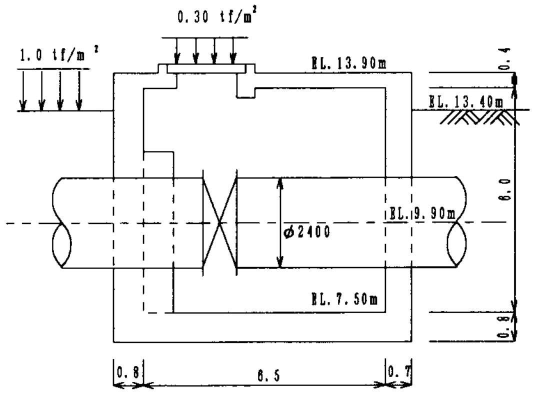
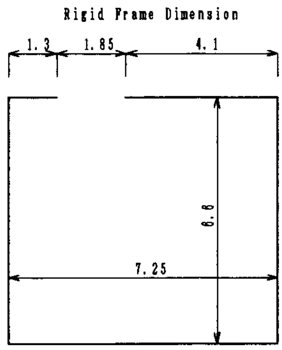
APPENDIX C.4.7-4 Structural Calculation of Valve Chamber

(1) Sectional Dimension for Calculation

Valve Chamber should be calculated by Gate Shaped Rigid Frame.



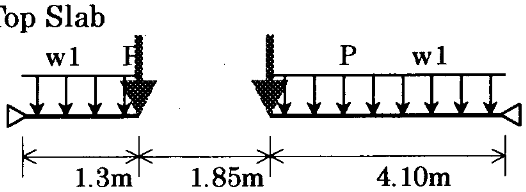


(2) Calculation of Load

(a) Case of Calculation

Case1	Upstream	; full (Max. W.L.130m)
	Downstream	; empty
Case2	Upstream	; empty
	Downstream	; full (Max. W.L.93.0m)

(b) Top Slab



w1: Own Weight of Top Slab

$w1 = 0.30 + 0.40 \times 2.45 = 1.280$ tf/m²

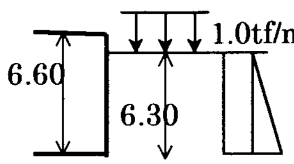
P : Own Weight of Cover

$P = (0.25 \times 2.60 \times 2.45 + 0.30 \times 2.60) / 2$

$\therefore P = 1.186$ tf/m

(c) Side Earth Pressure (P_1)

Side earth pressure should be calculated by following equation; $P = K_a \times \gamma_t \times H$



$P_1 = 0.5 \times 1.0 = 0.5$ tf/m²

$P_2 = 0.5 \times (1.0 + 1.8 \times 6.30) = 6.170$ tf/m²

(d) Thrust Force

Case 1

$S = \pi/4 \times 2.4^2 \times (130.0 - 9.9) \times 3 = 1{,}630$ tf/m²

S_v ; Thrust Force against valve chamber wall $S_v = 1/2 \times S = 815$ tf

This force should be distributed into valve depth and pipe width;

$P_s = S_v / 19.60 \times 2.40 = 815 / 19.60 \times 2.40 = 17.326$ tf/m²

Case 2

$S = \pi/4 \times 2.4^2 \times (93.0 - 9.9) \times 3 = 1{,}128$ tf/m²

S_v ; Thrust Force against valve chamber wall $S_v = 1/2 \times S = 564$ tf

This force should be distributed into valve depth and pipe width;

$P_s = S_v / 19.60 \times 2.40 = 564 / 19.60 \times 2.40 = 11.990$ tf/m^2

(e) Soil Pressure acting Wall

Case 1

[Soil Pressure acting on Wall]

= [Static Soil Pressure]+{[Thrust Force]-[Slip Reaction Force of Bottom Slab]}

*Consider only Concrete Weight.

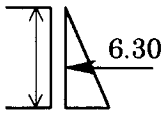
$V = \{8.00 \times 7.20 \times 19.60 - 6.50 \times 6.00 \times 18.20 + 0.80 \times (3.60 \times 4.20 \times 3 + 1.40 \times 1.80 \times 3)$
$- \pi /4 \times 2.40^2 \times (1.60 + 0.70) \times 3 + 2.80 \times 0.95 \times 0.50 \times 3\} \times 2.45$

$= 455.09 \times 2.45 = 1{,}115$ tf

R_H ; Slip Reaction Force of Bottom Slab

$R_H = \mu V / F = 0.50 \times 1{,}115 / 1.5 = 372$ tf

$\Delta R = Sv - R_H = 815.0 - 372 = 443$ tf



$\Delta R = 443$ tf

$\Delta P = 7.175$ tf/m^2

Soil Pressure Distribution should be considered as a triangle;

$\Delta P = 2 \times \Delta R / (19.60 \times 6.30) = 2 \times 443 / (19.60 \times 6.30) = 7.175$ tf/m^2

Case 2 Not Considered (Only Static Soil Pressure)

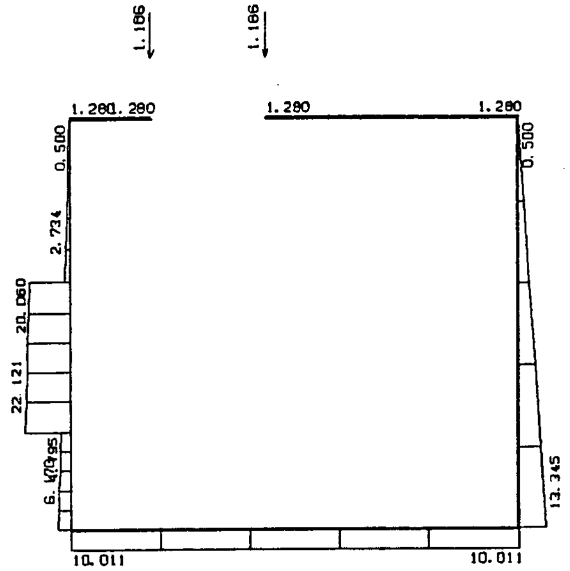
(f) Reaction Force of Bottom Slab (W_2) (tf)

Concrete Weight	1,063.9
Valve ϕ2400	63.4
Pipe Weight ϕ2400	252.3
Crowd Load for Top Slab	47.0
+) Soil Weight	143.1
Total	1569.7

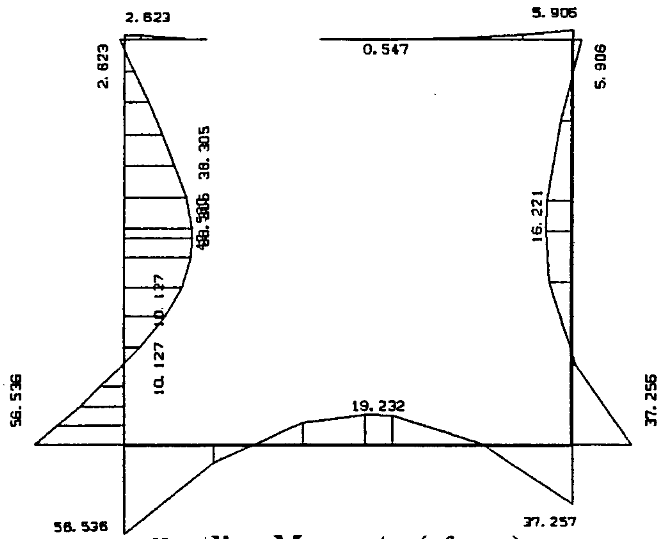
Reaction Force of Bottom Slab $w_2 = 1569.7 / (8.0 \times 19.6) = 10.011$ tf/m^2

(3) Result of Analysis

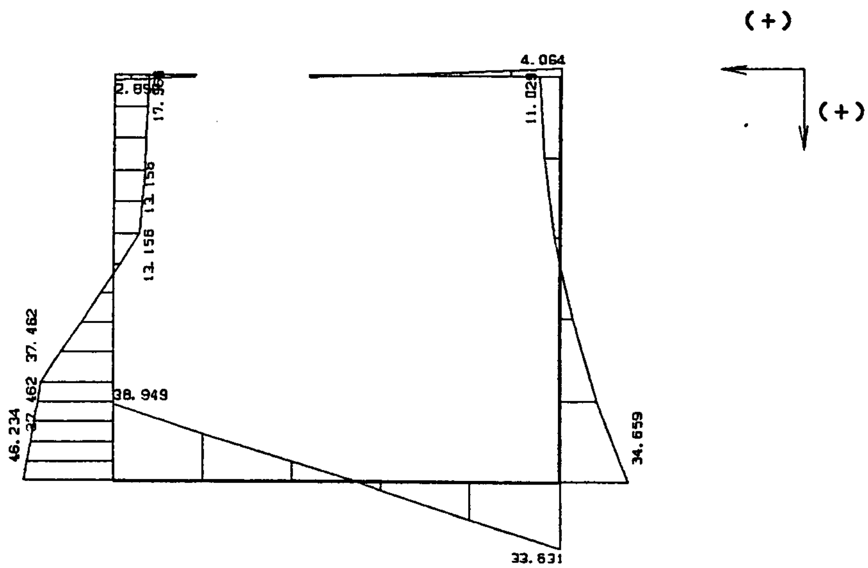
Load and sectional force are showed Figure1 and Figure 2,and results of analysis are showed Table 1. And design of reinforcement is decided by using biggest required area of tension reinforcement.



Load Distribution (tf/m, tf/m^2)

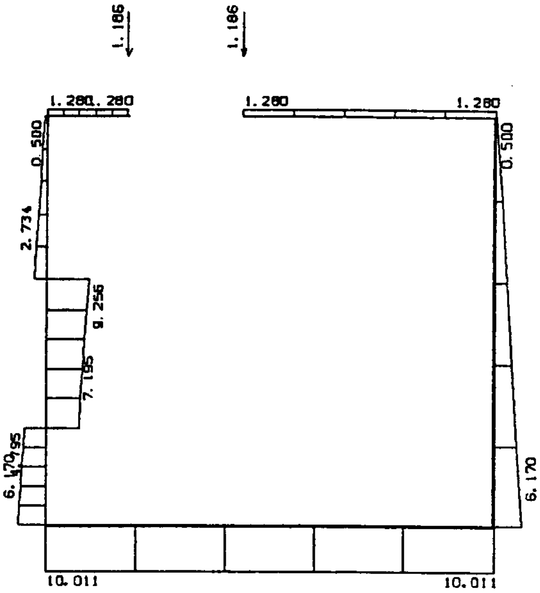


Bending Moment (tf · m)

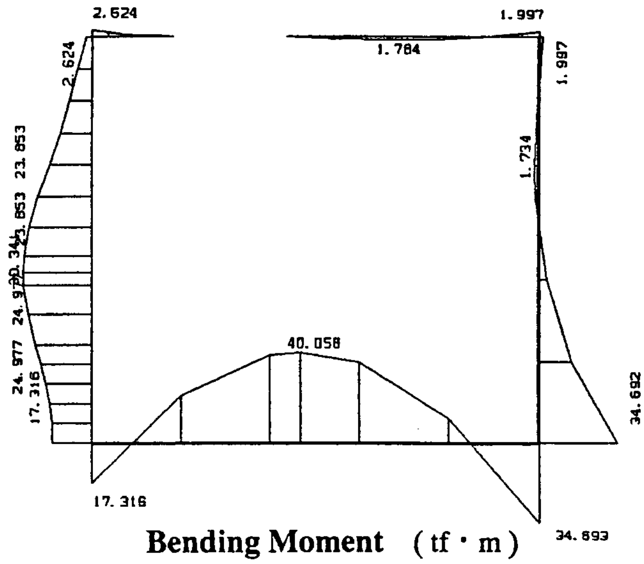


Shearing Force (tf)

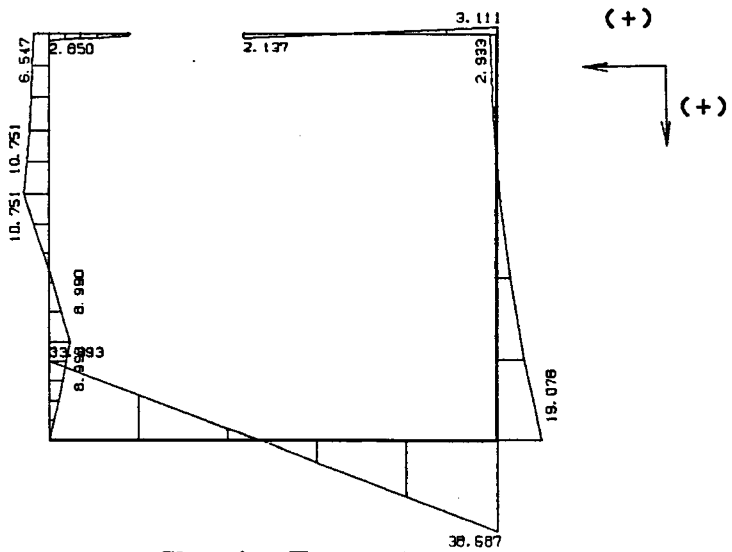
Figure 1 Load and Sectional Force of Case 1 (Upstream ; Full)



Load Distribution (tf/m, tf/m^2)



Bending Moment (tf · m)



Shearing Force (tf)

Figure 2 Load and Sectional Force of Case 2 (Downstream ; Full)

Table 1 Calculation of Section Force and Reinforcement (1/3)

σ = 1800 (kgf/cm^2) σ_{ca} = 85 (kgf/cm^2) k = 0.415 j = 0.862 c1 = 0.257

Element Number No.	Thickness T (m)	Cover TT (m)	Location (m)	Bending Moment M (tf · m)	Axial Force N (tf)	M + N * C MS (tf · m)	Required Effective Depth D (m)	Effective Depth T - TT (m)	Required Area of Tensil Reinforcement AS (cm^2)	Shearing Force S (tf)	Shear Stress TA (kgf / cm^2)
1	0.800	0.070	0.0	2.623	2.850	3.564	0.153	0.730	1.564	-17.360	2.759
		0.070	0.520	-6.316	2.850	7.257	0.219	0.730	-4.825	-16.984	2.700
		0.070	1.040	-14.999	2.850	15.940	0.324	0.730	-12.493	-16.375	2.603
		0.070	1.560	-23.306	2.850	24.246	0.400	0.730	-19.828	-15.534	2.469
		0.070	2.080	-31.115	2.850	32.055	0.459	0.730	-26.724	-14.461	2.299
		0.070	2.600	-38.305	2.850	39.246	0.508	0.730	-33.074	-13.156	2.091
2	0.800	0.070	0.0	-38.305	2.850	39.246	0.508	0.730	-33.074	-13.156	2.091
		0.070	0.480	-42.293	2.850	43.234	0.534	0.730	-36.596	-3.428	0.545
		0.070	0.960	-41.564	2.850	42.505	0.529	0.730	-35.952	6.498	1.033
		0.070	1.440	-36.024	2.850	36.964	0.493	0.730	-31.059	16.621	2.642
		0.070	1.920	-25.576	2.850	26.517	0.418	0.730	-21.833	26.942	4.283
		0.070	2.400	-10.127	2.850	11.068	0.270	0.730	-8.190	37.462	5.955
	MAX	0.070	0.647	-42.579	2.850	43.520	0.535	0.730	-36.849	-0.000	0.000
3	0.800	0.070	0.0	-10.127	2.850	11.068	0.270	0.730	-8.190	37.462	5.955
		0.070	0.320	2.111	2.850	3.051	0.142	0.730	1.111	39.040	6.206
		0.070	0.640	14.868	2.850	15.809	0.323	0.730	12.377	40.707	6.471
		0.070	0.960	28.173	2.850	29.113	0.438	0.730	24.126	42.461	6.749
		0.070	1.280	42.053	2.850	42.993	0.532	0.730	36.383	44.303	7.042
		0.070	1.600	56.536	2.850	57.477	0.615	0.730	49.174	46.234	7.349
4	0.400	0.070	0.0	-2.623	17.360	4.880	0.179	0.330	0.0	2.850	1.002
		0.070	0.650	-1.041	17.360	3.298	0.147	0.330	0.0	2.018	0.710
		0.070	1.300	0.000	17.360	2.257	0.122	0.330	0.0	1.186	0.417

Table 1 Calculation of Section Force and Reinforcement (2/3)

σ = 1800 (kgf/cm^2) σ_{ca} = 85 (kgf/cm^2) k = 0.415 j = 0.862 c1 = 0.257

Element Number No.	Thickness T (m)	Cover TT (m)	Location (m)	Bending Moment M (tf · m)	Axial Force N (tf)	M + N * C MS (tf · m)	Required Effective Depth D (m)	Effective Depth T - TT (m)	Required Area of Tensil Reinforcement AS (cm^2)	Shearing Force S (tf)	Shear Stress TA (kgf / cm^2)
5	0.400	0.070	0.0	-0.000	0.0	0.000	0.000	0.330	-0.000	1.184	0.416
		0.070	0.820	0.540	0.0	0.540	0.060	0.330	1.055	0.134	0.047
		0.070	1.640	0.220	0.0	0.220	0.038	0.330	0.429	-0.916	0.322
		0.070	2.460	-0.961	0.0	0.961	0.080	0.330	-1.878	-1.965	0.691
		0.070	3.280	-3.003	0.0	3.003	0.141	0.330	-5.866	-3.015	1.060
		0.070	4.100	-5.905	0.0	5.905	0.197	0.330	-11.536	-4.064	1.429
	MAX	0.070	0.925	0.547	0.0	0.547	0.060	0.330	1.069	0.000	0.000
6	0.700	0.070	0.0	-5.905	4.064	7.044	0.215	0.630	-4.949	11.029	2.031
		0.070	0.660	1.172	4.064	2.310	0.123	0.630	0.106	10.275	1.893
		0.070	1.320	7.472	4.064	8.610	0.238	0.630	6.552	8.674	1.598
		0.070	1.980	12.435	4.064	13.573	0.299	0.630	11.630	6.224	1.146
		0.070	2.640	15.501	4.064	16.639	0.331	0.630	14.768	2.927	0.539
		0.070	3.300	16.112	4.064	17.250	0.337	0.630	15.393	-1.218	0.224
		0.070	3.960	13.707	4.064	14.845	0.313	0.630	12.933	-6.210	1.144
		0.070	4.620	7.728	4.064	8.866	0.242	0.630	6.814	-12.051	2.220
		0.070	5.280	-2.386	4.064	3.524	0.152	0.630	-1.348	-18.739	3.452
		0.070	5.940	-17.195	4.064	18.333	0.347	0.630	-16.501	-26.275	4.840
		0.070	6.600	-37.256	4.064	38.394	0.503	0.630	-37.029	-34.659	6.384
	MAX	0.070	3.120	16.221	4.064	17.359	0.338	0.630	15.505	0.000	0.000

Table 1 Calculation of Section Force and Reinforcement (3/3)

