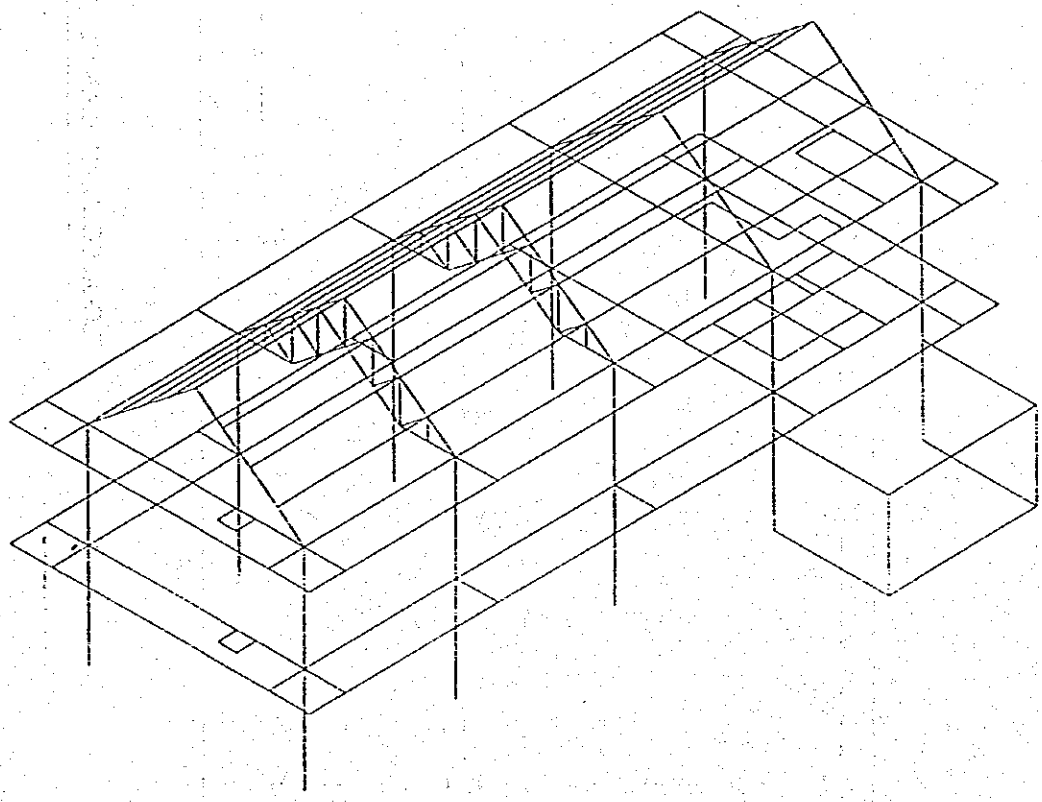
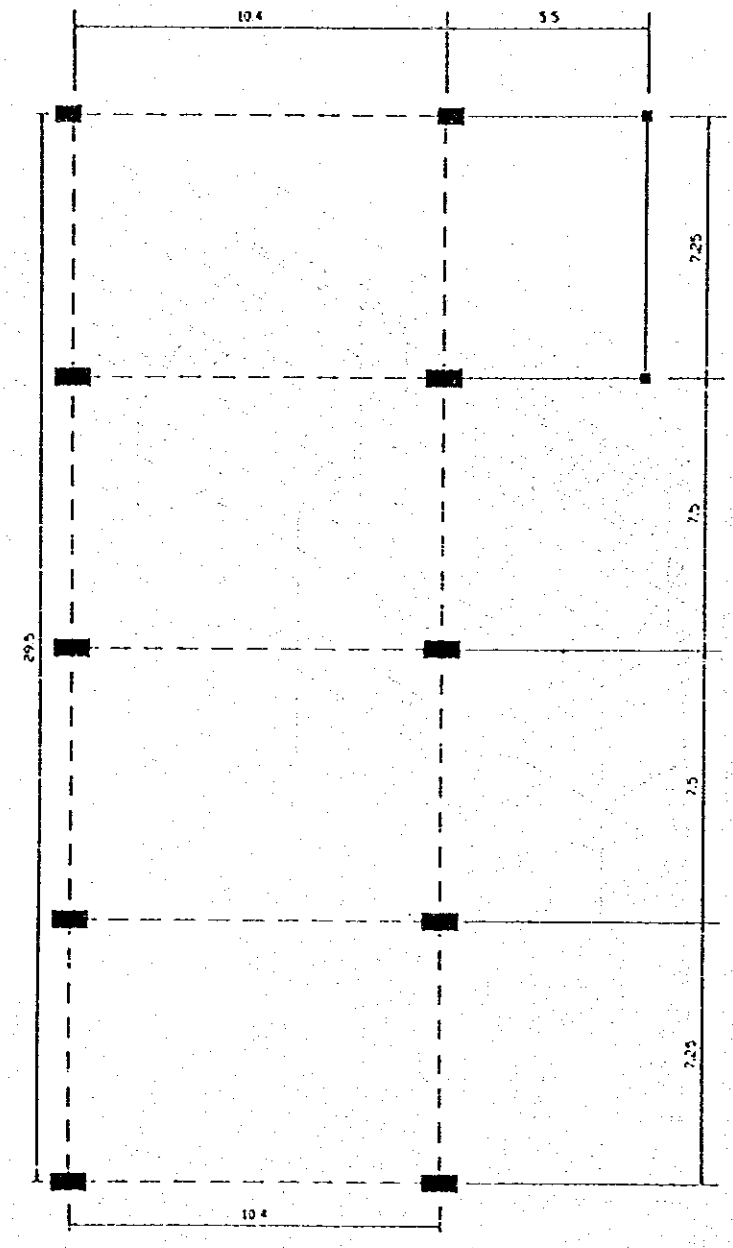
5.2 Design of Upper Structure of Hydropower Station

JATIBARANG HYDROPOWER STATION
UPPER STRUCTURE CALCULATION

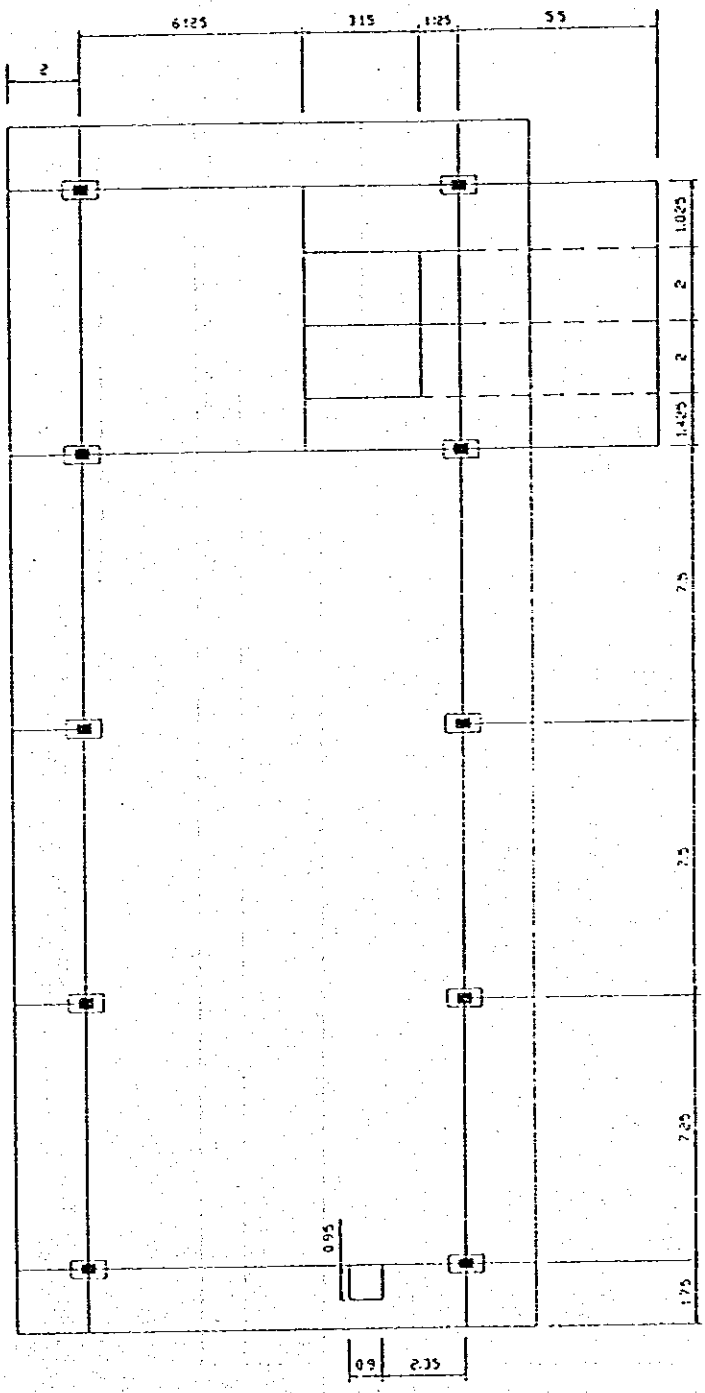
CONTENT : Page :

