1.2 Alignment Calculation of Semarang River

Name of Structure	Semarang River	Category of calculation	Allgment	Page	1/4

SEMARANG RIVER

DRAW NO.	IP	N	E	R	DISTANCE	α		∠	TL	TL	CL		Acc. Dis	
1	BP	9,232,011.5	434,471.0											
					575.588				32.505			543.08	543.083	
	IP1	9,231,455.0	434,618.0	300		167.63					64.788	64.79	607.871	1.756
					127.016		117.17		32.505	17.714		76.80	684.668	
	IP2	9,231,342.0	434,676.0	190				169.34			35.343	35.34	720.011	0.824
					215.230		307.83		-	17.714		197.52	917.527	
	IP3	9,231,172.0	434,808.0			136.98					-	-	917.527	-
					226.381		170.85		-	34.411		191.97	1,109.497	
	IP4	9,231,136.0	435,031.5	80				133.43			65.025	65.03	1,174.522	7.087
					134.938		304.28		-	34.411		100.53	1,275.049	
	IP5	9,231,024.5	435,107.5			177.78					-	-	1,275.049	-
					93.302		126.50		-	-		93.30	1,368.351	
2	IP6	9,230,949.5	435,163.0					176.19			-	-	1,368.351	-
					175.866		302.69		26.911	-		148.96	1,517.306	
	IP7	9,230,801.5	435,258.0	320		170.38					53.721	53.72	1,571.027	1.130
					93.582		132.31		26.911	22.840		43.83	1,614.859	
	IP8	9,230,732.3	435,321.0	130				160.06			45.240	45.24	1,660.099	1.991
					108.472		332.25		37.985	22.840		47.65	1,707.746	
	IP9	9,230,681.8	435,417.0	91		134.66					72.003	72.00	1,779.749	7.610
					104.904		197.59		37.985	40.185		26.73	1,806.483	
3	IP10	9,230,713.5	435,517.0	80				126.63			74.515	74.52	1,880.998	9.526
					110.320		324.22		29.660	40.185		40.47	1,921.473	
	IP11	9,230,649.0	435,606.5	90		143.50					57.330	57.33	1,978.803	4.761
					101.833		107.72		29.660	46.244		25.93	2,004.731	
	IP12	9,230,552.0	435,637.5	190				152.63			90.768	90.77	2,095.499	5.547
					213.193		315.09		70.052	46.244		96.90	2,192.396	
	IP13	9,230,401.5	435,788.5	320		155.29					137.994	137.99	2,330.390	7.578
					102.823		159.80		70.052	24.765		8.01	2,338.395	
	IP14	9,230,366.0	435,885.0	280				169.89			49.426	49.43	2,387.821	1.093
					112.939		329.69		42.174	24.765		46.00	2,433.821	
	IP15	9,230,309.0	435,982.5	380		167.53					84.045	84.04	2,517.866	2.333
					200.943		137.02		42.174	37.226		121.54	2,639.408	
4	IP16	9,230,172.0	436,129.5	110				142.59			71.824	71.82	2,711.233	6.128
					102.987		354.43		35.825	37.226		29.94	2,741.169	
	IP17	9,230,162.0	436,232.0	50		108.72					62.201	62.20	2,803.369	11.509
					109.882		103.15		35.825	36.801		37.26	2,840.625	
	IP18	9,230,055.0	436,257.0	120				145.88			71.451	71.45	2,912.076	5.516
					121.550		249.03		-	36.801		84.75	2,996.826	

Name of Structure	Semarang River	Category of calculation	Allgment	Page	2/4

	IP19	9,229,941.5	436,213.5			174.80					-	-	2,996.826	-
					97.495		63.83		-	46.499		51.00	3,047.821	
	IP20	9,229,854.0	436,170.5	130				140.62			89.355	89.35	3,137.176	8.066
					67.796		283.21		20.619	46.499		0.68	3,137.853	
	IP21	9,229,788.0	436,186.0	40		125.43					38.094	38.09	3,175.947	5.002
					76.694		157.78		20.619	24.072		32.00	3,207.950	
	IP22	9,229,759.0	436,257.0	100				152.92			47.267	47.27	3,255.218	2.856
					47.170		4.86		15.512	24.072		7.59	3,262.804	
	IP23	9,229,763.0	436,304.0	70		155.00					30.544	30.54	3,293.349	1.698
					159.765		159.86		15.512	29.601		114.65	3,408.002	
	IP24	9,229,708.0	436,454.0	100				147.01			57.585	57.59	3,465.587	4.289
					32.500		306.87		-	29.601		2.90	3,468.487	
	IP25	9,229,682.0	436,473.5			179.57					-	-	3,468.487	-
					40.401		126.44		-			40.40	3,508.888	
	IP26	9,229,649.5	436,497.5					178.50				-	3,508.888	-
					50.629		304.94		23.075			27.55	3,536.441	
	IP27	9,229,608.0	436,526.5	250		169.45					46.041	46.04	3,582.483	1.063
					47.215		114.39		23.075	22.884		1.26	3,583.739	
5	IP28	9,229,565.0	436,546.0	100				154.21			45.014	45.01	3,628.753	2.585
					245.073		268.60		50.942	22.884		171.25	3,800.001	
	IP29	9,229,320.0	436,540.0	90		120.95					92.756	92.76	3,892.756	13.417
					124.287		147.65		50.942	17.938		55.41	3,948.165	
	IP30	9,229,253.5	436,645.0	100				159.65			35.515	35.52	3,983.678	1.596
					66.002		307.30		20.508	17.938		27.56	4,011.235	
	IP31	9,229,201.0	436,685.0	90		154.31					40.347	40.35	4,051.581	2.307
					109.238		101.62		20.508	43.538		45.19	4,096.773	
	IP32	9,229,094.0	436,707.0	140				145.43			84.462	84.46	4,181.235	6.614
					102.552		316.18		48.482	43.538		10.53	4,191.768	
	IP33	9,229,023.0	436,781.0	110		132.41					91.372	91.37	4,283.140	10.210
					106.251		183.78		48.482	11.070		46.68	4,329.819	
	IP34	9,229,030.0	436,887.0	100				167.36			22.060	22.06	4,351.879	0.611
					90.885		351.14		13.798	11.070		66.02	4,417.897	
	IP35	9,229,016.0	436,976.8	70		157.69					27.259	27.26	4,445.156	1.347
					65.684		148.83		13.798	26.132		25.75	4,470.910	
	IP36	9,228,982.0	437,033.0	40				113.65			46.318	46.32	4,517.228	7.780
					53.460		262.48		16.154	26.132		11.17	4,528.402	
6	IP37	9,228,929.0	437,026.0	90		159.64					31.984	31.98	4,560.385	1.438
					73.765		62.12		16.154	17.592		40.02	4,600.404	
	IP38	9,228,863.8	436,991.5	50				141.21			33.848	33.85	4,634.252	3.005
					34.849		203.33		17.206	17.592		0.05	4,634.302	

