3.5 Pump Control Building

3.5 Pump Control Building

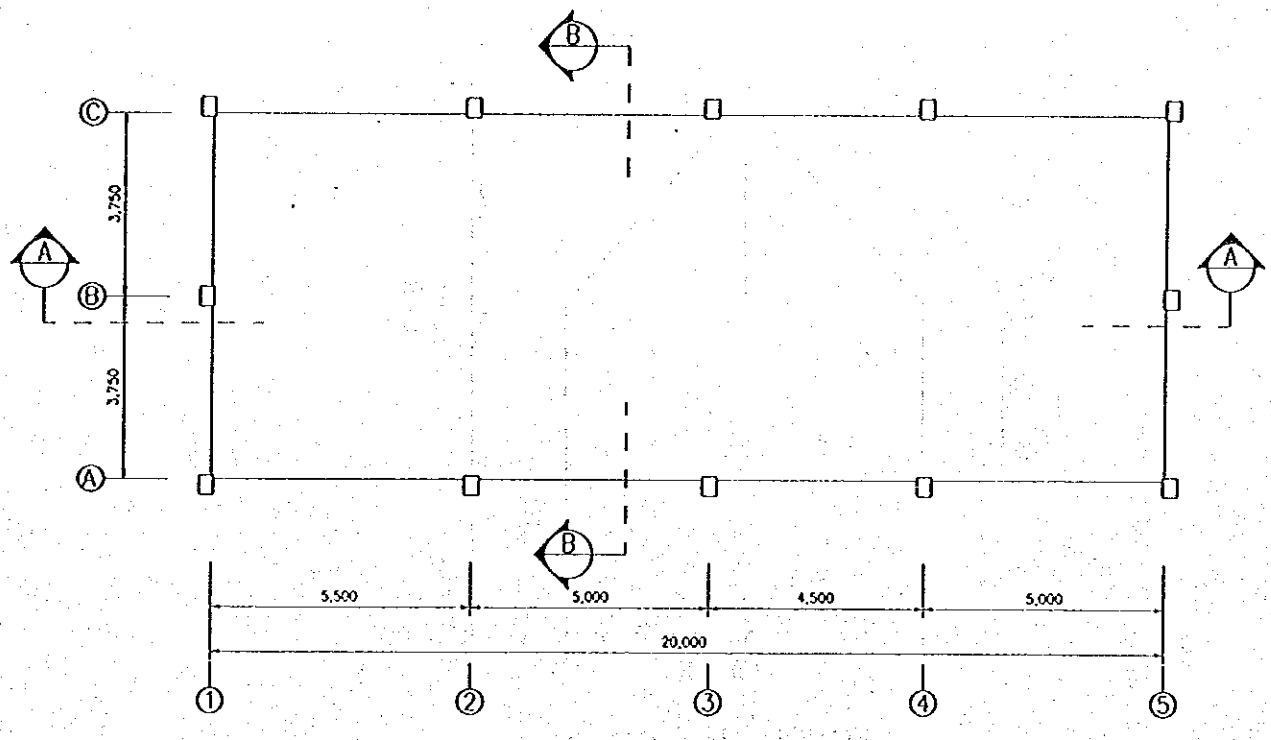
3.5.1 Structural Calculation

STRUCTURE CALCULATION

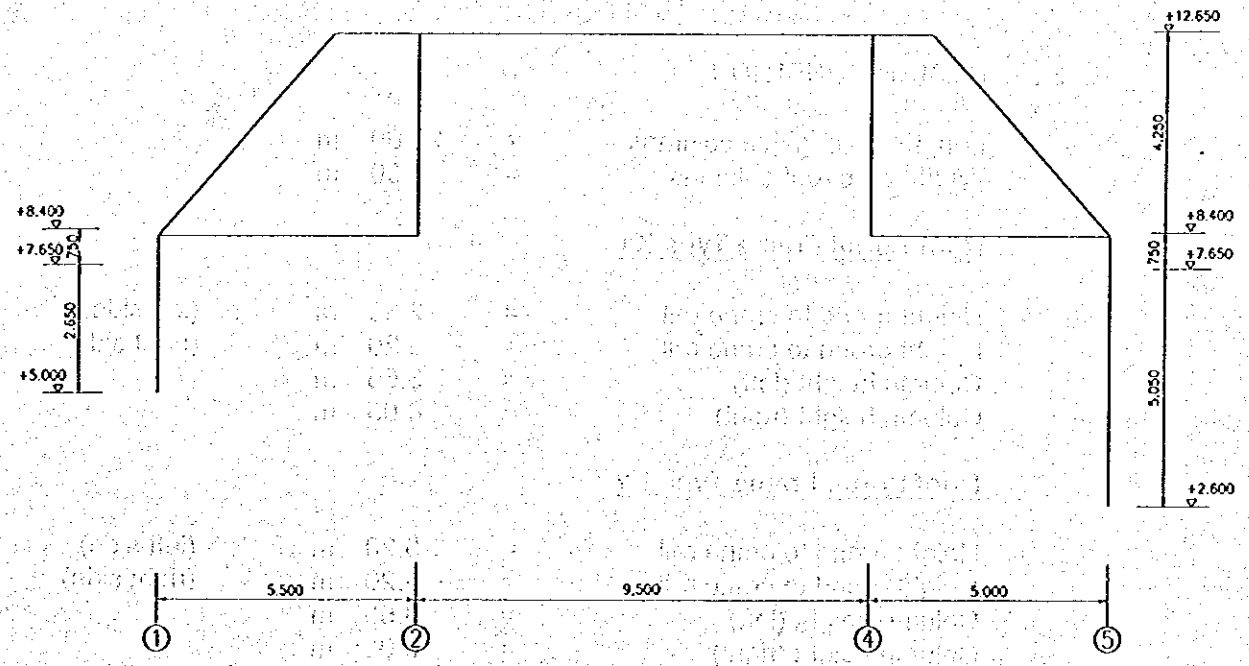
PUMP CONTROL BUILDING

BARU PUMPING STATION COMPLEX

1. STRUCTURE

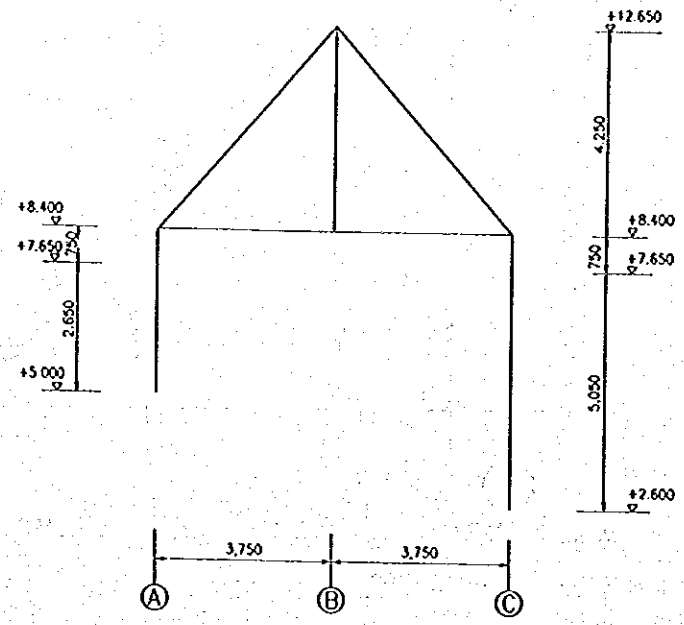


PLAN



SECTION A–A

PUMP CONTROL BUILDING
BARU PUMPING STATION COMPLEX



SECTION B-B

PUMP CONTROL BUILDING
BARU PUMPING STATION COMPLEX

2 . DESIGN CONDITION

Length c - c gable columns	=	20.00	m	
Width c - c roof columns	=	7.50	m	

Roof Portal Frame Type K1

Height grond to crane rail	=	2.80	m	(left side)
Height grond to crane rail	=	5.20	m	(right side)
Column height (left)	=	3.65	m	
Column height (right)	=	6.05	m	

Roof Portal Frame Type K2

Height grond to crane rail	=	5.20	m	(left side)
Height grond to crane rail	=	5.20	m	(right side)
Column height (left)	=	3.65	m	
Column height (right)	=	6.05	m	

Roof covering	=	Ceramic roof tile	
Crane span	=	6.70	m
End clearence	=	0.10	m
Weight of crane without carb	=	2.00	Ton
Weight of carb	=	0.80	Ton

3. Loading Condition

a. Dead load

- Roof cover (ceramic tile + timber rafter) = 70 kg/m²
- Ceiling (fiber cement) = 10 kg/m²
- Reinforced concrete = 2,400 kg/m³
- Brick wall 0.15 m thick = 250 kg/m²
- Weight of a worker as point load = 100 kg

