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					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		
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					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		
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					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		
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					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		
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					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		
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					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		
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

ROOF K-3
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	6,174	0	0	251,148	8D16	o10-250	6,176	680,296	14,822
14	5,682	0	0	157,444	8D16	o10-250	5,684	676,483	13,641
15	5,086	0	0	388,983	8D16	o10-250	5,088	671,841	12,212
16	1,333	0	0	48,563	8D16	o10-250	1,333	641,966	3,200
17	1,170	0	0	60,131	8D16	o10-250	1,170	640,647	1,808
18	6,204	0	0	415,873	8D16	o10-250	6,206	680,528	16,894

ROOF K-3
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)
3	3,776	0	0	252,370	8D16	o10-250	3,777	642,775	8,499
4	2,749	0	0	163,224	8D16	o10-250	2,750	635,846	6,187
5	1,723	0	0	163,324	8D16	o10-250	1,724	628,872	3,879
10	212	0	0	153,402	8D16	o10-250	212	618,422	478
11	1,173	0	0	153,402	8D16	o10-250	1,173	625,086	2,640
12	2,199	0	0	158,666	8D16	o10-250	2,199	632,124	4,949

ROOF K-3
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)
25	60	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	1,348	3,224	0	531,420	D16	2D16	2o12	3D16	3D16	2o12	2D16	3D16	-	2D16	o8-250	785,443

ROOF K-3
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)
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		
7	2,643	968	0	142,436	D16	2D16	2o12	2D16	2D16	2o12	2D16	2D16	-	2D16	o10-300	341,292
8	3,306	980	0	148,756	D16	2D16	2o12	2D16	2D16	2o12	2D16	2D16	-	2D16	o10-300	341,946
19	365	723	0	60,954	D16	2D16	2o12	2D16	2D16	2o12	2D16	2D16	-	2D16	o10-300	338,666

ROOF K-3
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)
12	20	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		
2	34	34	0	1,224	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-200	114,429
13	34	34	0	1,224	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-200	114,435

WALL type 3
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	3,735	0	0	60,588	8D16	o8-250	37,355	664,960	89,662
2	1,936	0	0	42,440	8D16	o8-250	1,937	650,377	46,493
3	439	0	0	40,262	8D16	o8-250	439	638,078	10,545
7	7,524	0	0	78,956	8D16	o8-250	7,525	694,881	180,608
8	5,743	0	0	24,257	8D16	o8-250	5,744	680,965	137,872
9	2,877	0	0	33,872	8D16	o8-250	2,679	656,416	64,293
10	600	0	0	9,477	8D16	o8-250	600	639,406	1,440
15	5,118	0	0	64,442	8D16	o8-250	5,119	676,020	12,297
16	3,324	0	0	37,825	8D16	o8-250	3,325	661,649	7,980
17	1,932	0	0	18,877	8D16	o8-250	1,932	650,338	4,637
18	437	0	0	16,337	8D16	o8-250	437	638,062	1,049

WALL type 3

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	204	162	0	0	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-200	131,229
11	326	162	0	0	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-200	131,199

WALL type 3

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)
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		
5	70	581	0	36,403	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-250	189,074
12	216	582	0	35,877	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-250	189,120
13	146	597	0	40,664	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-250	189,065

WALL type 3
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		
6	4	1,660	0	103,006	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-100	189,035
14	673	1,655	0	102,262	D16	3D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-100	188,800

WALL type 4
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					D e s i g n				
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	4,408	0	0	55,504	8D16	o8-250	4,407	870,343	10,577
2	1,928	0	0	45,108	8D16	o8-250	1,930	650,318	4,632
3	437	0	0	9,822	8D16	o8-250	437	638,062	1,049
7	887	0	0	10,590	8D16	o8-250	124,489	336,122	298,775
8	5,755	0	0	32,880	8D16	o8-250	5,757	681,064	13,817
9	2,682	0	0	29,355	8D16	o8-250	2,683	656,454	8,440
10	501	0	0	8,738	8D16	o8-250	601	639,418	1,444
15	4,942	0	0	55,431	8D16	o8-250	4,944	674,625	11,865
16	3,332	0	0	34,542	8D16	o8-250	33,322	661,712	7,999
17	1,934	0	0	21,045	8D16	o8-250	1,934	650,359	4,643
18	438	0	0	14,608	8D16	o8-250	438	638,067	1,051
19	6,013	0	0	45,462	8D16	o8-250	6,014	68,309	14,435

WALL type 4
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	119	163	0	10,202	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-200	131,229
11	306	162	0	10,029	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-200	131,204

WALL type 4
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)
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		
5	81	581	0	36,994	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o10-250	189,071
6	135	1,651	0	101,569	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o10-250	189,938
12	174	560	0	35,654	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o10-250	189,113
13	99	592	0	39,366	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o10-250	189,065

WALL type 4
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		
14	336	1,489	0	93,200	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-200	131,229
20	136	1,492	0	94,334	D16	2D16	-	2D16	2D16	-	2D16	2D16	-	2D16	o8-200	188,937

- 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 $\longrightarrow \bar{\sigma}'_b = 130$ kg/cm²
Fu	= 3,200 kg/cm² —— $\bar{\sigma}_a = 2,600$ kg/cm²
n	= 14

$\delta = 1$ (symetrical reinforcement)

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

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

$\longrightarrow \phi = 4.31 > \phi_o = 1.43$ (OK)

$\phi' = 8.11$

$n\omega = 0.028$

. 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

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

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

Hence applied :

A_{steel} = 8 D 16

$$= 16.08 \text{ cm}^2 = \frac{16.08}{30x40} x 100 \% A_{concrete}$$

$= 1.34 \% A_{concrete}$ (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 $\longrightarrow \bar{\sigma}'_b$ = 130 kg/cm²
Fu = 3,200 kg/cm² $\longrightarrow \bar{\sigma}_a$ = 2,600 kg/cm²
n = 14
$\delta = 1$ (symetrical reinforcement)

$$\phi_0 = \frac{\sigma_a}{n x \bar{\sigma}'_b} = \frac{2{,}600}{14x130} = 1.43$$

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

$\longrightarrow \phi$ = 3.6 > ϕ_0 = 1.43 (OK)
ϕ' = 6.65
$n\omega$ = 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

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

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

Hence applied :
A_{steel} = 8 D 16

$$= 16.08 \text{ cm}^2 = \frac{16.08}{25x40} x\ 100\ \%\ A_{concrete}$$

= 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

$\delta = 1$ (symetrical reinforcement)

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

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

⟶ ϕ = 5.45 > ϕ_o = 1.43 (OK)

ϕ' = 15.36

$n\omega$ = 0.0152

. Stresses

$\bar{\sigma}_a$ = 2,600 kg/cm²

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

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

. Reinforcement

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

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

$n = 14$

$\delta = 1$ (symetrical reinforcement)

$$\phi_0 = \frac{\sigma_a}{n x \overline{\sigma'_b}} = \frac{2{,}600}{14x130} = 1.43$$

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

$\longrightarrow \phi = 4.41 > \phi_0 = 1.43$ (OK)

$\phi' = 9.59$

$n\omega = 0.023$

. Stresses

$\overline{\sigma_a} = 2{,}600\ kg/cm^2$

$$\overline{\sigma_b} = \frac{\overline{\sigma_a}}{nx\phi} = \frac{2{,}600}{14x4.41} = 42.11\ kg/cm^2 < \overline{\sigma'_b} = 130\ kg/cm^2 \text{ (OK)}$$

