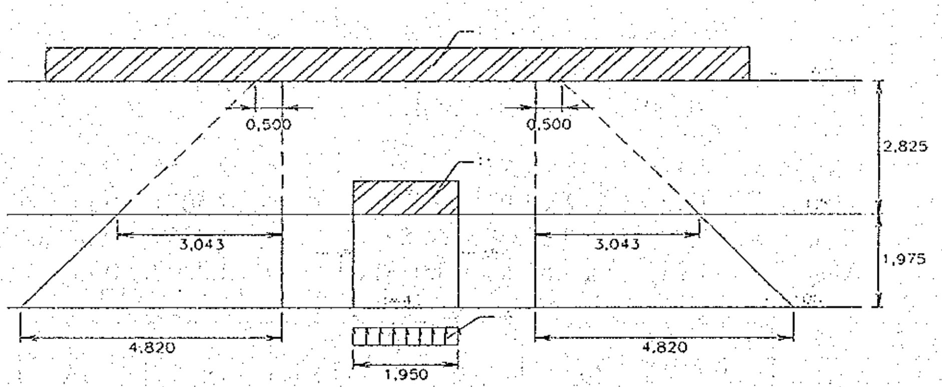
CHAPTER 6. DRAINAGE SLUICEWAY AND OUTLET WORKS

6.1 Drainage Sluiceway at WF.172R+15.0m

6.1.1 Standard Box Culvert

(a) Normal Condition



Load Diagram for Normal Case

Uniform Load

Weight of live load			= 1.0	tf/m^2
Weight of soil	=	2.65 x 1.8	= 4.77	tf/m^2
Weight of top slab	=	0.35 x 2.5	= 0.875	tf/m^2
			= 6.645	tf/m^2

Reaction Subgrade

Weight of live load	=	2.30 x 1	= 2.30	tf/m
Weight of soil	=	2.65 x 2.30 x 1.8	= 10.971	tf/m
Weight of top slab	=	0.35 x 2.3 x 2.5	= 2.013	tf/m
Weight of wall	=	2 x (0.35 x 1.6 x 2.5)	= 2.80	tf/m
Weight of other concrete	=	$4 \times \frac{0.15 \times 0.15}{2} \times 2.5$	= 0.113	tf/m
			= 18.197	tf/m

$$q_K = \frac{18.197}{2.30} = 7.912 \ t/m^2$$

$$\mu_{AB} = \frac{\frac{1}{12} \times 1 \times 0.35^2 E}{1.95} = 0.001832E$$

$$\mu_{DC} = \frac{\frac{1}{12} \times 1 \times 0.4^3 E}{1.95} = 0.002735$$

Joint A

$$k_{AB} = \frac{0.001832E}{0.001832E + 0.001809E} = 0.5032$$

$$k_{AD} = \frac{0.001809E}{0.001832E + 0.001809E} = 0.4968$$

Joint D

$$k_{DA} = \frac{0.001809E}{(0.001809E + 0.002735)E} = 0.3981$$

$$k_{DC} = \frac{0.002735E}{(0.001809E + 0.002735)E} = 0.6019$$

$M_{AB} = -M_{BA} = 1/12 \times 6.645 \times 1.95^2 = 2.1056$ tf m
$M_{DC} = -M_{CD} = 1/12 \times 7.912 \times 1.95^2 = 2.5071$ tf m
$M_{DA} = M_{CB} = 1.975^2 (2 \times 3.043 + 3 \times 4.82)/60 = 1.3357$ tf m
$M_{AD} = M_{BC} = 1.975^2 (2 \times 4.82 + 3 \times 3.043)/60 = 1.2202$ tf m

A		B		C		D	
AD	AB	BA	BC	CB	CD	DC	DA
0.4968	0.5032	0.5032	0.4968	0.3981	0.6019	0.6019	0.3981
+1.2202	-2.1056	2.1056	-1.2202	1.3354	-2.5071	+2.5071	-1.3354
+0.4399	+0.4455	+0.2228	+0.2332	+0.4665	+0.7052	+0.3526	+0.2199
-0.3472	-0.3375	-0.6750	-0.6664	-0.3332	-0.5249	-1.0498	-0.6944
+0.3402	+0.3445	+0.1723	+0.1708	+0.3416	+0.5165	+0.2582	+0.1701
-0.0853	-0.0863	-0.1726	-0.1705	-0.0852	-0.1289	-0.2578	-0.1705
+0.0853	+0.0863	+0.0432	+0.0426	+0.0852	+0.1289	+0.0644	+0.0426
-0.0213	-0.0216	-0.0432	-0.0426	-0.0213	-0.0332	-0.0644	-0.0426
+0.0213	+0.0216	+0.0108	+0.0106	+0.0213	+0.0322	+0.0161	+0.0107
-0.0053	0.0054	-0.0108	-0.0106	-0.0053	-0.0081	-0.0161	-0.0107
+0.0053	+0.0054	+0.0027	+0.0027	+0.0053	+0.0081	+0.0040	+0.0027
		-0.0027	-0.0027			+0.0040	-0.0027
1.6531	-1.6531	+1.6531	-1.6531	+1.8103	-1.8103	+1.8103	-1.8103

Top Slab AB

$S_{AB} = \frac{1}{2} \times 1.95 \times 6.645 = 6.479$ tf

$M_{max} = \frac{1}{8} \times 6.645 \times 1.95^2 - 1.6531 = 1.5054$ tf m

Bottom Slab BC

Bottom Slab BC

S_{CD} = ½ x 1.95 x 7.912 = 7.714 t

M_{max} = $^1/_8$ x 7.912 x 1.95^2 – 1.8103 = 1.9504 tf.m

Wall AD

$$S_{AD} = \frac{(2 \times 3.043 + 4.82) \times 1.975}{6} - \frac{1.8103 - 1.6531}{1.975} = 3.5103$$

$$S_{BA} = \frac{(2 \times 4.82 + 3.043) \times 1.975}{6} - \frac{1.6531 - 1.8103}{1.975} = 4.2544$$

$$S = 0 \rightarrow \quad 3.5103 - 3.043\,x - \frac{4.82 - 3.043}{2 \times 1.975}\,x^2 = 0$$

$$3.51031 - 3.043\,x - 0.449\,x^2 = 0$$

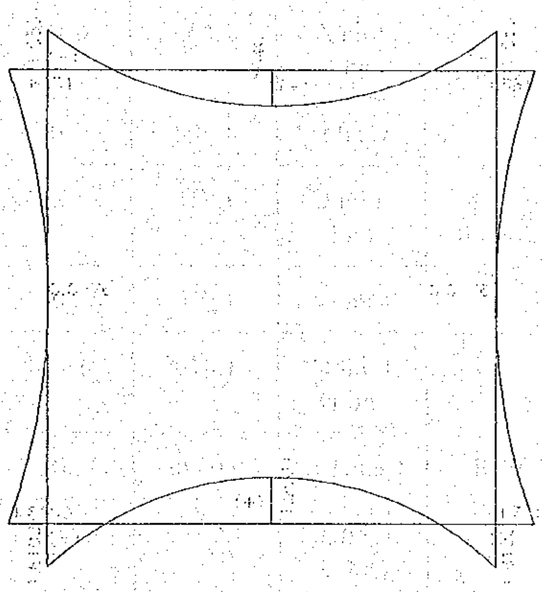
$$x^2 + 6.764\,x - 7.8024 = 0$$

$$x = \frac{-6.764 \pm \sqrt{6.764^2 + 4 \times 7.8024}}{2}$$

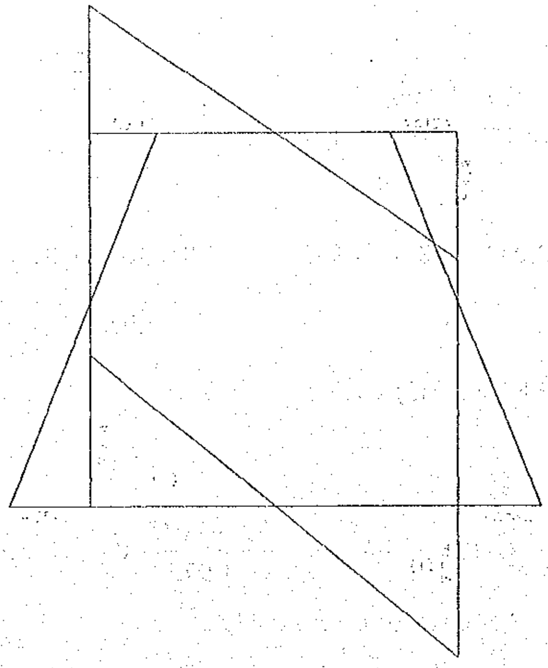
$$x = 1.0041 \text{ m}^2$$

$$M_{max} = 3.5103 \times 1.0041 - \frac{3.043}{2} \times 1.0041^2 - \frac{4.82 - 3.042}{6 \times 1.975} \times 1.0041^3 - 1.6531$$