σ = 1800 (kgf/cm^2) σ_{ca} = 85 (kgf/cm^2) k = 0.415 j = 0.862 c1 = 0.257

Element Number No.	Thickness T (m)	Cover TT (m)	Location (m)	Bending Moment M (tf · m)	Axial Force N (tf)	M + N * C MS (tf · m)	Required Effective Depth D (m)	Effective Depth T - TT (m)	Required Area of Tensil Reinforcement AS (cm^2)	Shearing Force S (tf)	Shear Stress TA (kgf / cm^2)
7	0.800	0.070	0.0	56.536	46.234	71.793	0.688	0.730	37.714	-38.949	6.191
		0.070	0.725	30.929	46.234	46.186	0.551	0.730	15.101	-31.691	5.037
		0.070	1.450	10.584	46.234	25.841	0.413	0.730	0.0	-24.433	3.884
		0.070	2.175	-4.499	46.234	19.756	0.361	0.730	0.0	-17.175	2.730
		0.070	2.900	-14.320	46.234	29.577	0.441	0.730	-0.434	-9.917	1.576
		0.070	3.625	-18.879	46.234	34.136	0.474	0.730	-4.460	-2.659	0.423
		0.070	4.350	-18.176	46.234	33.433	0.469	0.730	-3.839	4.599	0.731
		0.070	5.075	-12.211	46.234	27.468	0.425	0.730	0.0	11.857	1.885
		0.070	5.800	-0.984	46.234	16.241	0.327	0.730	0.0	19.115	3.038
		0.070	6.525	15.506	46.234	30.763	0.450	0.730	1.481	26.373	4.192
		0.070	7.250	37.257	46.234	52.514	0.588	0.730	20.689	33.631	5.346
	MAX	0.070	3.891	-19.232	46.234	34.489	0.477	0.730	-4.771	-0.000	0.000

Table 2 Calculation of Section Force and Reinforcement (1/3)

σ = 1800 (kgf/cm^2) σ_{ca} = 85 (kgf/cm^2) k = 0.415 j = 0.862 c1 = 0.257

Element Number No.	Thickness T (m)	Cover TT (m)	Location (m)	Bending Moment M (tf·m)	Axial Force N (tf)	M + N * C MS (tf·m)	Required Effective Depth D (m)	Effective Depth T - TT (m)	Required Area of Tensil Reinforcement AS (cm^2)	Shearing Force S (tf)	Shear Stress TA (kgf/cm^2)
1	0.800	0.070	0.0	2.623	2.850	3.564	0.153	0.730	1.564	6.547	1.041
		0.070	0.520	6.116	2.850	7.056	0.216	0.730	4.648	6.923	1.100
		0.070	1.040	9.864	2.850	10.804	0.267	0.730	7.958	7.532	1.197
		0.070	1.560	13.989	2.850	14.929	0.314	0.730	11.601	8.373	1.331
		0.070	2.080	18.612	2.850	19.552	0.359	0.730	15.683	9.446	1.501
		0.070	2.600	23.853	2.850	24.793	0.404	0.730	20.311	10.751	1.709
2	0.800	0.070	0.0	23.853	2.850	24.793	0.404	0.730	20.311	10.751	1.709
		0.070	0.480	27.963	2.850	28.903	0.436	0.730	23.941	6.407	1.018
		0.070	0.960	30.035	2.850	30.976	0.452	0.730	25.771	2.261	0.359
		0.070	1.440	30.165	2.850	31.106	0.453	0.730	25.886	-1.687	0.268
		0.070	1.920	28.447	2.850	29.388	0.440	0.730	24.369	-5.438	0.864
		0.070	2.400	24.977	2.850	25.917	0.413	0.730	21.304	-8.990	1.429
	MAX	0.070	1.232	30.341	2.850	31.282	0.454	0.730	26.041	-0.000	0.000
3	0.800	0.070	0.0	24.977	2.850	25.917	0.413	0.730	21.304	-8.990	1.429
		0.070	0.320	22.350	2.850	23.290	0.392	0.730	18.984	-7.412	1.178
		0.070	0.640	20.242	2.850	21.183	0.373	0.730	17.123	-5.746	0.913
		0.070	0.960	18.682	2.850	19.623	0.359	0.730	15.745	-3.991	0.634
		0.070	1.280	17.697	2.850	18.638	0.350	0.730	14.876	-2.149	0.342
		0.070	1.600	17.316	2.850	18.257	0.347	0.730	14.539	-0.218	0.035
4	0.400	0.070	0.0	-2.623	-6.547	1.772	0.108	0.330	-7.100	2.850	1.002
		0.070	0.650	-1.041	-6.547	0.190	0.035	0.330	-4.009	2.018	0.710
		0.070	1.300	0.000	-6.547	0.0	0.0	0.330	3.637	1.186	0.417

Table 2 Calculation of Section Force and Reinforcement (2/3)

σ = 1800 (kgf/cm^2) σ_{ca} = 85 (kgf/cm^2) k = 0.415 j = 0.862 c1 = 0.257

Element Number No.	Thickness T (m)	Cover TT (m)	Location (m)	Bending Moment M (tf·m)	Axial Force N (tf)	M + N * C MS (tf·m)	Required Effective Depth D (m)	Effective Depth T - TT (m)	Required Area of Tensil Reinforcement AS (cm^2)	Shearing Force S (tf)	Shear Stress TA (kgf / cm^2)
5	0.400	0.070	0.0	-0.000	0.0	0.000	0.000	0.330	-0.000	2.137	0.751
		0.070	0.820	1.322	0.0	1.322	0.093	0.330	2.582	1.087	0.382
		0.070	1.640	1.783	0.0	1.783	0.108	0.330	3.484	0.038	0.013
		0.070	2.460	1.384	0.0	1.384	0.095	0.330	2.703	-1.012	0.356
		0.070	3.280	0.124	0.0	0.124	0.029	0.330	0.242	-2.061	0.725
		0.070	4.100	-1.997	0.0	1.997	0.115	0.330	-3.901	-3.111	1.094
	MAX	0.070	1.669	1.784	0.0	1.784	0.108	0.330	3.485	0.000	0.000
6	0.700	0.070	0.0	-1.997	3.111	2.868	0.137	0.630	-1.206	2.933	0.540
		0.070	0.660	-0.211	3.111	1.082	0.084	0.630	0.0	2.416	0.445
		0.070	1.320	1.110	3.111	1.981	0.114	0.630	0.299	1.525	0.281
		0.070	1.980	1.719	3.111	2.590	0.131	0.630	0.922	0.259	0.048
		0.070	2.640	1.370	3.111	2.241	0.121	0.630	0.565	-1.381	0.254
		0.070	3.300	-0.186	3.111	1.057	0.083	0.630	0.0	-3.395	0.625
		0.070	3.960	-3.193	3.111	4.065	0.164	0.630	-2.431	-5.783	1.065
		0.070	4.620	-7.901	3.111	8.772	0.240	0.630	-7.248	-8.545	1.574
		0.070	5.280	-14.555	3.111	15.427	0.319	0.630	-14.057	-11.682	2.152
		0.070	5.940	-23.403	3.111	24.275	0.400	0.630	-23.111	-15.193	2.798
		0.070	6.600	-34.692	3.111	35.563	0.484	0.630	-34.662	-19.078	3.514
	MAX	0.070	2.095	1.734	3.111	2.605	0.131	0.630	0.938	0.000	0.000

Table 2 Calculation of Section Force and Reinforcement (3/3)

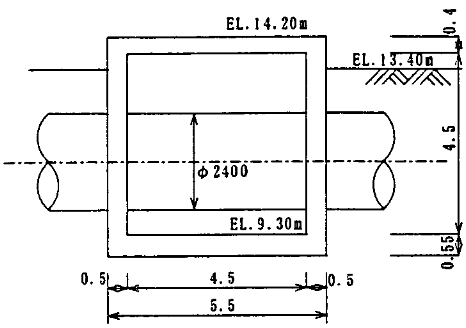
$\sigma = 1800$ (kgf/cm^2)　　$\sigma_{ca} = 85$ (kgf/cm^2)　　k = 0.415　　j = 0.862　　c1 = 0.257

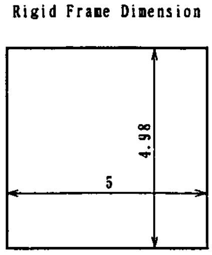
Element Number No.	Thickness T (m)	Cover TT (m)	Location (m)	Bending Moment M (tf·m)	Axial Force N (tf)	M + N * C MS (tf·m)	Required Effective Depth D (m)	Effective Depth T - TT (m)	Required Area of Tensil Reinforcement AS (cm^2)	Shearing Force S (tf)	Shear Stress TA (kgf/cm^2)
7	0.800	0.070	0.0	17.316	-0.218	17.244	0.337	0.730	15.349	-33.893	5.388
		0.070	0.725	-4.625	-0.218	4.553	0.173	0.730	-4.142	-26.635	4.234
		0.070	1.450	-21.305	-0.218	21.233	0.374	0.730	-18.872	-19.377	3.080
		0.070	2.175	-32.722	-0.218	32.650	0.464	0.730	-28.954	-12.119	1.926
		0.070	2.900	-38.877	-0.218	38.805	0.505	0.730	-34.390	-4.861	0.773
		0.070	3.625	-39.771	-0.218	39.699	0.511	0.730	-35.179	2.397	0.381
		0.070	4.350	-35.402	-0.218	35.330	0.482	0.730	-31.321	9.655	1.535
		0.070	5.075	-25.772	-0.218	25.699	0.411	0.730	-22.816	16.913	2.688
		0.070	5.800	-10.879	-0.218	10.807	0.267	0.730	-9.665	24.171	3.842
		0.070	6.525	9.276	-0.218	9.204	0.246	0.730	8.249	31.429	4.996
		0.070	7.250	34.693	-0.218	34.620	0.477	0.730	30.694	38.687	6.149
	MAX	0.070	3.386	-40.058	-0.218	39.986	0.513	0.730	-35.432	-0.000	0.000

APPENDIX C.4.7-5 Structural Calculation of Flow Meter Chamber

(1) Sectional Dimension for Calculation

Valve Chamber should be calculated by Gate Shaped Rigid Frame.



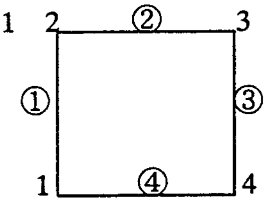


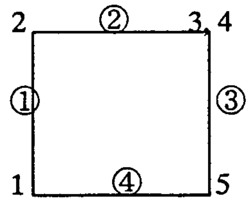
(2) Calculation of Load

(a) Case of Calculation

Case1 not consider opening top cover (fixed)

Case2 Consider opening top cover (hinge)





X-restrict; 4 Y-restrict; 1,4 X-restrict; 3,4,5 Y-restrict; 1,3,5

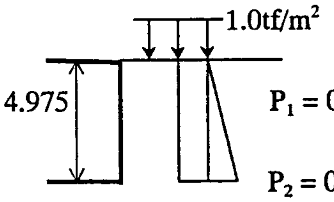
(b) Top Slab

w_1: Own Weight of Top Slab	$w_1 = 0.40 \times 2.45 = 0.980$
w_2 : Crowd Load of Top Slab	$w_2 = 0.30$
	$w = 1.280$ tf/m^2

(c) Side Earth Pressure (P_1)

Side earth pressure should be calculated by following equation; $P = K_a \times \gamma_t \times H$

Earth cover elevation should be considered as around road elevation,E.L.14.00(±).



$P_1 = 0.5 \times 1.0 = 0.5$ tf/m^2

$P_2 = 0.5 \times (1.0 + 1.8 \times 4.975) = 4.978$ tf/m^2

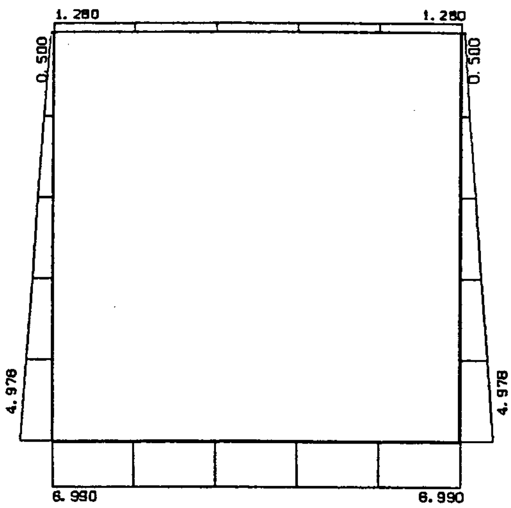
(d) Reaction Force of Bottom Slab (W_2)

	(tf)
Concrete Weight	279.0
Pipe Weight φ 2400	216.5
Crowd Load for Top Slab	26.4
+) Soil Weight	93.3
Total	615.2

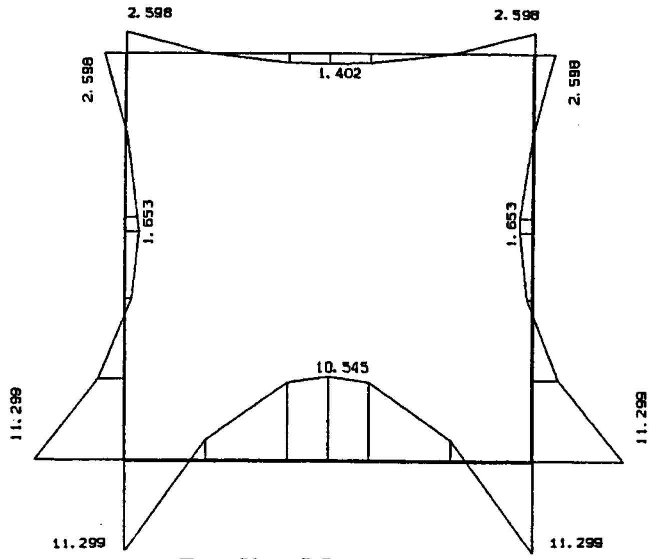
Reaction Force of Bottom Slab $w_2 = 615.2 / (5.5 \times 16.0) = 6.990$ tf/m^2

(3) Result of Analysis

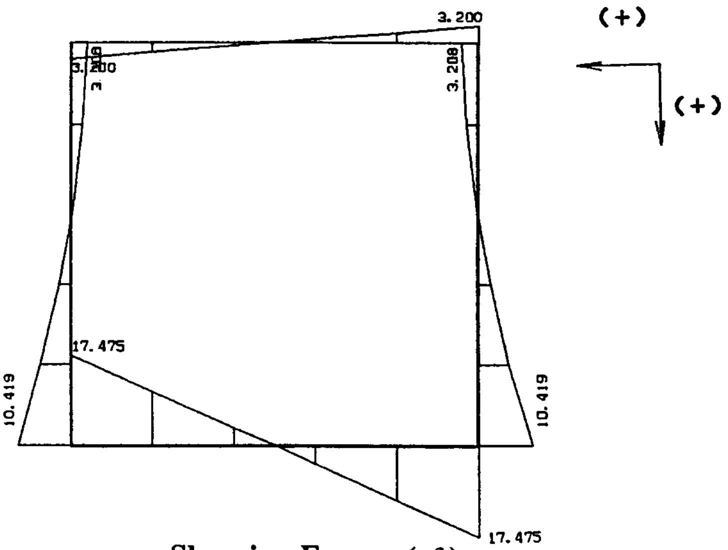
Load and sectional force are showed Figure1 and Figure 2,and results of analysis are showed Table 1and Table 2. And design of reinforcement is decided by using biggest required area of tension reinforcement.



Load Distribution (tf/m, tf/m^2)

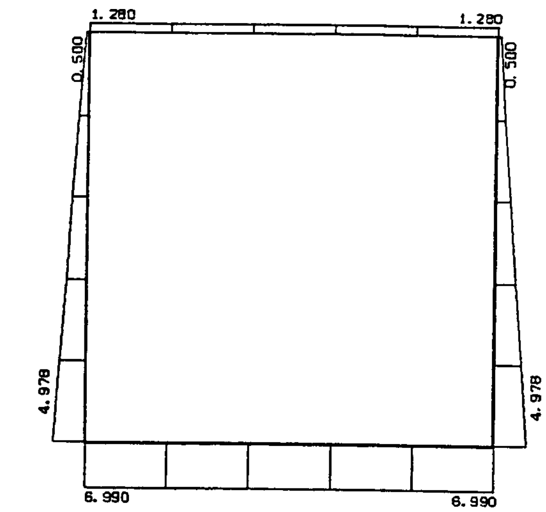


Bending Moment (tf · m)

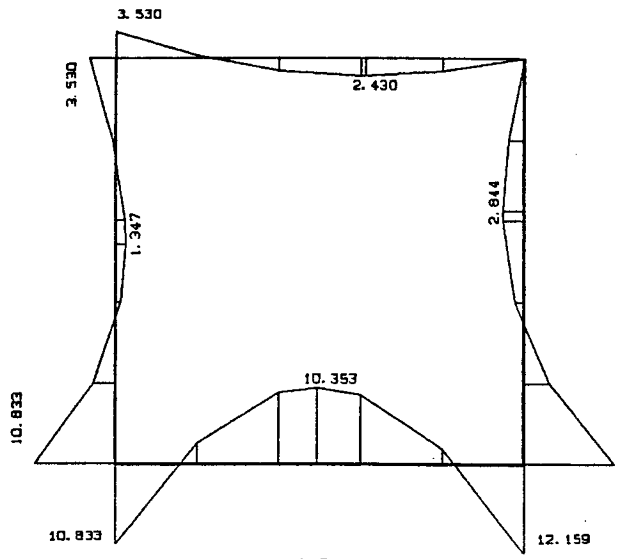


Shearing Force (tf)

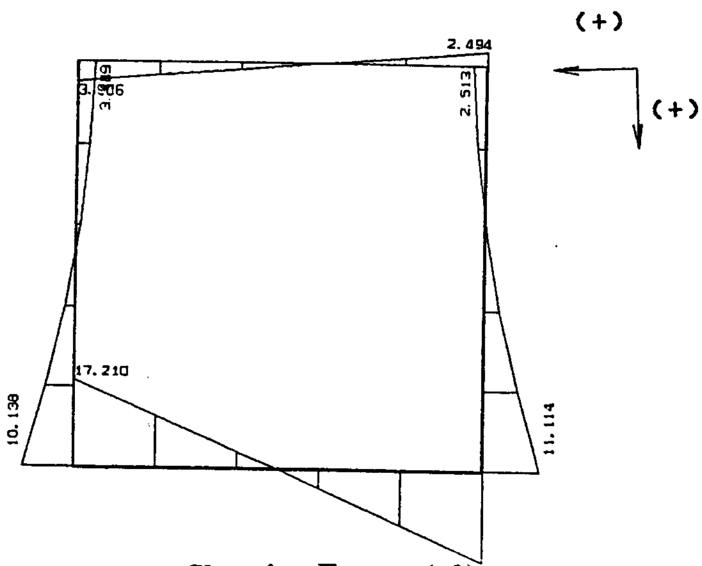
Figure 1 Load and Sectional Force of Case 1



Load Distribution (tf/m, tf/m²)



Bending Moment (tf · m)



Shearing Force (tf)

Figure 2 Load and Sectional Force of Case 2

Table 1 Calculation of Section Force and Reinforcement (1/2)