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

. Reinforcement

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

$A_{steel} = 2.44\ cm^2$

Hence applied :

$A_{steel} = 2\ D\ 16$

$= 4.16\ cm^2 > A_{steel} = 1.44\ cm^2$ (OK)

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

On Beam No. F14

Maximum Bending Moment	= 124,178	kgcm		
b (width)	= 30	cm		
h_t (height)	= 50	cm		
Concrete cover	= 4	cm		
Fc	= 225	kg/cm^2	$\longrightarrow$	$\overline{\sigma'}_b = 130\ kg/cm^2$
Fu	= 3,200	kg/cm^2	$\longrightarrow$	$\overline{\sigma}_a = 2{,}600\ kg/cm^2$
ns	= 14			

$$\phi_0 = \frac{\overline{\sigma}_a}{n\,\overline{\sigma'}_b} = \frac{2{,}600}{14x130} = 1.43$$

For Maximum BM, M = 124,178 kgcm

$b = 30$

$h_t = 50\ ;\ d = 4 \longrightarrow h = h_t - d = 50 - 4 = 46\ cm$

$$Ca = \frac{h}{\sqrt{\frac{nM}{b\sigma_a}}} = \frac{46}{\sqrt{\frac{14x124{,}178}{30x2{,}600}}} = 9.74$$

$\delta = 0.4$ (required of minimum compression reinforcement bar)

$\longrightarrow \phi = 1.546 > \phi_0 = 1.43$ (OK)

$\phi' = 2.103$

$n\omega = 0.0602$

. Stresses

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

$$\overline{\sigma}_b = \frac{\overline{\sigma}_a}{n\phi} = \frac{2{,}600}{14x1.546} = 120.13\ kg/cm^2 < \overline{\sigma'}_b = 130\ kg/cm^2\ \text{(OK)}$$

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

. Reinforcement bar

$$A_{steel\ (tensile)} = \frac{\omega bh}{14} = 0.0043 \times 30 \times 46 = 5.934\ cm^2$$

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

$$= 0.4 \times 5.934\ cm^2 = 2.374\ cm^2$$

Used $A_{steel\ (tensile)}$ = 3 D 16 = 6.028 cm^2(OK)

Used $A_{steel\ (compression)}$ = 2 D 16 = 4.02 cm^2(OK)

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

On Column No. F15

Maximum Bending Moment	= 258,070 kgcm	
b (width)	= 30 cm	
h_t (height)	= 40 cm	
Concrete cover	= 4 cm	
$h = h_t - d$	= 40 − 4 = 36 cm	
Fc	= 225 kg/cm²	$\longrightarrow \bar{\sigma}'_b = 130$ kg/cm²
Fu	= 3,200 kg/cm²	$\longrightarrow \bar{\sigma}_a = 2,600$ kg/cm²
ns	= 14	

$$\phi_0 = \frac{\bar{\sigma}_a}{n\,\bar{\sigma}'_b} = \frac{2,600}{14x130} = 1.43$$

For Maximum BM M = 258,070 kgcm

$$Ca = \frac{h}{\sqrt{\frac{nM}{b\sigma_a}}} = \frac{36}{\sqrt{\frac{14x258,070}{30x2,600}}} = 5,28$$

$\delta = 1$ (for symetrical reinforcement)

$\longrightarrow \phi = 5.28 > \phi_0 = 1.43$ (OK)

$\phi' = 14.00$

$n\omega = 0.0164$

. Stresses

$\bar{\sigma}_a = 2,600$ kg/cm²

$$\bar{\sigma}_b = \frac{\bar{\sigma}_a}{n\,\phi} = \frac{2,600}{14x5.25} = 35.37 \text{ kg/cm}^2 < \bar{\sigma}'_b = 130 \text{ kg/cm}^2$$

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

. Reinforcement

$$A = \omega bh = \frac{0.0164}{14} x\ 30\ x\ 36 = 1.265 \text{ cm}^2$$

$A_{steel} = 1.265$ cm² < 1 % x 1,500 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)

CHAPTER 3
BANDARHARJO DRAINAGE SYSTEM IMPROVEMENT

3.1 Baru Pumping Station

3.1 Baru Pumping Station

3.1.1 Structural Calculation of Gate Leaf and Hoist

I) Design Conditions

1. Function of the gate

Tidal barrier

2. Top elevation of the gate

As the gate acts as a tidal barrier, the top elevation of the gate should be identical to that of the tidal dike.

The top elevation of the tidal dike is +0.45m+0.4m=+0.85m.

Therefore, the top elevation of the gate should be **+0.85m**.

3. Bottom elevation of the gate

Design river bed elevation of Semarang River at No.31+8 is -2.405m.

L.W.L. in Baru Retarding Pond is -2.4m.

Design river bed of Baru River is also =-2.4m

Therefore, the bottom elevation of the gate should be -2.4m.

4 Height of the gate

According to 2 and 3 the height of the gate is **3.25m**.

5 Design Water Level Semarang River Side

In definitive plan the water level was assumed as 0.25+0.1=0.35m and pump station was designed.

Same elevation shall be used for gate design.

Therefore, the design water level upstream is **0.35m**.

6 Design Water Level Asin River Side

The bottom elevation of the gate is -2.4m.

Therefore, the design water level downstream is -2.4m.

7 Load Condition

(case-1) normal condition

hydraulic static load (U/S: +0.35m, D/S; -2.4m)

incremental coefficient: 1.00 (same as Japanese standard) (case-2) seismic condition

hydraulic static load (U/S; +0.35m+0.10m, D/S; -2.4m)

calculation of seismic wave

$$he=K\tau(\sqrt{(gH)})/(2*\pi)$$

$K=0.11\ m/s^2$

$\tau=1$ sec

hydraulic dynamic load (Westergaard formula)

$$7/12*Kh*W*b*h^2$$

where $Kh=0.11$

incremental coefficient: 1.50 (same as Japanese standard)

II) Structural Calculation

See attached calculation sheets.

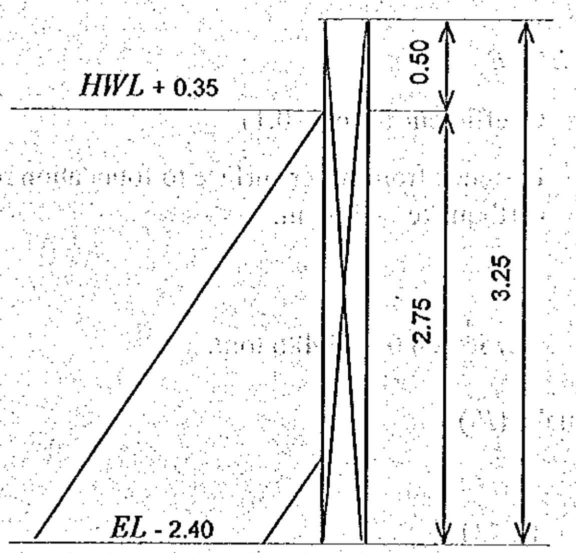
SPILLWAY GATE AND HOIST

I. DESIGN CONDITION

Type	:	Fixed wheel gate made of steel
Quantity	:	1 (one) set
Clear span	:	4.0 m.
Gate height	:	3.25 m.
Hwl	:	EL. $\pm$ 0.35 m.
Sill elevation	:	EL. - 2.40 m.
Design head	:	2,750 m [(+ 0.35 - (-2.40 m)]
Sealing method	:	3 edges rubber seal at upstream
Seismic coefficient (*Kh*)	:	0.11
Seismic wave height	:	0.10 m.
Maximum deflection of beam	:	1/800
Corrosion allowance	:	3.0 mm.
Type of hoist	:	Electrically driven wire rope wound type stationary hoist (1 m 2 D type)
Operation speed	:	0.3 m/min $\pm$ 10%
Hoisting height	:	5.0 m.
Operating method	:	Local

II. HYDRAULIC LOAD (*P*)

1. Hydrostatic Pressure



$$P_1 = \frac{W_0 \times H_0^2 \times B}{2}$$

where ;

P_1 = Hydraulic load (t)

H_0 = Water head of bottom = 2.86 m.