Name of Structure	Semarang River	Category of calculation	Aligment	Page	3/4

SEMARANG RIVER

DRAW NO.	IP	N	E	R	DISTANCE	α		∝	TL		CL		Acc. Dis	
	IP39	9,228,850.0	436,959.5	100		160.46					34.095	34.09	4,668.397	1.469
					94.818		42.86		17.206	-		77.61	4,746.009	
	IP40	9,228,785.5	436,890.0					168.40			-	-	4,746.009	-
					8.602		234.46		-	-		8.60	4,754.612	
	IP41	9,228,778.5	436,885.0			169.05					-	-	4,754.612	-
					54.466		43.51		-	13.103		41.36	4,795.975	
	IP42	9,228,741.0	436,845.5	180				171.67			26.171	26.17	4,822.146	0.476
					17.804		231.84		-	13.103		4.70	4,826.848	
	IP43	9,228,727.0	436,834.5			175.28					-	-	4,826.848	-
					9.552		47.12		-	-		9.55	4,836.400	
	IP44	9,228,720.0	436,828.0					175.41			-	-	4,836.400	-
					36.311		231.71		26.108	-		10.20	4,846.604	
	IP45	9,228,691.5	436,805.5	230		167.04					52.018	52.02	4,898.622	1.477
					97.453		38.75		26.108	17.746		53.60	4,952.220	
	IP46	9,228,630.5	436,729.5	100				159.86			35.144	35.14	4,987.364	1.562
					50.122		198.62		21.722	17.746		10.65	4,998.018	
	IP47	9,228,614.5	436,682.0	220		168.72					43.324	43.32	5,041.342	1.070
					23.071		29.90		21.722	-		1.35	5,042.691	
	IP48	9,228,603.0	436,662.0					176.67			-	-	5,042.691	-
					8.944		206.57		-	-		8.94	5,051.635	
	IP49	9,228,599.0	436,654.0			176.58					-	-	5,051.635	-
					15.008		29.98		-	-		15.01	5,066.643	
	IP50	9,228,591.5	436,641.0					176.79			-	-	5,066.643	-
					79.464		213.19		35.861	-		43.60	5,110.246	
	IP51	9,228,548.0	436,574.5	140		151.25					70.247	70.25	5,180.493	4.520
					51.655		4.44		35.861	10.820		4.97	5,185.466	
	IP52	9,228,544.0	436,523.0	100				167.64			21.567	21.57	5,207.033	0.584
					27.681		196.80		8.217	10.820		8.64	5,215.677	
	IP53	9,228,536.0	436,496.5	17.5		129.67					15.372	15.37	5,231.049	1.833
					34.731		67.13		8.217	19.564		6.95	5,237.999	
	IP54	9,228,504.0	436,483.0	150				165.13			38.927	38.93	5,276.926	1.270
					64.630		262.00		27.048	19.564		18.02	5,294.943	
	IP55	9,228,440.0	436,474.0	40		111.83					47.589	47.59	5,342.532	8.287
					66.940		13.83		27.048	21.200		18.69	5,361.224	
	IP56	9,228,424.0	436,409.0	30				109.47			36.929	36.93	5,398.153	6.735
					61.018		123.30		19.794	21.200		20.02	5,418.178	
	IP57	9,228,475.0	436,375.5	270		171.61					39.535	39.54	5,457.713	0.725
					42.851		311.69		19.794	-		23.06	5,480.771	