σ = 1800 (kgf/cm^2) σ_{ca} = 85 (kgf/cm^2) k = 0.415 j = 0.862 c1 = 0.257

Element Number No.	Thickness T (m)	Cover TT (m)	Location (m)	Bending Moment M (tf·m)	Axial Force N (tf)	M + N * C MS (tf·m)	Required Effective Depth D (m)	Effective Depth T - TT (m)	Required Area of Tensil Reinforcement AS (cm^2)	Shearing Force S (tf)	Shear Stress TA (kgf/cm^2)
1	0.500	0.070	0.0	2.598	3.200	3.174	0.145	0.430	2.981	-3.208	0.866
		0.070	0.995	-0.198	3.200	0.774	0.071	0.430	0.0	-2.265	0.611
		0.070	1.990	-1.613	3.200	2.189	0.120	0.430	-1.504	-0.431	0.116
		0.070	2.985	-0.760	3.200	1.336	0.094	0.430	-0.225	2.295	0.619
		0.070	3.980	3.249	3.200	3.825	0.159	0.430	3.956	5.911	1.595
		0.070	4.975	11.299	3.200	11.875	0.280	0.430	16.025	10.419	2.812
	MAX	0.070	2.172	-1.653	3.200	2.229	0.121	0.430	-1.563	-0.000	0.000
2	0.400	0.070	0.0	-2.598	3.208	3.015	0.141	0.330	-4.108	3.200	1.125
		0.070	1.000	-0.038	3.208	0.455	0.055	0.330	0.0	1.920	0.675
		0.070	2.000	1.242	3.208	1.659	0.105	0.330	1.458	0.640	0.225
		0.070	3.000	1.242	3.208	1.659	0.105	0.330	1.458	-0.640	0.225
		0.070	4.000	-0.038	3.208	0.455	0.055	0.330	0.0	-1.920	0.675
		0.070	5.000	-2.598	3.208	3.015	0.141	0.330	-4.108	-3.200	1.125
	MAX	0.070	2.500	1.402	3.208	1.819	0.109	0.330	1.771	0.000	0.000
3	0.500	0.070	0.0	-2.598	3.200	3.174	0.145	0.430	-2.981	3.208	0.866
		0.070	0.995	0.198	3.200	0.774	0.071	0.430	0.0	2.265	0.611
		0.070	1.990	1.613	3.200	2.189	0.120	0.430	1.504	0.431	0.116
		0.070	2.985	0.760	3.200	1.336	0.094	0.430	0.225	-2.295	0.619
		0.070	3.980	-3.249	3.200	3.825	0.159	0.430	-3.956	-5.911	1.595
		0.070	4.975	-11.299	3.200	11.875	0.280	0.430	-16.025	-10.419	2.812
	MAX	0.070	2.172	1.653	3.200	2.229	0.121	0.430	1.563	0.000	0.000

Table 1 Calculation of Section Force and Reinforcement (2/2)

σ = 1800 (kgf/cm^2) σ_{ca} = 85 (kgf/cm^2) k = 0.415 j = 0.862 c1 = 0.257

Element Number No.	Thickness T (m)	Cover TT (m)	Location (m)	Bending Moment M (tf・m)	Axial Force N (tf)	M + N * C MS (tf・m)	Required Effective Depth D (m)	Effective Depth T - TT (m)	Required Area of Tensil Reinforcement AS (cm^2)	Shearing Force S (tf)	Shear Stress TA (kgf / cm^2)
4	0.550	0.070	0.0	11.299	10.419	13.435	0.297	0.480	12.255	-17.475	4.224
		0.070	1.000	-2.681	10.419	4.817	0.178	0.480	-0.681	-10.485	2.535
		0.070	2.000	-9.671	10.419	11.807	0.279	0.480	-10.069	-3.495	0.845
		0.070	3.000	-9.671	10.419	11.807	0.279	0.480	-10.069	3.495	0.845
		0.070	4.000	-2.681	10.419	4.817	0.178	0.480	-0.681	10.485	2.535
		0.070	5.000	11.299	10.419	13.435	0.297	0.480	12.255	17.475	4.225
	MAX	0.070	2.500	-10.545	10.419	12.681	0.289	0.480	-11.243	-0.000	0.000

Table 2 Calculation of Section Force and Reinforcement (1/2)

σ = 1800 (kgf/cm²) σ_{ca} = 85 (kgf/cm²) k = 0.415 j = 0.862 c1 = 0.257

Element Number No.	Thickness T (m)	Cover TT (m)	Location (m)	Bending Moment M (tf·m)	Axial Force N (tf)	M + N * C MS (tf·m)	Required Effective Depth D (m)	Effective Depth T - TT (m)	Required Area of Tensil Reinforcement AS (cm²)	Shearing Force S (tf)	Shear Stress TA (kgf / cm²)
1	0.500	0.070	0.0	3.530	3.906	4.233	0.167	0.430	4.177	-3.489	0.941
		0.070	0.995	0.454	3.906	1.157	0.087	0.430	0.0	-2.546	0.687
		0.070	1.990	-1.240	3.906	1.943	0.113	0.430	-0.744	-0.712	0.192
		0.070	2.985	-0.666	3.906	1.370	0.095	0.430	0.0	2.014	0.543
		0.070	3.980	3.062	3.906	3.765	0.157	0.430	3.475	5.630	1.519
		0.070	4.975	10.833	3.906	11.536	0.276	0.430	15.125	10.138	2.736
	MAX	0.070	2.284	-1.347	3.906	2.050	0.116	0.430	-0.903	-0.000	0.000
2	0.400	0.070	0.0	-3.530	3.489	3.984	0.162	0.330	-5.844	3.906	1.373
		0.070	1.000	-0.264	3.489	0.718	0.069	0.330	0.0	2.626	0.923
		0.070	2.000	1.722	3.489	2.175	0.120	0.330	2.311	1.346	0.473
		0.070	3.000	2.428	3.489	2.881	0.138	0.330	3.691	0.066	0.023
		0.070	4.000	1.854	3.489	2.307	0.123	0.330	2.569	-1.214	0.427
		0.070	5.000	-0.000	3.489	0.454	0.055	0.330	0.0	-2.494	0.877
	MAX	0.070	3.052	2.430	3.489	2.883	0.138	0.330	3.694	0.000	0.000
3	0.500	0.070	0.0	-0.000	2.494	0.449	0.054	0.430	0.0	2.513	0.678
		0.070	0.995	2.105	2.494	2.554	0.130	0.430	2.443	1.570	0.424
		0.070	1.990	2.828	2.494	3.277	0.147	0.430	3.527	-0.264	0.071
		0.070	2.985	1.283	2.494	1.732	0.107	0.430	1.211	-2.990	0.807
		0.070	3.980	-3.417	2.494	3.866	0.160	0.430	-4.410	-6.606	1.783
		0.070	4.975	-12.159	2.494	12.608	0.288	0.430	-17.516	-11.114	2.999
	MAX	0.070	1.872	2.844	2.494	3.293	0.147	0.430	3.551	0.000	0.000

Table 2 Calculation of Section Force and Reinforcement (2/2)

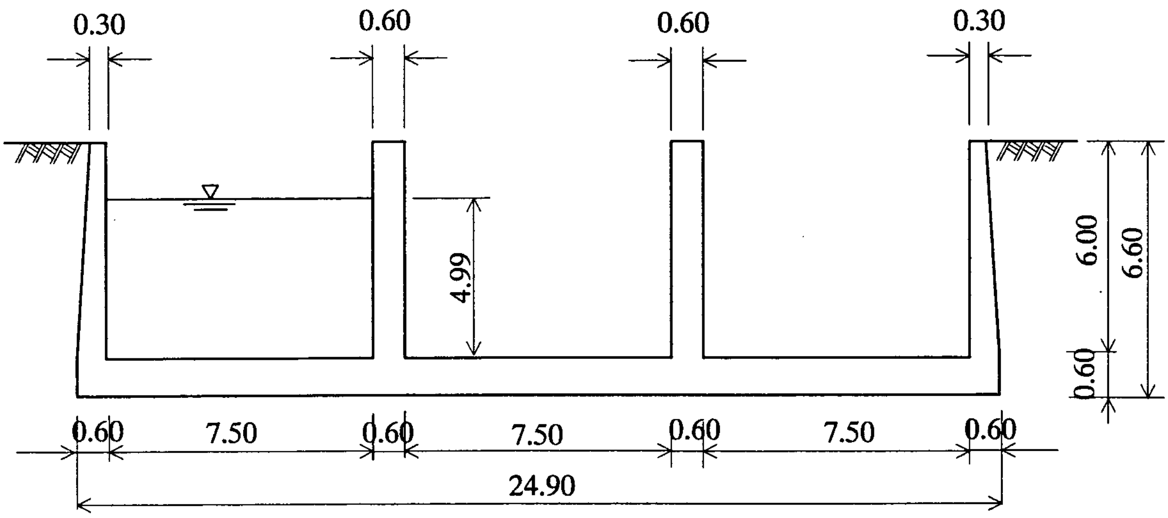
σ = 1800 (kgf/cm^2) σ_{ca} = 85 (kgf/cm^2) k = 0.415 j = 0.862 c1 = 0.257

Element Number No.	Thickness T (m)	Cover TT (m)	Location (m)	Bending Moment M (tf·m)	Axial Force N (tf)	M + N * C MS (tf·m)	Required Effective Depth D (m)	Effective Depth T - TT (m)	Required Area of Tensil Reinforcement AS (cm^2)	Shearing Force S (tf)	Shear Stress TA (kgf / cm^2)
4	0.550	0.070	0.0	10.833	10.138	12.911	0.292	0.480	11.708	-17.210	4.160
		0.070	1.000	-2.882	10.138	4.960	0.181	0.480	-1.029	-10.220	2.471
		0.070	2.000	-9.607	10.138	11.685	0.277	0.480	-10.061	-3.230	0.781
		0.070	3.000	-9.341	10.138	11.420	0.274	0.480	-9.705	3.760	0.909
		0.070	4.000	-2.086	10.138	4.165	0.166	0.480	0.0	10.750	2.599
		0.070	5.000	12.159	10.138	14.237	0.306	0.480	13.489	17.740	4.289
	MAX	0.070	2.462	-10.353	10.138	12.431	0.286	0.480	-11.063	-0.000	0.000

APPENDIX C.4.8-1 Structural Analysis for Discharge Tank

(1) Design Criteria

(a) Sectional Dimension for Analysis



Discharge Tank

(b) Case of analysis

Considering condition, next cases should be analyzed.

Case 1 ; Empty

Case 2 ; 1 Cells are filled by water (Depth=4.99m)

Case 3 ; 2 Cell is filled by water (Depth=4.99m)

(c) Active Load

Live Load ; Q = 2.00 tf/m^2

(d) Earth Pressure

Coefficient of Earth Pressure ; Ka=0.333

Earth Weight ; γ_t = 1.8 tf/m^3

(e) Calculation of Soil Reaction

Case 1 (Empty)

Item	Vertical Load (tf)
Weight of Top Slab & Wall	30.87

Bottom Slab Length = 24.3 (m) (Rigid Frame Dimension)

Soil Reaction = 1.270 (tf/m^2)

Case 2 (1cell filled by water)

Item	Vertical Load (tf)	χ (m)	Moment (tf•m)
Own Weight	67.47	12.15	819.80
Water Weight	37.43	4.05	151.57
Total	104.90		971.37

χ = (ΣM/ΣV) = 9.260 (m)

Bottom Slab Length = 24.3 (m) (Rigid Frame Dimension)

Eccentric Length e = 2.890 (m)

Soil Reaction Q_1 = 7.397 (tf/m^2)

Q_2 = 1.236 (tf/m^2)

Case 3 (2cells filled by water)

Item	Vertical Load (tf)	χ (m)	Moment (tf•m)
Own Weight	67.47	12.15	819.80
Water Weight (Left)	37.43	4.05	151.57
Water Weight (Center)	37.43	12.15	454.71
Total	142.33		1,426.08

χ = (ΣM/ΣV) = 10.020 (m)

Bottom Slab Length = 24.3 (m) (Rigid Frame Dimension)

Eccentric Length e = 2.130 (m)

Soil Reaction Q_1 = 8.937 (tf/m^2)

Q_2 = 2.777 (tf/m^2)

(f) Design of Reinforcement

Design of reinforcement is decided by using biggest required area of tension reinforcement.

(2) Result of Structural Analysis

Load and sectional force are showed Figure1~3, and results of analysis are showed Table1~3.

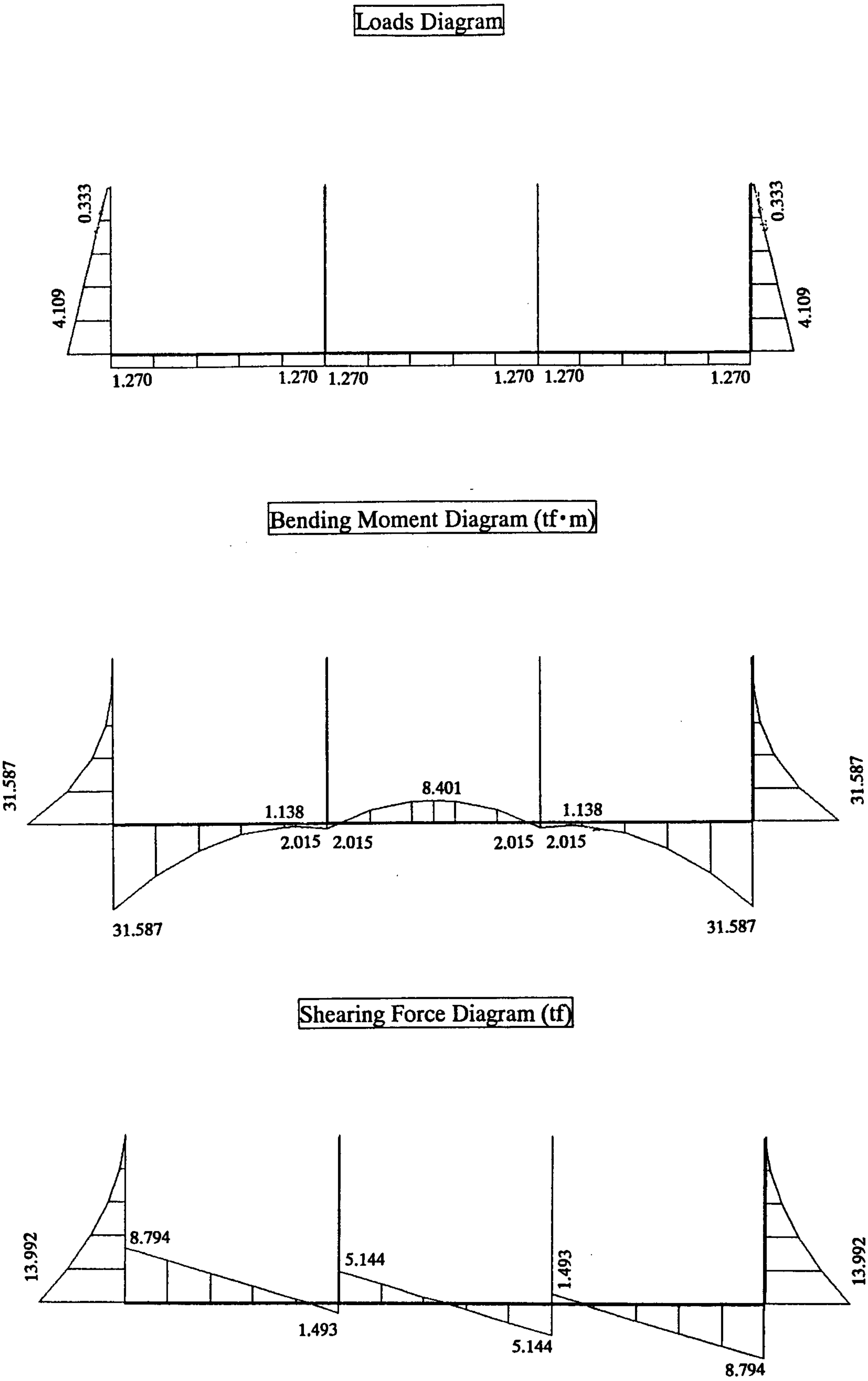
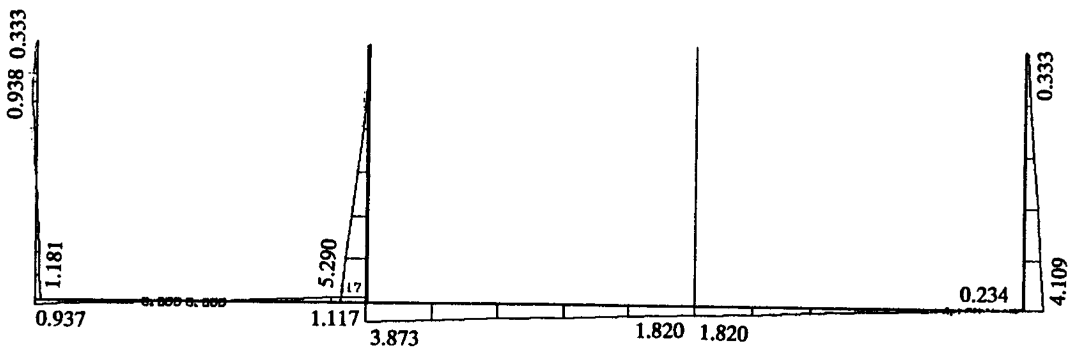
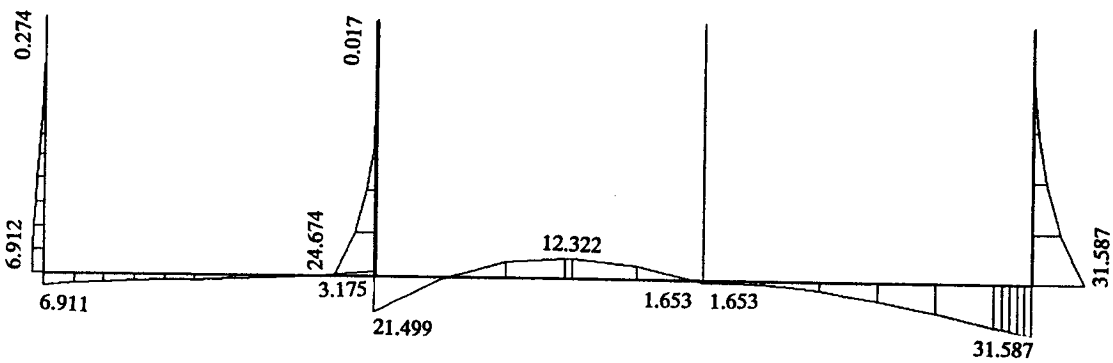


Figure 1 Load and Sectional Force of Case 1 (Empty)

Loads Diagram



Bending Moment Diagram (tf·m)



Shearing Force Diagram (tf)