B = Sealing span = 4.0 m.

W_0 = 1.0 t/m³

Thus ;

$$P_1 = \frac{1.0 \times 2.75^2 \times 4.0}{2}$$

$$= 16.36\ tf.$$

2. Water Pressure During Earthquake

2.1. Hydrostatic Pressure During Earthquake

$$Ps = \tfrac{1}{2} \times (hw + h)^2 \times B$$

where : hw = Height of waves due to earthquake = 0.1 m.

h = Water head = 2.75 m.

B = Sealing span = 4.0 m.

$$Ps = \tfrac{1}{2} \times (0.1 + 2.75)^2 \times 4.0$$

$$= 16.245\ \text{ton}f$$

2.2. Dynamic Water Pressure During Earthquake

$$Pd = \tfrac{7}{12} \times K_h \times h_m^{\frac{1}{2}} \times h^{\frac{3}{2}} \times B$$

where : K_h = Coefficient factor = 0.11

h_m = Distance from water surface to foundation rock during earthquake. = 4.51 m.

Thus ;

$$Pd = \tfrac{7}{12} \times 0.11 \times 4.51^{\frac{1}{2}} \times 2.75^{\frac{3}{2}} \times 4.0 = 2.486\ \text{ton}f.$$

Total load during earthquake (P_2)

$$P_2 = P_s + P_d$$

$$= 16.245 + 2.486 = 18.731\ t.$$

Thus ;

$P_1 \langle P_2$

15.125 tf $\langle$ 18.731 tf.

There fore design shall be carried out based on the water pressures during earthquake.

$$P_2 = \frac{W_0 \times H_0^{\,2} \times B}{2}$$

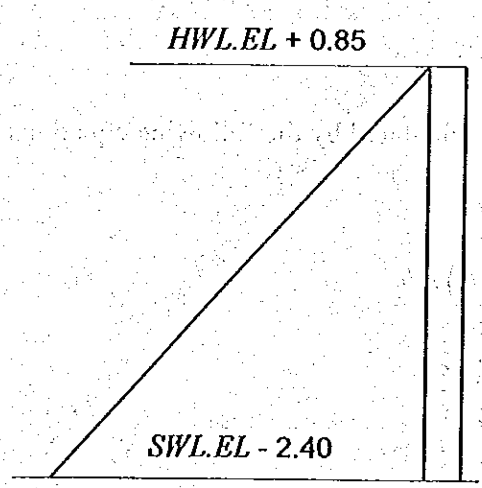
$$18.731 = \frac{1.0 \times H_0^{\,2} \times 4.0}{2}$$

$$H_0 = \sqrt{\frac{18.731 \times 2}{1.0 \times 4.0}}$$

$$= 3.060 \text{ m.}$$

Thus : Design head of water is determined 3.25 m.

3. Hydraulic Load During Earthquake (P)



$$P = \frac{W_0 \times H^2 \times B}{2}$$ where ;

P = Hydraulic load during earthquake (tf)

H = Water head of Bottom = 3.25 m.

B = Sealing span = 4.0 m

W_0 = 1.0 t/m³

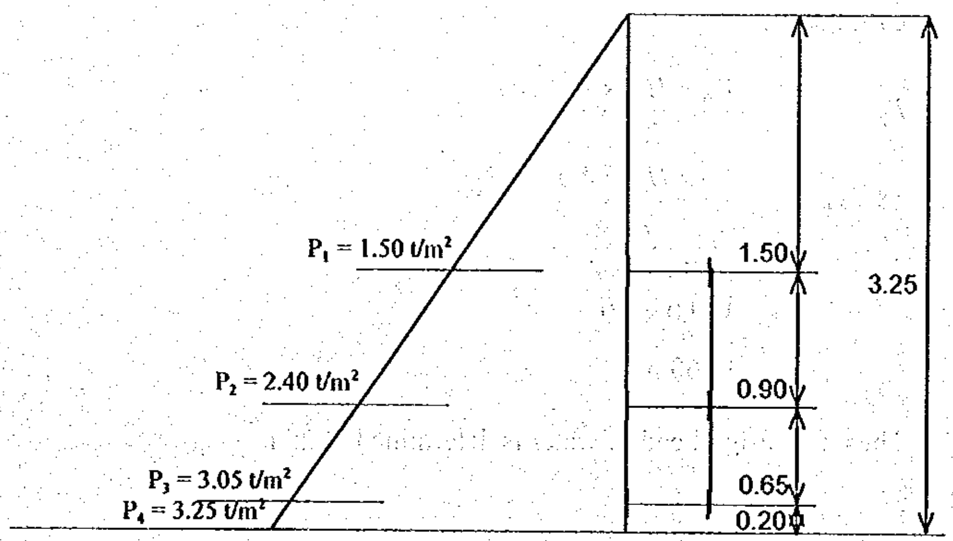
$$P = \frac{1.0 \times 3.25^2 \times 4.0}{2}$$

$$= 21{,}125 \; tf$$

III. HORIZONTAL MAIN BEAM

1. Arrangement of Main Beam

Three (3) numbers of main beam are arranged as follows ;



2. Charging Load on Each Beam.

Charging load acting on each beam is calculated by the following equations

$$\text{Beam A} = 0.5\times P_1^2+\frac{(2P_1+P_2)\times b_2}{6}$$

$$\text{Beam B} = \frac{(P_1+2P_2)\times b_2}{6}+\frac{(2P_2+P_3)\times b_3}{6}$$

$$\text{Beam C} = \frac{(P_2+2P_3)\times b_3}{6}+\frac{(P_3+P_4)\times b_4}{2}$$

Thus, calculation result is as follows ;

Beam A

$$P_A = 0.5\times 1.50^2+\frac{0.9\times(2\times 1.50+2.40)}{6} = 1.935\ tf/\text{m}$$

Beam B

$$P_B = \frac{0.9\times(1.50+2\times 2.40)}{6}+0.65\times\frac{(2\times 2.40+3.05)}{6} = 1.795\ tf/\text{m}$$

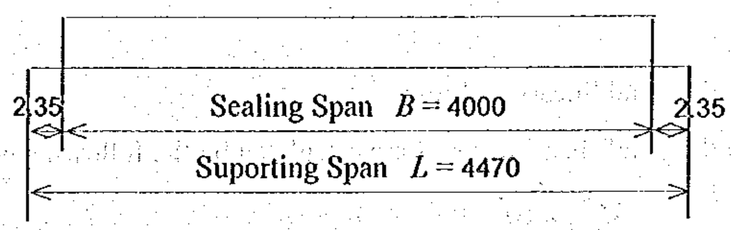
Beam C

$$P_C = 0.65\times\frac{(2.40+2\times 3.05)}{6}+0.5\times(3.05+3.25)\times 0.2 = 1.551\ tf/\text{m}$$