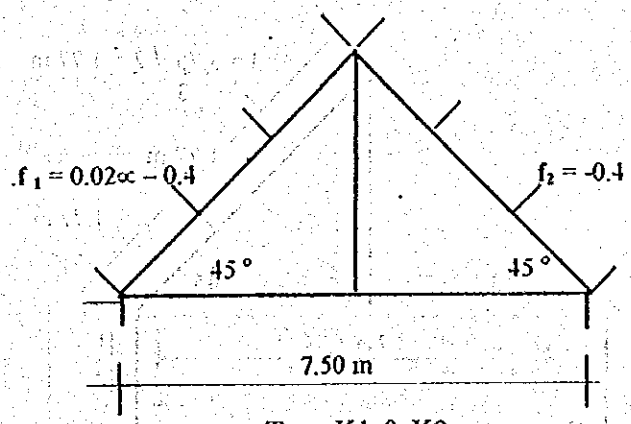
b. Wind Load

- Wind pressure at coastal up to 5 km far = 40 kg/m²
- Pressure coefficient (f)
  - Windward $f = 0.02 \times \alpha - 0.5$
    α = (angle of roof slope) $\leq 65^{0}$
  - Leeward $f = -0.4$

c. Live Load :

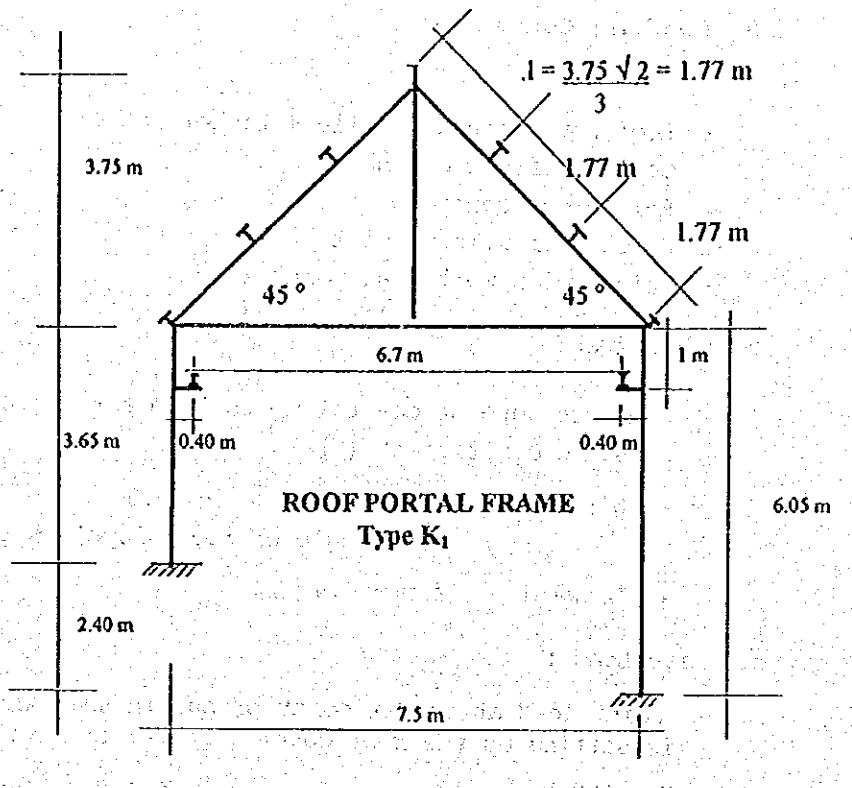
- Point load at center point of purlin span when a worker is setting up the roof cover (rafter and ceramic tile)

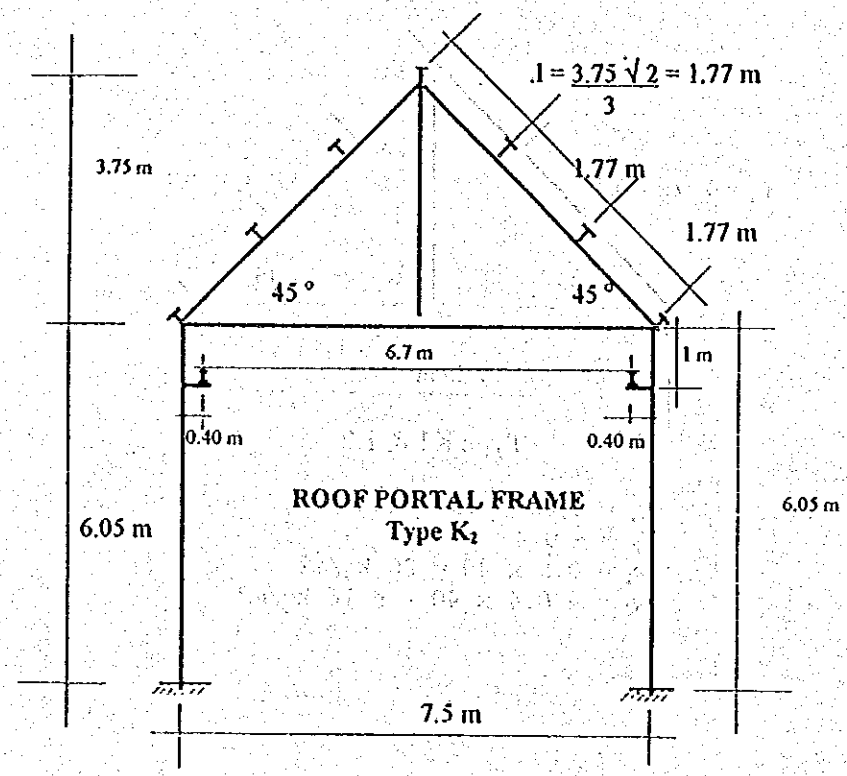
P = 100 kg ——— $P_1 = P_2 = P \cos 45^{\circ}$
$= 71$ kg



Type K1 & K2

$f_1 = 0.02 \times 45^{\circ} - 0.4 \cong 0,5$
$f_2 = -0.4$
$w_1 = 0.5 \times 40 = 20$ kg/m2
$w_2 = -0.4 \times 40 = -16$ kg/m2


.1 = 3.75 √ 2 = 1.77 m
3
3.75 m
1.77 m
1.77 m
45 °
45 °
6.7 m
1 m
3.65 m
0.40 m
0.40 m
ROOF PORTAL FRAME
Type K1
6.05 m
2.40 m
7.5 m


.1 = 3.75 √ 2 = 1.77 m
3
3.75 m
1.77 m
1.77 m
45 °
45 °
6.7 m
1 m
0.40 m
0.40 m
ROOF PORTAL FRAME
Type K2
6.05 m
6.05 m
7.5 m

4. Design of members
Purlins 5 m span ; 1.77 m centers

Dead load :

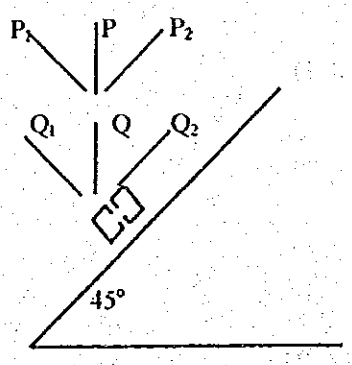
- Roof cover (ceramic tile) + timber rafter = 70 kg/ m2
- Ceiling (fiber cement) = 10 kg/ m2

= 80 kg/ m2

$q_1 = 1.77 \times 80 = 141.6 \approx 142$ kg/ m'

- Purlin self weight(q_2) say = 15 kg/ m'

Q = 157 kg/ m'



$Q_1 = Q_2 = Q \cos 45° = 157 \cos 45° = 111$ kg/ m'

- Try purlin of Lip Channel type :

150 x 130 x 20 x 3.2
Ix = 664 cm⁴ ; Wx = 88.6 cm³
Iy = 476 cm⁴ ; Wy = 73.2 cm³

- Bending Moment at center point of purlin span :

$Mx = \frac{1}{8} \times 111 \times 5^2 + \frac{1}{4} \times 71 \times 5 = 435.625$ kgm

My = Mx = 435.625 kgm ≈ 43,563 kg cm

Stress :

$$\sigma = \sigma x + \sigma y = \frac{Mx}{Wx} + \frac{My}{Wy}$$

$$= \frac{43.563}{88.6} + \frac{43.563}{73.2}$$

$= \sigma$ 1,087 kg/ cm² < $\bar{\sigma}_{allowable}$ = 1,400 kg/ cm² (OK!)