Name of Structure	Semarong River	Category of calculation	Allgment	Page	4/4

	IP58	9,228,507.0	436,347.0					155.21				-	5,480.771	-
					9.270		156.48		-			9.27	5,490.041	
7	IP59	9,228,510.7	436,338.5			176.19					-	-	5,490.041	-
					119,500		340.29		-	32.827		86.67	5,576.715	
	IP60	9,228,551.0	436,226.0	25				74.53			46.018	46.02	5,622.733	16.262
					137.878		265.76		19.957	32.827		85.09	5,707.827	
	IP61	9,228,413.5	436,215.8	30		112.70					35.238	35.24	5,743.065	6.032
					153.181		18.46		19.957			133.22	5,876.289	
	IP62	9,228,365.0	436,070.5					177.76				-	5,876.289	-
					120.288		196.22		20.524			99.76	5,976.052	
	IP63	9,228,331.4	435,955.0	120		160.58					40.675	40.67	6,016.727	1.743
					148.274		35.64		20.524	74.096		53.65	6,070.381	
	IP64	9,228,245.0	435,834.5	400				159.00			146.601	146.60	6,216.982	6.805
					172.089		194.64		-	74.096		97.99	6,314.974	
	IP65	9,228,201.5	435,668.0			176.21					-	-	6,314.974	-
					17.393		18.44		-			17.39	6,332.367	
8	IP66	9,228,196.0	435,651.5					172.26				-	6,332.367	-
					91.591		190.70		29.276			62.32	6,394.683	
	IP67	9,228,179.0	435,561.5	700		175.21					58.545	58.55	6,453.228	0.612
					86.128		15.49		29.276	40.207		16.65	6,469.873	
	IP68	9,228,156.0	435,478.5	270				163.05			79.866	79.87	6,549.739	2.977
					126.779		212.44		59.676	40.207		26.90	6,576.635	
	IP69	9,228,088.0	435,371.5	480		165.82					118.799	118.80	6,695.434	3.695
					238.036		46.62		59.676	30.707		147.65	6,843.088	
	IP70	9,227,915.0	435,208.0	80				137.98			58.667	58.67	6,901.755	5.691
					87.281		184.60		41.516	30.707		15.06	6,916.813	
	IP71	9,227,908.0	435,121.0	280		163.12					82.471	82.47	6,999.284	3.061
					110.527		347.72		41.516	10.174		58.84	7,058.121	
	IP72	9,227,931.5	435,013.0	80				165.50			20.250	20.25	7,078.371	0.644
					54.041		182.23		19.550	10.174		24.32	7,102.687	
	IP73	9,227,929.4	434,959.0	400		174.40					39.088	39.09	7,141.775	0.477
					114.567		7.83		19.550			95.02	7,236.792	
	IP74	9,227,913.8	434,845.5	-								-	7,236.792	
									-			-		

1.3 Stability Analysis of Existing Revetment

Name of Structure	Existing Revetment	Category of calculation	Stability Analysis	Page	1/2

concrete weight

No.	shape	b	h	A	X	Y	Wc	M	Ic	Mi
		m	m	m2	m	m	t	tm	t	tm
1	triangle	0.125	2.5	0.16	0.08	0.83	0.36	0.03	0.040	-0.03
2	rectangular	0.35	2.5	0.88	0.30	1.25	2.01	0.60	0.221	-0.28
3	triangle	1.401	2.5	1.75	0.94	0.83	4.03	3.79	0.443	-0.37
	total						6.40	4.43	0.704	-0.68

earth pressure

	Coe	Pe	Peo	total	h	v	Mv	Mh
(normal)								
Ea	0.786	4.91	1.97	6.88	4.4	5.27	7.42	-3.7
Ep	1.995	3.12	0.00	3.12				
(earthquake)								
Ea	0.875	5.47	0.00	5.47	3.5	4.19	5.9	-2.9
Ep	2.340	7.31	0.00	7.31				

ϕ along the foundation 20

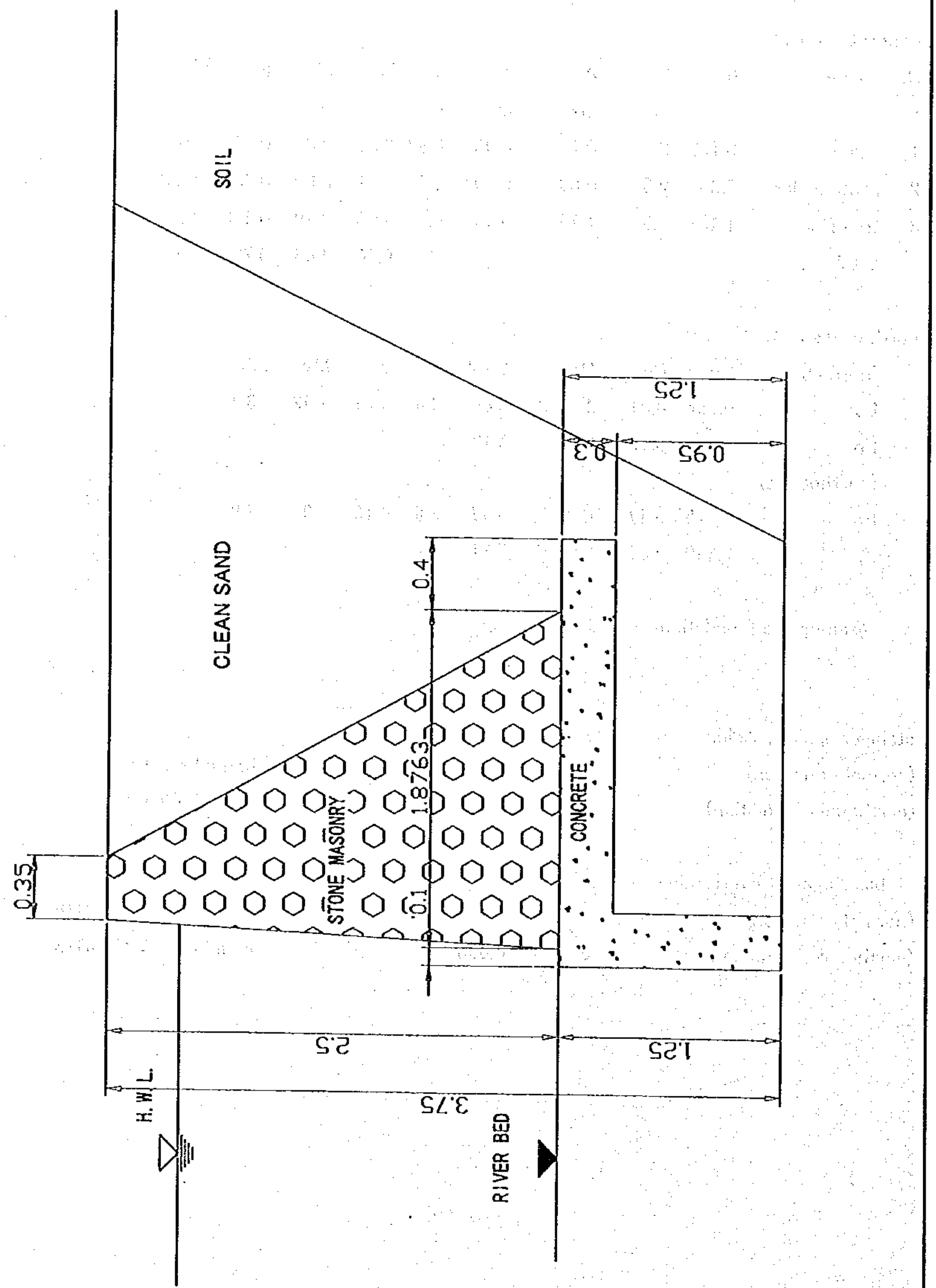
stability against sliding

(normal condition)	S.F.=	1.66	should be > 1.5
(earthquake condition)	S.F.=	2.64	should be > 1.2

stability against overturning

(normal condition)	e=	0.297	should be < 0.396=B/6
(earthquake condition)	e=	0.658	should be < 0.792=B/3