3. Bending Moment and Shearing Force.

3.1. Bending Moment.

Maximum bending moment is calculated by the following equation.



$$M_{max} = \frac{W \times (2 \times L - B)}{8}$$

Where ; M_{max} = Maximum bending moment (tf-m)

W = Hydraulic load acting on each beam (tf)

$= P_B \times A$

$= 1.935 \times 4.0 = 7.740\ tf$

L = Supporting length 4.47 m

B = Sealing span = 4.0 mt.

$$M_{max} = \frac{7.740 \times (2 \times 4.47 - 4.0)}{8} = 3.780\ tf\text{-m}$$

3.2. Shearing Force.

Maximum shearing force is calculated by the following equation ;

$$S_{max} = \frac{W}{2}$$

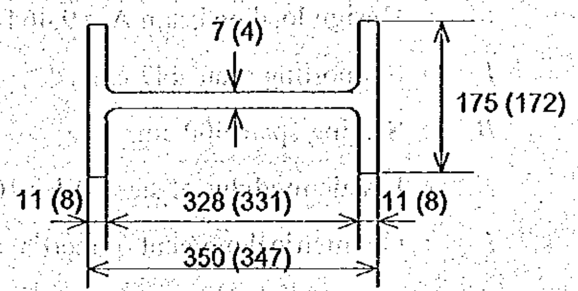
Where ; S_{max} = Max shearing force (tf)

W = Hydraulic load (tf)

$$S_{max} = \frac{7.740}{2} = 3.870\ tf$$

Note ; As major design load acting's on beam A, bending moment and shearing force are calculated only beam A.

Sectional property of beams.



Moment of inertia $I = 9116{,}8\ cm^4$

Modulus section $Z = 525.5\ cm^3$

Area of web at both end $AW = 13.24\ cm^2$

Area $A = 40.76\ cm^2$

3.3. Bending and Shearing Stress

Bending and shearing stress are calculated by the following equations ;

$$\sigma b_{max} = \frac{M_{max} \times 10^5}{Z}$$

$$\tau_{max} = \frac{S_{max} \times 10^3}{AW}$$

Where ;

σb_{max} = Maximum bending stress (kg/cm²)

M_{max} = Maximum bending moment (tf-m)

Z = Modulus of section (cm³)

τ_{max} = Maximum shearing stress (kg$f$/cm²)

S_{max} = Maximum shearing force (tf)

AW = Area of web at both end.

Thus ;

$$\sigma b_{max} = \frac{4.780 \times 10^5}{525} = 910\ \text{kg.f/cm}^2 \ \langle\ 1{,}200\ \text{kg}f/\text{cm}^2$$

$$\tau_{max} = \frac{3.870 \times 10^3}{13.24} = 292\ \text{kg}f/\text{cm}^2 \ \langle\ 700\ \text{kg}f/\text{cm}^2$$

3.4. Deflection (∂)

Maximum deflection of each beam is calculated by the following equation.

$$\partial = \frac{W}{48EI} \times \left(L^3 - \frac{L \times B^2}{2} + \frac{B^3}{8} \right)$$

Where ;

∂_{max} = Maximum deflection of beam A (cm)

W = Design load on beam A = 9,464 kg$f$

L = Supporting span 447 cm.

B = Sealing span 400 cm.

E = Elastic modulus of steel 2.1×10^6 kg$f$/cm²

I = Geometrical moment of inertia = 20,299 cm⁴

Thus ;

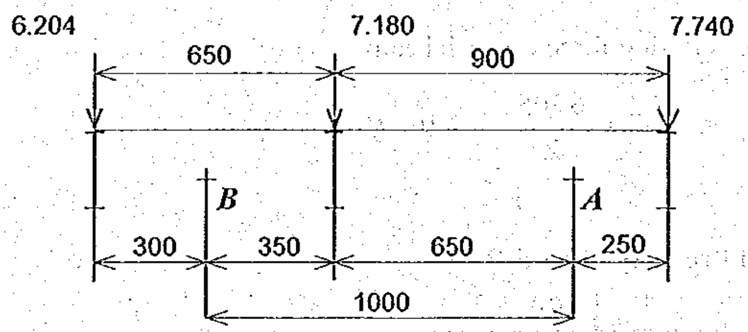
$$\partial = 0.611\times\frac{W}{I} = 0.611\times\frac{7,740}{9116.8} = 0.518\text{ cm}$$

$$\frac{\partial}{L} = \frac{0.518}{447} = \frac{1}{863} \langle \frac{1}{800}\text{ (allowable deflection)}$$

IV. END BEAM

1. Arrangement of Main Wheels

Two main wheel are provided in each end beam of gate leaf and their arrangement is as follows ;



2. Reaction Force.

Moment at *RA*

$7.740\times 0.25 - 7.180\times 0.65 + RB\times 1.0 - 6.204\times 1.3 = 0$

$1.935 - 4.667 + RB - 6.065 = 0$

$RB = 10.797\ tf$

$RA = 21.125 - 10.797 = 10.328\ tf$

Distributed load on each main wheel.

$RB' = RB/2 = 10.797/2 = 5.396\ tf$

$RA' = RA/2 = 10.328/2 = 5.164\ tf$

3. Bending Moment and Shearing Force.

3.1. Bending Moment.

$M_1 = 0$

$M_2 = 7.74\times 0.25 = 1.935\ tf.\text{m}$

$M_3 = 7.74\times 0.9 - 10.328\times 0.65 = 0.253\ tf.\text{m}$

$M_4 = 6.204\times 0.3 = 1.861\ tf.\text{m}$

Maximum Bending Moment ;

$$M_{\max} = \frac{M_3}{2} = \frac{1.935}{2} = 0.968\ tf.\mathrm{m}$$

3.2. Shearing Force.

$S_1 = 7.74\ tf.$

$S_2 = 7.74 - 10.328 = -2.588\ tf.$

$S_3 = 7.74 - 10.328 + 7.180 = 4.592\ tf.$

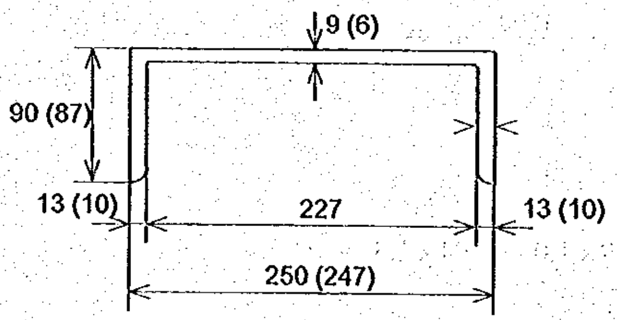
$S_4 = 7.74 - 10.328 + 7.180 - 10.797 = -6.205\ tf.$