1. General Construction

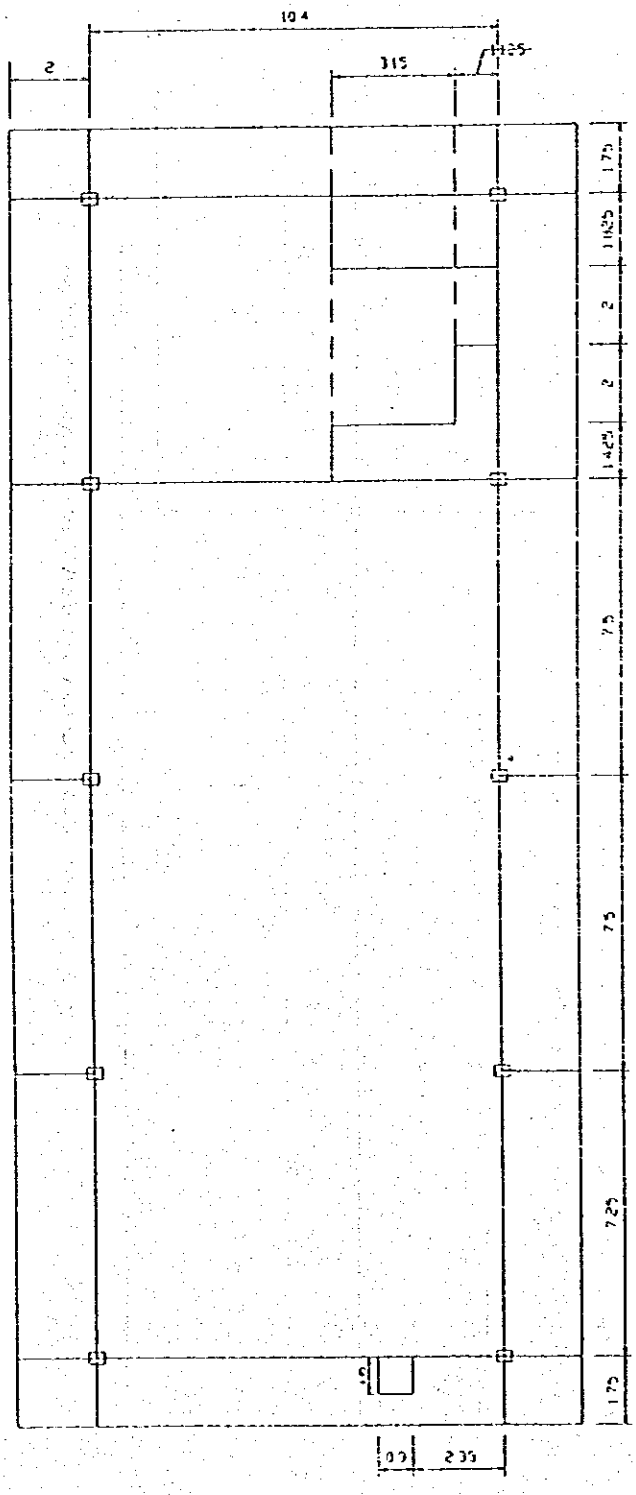




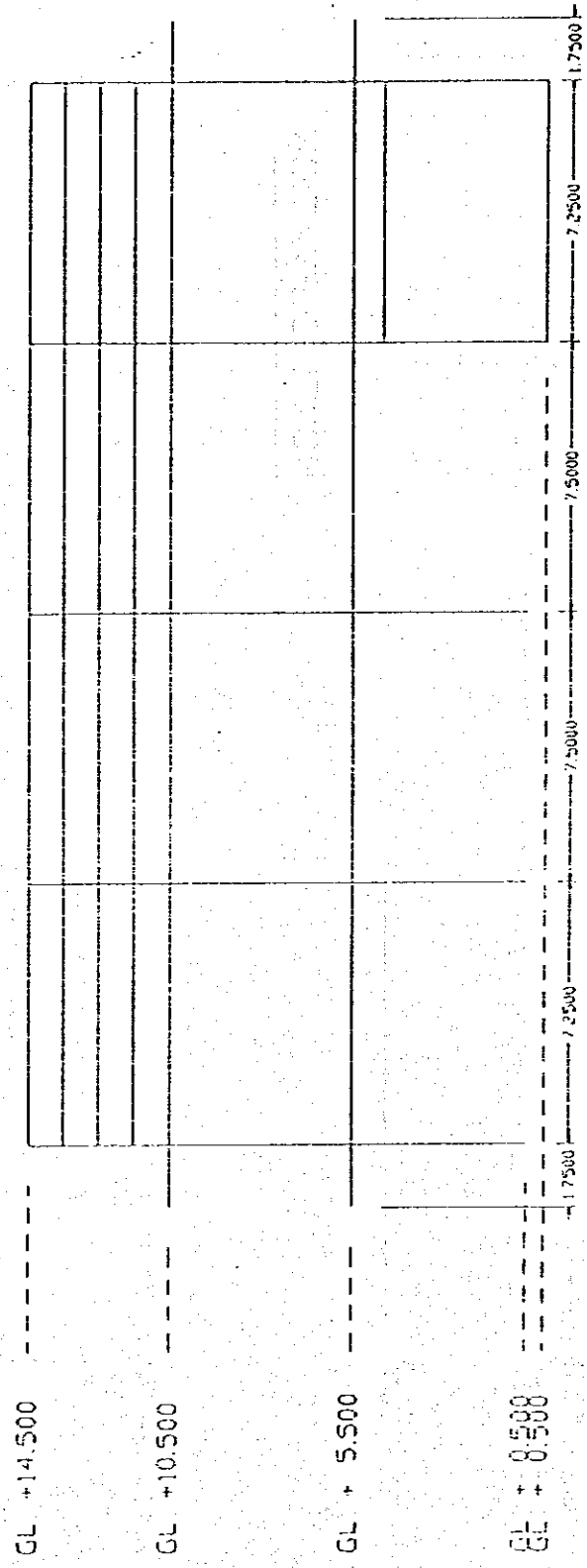
1st.FLOOR COLUMN PLAN GL+0.5



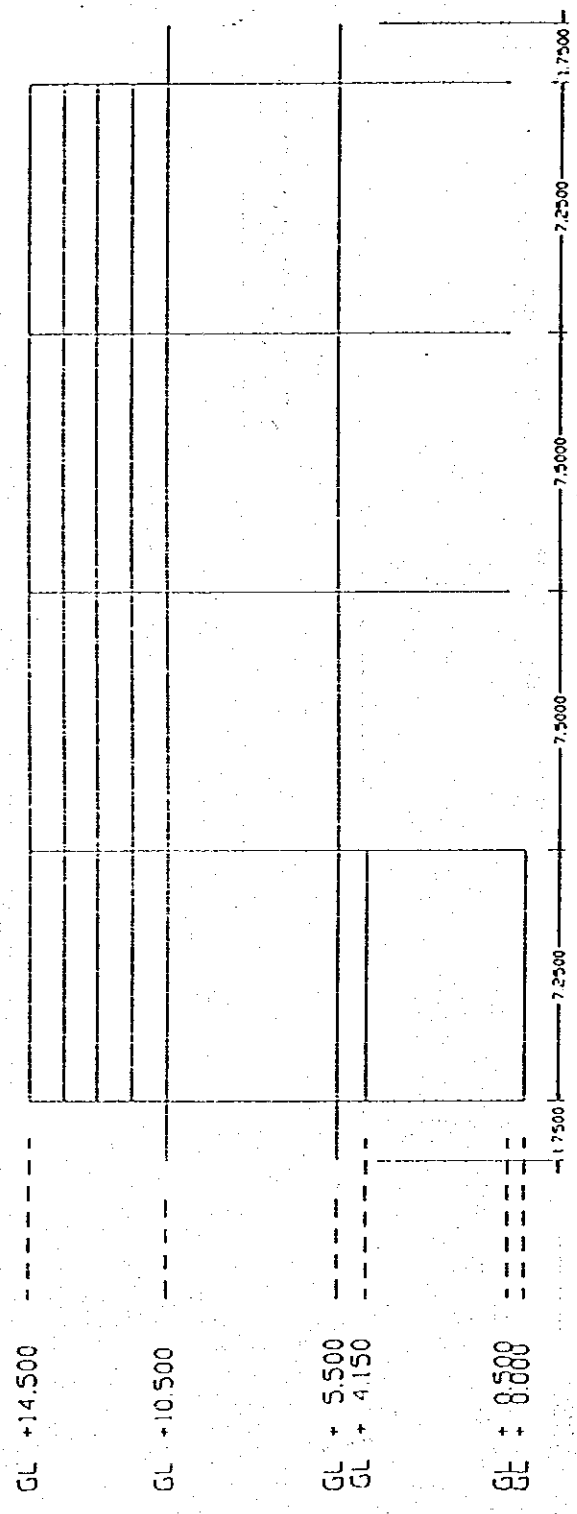
2nd. FLOOR TIE BEAM AND COLUMN PLAN GL+5.5