= +0.0376 tf.m



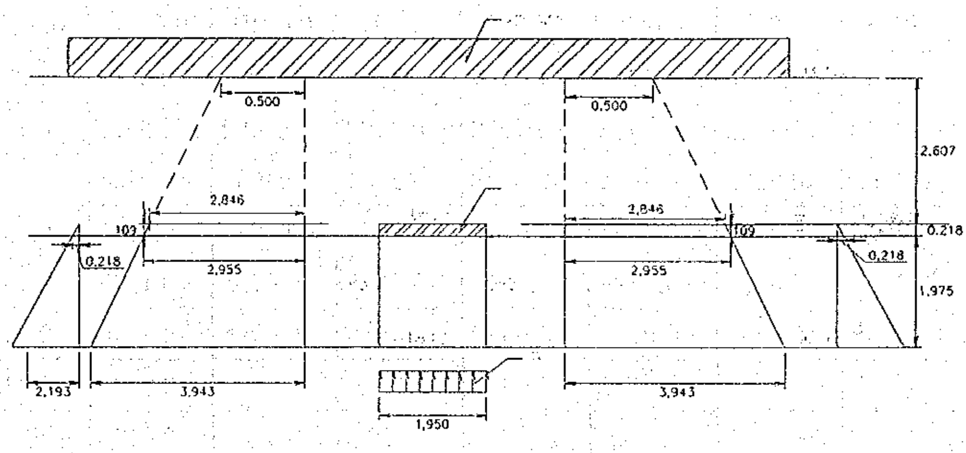
Bending Moment Diagram for Normal Case



Shearing Force Diagram for Normal Case

Location		Bending Moment (tf.m)	Shearing Force (tf)	Axial load (tf)
Top Slab	Join A and B	1.653	6.476	3.510
	Center	1.504	0	3.510
Bottom Slab	Joint C and D	1.810	7.714	4.254
	Center	1.950	0	4.254
Wall	Joint C and D	1.810	4.254	7.414
	Center B	0.0376	0	6.947
	Joint A and B	1.6531	3.510	6.479

(b) Flooding Case



Load Diagram for Flooding Case

Uniform Load

Weight of live load		= 1	tf/m^2
Weight of soil	= 2.65 x 1.8	= 4.77	tf/m^2
Weight of top slab	= 0.35 x 2.5	= 0.875	tf/m^2
		= 6.645	tf/m^2

Reaction Subgrade

Weight of live load	= 2.30 x 1	= 2.30	tf/m
Weight of soil	= 2.65 x 2.30 x 1.8	= 10.971	tf/m
Weight of top slab	= 0.35 x 2.3 x 2.5	= 2.013	tf/m
Weight of wall	= 2 x (0.35 x 1.6 x 2.5)	= 2.80	tf/m
Weight of other concrete	= $4 \times \frac{0.15 \times 0.15}{2} \times 2.5$	= 0.113	tf/m
		= 18.197	tf/m

$$q_K = \frac{18.197}{2.30} = 7.612 \ t/m^2$$

M_{AB} = M_{BA} = $1/12 \times 6.645 \times 1.95^2$ = 2.1056 tf m

M_{DC} = $-M_{CD}$ = $1/12 \times 7.912 \times 1.95^2$ = 2.5071 tf m

M_{DA} = M_{CB} = $1.975^2 \times \{2 \times (2.9553 + 0.213) + 3\,(3.9428 + 2.193)\}/60$ = 1.6086

M_{AD} = M_{BC} = $1.975^2 \times \{2 \times (3.9428 + 2.193) + 3\,(3.9553 + 0.213)\}/60$ = 1.4157

A		B		C		D	
AD	AB	BA	BC	CB	CD	DC	DA
0.4968	0.5032	0.5032	0.4968	0.3981	0.6019	0.6019	0.3981
+1.4157	-2.1056	2.1056	-1.4157	+1.6086	-2.5071	0.6019	-1.6086
+0.3428	+0.3472	+0.1736	+0.1788	+0.3577	+0.5408	2.5071	+0.1714
-0.2668	-0.2622	-0.5245	-0.5178	-0.2589	-0.4033	+0.2704	-0.5336
+0.2628	+0.2662	+0.1331	+0.1318	+0.2636	+0.3986	-0.8067	+0.1314
-0.0658	-0.0666	+0.1333	+0.1316	-0.0658	-0.0995	+0.1993	-0.1317
+0.0658	+0.0666	+0.0333	+0.0329	+0.0658	+0.0995	-0.1990	+0.0329
		-0.0333	-0.0329			+0.0497	-0.0329
						-0.0497	
+1.7545	-1.7545	+1.7545	-1.7545	+1.9711	-1.9711	+1.9711	1.9711

Top Slab BC

$S_{AB} = \frac{1}{2} \times 1.95 \times 6.645 = 6.479$ tf

$M_{max} = \frac{1}{8} \times 6.645 \times 1.95^2 - 1.7545 = 1.4040$ tf.m

Bottom Slab

$M_{CD} = \frac{1}{2} \times 1.95 \times 7.912 = 7.714$ t

$M_{max} = \frac{1}{8} \times 7.912 \times 1.95^2 - 1.9711 = 1.7896$ tf.m

Wall

$$AB = \frac{2(2.9553+0.218)+(3.9428+2.193)}{6} \times 1.975 - \frac{(1.9711-1.7545)}{1.975} = 3.999$$

$$BA = \frac{2(3.428+2.193)+(2.9553+0.218)}{6} \times 1.975 - \frac{(1.7545-1.9711)}{1.975} = 5.1936$$

$$S = 0 \rightarrow 3.9991-(2.9553+0.218)x - \{(3.9428+2.198) - (2.9553+0.218)\}x^2 = 0$$

$$3.9991 - 3.1733\,x - 0.7513\,x^2 = 0$$

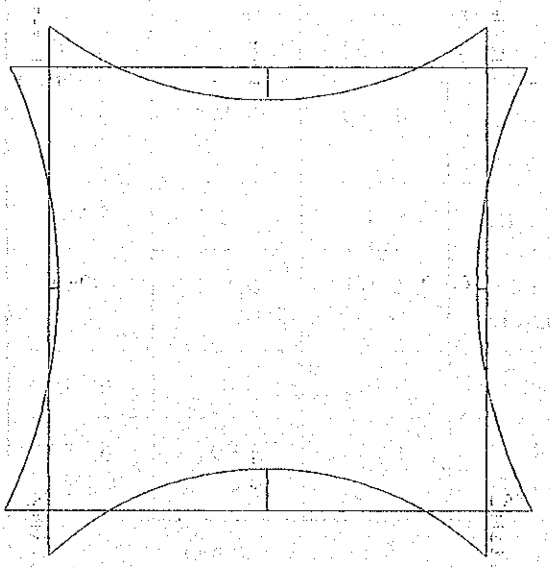
$$x^2 + 4.2239\,x - 5.323 = 0$$

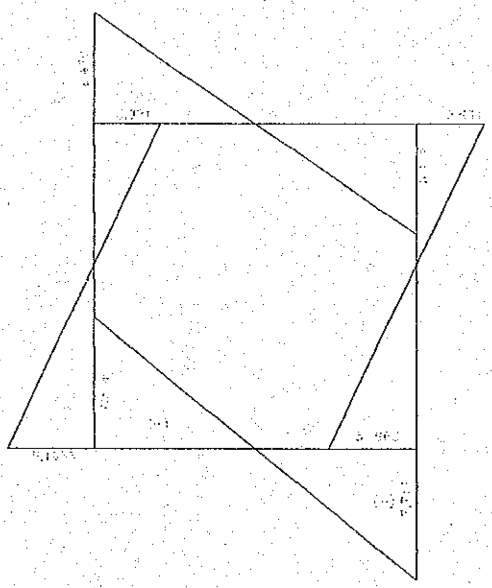
$$x = \frac{-4.2239 \pm \sqrt{4.2239^2 + 4 \times 5.323}}{2}$$

$$x = 1.0159 \text{ m}^2$$

$$M_{max} = 3.9991 \text{ x } 1.0159 - \frac{(2.9553 + 0.218)}{2} \text{ x } x^2$$

$$- \frac{(3.9428 + 2.198) - (2.9553 + 0.218)}{6 \times 1.975} \times x^3 - 1.7545 \quad = \quad 0.4081 \quad \text{tf}$$





Location		Bending Moment (tf.m)	Shearing Force (tf)	Axial load (tf)
Top Slab	Join A and B	1.7545	6.479	3.991
	Center	1.404	0	3.991
Bottom Slab	Joint C and D	1.789	7.414	5.194
	Center	0	0	5.194
Wall	Joint C and D	1.971	5.194	7.414
	Center B	0.408	0	6.947
	Joint A and B	1.754	3.991	6.479