$S_5 = 6.205\ tf.$

Max shearing force on each beam

$$S_{\max} = \frac{S_4}{2} = \frac{6.205}{2} = 3.102\ tf.$$

4. Sectional Property of End Beam



$I = 3030\ \mathrm{cm}^4$

$Z = 245.3\ \mathrm{cm}^3$

$AW = 14.82\ \mathrm{cm}^2$

$A = 31.02\ \mathrm{cm}^2$

5. Bending and Shearing Stress

Bending stress (σb)

$$\sigma b = \frac{M_{\max}}{Z}$$

$$= \frac{0.968 \times W^5}{245.3} = 395\ \mathrm{kgf/cm^2}\ \langle\ 1{,}200\ \mathrm{kgf/cm^2}$$

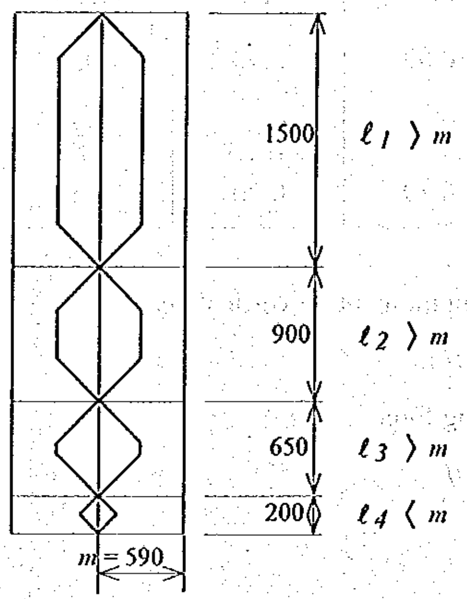
Shearing Stress (τs)

$$\tau s = \frac{S_{\max}}{AW}$$

$$= \frac{3.102 \times W^3}{14.82} = 209\ \mathrm{kgf/cm^2}\ \langle\ 700\ \mathrm{kg\ kgf/cm^2}$$

V. VERTICAL GIRDER

1. Bending moment and shearing force are calculated by the following formula.



1.1. $\ell \rangle m$

Bending moment

$$M = \frac{p \times m \times \left(3\ell^2 - m^2\right)}{24}$$

Shearing force

$$S = \frac{p \times m \times \left(\ell - \frac{m}{2}\right)}{2}$$

1.2. $\ell \leq m$

$$M = \frac{p \times m \times \ell^2}{12}$$

Shearing force

$$S = \frac{p \times m \times \ell}{4}$$

where ; M = Maximum bending moment ($t/$-m)

p = Mean water pressure ($t/$/m^2)

m = Pitch of vertical girder (m)

ℓ = Distance between horizontal beam (m)

S = Maximum shearing force ($t/$)

PORTION	m	ℓ	p	M	S
1.	0.59	1.50	0.750	0.1180	0.2666
2.	0.59	0.90	1.950	0.0998	0.3480
3.	0.59	0.65	2.725	0.0616	0.2854
4.	0.59	0.20	3.150	0.0062	0.0929

Maximum bending moment on vertical beam

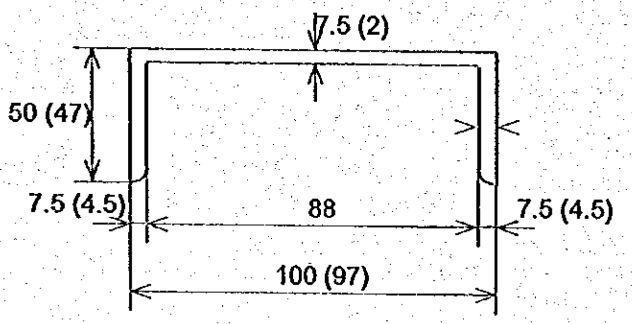
$M_{max} = 0.1180\ tf\text{-m}$

Maximum shearing force

$S_{max} = 0.3480\ tf$

2. Sectional Property

JIS G.3192 hot ruller steel section H.350 × 175 × 7/11 and following section are used.



$I = 102\ cm^4$

$Z = 21.0\ cm^3$

$Aw = 1.94\ cm^2$

$A = 5.99\ cm^2$

3. Bending Stress and Shearing Stress

Bending Stress (σb)

$$\sigma b = \frac{M_{max}}{Z}$$

$$= \frac{0.1180 \times 10^5}{21.0} = 562\ kg.f/cm^2 \ \langle \ 1{,}200\ kg.f/cm^2$$

Shearing Stress (τs)

$$\tau s = \frac{0.348 \times 10^3}{1.94} = 179\ kg/cm^2 \ \langle \ 700\ kg.f/cm^2$$

VI. SKIN PLATE

PORTION	m	ℓ	p	M	S
1.	0.59	1.50	0.750	0.1180	0.2666
2.	0.59	0.90	1.950	0.0998	0.3480
3.	0.59	0.65	2.725	0.0616	0.2854
4.	0.59	0.20	3.150	0.0062	0.0929

Maximum bending moment on vertical beam

$M_{max} = 0.1180\ tf\text{-m}$

Maximum shearing force

$S_{max} = 0.3480\ tf$

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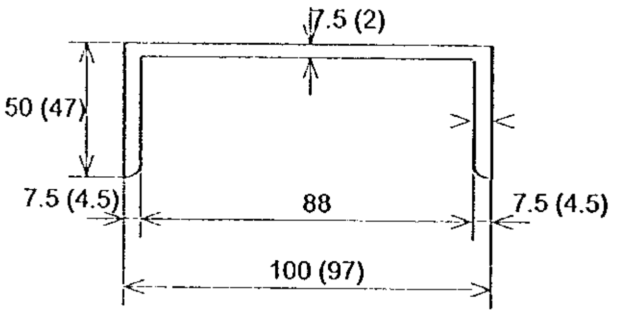
JIS G.3192 hot ruller steel section H.350 × 175 × 7/11 and following section are used.



$I = 102\ cm^4$

$Z = 21.0\ cm^3$

$Aw = 1.94\ cm^2$

$A = 5.99\ cm^2$

3. Bending Stress and Shearing Stress

Bending Stress (σb)

$$\sigma b = \frac{M_{max}}{Z}$$

$$= \frac{0.1180 \times 10^5}{21.0} = 562\ kgf/cm^2 < 1{,}200\ kgf/cm^2$$

Shearing Stress (τs)

$$\tau s = \frac{0.348 \times 10^3}{1.94} = 179\ kg/cm^2 < 700\ kgf/cm^2$$

VI. SKIN PLATE

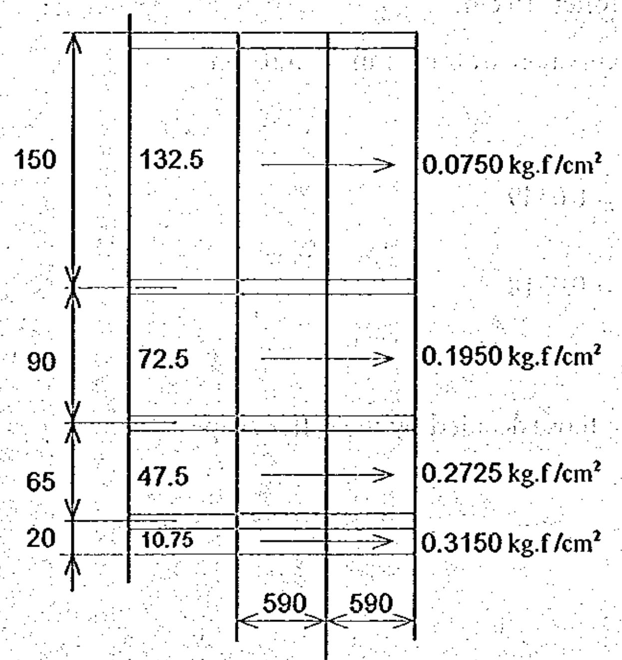
Bending stress of skin plate is calculated in accordance with following Timoshenko's formula.