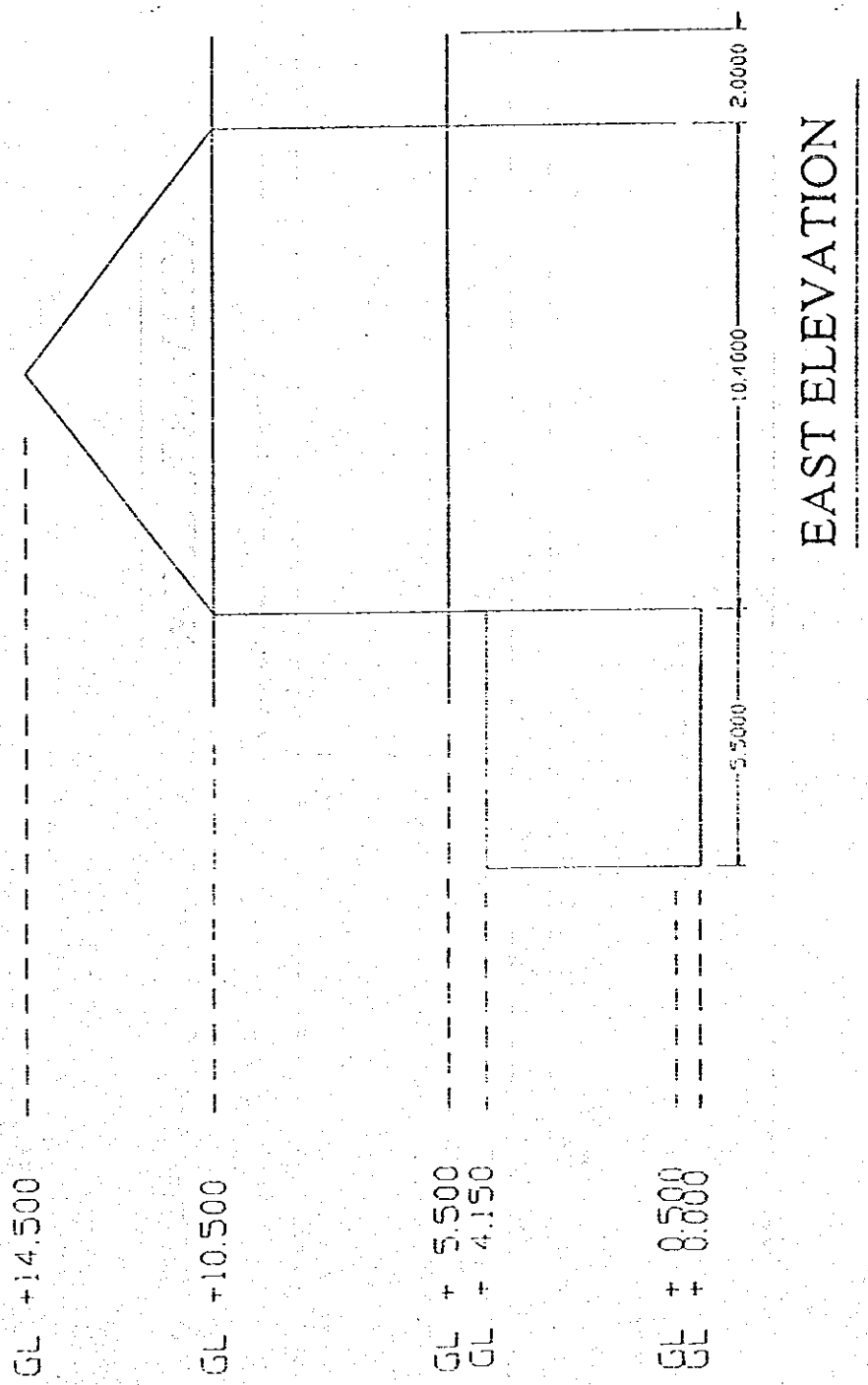
ROOF LEVEL TIE BEAM PLAN GL+10.5



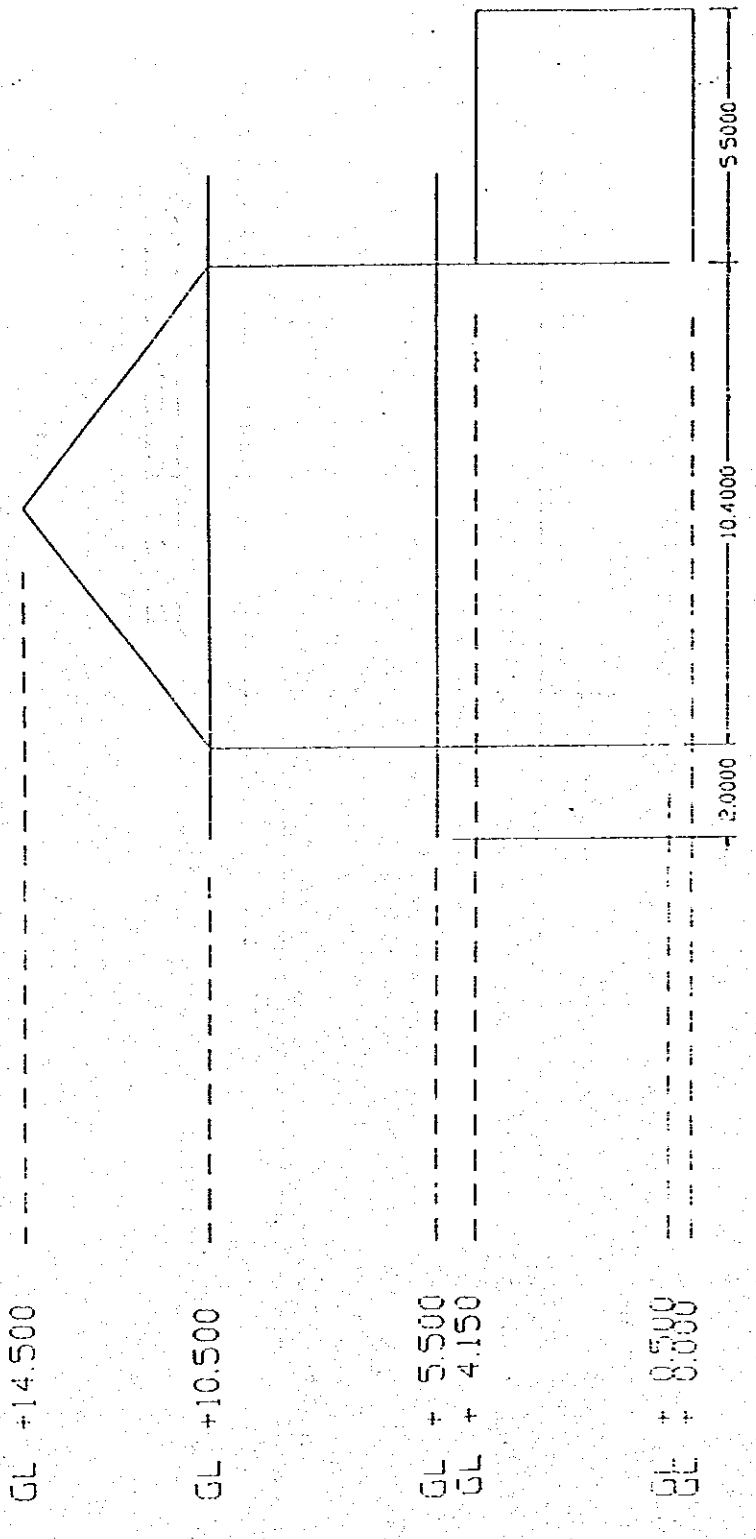
SOUTH ELEVATION



NORTH ELEVATION



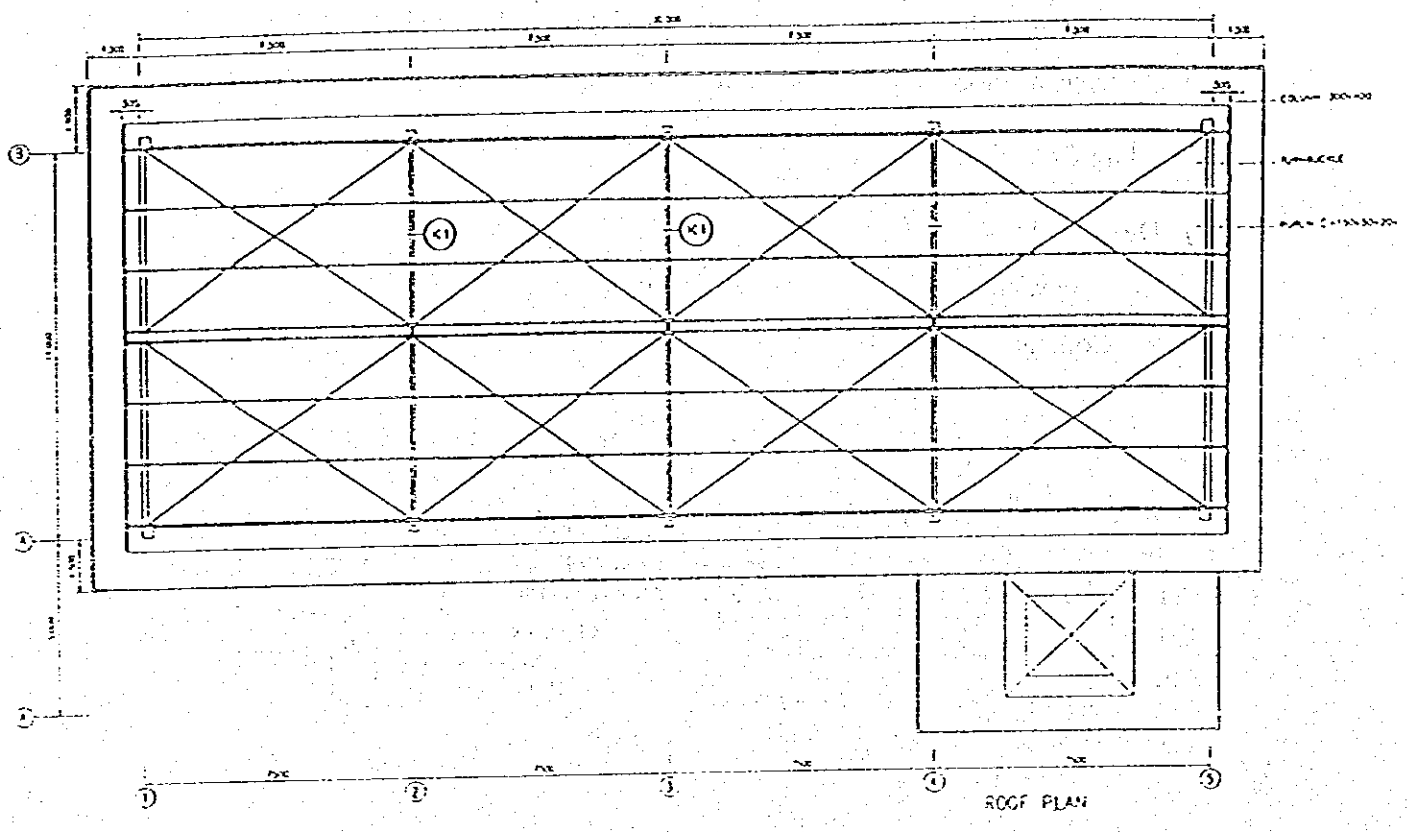
EAST ELEVATION

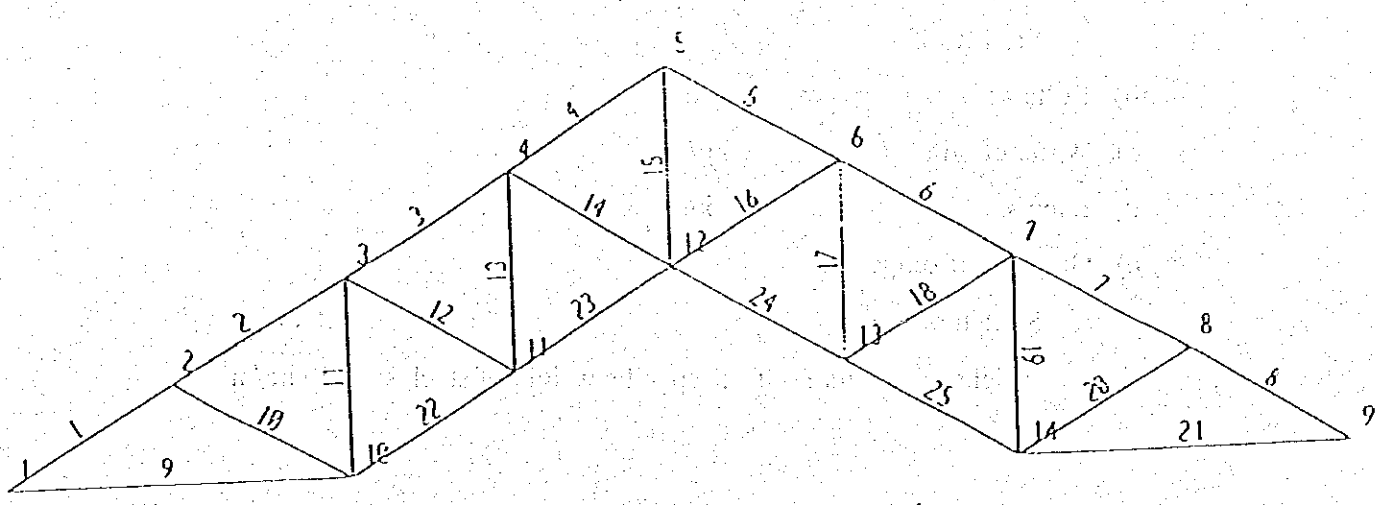


WEST ELEVATION

2. Design Of Roof Steel Truss

a. Structure of Roof Steel Truss



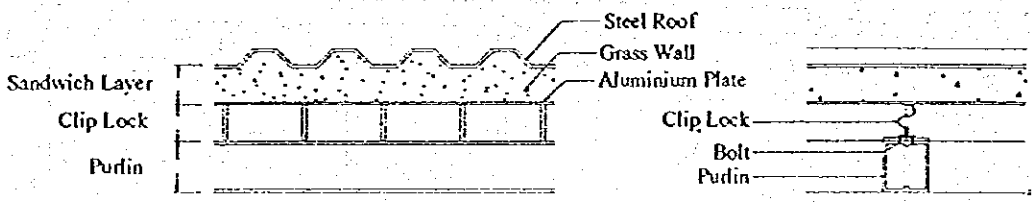


b. Design Condition

1) Roof truss members : double angle steel
   tensile strength (Fy) : 2400 kg/cm^2
2) Structural model : plane (xy axis) truss, linear elastic
3) Analysis method : static

c. Loading Condition

1) Dead load :
   a) Sandwich Layer : = 20 kg/m^2
      Contents :



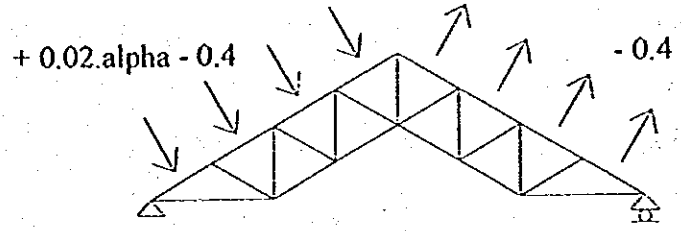
- Grass Wall
- Aluminum Plate
- Steel Roof

   b) Bolts = 2 kg/m^2
   c) Water of rain = 2 kg/m^2
   d) Lamps = 20 kg
   e) On point of support :
      - Stretch of length = 7.5 m
      - Weight of structure self : specific weight of steel = 7850 kg/m^3

2) Wind load :

$P = V^2 / 16$ .....kg/m^2

Where $V = 20\ kg/m^2$



$P_{min} = 25\ kg/m^2$

Alpha $= \alpha$ = angle of roof

$+ 0.02*\alpha - 0.4 = 0.02*30° - 0.4$

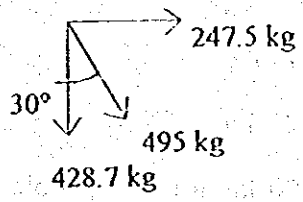
$= 0.2$

$P_P = 25\ kg/m^2 + 0.2*25\ kg/m^2$

$= 30\ kg/m^2$

where : P_P = pressure load

$F_P = P_P * A_P = 30\ kg/m^2 * 7.5\ m * 6.6\ m$



$= 1485\ kg$

$i_{FP} = F_P / 3 = 495\ kg$

P_S = 25 kg/m² - 0.4*25 kg/m²

= 15 kg/m²

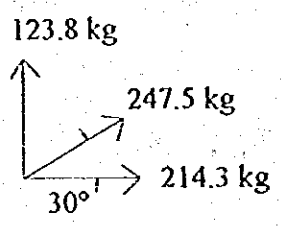
where : P_S = stuck load

F_S = P_S * A_S = 15 kg/m² * 7.5 m * 6.6 m

= 742.5 kg

i_{FS} = F_S / 3

= 247.5 kg



3) Live load :

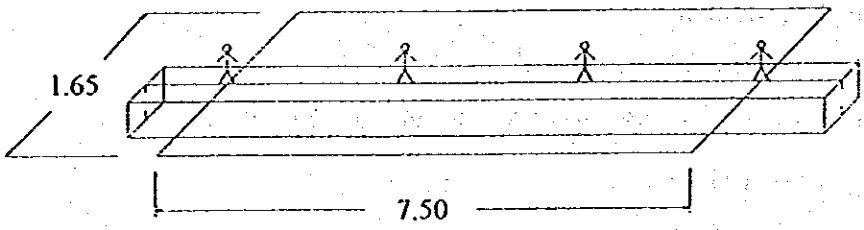
- Man load = 75 kg
- Vehicle taken people = 25 kg +

Total Load = 100 kg for each people

d. Design of Purlin

Technique data :

- Purlin distance = 1.65 m
- Purlin span = 7.5 m with track stank
  = 7.5 m / 2
  = 3.5 m
- Assumption : loaded 4 people that take work tool
  Load of each people = 100 kg



1) Dead load:

- Sandwich layer = 12 kg
- Bolt = 2 kg
- Water of rain = 2 kg

2) Wind load = 30 kg +

Total Load = 46 kg

Purlin load with purlin span 1.65 m = 46 x 1.65

= 75.9 kg/m

≈ 76 kg/m

Purlin weight = 15 kg/m

Q = 76 + 15 = 91 kg/m

$Q_1 = Q_2 = Q \cos 30°$

= 91 * 0.866

= 78.086 kg/m

≈ 78 kg/m

3) Live load : weight of workers as point load = 100 kg

$Px = Py = P \cos \alpha$

= 100 cos 30°

$= 86.6$

≈ 87 kg

4) Bending Moment.

$Mx = 1/8 \times Q_1 \times L^2 + ¼ \times P_x \times L$

$Mx = 1/8 \times 78 \times 3.5^2 + ¼ \times 87 \times 3.5$

$= 195.56$

≈ 196 kgm

$Mx = My = 196$ kgm $= 19600$ kgcm

Tried type of Purlin Lip Channel in front to front arrangement $150x130x20x3^2$

Where: $Ix = 1432$ cm^4

$Iy = 834$ cm^4

$Wx = 143$ cm^3

$Wy = 111$ cm^3

Checking :

Stresses :

$\sigma = \sigma x + \sigma y$

$= Mx/Wx + My/Wy$

$= 19600/143 + 19600/111$

$= 137.06 + 176.58$

$= 313.64$

$\approx 314 < \sigma_{all} = 1400 \text{ kg/cm}^2$ (OK)

Deflection :

$fx = 5/384 \times Q_1 \times L^4/EI_x + 1/48 \times P_x L^3/EI_x$

$= 5/384 \times 0.78 \times 350^4/2.1\times10^6 \times 1432$

$+ 1/48 \times 87\times350^3/2.1\times10^6 \times 1432$

$= 0.05 + 0.03$

$= 0.08$ cm

$fy = 5/384 \times Q_1 \times L^4/EI_y + 1/48 \times P_y L^3/EI_y$

$= 5/384 \times 0.78 \times 350^4/2.1\times10^6 \times 834 + 1/48 \times 87\times350^3/2.1\times10^6 \times 834$

$= 0.09 + 0.04$

$= 0.13$ cm

$f = (fx^2 + fy^2)^{1/2}$

$= (0.08^2 + 0.13^2)^{1/2}$

$= 0.15$ cm $< f_{all} = 1/500\ L = 1/500 \times 750 = 1.50$ cm (OK)

Shear Stress :