Item	Unit	Normal Condition	Flood Condition
Top Slab			
S_{max}	kgf	6479	6479
h	cm	26	26
$\tau = \dfrac{S}{7/8 \times 100 \times h}$	kgf/cm²	2.878	2.878
Bottom Slab			
S_{max}	kgf	7414	7414
h	cm	31	31
$\tau = \dfrac{S}{7/8 \times 100 \times h}$	kgf/cm²	2.733	2.733
Wall			
S_{max}	kgf	4254	5194
h	cm	26	26
$\tau = \dfrac{S}{7/8 \times 100 \times h}$	kgf/cm²	1.870	2.283
All of $\tau \leq \bar{\tau} = 7.5$	kgf/cm²		

Top Slab (Joint A and B)

Description	Unit	Flood Condition	Normal Condition
M	tfm	1.755	1.653
N	t	3.991	3.510
ht	m	0.35	0.35
h	m	0.26	0.26
LK		1.95	1.95
eo_1 = M/N	m	0.440	0.471
eo_2 = 1/30 ht and ≥ 0.02 m	m	0.020	0.02
$eo = eo_1 + eo_2$	m	0.460	0.491
eo/ht	-	1.314	1.403
C_2	-	7	7
$e_1 = C_2 \left(\frac{ek}{100\,ht} \right)^2 \times ht$	m	0.008	0.008
e_2 = 0.5 x ht	m	0.053	0.053
$e = eo + e_1 + e_2$	m	0.520	0.551
$ea = eo + \frac{1}{2}ht - d$	m	0.605	0.636
$N \cdot ea$	tfm	2.414	2.233
$Ca = \frac{h}{\sqrt{\frac{n \cdot N \cdot ea}{b \cdot \sigma a}}}$	-	5.465	5.683
δ	-	0	0
ϕ	-	3.243	3.395
nw	-	0.0363	0.0335
ζ	-	0.914	0.924
i	-	1.656	1.607
iA	cm^2	6.297	5.807
A	cm^2	3.803	3.613

Used D16 a 250 → A = 8.042 cm^2

Top Slab (Center)

Description	Unit	Flood Condition	Normal Condition
M	tfm	1.404	1.504
N	t	3.991	3.510
ht	m	0.35	0.35
h	m	0.26	0.26
LK		1.975	1.975
$eo_1 = M/N$	m	0.352	0.428
$eo_2 = 1/30$ ht and ≥ 0.02 m	m	0.02	0.02
$eo = eo_1 + eo_2$	m	0.372	0.448
eo/ht	-	1.062	1.281
C_2	-	7	7
$e_1 = C_2 \left(\frac{ek}{100\,ht} \right)^2 \times ht$	m	0.008	0.008
$e_2 = 0.5 \times ht$	m	0.053	0.53
$e = eo + e_1 + e_2$	m	0.432	0.509
$ea = eo + \frac{1}{2} ht - d$	m	0.517	0.594
$N \cdot ea$	tfm	2.064	2.084
$Ca = \dfrac{h}{\sqrt{\dfrac{n \cdot N \cdot ea}{b \cdot \sigma a}}}$	-	5.911	5.882
δ	-	0	0
ϕ	-	3.555	3.534
nw	-	0.031	0.0312
ζ	-	0.927	10.926
i	-	1.873	1.683
iA	cm^2	5.353	5.408
A	cm^2	2.858	3.214

Used D16 a 250 → A = 8.042 cm^2

Bottom Slab Joint C and D

Description	Unit	Flood Condition	Normal Condition
M	tfm	1.971	1.810
N	t	5.194	4.254
ht	m	0.40	0.40
h	m	0.31	0.31
LK		1.95	1.95
$eo_1 = M/N$	m	0.379	0.425
$eo_2 = 1/30$ ht and ≥ 0.02 m	m	0.02	0.02
$eo = eo_1 + eo_2$	m	0.399	0.445
eo/ht	-	0.999	1.114
C_2	-	6.99	7
$e_1 = C_2 \left(\frac{ek}{100\,ht} \right)^2 \times ht$	m	0.007	0.007
$e_2 = 0.5 \times ht$	m	0.06	0.06
$e = eo + e_1 + e_2$	m	0.466	0.512
$ea = eo + ½\,ht - d$	m	0.576	0.622
$N \cdot ea$	tfm	2.992	2.647
$Ca = \frac{h}{\sqrt{\frac{n \cdot N \cdot ea}{b \cdot \sigma a}}}$	-	5.853	6.223
δ	-	0	0
ϕ	-	3.514	3.776
nw	-	0.0312	0.028
ζ	-	0.926	0.930
i	-	1.993	1.864
iA	cm^2	6.514	5.736
A	cm^2	3.268	3.078

Used D16 a 250 $\rightarrow$ A = 8.042 cm^2

Bottom Slab (Center)

Description	Unit	Flood Condition	Normal Condition
M	tfm	1.790	1.950
N	t	5.194	4.251
ht	m	0.40	0.40
h	m	0.31	0.31
LK		1.95	1.95
$eo_1 = M/N$	m	0.345	0.459
$eo_2 = 1/30$ ht and ≥ 0.02 m	m	0.02	0.02
$eo = eo_1 + eo_2$	m	0.365	0.479
eo/ht	-	0.912	1.197
C_2	-	6.99	7
$e_1 = C_2 \left(\frac{ek}{100\,ht} \right)^2 \times ht$	m	0.007	0.007
$e_2 = 0.5 \times ht$	m	0.06	0.06
$e = eo + e_1 + e_2$	m	0.431	0.545
$ea = eo + \frac{1}{2} ht - d$	m	0.541	0.655
$N \cdot ea$	tfm	2.811	2.786
$Ca = \frac{h}{\sqrt{\frac{n \cdot N \cdot ea}{b \cdot \sigma a}}}$	-	6.038	6.066
δ	-	0	0
ϕ	-	3.644	3.663
nw	-	0.0295	0.0293
ζ	-	0.928	0.929
i	-	2.135	1.783
iA	cm^2	6.106	6.049
A	cm^2	2.860	3.392

Used D16 a 250 $\rightarrow$ A = 8.042 cm^2

Wall (Joint D and C)

Description	Unit	Flood Condition	Normal Condition
M	tfm	1.971	1.810
N	t	7.414	7.414
ht	m	0.35	0.35
h	m	0.26	0.26
LK		1.975	1.975
$eo_1 = M/N$	m	0.266	0.266
$eo_2 = 1/30$ ht and ≥ 0.02 m	m	0.02	0.02
$eo = eo_1 + eo_2$	m	0.286	0.286
eo/ht	-	0.817	0.817
C_2	-	6.98	6.98
$e_1 = C_2\left(\frac{ek}{100\,ht}\right)^2 \times ht$	m	0.008	0.008
$e_2 = 0.5 \times ht$	m	0.053	0.053
$e = eo + e_1 + e_2$	m	0.346	0.346
$ea = eo + \frac{1}{2} ht - d$	m	0.431	0.431
$N \cdot ea$	tfm	3.196	3.196
$Ca = \frac{h}{\sqrt{\frac{n \cdot N \cdot ea}{b \cdot \sigma a}}}$	-	4.750	4.327
δ	-	0	0
ϕ	-	2.744	2.744
nw	-	0.0487	0.0487
ζ	-	0.939	0.919
i	-	2.280	3.280
iA	cm^2	8.435	8.435
A	cm^2	3.301	3.301

Used D16 a 250 → A = 8.042 cm^2

Wall (Joint A and B)

Description	Unit	Flood Condition	Normal Condition
M	tfm	1.755	1.653
N	t	6.479	6.479
ht	m	0.35	0.35
h	m	0.26	0.26
LK		1.975	1.975
$eo_1 = M/N$	m	0.275	0.255
$eo_2 = 1/30\ ht$ and ≥ 0.02 m	m	0.02	0.02
$eo = eo_1 + eo_2$	m	0.291	0.275
eo/ht	-	0.831	0.786
C_2	-	6.98	6.96
$e_1 = C_2 \left(\frac{ek}{100\,ht} \right)^2 \times ht$	m	0.008	0.008
$e_2 = 0.5 \times ht$	m	0.053	0.053
$e = eo + e_1 + e_2$	m	0.351	0.0335
$ea = eo + ½\,ht - d$	m	0.436	0.420
$N \cdot ea$	tfm	2.826	2.724
$Ca = \frac{h}{\sqrt{\frac{n \cdot N \cdot ea}{b \cdot \sigma a}}}$	-	5.051	5.145
δ	-	0	0
ϕ	-	2.954	3.098
nw	-	0.0428	0.0412
ζ	-	0.916	0.917
i	-	2.202	2.231
iA	cm^2	7.418	7.139
A	cm^2	3.369	3.090