$$t = \sqrt{\frac{K \times 0^2 \times p}{\sigma a \times 100}}$$

where :
σa = Bending stress (kg.f /cm^2)
K = Coefficient by b/a
a = Short span of plate (cm)
b = Long span of plate (cm)
p = Mean design pressure (kg.f /cm^2)
t = Thickness of plate (cm)
ε = Corrsion allowance 0.3 cm

No.	Beam	a	b	b/a	K	P	t	$t+\varepsilon$
1.	1 - 2	59.00	132.50	2.24	50.00	0.0750	0.33	0.63
2.	2 - 3	59.00	72.50	1.23	39.80	0.1950	0.47	0.77
3.	3 - 4	47.50	59.00	1.24	40.10	0.2725	0.45	0.75
4.	4 - 5	10.75	59.00	5.49	50.00	0.3150	0.12	0.42

Thickness of skin plate t = 9.0 mm



Bending stress of skin plate is calculated in accordance with following Timoshenko's formula.

$$t = \sqrt{\frac{K \times 0^2 \times p}{\sigma a \times 100}}$$

where : σa = Bending stress (kg.f/cm^2)

K = Coefficient by b/a

a = Short span of plate (cm)

b = Long span of plate (cm)

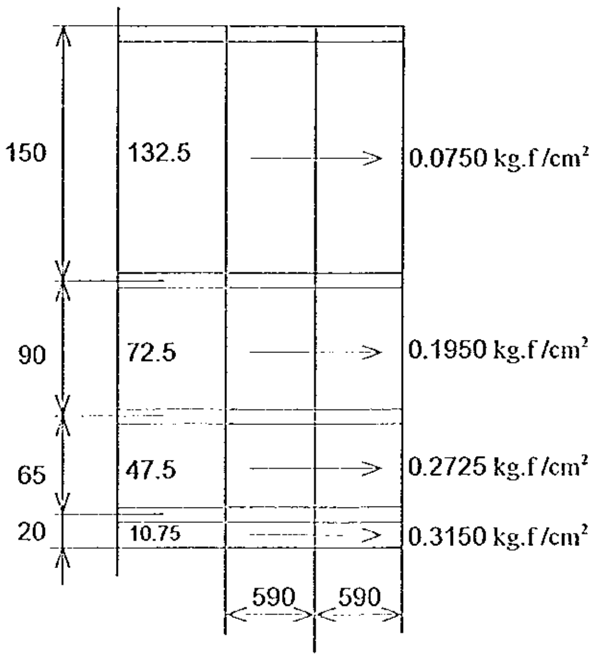
p = Mean design pressure (kg.f /cm^2)

t = Thickness of plate (cm)

ε = Corrsion allowance 0.3 cm

No.	Beam	a	b	b/a	K	P	t	$t+\varepsilon$
1.	1 - 2	59.00	132.50	2.24	50.00	0.0750	0.33	0.63
2.	2 - 3	59.00	72.50	1.23	39.80	0.1950	0.47	0.77
3.	3 - 4	47.50	59.00	1.24	40.10	0.2725	0.45	0.75
4.	4 - 5	10.75	59.00	5.49	50.00	0.3150	0.12	0.42

Thickness of skin plate t = 9.0 mm



VII. MAIN WHEEL ASSEMBLY

1. Main Wheels.

Main wheels are of point contact type, and their strength is calculated by the following Hertz's formula ;

$$p = \frac{3}{2\times\pi}\times\frac{P}{a\times b}$$

$$a = 1.109\times m\times\sqrt[3]{\frac{P}{(A+B).E}}$$

$$b = 1.109\times n\times\sqrt[3]{\frac{P}{(A+B).E}}$$

$$Z = \beta\times b$$

$$A+B = \frac{1}{2}\times\left(\frac{1}{R}+\frac{1}{R'}\right) \qquad B-A = \frac{1}{2}\times\left(\frac{1}{R}-\frac{1}{R'}\right)$$

Where ; p = Hertz's contact stress ($kg.f/cm^2$)

P = Working loaded one wheel = 6,291 kg.f

a = Half the contact width (major diameter) (cm)

b = Half the contact width (minor diameter) (cm)

E = Modulus of elasticity of wheel = 2.1×10^6 $kg.f/cm^2$

Z = Depth where maximum shearing stress cm.

β = Factor to give the depth where max shearing stress accurs (cm)

R = Radius of roller 15 cm.

R' = Radius of curvature of track rail = 320 cm.

Thus ;

$$A+B = \frac{1}{2}\times\left(\frac{1}{15}+\frac{1}{320}\right) = 0.0349$$

$$B-A = \frac{1}{2}\times\left(\frac{1}{15}-\frac{1}{320}\right) = 0.0318$$

Shape factor (m and n) are those decided by the roller shape.

$$\theta = Cos^{-1}\times\frac{(B-A)}{(A+B)}$$

$$= Cos^{-1}\times\frac{0.0318}{0.0349}$$

$$= 24^{0}19'54.46'' = 24^{0}$$

m = 3.280 n = 0.446

$$a = 1.109 \times 3.280 \times \sqrt[3]{\frac{5,396}{0.0349 \times 2.1 \times 10^6}} = 1.524 \text{ cm.}$$

$$b = 1.109 \times 0.446 \times \sqrt[3]{\frac{5.396}{0.0349 \times 2.1 \times 10^6}} = 0.207 \text{ cm.}$$

$$p = \frac{3}{2 \times \pi} \times \frac{5,396}{1.524 \times 0.207} = 8167 \text{ kg.}f/\text{cm}^2$$

Allowable contact stress (pa)

$$pa = \frac{100 \times HB}{2 \times V}$$

where ; pa = Allowable contact stress (kg.f/cm^2)
V = Safety factor = 1.0
HB = Brinell hardness
= 185 kg.f/cm^2

$$pa = \frac{185 \times 100}{2 \times 1.0} = 9250 \text{ kg.}f/\text{cm}^2$$

Thus ;

$$pa = 9,250 \text{ kg.f/cm}^2 \rangle 8,167 \text{ kg.}f/\text{cm}^2$$

$Z = \beta \times b \rightarrow$ $\quad \beta = a/b = \frac{1.524}{0.207} = 7.36 \approx 7.4$

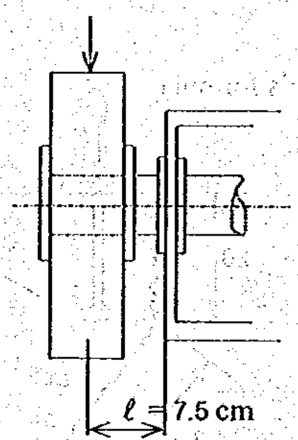
$= 0.90 \times 0.207$ $\quad \beta = 0.90$

$= 0.186$ cm

Thickness of track frame $\quad T \geq 4 \times Z$

$T = 4 \times 0.186 = 0.74$ cm ≈ 10.0 mm.