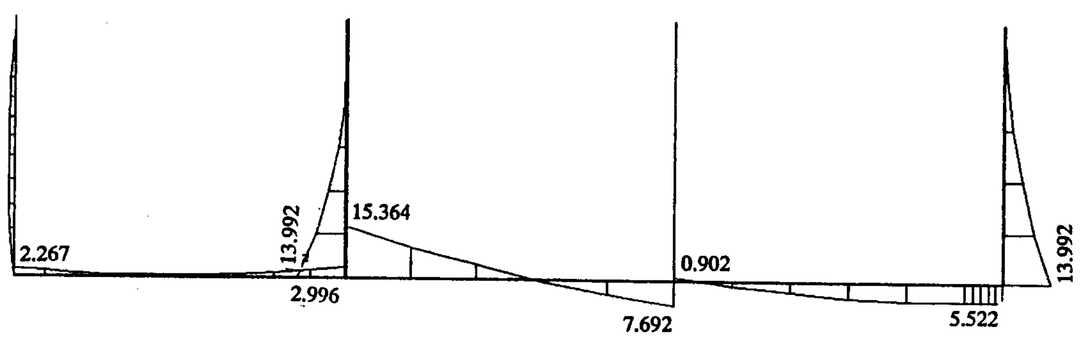
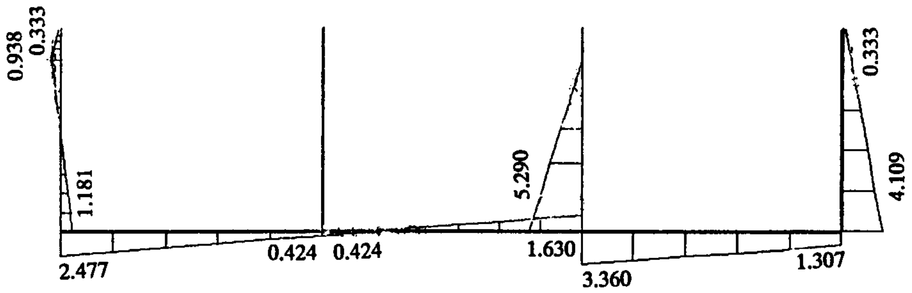
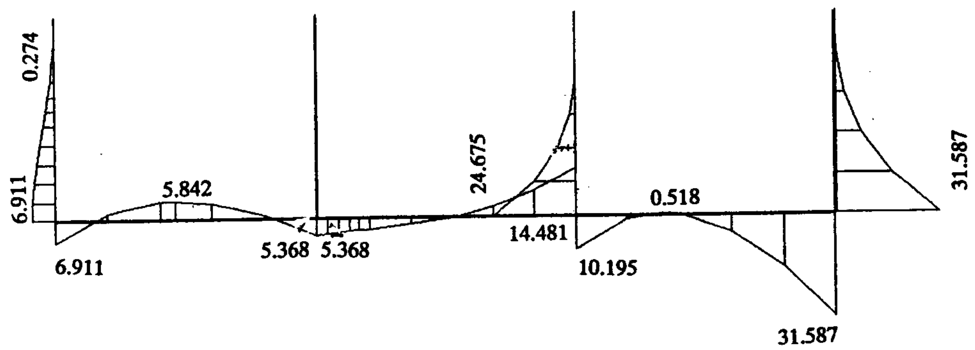


Figure 2 Load and Sectional Force of Case 2 (1 cell filled by water)

Loads Diagram



Bending Moment Diagram (tf•m)



Shearing Force Diagram (tf)

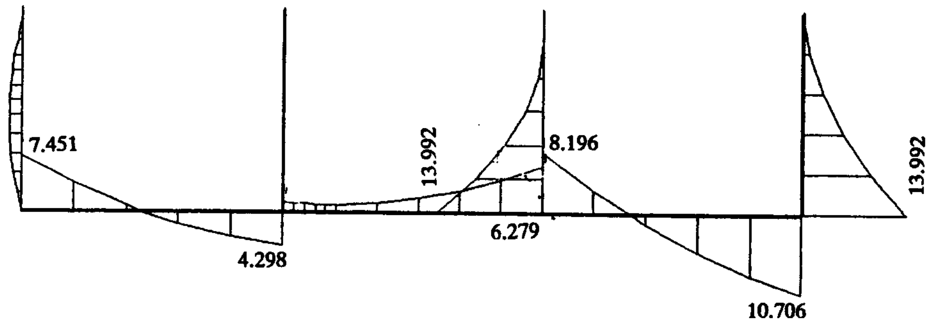


Figure 3 Load and Sectional Force of Case 3 (2 cell filled by water)

Table 1. Structural Analysis of Discharge Tank Case 1 (Empty)

Item		Bending Moment (tf·m)	Shearing Force (tf)	Axial Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)	Reinforcing Bar Schedule (cm^2)
Side Wall (Left)	Upper End	0.000	0.000	0.000	0.530	0.000	0.000	5-D16=10.05
	Lower End	**31.587**	**13.992**	**0.000**	**0.530**	**0.456**	**38.420**	**5-D19+5-D25=38.73**
Separate Wall (Left)	Upper End	0.000	0.000	0.000	0.530	0.000	0.000	5-D16=10.05
	Lower End	0.000	0.000	0.000	0.530	0.000	0.000	5-D16+5-D25=34.60
Separate Wall (Right)	Upper End	0.000	0.000	0.000	0.530	0.000	0.000	5-D16=10.05
	Lower End	0.000	0.000	0.000	0.530	0.000	0.000	5-D16+5-D25=34.60
Side Wall (Right)	Upper End	0.000	0.000	0.000	0.530	0.000	0.000	5-D16=10.05
	Lower End	**31.587**	**13.992**	**0.000**	**0.530**	**0.456**	**38.420**	**5-D19+5-D25=38.73**
Bottom Plate (Left)	Left End	**31.587**	**8.794**	**13.992**	**0.530**	**0.479**	**34.561**	**5-D19+5-D25=38.73**
	Center	1.138	0.000	13.992	0.530	0.169	0.000	5-D16+5-D19=24.23
	Right End	2.015	1.493	13.992	0.530	0.186	0.000	5-D16+5-D19=24.23
Bottom Plate (Center)	Left End	2.015	5.144	13.992	0.530	0.186	0.000	5-D16+5-D19=24.23
	Center	8.401	0.000	13.992	0.530	0.277	6.359	5-D19=14.18
	Right End	2.015	5.143	13.992	0.530	0.186	0.000	5-D16+5-D19=24.23
Bottom Plate (Right)	Left End	2.015	1.493	13.992	0.530	0.186	0.000	5-D16+5-D19=24.23
	Center	1.138	0.000	13.992	0.530	0.169	0.000	5-D16+5-D19=24.23
	Right End	**31.587**	**8.794**	**13.992**	**0.530**	**0.479**	**34.561**	**5-D19+5-D25=38.73**

Table 2. Structural Analysis of Discharge Tank Case 2 (1 Cell filled by water)

Item		Bending Moment (tf·m)	Shearing Force (tf)	Axial Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)	Reinforcing Bar Schedule (cm^2)
Side Wall (Left)	Upper End	0.005	0.009	0.000	0.530	0.005	0.000	5-D16=10.05
	Lower End	6.912	0.000	0.000	0.530	0.213	8.407	5-D19+5-D25=38.73
Separate Wall(Left)	Upper End	0.017	0.034	0.000	0.530	0.011	0.021	5-D16=10.05
	Lower End	**24.674**	**13.992**	**0.000**	**0.530**	**0.403**	**30.011**	**5-D16+5-D25=34.60**
Separate Wall (Right)	Upper End	0.001	0.000	0.000	0.530	0.003	0.002	5-D16=10.05
	Lower End	0.001	0.000	0.000	0.530	0.003	0.001	5-D16+5-D25=34.60
Side Wall (Right)	Upper End	0.000	0.000	0.000	0.530	0.000	0.000	5-D16=10.05
	Lower End	31.587	13.992	0.000	0.530	0.456	38.420	5-D19+5-D25=38.73
Bottom Plate (Left)	Left End	6.911	2.267	0.000	0.530	0.213	8.406	5-D19+5-D25=38.73
	Center	2.799	0.536	0.000	0.530	0.136	3.404	5-D16+5-D19=24.23
	Right End	3.175	2.996	0.000	0.530	0.145	3.862	5-D16+5-D19=24.23
Bottom Plate (Center)	Left End	**21.499**	**15.364**	**13.992**	**0.530**	**0.403**	**22.291**	**5-D16+5-D19=24.23**
	Center	**12.322**	**0.000**	**13.992**	**0.530**	**0.320**	**11.128**	**5-D19=14.18**
	Right End	1.653	7.692	13.992	0.530	0.179	0.000	5-D16+5-D19=24.23
Bottom Plate (Right)	Left End	1.653	0.902	13.992	0.530	0.179	0.000	5-D16+5-D19=24.23
	Center	9.842	4.338	13.992	0.530	0.293	8.112	5-D16+5-D19=24.23
	Right End	31.587	5.522	13.992	0.530	0.479	34.562	5-D19+5-D25=38.73

Table 3. Structural Analysis of Discharge Tank Case 3 2 Cells filled by water

Item		Bending Moment (tf·m)	Shearing Force (tf)	Axial Force (tf)	Effective Depth (m)	Required Effective Depth (m)	Required Area of Tension Reinforcement (cm^2)	Reinforcing Bar Schedule (cm^2)
Side Wall (Left)	Upper End	0.003	0.006	0.000	0.530	0.005	0.004	5-D16=10.05
	Lower End	6.911	0.000	0.000	0.530	0.213	8.406	5-D19+5-D25=38.73
Separate Wall (Left)	Upper End	0.000	0.000	0.000	0.530	0.001	0.000	5-D16=10.05
	Lower End	0.000	0.000	0.000	0.530	0.001	0.000	5-D16+5-D25=34.60
Separate Wall (Right)	Upper End	0.002	0.004	0.000	0.530	0.004	0.003	5-D16=10.05
	Lower End	**24.675**	**13.992**	**0.000**	**0.530**	**0.403**	**30.013**	**5-D16+5-D25=34.60**
Side Wall (Right)	Upper End	0.000	0.000	0.000	0.530	0.001	0.000	5-D16=10.05
	Lower End	31.587	13.992	0.000	0.530	0.456	38.420	5-D19+5-D25=38.73
Bottom Plate (Left)	Left End	6.911	7.451	0.001	0.530	0.213	8.406	5-D19+5-D25=38.73
	Center	**5.842**	**0.000**	**0.001**	**0.530**	**0.196**	**7.106**	**5-D16+5-D19=24.23**
	Right End	**5.368**	**4.298**	**0.001**	**0.530**	**0.188**	**6.529**	**5-D16+5-D19=24.23**
Bottom Plate (Center)	Left End	5.368	1.395	0.001	0.530	0.188	6.529	5-D16+5-D19=24.23
	Center	0.786	1.622	0.001	0.530	0.072	0.957	5-D19=14.18
	Right End	**14.480**	**6.279**	**0.001**	**0.530**	**0.309**	**17.613**	**5-D16+5-D19=24.23**
Bottom Plate (Right)	Left End	**10.195**	**8.196**	**13.992**	**0.530**	**0.297**	**8.542**	**5-D16+5-D19=24.23**
	Center	0.517	0.000	13.992	0.530	0.157	0.000	5-D16+5-D19=24.23
	Right End	31.587	10.706	13.992	0.530	0.479	34.561	5-D19+5-D25=38.73

APPENDIX C.4.9-1 Structural Calculation of Pump Huose

(1) FRAME MODEL

(a) JOINT NUMBER

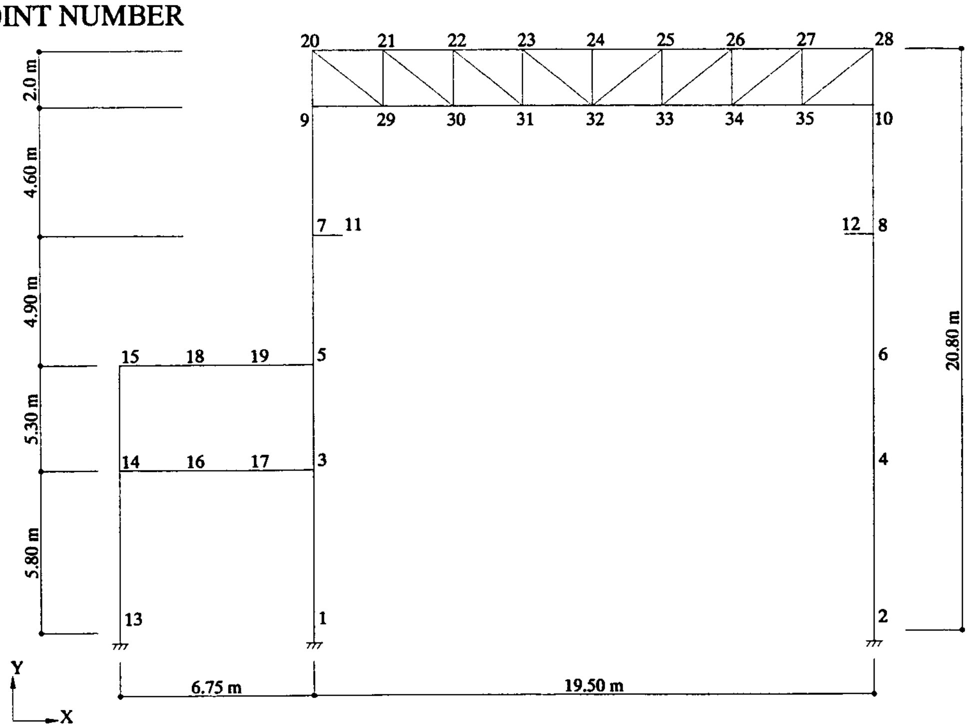


Figure 1

(b) MEMBER NUMBER

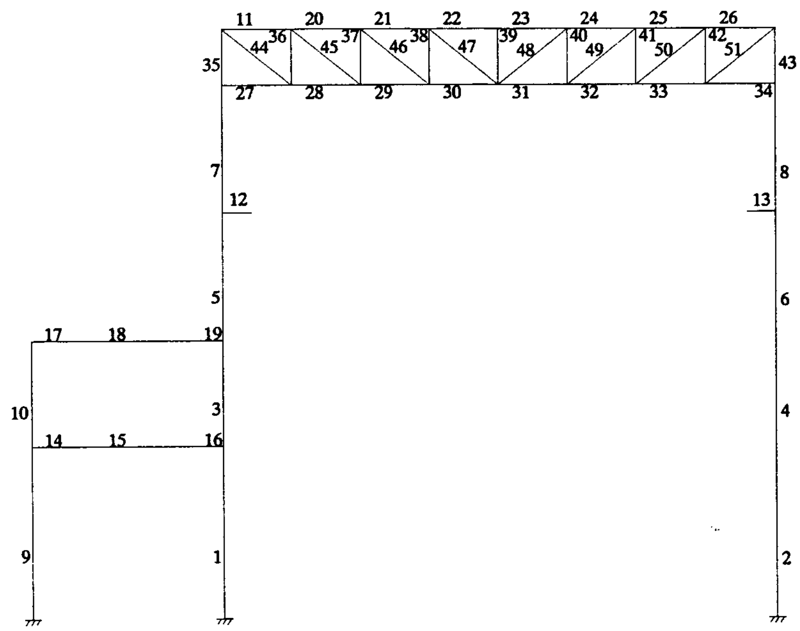


Figure 2

(2) **LOADING DIAGRAM**

(a) LOADING 1
DEAD LOAD (D.L)

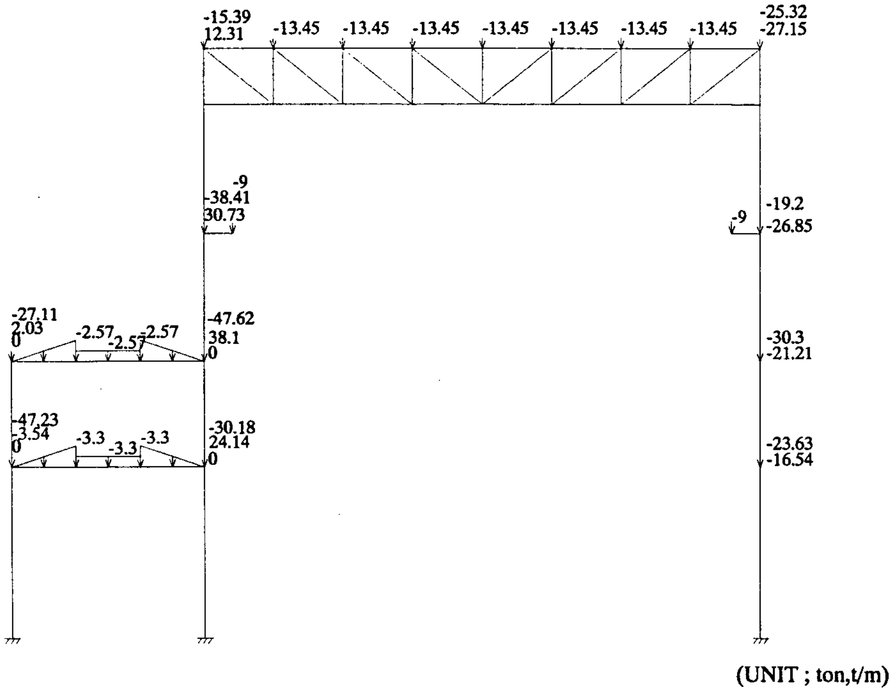


Figure 3

(b) LOADING 2
LIVE LOAD (L.L)

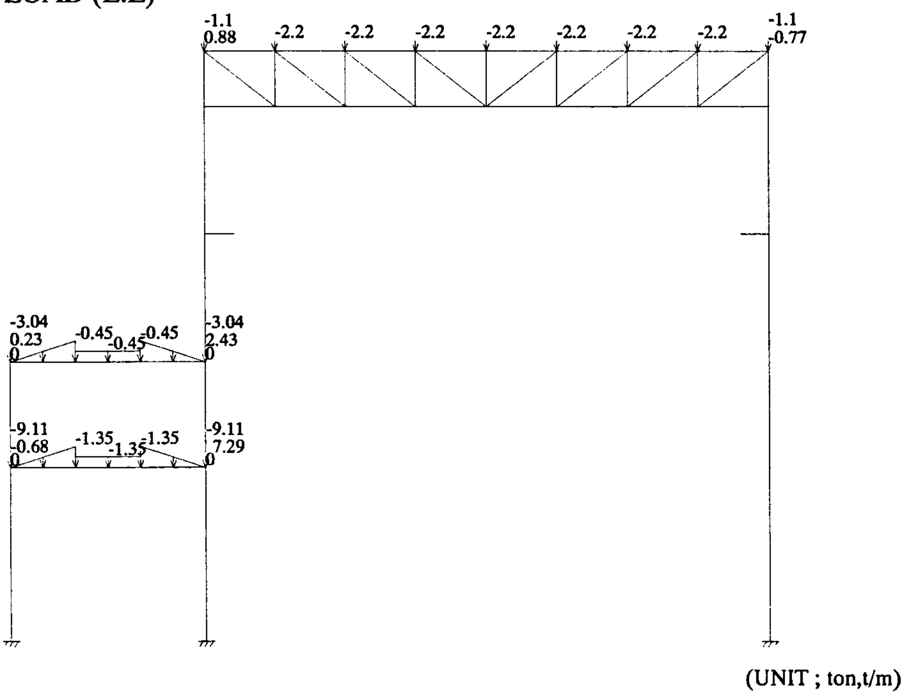


Figure 4

(c) LOADING 3
CRANE LOAD (C.L)