Name of Structure	Existing Revetment	Category of calculation	Stability Analysis	Page	2/2



CHAPTER 2
ASIN RIVER DRAINAGE SYSTEM IMPROVEMENT

2.1 Asin Pumping Station

2.1 Asin Pumping Station

2.1.1 Structural Calculation of Gate Leaf and Hoist

I) Design Conditions

1. Function of the gate

Dike

2. Top elevation of the gate

As the gate acts as a part of the dike of Semarang River, the top elevation of the gate should be identical to that of the dike at the point.

H.W.L. at No.31+8 is 0.426 m according to the hydraulic calculation.

In definitive plan the water level was assumed as 0.25+0.1+0.1=0.45m and pump station was designed.

As the free board is 0.6m at the point, the dike top elevation is +1.026m.
Taking the same freeboard, the gate top elevation is 0.45+0.6=1.05

Therefore, the top elevation of the gate should be **+1.05m**

3. Bottom elevation of the gate

Design river bed elevation of Semarang River at No.31+8 is -2.405m.
D.L.W.L. in Asin Retarding Pond is -2.5m.
The bottom elevation of the gate is made as low as the Semarang River bed.

Therefore, the bottom elevation of the gate should be **-2.41m**.

4 Height of the gate

According to 2 and 3 the height of the gate is **3.46m**

5 Design Water Level Semarang River Side

In definitive plan the water level was assumed as 0.25+0.1+0.1=0.45m and pump station was designed.
Same elevation shall be used for gate design.

Therefore, the design water level Semarang River Side is 0.45m.

6 Design Water Level Asin River Side

Identical to the bottom of the gate as the D.L.W.L. of Asin river is lower than the bottom of the gate.

Therefore, the design water level downstream is **-2.41m**.

7 Load Condition

(case-1) normal condition

hydraulic static load (U/S: +0.45m, D/S; -2.41m)

incremental coefficient: 1.00 (same as Japanese standard)

(case-2) seismic condition

hydraulic static load (U/S; +0.45m+0.10m, D/S; -2.41m)

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.

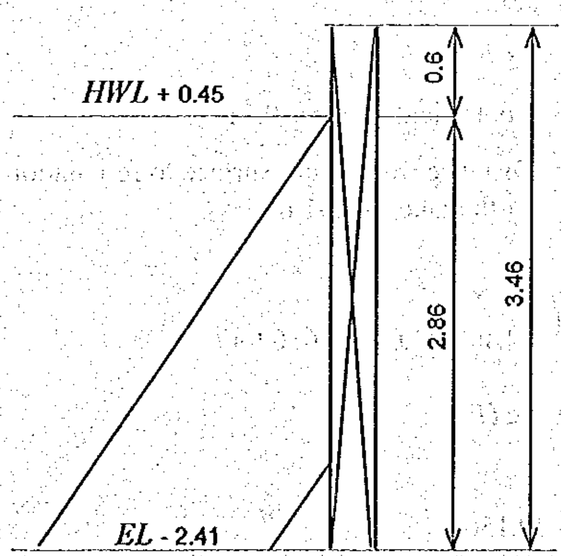
SPILLWAY GATE AND HOIST

I. DESIGN CONDITION

Type	:	Fixed wheel gate made of steel
Quantity	:	2 (two) sets
Clear span	:	4.0 m.
Gate height	:	3.46 m.
Hwl	:	EL. ± 0.45 m.
Sill elevation	:	EL. - 2.41 m.
Design head	:	2,860 m [(+ 0.45 - (-2.41 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 ± 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 ;

$$P_1 = \frac{1.0 \times 2.86^2 \times 4.0}{2}$$

$= 16.36\ tf.$

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 = 2.86 m.

B = Sealing span = 4.0 m.

$$Ps = \tfrac{1}{2} \times (0.1 + 2.86)^2 \times 4.0$$

$= 17.52\ ton.f$

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 ;

$$Pd = \tfrac{7}{12} \times 0.11 \times 4.51^{\frac{1}{2}} \times 2.86^{\frac{3}{2}} \times 4.0 = 2.636\ ton.f.$$

Total load during earthquake (P_2)

$$P_2 = P_s + P_d$$

$= 17.52 + 2.636 = 20.156$ t.

Thus ;

$P_1 \langle P_2$

16.36 tf $\langle$ 20.156 tf.

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

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

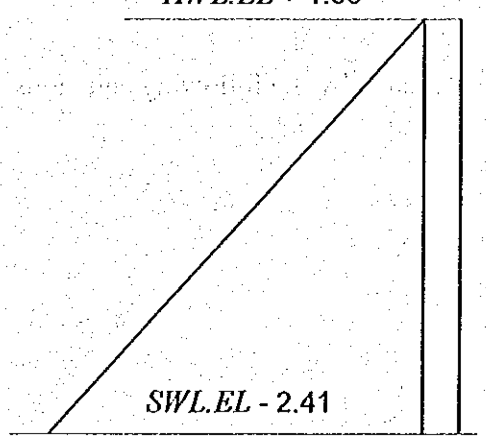
$$20.156 = \frac{1.0 \times H_0^2 \times 4.0}{2}$$

$$H_0 = \sqrt{\frac{20.156 \times 2}{1.0 \times 4.0}}$$

$$= 3.175 \text{ m.}$$

Thus : Design head of water is determined 3.46 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 = 3.46 m.