$\sigma = \sqrt{(\sigma^2 + 3\tau^2)}$

where $\tau = 0.58 \times 1400$

$= 812$ kg/cm^2

$\sigma = \sqrt{(314^2 + 3x812^2)}$

$= 1441$ kg/cm$^2 < 1.3\ \sigma_{all} = 1820$ kg/cm^2 (OK)

e. Design of Truss

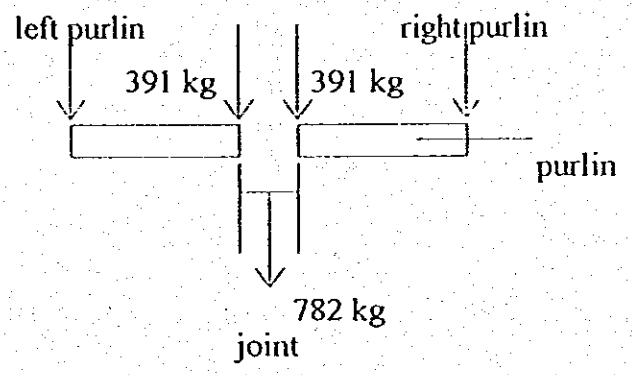
1) Point of support reaction on roof

Point of support reaction = load of roof + live load + purlin load

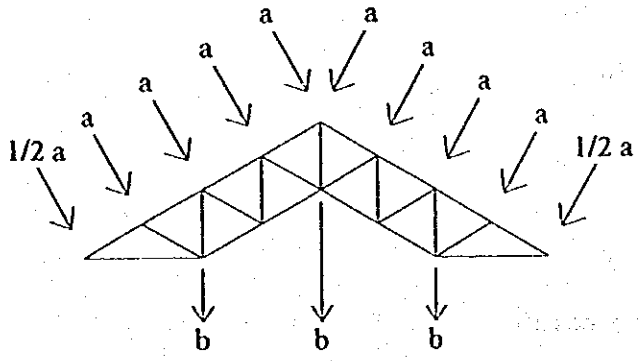
= (46x1.65x7.5) +.100 + (15.6x7.5)

= 781.75

≈ 782 kg

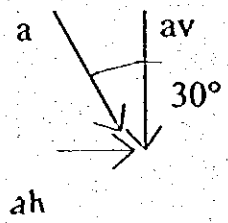


2) Truss calculation



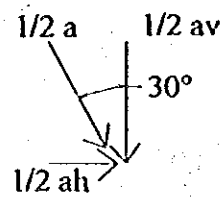
a = Point of support reaction caused load from roof + live load + purlin
= 782 kg

b = load from hung lamp
= 20 kg



av = a x cos 30°
= 782 x cos 30°
= 677.23
≈ 678 kg

ah = a x sin 30°
= 782 x sin 30°
= 391 kg



1/2av = 1/2a x cos 30°

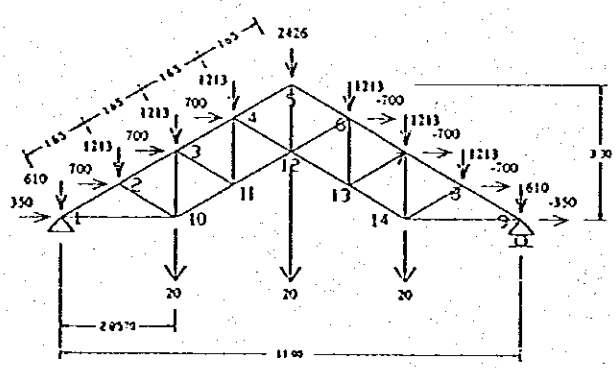
= 391 x cos 30°

= 338.6 ≈ 339 kg

1/2ah = 1/2a x sin 30°

= 391 x sin 30°

= 195.5 kg ≈ 196 kg



f. Prototype of Element

Profile	Plate Thickness (mm)	Fy (kg/cm^2)	Fu (kg/cm^2)	Diameter Bolt (mm)
2 L – 70x70x7	8	3700	2400	17

g. Recapitulation of Truss Element Force and Bolted Connection Design

Maximum reactions and applied forces from three combinations.

Joint	Forces-X (Fx) (kg)	Forces-Y (Fy) (kg)	Moments (M) (kg.cm)
1	1847.20	5572.76	0
2	947.50	-1641.70	0
3	947.50	-1641.70	0
4	947.50	-1641.70	0
5	461.80	-2730.90	0
6	947.50	-1641.70	0
7	947.50	-1641.70	0
8	947.50	-1641.70	0
9	0	5573.00	0
10	0	-20.00	0
11	0	0	0
12	0	-20.00	0
13	0	0	0
14	0	-20.00	0

Maximum from three combinations.

No	Members	Axial Force (kg)	Bolts	Stress (kg/cm^2)	Status Stress ≤ 1400 kg/cm^2
1	1	-11145.40	3	1048.82	OK!
2	2	-10050.80	3	945.81	OK!
3	3	-13386.60	3	1259.72	OK!
4	4	-14533.70	4	1367.67	OK!
5	5	-15067.20	4	1166.92	OK!
6	6	-13224.80	3	1244.44	OK!
7	7	-10050.90	3	945.78	OK!
8	8	-11145.30	3	1048.76	OK!
9	9	11499.12	3	718.71	OK!
10	10	-2188.71	2	205.96	OK!
11	11	-4430.49	2	416.92	OK!
12	12	2241.64	2	140.10	OK!
13	13	-2241.67	2	210.95	OK!
14	14	215.15	2	13.45	OK!
15	15	12070.09	3	754.38	OK!
16	16	-1013.73	2	95.39	OK!
17	17	-2651.14	2	249.48	OK!
18	18	2650.92	2	165.68	OK!
19	19	-4021.13	2	378.40	OK!
20	20	-2188.55	2	205.92	OK!
21	21	9651.94	3	603.25	OK!
22	22	11089.82	3	693.11	OK!
23	23	13331.47	4	833.22	OK!
24	24	12103.10	4	756.44	OK!
25	25	9452.07	3	590.75	OK!

h. Checking of Members Strength

1) Due to tensile force

Maximum force on member 23.

Force (F) = 13331.47 kg

Length = 165 cm

Tried : 2 L – 70x70x7

Cross section area A = 2 x 9.40 = 18.80 cm^2

σ_{all} = 0.6 x Fy

= 0.6 x 2400

= 1440 kg/cm^2

Stress

σ = F/A

= 13331.47/18.80

= 709.12 kg/cm^2 < σ_{all} (OK!)

2) Due to compression force

Maximum force on member 5.

Force (F) = 15067.20 kg

Length = 165 cm

Tried : 2 L – 70x70x7

Cross section area A = 2 x 9.40 = 18.80 cm^2

ix = 2.28 cm

Ix = 2 x 42.4 = 84.80 cm^4

λ = L/ix

= 165/2.28

= 72.37

$\lambda g = \pi (E/0.7x\sigma_i)^{1/2}$

$= 3.14 (2.1 \times 10^6 / 0.7 \times 2400)^{1/2}$

= 111.07

$\lambda s = \lambda/\lambda g$

= 72.37 / 111.07

= 0.65

for 0.183 < λs < 1 : ω = 1.41 / (1.593 - λs)

= 1.41 / (1.593 – 0.65)

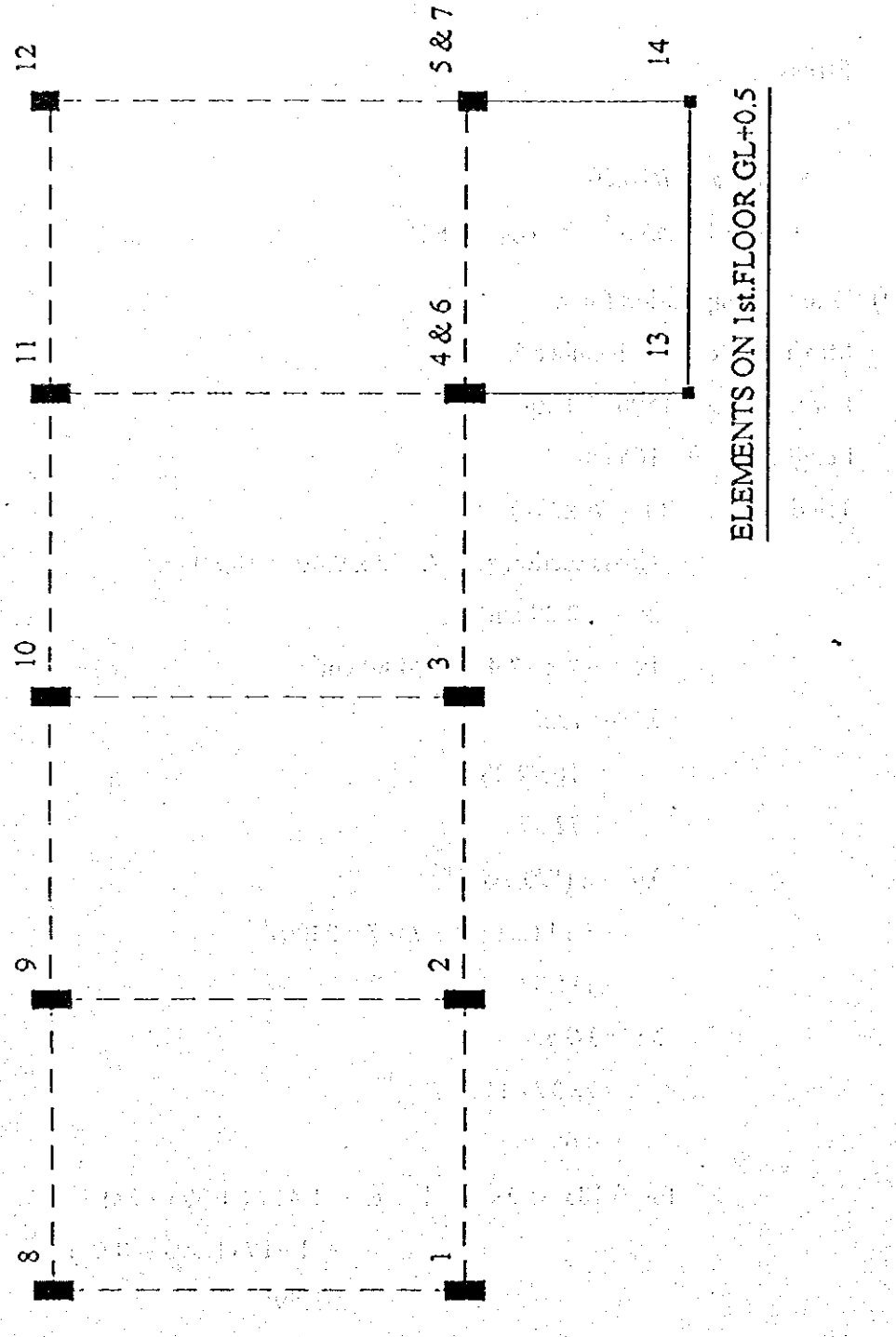
=1.495

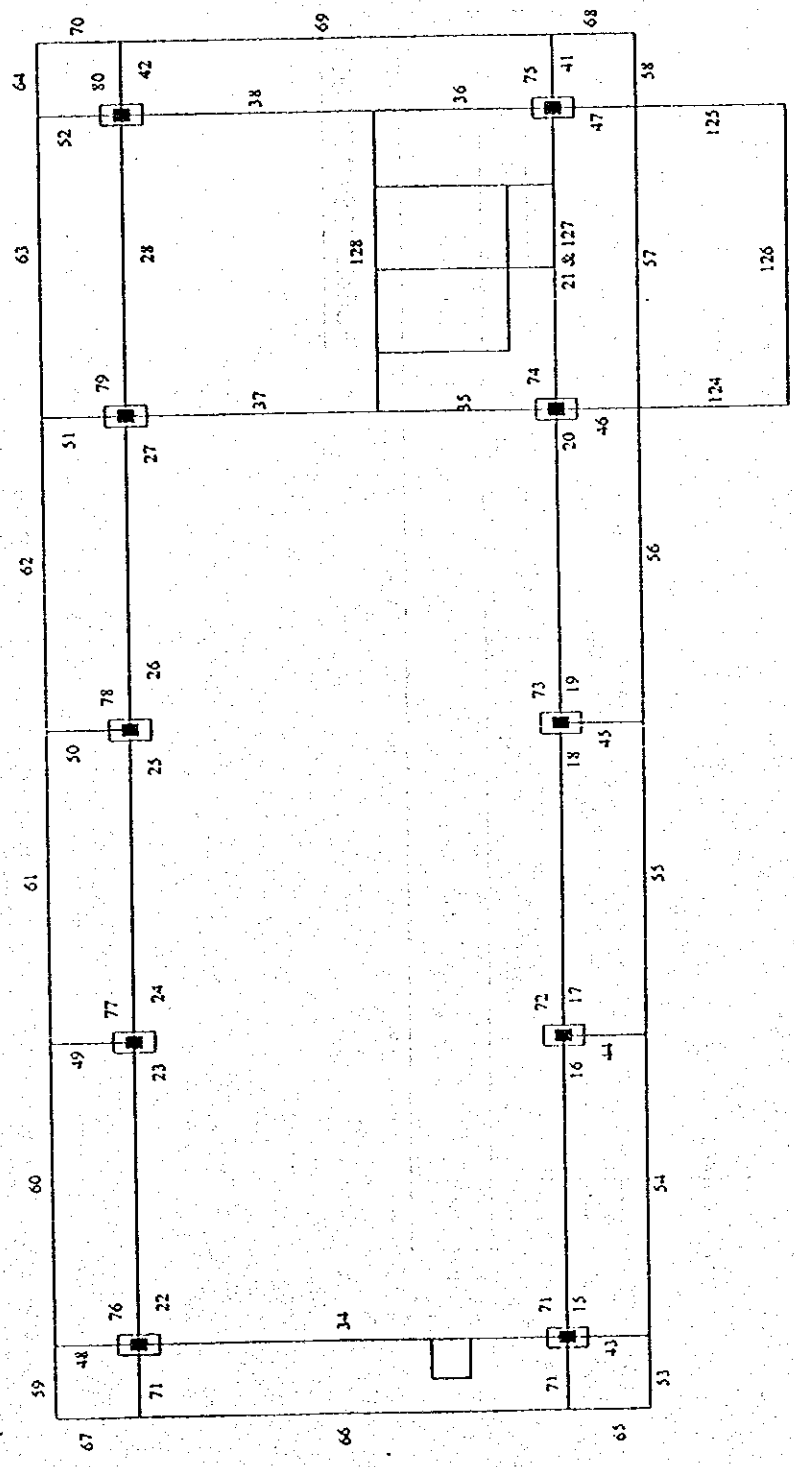
ω x F/ A < σ

1.495 x 15067.20/18.80 = 1202.17 < σ =1400 kg/cm^2 (OK!)