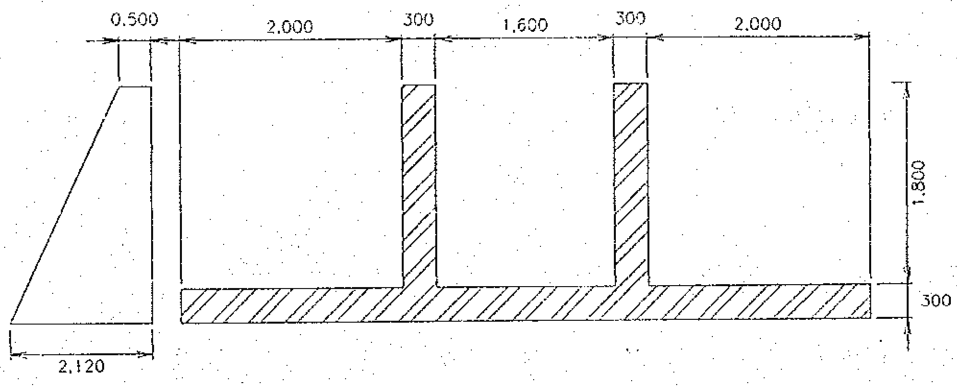
Used D16 a 250 → A = 8.042 cm^2

Wall (Center)

Description	Unit	Flood Condition	Normal Condition
M	tfm	0.408	0.0376
N	t	6.947	6.947
ht	m	0.35	0.35
h	m	0.29	0.29
LK		1.975	1.975
$eo_1 = M/N$	m	0.0059	0.0054
eo_2 = 1/30 ht and ≥ 0.02 m	m	0.02	0.02
$eo = eo_1 + eo_2$	m	0.079	0.0254
eo/ht	-	0.225	0.073
C_2	-	6.66	5.86
$e_1 = C_2 \left(\frac{ek}{100\,ht}\right)^2 \times ht$	m	0.007	0.007
$e_2 = 0.5 \times ht$	m	0.053	0.053
$e = eo + e_1 + e_2$	m	0.0139	0.084
$ea = eo + \frac{1}{2}\,ht - d$	m	0.254	0.199
$N \cdot ea$	tfm	1.762	1.386
$Ca = \dfrac{h}{\sqrt{\dfrac{n \cdot N \cdot ea}{b \cdot \sigma a}}}$	-	7.135	8.046
δ	-	0	0
ϕ	-	4.413	5.053
nw	-	0.021	0.0163
ζ	-	0.938	0.945
i	-	-13.719	-2.674
iA	cm^2	4.046	3.160
A	cm^2	-0.295	-1.182

Used D16 a 250 → A = 8.042 cm^2

6.1.2 Wing Wall



Wall

$$P = \frac{0.5 + 2.12}{2} \times 1.80 \qquad = 2.358 \text{ tf}$$

$$Z = \frac{2 \times 0.5 + 2.12}{3(0.5 + 2.12)} \times 1.80 \qquad = 0.715 \text{ m}$$

$$M = 2.358 \times 0.715 \qquad = 1.686 \text{ tfm}$$

Check Shear Stress

$$C = \frac{2358}{\frac{7}{8} \times 100 \times 21} = 1.283 \text{ kgf/m} < \bar{\tau} = 7.5 \text{ kgf/m}$$

$$Z = 1.686 \text{ tf}$$

$$Ca = \frac{21}{\sqrt{\frac{15 \times 168600}{100 \times 1600}}} = 5.282$$

$$\left.\begin{array}{l} Ca = 5.282 \\ \delta = 0 \end{array}\right\} \quad \begin{array}{l} \phi = 3.065 \\ nw = 0.04013 \end{array}$$

$$nw = \frac{0.0403}{15} \times 100 \times 21 = 5.642$$

Used D16 a 250 → A = 8.042 cm^2

Slab A – B

$$M = 2.358 \times (0.715 + 0.15) = 2.040$$

$$Ca = \frac{21}{\sqrt{\frac{15 \times 204000}{100 \times 1600}}} = 4.802$$

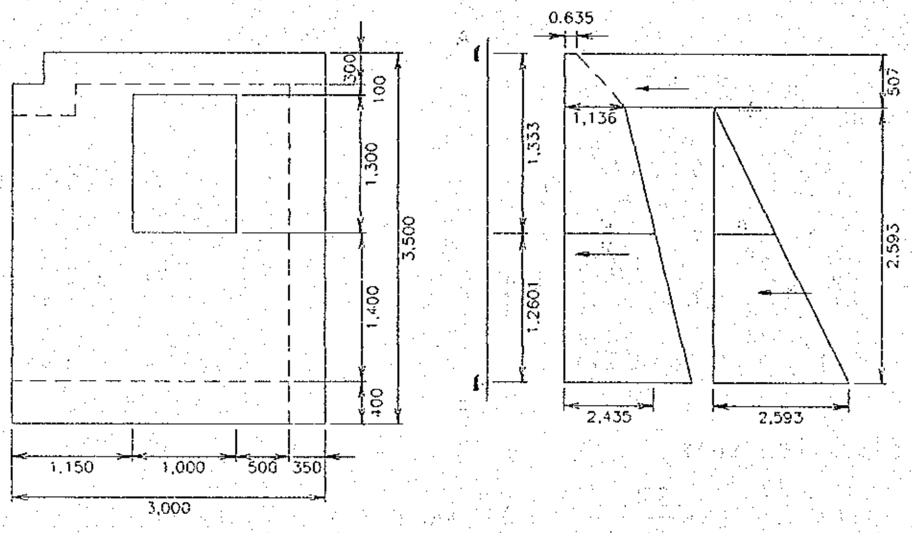
$$\left. \begin{array}{l} Ca = 4.802 \\ \delta = 0 \end{array} \right\} \quad \begin{array}{l} \phi = 0.774 \\ nw = 0.04777 \end{array}$$

$$A = \frac{0.04777}{15} \text{ x } 100 \text{ x } 21 = 6.6878 \text{ cm}^2$$

Used D16 a 250

6.1.3 Connecting Box

Wall Type I



- $$P_1 = \frac{0.635 + 1.136}{2} \times 0.557 = 0.493 \text{ tf}$$

$$Z_1 = \frac{2 \times 0.635 + 1.136}{3(0.635 + 1.136)} \times 0.557 + 2.593 = 2.845 \text{ m}$$

- $$P_2 = \frac{1.136 + 2.435}{2} \times 2.593 = 4.633 \text{ tf}$$

$$Z_2 = \frac{2 \times 1.136 + 2.436}{3(1.136 + 2.435)} \times 2.593 = 1.140 \text{ m}$$

- $$P_3 = \tfrac{1}{2} \text{ x } 2.395^2 = 2.868 \text{ tf}$$

$Z_3 \quad = \quad 1/3 \ \text{x} \ 2.395 \qquad\qquad = \quad 0.798 \quad \text{m}$

$$R_A = \frac{(0.493\times 2.845)+(4.633\times 1.140)+(2.868\times 0.798)}{3.15} = 2.849$$

$$R_B = 0.493 + 4.633 + 2.868 - 2.849 = 5.145$$

$$S = 0 \rightarrow \quad 5.145 - (2.435 + 2.93)\ \text{x}\ \frac{1.136-(2.435+2.593)}{2\times 2.593}\ x^2$$

$$5.145 - 5.028\,x + 0.7505\,x^2 = 0$$

$$x^2 - 6.700\,x + 6.8555 = 0$$

$$x = \frac{6700 \pm \sqrt{6.700^2 - 4\times 6.8555}}{2}$$

$$x = 1.2601 \ \text{m}$$

$$x_1 + x_2 = \frac{1.2601\times 1.136 + 1.333\times(2.435+2.593)}{2.593} = 3.1366$$

$$Z = \frac{2\times(2.435+2.593)+3.1366}{3(2.435+2.593)+3.1366}\ \text{x}\ 1.2601 = 0.6787$$

$$M_{max} = 5.145\ \text{x}\ 1.2601 - 5.145\ \text{x}\ 0.6787 = 2.991 \quad \text{tfm}$$

$M = 2.991$ tfm

$b = 50$ cm

$h = 26$ cm

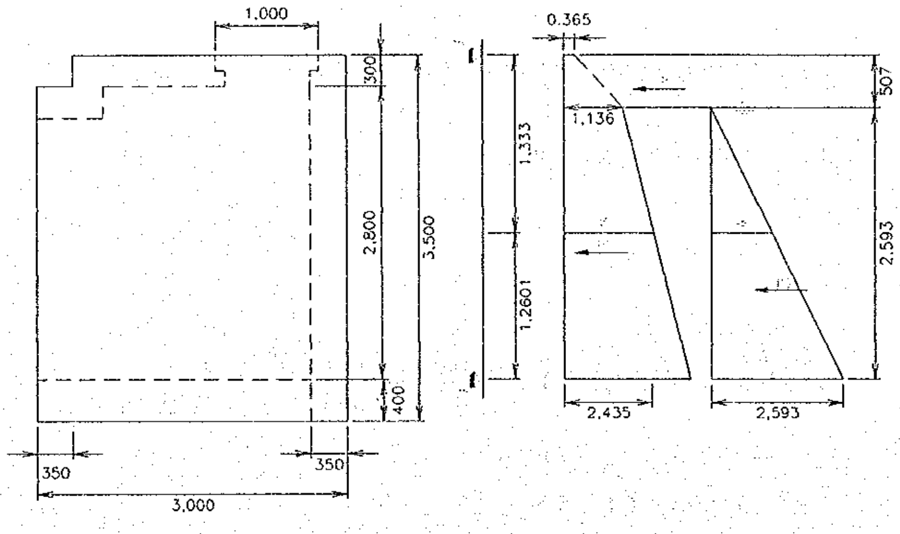
$$Ca = \frac{26}{\sqrt{\dfrac{15\times 299100}{50\times 1600}}} = 3.472$$

$$\left.\begin{aligned} Ca &= 3.472 \\ \delta &= 0 \end{aligned}\right\} \quad \begin{aligned} \phi &= 1.857 \\ nw &= 0.0942 \end{aligned}$$

$$A = \frac{0.0942}{15}\ \text{x}\ 50\ \text{x}\ 26 = 8.164\ \text{cm}^2$$

Used D16 a 125 → $A = 16.085\ \text{cm}^2$

Wall Type 2



- $P_1 = \dfrac{0.635+1.136}{2} \times 0.557 = 0.493$ tf

$Z_1 = \dfrac{2\times 0.635+1.136}{3(0.635+1.136)} \times 0.557 + 2.593 = 2.845$ m

