

Japan International Cooperation Agency (JICA)

Earthquake Reconstruction and Rehabilitation Authority (ERRA)

Urgent Rehabilitation Project: West Bank Bypass Design

Under the Urgent Development Study on

Rehabilitation and Reconstruction in Muzaffarabad City

In the Islamic Republic of Pakistan

FINAL REPORT

APPENDIX F

STRUCTURAL CALCULATION (Culvert and Retaining Wall)

March 2008

NIPPON KOEI CO., LTD.

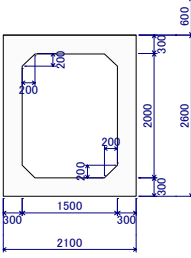
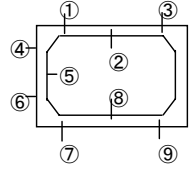









APPENDIX F
Table of Contents

Structrual Calculation of Box Culverts	1
Structrual Calculation of Pipe Culverts	13
Structrual Calculation of Retaining Wall	17

Structural Calculation of Box Culverts

Type I (B=1.5m x H=2.0m)

Table A.5.2 Design Result for Box Culvert Type I

Schematic Figure		Dimension						Stress Calculation Position				
												
Member		Top Slab			Side Wall			Bottom Slab				
Calculation Position		①	②	③	④	⑤	⑥	⑦	⑧	⑨		
Reinforcing Diagram												
Sectional Force	M	kN·m	-10.8	12.7	-10.8	-14.3	4.8	-16.5	-12.6	12.4	-12.6	
	N	kN	47.4	10.3	47.4	69.2	26.1	83.1	59.0	12.5	59.0	
	S	kN	53.5	38.2	-53.5	-40.1	37.0	47.8	-63.6	47.3	63.6	
Reinforcing	Required	cm ²	1.30	2.93	1.30	1.33	0.27	1.47	1.48	3.39	1.48	
	Design	cm ²	10.14	10.14	10.14	10.14	10.14	10.14	10.14	10.14	10.14	
	Dia.	mm	13	13	13	13	13	13	13	13	13	
	Pitch	mm	125	125	125	125	125	125	125	125	125	
	Concrete Cove	mm	100	100	100	100	100	100	110	110	110	
Stress	Design	σ_c	N/mm ²	1.69	2.25	1.69	2.20	0.71	2.53	2.07	2.31	2.07
		σ_s	N/mm ²	29.79	58.69	29.79	35.39	10.33	39.39	34.21	63.75	34.21
		τ_m	N/mm ²	0.268	0.191	0.268	0.200	0.185	0.239	0.335	0.249	0.335
	Allowable	σ_{ca}	N/mm ²	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
		σ_{sa}	N/mm ²	180.00	180.00	180.00	180.00	180.00	180.00	180.00	180.00	180.00
		τ_a	N/mm ²	0.780	0.390	0.780	0.780	0.390	0.780	0.780	0.390	0.780

Source: JICA Study Team

Sectional Force and Reinforcing Schedule (B x H = 1.0m x 2.0m)

Moment Diagram	Main Reinforcing	Concrete Cover

Type II (B=2.0m x H=2.5m)

Table A.5.3 Design Result for Box Culvert Type II

Schematic Figure			Dimension					Stress Calculation Position				
Member			Top Slab			Side Wall		Bottom Slab				
Calculation Position			①	②	③	④	⑤	⑥	⑦	⑧	⑨	
Reinforcing Diagram												
Sectional Force	M	kN·m	-20.1	17.4	-20.1	-24.8	8.3	-26.1	-24.9	19.6	-24.9	
	N	kN	60.7	18.6	60.7	88.3	33.3	105.9	76.6	20.5	76.6	
	S	kN	72.6	-57.3	-72.6	-53.3	52.8	63.0	-88.7	-60.9	88.7	
Reinforcing	Required	cm ²	3.72	4.52	3.72	3.71	0.94	3.48	3.32	4.10	3.32	
	Design	cm ²	10.14	10.14	10.14	10.14	10.14	10.14	10.14	10.14	10.14	
	Dia.	mm	13	13	13	13	13	13	13	13	13	
	Pitch	mm	125	125	125	125	125	125	125	125	125	
	Concrete Cove	mm	100	100	100	100	100	100	110	110	110	
Stress	Design	σc	N/mm ²	3.30	2.98	3.30	4.03	1.32	4.16	2.97	2.49	2.97
		σs	N/mm ²	72.32	83.87	72.32	77.87	23.99	75.14	66.08	76.40	66.08
		τm	N/mm ²	0.363	0.287	0.363	0.267	0.264	0.315	0.369	0.254	0.369
	Allowable	σca	N/mm ²	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
		σsa	N/mm ²	180.00	180.00	180.00	180.00	180.00	180.00	180.00	180.00	180.00
		τa	N/mm ²	0.780	0.390	0.780	0.780	0.390	0.780	0.780	0.390	0.780