Deflection

$$fx = \frac{5}{384} \times \frac{111}{100} \times \frac{500^4}{2.1E6 \times 664} + \frac{1}{48} \times 71 \times \frac{500^3}{2.1E6 \times 664}$$

$= 0.64 \text{ cm} + 0.13 \text{ cm}$

$= 0.77 \text{ cm}$

$fy = 0.90 + 0.18$

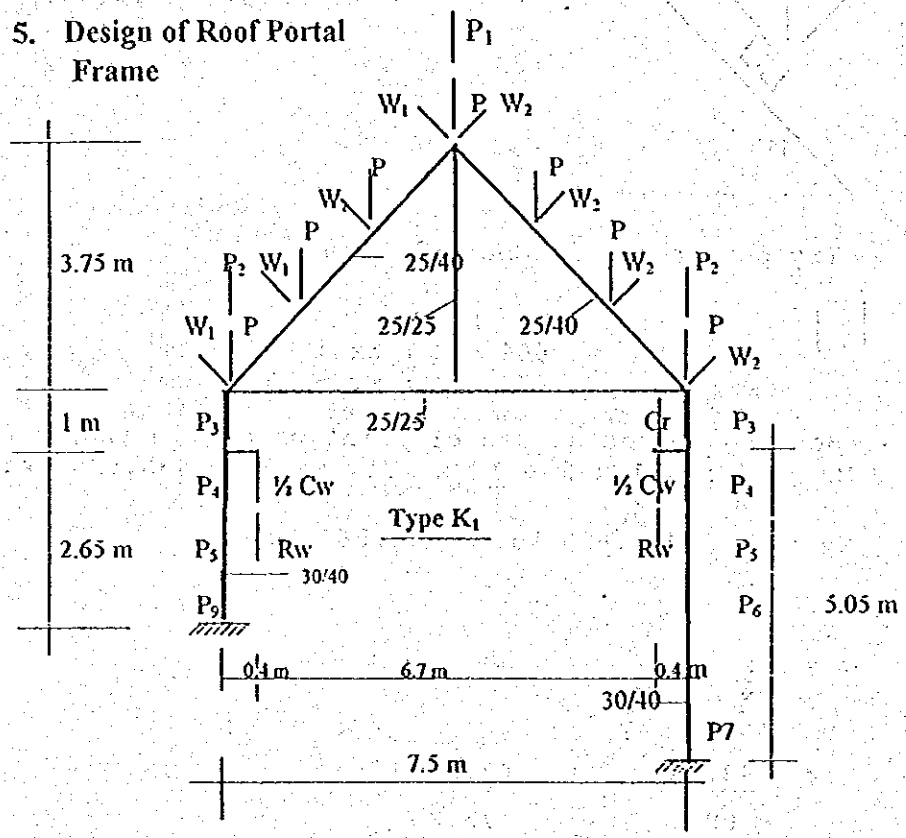
$= 1.08$

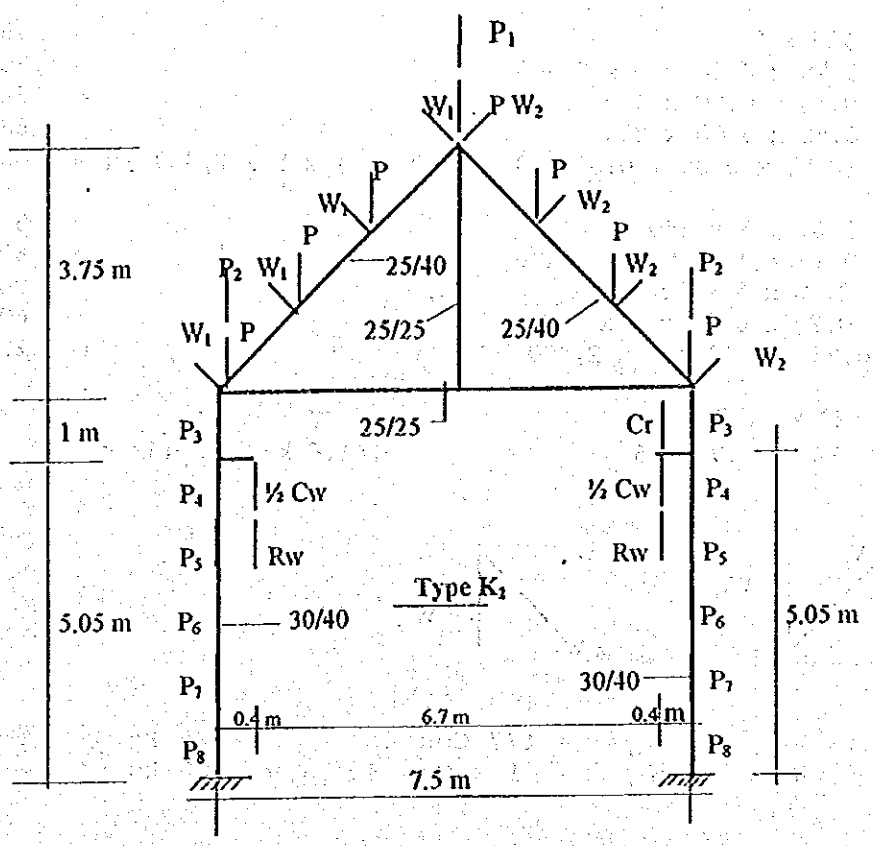
$f = (0.77^2 + 1.08^2)^{1/2} = 1.3 \text{ cm}$

$\bar{f}_{all.} = \frac{1}{360} L = \frac{500}{360} = 1.4 \text{ cm}$

——— $f < \bar{f}_{allowable}$ (OK !)

5. Design of Roof Portal Frame



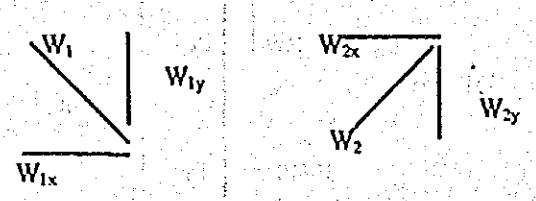


Loads

Cr = Crane Weight = 2 Tons (alternate on right side)
Cw = Carb Weight = 0.8 Ton
½ Cw = 0.4 ton
Rw = Rail Weight = 22.9 x 5 ≈ 115 kg
P = Roof Cover weight (include purlin self weight)
P_1 = Ridge reinforcement concrete (r.c.) beam 25/40
P_2 = Ring r.c. beam 15/20
P_3 = Brick wall weight
P_4 = Crane rail supported r.c. beam
P_5 = Brick wall weight
P_6 = Bracing r.c. beam
P_7 = Brick wall weight
P_8 = Tied beam weight (20/25)
P_9 = Tied beam weight (25/40)

P = 157 x 5 = 785 kg
P_1 = 0.25 x 0.40 x 5 x 2,400 = 1,200 kg
P_2 = 0.15 x 0.20 x 5 x 2,400 = 360 kg
P_3 = 0.55 x 5.00 x 250 = 688 kg
P_4 = $(0.55 \times 0.35 + \frac{0.55 + 0.40}{2} \times 0.15) \times 5 \times 2{,}400$ kg = 855 kg
P_5 = 2.65 x 5 x 250 = 3,313 kg
P_6 = 0.20 x 0.25 x 5 x 2,400 = 600 kg
P_7 = 2.40 x 5 x 250 = 3,000 kg
P_8 = 0.20 x 0.25 x 5 x 2,400 = 600 kg
P_9 = 0.25 x 0.40 x 5 x 2,400 = 1,200 kg

W_1 = 20 x 1.77 x 5 = 177 kg
W_2 = -16 x 1.77 x 5 = -141.6 kg ≈ -142 kg



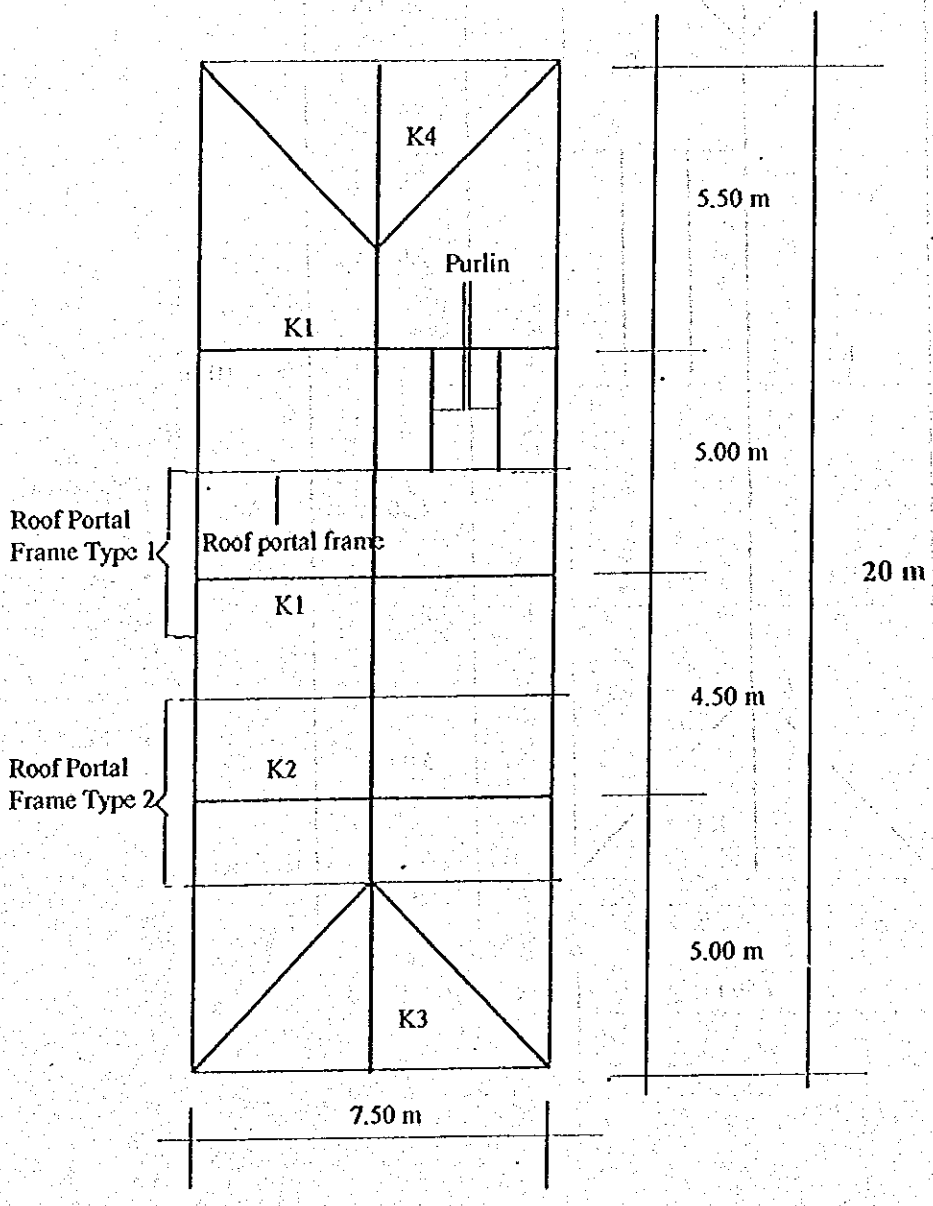
$W_{1x} = W_{1y}$ = 177 Cos 45° = 125 kg
$W_{2x} = W_{2y}$ = -142 Cos 45° = -100 kg