- $P_2 = \dfrac{1.136+2.435}{2} \times 2.593 = 4.633$ tf

$Z_2 = \dfrac{2\times 1.136+2.436}{3(1.136+2.435)} \times 2.593 = 1.140$ m

- $P_3 = ½ \times 2.395^2 = 2.868$ tf

$Z_3 = 1/3 \times 2.395 = 0.798$ m

$R_A = \dfrac{(0.493\times 2.845)+(4.633\times 1.140)+(2.868\times 0.798)}{3.15} = 2.849$

$R_B = 0.493 + 4.633 + 2.868 - 2.849 = 5.145$

$S = 0 \rightarrow \quad 5.145 - (2.435 + 2.593) \times \dfrac{1.136-(2.435+2.593)}{2\times 2.593} x^2$

$5.145 - 5.028\,x + 0.7505\,x^2 = 0$

$$x^2 - 6.700\,x + 6.8555 = 0$$

$$x = \frac{6700 \pm \sqrt{6.700^2 + 4 \times 6.8555}}{2}$$

$$x = 1.2601 \text{ m}$$

$$x_1 + x_2 = \frac{1.2601 \times 1.136 + 1.333 \times (2.435 + 2.593)}{2.593} = 3.1366$$

$$Z = \frac{2 \times (2.435 + 2.593) + 3.1366}{3(2.435 + 2.593) + 3.1366} \text{ x } 1.2601 = 0.6787$$

$$M_{max} = 5.145 \text{ x } 1.2601 - 5.145 \text{ x } 0.6787 = 2.991 \text{ tfm}$$

M = 2.991 tfm

Assume b = 0.55 cm

h = 26 cm

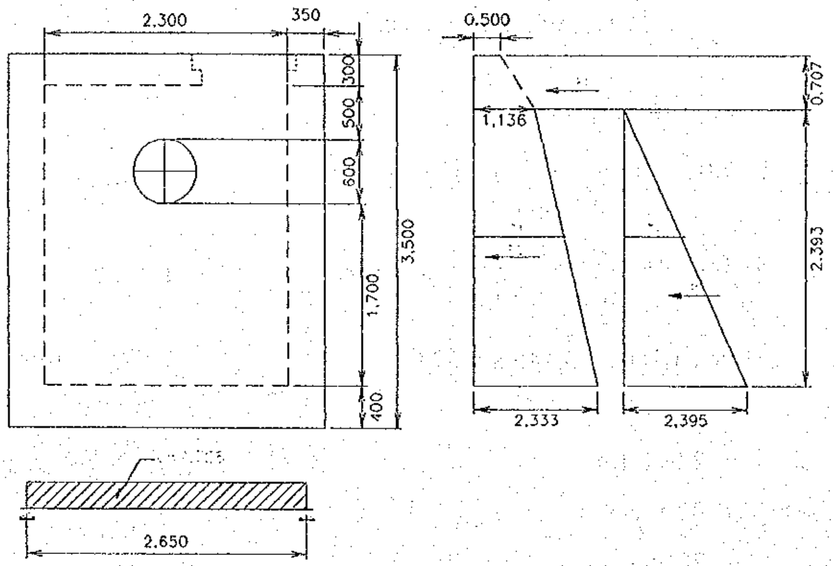
$$Ca = \frac{26}{\sqrt{\frac{15 \times 299100}{55 \times 1600}}} = 3.641$$

$$\left.\begin{array}{l} Ca = 3.641 \\ \delta = 0 \end{array}\right\} \begin{array}{l} \phi = 1.976 \\ nw = 0.08501 \end{array}$$

$$A = \frac{0.08501}{15} \text{ x } 100 \text{ x } 26 = 14.328 \text{ cm}^2$$

Used D16 a 125 → A = 16.085 cm^2

Wall Type 3



$$q = 2.333 + 2.395 = 4.728 \quad tf/m^2$$

$$M = {}^1/_8 \times 4.728 \times 2.65^2 = 4.150 \quad tfm$$

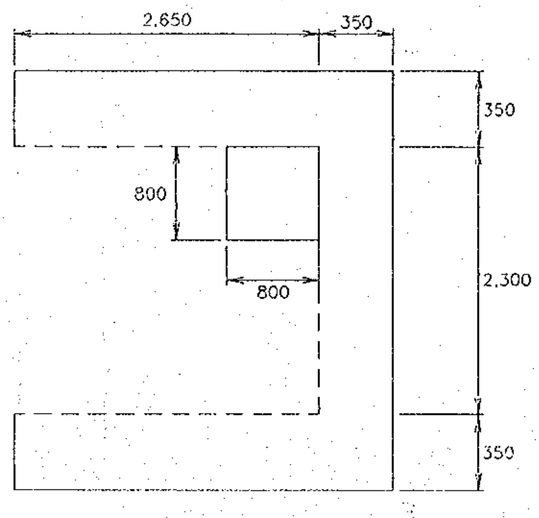
$$Ca = \frac{26}{\sqrt{\frac{15 \times 415000}{55 \times 1600}}} = 4.168$$

$$\left.\begin{array}{ll} Ca & = 4.168 \\ \delta & = 0 \end{array}\right\} \begin{array}{ll} \phi & = 2.311 \\ nw & = 0.06533 \end{array}$$

$$A = \frac{0.0653}{15} \times 100 \times 26 = 11.326 \quad cm^2$$

Used D16 a 125→ $A = 16.085 \ cm^2$

Top Slab



Live load	=	0.30	t/m^2
Weight of slab = 0.3 x 2.5	=	0.75	t/m^2
	=	1.05	t/m^2

M = $\frac{1}{8} \times 1.05 \times 2.65^2$ = 0.9217

Assume b = 60 cm

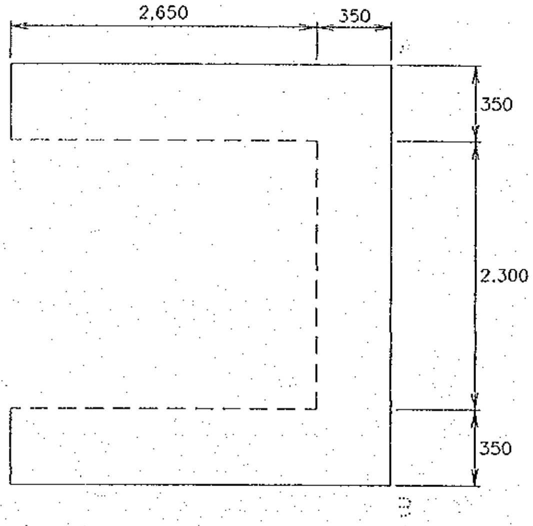
$$Ca = \frac{21}{\sqrt{\frac{15 \times 921700}{60 \times 1600}}} = 5.534$$

$$\left.\begin{array}{l} Ca = 5.534 \\ \delta = 0 \end{array}\right\} \begin{array}{l} \phi = 3.292 \\ nw = 0.03574 \end{array}$$

$$A = \frac{0.03574}{15} \times 100 \times 21 = 5.004 \ cm^2$$

Used D13 a 250 → A = 5.309 cm^2

Bottom Slab



Weight of wall A B	=	0.35 x 2.8 x 3 x 2.5	= 7.35	tf
Total Weight				
- Weight of Wall	=	3 x (3 x 0.35 x 2.8) x 2.5	= 22.05	tf/m
- Weight of Slab	=	0.3 x 3 x 3 x 2.5	= 6.75	tf/m
- Live load	=	3 x 3 x 0.3	= 2.70	tf/m
			= 31.50	tf/m

$$e = \frac{7.35 \times 1.325}{31.50} = 0.309$$

$$q_{max} = \frac{31.50}{3 \times 3}\left(1 + \frac{6 \times 0.3091}{3}\right) = 5.6637$$