B = Sealing span = 4.0 m

W_0 = 1.0 t/m³

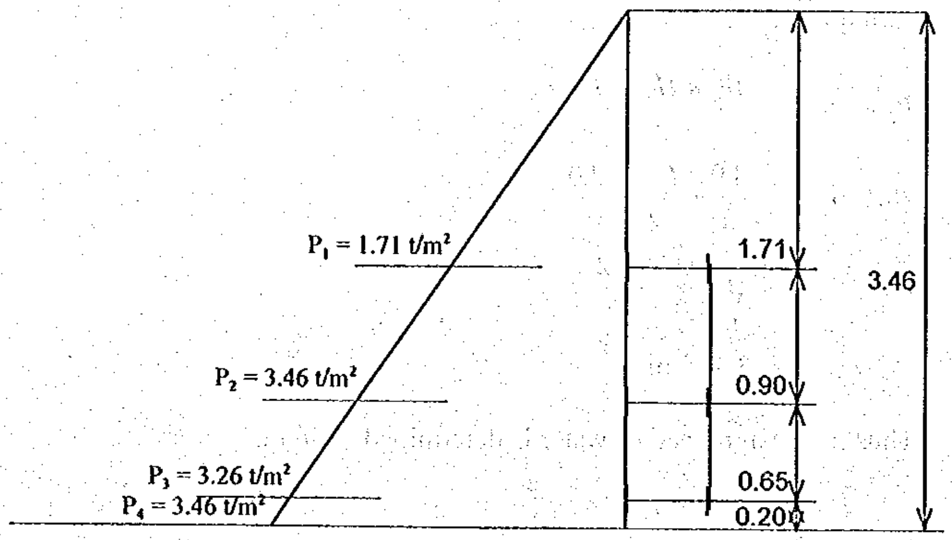
$$P = \frac{1.0 \times 3.46^2 \times 4.0}{2}$$

$$= 23,943 \text{ tf}$$

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

$$P_A = 0.5\times 1.71^2+\frac{0.9\times(2\times 1.71+2.61)}{6} = 2.366\ tf/m$$

Beam B

$$P_B = \frac{0.9\times(1.71+2\times 2.61)}{6}+0.65\times\frac{(2\times 2.61+3.26)}{6} = 1.959\ tf/m$$

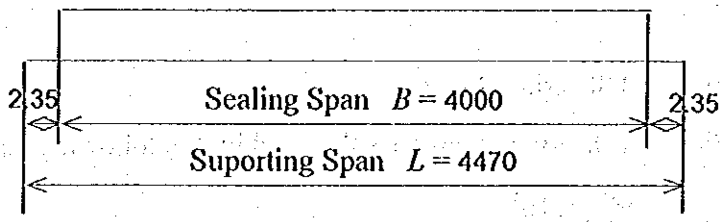
Beam C

$$P_C = 0.65\times\frac{(2.61+2\times 3.26)}{6}+0.5\times(3.26+3.46)\times 0.2 = 1.661\ tf/m$$

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*)

$= P_A \times B$

$= 2.366 \times 4.0 = 9.464$ *tf*

L = Supporting length 4.47 m

B = Sealing span = 4.0 mt.

$$M_{max} = \frac{9.464 \times (2 \times 4.47 - 4.0)}{8}$$

$= 5.844$ *tf*-m

3.2. Shearing Force.

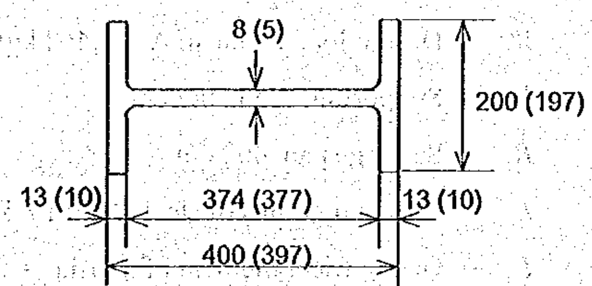
Maximum shearing force is calculated by the following equation ;

$$S_{max} = \frac{9.464}{2}$$

$= 4.732$ *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	$= 16{,}988\ cm^4$
Modulus section	Z	$= 855.8\ cm^3$
Area of web at both end	AW	$= 18.85\ cm^2$
Area	A	$= 58.25\ cm^2$

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/cm^2)

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

Z = Modulus of section (cm^3)

τ_{max} = Maximum shearing stress (kg$f$/cm^2)

S_{max} = Maximum shearing force (tf)

AW = Area of web at both end.

Thus ;

$$\sigma b_{max} = \frac{5.844 \times 10^5}{855.8} = 683\ kg.f/cm^2\ \langle\ 1{,}200\ kgf/cm^2$$

$$\tau_{max} = \frac{4.732 \times 10^3}{18.85} = 251\ kgf/cm^2\ \langle\ 700\ kgf/cm^2$$

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$f$/cm^2

I = Geometrical moment of inertia = 20,299 cm^4

Thus ;

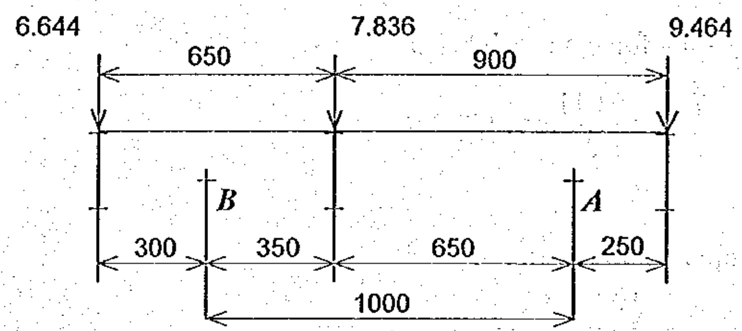
$$\partial = 0.611 \times \frac{W}{I} = 0.611 \times \frac{9,464}{16,988} = 0.34$$

$$\frac{\partial}{L} = \frac{1}{1315} \langle \frac{1}{800} \text{ (allowable deflection)}$$

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*

$9.464 \times 0.25 - 7.832 \times 0.65 + RB \times 1.0 - 6.644 \times 1.3 = 0$

$2.366 - 5.091 + RB - 8.637 = 0$

$RB = 11.362\ tf$

$RA = 23.944 - 11.362 = 12.582\ tf$

Distributed load on each main wheel.