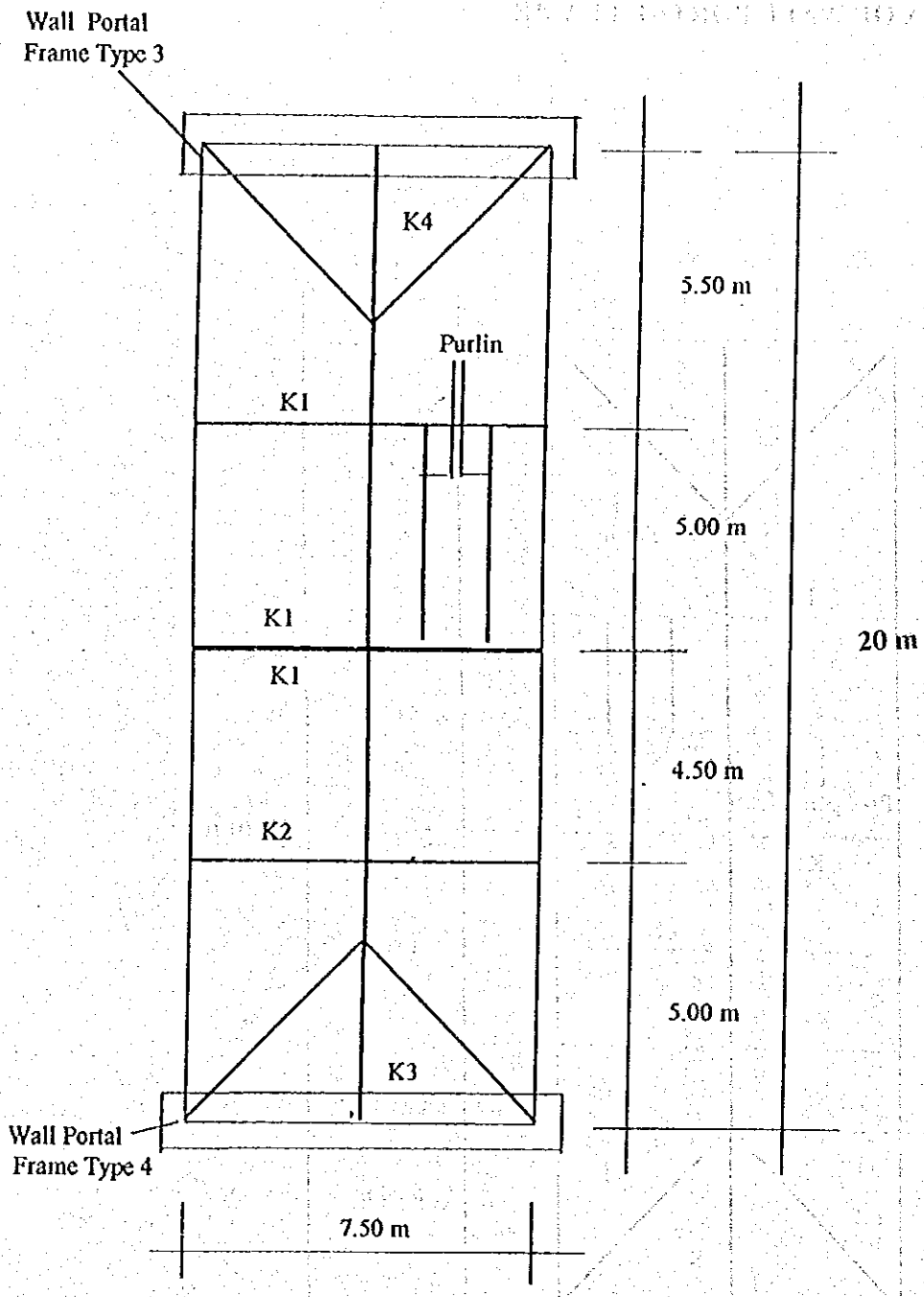
- Further structure calculation, a part of loads can be simplified as :
  a. Roof Portal Frame Type K_1
     - Left Side : $P_A = P_2 + P_3 + P_4 + P_5$ = 5,216 kg
     - Right Side : $P_B = P_2 + P_3 + P_4 + P_5 + P_6 + P_7 + P_9$ = 10,016 kg

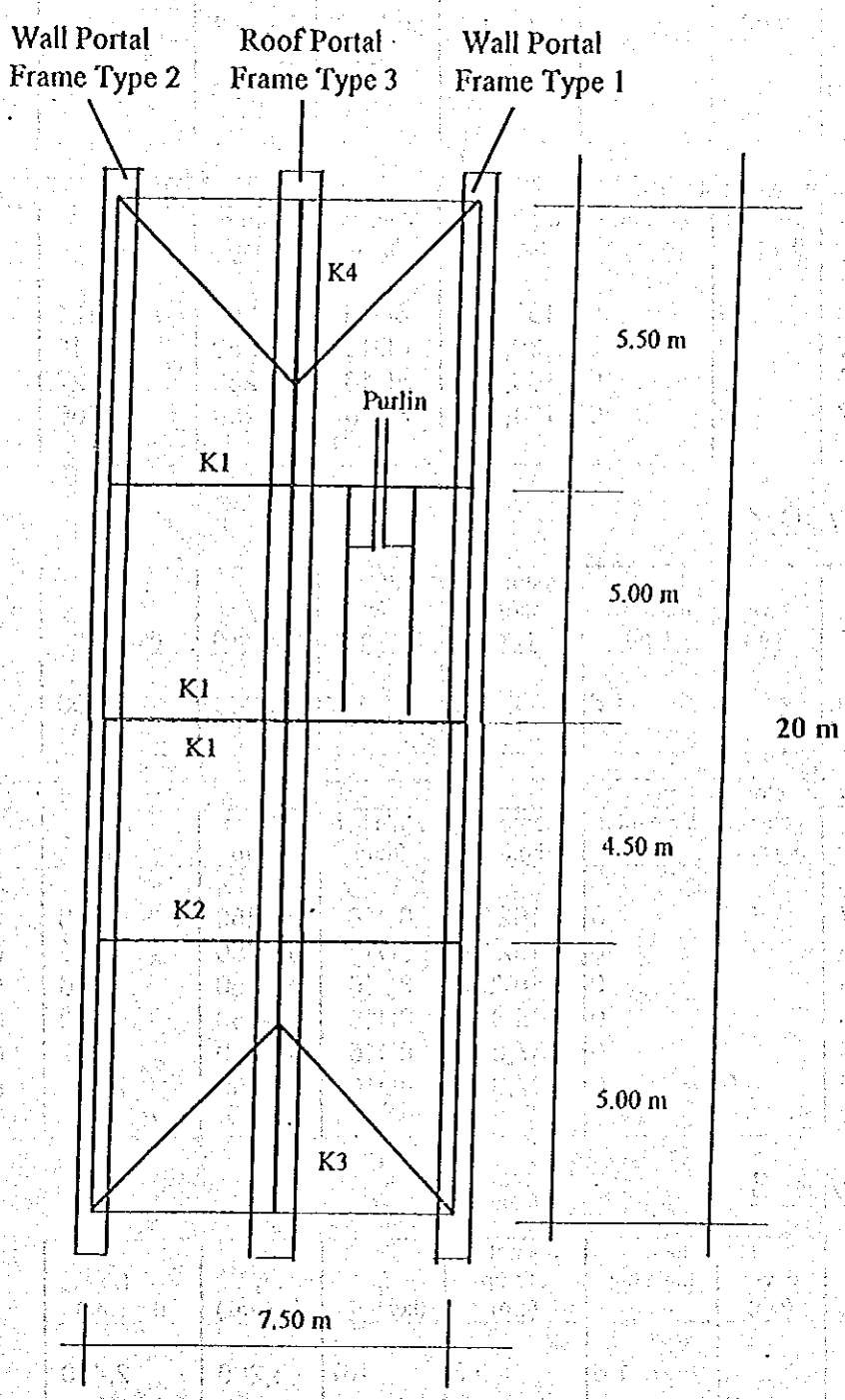
  b. Roof Portal Frame Type K_2
     - Right Side : $P_A = P_2 + P_3 + P_4 + P_5 + P_6 + P_7 + P_8$ = 9,416 kg
     - Left Side : $P_B = P_A$ = 9,416 kg

- Structure Calculation of Roof Portal Frame by using computer programming, including self weight of structure. The software is Structure Analysis and Design System (SANS/89) Version 3.5 (1994), Engineering Software Research, Indonesia.