$$M = \tfrac{1}{8} \times 5.664 \times 2.65^2 = 4.972$$

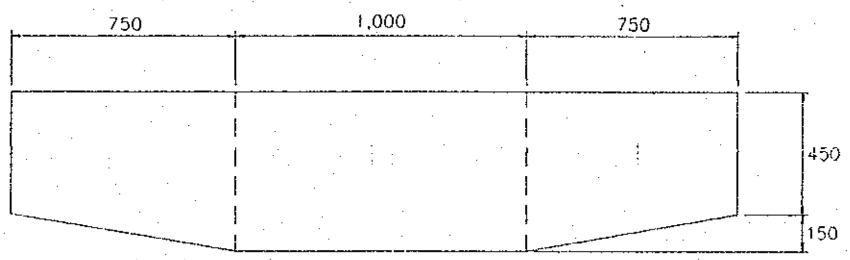
$$Ca = \frac{31}{\sqrt{\dfrac{15 \times 497200}{100 \times 1600}}} = 4.5406$$

$$\left.\begin{array}{l} Ca = 4.541 \\ \delta = 0 \end{array}\right\} \quad \begin{array}{l} \phi = 2.597 \\ nw = 0.04538 \end{array}$$

$$A = \frac{0.04538}{15} \times 100 \times 31 = 9.3785 \text{ cm}^2$$

Used D16 a 125 → A = 16.085 cm^2

6.1.4 Control Deck



Weight of concrete I	=	2 x 0.75 x (0.45 + 0.60)/2 x 2.5	=	1.969	tf/m
Weight of concrete II	=	1 x 0.6 x 2.5	=	1.500	tf/m
Weight of live load	=	0.3 x 2.5	=	0.750	tf/m
			=	4.219	tf/m

Weight of gate = 2 t

$M = \frac{1}{8} \times 4.219 \times 2.2^2 \times \frac{1}{4} \times 2 \times 2.2 \quad = 3.652 \text{ tf m}$

$$Ca = \frac{45}{\sqrt{\dfrac{15 \times 3.652}{60 \times 1800}}} = 8.157$$

$$\left.\begin{array}{l} Ca = 8.157 \\ \delta = 0 \end{array}\right\} \begin{array}{l} \phi = 5.098 \\ nw = 0.01609 \end{array}$$

$$A = \frac{0.0123}{15} \times 100 \times 51 \quad = 4.182 \text{ cm}^2$$

Used D16 – 250 → A = 8.042 cm^2

CHAPTER 7 RAISING OF RAILWAY BRIDGE

7.1 DESIGN CONCEPT

1
INTRODUCTION

We have the honor to submit Design of Railway Bridge Sub-structure Which are arranged based on the data of soil investigation and topographic survey and also The Memorandum of meeting for Design of Railway Bridge Raising on The West Flood Way in Semarang, dated October 2, 1998 in The Jrantunseluna Office and Perumka data's.

This report is consist of 4 bridges and track design :

- ❑ BH 10, Km. 01+577
- ❑ BH 5, Km. 00+816
- ❑ BH 6, Km. 00+177
- ❑ BH 13, Km. 02+331
- ❑ and track work between Km. 0+677 to Km. 02+521, Cirebon - Semarang Line

Design of the bridges have considered many aspect such as financial, construction, maintenance aspect, local condition and also are based on The Perumka's Regulation and memorandum of meeting.

2
COMPREHENSION OF SITE CONDITION

A. General

We have carried out the site survey and acquainted deeply with the site condition and comprehends such principal matters for design as geographical or geological feature, existing track alignments, condition of existing bridge and circumference thereby. We have also acquainted with the data and informations which the client (PCI) possesses regarding the project.

The data and informations that have been received from the client is mentioned in the appendix A hereinafter.

Beside that, we have also discussed with Perumka's staff and have presented the data and information which related with this project.

The data that we have obtained from Perumka are as follows:
- Super-structure drawings.
- Longitudinal section of track on this bridge
- Sub-structure data.
- etc.

B. Description Situation of Project

1. General

Location of Railway Bridge (BH 10 Km 1 + 577) are laid on the rather flat land in Semarang City arround the dense population and housing complex and also the location is near by The Java Sea (about 6.5 Km from this Bridge). Accesibility is very easy because the location of bridge is between two roads with flexible pavement (Madukoro street at Cirebon side and Kokrosono street at Semarang side). Train's frequency on this segment (between Cirebon - Semarang) are very high due to this Bridge is laid on the two Railway trunk lines: Jakarta - Surabaya Line through Semarang (The North Line) and Jakarta - Surabaya, high and the maximum speed is 100 km/hour.

2. Present situation

a). Topographical condition

Landscape	: Flat area
Circumstance around bridge	: - Urban area/housing complex - Bridge is laid between two roads

b). Geotechnical condition

Formation	: - Topsoil + embankment material - Alluvial clays with locally some more sandy and sillty pitches

c). Characteristic of river

1). Name	: Garang River
2) Characterisric of river	: Relative straight ; permanent river flow
3) Type of river cross section	: Trapeze
4) Width of river bottom	: 40.00 m
5) Slope of river bank	: Relative regular
6) Sedimentation	: Available
7) Scouring	: to be accured around pier at Semarang Side
8) Scouring protection	: Not available
9) River bed material	: Mud sedimentation, sand and silty clay
10)Other information	: Flood problems

d). Existing track

1). Track alignment

Horizontal alignment	: Straight
Vertical alignment	: Horizontal on bridge

2). Rail

a. Type	: R 42
b. Condition	: Good

3). Fastenings : Rigid / elastic fastenings

4). Sleepers

a. Type : - Wooden sleeper on bridge
- Concrete sleeper on tracks

b. Condition : Good (on track)
: Fair (on bridge)

5). Ballast and subgrade : Ballast and subgrade structure have been rehabilited.
Beside of the track, ballast to be supported by concrete panel that was retained by H-steel piles.

e) Bridge

1). Superstructure

DESCRIPTION	span 1	span 2	span 3
a. Material	Steel	Steel	Steel
b. Type	Truss	Truss	Truss
c. Clear width	31.00 m	31.00 m	31.00 m
d. Center to center of shoes	31.20 m	31.20 m	31.20 m
e. Total length of stringer	32.40 m	32.40 m	32.40 m
f Construction depth	1.67 m	1.67 m	1.67 m
g. CTC distance between truss girder	4.60 m	4.60 m	4.60 m
h. Waking (freeboard)	0.30 m	0.30 m	0.30 m
i. Material bearing / shoe	Steel	Steel	Steel
J. Other information	- The erection of replacing of super structure are still carried out by the Contractor. - There are many coconut/palm tree piles are constructed around this bridge for temporary structure of superstructure.		

2). Substructure

DESCRIPTION	Abutment	Pier	Pier	Abutment
	Cirebon Side	Cirebon Side	Semarang Side	Semarang Side
a. Material	stone masonry	stone masonry	stone masonry	stone masonry
b. Type	gravity	gravity	gravity	gravity
c. Condition				
1). Visual Condition	good	good	good	good
2). Crack onstructure	nothing	nothing	nothing	nothing
3). Displacement	nothing	nothing	nothing	nothing
d. Foundation *)	concrete	concrete	concrete	concrete
	*). References data of Perumka			

3. PROBLEMS

a). With regard to The Planned Works concerning The West Floodway / Garang River Improvement and Urban Drainage System Improvement, now under study by JICA Study Team, the existing watted area of Garang River to be normalized and improved due to the Design of River Improvement, the railway Bridge that was through this river shall be increase by 0.70 m therefore the freeboard will become 1.00 m.

b). JICA Team, PERUMKA and PROJECT have been discussed and aggreed about The Planned of Design of Railway Bridge Raising (BH 10) on this location. The result of meeting that is mentioned in the memorandum of meeting for design of railway bridge raising on the west flood way in Semarang that was performed in Jrantunseluna Office on dated October 2, 1998.
(see appendix B)

The principle scope of Design of Railway Bridge (BH 10 Km 1+577) are as follows:

1) Increasing the existing superstructure up to 0.70 m
2). Design of substructures
3). Design Improvement of existing track around this bridge
4). Design Improvement of existing road or level crossing beside this bridge
5) Design of other related structure due tothe increasing level of bridge up to 0.70 m

4. PRELIMINARY DESIGN PROPOSAL

a. Basic consideration

The basic consideration on the choosing of preliminary design proposal are as follows:

1). Financial Aspect
2). Construction Aspect
3). Maintenance Aspect
4). Topographical and Geological local condition
5). Based on the Memorandum of Meeting between Project's Staff, JICA Team and Perumka's Staff. (see appendix B)

b. Preliminary Design

1). Superstructure

a). Existing superstructure shall be reutilized. (no design of superstructure)
b). Bottom soffit of truss girder shall be up to 0.70 m (elevation + 4.07 m), therefore the free board is 1.00 m above the highest water level.

