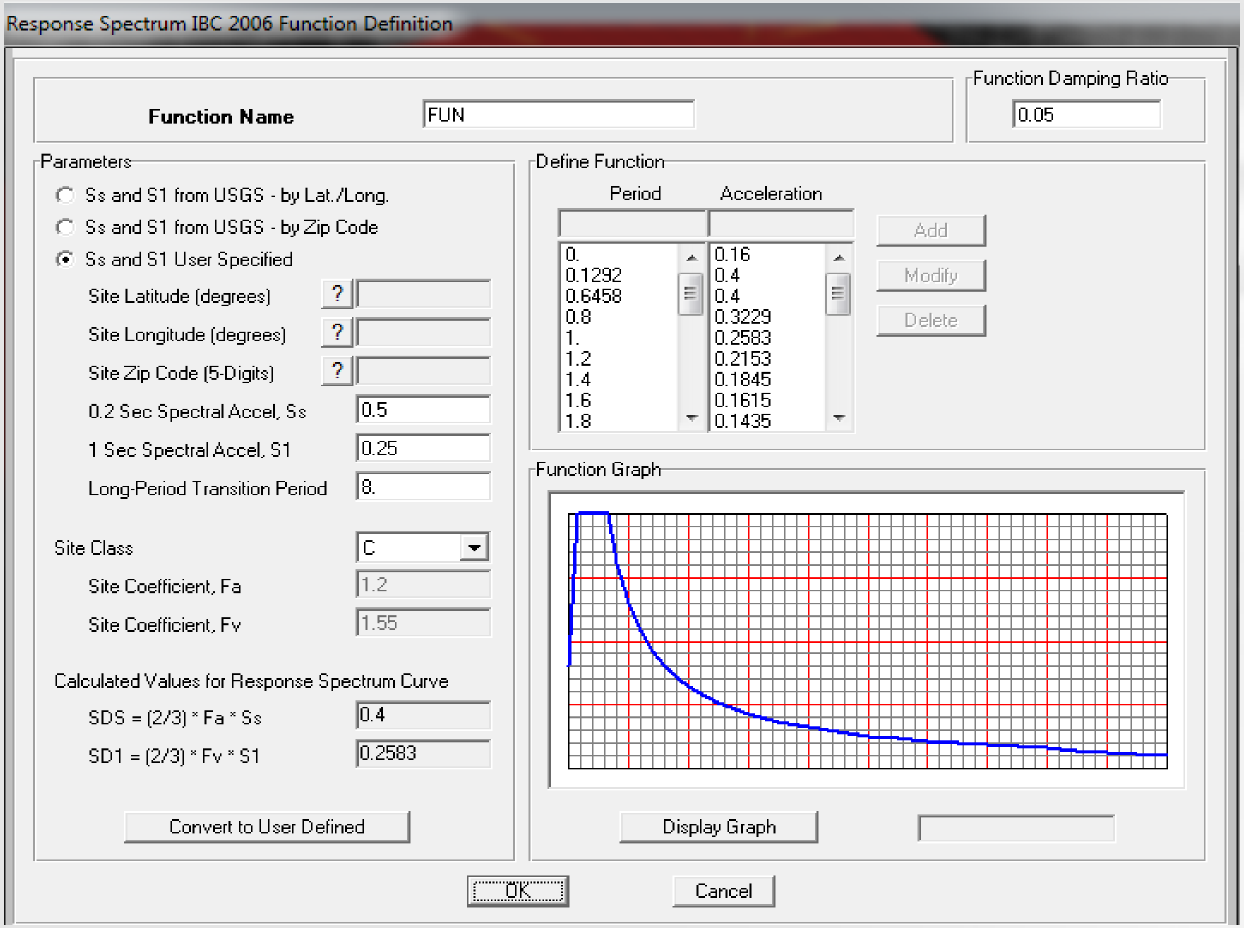
*Define seismic properties needed for equivalent static method (A sample is shown in the following figure).

*Calculate the value of base reaction from equivalent static method manually to compare later with sap result.