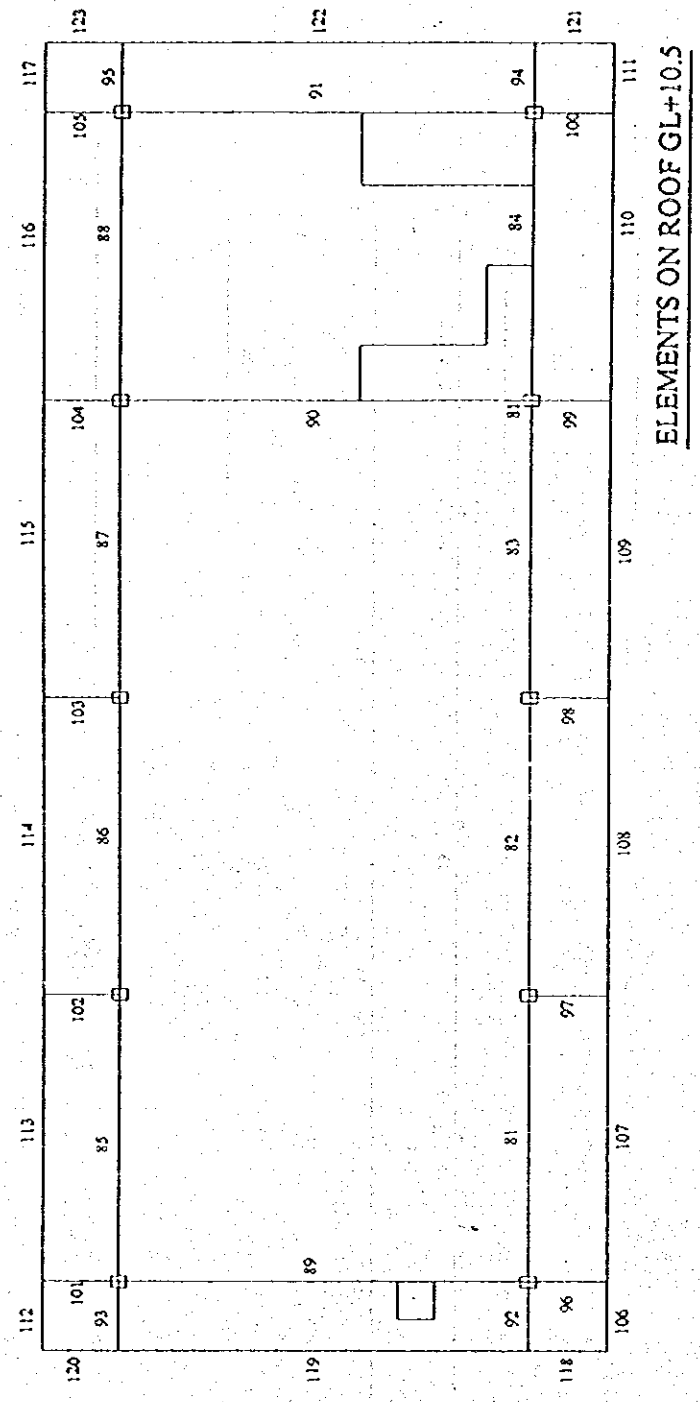
3. Design of Reinforcement Concrete Frame

a. Structure of Reinforcement Concrete Frame





ELEMENTS ON 2nd. FLOOR GL+5.5


ELEMENTS ON ROOF GL+10.5

b. Dimensions

- length c – c column = 29.50 m
- width c – c column = 10.40 m
- height ground to 2nd floor : 5.5 m
- height ground to roof truss : 10.5 m

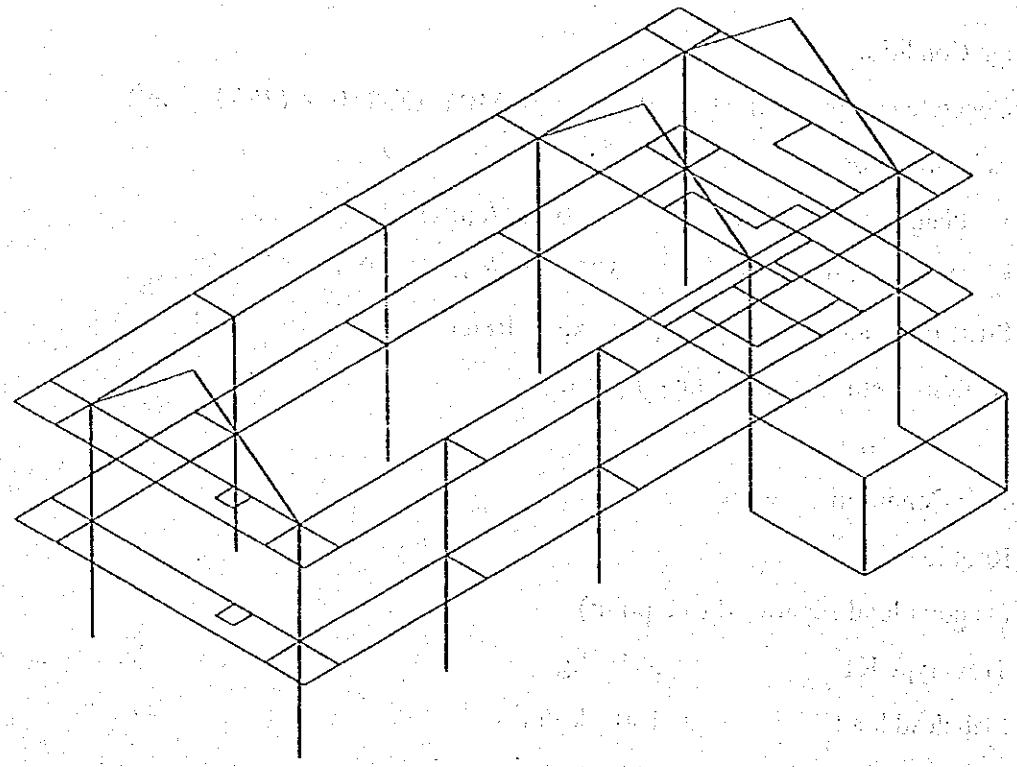
c. Design Condition

1) Concrete compression strength fc' = 30 MPa (K-250 = (250 kg/cm^2)
2) Reinforcing bar :
   - Plain bar fy = 2400 kg/cm^2(BJTP 24)
   - Deformed bar fy = 3700 kg/cm^2(BJTP 32)
3) Structural model : space (xyz axis) frame
4) Analysis method : static – rigid floor

d. Loading Condition

1) Roof load :
   (as point load separated to 2 point)
   Truss type K1 = 391 kg
2) Slab dead load = 150 kg/m^2
3) Live load = 400 kg/m^2
4) Concrete self weight = 2400 kg/m^3
5) Brick wall 15 cm thick = 250 kg/m^2

e. Design of Frame



f. Prototype of Element and Recapitulation of Frame Element Force

1) Column

a) Column type 1

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
50	100	10	25	12	300	3700	2400

Frame Element Force					Design			
Members	Axial (kg)	Shear (kg)	Torsion (kgcm)	Moment (kgcm)	Main bar (mm)	Stirrup (mm)	Pu (kg)	Mu (kg)
1	271730	7060	0	3886000	16D25	ϕ12-@150	639209	13659711
2	281350	2000	0	1101000	16D25	ϕ12-@150	639209	13659711
3	269250	1430	0	789000	16D25	ϕ12-@150	639209	13659711
4	398940	7890	0	3155000	16D25	ϕ12-@150	639209	13659711
6	352880	20190	0	62640000	16D25	ϕ12-@150	639209	13659711
8	271690	7030	0	3867000	16D25	ϕ12-@150	639209	13659711
9	281690	1990	0	1096000	16D25	ϕ12-@150	639209	13659711
10	267560	1280	0	708000	16D25	ϕ12-@150	639209	13659711
11	367690	10790	0	5932000	16D25	ϕ12-@150	639209	13659711

b) Column type 2

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
50	70	10	25	12	300	3700	2400

Frame Element Force					Design			
Members	Axial (kg)	Shear (kg)	Torsion (kgcm)	Moment (kgcm)	Main bar (mm)	Stirrup (mm)	Pu (kg)	Mu (kg)
5	317430	11490	0	4594000	16D25	ϕ12-@150	639209	13659711
7	271340	20970	0	8352000	16D25	ϕ12-@150	639209	13659711
12	283340	14660	0	8065000	16D25	ϕ12-@150	639209	13659711

c) Column type 3

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
30	40	10	25	12	300	3700	2400

Frame Element Force					Design			
Members	Axial (kg)	Shear (kg)	Torsion (kgcm)	Moment (kgcm)	Main bar (mm)	Stirrup (mm)	Pu (kg)	Mu (kg)
71	861300	7950	0	2175000	8D25	ϕ12-@150	73559	2558345
72	63820	1850	0	1648000	8D25	ϕ12-@150	73559	2558345
73	64210	900	0	1653000	8D25	ϕ12-@150	73559	2558345
74	87980	6530	0	1813000	8D25	ϕ12-@150	73559	2558345
75	84960	3270	0	2846000	8D25	ϕ12-@150	73559	2558345
76	86150	7940	0	2173000	8D25	ϕ12-@150	73559	2558345
77	63980	1800	0	1648000	8D25	ϕ12-@150	73559	2558345
78	64210	900	0	1652000	8D25	ϕ12-@150	73559	2558345
79	88140	6530	0	1824000	8D25	ϕ12-@150	73559	2558345
80	84620	11200	0	2861000	8D25	ϕ12-@150	73559	2558345

d) Column type 4

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm^2)	fy (kg/cm^2)	fv (kg/cm^2)
30	30	10	25	12	300	3700	2400

Frame Element Force					Design			
Members	Axial (kg)	Shear (kg)	Torsion (kgcm)	Moment (kgcm)	Main bar (mm)	Stirrup (mm)	Pu (kg)	Mu (kg)
13	69548	7500	0	2245897	8D25	ϕ12-@200	73559	2558345
14	64287	7590	0	2145679	8D25	ϕ12-@200	73559	2558345

2) Beam

a) Beam type a

Prototype of Element

b (cm)	H (cm)	cover (mm)	dia. Main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm^2)	fy (kg/cm^2)	fv (kg/cm^2)
60	100	10	25	16	300	3700	2400

Frame Element Force				
Members	Axial (kg)	Shear (kg)	Torsion (kgcm)	Moment (kgcm)
15	2350	49780	2115000	7222000
16	2350	90360	2115000	10597000
17	1690	82450	171000	10430000
18	1690	80130	171000	9293000
19	1960	79720	2602000	9439000
20	1960	82860	2602000	9629000
22	2310	72230	2107000	10581000
23	2310	90520	2107000	10581000
24	1640	82810	188000	11090000
25	1640	79770	188000	9954000
26	1610	65920	2688000	9992000
27	1340	83880	2688000	11940000

Design			
Members	Main Bar (mm)	Stirrup Bar (mm)	Mu (kgcm)
15	D25	ϕ16@-250	12593676
16	D25	ϕ16-@250	12593676
17	D25	ϕ16-@250	12593676
18	D25	ϕ16-@250	12593676
19	D25	ϕ16-@250	12593676
20	D25	ϕ16-@250	12593676
22	D25	ϕ16-@250	12593676
23	D25	ϕ16-@250	12593676
24	D25	ϕ16-@250	12593676
25	D25	ϕ16-@250	12593676
26	D25	ϕ16-@250	12593676
27	D25	ϕ16-@250	12593676

Design									
Members	Left Bar			Middle Bar			Right Bar		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
15	9D25	4ϕ10	4D25	4D25	4ϕ10	9D25	9D25	4ϕ10	4D25
16	9D25	4ϕ10	4D25	4D25	4ϕ10	9D25	9D25	4ϕ10	4D25
17	9D25	4ϕ10	4D25	4D25	4ϕ10	9D25	9D25	4ϕ10	4D25
18	9D25	4ϕ10	4D25	4D25	4ϕ10	9D25	9D25	4ϕ10	4D25
19	9D25	4ϕ10	4D25	4D25	4ϕ10	9D25	9D25	4ϕ10	4D25
20	9D25	4ϕ10	4D25	4D25	4ϕ10	9D25	9D25	4ϕ10	4D25
22	9D25	4ϕ10	4D25	4D25	4ϕ10	9D25	9D25	4ϕ10	4D25
23	9D25	4ϕ10	4D25	4D25	4ϕ10	9D25	9D25	4ϕ10	4D25
24	9D25	4ϕ10	4D25	4D25	4ϕ10	9D25	9D25	4ϕ10	4D25
25	9D25	4ϕ10	4D25	4D25	4ϕ10	9D25	9D25	4ϕ10	4D25
26	9D25	4ϕ10	4D25	4D25	4ϕ10	9D25	9D25	4ϕ10	4D25
27	9D25	4ϕ10	4D25	4D25	4ϕ10	9D25	9D25	4ϕ10	4D25

b) Beam type b

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
40	100	10	25	12	300	3700	2400