6. DESIGN OF WALL PORTAL FRAME




Wall Portal
Frame Type 3
K4
5.50 m
Purlin
K1
5.00 m
K1
K1
20 m
4.50 m
K2
5.00 m
K3
Wall Portal
Frame Type 4
7.50 m


Wall Portal
Frame Type 2
Roof Portal
Frame Type 3
Wall Portal
Frame Type 1
K4
Purlin
K1
K1
K1
K2
K3
5.50 m
5.00 m
4.50 m
5.00 m
20 m
7.50 m

COLUMN type 1

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
30	40	4	1.6	0.8	187	3,200	2,400

Frame element Force					Design				
Member	Axial (kg)	Torsion (kg.cm)	Moment 2 (kg.cm)	Moment 3 (kg.cm)	Main bar (mm)	Stirrup (mm)	Pu (kg)	Max (kg.cm)	May (kg.cm)
1	9,122	0	0	165,315	8D16	o8-250	9,121	707,047	21,891
2	7,416	0	0	30,190	8D16	o8-250	7,416	694,023	17,800
13	7,380	0	0	106,215	8D16	o8-250	7,727	696,415	18,577
15	12,662	0	0	124,176	8D16	o8-250	1,266	732,991	30,397

COLUMN type 2

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
25	40	4	1.6	0.8	187	3,200	2,400

Frame element Force					Design				
Member	Axial (kg)	Torsion (kg.cm)	Moment 2 (kg.cm)	Moment 3 (kg.cm)	Main bar (mm)	Stirrup (mm)	Pu (kg)	Max (kg.cm)	May (kg.cm)
4	6,717	0	0	162151	8D16	o8-250	6,718	691,885	15,115
5	5,578	0	0	162151	8D16	o8-250	5,579	683,815	12,554
6	4,438	0	0	187366	8D16	o8-250	4,440	675,596	9,920
7	5,226	0	0	165,803	8D16	o8-250	5,229	681,294	11,765
8	6,366	0	0	57,863	8D16	o8-250	6,367	689,416	14,326
9	7,505	0	0	87,386	8D16	o8-250	7,504	697,363	16,886

COLUMN type 3

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
25	25	4	1.6	0.8	187	3,200	2,400

Frame element Force					Design				
Member	Axial (kg)	Torsion (kg.cm)	Moment 2 (kg.cm)	Moment 3 (kg.cm)	Main bar (mm)	Stirrup (mm)	Pu (kg)	Max (kg.cm)	May (kg.cm)
11	1,532	0	0	21,562	4D16	o8-250	1,532	195,257	3,447

BEAM type a

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
30	50	4	1.6	0.8	187	3,200	2,400

Frame Element Force					Design											
Member	Axial (kg)	Shear (kg)	Torsion (kg.cm)	Moment (kg.cm)	Main bar (mm)	Left bars			Mid bars			Right bars			Stirrup (mm)	Mu (kg.cm)
						Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom		
3	0	790	0	28,176	D16	3D16	2o12	2D16	3D16	2o12	2D16	3D16	2o12	2D16	o10-300	653,947
14	0	3,018	0	124,176	D16	3D16	2o12	2D16	3D16	2o12	2D16	3D16	2o12	2D16	o10-200	653,947

BEAM type b

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
12	20	4	1.6	0.8	187	3,200	2,400

Frame Element Force					Design											
Member	Axial (kg)	Shear (kg)	Torsion (kg.cm)	Moment (kg.cm)	Main bar (mm)	Left bars			Mid bars			Right bars			Stirrup (mm)	Mu (kg.cm)
						Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom		
16	34	34	0	1,221	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-200	127,296
17	34	34	0	1,221	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-200	127,296

BEAM type c

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
25	25	4	1.6	0.8	187	3,200	2,400

Frame Element Force					Design											
Member	Axial (kg)	Shear (kg)	Torsion (kg.cm)	Moment (kg.cm)	Main bar (mm)	Left bars			Mid bars			Right bars			Stirrup (mm)	Mu (kg.cm)
						Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom		
10	4,141	516	0	36,857	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-250	191,318
12	4,042	340	0	21,143	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-250	191,278

COLUMN type 1

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
30	40	4	1.6	0.8	187	3,200	2,400

Frame element Force					Design				
Member	Axial (kg)	Torsion (kg.cm)	Moment 2 (kg.cm)	Moment 3 (kg.cm)	Main bar (mm)	Stirrup (mm)	Pu (kg)	Max (kg.cm)	May (kg.cm)
1	9,859	0	0	113,536	8D16	o8-250	9,865	712,628	23,677
2	7,323	0	0	24,258	8D16	o8-250	124,489	412,345	29,877
13	7,819	0	0	161,532	8D16	o8-250	7,819	697,126	18,766
15	12,755	0	0	258,070	8D16	o8-250	12,758	733,645	30,619

COLUMN type 2

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
25	40	4	1.6	0.8	187	3,200	2,400

Frame element Force					Design				
Member	Axial (kg)	Torsion (kg.cm)	Moment 2 (kg.cm)	Moment 3 (kg.cm)	Main bar (mm)	Stirrup (mm)	Pu (kg)	Max (kg.cm)	May (kg.cm)
4	6,613	0	0	170,149	8D16	o8-250	6,614	691,156	14,882
5	5,474	0	0	170,149	8D16	o8-250	5,476	683,070	12,321
6	4,334	0	0	183,050	8D16	o8-250	4,336	674,819	9,758
7	5,187	0	0	155,583	8D16	o8-250	5,189	681,010	11,676
8	6,326	0	0	37,564	8D16	o8-250	6,328	689,139	14,238
9	7,446	0	0	38,928	8D16	o8-250	7,465	697,091	16,797

COLUMN type 3

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
25	25	4	1.6	0.8	187	3,200	2,400

Frame element Force					Design				
Member	Axial (kg)	Torsion (kg.cm)	Moment 2 (kg.cm)	Moment 3 (kg.cm)	Main bar (mm)	Stirrup (mm)	Pu (kg)	Max (kg.cm)	May (kg.cm)
11	1,491	0	0	27,467	4D16	o8-250	1,491	195,079	335,566

BEAM type a

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
30	50	4	1.6	0.8	187	3,200	2,400

Frame Element Force					Design											
Member	Axial (kg)	Shear (kg)	Torsion (kg.cm)	Moment (kg.cm)	Main bar (mm)	Left bars			Mid bars			Right bars			Stirrup (mm)	Mu (kg.cm)
						Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom		
3	0	790	0	28,176	D16	3D16	2o12	3D16	3D16	2o12	3D16	3D16	2o12	3D16	o12-300	653,947
14	0	3,190	0	124,176	D16	3D16	2o12	3D16	3D16	2o12	3D16	3D16	2o12	3D16	o12-200	653,947

BEAM type b

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
12	20	4	1.6	0.8	187	3,200	2,400

Frame Element Force					Design											
Member	Axial (kg)	Shear (kg)	Torsion (kg.cm)	Moment (kg.cm)	Main bar (mm)	Left bars			Mid bars			Right bars			Stirrup (mm)	Mu (kg.cm)
						Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom		
16	34	34	0	1,221	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o12-200	121,989
17	34	34	0	1,221	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o12-200	121,989

BEAM type c

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
25	25	4	1.6	0.8	187	3,200	2,400

Frame Element Force					Design											
Member	Axial (kg)	Shear (kg)	Torsion (kg.cm)	Moment (kg.cm)	Main bar (mm)	Left bars			Mid bars			Right bars			Stirrup (mm)	Mu (kg.cm)
						Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom		
10	3,853	528	0	36,989	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o12-250	189,207
12	3,724	387	0	34,777	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o12-250	189,207

WALL type 1
COLUMN type 1

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
30	40	4	1.6	0.8	187	3,200	2,400