2. Shaft.



Maximum bending moment

$$M_{max} = p \times \ell$$
$$= 5,396 \times 7.5$$
$$= 40,470 \text{ kg.}f\text{-cm}$$

Material of shaft

SUS.304 (JIS G.4303)

Allowable stress (σb)

$$\sigma b = \frac{5,300}{5} = 1,060 \text{ kg.}f/\text{cm}^2$$

Diameter of shaft (d)

$$d = \sqrt[3]{\frac{32 \times M_{max}}{\pi \times \sigma b}}$$

$$= \sqrt[3]{\frac{32 \times 40{,}470}{\pi \times 1060}} = 7.30 \text{ cm} \approx 7.50 \text{ mm.}$$

Rechecking of bending and shearing stress

Section modulus (Z)

$$Z = \frac{\pi}{32} \times d^3 = \frac{\pi}{32} \times 7.50^3 = 41.42 \text{ cm}^3$$

Bending stress (σb)

$$\sigma b = \frac{M_{max}}{Z}$$

$$= \frac{40{,}470}{41.42} = 977 \text{ kg}f/\text{cm}^2 \langle \ 1{,}060 \text{ kg}f/\text{cm}^2$$

Shearing stress (τs)

$$\tau = \frac{4 \times P}{\pi \times d^2}$$

$$= \frac{4 \times 5{,}396}{\pi \times 7.50^2} = 122 \text{ kg}f/\text{cm}^2 \langle \ 0.6 \times 1{,}060 \text{ kg}f/\text{cm}^2$$

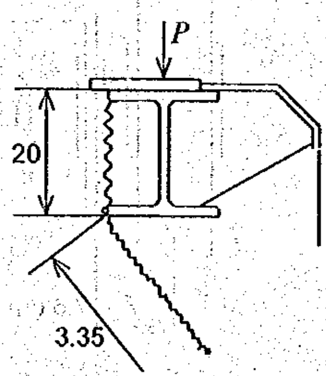
VIII. GUIDE FRAME

Strength of the track frame is examined by Andre's formula

$$K = 0.0588 \times \frac{P}{\sqrt[3]{B^2 \times I}}$$

$$a = 0.75 \times \frac{P}{K \times B}$$

$$M = \frac{K \times a^2 \times B}{4}$$



Where ;

K = Concrete bearing stress (kg.f/cm^2)

P = Maximum distributed load wheel = 5,396 kg.f

B = Bottom width of flange (cm)

I = Geometrical moment of inertia (cm^4)

M = Bending moment acting on track frame (kg.f-cm)

a = Half of stress distribution length of concrete at the bottom of track frame (cm)

Built up shape H 200 × 200 × 8/12

I = 4720 cm^4

Z = 472 cm^3

A = 63.53 cm^2

$$K = 0.0588 \times \frac{5{,}396}{\sqrt[3]{20^2 \times 4720}}$$

$$= 2.57 \text{ kg.}f/\text{cm}^2 \ \langle \ 50 \text{ kg.}f/\text{cm}^2$$

$$a = 0.75 \times \frac{5{,}396}{2.57 \times 20} = 78.74 \text{ cm.}$$

Bending moment on track frame (M)

$$M = \frac{2.57 \times 78.74^2 \times 20}{4} = 79{,}670 \text{ kg.}f\text{-cm}$$

Bending stress of track frame.

$$\sigma b = \frac{M}{Z}$$

$$= \frac{79{,}670}{472} = 169 \text{ kg.}f/\text{cm}^2 \ \langle \ 1200 \text{ kg.}f/\text{cm}^2$$

Shearing stress of concrete

$$\tau c = \frac{P}{Ac}$$ where ; τc = Maximum shearing stress (kg.f/cm^2)

Ac = Shearing area of concrete

$= 20 + 33.5\sqrt{2} = 67.37$ cm.

Thus ;

$$\tau c = \frac{2.57 \times 20}{67.37}$$

$$= 0.76 \text{ kg.}f/\text{cm}^2 \ \langle \ 8.0 \text{ kg.}f/\text{cm}^2$$

IX. OPERATING LOAD

1. Operating Condition.

The gate is normally closed and is designed to raise under water head 3.25 m.

2. Operation Load.

2.1. Weight of gate (wg) = 4.0 tf

2.2. Friction force due to main roller (Fw)

$$Fr = P \times \frac{(\mu_1 + \mu_2 \times r)}{R}$$

Where ;

Fw = Friction force due to main roller

P = Design load = 21.125 tf

μ_1 = Rolling frictional coefficient 0.1

μ_2 = Sliding frictional coefficient

at raising 0.2

at lowering 0.1

r = Radius of wheel shaft 3.75 cm

R = Radius of wheel 15 cm

Thus ;

2.2.1. At Raising.

$$FwR = \frac{21.125 \times (0.1 + 0.2 \times 3.75)}{15}$$

$$= 1.197 \text{ tf}$$

2.2.2. At Lowering

$$FwL = \frac{21.125 \times (0.1 + 0.1 \times 3.75)}{15}$$

$$= 0.669 \text{ tf}$$

2.3. Friction force due to rubber seal (Fr)

$$Fr = \mu \times (q + P \times b) \times \varepsilon\ell$$

Where ;

Fr = Friction force to rubber seal tf

μ = Friction coefficient of rubber seal

at starting = 1.5

at sliding = 0.7

P = Mean design pressure = 1.625 tf/m^2

q = Initial compression load on rubber seal = 0.05 tf/m

b = Contact width of rubber seal = 0.05

$\varepsilon\ell$ = Total sliding length of rubber seal = 6.5 m.

Thus ;

2.3.1. At Raising

$$FrR = 1.5 \times (0.05 + 1.625 \times 0.05) \times 6.5$$
$$= 1.280\ tf$$

2.3.2. At Lowering

$$FrL = 0.7 \times (0.05 + 1.625 \times 0.05) \times 6.5$$
$$= 0.597\ tf$$

2.4. Down pull force at opening (Fd)

$$Fd = K \times Gw \times Hh \times Ad$$

Where ;

Fd = Down pull force (tf)

K = Down pull coefficient 0.15

Gw = Specific gravity of water = 1.0 tf/m^3

Hh = Design head = 3.25 m

Ad = Project area of bottom gate = 0.24×4.0 = 0.96 m^2

Thus ;

$Fd = 0.15 \times 1.0 \times 3.25 \times 0.96 = 0.468$ ton.

2.5. Total Operation Load.

Description	Raising	Lowering
- Gate weight (Wg)	+ 4.000	+ 4.000
- Friction force due to main roller (Fw)	+ 1.197	- 0.669
- Friction force due rubber seal (Fr)	+ 1.280	- 0.597
- Down pull force (Fd)	+ 0.468	- 0.468
Total =	**6.945**	**2.266**

Thus ;

Operating Load

Raising (incl. allowable) = 7.5 ton.f

Lowering = 3.0 ton.f

X. HOISTING EQUIPMENT

Hoisting Load (Fo) = 7.5 ton.f

Operating Speed = 0.3 m/min $\pm$ 10%

Operating Height = 6.0 m

Type of hoist = 1 M 2 D Type

Electrically driven wire rope wound type stationary hoist.