Frame Element Force				
Members	Axial (kg)	Shear (kg)	Torsion (kgcm)	Moment (kgcm)
34	2100	53570	96000	8737000
35	3120	68780	1344000	12196000
36	3900	77270	1084000	13062000
37	3120	68420	1385000	11963000
38	3890	76790	1014000	12791000

Design			
Members	Main Bar (mm)	Stirrup Bar (mm)	Mu (kgcm)
34	D25	ϕ12-@250	13139677
35	D25	ϕ12-@250	13139677
36	D25	ϕ12-@250	13139677
37	D25	ϕ12-@250	13139677
38	D25	ϕ12-@250	13139677

Design									
Members	Left Bar			Middle Bar			Right Bar		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
34	15D25	4ϕ10	6D25	6D25	4ϕ10	15D25	15D25	4ϕ10	6D25
35	15D25	4ϕ10	6D25	6D25	4ϕ10	15D25	15D25	4ϕ10	6D25
36	15D25	4ϕ10	6D25	6D25	4ϕ10	15D25	15D25	4ϕ10	6D25
37	15D25	4ϕ10	6D25	6D25	4ϕ10	15D25	15D25	4ϕ10	6D25
38	15D25	4ϕ10	6D25	6D25	4ϕ10	15D25	15D25	4ϕ10	6D25

c) Beam type c

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
35	100	10	25	10	300	3700	2400

Frame Element Force				
Members	Axial (kg)	Shear (kg)	Torsion (kgcm)	Moment (kgcm)
21	2156	53540	1244000	10685882
28	2250	55470	1124000	13546854

Design			
Members	Main Bar (mm)	Stirrup Bar (mm)	Mu (kgcm)
21	D25	ϕ10-@40	11736664
28	D25	ϕ10-@40	11736664

Design									
Members	Left Bar			Middle Bar			Right Bar		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
21	13D25	4ϕ10	6D25	6D25	4ϕ10	13D25	13D25	4ϕ10	6D25
28	13D25	4ϕ10	6D25	6D25	4ϕ10	13D25	13D25	4ϕ10	6D25

d) Beam type d

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm^2)	fy (kg/cm^2)	fv (kg/cm^2)
30	75	8	25	12	300	3700	2400

Frame Element Force				
Members	Axial (kg)	Shear (kg)	Torsion (kgcm)	Moment (kgcm)
81	5050	14780	297000	2048000
82	5660	14810	0	1989000
83	3820	14990	259000	2103000
84	2340	14850	42000	2078000
85	5110	14790	297000	2042000
86	5740	14660	0	1989000
87	3810	15000	259000	2101000
88	2720	14840	41000	2080000

Design			
Members	Main Bar (mm)	Stirrup Bar (mm)	Mu (kgcm)
81	D25	ϕ12-@50	2884256
82	D25	ϕ12-@50	2884256
83	D25	ϕ12-@50	2884256
84	D25	ϕ12-@50	2884256
85	D25	ϕ12-@50	2884256
86	D25	ϕ12-@50	2884256
87	D25	ϕ12-@50	2884256
88	D25	ϕ12-@50	2884256

Design									
Members	Left Bar			Middle Bar			Right Bar		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
81	3D25	4ϕ10	2D25	2D25	4ϕ10	3D25	3D25	4ϕ10	2D25
82	3D25	4ϕ10	2D25	2D25	4ϕ10	3D25	3D25	4ϕ10	2D25
83	3D25	4ϕ10	2D25	2D25	4ϕ10	3D25	3D25	4ϕ10	2D25
84	3D25	4ϕ10	2D25	2D25	4ϕ10	3D25	3D25	4ϕ10	2D25
85	3D25	4ϕ10	2D25	2D25	4ϕ10	3D25	3D25	4ϕ10	2D25
86	3D25	4ϕ10	2D25	2D25	4ϕ10	3D25	3D25	4ϕ10	2D25
87	3D25	4ϕ10	2D25	2D25	4ϕ10	3D25	3D25	4ϕ10	2D25
88	3D25	4ϕ10	2D25	2D25	4ϕ10	3D25	3D25	4ϕ10	2D25

e) Beam type e

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm^2)	fy (kg/cm^2)	fv (kg/cm^2)
30	75	8	25	12	300	3700	2400

Frame Element Force				
Members	Axial (kg)	Shear (kg)	Torsion (kgcm)	Moment (kgcm)
89	5380	21980	0	3927000
90	5430	21980	0	4094000
91	10510	21980	0	3909000

Design			
Members	Main Bar (mm)	Stirrup Bar (mm)	Mu (kgcm)
89	D25	ϕ12-@50	4611165
90	D25	ϕ12-@50	4611165
91	D25	ϕ12-@50	4611165

Design									
Members	Left Bar			Middle Bar			Right Bar		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
89	5D25	4ϕ10	2D25	2D25	4ϕ10	5D25	5D25	4ϕ10	2D25
90	5D25	4ϕ10	2D25	2D25	4ϕ10	5D25	5D25	4ϕ10	2D25
91	5D25	4ϕ10	2D25	2D25	4ϕ10	5D25	5D25	4ϕ10	2D25

f) Beam type f

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
35	70	8	25	12	300	3700	2400

Frame Element Force				
Members	Axial (kg)	Shear (kg)	Torsion (kgcm)	Moment (kgcm)
128	190	29030	0	2902000

Design			
Members	Main Bar (mm)	Stirrup Bar (mm)	Mu (kgcm)
128	D25	ϕ12-@50	4261033

Design									
Members	Left Bar			Middle Bar			Right Bar		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
128	5D25	4ϕ10	2D25	2D25	4ϕ10	5D25	5D25	4ϕ10	2D25

g) Beam type g

Prototype of Element

B (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
30	60	8	25	12	300	3700	2400

Frame Element Force				
Members	Axial (kg)	Shear (kg)	Torsion (kgcm)	Moment (kgcm)
124	3110	12970	55000	1470000
125	3100	13130	48000	1562000
126	3480	14580	5000	1458000
127	19240	14640	6000	1768000

Design			
Members	Main Bar (mm)	Stirrup Bar (mm)	Mu (kgcm)
124	D25	ϕ12-@50	2127644
125	D25	ϕ12-@50	2127644
126	D25	ϕ12-@50	2127644
127	D25	ϕ12-@50	2127644

Members	Design								
	Left Bar			Middle Bar			Right Bar		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
124	3D25	4ϕ10	2D25	2D25	4ϕ10	3D25	3D25	4ϕ10	2D25
125	3D25	4ϕ10	2D25	2D25	4ϕ10	3D25	3D25	4ϕ10	2D25
126	3D25	4ϕ10	2D25	2D25	4ϕ10	3D25	3D25	4ϕ10	2D25
127	3D25	4ϕ10	2D25	2D25	4ϕ10	3D25	3D25	4ϕ10	2D25

h) Beam type h

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (plain)	dia. stirrup (mm)	fc' (kg/cm^2)	fy (kg/cm^2)	fv (kg/cm^2)
10	110	4	10	8	300	3700	2400

Frame Element Force				
Members	Axial (kg)	Shear (kg)	Torsion (kgcm)	Moment (kgcm)
53	10	1950	0	195000
54	270	5930	0	766000
55	600	5230	0	706000
56	600	5230	0	706000
57	270	5930	0	766000
58	10	1950	0	195000
59	10	1940	0	194000
60	10	1950	0	195000
61	620	5250	0	707000
62	620	5250	0	707000
63	70	5990	0	772000
64	10	1950	0	195000
65	0	3970	0	472000
66	30	7400	0	1436000
67	0	3960	0	470000
68	0	3970	0	472000
69	30	7400	0	1436000
70	0	3960	0	470000
106	10	1950	0	195000
107	270	5930	0	766000
108	600	5230	0	706000
109	600	5230	0	706000
110	270	5930	0	766000
111	10	1950	0	195000
112	10	1940	0	194000
113	10	1950	0	195000
114	620	5250	0	707000
115	620	5250	0	707000
116	70	5990	0	772000
117	10	1950	0	195000
118	0	3970	0	472000
119	30	7400	0	1436000
120	0	3960	0	470000
121	0	3970	0	472000
122	30	7400	0	1436000
123	0	3960	0	470000

Design			
Members	Main Bar (mm)	Stirrup Bar (mm)	Mu (kgcm)
53	ϕ10	ϕ8-@150	1767837
54	ϕ10	ϕ8-@150	1767837
55	ϕ10	ϕ8-@150	1767837
56	ϕ10	ϕ8-@150	1767837
57	ϕ10	ϕ8-@150	1767837
58	ϕ10	ϕ8-@150	1767837
59	ϕ10	ϕ8-@150	1767837
60	ϕ10	ϕ8-@150	1767837
61	ϕ10	ϕ8-@150	1767837
62	ϕ10	ϕ8-@150	1767837
63	ϕ10	ϕ8-@150	1767837
64	ϕ10	ϕ8-@150	1767837
65	ϕ10	ϕ8-@150	1767837
66	ϕ10	ϕ8-@150	1767837
67	ϕ10	ϕ8-@150	1767837
68	ϕ10	ϕ8-@150	1767837
69	ϕ10	ϕ8-@150	1767837
70	ϕ10	ϕ8-@150	1767837
106	ϕ10	ϕ8-@150	1767837
107	ϕ10	ϕ8-@150	1767837
108	ϕ10	ϕ8-@150	1767837
109	ϕ10	ϕ8-@150	1767837
110	ϕ10	ϕ8-@150	1767837
111	ϕ10	ϕ8-@150	1767837
112	ϕ10	ϕ8-@150	1767837
113	ϕ10	ϕ8-@150	1767837
114	ϕ10	ϕ8-@150	1767837
115	ϕ10	ϕ8-@150	1767837
116	ϕ10	ϕ8-@150	1767837
117	ϕ10	ϕ8-@150	1767837
118	ϕ10	ϕ8-@150	1767837
119	ϕ10	ϕ8-@150	1767837
120	ϕ10	ϕ8-@150	1767837
121	ϕ10	ϕ8-@150	1767837
122	ϕ10	ϕ8-@150	1767837
123	ϕ10	ϕ8-@150	1767837

Design									
Members	Left Bar			Middle Bar			Right Bar		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
53	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
54	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
55	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
56	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
57	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
58	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
59	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
60	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
61	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
62	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
63	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
64	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
65	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
66	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
67	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
68	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
69	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
70	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
106	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
107	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
108	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
109	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
110	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
111	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
112	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
113	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
114	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
115	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
116	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
117	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
118	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
119	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
120	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
121	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
122	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
123	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10

i) Beam type i

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
20	50	4	25	10	300	3700	2400

Design			
Stirrup Bar (mm)	Left , Mid and Right Bar		
	Top	Mid	Bottom
ϕ10-@150	6D25	2ϕ10	3D25

j) Beam type j

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
20	45	4	25	10	300	3700	2400

Design			
Stirrup Bar (mm)	Left, Mid and Right Bar		
	Top	Mid	Bottom
ϕ10-@150	3D25	2ϕ10	2D25

k) Beam type k

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
15	30	4	25	10	300	3700	2400

Design									
Stirrup Bar (mm)	Left Bar			Middle Bar			Right Bar		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
ϕ10-@150	2D25	-	2D25	2D25	-	2D25	2D25	-	2D25

l) Beam type l

Prototype of Element

b (cm)	H (cm)	cover (mm)	dia. Main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
20	30	4	25	10	300	3700	2400

Design			
Stirrup Bar (mm)	Left, Mid and Right Bar		
	Top	Mid	Bottom
ϕ10-@150	3D25	2ϕ10	3D25

m) Beam type m

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (plain)	dia. stirrup (mm)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
10	75	4	10	8	300	3700	2400

Design			
Stirrup Bar (mm)	Bar		
	Top	Mid	Bottom
ϕ8-@150	2ϕ10	10ϕ10	2ϕ10

n) Beam type n

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (deform)	dia. stirrup (mm)	fc (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
25	45	4	25	10	300	3700	2400

Design									
Stirrup Bar (mm)	Left Bar			Middle Bar			Right Bar		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
ϕ10-@150	3D25	2ϕ10	2D25	2D25	2ϕ10	3D25	3D25	2ϕ10	2D25

o) Beam type o

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (plain)	dia. stirrup (mm)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
15	15	4	12	10	300	3700	2400

Design									
Stirrup Bar (mm)	Left Bar			Middle Bar			Right Bar		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
ϕ10@-150	2D12	-	2D12	2D12	-	2D12	2D12	-	2D12

p) Beam type p

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
15	20	4	16	8	300	3700	2400

Design									
Stirrup Bar (mm)	Left Bar			Middle Bar			Right Bar		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
ϕ8-@200	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16

q) Beam type q

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (plain)	dia. stirrup (mm)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
10	22	4	12	8	300	3700	2400