Frame element Force					Design				
Member	Axial (kg)	Torsion (kg.cm)	Moment 2 (kg.cm)	Moment 3 (kg.cm)	Main bar (mm)	Stirrup (mm)	Pu (kg)	Max (kg.cm)	May (kg.cm)
1	7,888	0	0	116,443	8D16	o10-250	7,887	693,387	18,934
2	4,444	0	0	108,029	8D16	o10-250	4,446	666,703	10,671
3	727	0	0	585,203	8D16	o10-250	727	336,122	1,745
7	14,209	0	0	22,000	8D16	o10-250	124,489	336,122	298,775
8	8,254	0	0	19,870	8D16	o10-250	124,489	640,845	298,775
9	1,194	0	0	47,294	8D16	o10-250	1,194	336,122	2,867
13	13,314	0	0	1,455	8D16	o10-250	124,489	336,122	298,775
14	7,660	0	0	456	8D16	o10-250	124,489	336,122	298,775
15	1,155	0	0	2,478	8D16	o10-250	124,489	336,122	298,775
19	16,900	0	0	35,415	8D16	o10-250	124,489	336,122	298,775
20	12,734	0	0	23,344	8D16	o10-250	124,489	336,122	298,775
21	73,299	0	0	14,412	8D16	o10-250	124,489	336,122	298,775
22	1,113	0	0	3,614	8D16	o10-250	124,489	404,152	298,775
27	16,739	0	0	16,574	8D16	o10-250	124,489	336,122	298,775
28	12,984	0	0	20,397	8D16	o10-250	124,489	336,122	298,775
29	752	0	0	16,348	8D16	o10-250	124,489	336,122	298,775
30	1,101	0	0	42,563	8D16	o10-250	1,101	640,092	2,644
35	9,405	0	0	78,808	8D16	o10-250	9,406	705,750	22,575
36	7,369	0	0	93,767	8D16	o10-250	7,369	689,454	17,687
37	4,162	0	0	909,773	8D16	o10-250	4,164	664,584	9,995
38	886	0	0	48,275	8D16	o10-250	686	636,726	1,647
42	10,548	0	0	115,549	8D16	o10-250	10,550	713,132	25,320
43	19,302	0	0	28,048	8D16	o10-250	124,489	336,122	289,775
44	18,132	0	0	5,042	8D16	o10-250	124,489	336,122	289,775

WALL type 1
BEAM type a

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
15	40	4	1.6	0.8	187	3,200	2,400

Frame Element Force					Design											
Member	Axial (kg)	Shear (kg)	Torsion (kg.cm)	Moment (kg.cm)	Main bar (mm)	Left bars			Mid bars			Right bars			Stirrup (mm)	Mu (kg.cm)
						Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom		
4	1,167	499	0	48,240	D16	2D16	2o12	2D16	2D16	2o12	2D16	2D16	2o12	2D16	o8-200	131,328
10	371	445	0	38,530	D16	2D16	2o12	2D16	2D16	2o12	2D16	2D16	2o12	2D16	o8-200	131,311
16	318	422	0	36,052	D16	2D16	2o12	2D16	2D16	2o12	2D16	2D16	2o12	2D16	o8-200	131,298
23	242	406	0	32,658	D16	2D16	2o12	2D16	2D16	2o12	2D16	2D16	2o12	2D16	o8-200	131,277
31	963	454	0	39,674	D16	2D16	2o12	2D16	2D16	2o12	2D16	2D16	2o12	2D16	o8-200	131,331

WALL type 1
BEAM type b

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
55	60	4	1.6	0.8	187	3,200	2,400

Frame Element Force					Design											
Member	Axial (kg)	Shear (kg)	Torsion (kg.cm)	Moment (kg.cm)	Main bar (mm)	Left bars			Mid bars			Right bars			Stirrup (mm)	Mu (kg.cm)
						Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom		
5	383	3,336	0	305,410	D16	6D16	2o12	4D16	6D16	2o12	4D16	4D16	2o12	6D16	o10-300	1,276,378
11	278	2,806	0	242,802	D16	6D16	2o12	4D16	6D16	2o12	4D16	4D16	2o12	6D16	o10-300	1,275,765
17	336	281	0	233,031	D16	6D16	2o12	4D16	6D16	2o12	4D16	4D16	2o12	6D16	o10-300	1,275,710
24	311	1,536	0	203,982	D16	6D16	2o12	4D16	6D16	2o12	4D16	4D16	2o12	6D16	o10-300	1,275,734
32	306	3,019	0	246,114	D16	6D16	2o12	4D16	6D16	2o12	4D16	4D16	2o12	6D16	o10-300	1,276,307

WALL type 1
BEAM type c

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
20	40	4	1.6	0.8	187	3,200	2,400

Frame Element Force					Design											
Member	Axial (kg)	Shear (kg)	Torsion (kg.cm)	Moment (kg.cm)	Main bar (mm)	Left bars			Mid bars			Right bars			Stirrup (mm)	Mu (kg.cm)
						Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom		
6	125	269	0	247,682	D16	3D16	2o12	2D16	3D16	2o12	2D16	3D16	2o12	2D16	o8-90	252,768
12	95	2,427	0	205,611	D16	3D16	2o12	2D16	3D16	2o12	2D16	3D16	2o12	2D16	o8-90	252,774
18	98	2,421	0	201,927	D16	3D16	2o12	2D16	3D16	2o12	2D16	3D16	2o12	2D16	o8-90	252,773
25	19	2,180	0	166,963	D16	2D16	2o12	2D16	3D16	2o12	2D16	3D16	2o12	2D16	o8-90	180,349
33	59	2,452	0	203,710	D16	3D16	2o12	2D16	3D16	2o12	2D16	3D16	2o12	2D16	o8-90	252,781

WALL type 1
BEAM type d

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
20	20	4	1.6	0.8	187	3,200	2,400

Frame Element Force					Design											
Member	Axial (kg)	Shear (kg)	Torsion (kg.cm)	Moment (kg.cm)	Main bar (mm)	Left bars			Mid bars			Right bars			Stirrup (mm)	Mu (kg.cm)
						Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom		
26	114	1,713	0	129,036	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-90	180,444
34	228	1,905	0	159,038	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-90	180,196

WALL type 1
BEAM type e

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
25	40	4	1.6	0.8	187	3,200	2,400

Frame Element Force					Design											
Member	Axial (kg)	Shear (kg)	Torsion (kg.cm)	Moment (kg.cm)	Main bar (mm)	Left bars			Mid bars			Right bars			Stirrup (mm)	Mu (kg.cm)
						Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom		
39	700	2,602	0	242,179	D16	2D16	2o12	2D16	2D16	2o12	2D16	2D16	2o12	2D16	o10-150	337,253
40	24	2,342	0	197,171	D16	2D16	2o12	2D16	2D16	2o12	2D16	2D16	2o12	2D16	o10-150	338,227
41	202	1,254	0	197,856	D16	2D16	2o12	2D16	2D16	2o12	2D16	2D16	2o12	2D16	o10-150	337,927

WALL type 2
COLUMN type 1

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
30	40	4	1.6	0.8	187	3,200	2,400

Frame element Force					Design				
Member	Axial (kg)	Torsion (kg.cm)	Moment 2 (kg.cm)	Moment 3 (kg.cm)	Main bar (mm)	Stirrup (mm)	Pu (kg)	Max (kg.cm)	May (kg.cm)
1	8,722	0	0	135,637	8D16	o10-250	8,723	884,516	18,137
2	3,826	0	0	101,721	8D16	o10-250	3,828	661,927	9,188
3	509	0	0	434,188	8D16	o10-250	509	635,287	1,221
7	12,491	0	0	35,949	8D16	o10-250	124,489	358,262	298,775
8	6,917	0	0	15,630	8D16	o10-250	124,489	336,122	298,775
9	732,592	0	0	47,357	8D16	o10-250	732	637,104	1,758
13	11,813	0	0	7,993	8D16	o10-250	124,489	336,122	298,775
14	6,492	0	0	8,427	8D16	o10-250	124,489	336,122	298,775
15	712	0	0	4,494	8D16	o10-250	712	636,939	1,709
19	13,251	0	0	90,174	8D16	o10-250	1,325	723,253	31,808
20	11,353	0	0	38,111	8D16	o10-250	124,489	417,874	298,775
21	6,048	0	0	32,469	8D16	o10-250	6,050	679,323	14,520
22	687	0	0	2,432	8D16	o10-250	124,489	440,666	298,775
27	15,285	0	0	14,422	8D16	o10-250	124,489	336,122	298,775
28	11,371	0	0	17,718	8D16	o10-250	124,489	336,122	298,775
29	6,362	0	0	18,340	8D16	o10-250	124,489	358,873	298,775
30	688	0	0	35,944	8D16	o10-250	688	636,743	1,652
35	873	0	0	1,047	8D16	o10-250	872,229	699,714	20,950
36	6,625	0	0	716	8D16	o10-250	6,626	683,769	15,904
37	3,606	0	0	645	8D16	o10-250	3,608	660,181	8,659
38	488	0	0	690	8D16	o10-250	488	635,120	1,172

WALL type 2
BEAM type a

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
15	20	4	1.6	0.8	187	3,200	2,400