1. Wire Rope.

1.1. Number of Falls

2 (two) falls of wire rope are provided on each side

Total number of wire rope falls (W) = 4

1.2. Tensile Load (T_L)

$$T_L = \frac{Fo}{W \times \eta_s}$$

where ;

T_L = Tensile load tf

Fo = Operating load = 7.5 tf

W = Number of falls = 4

η_s = Sheave effy. = 0.95

$$= \frac{7.5}{4 \times (0.95)^2} = 2.078 \text{ ton.}f\text{/drum}$$

1.3. Selection of Wire Rope

6×37 galvanized wire rope per JIS G.3525 Class A wire rope diameter $\{Dr\}$ = 18 mm

Breaking load = 17.5 ton.f

Safety factor = $17.5/2.078 = 8.42 \rangle 8$

2. Shaeve.

2.1. Diameter of sheave

$Ds = 17 \times Dr$ Where ;

Ds = Diameter of sheave

Dr = Diameter of wire rope = 18 mm

$= 17 \times 18 = 306$ mm.

Diameter of sheave is determined 350 mm.

2.2. Diameter of Drum

$Dd = 19 \times Dr$ Where ;

Dd = Diameter of drum

Dr = Diameter of wire rope = 18 mm

$= 19 \times 18 = 342$ mm.

Diameter of drum is determined = 500 mm.

2.3. Winding Number of Wire Rope (Nw)

$$Nw = \frac{Ns \times Oh}{\pi \times Dd} + dt$$

Where ;

Nw = Number of winding

Ns = Number of falls on each side = 2

Oh = Operating height = 5.0 mt.

Dd = Diameter of drum = 0.5 m

dt = Number of dead turn = 3.

$$Nw = \frac{2 \times 5.0}{\pi \times 0.5} + 3 = 9.36$$

There fore number of winding is determined 12

2.4. Revolution

$$Nd = (Vo \times Ns) / (\pi \times Dd)$$

Where ;

Nd = Drum revolution per minute (Rpm)

Vo = Operating speed 0.3 m/min

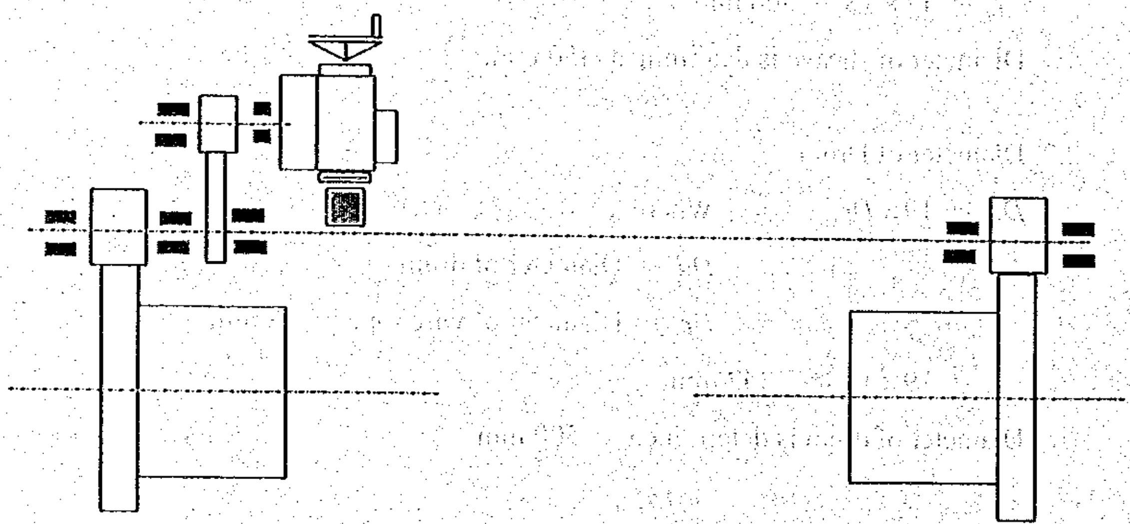
Ns = Number of wire rope falls on each side = 2

Dd = Diameter of drum 0.5 m.

Thus ;

$$Nd = \frac{0.3 \times 2}{\pi \times 0.5} = 0.382 \text{ Rpm.}$$

3. Arrangement of Hosit.



3.1. Reduction Ratio.

3.1.1. Required Ratio

$$\iota R = \frac{Nd}{Nm}$$

Where ;

ιR = Required Gear Ratio

Nd = Rpm of drum = 0.382 Rpm.

Nm = Full load Rpm of motor = 1420 Rpm.

$$\iota R = \frac{0.382}{1420}$$

$$= \frac{1}{3717.28}$$

3.1.2. Selected Ratio

Drum gear / pinion = $^{16}/_{97}$

Intermediate gear = $^{16}/_{52}$

Bevel Gear = $^{1}/_{3}$

Worm Gear = $^{1}/_{63.33}$

Total actual gear ratio = $^{1}/_{3743.4}$

Thus ;

Actual Rpm of drum = $^{1420}/_{3743.4}$ = 0.379

3.1.3. Hoisting Speed.

$$Vs = \frac{Na}{Nd} \times Vo$$

Where ;

Vs = Hoisting speed

Na = Actual Rpm of Drum 0.379 Rpm

Nd = Required Rpm of drum 0.382 Rpm

Vo = Operating speed = 0.3 m/min

Thus ;

$$Vs = \frac{0.379}{0.382} \times 0.3$$

$= 0.298$ m/min

4. Electric Motor Operation.

4.1. Mechanical Efficiency

Sheave	0.95
Drum	0.95
Drum gear / pinion	0.95
Intermediate Gear	0.95
Bevel Gear	0.90
Worm Gear	0.44

Thus ; Total mechanical efficiency on motor operation $(Mt) = 0.3225$

4.2. Motor Capacity.

$$Q = \frac{Fo \times Vo}{6.12 \times \eta t}$$

Where ;

Q = Motor KW required

Fo = Operating load 7.5 ton.f

Vo = Operating speed = 0.298 m/min

ηt = Total efficiency = 0.3225

$$Q = \frac{8.0 \times 0.298}{6.12 \times 0.3225}$$

$$= 1.13 \text{ ton} \times 1.5 = 1.7 \text{ KW.}$$

There fore 2.2 KW motor is adopted

Motor specification ;

Type : TEFC Class B with magnetic brake

Supply : 3 PH / 380 V AC / 50 HZ / 2.2 KW / 1420 Rpm.

Rating : Continuous duty.

5. Manual Operation ;

5.1. Reduction Ratio (it)		Mechanical Effy.
Drum gear / pinion	(16/97)	0.95
Intermediate gear	(16/52	0.95
Bevel gear	(1/3)	0.90
Worm gear (manual)	(1/38)	0.30

Total = 2,246.16 0.2437

5.2. Torque at Drum

$$TD = \frac{TL \times R.Drum}{\eta} \times \eta d$$

Where ;

TD = Torque at drum

TL = Tensile load = 2.078 ton.f

$R.Drum$ = Drum Radius = 0.25 m.

η = Drum efficiency = 0.95

nd = Number of drum = 2

$$TD = \frac{2.078 \times 0.25}{0.95} \times 2$$

= 1.094 ton.f-m

= 1,094 kg.f-m

5.3. Rimpull Force ;

$$F = \frac{TD}{it \times \eta t \times Rh}$$

Where ;

F = Rimpull force

TD = Torque at drum 1,094 kg.f-m

it = Total manual reduction ratio = 2,246.16

ηt = Total manual mechanical efficiency = 0.2437

Rh = H wheel Radius = 0.23 m.

Thus ;

$$F = \frac{1,094}{2,246.16 \times 0.2437 \times 0.23}$$

= 8.7 kg.f 〈 10 kg.f

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