$RA' = RA/2 = 12.582/2 = 6.291\ tf$

$RB' = RB/2 = 11.362/2 = 5.681\ tf$

3. Bending Moment and Shearing Force.

3.1. Bending Moment.

$M_1 = 0$

$M_2 = 9.464 \times 0.25 = 2.366\ tf.m$

$M_3 = 9.464 \times 0.9 - 12.582 \times 0.65 = 0.3393\ tf.m$

$M_4 = 6.644 \times 0.3 = 1.993\ tf.m$

Maximum Bending Moment ;

$$M_{max} = \frac{M_3}{2} = \frac{2.366}{2} = 1.183\ tf.\text{m}$$

3.2. Shearing Force.

$S_1 = 9.464\ tf.$

$S_2 = 9.464 - 12.582 = 3.118\ tf.$

$S_3 = 9.464 - 12.582 + 7.836 = 4.718\ tf.$

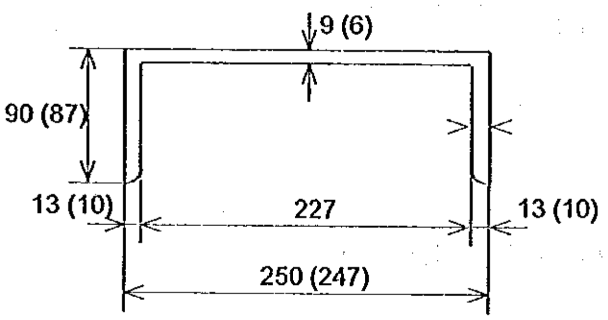
$S_4 = 9.464 - 12.582 + 7.836 - 11.362 = -6.644\ tf.$

$S_5 = 6.644\ tf.$

Max shearing force on each beam

$$S_{max} = \frac{S_4}{2} = \frac{6.644}{2} = 3.322\ tf.$$

4. Sectional Property of End Beam



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

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

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

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

5. Bending and Shearing Stress

Bending stress (σb)

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

$$= \frac{1.183 \times W^5}{245.3} = 482\ \text{kg}f/\text{cm}^2 \ \langle\ 1{,}200\ \text{kg}f/\text{cm}^2$$

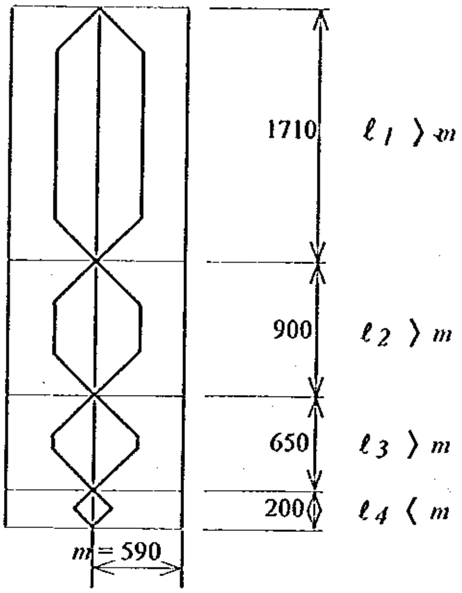
Shearing Stress (τs)

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

$$= \frac{3.322 \times W^3}{14.82} = 224\ \text{kg}f/\text{cm}^2 \ \langle\ 700\ \text{kg kg}f/\text{cm}^2$$

V. VERTICAL GIRDER

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



1.1. $\ell > m$

Bending moment

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

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	1.71	0.855	0.1770	0.357
2.	0.59	0.90	2.160	0.1110	0.386
3.	0.59	0.65	2.935	0.0660	0.307
4.	0.59	0.20	3.360	0.0066	0.099

Maximum bending moment on vertical beam

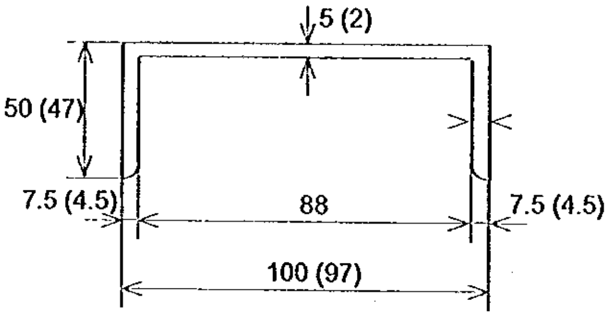
$M_{max} \;=\; 0.177\ tf\text{-m}$

Maximum shearing force

$S_{max} \;=\; 0.386\ tf$

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)

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

$$= \frac{0.177 \times 10^5}{21.0} = 843\ kg.f/cm^2 \ \langle\ 1{,}200\ kg.f/cm^2$$

Shearing Stress (τs)

$$\tau s = \frac{0.386 \times 10^3}{1.94} = 199\ kg/cm^2 \ \langle\ 700\ kg.f/cm^2$$