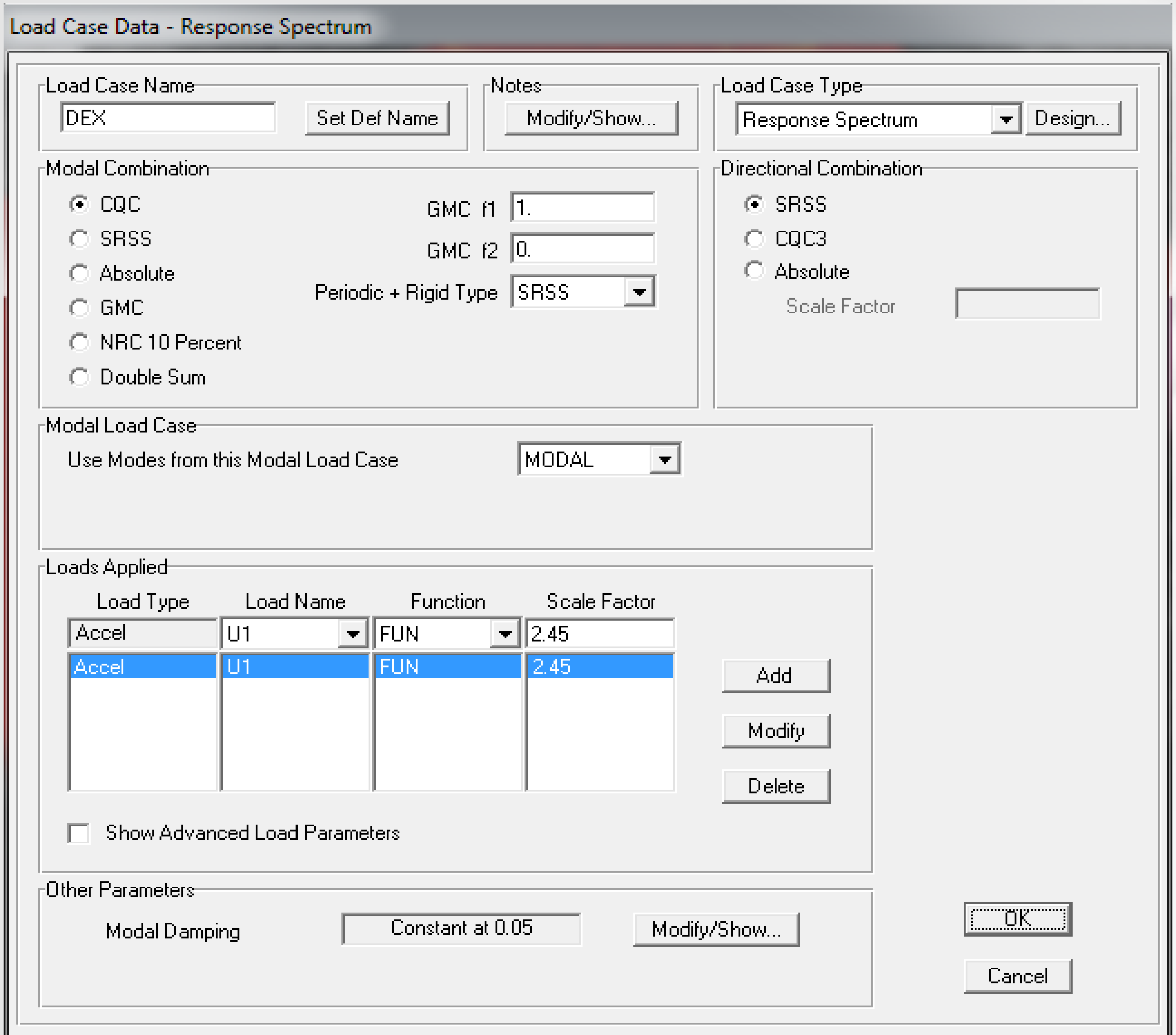

IBC 2006 Seismic Load Pattern
Load Direction and Diaphragm Eccentricity
Global X Direction
Global Y Direction
Ecc. Ratio (All Diaph.)
-0.05
Override Diaph. Eccen.
Override...
Time Period
Approx. Period
Ct (ft), x =
Program Calc
Ct (ft), x =
User Defined
T =
.426
Lateral Load Elevation Range
Program Calculated
User Specified
Reset Defaults
Max Z
Min Z
Factors
Response Modification, R
5.
System Overstrength, Omega
2.5
Deflection Amplification, Cd
4.5
Occupancy Importance, I
1.25
Seismic Coefficients
Ss and S1 from USGS - by Lat./Long.
Ss and S1 from USGS - by Zip Code
Ss and S1 User Specified
Site Latitude (degrees)
Site Longitude (degrees)
Site Zip Code (5-Digits)
0.2 Sec Spectral Accel, Ss
0.5
1 Sec Spectral Accel, S1
0.25
Long-Period Transition Period
8.
Site Class
C
Site Coefficient, Fa
1.2
Site Coefficient, Fv
1.55
Calculated Coefficients
SDS = (2/3) * Fa * Ss
0.4
SD1 = (2/3) * Fv * S1
0.2583
Update Data
OK
Cancel

*Dynamic Analysis:

-Define response spectrum function as shown in the following figure:



-Define dynamic load case as shown in the following figure:



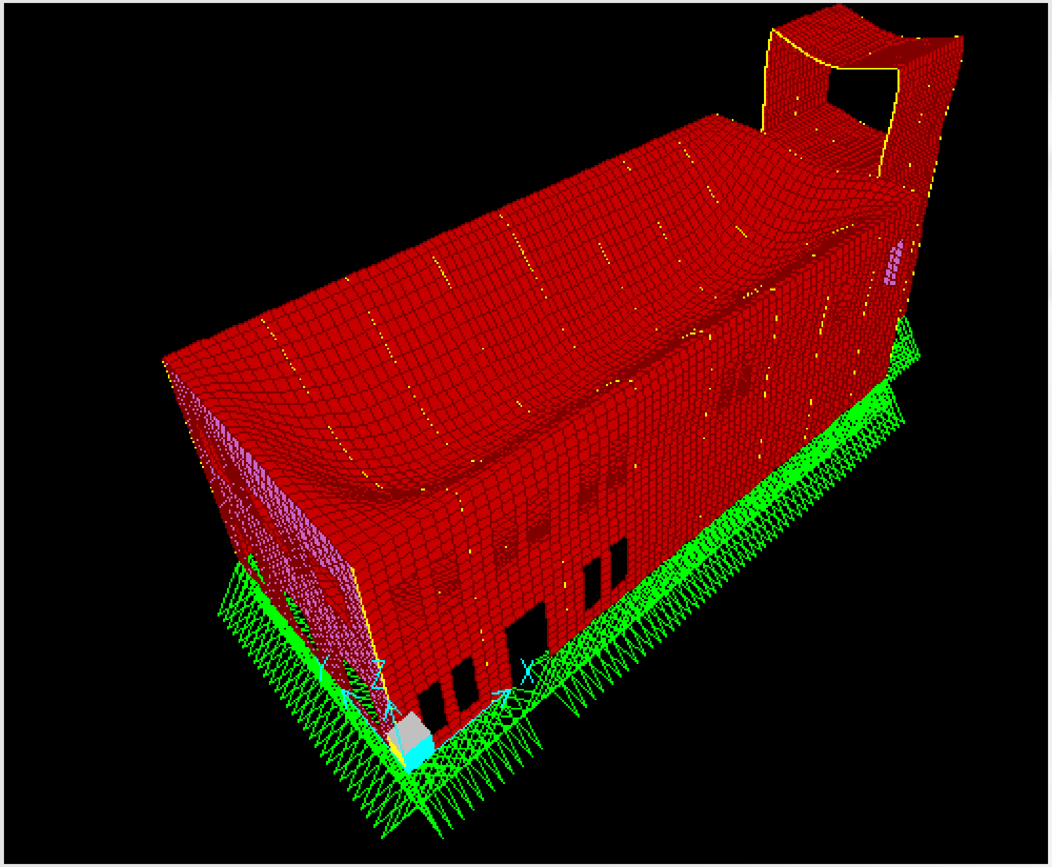
Ritz Vectors approach is used in modal analysis.