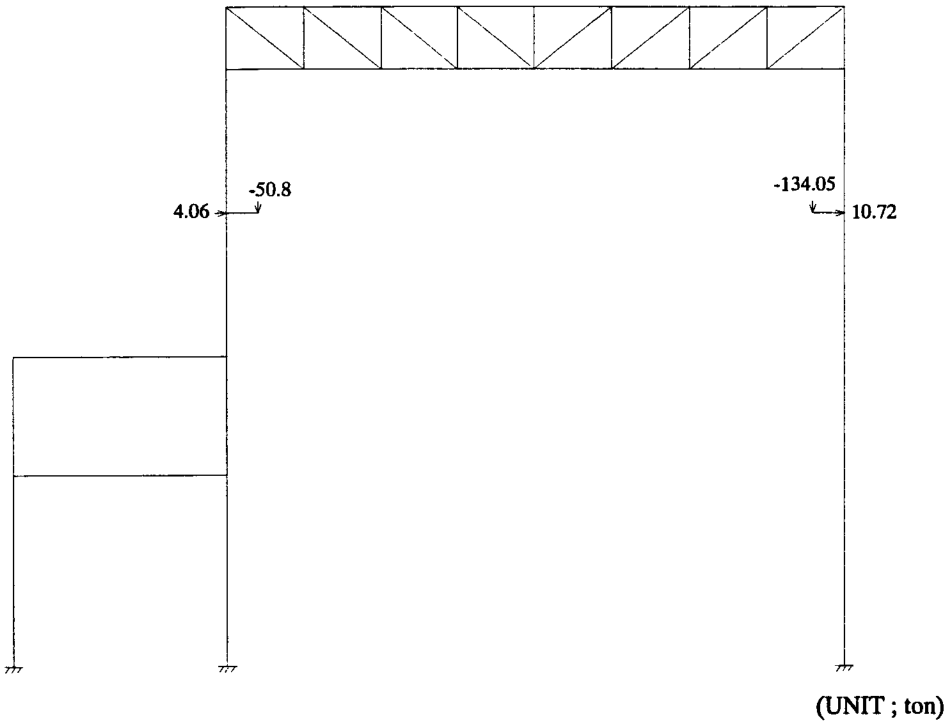


Figure 5

(3) RESULTS OF ANALYSIS

(a) BENDING MOMENT MZ

LOAD CASE
1.4D.L + 1.6 l.L + 1.6C.L

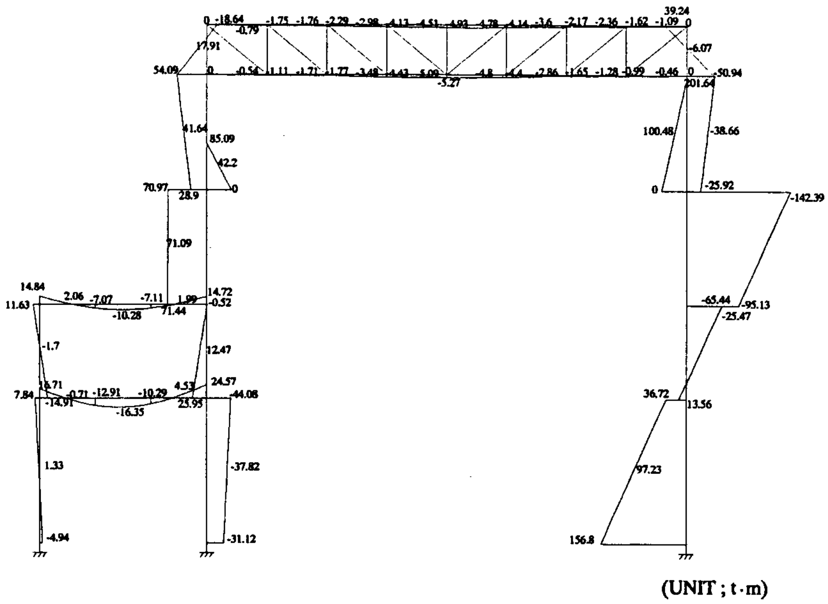


Figure 6

(b) SHARE FORCE

LOAD CASE
1.4D.L + 1.6L.L + 1.6C.L

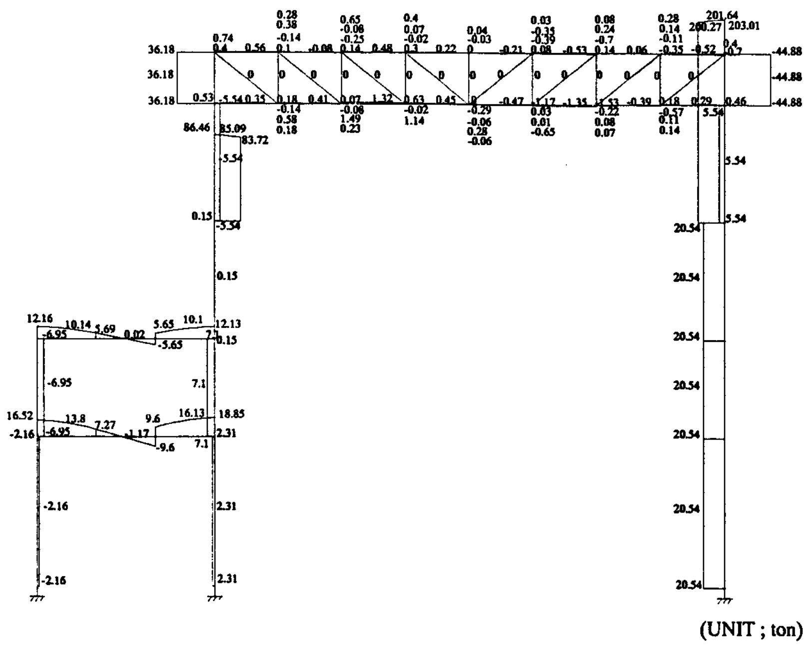


Figure 7

APPENDIX C 4.10-1 Structural Calculation of Stop Logs for Pumping Station

(1) Design data

Elevation of max. water surface	EL. 11.94 m
Elevation of the gate sill	EL. 4.40 m
Design head	7.54 m
Clear span of the water canal	5.50 m
Total height of the stop log	7.75 m
Number of the stop log leaf	5 sets
Height of the stop log leaf	1.55 m

(2) Calculation

(a) Hydrostatic load calculation

Water pressure at intended point can be calculated using the following equation :

$P_i = W_o \bullet H_i$

Where:

P_i: Water pressure at intended point (t/m^2)

W_o: Specific weight of water 1.0 ($t/m^{3)}$

H_i: tended water depth from the highest water level (m)

(b) Strength of skin plate

Max. bending stress of the skin plate can be calculated from the equation :

$\sigma = 1/100 \bullet K \bullet a^2 \bullet P / t_s{}^2$

Where:

σ: Max. bending stress of the skin plate (kgf/cm^2)

K: Coefficient of b / a (refer to Table 1)

a: Short side length of the skin plate (cm)

b: Long side length of the skin plate (cm)

P_U: Upper side water pressure at intended point (t/m^2)

P_L: Lower side water pressure at intended point (t/m^2)

P: Mean water pressure =$(P_U + P_L) / 20$ (kgf/cm^2)

t_s: Effective thickness of the skin plate = t – 2C (cm)

t: thickness of the skin plate (cm)

C: corrosion allowance 0.05 (cm)

Table 1 K values

b/a	1.00	1.25	1.50	1.75	2.00	2.50	3.0	∞
K	30.9	40.3	45.5	48.4	49.9	50.0	50.0	50.0

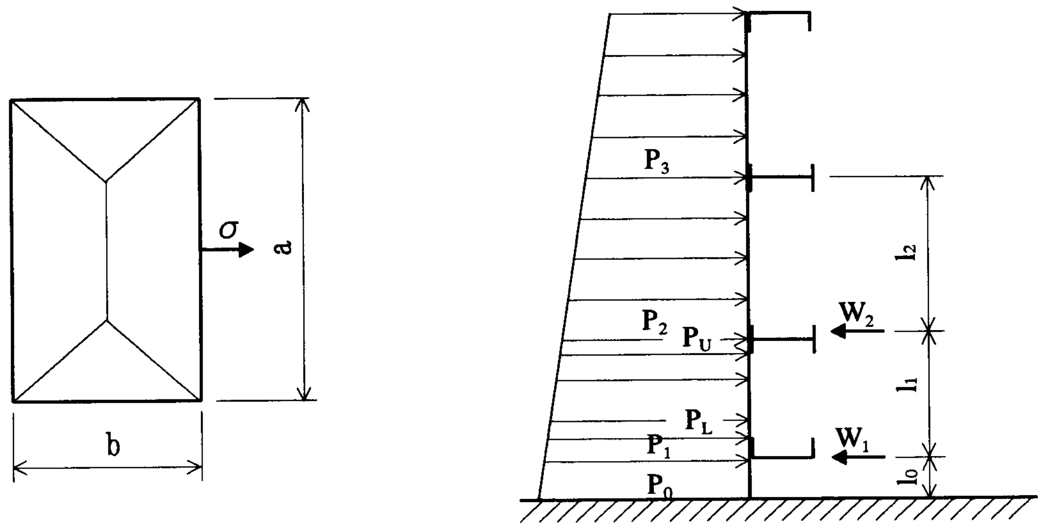


Figure 1　Loading condition of the stop log

(c) Strength of the main beam

Max. stress of the main beam can be calculated using the following equations :

Bending moment

$M = W/8 \bullet B$

Where:

M: Bending moment acting on the main beam (kgf-cm)

W: Water load (kgf)

B: Span of the supports which bears water load (cm)

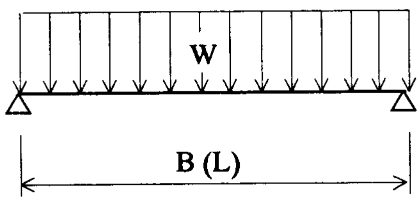


Figure 2　Loading condition of the beam

Sectional property of beam

$I_x = 1/12 \cdot (B_f \cdot H_b{}^3 - B_w \cdot H_w{}^3)$

Where

I_x Moment of inertia of the gate beam (cm^4)

H_b Height of the beam (cm)

H_w Height of the web deduct 2 t_f (cm)

B_f Width of the flange (cm)

B_w Width of the flange deduct t_w (cm)

t_f Thickness of the flange (cm)

t_w Thickness of the web (cm)

$Z_x = 2 I / H_b$

Where:

Z_x: Section modulus of the gate beam (cm^3)

A_{web} = Hw tw

Where:

A_{web} :Sectional area of the beam web at the support (cm^2)

Bending stress

$\sigma = M / Z$ (kgf/cm^2)

Shear force

F = W / 2 (kgf)

Shear stress

$\tau = F / A_{web}$ (kgf / cm^2)

Deflection

Deflection at center of the beam can be calculated by using equation:

$\delta = 5 / 384 \bullet l^3 W / E I$ (cm)

Where :

E: Young's modulus of material of the gate beam 2.1×10^6 (kgf/cm^2)

Allowable stress

$\sigma_{al} = 0.5 \ \sigma_y$ (kgf/cm^2)

$\tau_{al} = 0.3 \ \sigma_y$ (kgf/cm^2)

Where:

σ_y: Yield strength of material of SS400 (JIS) = 2,400 (kgf/cm^2)

Allowable deflection

$\delta_{max} / B < 1 / 800$

(3) Examination

(a) Strength of the skin plate

$P_U = 7.135$	(t/m^2)
$P_L = 7.360$	(t/m^2)
$P = (7.135 + 7.360) / 2\,0 = 0.725$	(kgf/cm^2)
$a = 22.5$	(cm)
$b = 67$	(cm)
$K = 50$	
$t_s = 0.8$	(cm)

$\sigma = 0.01 \times 50 \times 22.5^2 \times 0.725 / 0.8^2 = 287 < 1,200$ (kgf/cm^2)

(b) Strength of the main beam

1) Strength of the main beam 1 (lowest beam)

$P_0 = 7.54$	(t/m^2)
$P_1 = 7.46$	(t/m^2)
$P_2 = 7.09$	(t/m^2)
$l_0 = 8$	(cm)
$l_1 = 37$	(cm)
$B = 550$	(cm)

$W_1 = [\{(P_2+2P_1) /60 \}\, l_1 + \{(P_1+P_0) / 20\}\, l_0]\, B$
$= [\{(7.09+2 \times 7.46) / 60 \} \times 37 + \{ (7.46 +7.54) /20 \} \times 8] \times 550$
$= 10,765$ (kgf)

$M_1 = 10,765 \times 550 / 8 = 740,094$ (kgf-cm)

$I_1 = 1 / 12 \times (9.9 \times 37.95^3 - 8.7 \times 34.1^3) = 16,343$ (cm^4) for [380 x 100 x 13/ 20)
$Z_i = 2 \times 16,343 / 37.95 = 861$ (cm^3)
$\sigma_1 = 740 \times 10^3 / 861 = 859 < 1,200$ (kgf/cm^2)

$F_1 = 10,765/ 2 = 5,383$ (kgf)
$A_{1\,web} = 26.1 \times 1.2 = 31.3$ (cm^2) for [300 x 100 x 13/20
$\tau_1 = 5,383 / 31.3 = 172 < 720$ (kgf/cm^2)

$\delta_{1\,max} = 5 / 384 \times \{(550^3 \times 10,765) / (2.1 \times 10^6 \times 16,343)\} = 0.68$ (cm)

$\delta_{1\,max} / B = 0.68 / 550 = 1 / 809 < 1 / 800$

2) Strength of the main beam 2 (next to lowest beam)

P_3 = 6.52 (t/m^2)

l_2 = 57 (cm)

$W_2 = [\{ (P_3+2P_2)\, l_2 + (2P_2+P_1)\, l_1\} / 60]\, B$

$= [\{ (6.52+2 \times 7.09) \times 57 + (2 \times 7.09 + 7.46) \times 37\} / 60] \times 550$

$= 18{,}155$ (kgf)

$M_2 = 18{,}155 \times 550 / 8 = 1{,}248 \times 10^3$ (kgf-cm)

$I_2 = 1 / 12 \times (14.9 \times 39.95^3 - 13.75 \times 35.1^3) = 29{,}619$ (cm^4) for I 400 x 150 x 12.5/ 25

$Z_2 = 2 \times 29{,}619 / 39.95 = 1{,}483$ (cm^3)

$\sigma_2 = 1{,}248 \times 10^3 / 1{,}483 = 842 < 1{,}200$ (kgf/cm^2)

$F_2 = 18{,}155 / 2 = 9{,}078$ (kgf)

$A_{2\,web} = 25.1 \times 1.15 = 28.9$ (cm^2) for I 300 x 150 x 12.5 / 25

$\tau_2 = 9{,}078 / 28.9 = 314 < 720$ (kgf/cm^2)

$\delta_{2\,max} = 5 / 384 \times \{(550^3 \times 18{,}155) / (2.1 \times 10^6 \times 29{,}619)\} = 0.63$ (cm)

$\delta_{2\,max} / B = 0.63 / 550 = 1 / 873 < 1 / 800$

APPENDIX C 4.10-2 Structural Calculation of Stop Log for Spillway

(1) Design data

Design head	3.35 m
Clear span of the water canal	4.00 m
Total height of the stop log	3.60 m
Number of the stop log leaf	3 sets
Height of the stop log leaf	1.20 m

(2) Examination

(a) Strength of the skin plate

P_U = 2.24 (t/m^2)
P_L = 3.18 (t/m^2)
P = (2.24+ 3.18) / 2 0 = 0.271 (kgf/cm^2)
a = 80 (cm)
b = 94 (cm)
K = 38.4
t_s = 0.8 (cm)
σ = 0.01 x 38.4 x 80^2 x 0.271 / 0.8 ^{2} = 1,041 < 1,200 (kgf/cm^2)

(b) Strength of the main beam

1) Strength of Main beam 1 (lowest beam)

P_0 = 3.35 (t/m^2)
P_1 = 3.27 (t/m^2)
P_2 = 2.15 (t/m^2)
l_0 = 8 (cm)
l_1 = 112 (cm)
B = 400 (cm)
W_1 = [{ (P_2+2P_1) /60}l_1+ { (P_1+P_0) / 20} l_0] B
= [{(2.15+2x3.27) /60 } x 112 + { (3.27+3.35) /20 }x 8] x 400
=7,548 (kgf)
M_1 = 7,548 x 400 / 8 = 377.4 x 10^3 (kgf-cm)
I_1 = 1 / 12 x (8.9 x 29.95 ^{3} –8.0 x 27.0 ^{3}) = 6,803 (cm^4) for [300 x 90 x 10 / 15.5
Z_1 = 2 x 6,803 / 29.95 = 454 (cm^3)
σ_1 = 377.4x 10^3 / 454 = 831 < 1,200 (kgf/cm^2)
F_1 = 7,548 / 2 = 3,774 (kgf)
$A_{1\ web}$ = 27.0 x 0.9 = 24.3 (cm^2)
τ_1 =3,774 / 24.3 =155 < 720 (kgf/cm^2)
I_1 = 6,803 (cm^4)
$\delta_{1\ max}$ = 5 / 384 x {(400^3 x 7,548) / (2.1 x 10 ^{6} x 6 ,803)} = 0.44 (cm)
$\delta_{1\ max}$ / B = 0.44/ 400= 1 / 909 < 1 / 800

2) Strength of the main beam 2

$W_2 = \{ (2P_2+P_1) / 60\} \, l_1 \;\; B$
$= \{ (2x2.15+ 3.27) / 60 \} \times 112 \times 400$
$= 5,652$ (kgf)

$M_2 = (5,652 \times 400) / 8 = 282,600$ (kgf-cm)

$I_2 = 1 / 12 \times (8.9 \times 29.95^3 - 8.0 \times 27.0^3) = 6,803$ (cm^4) for [300 x 90 x 10 / 15.5

$Z_2 = 2 \times 6,803 / 29.95 = 454$ (cm^3)

$\sigma_2 = 282,600/ 454 = 622 < 1,200$ (kgf/cm^2)

$F_2 = 5,652 / 2 = 2,826$ (kgf)

$A_{2\,web} = 27.0 \times 0.9 = 24.3$ (cm^2)

$\tau_2 = 2,826 / 24.3 = 116 < 720$ (kgf/cm^2)

$\delta_{2\,max} = 5 / 384 \times \{(400^3 \times 5,652) / (2.1 \times 10^6 \times 6,803)\} = 0.33$ (cm)

$\delta_{2\,max} / B = 0.33 / 400 = 1 / 1,212 < 1 / 800$

APPENDIX C 4.10-3 Structural Calculation of Stop Log for Box Culvert

(1) Design data

Design head	3.35 m
Clear span of the water canal	3.70 m
Total height of the stop log	3.60 m
Number of the stop log	3 sets
Height of the stop log leaf	1.20 m

(2) Examination

(a) Strength of the skin plate

P_U = 2.24 (t/m^2)

P_L = 3.18 (t/m^2)

P = (2.24+ 3.18) / 2 = 2.71 (t/m^2)

a = 72 (cm)

b = 94 (cm)

K = 41.9 (cm)

σ = 0.01 x 41.9 x 72.0^2 x 0.271 / 0.8^2 = 920 < 1,200 (kgf/cm^2)

(b) Strength of the main beam

1) Strength of the main beam 1 (lowest beam)

P_0 = 3.35 (t/m^2)

P_1 = 3.27 (t/m^2)

P_2 = 2.15 (t/m^2)

l_0 = 8 (cm)

l_1 = 112 (cm)

B = 370 (cm)

$W_1 = [\{(P_2+2P_1)/60\}\ l_1 + \{(P_1+P_0)/20\}\ l_0]\ B$

= [{(2.15+2x3.27) /60 } x 112 + { (3.27+3.35) /20 }x8] x 370

= 6,982 (kgf)

M_1 = 6,982 x 370 / 8 =322,918 (kgf-cm)

I_1 = 1 / 12 x (8.9 x 29.95^3 – 8.1 x 27.5^3) = 5,887 (cm^4) for [300 x 90 x 9 / 13

Z_1 = 2 x 5,887 / 29.95 = 393 (cm^3)

σ_1 = 322,918 / 393= 822 < 1,200 (kgf/cm^2)