VI. SKIN PLATE

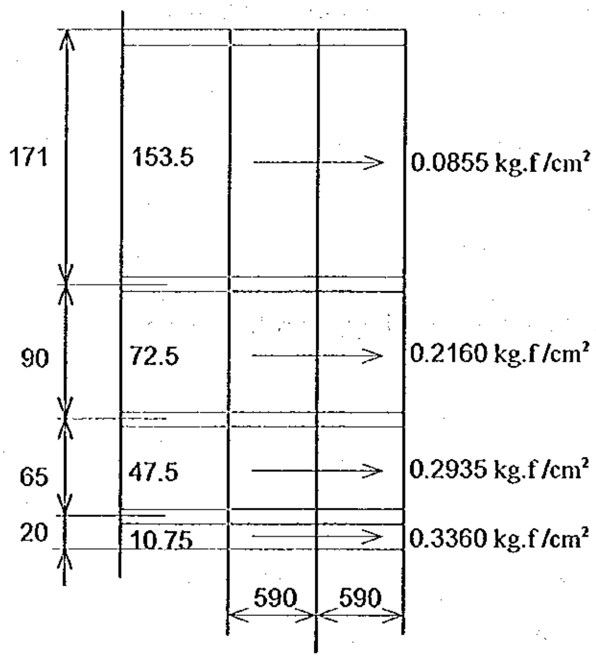
Bending stress of skin plate is calculated in accordance with following Timoshenko's formula.

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

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	l	$l+\varepsilon$
1.	1 - 2	59.00	153.50	2.60	50.00	0.0855	0.35	0.65
2.	2 - 3	59.00	72.50	1.23	39.80	0.2160	0.50	0.80
3.	3 - 4	47.50	59.00	1.24	40.10	0.2935	0.47	0.77
4.	4 - 5	10.75	59.00	5.49	50.00	0.3360	0.13	0.43

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 $= 2.1 \times 10^6$ kg.f/cm²

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.

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

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

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

$m = 3.280 \qquad n = 0.446$

$$a = 1.109 \times 3.280 \times \sqrt[3]{\frac{6,291}{0.0349 \times 2.1 \times 10^6}} = 1.604 \text{ cm.}$$

$$b = 1.109 \times 0.446 \times \sqrt[3]{\frac{6.291}{0.0349 \times 2.1 \times 10^6}} = 0.218 \text{ cm.}$$

$$p = \frac{3}{2 \times \pi} \times \frac{6,291}{1.604 \times 0.218} = 8590 \text{ kg.}f/\text{cm}^2$$

Allowable contact stress (pa)

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

where ; pa = Allowable contact stress (kg.f/cm²)

V = Safety factor = 1.0

HB = Brinell hardness

= 185 kg.f/cm²

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

Thus ;

$pa = 9{,}250 \text{ kg.f/cm}^2 > 8{,}950 \text{ kg.f/cm}^2$

$Z = \beta \times b \rightarrow \qquad \beta = a/b = \dfrac{1.604}{0.218} = 7.357 \approx 7.4$

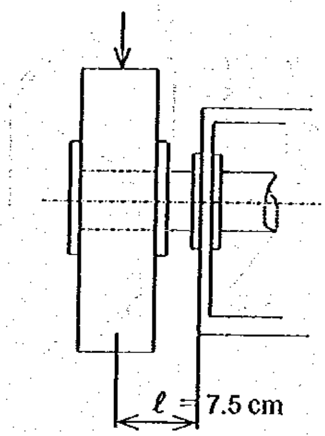
$= 0.90 \times 0.218 \qquad \beta = 0.90$

$= 0.196 \text{ cm}$

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

$T = 4 \times 0.196 = 0.78 \text{ cm} \approx 10.0 \text{ mm.}$

2. Shaft.



Maximum bending moment

$M_{max} = p \times \ell$

$= 6{,}291 \times 7.5$

$= 47{,}182.5 \text{ kg.f-cm}$

Material of shaft

SUS.304 (jis G.4303)

Allowable stress (σb)

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

Diameter of shaft (d)

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

$$= \sqrt[3]{\frac{32 \times 47{,}182.5}{\pi \times 1060}} = 7.68 \text{ cm} \approx 80 \text{ mm.}$$

Rechecking of bending and shearing stress

Section modulus (Z)

$$Z = \frac{\pi}{32} \times d^3 = \frac{\pi}{32} \times d^3 = 50.26 \text{ cm}^3$$

Bending stress (σb)

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

$$= \frac{47{,}182.5}{50.26} = 938.8 \text{ kg.f/cm}^2 < 1{,}060 \text{ kg.f/cm}^2$$

Shearing stress (τs)

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

$$= \frac{4 \times 6{,}291}{\pi \times 8.0^2} = 125 \text{ kg.}f/\text{cm}^2 \;\langle\; 0.6 \times 1{,}060 \text{ kg.}f/\text{cm}^2$$

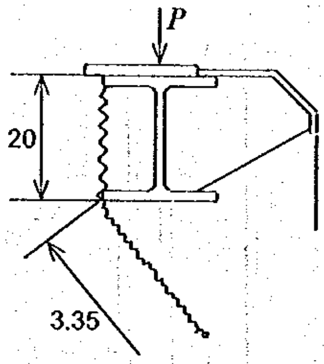
VIII. GUIDE FRAME

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 = 6,291 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

$$K = 0.0588 \times \frac{6{,}291}{\sqrt[3]{20^2 \times 4720}}$$

$$= 2.99 \text{ kg.}f/\text{cm}^2 \;\langle\; 50 \text{ kg.}f/\text{cm}^2$$

$$a = 0.75 \times \frac{6{,}291}{2.99 \times 20} = 78.90 \text{ cm.}$$

Bending moment on track frame (M)

$$M = \frac{2.99 \times 78.90^2 \times 20}{4} = 93{,}066.9 \text{ kg.}f\text{-cm}$$

Bending stress of track frame.