Frame Element Force					Design											
Member	Axial (kg)	Shear (kg)	Torsion (kg.cm)	Moment (kg.cm)	Main bar (mm)	Left bars			Mid bars			Right bars			Stirrup (mm)	Mu (kg.cm)
						Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom		
4	794	242	0	22,869	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-200	131,240
10	133	218	0	18,417	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-200	131,243
16	190	218	0	18,444	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-200	13,123
23	181	196	0	15,004	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-200	131,233
31	690	219	0	18,738	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-200	131,090

WALL type 2
BEAM type b

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
55	50	4	1.6	0.8	187	3,200	2,400

Frame Element Force					Design											
Member	Axial (kg)	Shear (kg)	Torsion (kg.cm)	Moment (kg.cm)	Main bar (mm)	Left bars			Mid bars			Right bars			Stirrup (mm)	Mu (kg.cm)
						Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom		
5	34	2,864	0	272,464	D16	6D16	2o12	4D16	6D16	2o12	4D16	4D16	2o12	6D16	o10-300	1,276,057
11	510	2,403	0	209,476	D16	6D16	2o12	4D16	6D16	2o12	4D16	4D16	2o12	6D16	o10-300	1,275,547
17	512	2,479	0	217,458	D16	6D16	2o12	4D16	6D16	2o12	4D16	4D16	2o12	6D16	o10-300	1,275,544
24	340	2,171	0	168,519	D16	6D16	2o12	4D16	6D16	2o12	4D16	4D16	2o12	6D16	o10-300	1,275,707
32	45	2,585	0	218,726	D16	6D16	2o12	4D16	6D16	2o12	4D16	4D16	2o12	6D16	o10-300	1,276,066

WALL type 2
BEAM type c

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
20	25	4	1.6	0.8	187	3,200	2,400

Frame Element Force					Design											
Member	Axial (kg)	Shear (kg)	Torsion (kg.cm)	Moment (kg.cm)	Main bar (mm)	Left bars			Mid bars			Right bars			Stirrup (mm)	Mu (kg.cm)
						Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom		
25	59	1,986	0	151,205	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-90	180,321
33	71	2,208	0	184,013	D16	3D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-90	252,779

WALL type 2
BEAM type d

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
20	25	4	1.6	0.8	187	3,200	2,400

Frame Element Force					Design											
Member	Axial (kg)	Shear (kg)	Torsion (kg.cm)	Moment (kg.cm)	Main bar (mm)	Left bars			Mid bars			Right bars			Stirrup (mm)	Mu (kg.cm)
						Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom		
26	363	1,758	0	136,235	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-90	180,094
34	330	1,981	0	165,315	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-90	180,119

WALL type 2
BEAM type e

b (cm)	h (cm)	cover (cm)	diameter main bar (cm)	diameter stirrup (cm)	fc (kg/cm2)	fy (kg/cm2)	fv (kg/cm2)
25	40	4	1.6	0.8	187	3,200	2,400

Frame Element Force					D e s i g n											
Member	Axial (kg)	Shear (kg)	Torsion (kg.cm)	Moment (kg.cm)	Main bar (mm)	Left bars			Mid bars			Right bars			Stirrup (mm)	Mu (kg.cm)
						Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom		
6	886	2,872	0	266,746	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o10-150	336,995
12	129	2,563	0	215,817	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o10-150	338,364
18	247	2,628	0	226,282	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o10-150	338,516

- **Checking of Column reinforcement bar & stress of Roof Portal Frame Type K - 1**

At support reaction of right column as the biggest bending moment.

Bending Moment = 178,841 kgcm
b (width) = 30 cm
h_t (height) = 40 cm
Concrete cover = 5 cm
$h = h_t - d$ = 40 - 5 = 35 cm
Fc = 225 kg/cm² ⟶ $\bar{\sigma}'_b$ = 130 kg/cm²
Fu = 3,200 kg/cm² ⟶ $\bar{\sigma}_a$ = 2,600 kg/cm²
n = 14
δ = 1 (symetrical reinforcement)

$$\phi_o = \frac{\sigma_a}{n x \bar{\sigma}'_b} = \frac{2,600}{14 x 130} = 1.43$$

$$Ca = \frac{h}{\sqrt{\frac{nxM}{bx\sigma_a}}} = \frac{35}{\sqrt{\frac{14x178,841}{30x2,600}}} = 6.18$$

⟶ ϕ = 4.31 > ϕ_o = 1.43 (OK)
ϕ' = 8.11
$n\omega$ = 0.028

. Stresses

$\bar{\sigma}_a$ = 2,600 kg/cm²

$$\bar{\sigma}_b = \frac{\bar{\sigma}_a}{nx\phi} = \frac{2,600}{14x4.31} = 43.09 \text{ kg/cm}^2 < \bar{\sigma}'_b = 130 \text{ kg/cm}^2 \text{ (OK)}$$

$$\sigma_a = \frac{\bar{\sigma}_a}{\phi'} = \frac{2,600}{8.11} = 320.59 \text{ kg/cm}^2 < \bar{\sigma}_a = 2,600 \text{ kg/cm}^2 \text{ (OK)}$$

. Reinforcement

$$A = \frac{\omega bh}{n} = \frac{0.028}{14} \times 30 \times 35 = 2.1 \text{ cm}^2$$

A_{steel} = 2.1 cm² <1 % x 900 cm² (sectional area of column)

Hence applied :
A_{steel} = 8 D 16
= 16.08 cm² = $\frac{16.08}{30x40}$ x 100 % $A_{concrete}$
= 1.34 % $A_{concrete}$ (OK)

- **Checking of Beam reinforcement bar & stress of Roof Portal Frame Type K - 1**

At left side roof slope as the biggest bending moment.

Bending Moment = 187,366 kgcm

b (width) = 25 cm
h_t (height) = 40 cm
Concrete cover = 5 cm
h = h_t - d = 40 - 5 = 35 cm
Fc = 225 kg/cm² ⟶ $\bar{\sigma}'_b$ = 130 kg/cm²
Fu = 3,200 kg/cm² ⟶ $\bar{\sigma}_a$ = 2,600 kg/cm²
n = 14
δ = 1 (symetrical reinforcement)

$$\phi_o = \frac{\sigma_a}{n\bar{\sigma}'_b} = \frac{2,600}{14x130} = 1.43$$

$$Ca = \frac{h}{\sqrt{\frac{nxM}{bx\sigma_a}}} = \frac{35}{\sqrt{\frac{14x187,366}{25x2,600}}} = 5.51$$

⟶ ϕ = 3.6 > ϕ_o = 1.43 (OK)
ϕ' = 6.65
nω = 0.035

. Stresses

$\bar{\sigma}_a$ = 2,600 kg/cm²

$$\bar{\sigma}_b = \frac{\bar{\sigma}_a}{nx\phi} = \frac{2,600}{14x3.6} = 51.59 \text{ kg/cm}^2 < \bar{\sigma}'_b = 130 \text{ kg/cm}^2 \text{ (OK)}$$

$$\sigma_a = \frac{\bar{\sigma}_a}{\phi'} = \frac{2,600}{6.65} = 390.98 \text{ kg/cm}^2 < \bar{\sigma}_a = 2,600 \text{ kg/cm}^2 \text{ (OK)}$$

. Reinforcement

$$A = \frac{\omega bh}{n} = \frac{0.035}{14} \times 25 \times 35 = 2.19 \text{ cm}^2$$

A_{steel} = 2.19 cm² <1 % x 1,000 cm² = $A_{concrete}$ (sectional area)

Hence applied :
A_{steel} = 8 D 16
= 16.08 cm² = $\frac{16.08}{25x40}$ x 100 % $A_{concrete}$
= 1.61 % $A_{concrete}$ (OK)

- Checking of Beam reinforcement bar & stress of Wall Portal Frame Type K - 1

On Rail Beam, member F5 as the biggest bending moment.

Bending Moment = 266,680 kgcm

b (width) = 50 cm
h_t (height) = 50 cm

Concrete cover = 5 cm
$h = h_t - d$ = 50 - 5 = 45 cm
Fc = 225 kg/cm² ⟶ $\bar{\sigma}'_b$ = 130 kg/cm²
Fu = 3,200 kg/cm² ⟶ $\bar{\sigma}_a$ = 2,600 kg/cm²
n = 14
δ = 1 (symetrical reinforcement)

$$\phi_o = \frac{\sigma_a}{n x \bar{\sigma}'_b} = \frac{2,600}{14x130} = 1.43$$

$$Ca = \frac{h}{\sqrt{\frac{nxM}{bx\sigma_a}}} = \frac{45}{\sqrt{\frac{14x266,680}{50x2,600}}} = 8.39$$

⟶ ϕ = 5.45 > ϕ_o = 1.43 (OK)
ϕ' = 15.36
$n\omega$ = 0.0152

. Stresses

$\bar{\sigma}_a$ = 2,600 kg/cm²

$$\bar{\sigma}_b = \frac{\bar{\sigma}_a}{n x \phi} = \frac{2,600}{14x5.45} = 34.08 \text{ kg/cm}^2 < \bar{\sigma}'_b = 130 \text{ kg/cm}^2 \text{ (OK)}$$

$$\sigma_a = \frac{\bar{\sigma}_a}{\phi'} = \frac{2,600}{15.36} = 169.27 \text{ kg/cm}^2 < \sigma_a = 2,600 \text{ kg/cm}^2 \text{ (OK)}$$

. Reinforcement

$$A = \frac{\omega bh}{n} = \frac{0.0152}{14} \times 50 \times 45 = 2.44 \text{ cm}^2$$

A_{steel} = 2.44 cm²

Hence applied :
A_{steel} = 10 D 16
= 20.11 cm² > A_{steel} = 2.44 cm² (OK)

- **Checking of Beam reinforcement bar & stress of Wall Portal Frame Type K - 1**

On Tunnel Beam, member F39 as the biggest bending moment.