Now the scale factors must be modified according to IBC code in a way that the base shear from dynamic analysis is not less than 0.85 the base shear from equivalent static method.

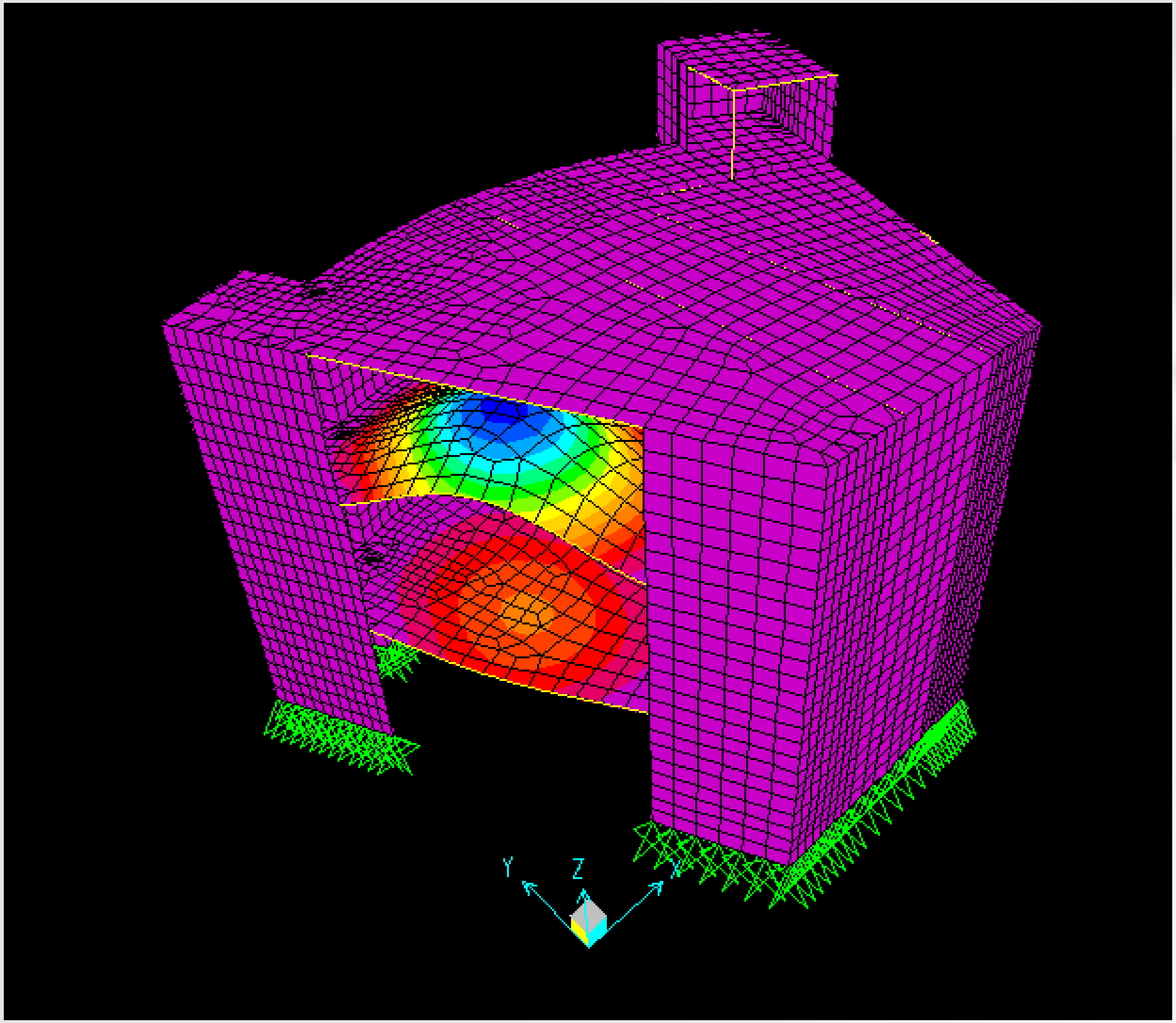
2)Run And Verification Of Model:

The following figures shown the complete models in sap:

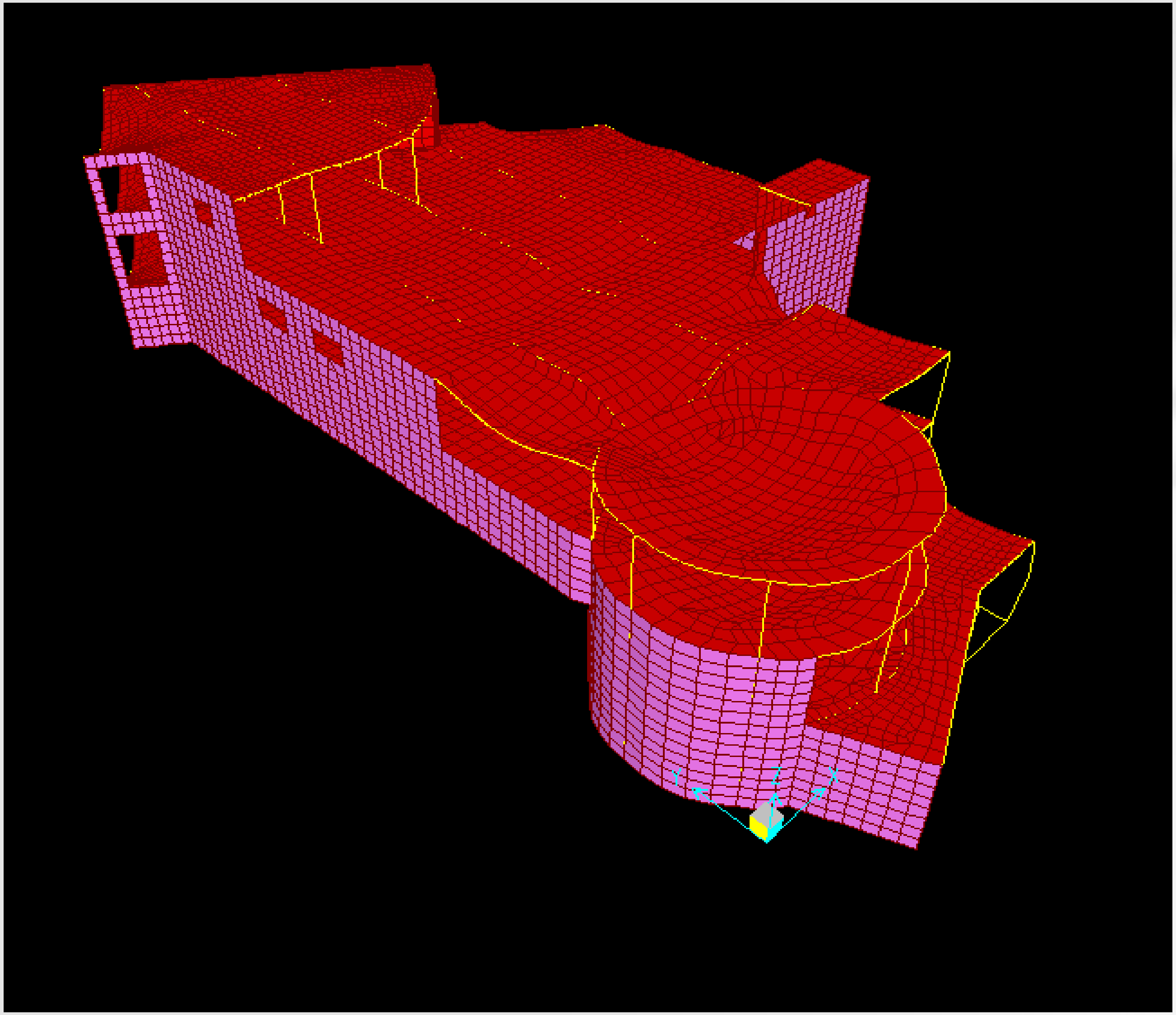
Part A:



Part B:



Part C:



3)Checks for the model:

a)Compatibility check.

b)Equilibrium check:

Check that total reactions from dead , and Live loads obtained by tables of SAP2000 are equal to the total dead and live loads exposed to the structure.

As example of table of base reactions from SAP:

OutputCase Text	CaseType Text	GlobalFX KN	GlobalFY KN	GlobalFZ KN	GlobalMX KN-m	GlobalMY KN-m	GlobalMZ KN-m	GlobalX m
DEAD	LinStatic	000000001754	000000003634	20791.293	144215.3523	-405770.59	000000002641	0

And for all parts the error was less than 5%.

c) Internal loads check(stress strain relationship):

To check that the manually calculated internal forces are not differ more than 10% of that analyzed by SAP (for the same load combination).

For each part one internal span for beam and slab were taken and checked and the errors were acceptable(<10%).

3) Final Design:

-Define Design Code: ACI318-08/IBC2009.

-Define sway type : Intermediate sway.

-Select Design load combination: Envelope.

-Start Design for structure and check that there are no overstressed members and try to have economical percentage of steel.

Columns Design:

The required area of longitudinal steel is obtained from SAP results , and then bars distributed.

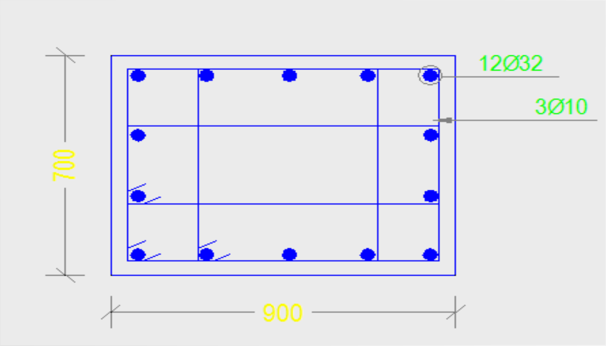
For transverse steel 10mm diameter bars were used , and spacing were calculated according to ACI code.

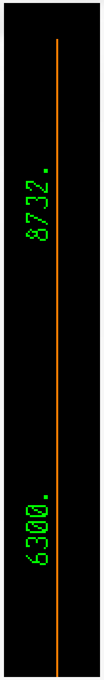
For example take column 5:

The required steel as shown in figure:

Use As=8732 mm2 (1.39% rebar percentage)

Use 12Φ32mm .





For spacing between stirrups according to ACI code chapter21 find distances So and Lo.

So=min {8*mind_b
24*ds
0.5*least dimension of column
or 300mm}

=200mm.

Lo=max {Clear span of column/6
maximum dimension of column
or 450 mm}

Clear span of column=6.0m-0.18m=5.82m

So Lo=970 mm. use Lo=1.0m.

At both ends of the column, stirrups shall be provided at spacing ***so*** over a length ***Lo*** measured from the joint face.

For other regions use spacing of:

Min{

$16 *d_b$ =400 mm

$48 *d_s$ =480 mm

Least dimension of column=700mm

}

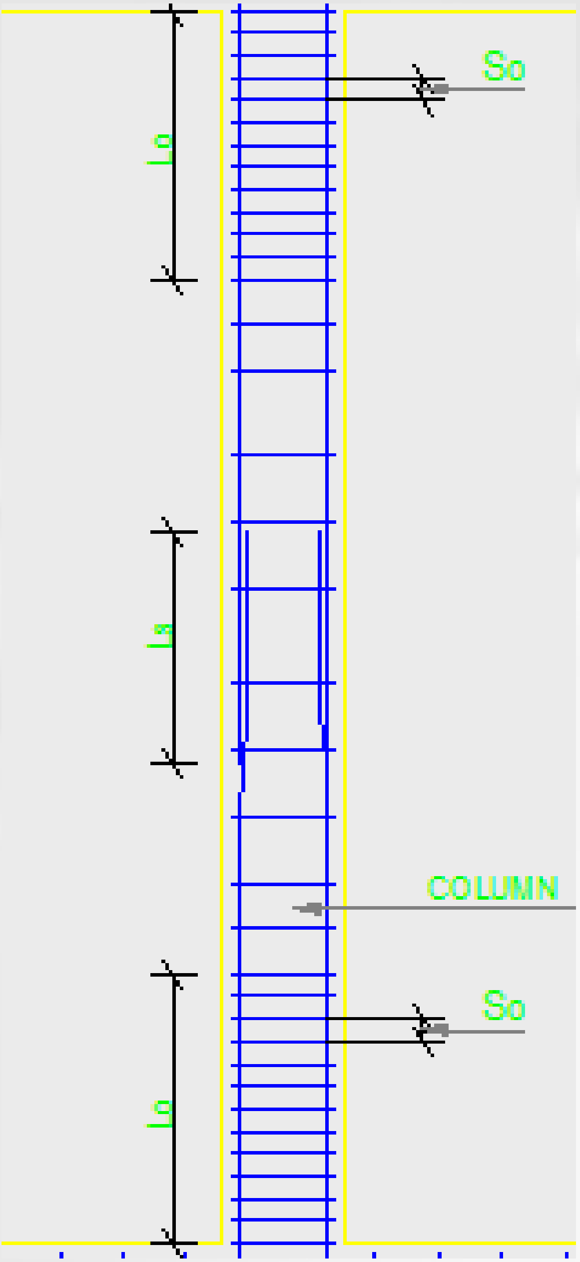
Use a spacing=400mm.

<u>Splicing length:</u>

Ls=1.3*Ldt

Ldt=46.83 db=1171mm.

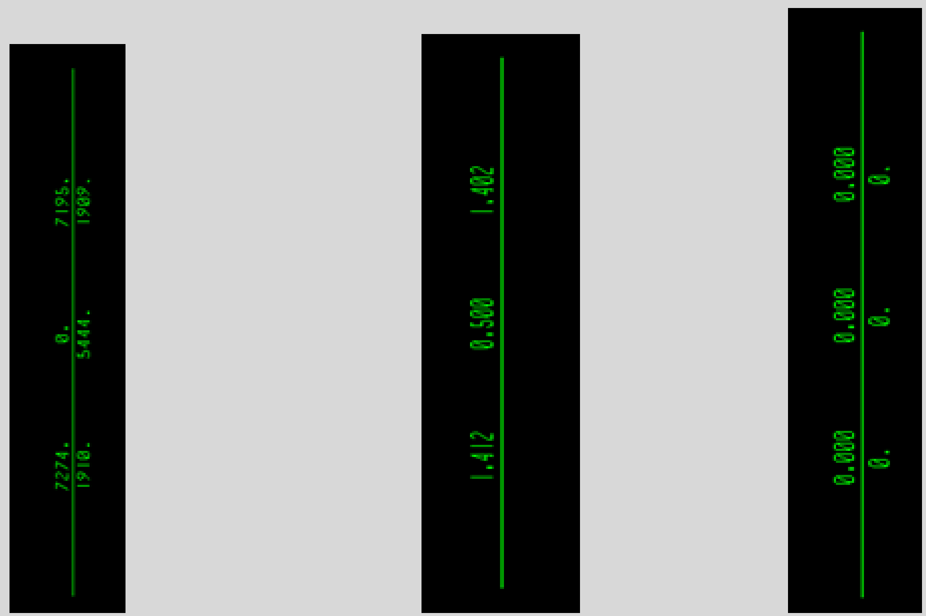
So Ls=1522mm use Ls=1600mm.



Beams Design:

The required longitudinal reinforcement is obtained from sap results , also for transverse steel.

Take beam B4 –first span as example:



a)flexural steel b)Shear steel c) Torsion steel

The total top steel=7195, use 15 Φ25mm(spacing

The total bottom steel=1909 mm^2 , use 4 Φ25mm.

For transverse steel:

Smax(shear steel)=min (600 or d/2)=275mm

(use one stirrup Φ10mm , Av =157mm^2)

S=157/1.402=112 mm.

But according to ACI Code:

At both ends of the beam, stirrups shall be provided over lengths not less than **2*h*** measured from the face of the supporting member toward midspan.

The first stirrup shall be located not more than 50 mm from the face of the supporting member.

Spacing of stirrups shall not exceed the smallest of (a), (b), (c), and (d):

(a) ***d*/4** (138mm)