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

$$= \frac{93{,}066.9}{472} = 197 \text{ kg.}f/\text{cm}^2 \ \langle \ 1200 \text{ kg.}f/\text{cm}^2$$

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 ;

$$\tau c = \frac{2.99 \times 20}{67.37}$$

$$= 0.89 \text{ kg.}f/\text{cm}^2 \ \langle \ 8.0 \text{ kg.}f/\text{cm}^2$$

IX. OPERATING LOAD

1. Operating Condition.

The gate is normally closed and is designed to raise under water head 2.86 m.

2. Operation Load.

2.1. Weight of gate (wg) = 4.5 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 = 23.943 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 4.0 cm

R = Radius of wheel 15 cm

Thus ;

2.2.1. At Raising.

$$FwR = \frac{23.943 \times (0.1 + 0.2 \times 4.0)}{15}$$

$$= 1.436 \ tf$$

2.2.2. At Lowering

$$FwL = \frac{23.943 \times (0.1 + 0.1 \times 4.0)}{15}$$

$$= 0.798 \ tf$$

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 = 1.73 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 = 6.92 m.

Thus ;

2.3.1. At Raising

$$FrR = 1.5 \times (0.05 + 1.730 \times 0.05) \times 6.92$$
$$= 1.417\ tf$$

2.3.2. At Lowering

$$FrL = 0.7 \times (0.05 + 1.730 \times 0.05) \times 6.92$$
$$= 0.661\ tf$$

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 = 3.460 m

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

Thus ;

$$Fd = 0.15 \times 1.0 \times 3.460 \times 0.96 = 0.498 \text{ ton.}$$

2.5. Total Operation Load.

Description	Raising	Lowering
- Gate weight (Wg)	+ 4.500	+ 4.500
- Friction force due to main roller (Fw)	+ 1.436	- 0.798
- Friction force due rubber seal (Fr)	+ 1.417	- 0.661
- Down pull force (Fd)	+ 0.498	- 0.498
Total =	7.851	2.543

Thus ;

Operating Load

Raising (incl. allowable) = 8.0 ton$f$

Lowering = 3.0 ton$f$

X. HOISTING EQUIPMENT

Hoisting Load (Fo) = 8.0 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 (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 = 8.0 tf

W = Number of falls = 4

η_s = Sheave effy. = 0.95

$$= \frac{8.0}{4 \times (0.95)^2} = 2.216 \text{ ton}f/\text{drum}$$

1.3. Selection of Wire Rope

6×37 galvanized wire rope per JIS G.3525 Class A wire rope diameter $\{Dr\}$ = 20 mm

Breaking load = 21.6 ton$f$

Safety factor $= 21.6/2.216 = 9.75 \rangle 8$

2. **Shaeve.**

2.1. Diameter of sheave

$Ds = 17 \times Dr$ Where ;

Ds = Diameter of sheave

Dr = Diameter of wire rope = 20 mm

$= 17 \times 20 = 340$ 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

$= 19 \times 20 = 380$ 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

$$Nd_{i} = (Vo \times Ns) / (\pi \times Dd)$$

Where ;

Nd = Drum revolution per minute (Rpm)

Vo = Operating speed 0.3 m/min

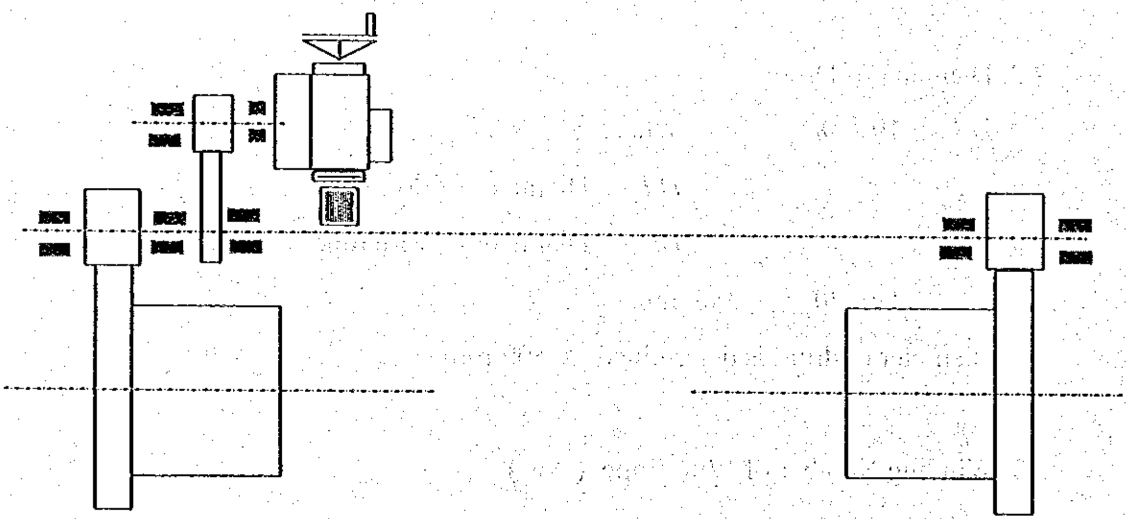
Ns = Number of wire rope falls on each side = 2

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

$$tR = \frac{Nd}{Nm}$$

Where ;

tR = Required Gear Ratio

Nd = Rpm of drum = 0.382 Rpm.

Nm = Full load Rpm of motor = 1420 Rpm.

$$tR = \frac{0.382}{1420}$$

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

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 ;

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

$$= 0.298 \text{ m/min}$$

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 $(M\eta) = 0.3225$

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

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

$$= 1.21 \text{ ton} \times 1.5 = 1.8 \text{ KW.}$$

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 = 2.216 ton.f
$R.Drum$	=	Drum Radius = 0.25 m.
η	=	Drum efficiency = 0.95
nd	=	Number of drum = 2

$$TD = \frac{2.216 \times 0.25}{0.95} \times 2$$

$= 1.166$ ton.f-m

$= 1,166$ 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 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 ;

$$F = \frac{1,166}{2,246.16 \times 0.2437 \times 0.23}$$

$= 9.26$ kg.f 〈 10 kg.f

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