2). Substructures

a) Material

Type of Material	: Reinforced concrete
Quality	: K-225
Rebar	: BJTD-40
Foundation	: Concrete Prestressed Pile K-500

b). Type of substructures

- Abutment

In this case, we propose 3 (three) alternatives Design of Abutments are as follows:

1. Alternative 1 : Concrete Beam above the pile caps to support the super-structure.

2. Alternative 2 : Abutment on Concrete Slab for Supporting the super-structure.

3. Alternative 3 : Ditto with alt.2, but the location of abutments are moved to Cirebon Side about 5.00 meter

- Pier

In this case, we propose 2 (two) alternatives Design of Pier, are as follows :

1. Alternative 1 : Pier on Concrete Slab for support the super-structure.
2. Alternative 2 : Ditto with alternative 1, the difference on the type dimension of concrete slab and formation of piles only.

The combination of substructure that will be proposed for this bridge is mentioned in table 1.

Table 1. Alternatives of Bridge Sub-structures Proposal

No.	Alternative		Type of Sub-	Structure	
		Abutment Cirebon	Pier Cirebon	Pier Semarang	Abutment Semarang
1.	A	alt.1.	alt. 1.	alt. 1.	alt. 1.
2.	B	alt.2.	alt. 1.	alt. 1.	alt. 2.
3.	C	alt.3.	alt. 1.	alt. 1.	alt. 3.
4.	D	alt.1.	alt. 2.	alt. 2.	alt. 1.
5.	E	alt.2.	alt. 2.	alt. 2.	alt. 2.
6.	F	alt.3.	alt. 2.	alt. 2.	alt. 3.
7.	G	alt.3	alt.1	alt. 1	alt.3

table 2. The Advantage and Disavantage of Alternative.

No.	Items.	Alternative A.	Alternative B.	Alternative C.	Alternative D.	Alternative E.	Alternative F.	Alternative G.
1.	**Super-structure (to be reutilized)**							
	a. Type	Through Truss Girder Type 446 / JIS A	Through Truss Girder Type 446 / JIS A	Through Truss Girder Type 446 / JIS A	Through Truss Girder Type 446 / JIS A	Through Truss Girder Type 446 / JIS A	Through Truss Girder Type 446 / JIS A	Through Truss Girder Type 446 / JIS A
	b. C.T.C. of Shoes	31.20 m	31.20 m	31.20 m	31.20 m	31.20 m	31.20 m	31.20 m
	c. C.T.C. of Girders	4.60 m	4.60 m	4.60 m	4.60 m	4.60 m	4.60 m	4.60 m
	d. Construction Depth	1.67 m	1.67 m	1.67 m	1.67 m	1.67 m	1.67 m	1.67 m
2.	**Sub-structure**							
	a. Material							
	- Type of Material	Reinforced concrete.	Reinforced concrete.	Reinforced concrete.	Reinforced concrete.	Reinforced concrete.	Reinforced concrete.	Reinforced concrete.
	- Quality.	K - 225	K - 225	K - 225	K - 225	K - 225	K - 225	K - 225
	- Rebar.	BJTD - 40	BJTD - 40	BJTD - 40	BJTD - 40	BJTD - 40	BJTD - 40	BJTD - 40
	- Foundation Concrete prestress pile	K - 500	K - 500	K - 500	K - 500	K - 500	K - 500	K - 500
	b. Type of Sub-structure							
	- Abutment	- Concrete Beam above piles cap to support the super-structure (alternative 1) - Existing abutment to be used as retaining wall and the top part of abutment will be improved for ballast. - Foundation: Concrete Prestress Pile	- Abutment on concrete slab for supporting the super-structure. (alternative 2) - Top part of existing abutment to be demolished up to 10 cm below the concrete slab. - Foundation : Concrete Prestress Pile	- ditto, with alternative 2 ; but the position of new abutment to be moved to Cirebon side about 3.45 m (alternative 3) - Top part of existing abutment to be demolished up to 10 cm below the concrete slab. - Foundation: Concrete Prestress Pile	- Concrete Beam above piles cap to support the super-structure (alternative 1) - Existing abutment to be used as retaining wall and the top part of abutment will be improved for ballast. - Foundatio: Concrete Prestress Pile	- Abutment on concrete slab for supporting the super-structure. (alternative 2) - Top part of existing abutment to be demolished up to 10 cm below the concrete slab. - Foundation: Concrete Prestress Pile	- ditto, with alternative 2 ; but the position of new abutment to be moved to Cirebon Side about 3.45 m (alternative 3) - Top part of existing abutment to be demolished up to 10 cm below the concrete slab. - Foundation: Concrete Prestress Pile	- ditto, with alternative 2 ; but the position of new abutment to be moved to Cirebon side about 5.00 m (alternative 3) - Foundation: Concrete Prestress Pile
	- Pier	- Pier on Concrete Slab for supporting the super-structure. (alternative 1) - Foundation: Concrete Prestress Pile	- Pier on Concrete Slab for supporting the super-structure. (alternative 1) - Foundation : Concrete Prestress Pile	- Pier on Concrete Slab for supporting the super-structure. (alternative 1) - Foundation : Concrete Prestress Pile	- Pier on Concrete Slab for supporting the super-structure. (alternative 2) - Foundatio: Concrete Prestress Pile	- Pier on Concrete Slab for supporting the super-structure. (alternative 2) - Foundation : Concrete Prestress Pile	- Pier on Concrete Slab for supporting the super-structure. (alternative 2) - Foundation : Concrete Prestress Pile	- Pier on Concrete Slab for supporting the super-structure. (alternative 1) - Foundation : Concrete Prestress Pile
3.	**Financial.**	92 %	95 %	89.5 %	93 %	100 %	91 %	71 %
4.	**Advantage and Disavantage.**							
	a. Advantage.	- Construction Cost is cheeper - Shape of piers are better than alternative D, E and F. - Scouring arround piers are less than alternative D, E & F.	- Shape of piers are better than alternative D, E and F. - Scouring arround piers are less than alternative D, E and F.	- Shape of piers are better than alternative D, E and F. - Scouring arround piers are less than alternative D, E & F. - Not neccessary to demolish the existing abutment Cirebon side.	-	-	- Not neccessary to demolish the existing abutment Cirebon side	- Shape of piers are better than alternative D, E and F. - Scouring arround piers are less than alternative D, E & F. - Not neccessary to demolish the existing sub structure - Temporary support cost is very cheap
	b. Disadvantage.	- Top part of existing abutment to be improved. - In the construction stage of new abutments aren't disturbed the existing road	- Construction Cost is higher than alternative A. - In the construction stage of new abutments are disturbed the existing road	- Construction Cost is higher than alternative A, B, D and E. - Watted Area are become small - Scouring will be occured around abutment Semarang side. - Width of flexible pavement at Cirebon Side will become small - In the construction stage of new abutment on Cirebon side is disturbed the existing road	- Construction Cost is higher than alternative A. - Top part of existing abutment to be improved. - The shape of pile caps are not smooth - Scouring Problems will be occured around both of piers - In the construction stage of new abument aren't disturbed the existing rod	- Construction Cost is higher than alternative A, B, C & D - In the construction stage of new abutments are disturbed the existing road - The shape of pile caps are not smooth - Scouring Problems will be occured around both of piers	- Construction Cost is higher than alternative A, B, C, D & E - Watted Area are become small - Scouring will be occured around abutment Semarang side. - Width of flexible pavement will become small on Cirebon side - In the construction stage of new abutment on Cirebon side is disturbed the existing road - The shape of pile caps are not smooth - Scouring Problems will be occured around both of piers	- Construction Cost is higher than alternative A, B - Watted Area are become small - Width of flexible pavement at will become small at Cirebon Side - In the construction stage of new abutment on Cirebon side is disturbed the existing road - Shall be request agreement from Government (Pemda or PU)

7.2 DESIGN CONDITION

1.1. DESIGN CONDITION

1.1. EXISTING SUPERSTRUCTURE

	span 1	span 2	span 3	
- Type	Truss	Truss	Truss	
- Total Weight	67.00	67.00	67.00	ton-f
- Effective Span (c.t.c.)	31.20	31.20	31.20	m
- Total Length of Stringer or truss girder	32.16	32.16	32.16	m
- Center to center of Main Girder	4.60	4.60	4.60	m
- Construction Depth	1.33	1.33	1.33	m
- Distance between top of rail up to top of concrete bearing	1.65	1.65	1.65	m
- Distance between top of rail up to HWL	2.33	2.33	2.33	m

1.2. TRACK CONDITION

- Track Plan : straight
- Track Elevation : horizontal on Bridge.