Design			
Stirrup Bar (mm)	Left, Mid and Right Bar		
	Top	Mid	Bottom
ϕ8-@200	2ϕ12	-	2ϕ12

3) Slab

a) Slab of control office in the 2nd floor

t (cm)	l max (cm)	w max (cm)	cover (mm)	dia. Main bar (mm) (plain)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
15	750	622.5	4	12	300	3700	2400

Moment			
Mlx (kgcm)	Mly (kgcm)	Mtix (kgcm)	Mtiy (kgcm)
72000	22000	- 110000	12000

Design (x and y direction)	
Point of support Bar	Yield Bar
ϕ12-@100	ϕ12-@150

b) Slab with lx = 1000 mm on canopy above windows and entrance

ly = 1000 mm

t (cm)	l (cm)	w (cm)	cover (mm)	dia. Main bar (mm) (plain)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
15	100	100	4	10	300	3700	2400

Design (x and y direction)	
Point of support Bar	Yield Bar
ϕ10-@150	ϕ10-@150

c) Slab with lx = 1000 mm between each console

ly = 1000 mm

t (cm)	l (cm)	w (cm)	cover (mm)	dia. Main bar (mm) (plain)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
12	100	100	4	12	300	3700	2400

Design (x and y direction)	
Point of support Bar	Yield Bar
ϕ12-@100	ϕ12-@100

d) Slab with lx = 1000 mm on stairs

ly = 1000 mm

t (cm)	l (cm)	w (cm)	cover (mm)	dia. Main bar (mm) (plain)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
15	100	100	4	12 16	300	3700	2400

Design (y direction)	D16-@150
Design (x direction)	ϕ12-@150

e) Slab of entrance roof

t (cm)	l max (cm)	w max (cm)	cover (mm)	dia. Main bar (mm) (plain)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
15	750	150	4	12	300	3700	2400

Design (x and y direction)	
Point of support Bar	Yield Bar
ϕ12-@100	ϕ12-@100

4. Design of Element Profile of Crane

Load crane = 25000 kg

Maximum moment = ¼ PL

= ¼ * 25000 * 750

= 4687500 kg.cm

Use IWF- 494 x 302 x 13 x 21

Ix = 83800 cm^4

Iy = 9660 cm^4

Wx = 3390 cm^3

Wy = 640 cm^3

Checking:

Stresses :

$\sigma = M_{max}/Wx$

= 4687500/3390

= 1382.74 < σ_{all} = 1400 kg/cm^2 (OK)

Deflection :

$f = 1/48 \times PL^3/EI_x$

$= 1/48 \times 25000 \times 750^3/2.1 \times 10^6 \times 83800$

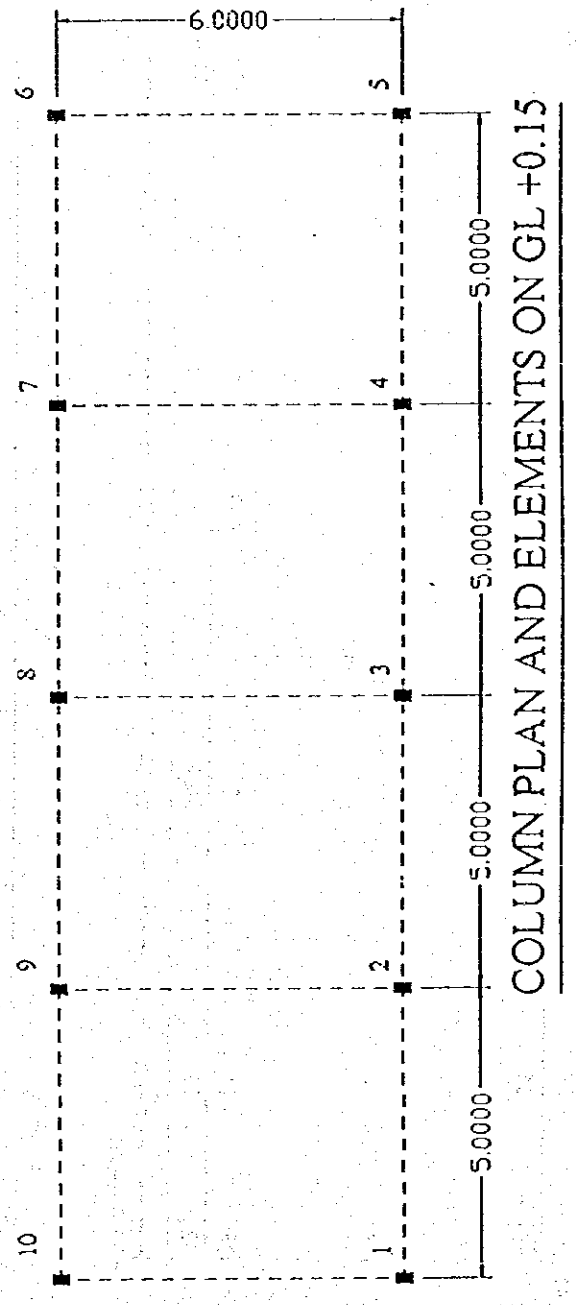
= 1.24 cm < f_{all} = 1/500 L = 1/500 x 750 = 1.50 cm (OK)

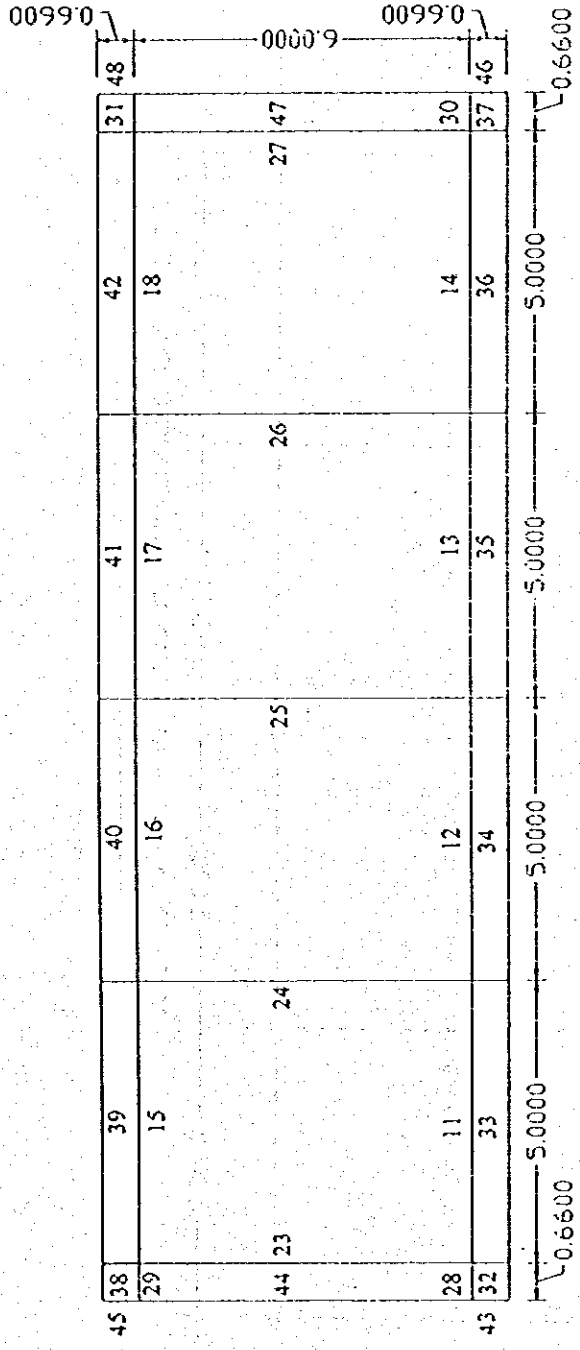
5.3 Design of Garage

JATIBARANG GARAGE
STRUCTURE CALCULATION

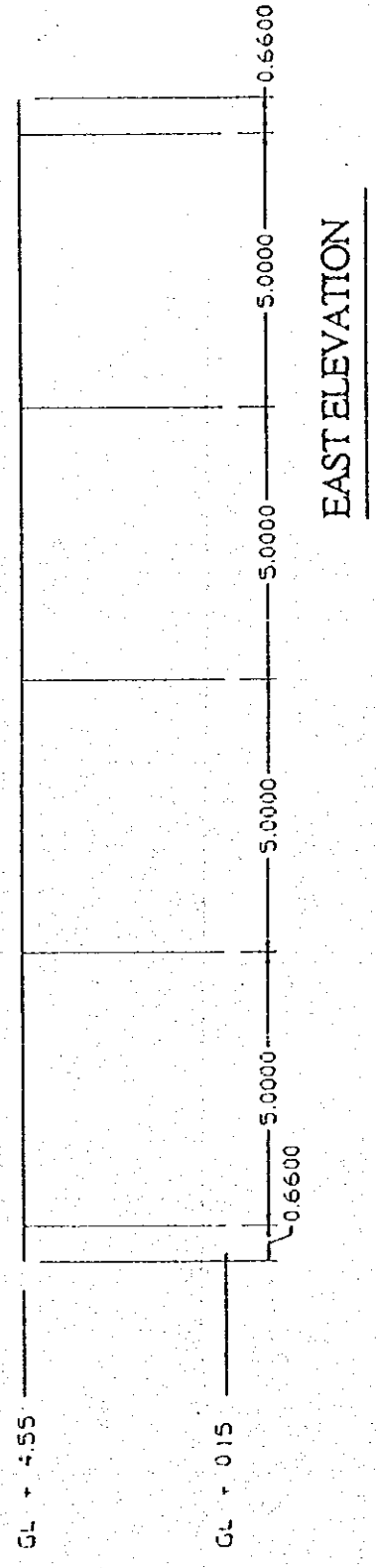
CONTENT :

1. General Construction

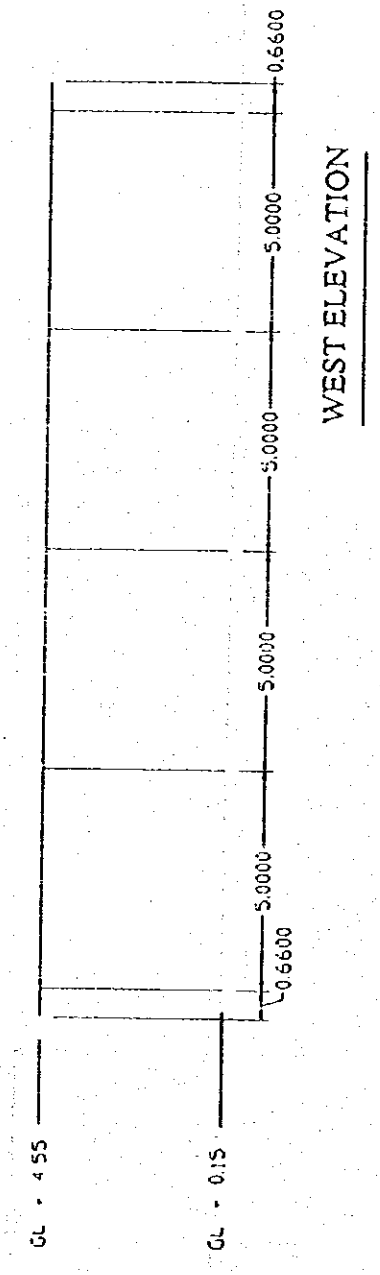




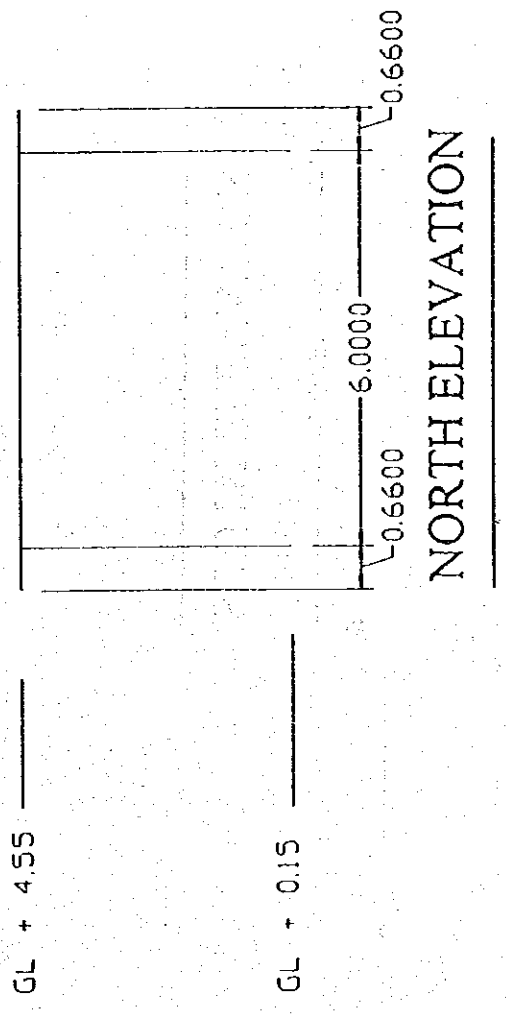
TIE BEAM AND CONSOLE BEAM PLAN GL + 4.55