F_1 = 6,982 / 2 = 3,491 (kgf)

$A_{1\,web}$ = 27.5 x 0.8 = 22.0 (cm^2)

τ_1 = 3,491 / 22.0 = 159 < 720 (kgf/cm^2)

I_1 = 5,887 (cm^4)

$\delta_{1\,max}$ = 5 / 384 x (370^3 x 6,982) / (2.1 x 10^6 x 5,887) = 0.37 (cm)

$\delta_{1\,max}$ / B = 0.37 / 370 = 1 / 1,000 < 1 / 800

2) Strength of the main beam 2

W_2 = { (P_2+2P_1) / 60 } l_1 B
= { (2.15+2 x3.27) / 60 } x 112 x 370
= 6,002 (kgf)
M_2 = 6,002 x 370 / 8 = 277,593 (kgf-cm)

I_2 = 1 / 12 x (8.9 x 29.95 ^{3} –8.1 x 27.5 ^{3}) = 5,887 (cm^4) for [300 x 90 x 9 / 13
Z_2 = 2 x 5,887 / 29.95 = 393 (cm^3)
σ_2 = 277,593 / 393 = 706 < 1200 (kgf/cm^2)

F_2 = 6,002 / 2 = 3,001 (kgf)
$A_{2\,web}$ = 27.5 x 0.8 = 22.0 (cm^2)
τ_2 =3,001 / 22.0 = 136 < 720 (kgf/cm^2)
$\delta_{2\,max}$ = 5 / 384 x (370^3 x 6,002) / (2.1 x 10 ^{6} x 5,887) = 0.32 (cm)
$\delta_{2\,max}$ / B = 0.32 / 370 = 1 / 1,156 < 1 / 800

APPENDIX C 4.10-4 Structural Calculation of Bulkhead Gate for Pumping Station

(1) Design data

Elevation of max. water surface	EL.11.94 m
Elevation of the gate sill	EL.4.40 m
Design head	7.40 m
Clear span of the water canal	5.50 m
Distance of the rubber seals	5.71 m
Distance of the main roller	5.91 m
Total height of the bulkhead gate	7.75 m
Height of the bulkhead gate leaf	1.55 m

(2) Calculation

(a) Hydrostatic load calculation

Water pressure at any point can be calculated using the equation ;

$P_i = W_o \bullet H_i$

Where:

P	= Water pressure at intended point	(t/m^2)
W_o	= Specific weight of water 1.0	($tons/m^3$)
H_i	= Intended water depth from the highest water level	(m)

(b) Strength of skin plate

Max. bending stress of the skin plate can be calculated by the equation :

$\sigma = 1/100 \bullet K \bullet a^2 \bullet P / t_s^{\ 2}$

Where:

σ	= Max. bending stress of the skin plate	(kgf/cm^2)
K	= Coefficient of b / a (refer to Table 1)	
a	= Short side length of the skin plate	(cm)
b	= Long side length of the skin plate	(cm)
P_U	= Upper side water pressure at intended point	(t/m^2)
P_L	=Lower side water pressure at intended point	(t/m^2)
P	= Mean water pressure =($P_U + P_L$) / 20	(kgf/cm^2)
t_s	= Effective thickness of the skin plate = t – 2C	(cm)
t	= thickness of the skin plate	(cm)
C	= corrosion allowance 0.05	(cm)

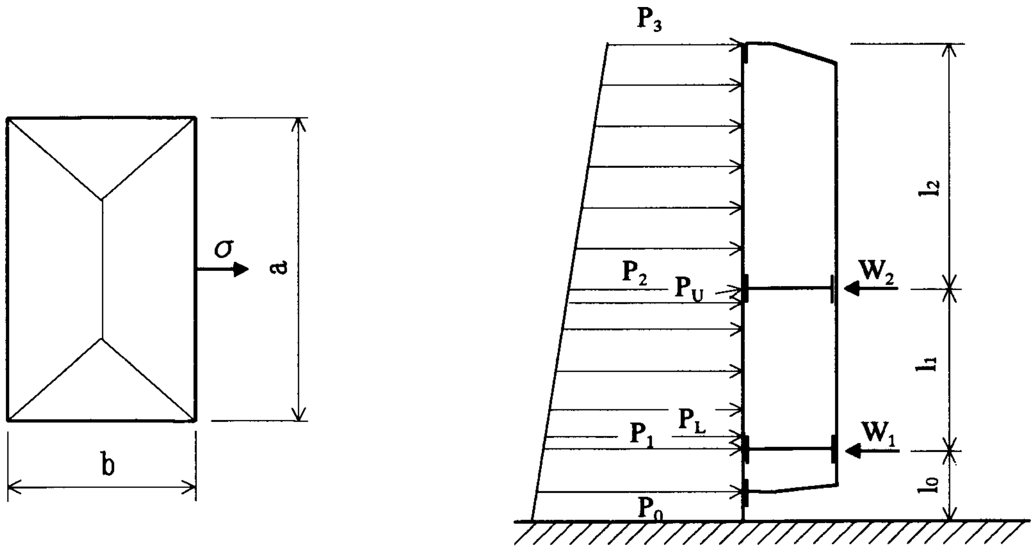


Figure 1　Loading condition of the gate

(c) Strength of the main beam

Max. stress of the main beam can be calculated using the following equation :

$M = W / 8 \bullet (2L - B_s)$

Where:

M:	Bending moment acting on the main beam	(kgf-cm)
W:	Hydraulic load	(kgf)
L:	Span of main roller	(cm)
B_s:	Span of supports bearing hydraulic load(cm)	

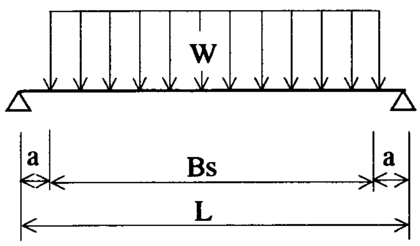


Figure 2　Loading condition of the beam

Sectional property of beam

$I_x = 1/12 \cdot (B_f \cdot H_b^3 - B_w \cdot H_w^3)$

Where:

I_x:	Moment of inertia of the gate beam	(cm^4)
H_b:	Height of beam	(cm)
H_w:	Height of web deduct 2 t	(cm)
B_f:	Width of flange	(cm)

B_w: Width of flange deduct t_w (cm)
t_f Thickness of flange (cm)
t_w: Thickness of web (cm)

Z_x:= 2 I / H_b
Where :
Z_x: Section modulus of the gate beam (cm^3)

A_{web}: H_w t_w
Where :
A_{web} :Sectional area of beam web at the support (cm^2)

Bending stress
σ = M / Z (kgf/cm^2)

Shear force
F = W / 2 (kgf)

Shear stress
τ = F / A_{web} (kgf/cm^2)

Deflection
Deflection at center of the beam can be calculated by using following equation :

δ = {w /48 E I} •{ L^3 −(L B^2 / 2) +(B^3 / 8)} (cm)
Where:
E = Young's modulus of material of the gate beam 2.1 x 10^6 (kgf / cm^2)

Allowable stress
σ_{al} = 0.5 σ_y
τ_{al} = 0.3 σ_y
Where:
σ_y = Yield strength of material of SS400 (JIS) = 2,400 (kgf/cm^2)

Allowable deflection
δ_{max} /B $\leqq$ 1 / 800

(3) Examination

(a) Strength of the skin plate

P_U = 1.0 x 7.285 = 7.285 (t/m^2)
P_L = 1.0 x 7.060 =7.060 (t/m^2)
P = (7.285+ 7.060) / 20 = 0.717 (kgf/m^2)
a = 22.5 (cm)

$b = 53$ (cm)

$K = 50$

$t = 0.8$ (cm)

$\sigma = 0.01 \times 50 \times 22.5^2 \times 0.717 / 0.8^2 = 284 < 1{,}200$ (kgf/cm^2)

(b) Strength of the main beam

1) Strength of the main beam 1 (lowest beam)

$P_0 = 7.54$ (t/m^2)

$P_1 = 7.30$ (t/m^2)

$P_2 = 6.91$ (t/m^2)

$l_0 = 25$ (cm)

$l_1 = 39$ (cm)

$B_s = 571$ (cm)

$W_1 = [\{(P_2+2P_1) / 60\} l_1 + \{(P_1+P_0) / 20\} l_0] B_s$

$= [\{(6.91+2 \times 7.30) / 60\} \times 39 + \{(7.30 + 7.54) / 20 \} \times 25] \times 571$

$= 18{,}575$ (kgf)

$M_1 = (18{,}575 / 8) \times (2 \times 591 - 571) = 1{,}419 \times 10^3$ (kgf-cm)

$I_1 = 1 / 12 \times (17.4 \times 44.95^3 - 16.4 \times 41.1^3) = 36{,}808$ (cm^4) for I 450 x 175 x 11/20

$Z_1 = 2 \times 36{,}808 / 44.95 = 1{,}638$ (cm^3)

$\sigma_1 = 1{,}419 \times 10^3 / 1{,}638 = 866 < 1{,}200$ (kgf/cm^2)

$F_1 = 18{,}575 / 2 = 9{,}288$ (kgf)

$A_{1\,web} = 36.1 \times 1.0 = 36.1$ (cm^2) for I 400 x 175 x 11/20

$\tau_1 = 9{,}288 / 36.1 = 257 < 720$ (kgf/cm^2)

$\delta_{1\,max} = \{18{,}575 / (48 \times 2.1 \times 10^6 \times 36{,}808)\} \times \{ 591^3 - (591 \times 571^2 / 2) + (571^3 / 8)\}$

$= 0.67$ (cm)

$\delta_{1\,max} / B = 0.67 / 571 = 1 / 853 < 1 / 800$

2) Strength of the main beam 2 (next to lowest beam)

$P_3 = 6.46$ (t/m^2)

$L_2 = 45$ (cm)

$W_2 = [\{(P_3+2P_2) l_2 + (2p_2+P_1) l_1\} / 60] B$

$= [\{(6.46+2 \times 6.91) \times 45 + (2 \times 6.91 + 7.30) \times 39 \} / 60] \times 571$

$= 16{,}524$ (kgf)

$M_2 = (16{,}524 / 8) \times (2 \times 591 - 571) = 1{,}262 \times 10^3$ (kgf-cm)

$I_2 = 1 / 12 \times (17.4 \times 44.95^3 - 16.4 \times 41.1^3) = 36{,}808$ (cm^4) for I 450 x 175 x 11/20

$Z_2 = 2 \times 36{,}808 / 44.95 = 1{,}638$ (cm^3)

$\sigma_2 = 1{,}262 \times 10^3 / 1{,}638 = 770 < 1{,}200$ (kgf/cm^2)

$F_2 = 16{,}524 / 2 = 8{,}262$ (kgf)

$A_{2\,web} = 36.1 \times 1.0 = 36.1$ (cm^2) for [400 x 175 x 11/20

τ_2 = 8,262 / 36.1 =229 < 720 (kgf/cm^2)

δ_{2max}= {16,524 /(48 x 2.1x 10^6 x 36,808)}x { 591^3 -(591x571^2 / 2) +(571^3 / 8)}

= 0.59 (cm)

δ_{2max} / B = 0.59 / 571= 1 / 968 < 1 / 800

APPENDIX C 4.10-5 Structural Calculation of Roller Gate for Sand Settling Basin

(1) Design data

Elevation of max. water surface	EL. 10.90 m
Elevation of the gate sill	EL. 7.40 m
Design head	3.50 m
Clear span of the water canal	10.00 m
Distance of the rubber seals	10.00 m
Distance of the main roller	10.50 m
Height of the roller gate leaf	3.50 m

(2) Calculation

(a) Hydrostatic load calculation

Water pressure at any point can be calculated by the following equation ;

$P_i = W_o \bullet H_i$

Where:

P_i:	hydrostatic pressure at intended point	(t/m^2)
W_o:	Specific weight of water 1.0	($tons/m^3$)
H_i:	Water depth at intended point from the highest water level	(m)

(b) Strength of skin plate

Max. bending stress of the skin plate can be calculated by the follows :

$\sigma = 1/100 \bullet K \bullet a^2 \bullet P / t^2$

Where:

σ:	Max. bending stress of the skin plate	(kgf/cm^2)
K:	Coefficient of b / a (refer to Table 1)	
a:	Short side length of the skin plate	(cm)
b:	Long side length of the skin plate	(cm)
P_U:	Upper side water pressure at any point	(t/m^2)
P_L:	Lower side water pressure at any point	(t/m^2)
P:	Mean water pressure = $(P_U + P_L) / 20$	(kgf/m^2)
t_s:	Effective thickness of the skin plate = t – 2C	(cm)
t:	Thickness of the skin plate	(cm)
C:	Corrosion allowance 0.05	(cm)

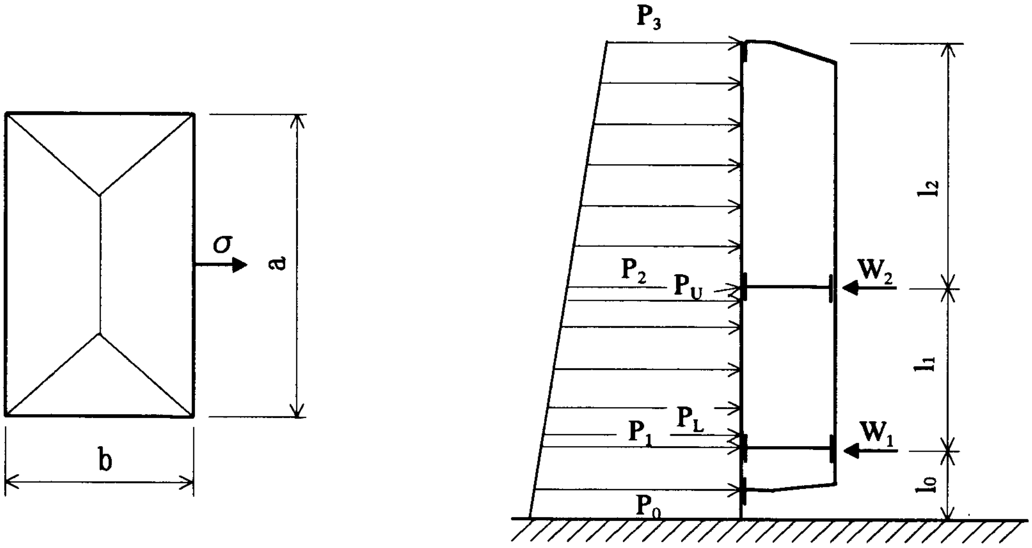


Figure 1 Loading condition of the gate

(c) Strength of the main beam

Max. stress of the main beam can be calculated by the following equation :

$M = W / 8 \cdot (2L - B_s)$

Where:

M:	Bending moment acting on the main beam	(kgf-cm)
W:	Hydraulic load	(kgf)
L:	Span of main roller	(cm)
B_s:	Span of supports bearing hydraulic load	(cm)

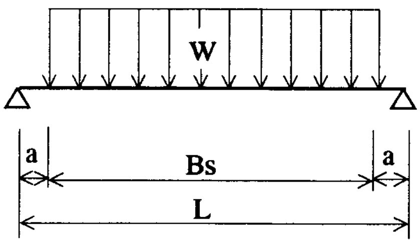


Figure 2 Loading condition of the gate

Sectional property of beam

$I_x = 1/12 \cdot (B_f \cdot H_b^3 - B_w \cdot H_w^3)$

Where:

I_x:	Moment of inertia of the gate beam	(cm^4)
H_b:	Height of beam	(cm)
H_w:	Height of web deduct 2 x Bf	(cm)

B_f: Width of flange (cm)
B_w: Width of flange deduct (cm)
t_f: Thickness of flange (cm)
t_w: Thickness of web (cm)

$Z_X = 2\,I\,x / H_b$

Where:

Z_X: Section modulus of the gate beam (cm^3)

$A_w = H_w\, t_w$

Where:

A_{web}: Sectional area of beam web at the support (cm^2)

Bending stress

$\sigma = M / Z$ (kgf/cm^2)

Shear force

$F = W / 2$ (kgf)

Shear stress

$\tau = F / A_{web}$ (kgf/cm^2)

Deflection

Deflection at center of the beam is calculated by using following formula :

$\delta = w / 48\,E\,I \bullet \{ L^3 - (L\,B^2 / 2) + (B^3 / 8) \}$ (cm)

Where:

E : Young's modulus of material of the gate beam 2.1 x 10^3 (t/cm^2)

Allowable stress

$\sigma_{al} = 0.5\ \sigma_{al}$ (kgf/cm^2)

$\tau_{al} = 0.3\ \sigma_{al}$ (kgf/cm^2)

Where:

σ_{al}: Yield strength of material of SS400 (JIS) = 2,400 (kgf/cm^2)

Allowable deflection

$\delta_{max} / B \leqq 1 / 800$

(3) Examination

(a) Strength of the skin plate

$P_U = 1.65$ (t/m^2)

$P_L = 2.75$ (t/m^2)

$P = (1.65+2.75) / 20 = 0.220$ (kgf/cm^2)

$a = 66$ (cm)

$b = 110$ (cm)

$K = 47.6$

$t = 0.8$ (cm)

$\sigma = 0.01 \times 47.6 \times 66.0^2 \times 0.22 / 0.8^2 = 713 < 1,200$ (kgf/cm²)

(b) Strength of the main beam

1) Strength of the main beam 1 (lowest beam)

$P_0 = 3.50$ (t/m²)

$P_1 = 2.90$ (t/m²)

$P_2 = 1.50$ (t/m²)

$l_0 = 6$ (cm)

$l_1 = 14$ (cm)

$B = 1,000$ (cm)

$W_1 = [\{(P_2+2P_1)/60\} l_1 + \{(P_1+P_0)/20\} l_0] B_s$

$= [\{(1.50+2 \times 2.90)/60\} \times 14.0 + \{(2.90+3.50)/20\} \times 6.0] \times 1,000$

$= 3,623$ (kgf)

$M_1 = (3,623 / 8) \times (2 \times 1,050 - 1,000) = 498.2 \times 10^3$ (kgf-cm)

$I_1 = 1/12 \times (29.9 \times 79.95^3 - 28.4 \times 75.1^3) = 270,906$ (cm⁴) for I 800 x 300 x 16/25

$Z_1 = 2 \times 270,906 / 79.95 = 6,777$ (cm³)

$\sigma_1 = 498.2 \times 10^3 / 6,777 = 74 < 1,200$ (kgf/cm²)

$F_1 = 3,623 / 2 = 1,812$ (kgf)

$A_{web} = 75.1 \times 1.5 = 113$ (cm²)

$\tau_1 = 1,812 / 113 = 16 < 720$ (kgf/cm²)

$\delta_{1\,max} = (3,623/48 \times 2.1 \times 10^6 \times 270,906) \times \{1,050^3 - (1,000 \times 1,000^2/2) + (1,000^3/8)\}$

$= 0.104$ (cm)

$\delta_{1\,max} / B = 0.104 / 1050 = 1 / 10,101 < 1/800$

2) Strength of the main beam 2 (next to lowest beam)

$P_3 = 0.0$ (t/m²)

$l_2 = 150$ (cm)

$W_2 = [\{(P_3+2P_2) l_2 + (2P_2+P_1) l_1\} / 6] B$

$= [\{(0+2 \times 1.50) \times 150 + (2 \times 1.50 + 2.90) \times 14\} / 60] \times 1,000$

$= 8,877$ (kgf)