Bending Moment = 123,478 kgcm

b (width) = 25 cm
h_t (height) = 40 cm
Concrete cover = 5 cm
$h = h_t - d$ = 40 - 5 = 35 cm
Fc = 225 kg/cm² ⟶ $\bar{\sigma}'_b$ = 130 kg/cm²
Fu = 3,200 kg/cm² ⟶ $\bar{\sigma}_a$ = 2,600 kg/cm²

n = 14

δ = 1 (symetrical reinforcement)

$$\phi_o = \frac{\sigma_a}{n x \bar{\sigma}'_b} = \frac{2,600}{14x130} = 1.43$$

$$Ca = \frac{h}{\sqrt{\frac{nxM}{bx\sigma_a}}} = \frac{35}{\sqrt{\frac{14x123,478}{25x2,600}}} = 6.79$$

⟶ ϕ = 4.41 > ϕ_o = 1.43 (OK)

ϕ' = 9.59

nω = 0.023

. Stresses

$\bar{\sigma}_a$ = 2,600 kg/cm²

$$\bar{\sigma}_b = \frac{\bar{\sigma}_a}{n x \phi} = \frac{2,600}{14x4.41} = 42.11 \text{ kg/cm}^2 < \bar{\sigma}'_b = 130 \text{ kg/cm}^2 \text{ (OK)}$$

$$\sigma_a = \frac{\bar{\sigma}_a}{\phi'} = \frac{2,600}{9.59} = 271.12 \text{ kg/cm}^2 < \sigma_a = 2,600 \text{ kg/cm}^2 \text{ (OK)}$$

. Reinforcement

$$A = \frac{\omega bh}{n} = \frac{0.023 \times 25 \times 35}{14} = 1.44 \text{ cm}^2$$

A_{steel} = 2.44 cm²

Hence applied :

A_{steel} = 2 D 16

= 4.16 cm² > A_{steel} = 1.44 cm² (OK)

- Checking of Column reinforcement bar & stress

On Column No. F5
(for loading combination 3)

Positive Bending Moment	= 178,266 kgcm		
Negative Bending Moment	= 186,498 kgcm		
b (width)	= 30 cm		
h_t (height)	= 50 cm		
Concrete cover	= 5 cm		
$h = h_t - d$	= 50 - 5 = 45 cm		
Fc	= 225 kg/cm²	⟶	$\bar{\sigma}'_b$ = 130 kg/cm²
Fu	= 3,200 kg/cm²	⟶	$\bar{\sigma}_a$ = 2,600 kg/cm²
ns	= 14		

$$\phi_0 = \frac{\bar{\sigma}_a}{n\,\bar{\sigma}'_b} = \frac{2,600}{14 \times 130} = 1.43$$

a) For Positive BM M = 178,266 kgcm

$$Ca = \frac{h}{\sqrt{\frac{nM}{b\sigma_a}}} = \frac{45}{\sqrt{\frac{14 \times 178,266}{30 \times 2,600}}} = 7.96$$

$\delta = 1$ (for symetrical reinforcement)

⟶ $\phi = 5.25 > \phi_0 = 1.43$ (OK)

$\phi' = 14.00$

$n\omega = 0.0164$

. Stresses

$\bar{\sigma}_a = 2,600$ kg/cm²

$$\bar{\sigma}_b = \frac{\bar{\sigma}_a}{n\,\phi} = \frac{2,600}{14 \times 5.25} = 35.37 \text{ kg/cm}^2 < \bar{\sigma}'_b = 130 \text{ kg/cm}^2$$

$$\sigma_a = \frac{\bar{\sigma}_a}{\phi'} = \frac{2,600}{14.00} = 185.71 \text{ kg/cm}^2 < \bar{\sigma}_a = 2,600 \text{ kg/cm}^2$$

. Reinforcement

$$A = \omega bh = \frac{0.0164 \times 30 \times 45}{14} = 1.581 \text{ cm}^2$$

$A_{steel} = 1.581 \text{cm}^2 < 1\ \% \times 1,500 \text{ cm}^2$ (sectional area of column)

Hence applied :

A_{steel} = 8 D 16

= 16.08 cm²

$$= \frac{16.08}{30 \times 50} \times 100\ \%\ A_{concrete}$$

$= 1.072\ \%\ A_{concrete}$ (OK)

a) For Negative BM M = 186,498 kgcm

$$Ca = \frac{h}{\sqrt{\frac{nM}{b\sigma_a}}} = \frac{45}{\sqrt{\frac{14 \times 186,498}{30 \times 2,600}}} = 7.78$$

$\delta = 1$ (symetrical reinforcement)

$\longrightarrow$ $\phi = 5.061 > \phi_0 = 1.43$ (OK)

$\phi' = 12.85$

$n\omega = 0.018$

. Stresses

$\bar{\sigma}_a = 2,600$ kg/cm^2

$\bar{\sigma}_b = \dfrac{\bar{\sigma}_a}{n\,\phi} = \dfrac{2,600}{14 \times 5.061} = 36.70$ kg/cm^2 $< \bar{\sigma}'_b = 130$ kg/cm^2

$\sigma_a = \dfrac{\bar{\sigma}_a}{\phi'} = \dfrac{2,600}{12.85} = 205$ kg/cm^2 $< \bar{\sigma}_a = 2,600$ kg/cm^2

. Reinforcement

$A = \omega bh = \dfrac{0.018}{14} \times 30 \times 45 = 1.73$ cm^2

$A_{steel} = 1.73$ cm^2 $< 1\ \% \times 900$ cm^2 (sectional area of column)

A_{steel} used as A_{steel} of Positive BM

$A_{steel} = 8$ D 16 (OK)

- **Checking of Beam reinforcement bar & stress**

On Beam No. F118 & F119
(for loading combination 1)

Positive Bending Moment	= 1,246,177	kgcm	
Negative Bending Moment	= 800,550	kgcm	
b (width)	= 25	cm	
h_t (height)	= 50	cm	
Concrete cover	= 5	cm	
Fc	= 225	kg/cm^2	$\longrightarrow \bar{\sigma}'_b = 130\ kg/cm^2$
Fu	= 3,200	kg/cm^2	$\longrightarrow \bar{\sigma}_a = 2,600\ kg/cm^2$
ns	= 14		

$$\phi_0 = \frac{\bar{\sigma}_a}{n\,\bar{\sigma}'_b} = \frac{2,600}{14 \times 130} = 1.43$$

a) For Positive BM, M = 1,246,177 kgcm

b = 25
h_t = 50 ; d = 5 $\longrightarrow$ h = h_t - d = 50 - 5 = 45 cm

$$Ca = \frac{h}{\sqrt{\frac{nM}{b\bar{\sigma}_a}}} = \frac{45}{\sqrt{\frac{14 \times 1,246,177}{25 \times 2,600}}} = 2.75$$

δ = 0.4 (required of minimum compression reinforcement bar)
$\longrightarrow$ ϕ = 1.546 > ϕ_0 = 1.43 (OK)
ϕ' = 2.103
$n\omega$ = 0.1539

. Stresses

$\bar{\sigma}_a$ = 2,600 kg/cm^2

$$\bar{\sigma}_b = \frac{\bar{\sigma}_a}{n\phi} = \frac{2,600}{14 \times 1.546} = 120.13\ kg/cm^2 < \bar{\sigma}'_b = 130\ kg/cm^2 \text{ (OK)}$$

$$\sigma_a = \frac{\bar{\sigma}_a}{\phi'} = \frac{2,600}{2.103} = 1,236\ kg/cm^2 < \bar{\sigma}_a = 2,600\ kg/cm^2 \text{ (OK)}$$

. Reinforcement bar

$$A_{\text{steel (tensile)}} = \frac{\omega bh}{14} = 0.1539 \times 25 \times 45 = 12.37\ cm^2$$

$$A_{\text{steel (compression)}} = \delta \times A_{\text{steel (tensile)}}$$

$$= 0.4 \times 12.37\ cm^2 = 4.948\ cm^2$$

Used $A_{\text{steel (tensile)}}$ = 6 D 16 = 12.06 cm^2 (OK)

Used $A_{\text{steel (compression)}}$ = 4 D 16 = 8.04 cm^2 (OK)

a) For Negative BM, M = 800,550 kgcm

Used A_{steel} as A_{steel} of Positive BM :

Used $A_{steel\ (tensile)}$ = 6 D 16 = 12.06 cm^2(OK)

Used $A_{steel\ (compression)}$ = 4 D 16 = 8.04 cm^2(OK)