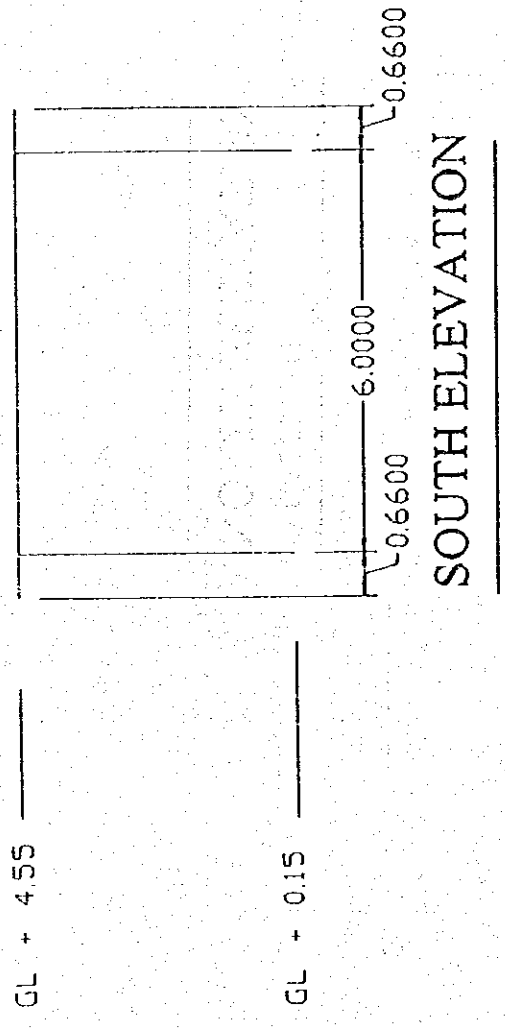
EAST ELEVATION



WEST ELEVATION



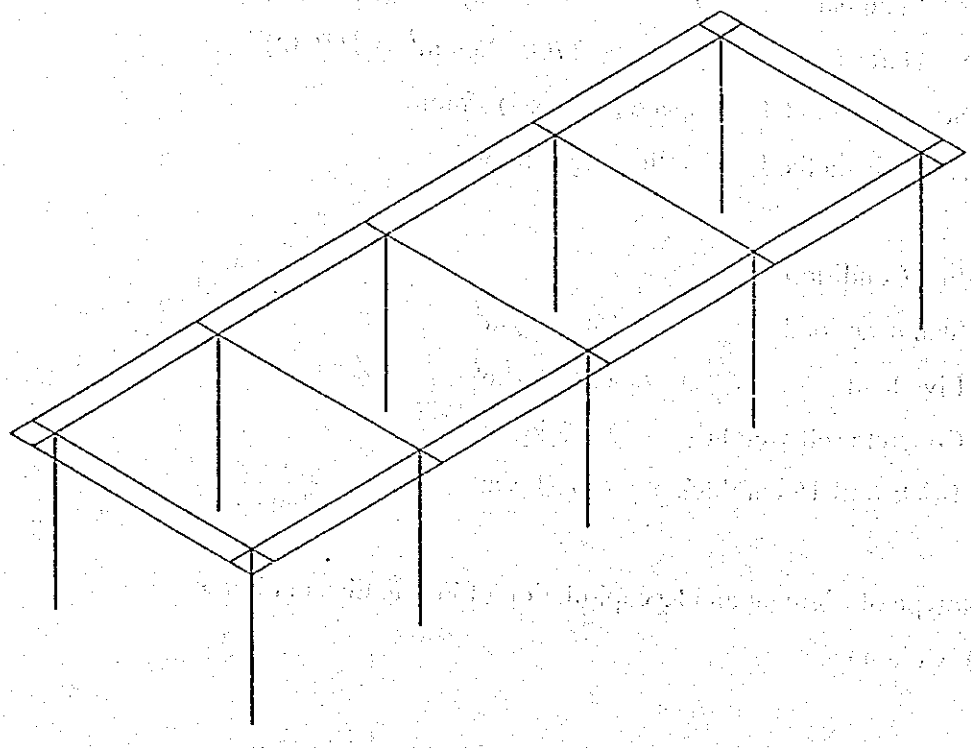
NORTH ELEVATION



SOUTH ELEVATION

2. Design Of Reinforcement Concrete Frame

a. Structure of Reinforcement Concrete Frame



b. Dimensions

- length c – c column = 20.00 m
- width c – c column = 6.00 m
- height ground to roof = 4.11 m

c. Design Condition

1) Concrete compression strength fc'= 30 MPa (K-250 = 250 kg/cm^2)
2) Reinforcing bar :
   - Plain bar fy = 2400 kg/cm^2 (BJTP 24)
   - Deformed bar fy = 3700 kg/cm^2 (BJTP 32)
3) Structural model : space (xyz axis) frame
4) Analysis method : static – rigid floor

d. Loading Condition

1) Slab dead load = 150 kg/m^2
2) Live load = 400 kg/m^2
3) Concrete self weight = 2400 kg/m^3
4) Brick wall 15 cm thick = 250 kg/m^2

e. Prototype of Element and Recapitulation of Frame Element Force

1). Column

a) Column type 1 (column in level 0+000 until 5+500)

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm^2)	fy (kg/cm^2)	fv (kg/cm^2)
20	30	10	25	10	300	3700	2400

Frame Element Force					Design			
Members	Axial (kg)	Shear (kg)	Torsion (kgcm)	Moment (kgcm)	Main bar (mm)	Stirrup (mm)	Pu (kg)	Mu (kgcm)
1	30410	1160	0	464000	4D25	ϕ10@-300	36354	611587
2	35290	1480	0	591000	4D25	ϕ10@-300	36354	611587
3	34510	1480	0	591000	4D25	ϕ10@-300	36354	611587
4	35290	1480	0	591000	4D25	ϕ10@-300	36354	611587
5	30410	1160	0	464000	4D25	ϕ10@-300	36354	611587
6	30410	1160	0	464000	4D25	ϕ10@-300	36354	611587
7	35290	1480	0	591000	4D25	ϕ10@-300	36354	611587
8	34510	1480	0	590000	4D25	ϕ10@-300	36354	611587
9	35290	1480	0	591000	4D25	ϕ10@-300	36354	611587
10	30410	1160	0	464000	4D25	ϕ10@-300	36354	611587

2). Beam

a) Beam type a

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm^2)	fy (kg/cm^2)	fv (kg/cm^2)
20	40	10	16	10	300	3700	2400

Frame Element Force				
Members	Axial (kg)	Shear (kg)	Torsion (kgcm)	Moment (kgcm)
11	80	6730	16000	666000
12	60	6990	0	664000
13	60	6990	0	664000
14	80	7140	16000	666000
15	80	7140	16000	666000
16	60	6990	0	664000
17	60	6990	0	664000
18	80	7140	16000	666000

Design			
Members	Main Bar (mm)	Stirrup Bar (mm)	Mu (kgcm)
11	D16	ϕ10-@50	673254
12	D16	ϕ10-@50	673254
13	D16	ϕ10-@50	673254
14	D16	ϕ10-@50	673254
15	D16	ϕ10-@50	673254
16	D16	ϕ10-@50	673254
17	D16	ϕ10-@50	673254
18	D16	ϕ10-@50	673254

Design									
Members	Left Bar			Middle Bar			Right Bar		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
11	2D16	2ϕ10	2D16	2D16	2ϕ10	2D16	2D16	2ϕ10	2D16
12	2D16	2ϕ10	2D16	2D16	2ϕ10	2D16	2D16	2ϕ10	2D16
13	2D16	2ϕ10	2D16	2D16	2ϕ10	2D16	2D16	2ϕ10	2D16
14	2D16	2ϕ10	2D16	2D16	2ϕ10	2D16	2D16	2ϕ10	2D16
15	2D16	2ϕ10	2D16	2D16	2ϕ10	2D16	2D16	2ϕ10	2D16
16	2D16	2ϕ10	2D16	2D16	2ϕ10	2D16	2D16	2ϕ10	2D16
17	2D16	2ϕ10	2D16	2D16	2ϕ10	2D16	2D16	2ϕ10	2D16
18	2D16	2ϕ10	2D16	2D16	2ϕ10	2D16	2D16	2ϕ10	2D16

b) Beam type b

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm^2)	fy (kg/cm^2)	fv (kg/cm^2)
20	40	10	16	10	300	3700	2400

Frame Element Force				
Members	Axial (kg)	Shear (kg)	Torsion (kgcm)	Moment (kgcm)
23	1150	11090	72000	1255000
24	1480	13240	4000	1661000
25	1480	12970	0	1621000
26	1480	13240	4000	1661000
27	1150	11090	72000	1255000

Design			
Members	Main Bar (mm)	Stirrup Bar (mm)	Mu (kgcm)
23	D19	ϕ10-@150	1756489
24	D19	ϕ10-@150	1756489
25	D19	ϕ10-@150	1756489
26	D19	ϕ10-@150	1756489
27	D19	ϕ10-@150	1756489

Design									
Members	Left Bar			Middle Bar			Right Bar		
	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
23	3D16	2ϕ10	2D16	2D16	2ϕ10	3D16	3D16	2ϕ10	2D16
24	3D16	2ϕ10	2D16	2D16	2ϕ10	3D16	3D16	2ϕ10	2D16
25	3D16	2ϕ10	2D16	2D16	2ϕ10	3D16	3D16	2ϕ10	2D16
26	3D16	2ϕ10	2D16	2D16	2ϕ10	3D16	3D16	2ϕ10	2D16
27	3D16	2ϕ10	2D16	2D16	2ϕ10	3D16	3D16	2ϕ10	2D16

c) Beam type c

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (deform)	dia. stirrup (mm)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
15	30	10	16	10	300	3700	2400

Frame Element Force				
Members	Axial (kg)	Shear (kg)	Torsion (kgcm)	Moment (kgcm)
28	0	5220	12000	590000
29	0	2640	0	232000
30	0	5220	12000	590000
31	0	5220	12000	590000

Design			
Members	Main Bar (mm)	Stirrup Bar (mm)	Mu (kgcm)
28	D16	ϕ10-@100	658457
29	D16	ϕ10-@100	658457
30	D16	ϕ10-@100	658457
31	D16	ϕ10-@100	658457

Design						
Members	Left Bar			Right Bar		
	Top	Mid	Bottom	Top	Mid	Bottom
28	3D16	2ϕ10	2D16	3D16	2ϕ10	2D16
29	3D16	2ϕ10	2D16	3D16	2ϕ10	2D16
30	3D16	2ϕ10	2D16	3D16	2ϕ10	2D16
31	3D16	2ϕ10	2D16	3D16	2ϕ10	2D16

d) Beam type d

Prototype of Element

b (cm)	h (cm)	cover (mm)	dia. Main bar (mm) (plain)	dia. stirrup (mm)	fc' (kg/cm²)	fy (kg/cm²)	fv (kg/cm²)
10	95	10	10	8	300	3700	2400

Frame Element Force				
Members	Axial (kg)	Shear (kg)	Torsion (kgcm)	Moment (kgcm)
32	0	900	7000	85000
33	10	1340	0	117000
34	10	1230	0	116000
35	10	1290	0	116000
36	10	1180	0	117000
37	0	900	7000	85000
38	0	900	7000	85000
39	10	1340	0	117000
40	10	1290	0	116000
41	10	1290	0	116000
42	10	1340	0	117000
43	0	90000	7000	85000
44	0	610	7000	42000
45	10	1660	7000	241000
46	10	1660	7000	241000
47	0	610	7000	42000
48	0	610	7000	42000

Design			
Members	Main Bar (mm)	Stirrup Bar (mm)	Mu (kgcm)
32	ϕ10	ϕ8-@150	245678
33	ϕ10	ϕ8-@150	245678
34	ϕ10	ϕ8-@150	245678
35	ϕ10	ϕ8-@150	245678
36	ϕ10	ϕ8-@150	245678
37	ϕ10	ϕ8-@150	245678
38	ϕ10	ϕ8-@150	245678
39	ϕ10	ϕ8-@150	245678
40	ϕ10	ϕ8-@150	245678
41	ϕ10	ϕ8-@150	245678
42	ϕ10	ϕ8-@150	245678
43	ϕ10	ϕ8-@150	245678
44	ϕ10	ϕ8-@150	245678
45	ϕ10	ϕ8-@150	245678
46	ϕ10	ϕ8-@150	245678
47	ϕ10	ϕ8-@150	245678
48	ϕ10	ϕ8-@150	245678

Design									
Members	Left Bar			Middle Bar			Right Bar		
32	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
33	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
34	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
35	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
36	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
37	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
38	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
39	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
40	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
41	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
42	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
43	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
44	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
45	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
46	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
47	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10
48	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10	2ϕ10	12ϕ10	2ϕ10

3). Slab between each console

t (cm)	l (cm)	w (cm)	cover (mm)	dia. Main bar (mm) (plain)	fc' (kg/cm^2)	fy (kg/cm^2)	fv (kg/cm^2)
12	100	100	4	12	300	3700	2400

Design (x and y direction)	
Point of support Bar	Yield Bar
ϕ12-@100	ϕ12-@150