1.3. REGULATION REFERENCE.

- Specification of Perumka Railway Bridge Design (AVBP 1932).
- PD - 10
- Indonesian Concrete Code (PBI 1971)
- Elastic Analysis of Reinforced Concrete Section (Departement PU)

1.4. MATERIAL QUALITY

- Concrete K - 225
- Plain / Lean Concrete K - 125
- Reinforced Steel Bar U - 39 (deform steel)

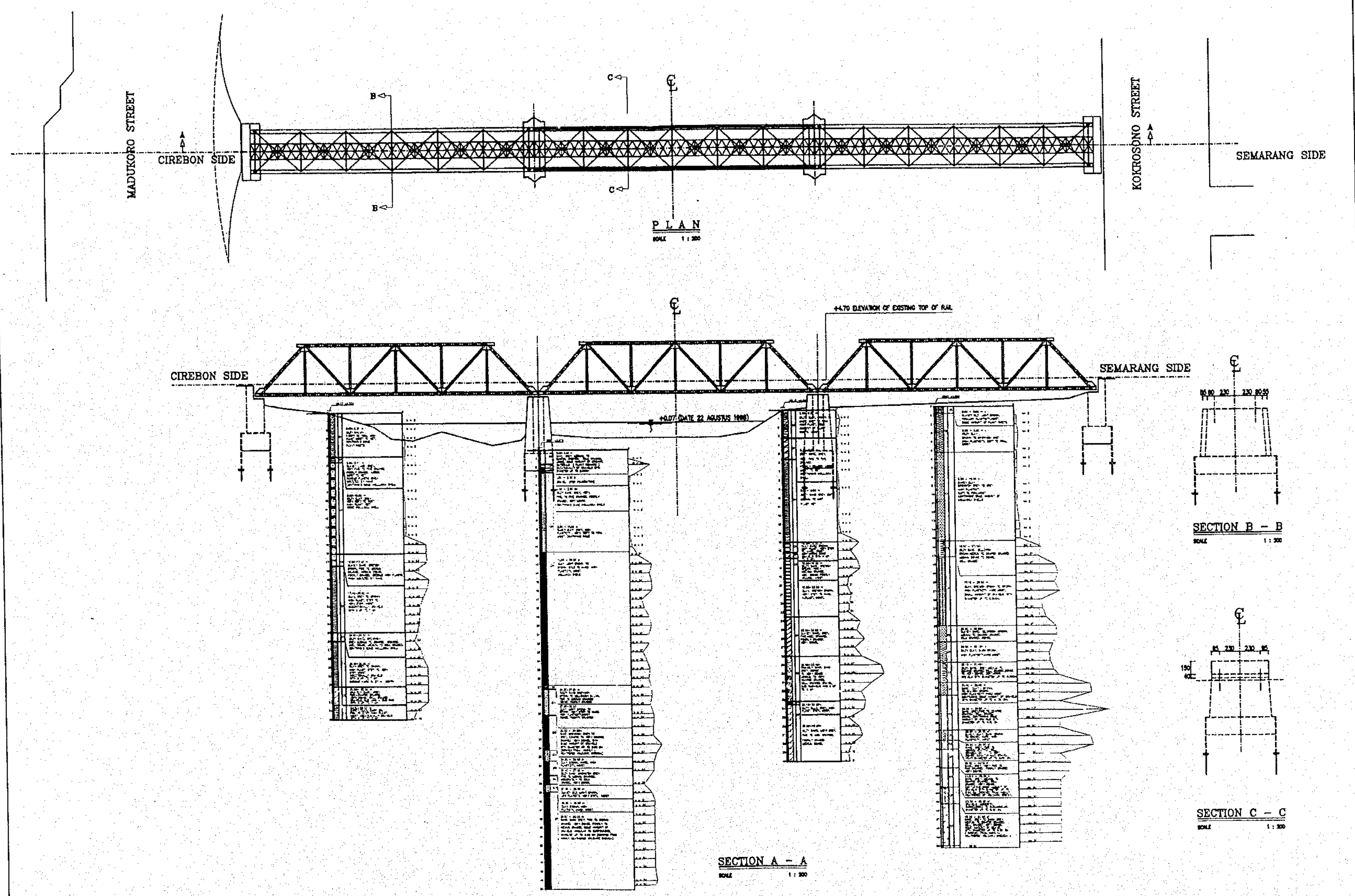
1.5. LOADINGS

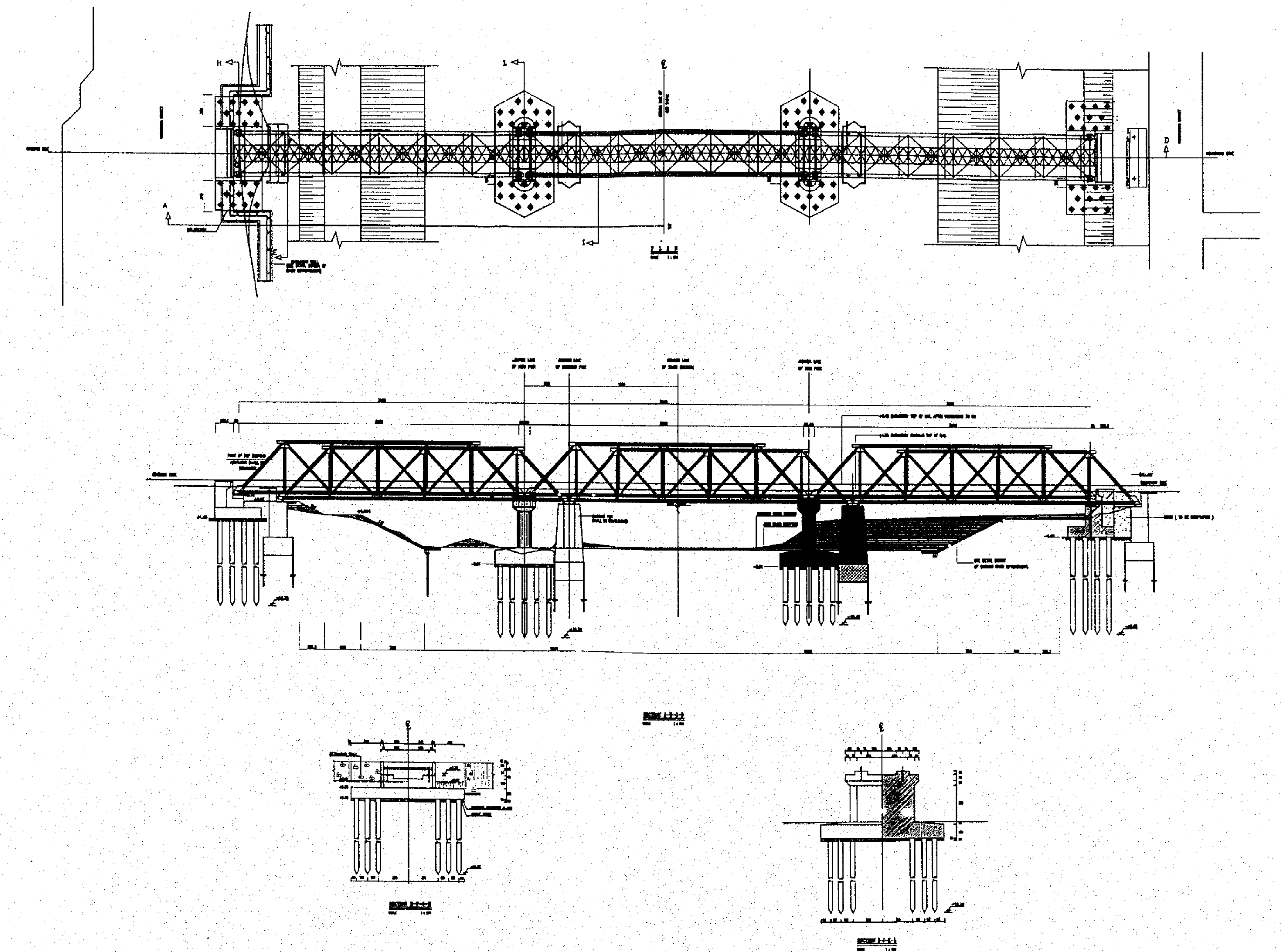
- Train Load : based on 100 % Load Scheme 1921.
- Impact : { 0.2 + 26 /(L + 50) } x train Load
- Longitudinal Load due to Long Rails : 1.00 tf / m' (per one track) , but max. 200 t f.
- Brake Load : 1 / 6 Locomotive + 1 / 10 Wagon
- Lateral Load : 1 / 10 Train Load
- Wind Load : 0.10 tf /m2.
- Earth Pressure : based on Coulomb's Theory
- Stream Flow : based on the velocity of stream on HWL Condition
- Seismic Load : based on the equivalent static force and design seismic intensity expressed as followings :

  KH = 0.18

  KV = 0.00

7.3 DESIGN DRAWING


MADUKORO STREET
CIREBON SIDE
KOKROSONO STREET
SEMARANG SIDE
PLAN
SCALE 1 : 300
+4.70 ELEVATION OF EXISTING TOP OF RAIL
CIREBON SIDE
SEMARANG SIDE
+0.07 (DATE 22 AGUSTUS 1998)
SECTION A - A
SCALE 1 : 300
SECTION B - B
SCALE 1 : 300
SECTION C - C
SCALE 1 : 300
EXISTING BRIDGE BH.10



GENERAL DRAWING OF RAILWAY BRIDGE BR.10