$M_2 = (8,887 / 8) \cdot (2 \times 1,050 - 1,000) = 1,221 \times 10^3$ (kgf-cm)

$I_2 = 270,906$ (cm⁴)

$Z_2 = 6,777$ (cm³)

$\sigma_2 = 1,221\ 4 \times 10^3 / 6,777 = 180 < 1,200$ (kgf/cm²)

$F_2 = 8{,}877 / 2 = 4{,}439$ (kgf)

$A_{web} = 113$ (cm^2)

$\tau_2 = 4{,}439 / 113 = 39 < 720$ (kgf/cm^2)

$\delta_{2\,max} = (8{,}877 / 48 \times 2.1 \times 10^6 \times 270{,}906) \times \{1{,}050^3 - (1{,}000 \times 1{,}000^2 / 2) + (1{,}000^3 / 8)\}$

$= 0.25$ (cm)

$\delta_{2\,max} / B = 0.25 / 1{,}050 = 1 / 4{,}200 < 1 / 800$

APPENDIX C 4.10-6 Structural Calculation of Roller Gate for Spillway

(1) Design data

Elevation of max. water surface	EL.11.94 m
Elevation of the gate sill	EL. 7.60 m
Design head	4.34 m
Clear span of the water canal	4.00 m
Total height of the radial gate	4.50 m

(2) Calculation

(a) Hydrostatic load calculation

Water pressure at the gate leaf can be calculated by the equation :

$P_i = W_o \bullet H_i$

Where:

P_i:	Water pressure at intended point of the gate leaf	(t/m^2)
W_o:	Specific weight of water 1.0	(tons/ $m^{3)}$
H_I:	Water depth at intended point from the highest water level	(m)

(b) Strength of faceplate

Max. bending stress of the faceplate can be calculated by the equations :

$M = w_L \ l_s{}^2 / 12$

$\sigma = 6 M / t_s{}^2$

Where:

M:	Max. bending moment of the faceplate	(kgf-cm)
σ	Max. bending stress of the faceplate	(kgf/cm^2)
l_S:	Width of the faceplate between vertical beams	(cm)
w_L:	Water pressure at the gate sill	(kgf/cm^2)
t_s:	Effective thickness of the faceplate = t – 2C	(cm)
t:	Thickness of the faceplate	(cm)
C:	Corrosion allowance 0.05	(cm)

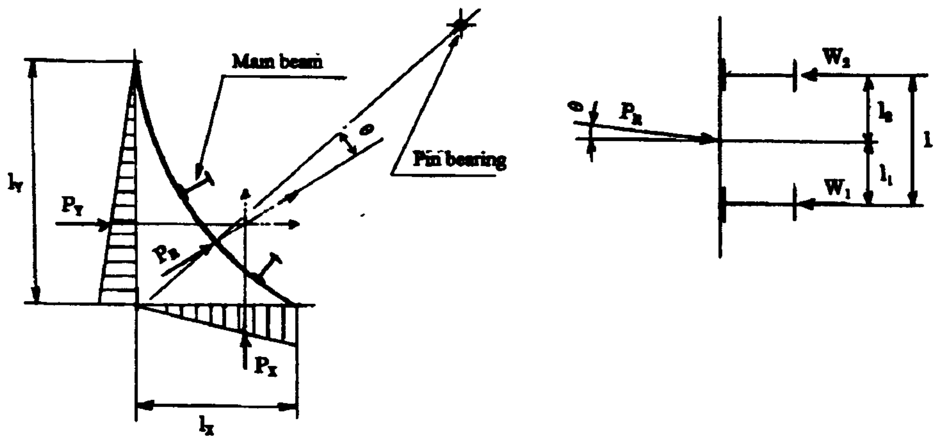


Figure 1 Loading Condition of the Radial Gate

(c) Strength of the main beam

Max. stress of the main beam can be calculated by the equations :

Water load

$P_X = w_L \ l_X / 2$	(kgf/cm)
$P_Y = w_L \ l_Y / 2$	(kgf/cm)
$P_R = (P_X{}^2 + P_Y{}^2)^{0.5}$	(kgf/cm)
$W_1 = \mathrm{Cos}\,\theta \ \ P_R \, l_2 / l$	(kgf/cm)
$W_2 = \mathrm{Cos}\,\theta \ \ P_R \, l_1 / l$	(kgf/cm)

Bending moment

$M = \{w\,B^2/2\}\cdot(0.25 - a/B)$

Where:

M:	Bending moment acting on the main beam	(kgf-cm)
W:	Water load	(kgf/cm)
B:	Length of supports bearing water load	(cm)
a:	Overhung length of beam	(cm)
L_A:	Span of supports bearing water load	(cm)

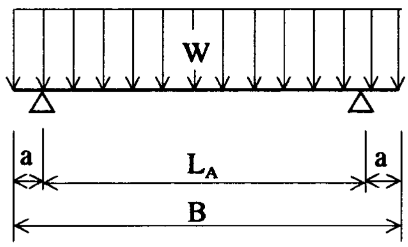


Figure 2 Loading Condition of the Beam

Sectional property of beam

$I_X = 1/12 \cdot (B_f \cdot H_b{}^3 - B_w \cdot H_w{}^3)$

Where:

I_X = Moment of inertia of the gate beam (cm^4)

H_b = Height of beam (cm)

H_w = Height of web deduct 2 x Bf (cm)

B_f = Width of flange (cm)

B_w = Width of flange deduct (cm)

t_f = Thickness of flange (cm)

t_w = Thickness of web (cm)

$Z_X = 2 I x / H_b$

Where:

Z_X = Section modulus of the gate beam (cm^3)

$A_{web} = H_w t_w$

Where:

A_{web} : Sectional area of beam web at the support (cm^2)

Bending stress

$\sigma = M / Z$ (kgf / cm^2)

Shear force

$F = W L_A / 2$ (kgf)

Shear stress

$\tau = F / A_{web}$ (kgf/cm^2)

Deflection

Deflection at center of the beam is calculated by using equation:

$\delta = \{w L_A{}^2 / 384 E I\} \bullet (5 L_A{}^2 - 24 a^2)$ (cm)

Where:

E: Young's modulus of material of the gate beam 2.1×10^6 (kgf/cm^2)

Allowable stress

σ_{al} = 0.5 σ_{al} (kgf/cm^2)
τ_{al} = 0.3 σ_{al} (kgf/cm^2)
Where:
σ_{al}: Yield strength of material of SS400 (JIS) = 2,400 (kgf/cm^2)

Allowable deflection

δ_{max} / B $\leqq$ 1 / 800

(3) Examination

(a) Strength of the faceplate

P_L = 4.34	(t/m^2)
$W_L = P_L$ / 10 = 0.434	(kgf/cm^2)
l_S = 40	(cm)
t_S = 0.8	(cm)
M = 0.434 x 40 ^{2}/ 12 =57.87	(kgf-cm)
σ = 6 x 57.87 / 0.8 ^{2}= 543 < 1,200	(kgf/cm^2)

(b) Strength of the main beam

Water load

l_X = 280	(cm)
l_Y = 434	(cm)
θ = 9	(degree)
$l_1 = l_2$ = 0.5 l	(cm)
l = $l_1 + l_2$	(cm)
P_X = 0.434 x 280 / 2 = 60.76	(kgf/cm)
P_Y = 0.434 x 434 / 2 = 94.18	(kgf/cm)
P_R = (60.76 ^{2} + 94.18 ^{2}) $^{0.5}$ = 112	(kgf/cm)
W_1= Cos 9 x 112 x 0.5 = 55.31	(kgf/cm)
W_2= W_1	(kgf/cm)
L_A = 250	(cm)

Strength of the main beam

B = 400	(cm)
A = 75	(cm)
L_A = 250	(cm)

M = {55.31 x 400 ^{2} / 2 } x { 0.25 -(75 / 400) } = 276.6x 10 ^{3} (kgf-cm)

$I = 1 / 12 \times (19.9 \times 39.95^3 - 19.2 \times 37.5^3) = 21,361$ (cm^4) for [400 x 200 x 8/ 13

$Z = 2 \times 21,361 / 39.95 = 1,069$ (cm^3)

$\sigma = 276.6 \times 10^3 / 1,069 = 259 < 1,200$ (kgf/cm^2)

$F = 55.31 \times 250 / 2 = 6,914$ (kgf)

$A_{web} = 37.5 \times 0.7 = 26.25$ (cm^2)

$\tau = 6,914 / 26.25 = 263 < 72$ (kgf/cm^2)

$\delta = \{55.31 \times 250^2 / (384 \times 2.1 \times 10^6 \times 21,361)\} \times (5 \times 250^2 - 24 \times 75^2)$

$= 0.04$ (cm)

$\delta_{1\,max} / B = 0.04 / 250 = 1 / 6,250 < 1 / 800$

APPENDIX C.6.4-1 Structural Calculation of Main Substation

(1) FRAME MODEL

(a) JOINT NUMBER

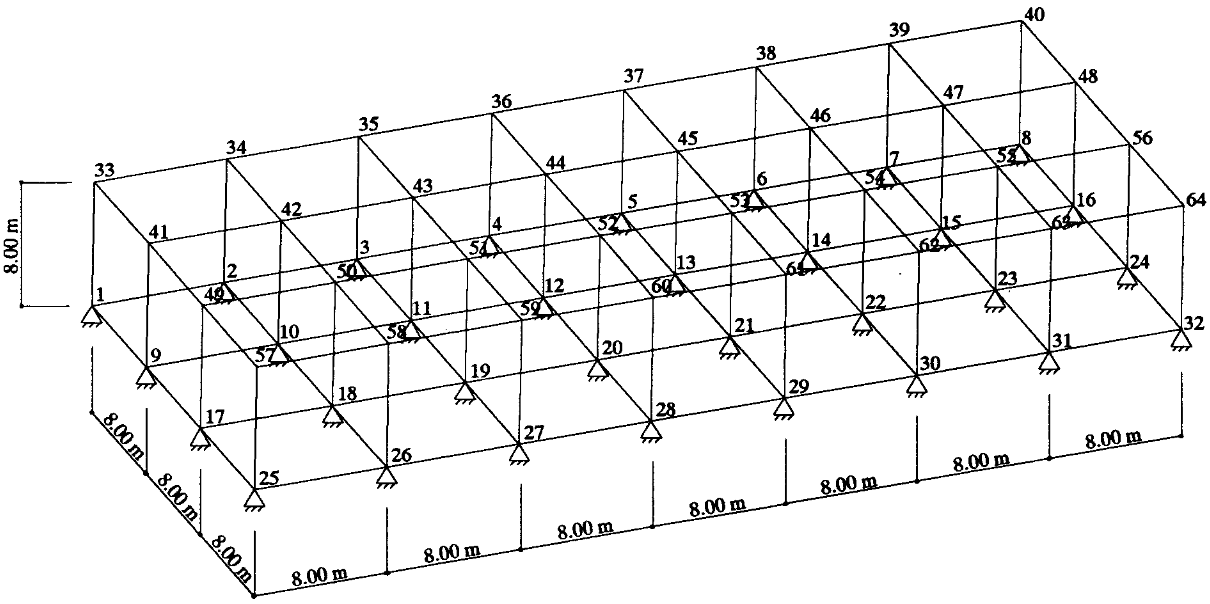


Figure 1

(b) MEMBER NUMBER

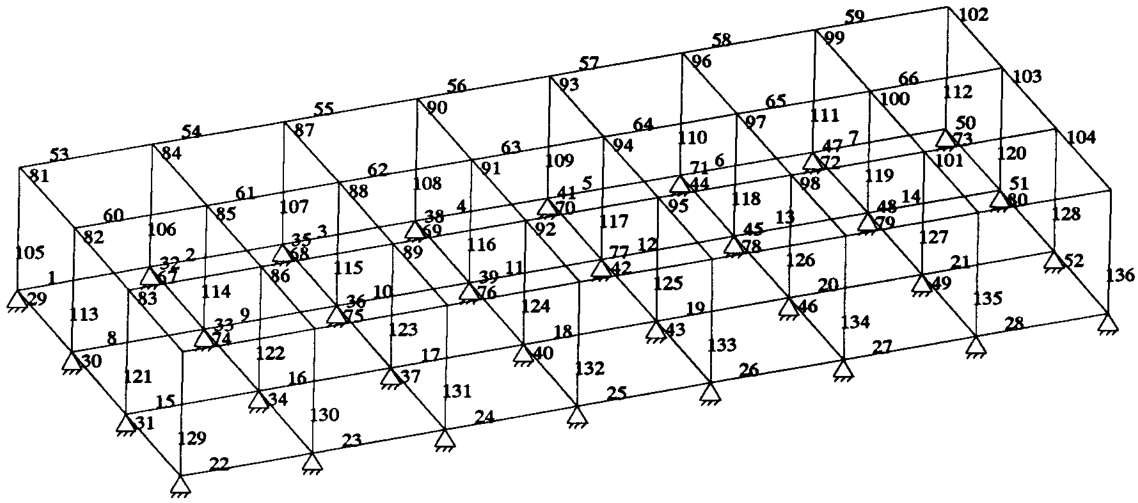


Figure 2

(c) MEMBER PROPERTIES

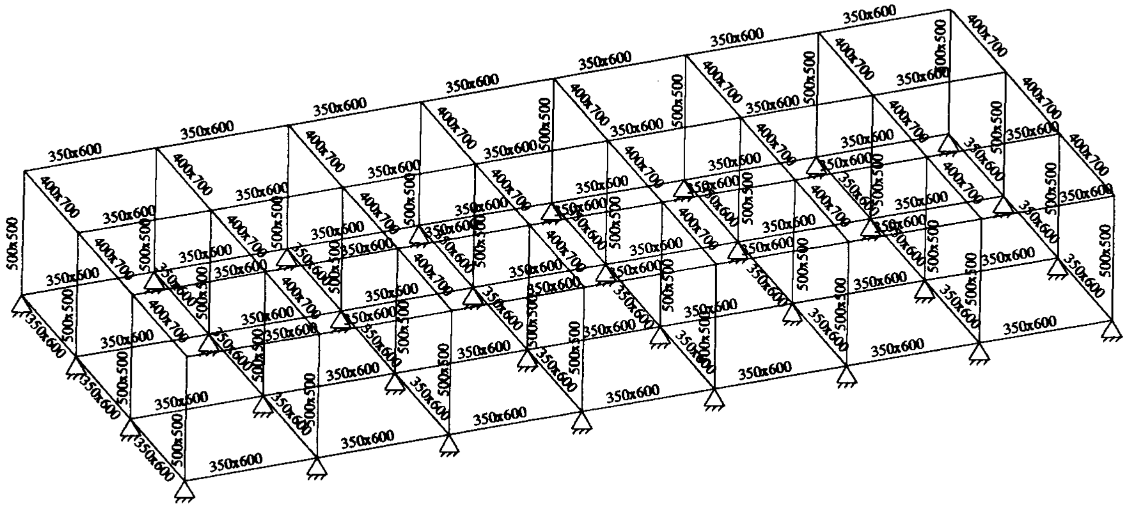


Figure 3

(2) LOADING DIAGRAM

(a) LOADING 1
DEAD LOAD (D.L)

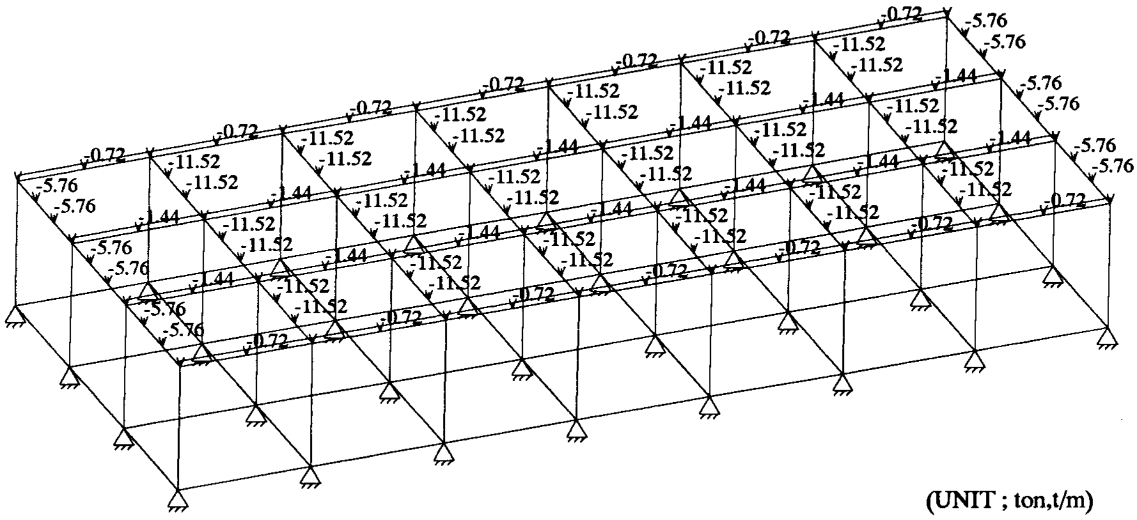


Figure 4

(b) LOADING 2
LIVE LOAD (L.L)