(b) Eight times the diameter of the smallest longitudinal

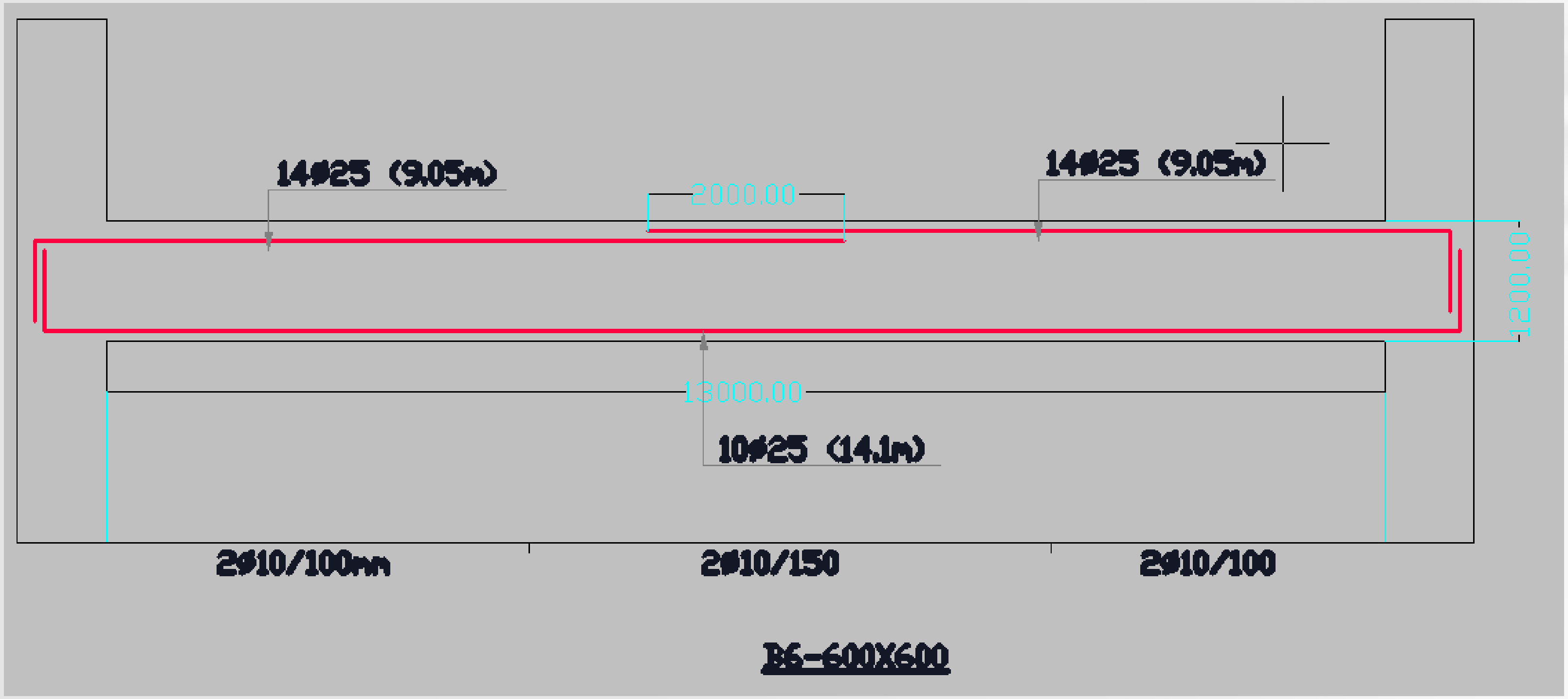
bar enclosed (200mm)

(c) 24 times the diameter of the hoop bar (240mm)

(d) 300 mm

So use 1 Φ10mm/100mm for these region.

The Reinforcement details as shown in this figure:

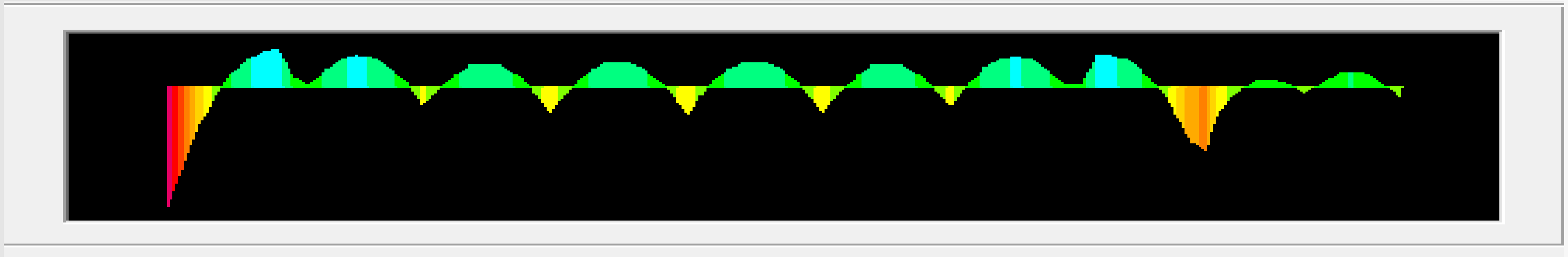


Slabs Design:

Moment values for the slab are taken from sap(for envelope load combination) and then were designed using the following equation:

$$\rho = \frac{0.85f'_c}{f_y}\left(1 - \sqrt{1 - \frac{2.61M_u}{bd^2f'_c}}\right)$$

Take the slab of part A (internal strip) , the moment diagram from SAP2000 :



Use draw section cut also to find values on the strip(use 1m strip):

Start from left side:

M-=48 Kn.m & M-=43 Kn.m

M+=20 Kn.m

ρ min=.0018*b*h=.0018*1000*180=324mm^2.

For Mu=48Kn.m ρ =.006 As=ρ*b*d=900 mm^2 use 8Φ12 mm/m.

The following table shows required reinforcement for other moments:

Mu (Kn.m)	ρ	Required As(mm^2)	Used As(mm^2)	Used bars/m
48	0.006	900	905	8Φ12
43	0.0053	795	905	8Φ12
20	0.0024	360	453	4Φ12

Analysis and Design of Shear Walls:

*Check wall thickness: •

$V_u < \varphi V_c$ •

*Horizontal steel design(Moment in horizontal • direction): Obtain moment values in X-direction.

*Vertical steel design(axial load & moment My interaction):Obtain axial load and moment in Y-direction.

Use SAP2000 to obtain Moment-Axial interaction diagram and check section adequacy.

Analysis and Design of Footings:

* All reactions on columns and walls are obtained from sap as service load, then areas of footings are determined:

σ max ≤ q all , service load/Area of footing ≤ q all

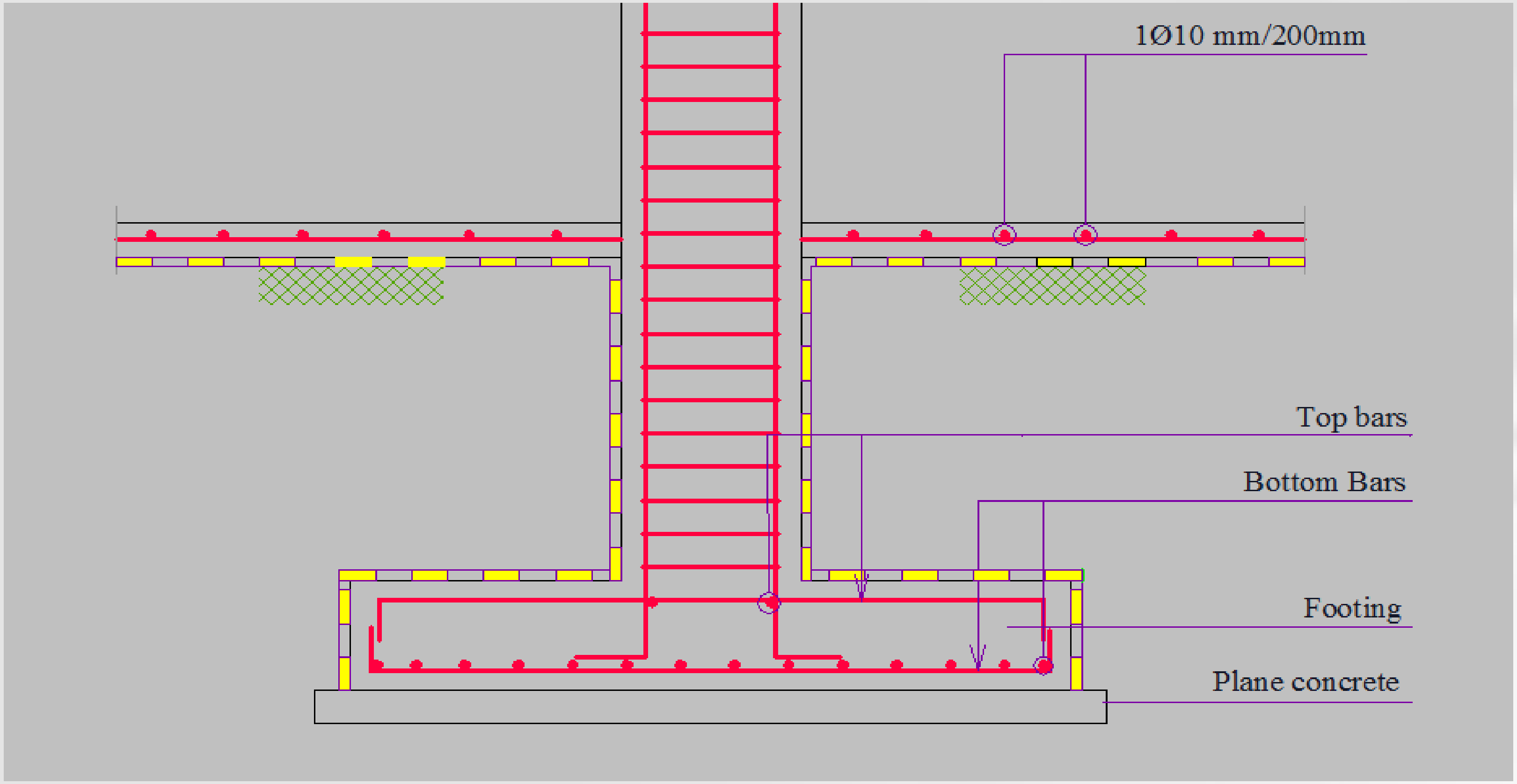
* Footings layout is drawn, in away that he minimum spacing between adjacent footings is 0.50 m, or combined footing is used if the spacing not sufficient.

* Footings thickness is computed in order that thickness of footing is sufficient to resist shear stresses (punching shear or/and wide beam shear).

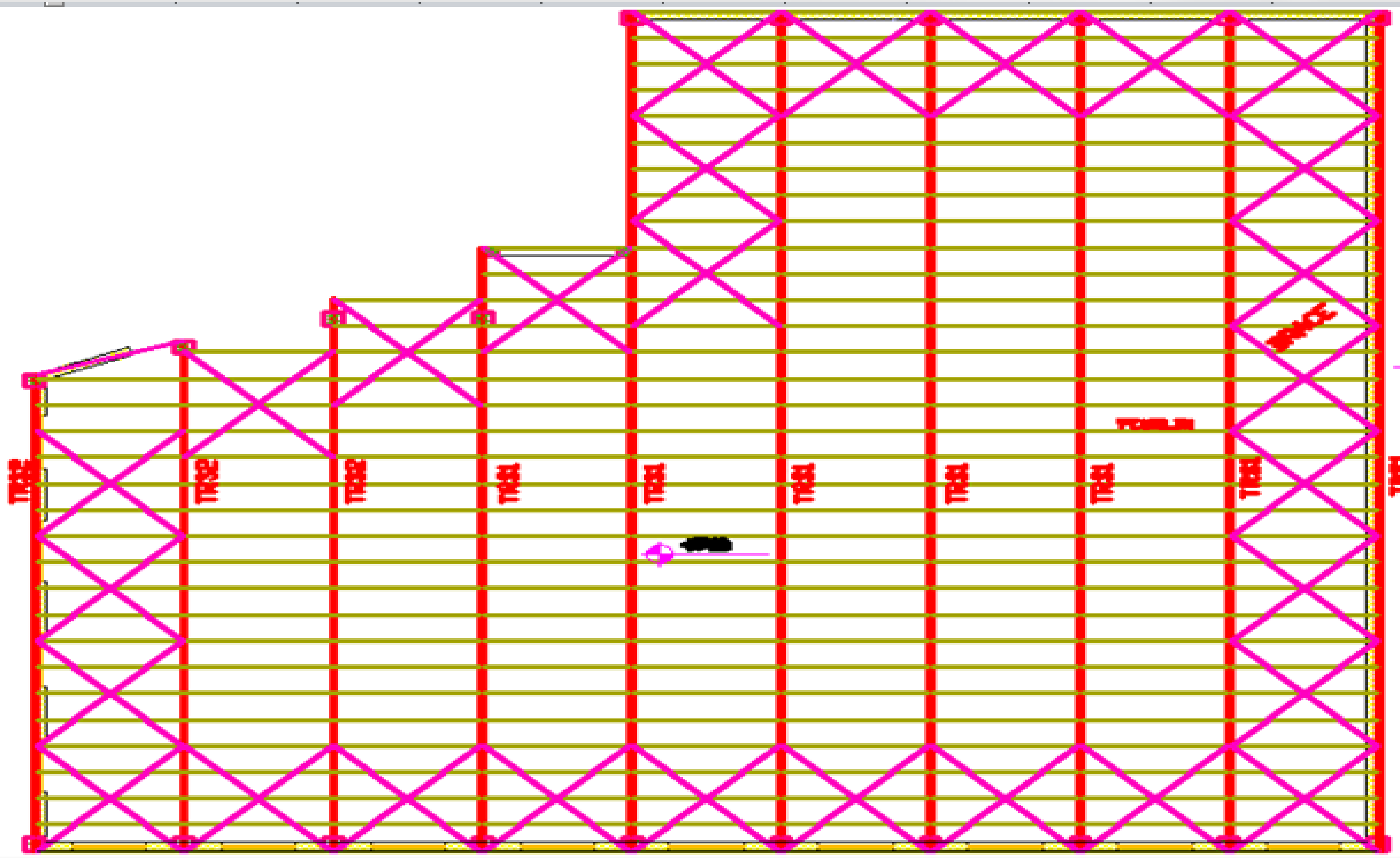
Flexural design:

* Moment values are obtained manually, and then design for these moments.

* Enough splicing length is provided for bars.


1Ø10 mm/200mm
Top bars
Bottom Bars
Footing
Plane concrete

Analysis and Design of roof steel structure:



Analysis and Design of roof steel structure:

- There are 3 types of loads:
- -Live load =2 kN/m2
- -Dead load =.
- -Wind load calculated using simplified procedure and found to be 0.25 kN/m2.

- **Simplified procedure equations:**
- $q_z = 0.613\ K_z\ K_{zt} K_d\ V^2\ I$ (N/m^2)
- $p = q\ GC_p$ (N/m^2)

Purlins Analysis and Design:

* Use tributary area to find loads on representative peurlin:

-Super imposed dead load=.035 kN/m (per 1m along purlin).

-Live load=1m*1kn/m^2=1 kN/m.

-Wind load =0.25 kn/m.

*Use Sap2000 to analyze and design this purlin (as steel beam).

*Use sap to design the peurlin section , obtained section TUBE 50mm*50mm*5mm.

Trusses Analysis And Design

* Reactions of purlins are the loads on truss.

*Apply these loads for the internal joints and at mid of upper members, and half of these loads for side joints.

* Construct a model for the truss and check this model:

* Edit bracing for top and bottom members to reduce lateral torsion buckling.

	Item	Value
1	Current Design Section	Program Determined
2	Framing Type	Program Determined
3	Omega0	Program Determined
4	Consider Deflection?	No
5	Deflection Check Type	Program Determined
6	DL Limit, L /	Program Determined
7	Super DL+LL Limit, L /	Program Determined
8	Live Load Limit, L /	Program Determined
9	Total Limit, L/	Program Determined
10	Total--Camber Limit, L/	Program Determined
11	DL Limit, abs	Program Determined
12	Super DL+LL Limit, abs	Program Determined
13	Live Load Limit, abs	Program Determined
14	Total Limit, abs	Program Determined
15	Total--Camber Limit, abs	Program Determined
16	Specified Camber	Program Determined
17	Net Area to Total Area Ratio	Program Determined
18	Live Load Reduction Factor	Program Determined
19	Unbraced Length Ratio (Major)	Program Determined
20	Unbraced Length Ratio (Minor)	0.25
21	Unbraced Length Ratio (LTB)	0.25

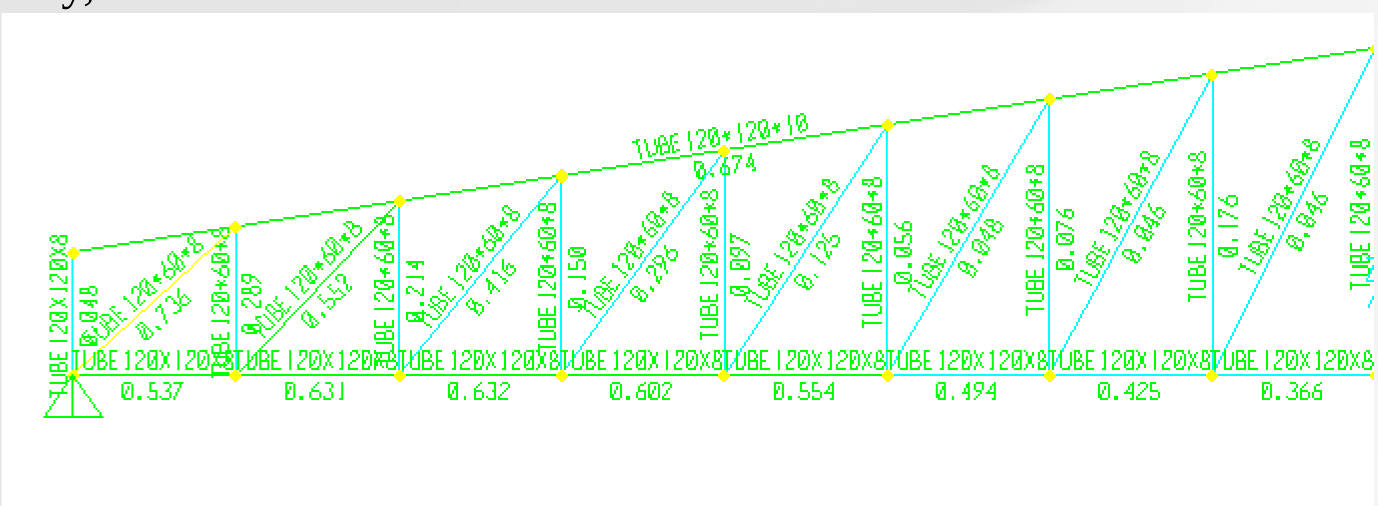
* Use sap to design the truss sections , and divide all members into 3 groups:

-Top chords.

-Bottom chords.

-Internal members.

* Finally, check that P-M interaction ratios < 0.85 for all members.



THANK YOU

for listening!