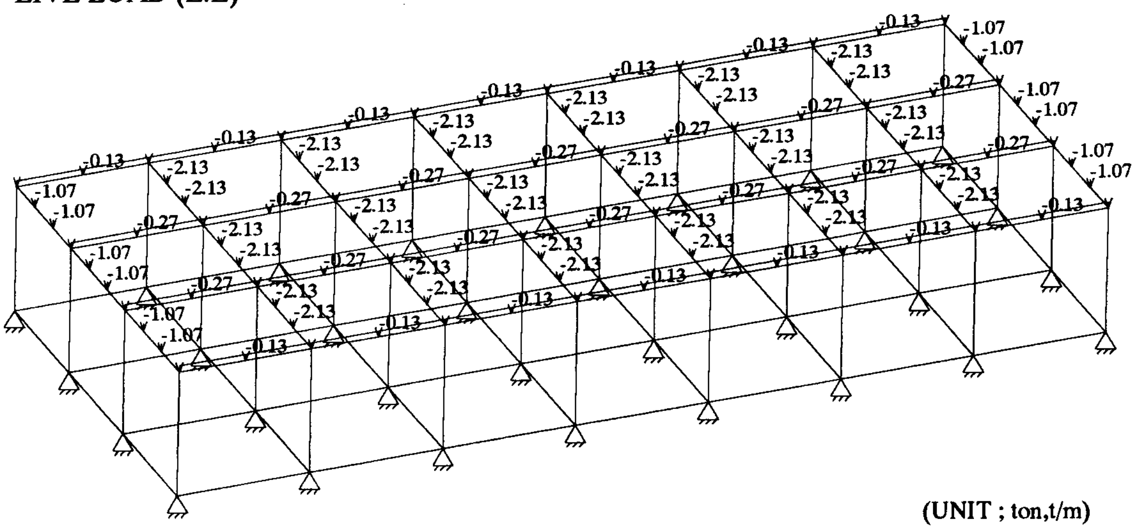
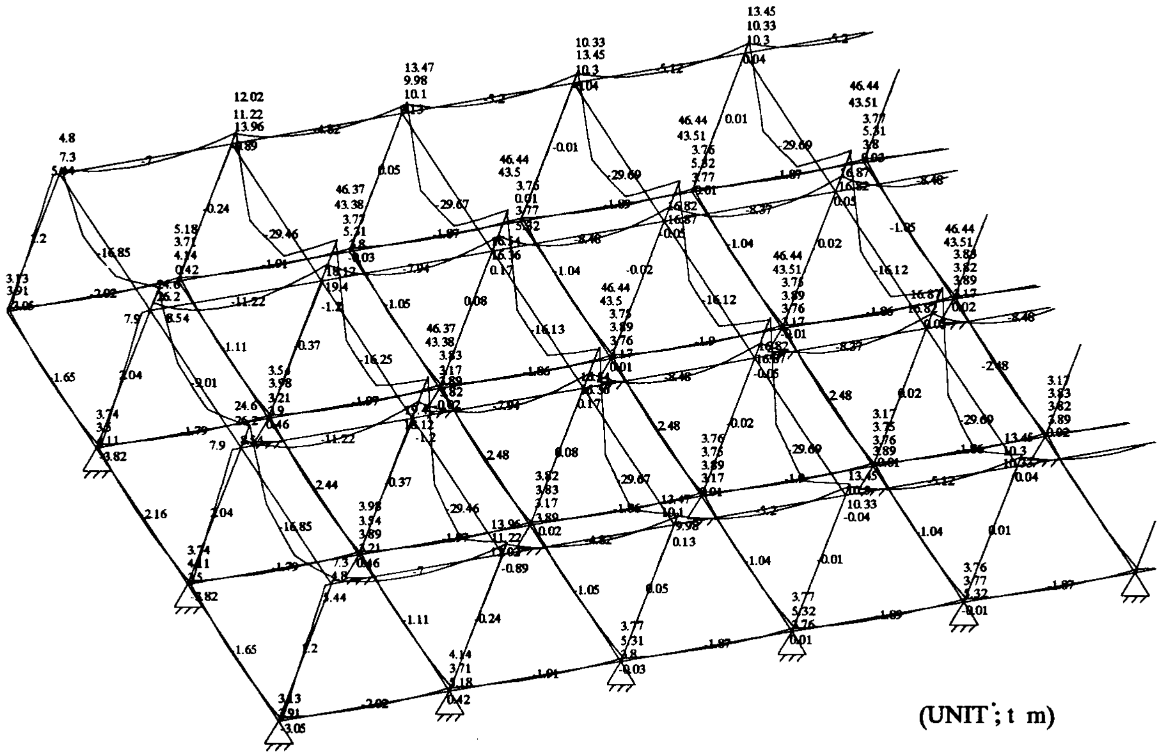


Figure 5

(3) RESULTS OF ANALYSIS

(a) BENDING MOMENT MZ

LOAD CASE
1.4D.L + 1.6L.L

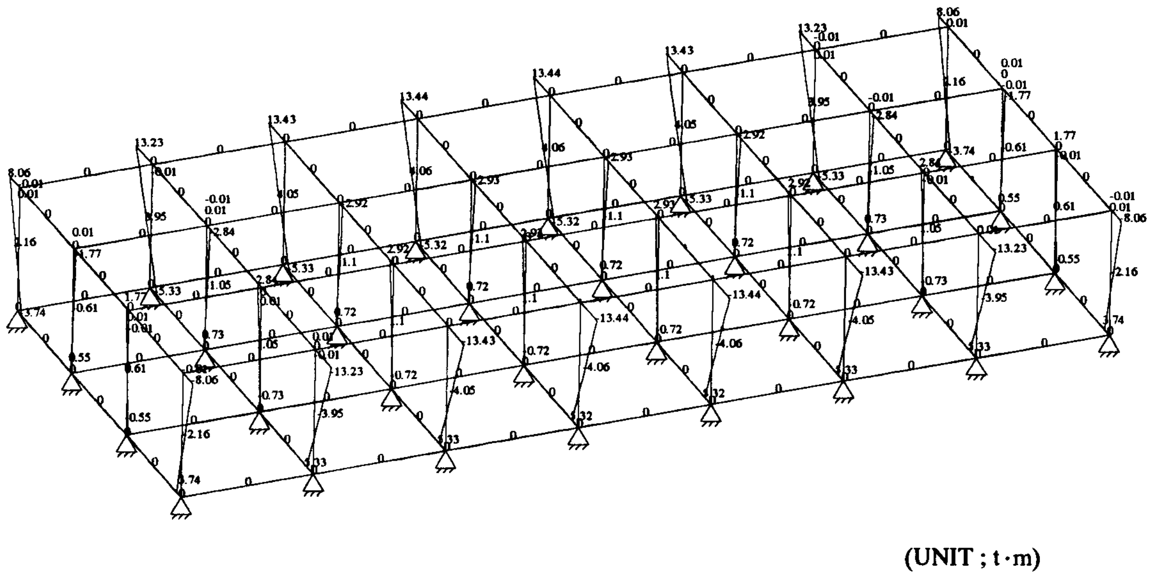


(UNIT ; t m)

Figure 6

(b) BENDING MOMENT MY

LOAD CASE
1.4D.L + 1.6L.L



(UNIT ; t·m)

Figure 7

APPENDIX C.6.4-2 Structural Calculation of Administration Building

(1) FRAME MODEL

(a) JOINT NUMBER

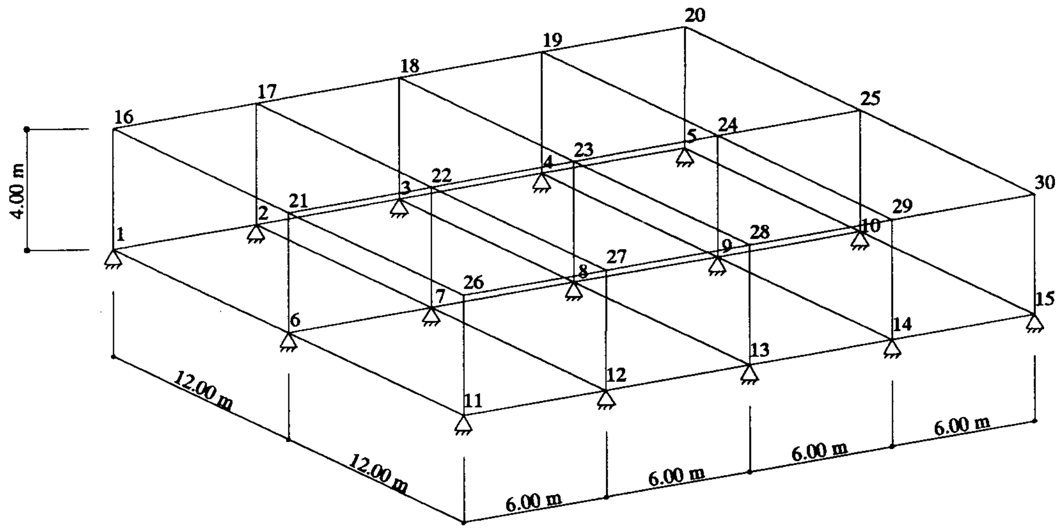


Figure 1

(b) MEMBER NUMBER

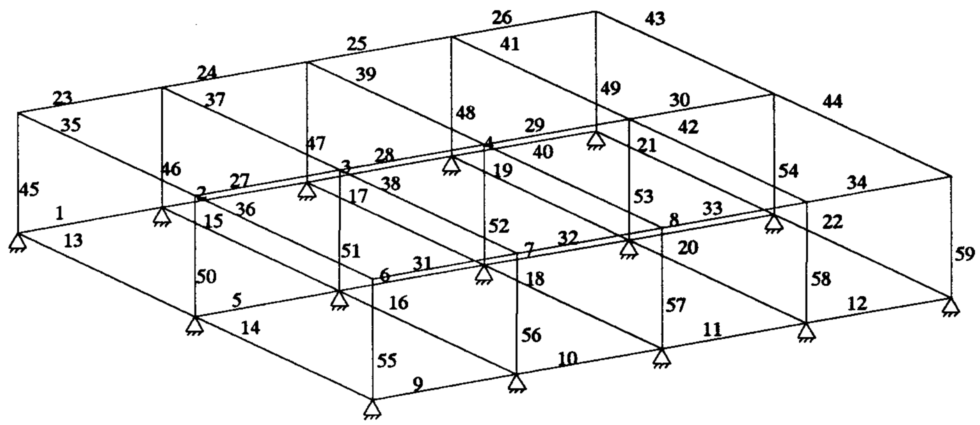


Figure 2

(c) MEMBER PROPERTIES

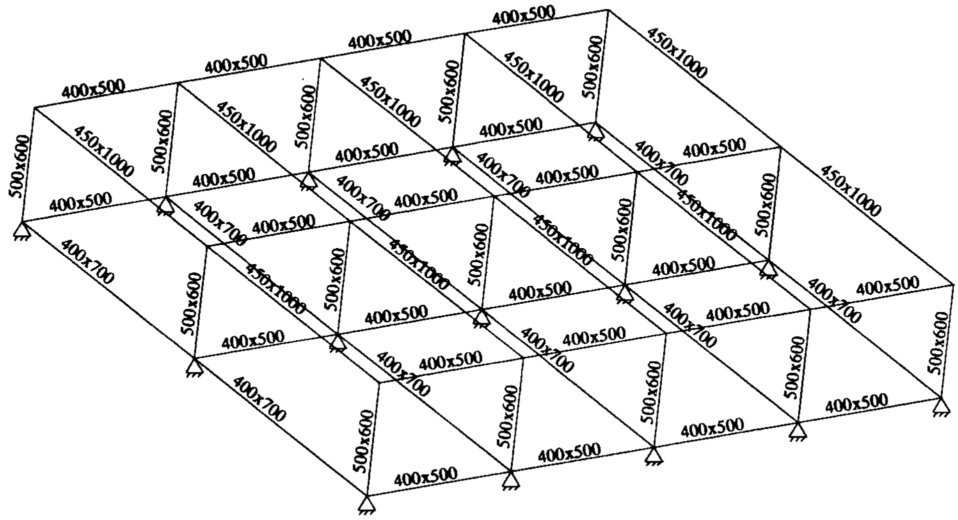
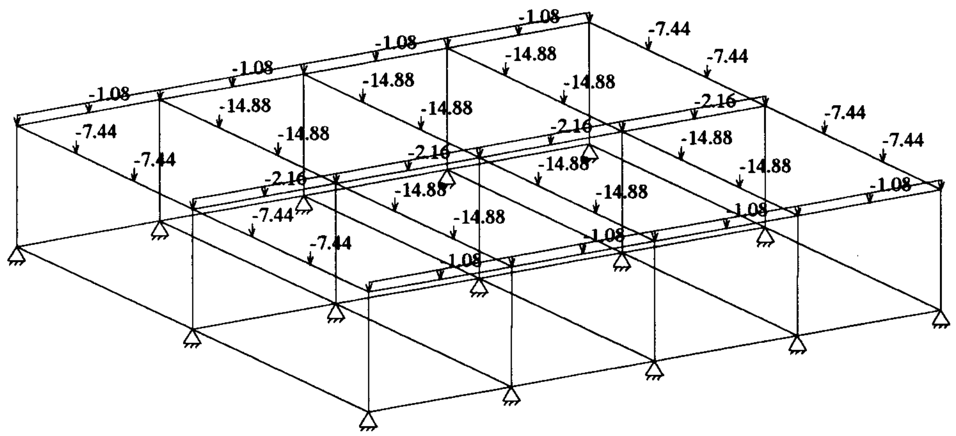


Figure 3

(2) LOADING DIAGRAM

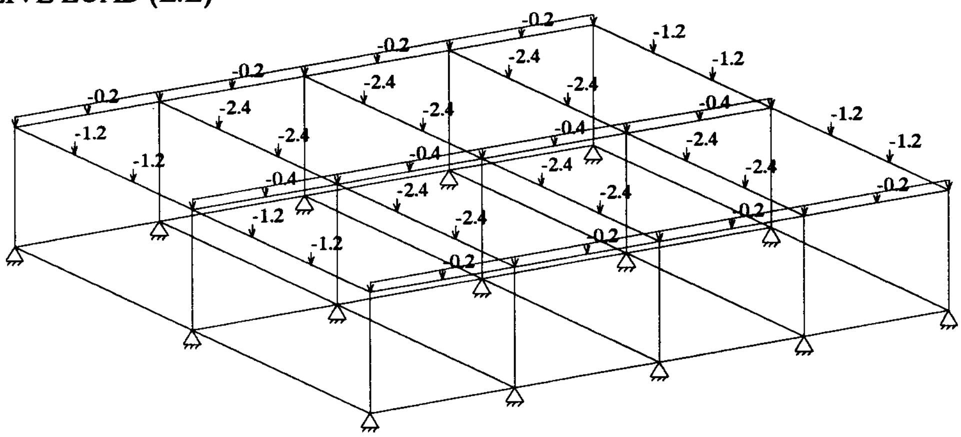
(a) LOADING 1
DEAD LOAD (D.L)



(UNIT ; ton,t/m)

Figure 4

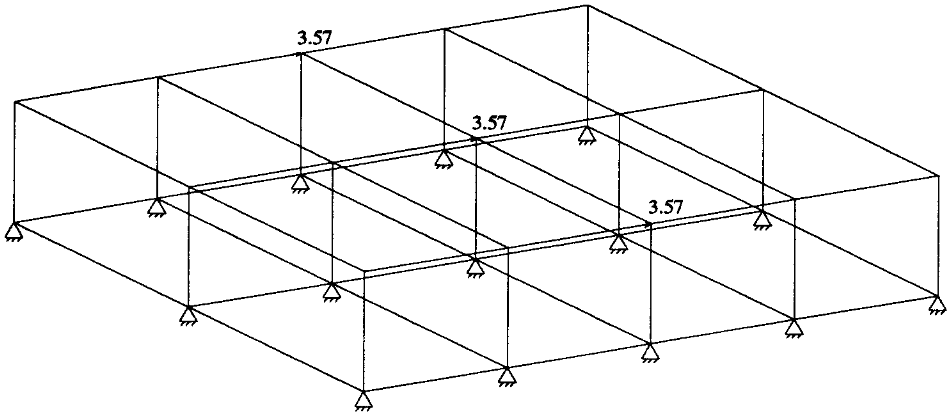
(b) LOADING 2
LIVE LOAD (L.L)



(UNIT ; ton,t/m)

Figure 5

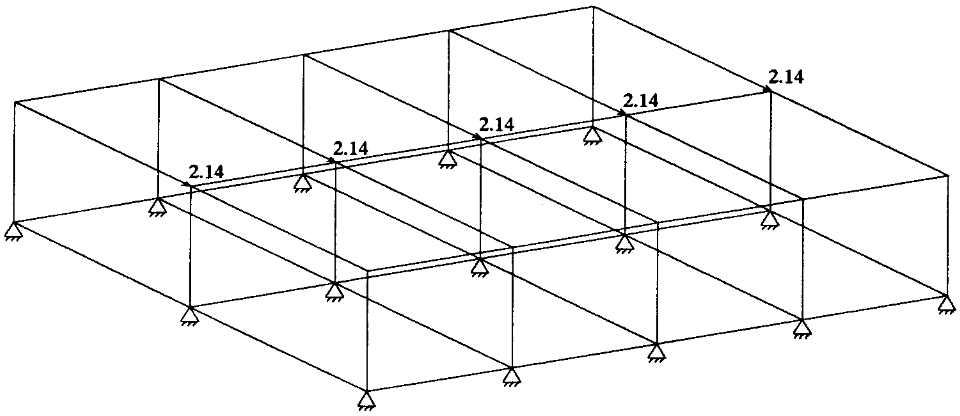
(c) LOADING 3
SEISMIC LOAD X-DIR. (S1)



(UNIT ; ton)

Figure 6

(d) LOADING 4
SEISMIC LOAD Z-DIR. (S2)



(UNIT ; ton)

Figure 7

(3) RESULTS OF ANALYSIS

(a) BENDING MOMENT MZ

LOAD CASE
1.4D.L + 1.6L.L

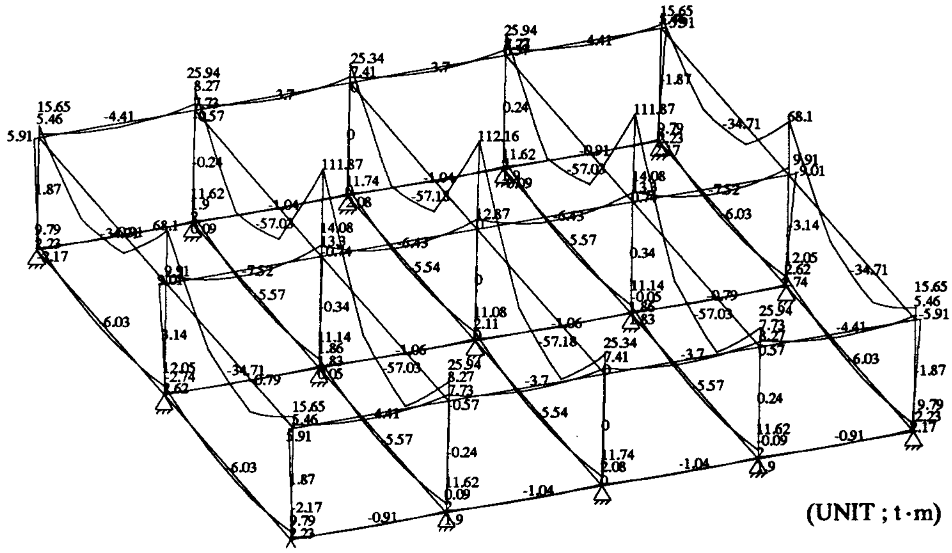


Figure 8

(b) BENDING MOMENT MU

LOAD CASE
1.4D.L + 1.6L.L

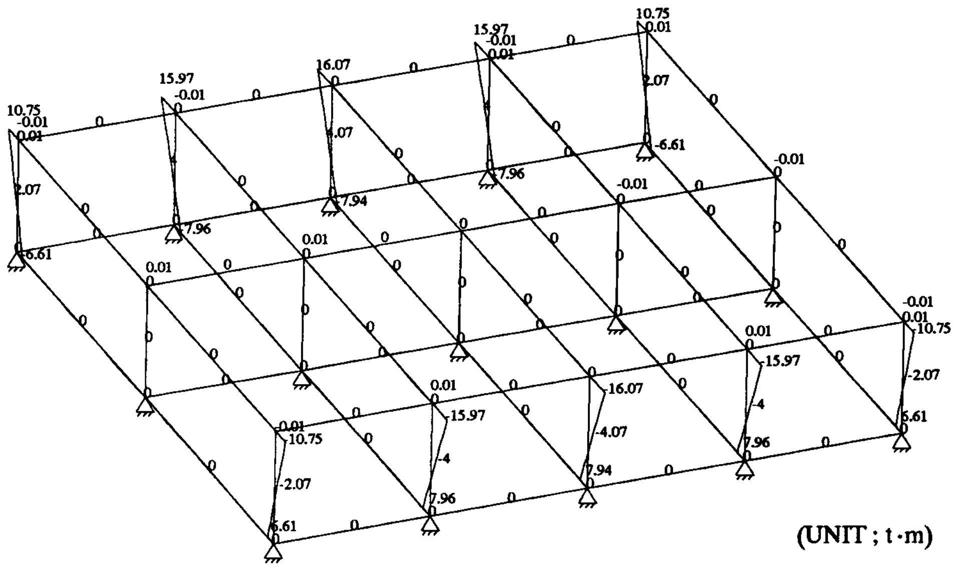


Figure 9