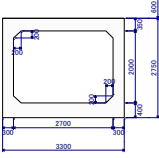
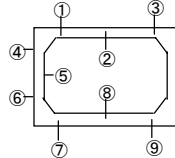









Source: JICA Study Team

Sectional Force and Reinforcing Schedule (B x H = 2.0m x 2.5m)

Moment Diagram	Main Reinforcing	Concrete Cover

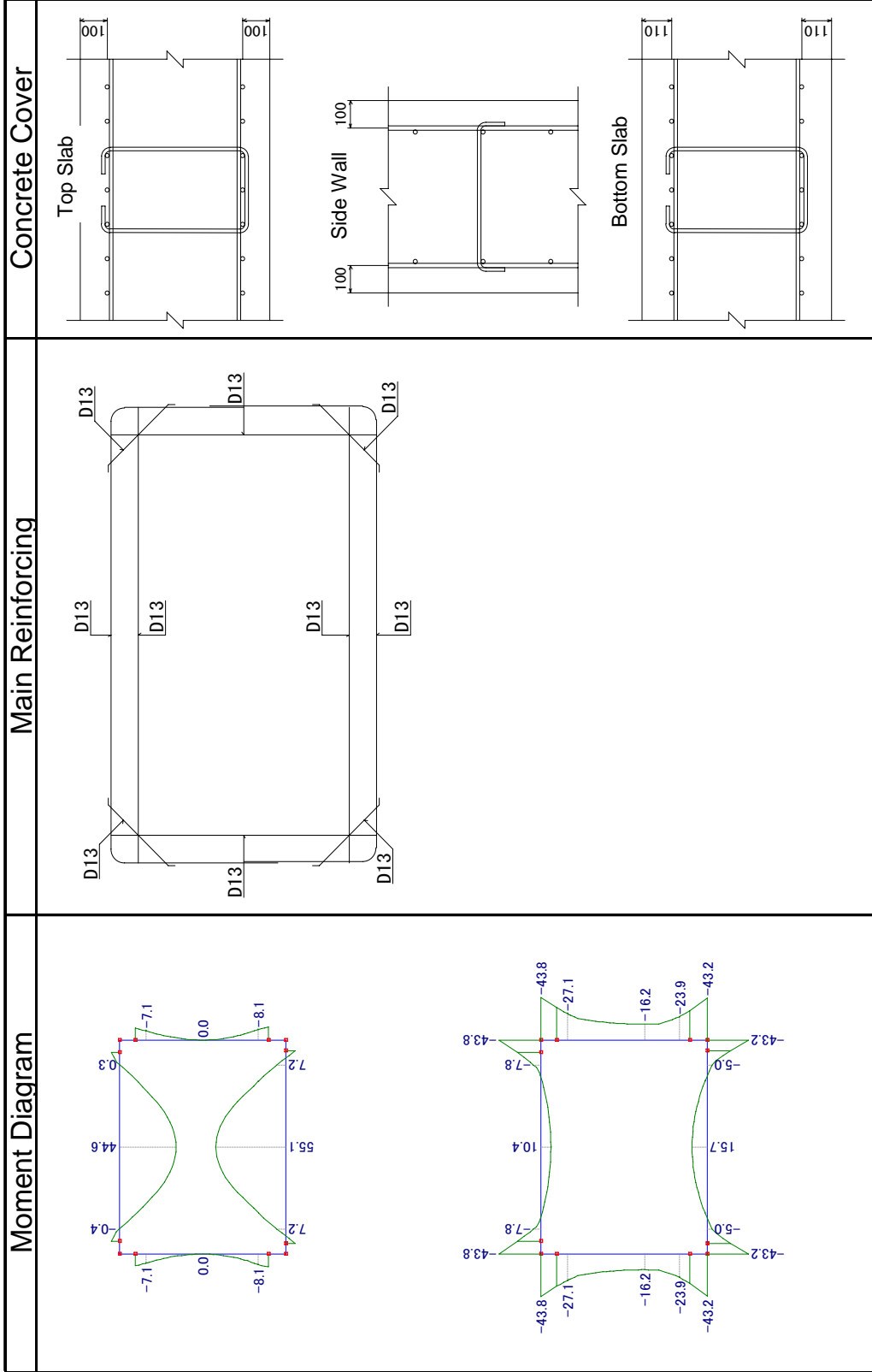
Type III (B=2.7m x H=2.0m)

Table A.5.4 Design Result for Box Culvert Type III

Schematic Figure			Dimension						Stress Calculation Position			
												
Member			Top Slab			Side Wall			Bottom Slab			
Calculation Position			①	②	③	④	⑤	⑥	⑦	⑧	⑨	
Reinforcing Diagram												
Sectional Force	M	kN·m	-7.8	42.8	-7.8	-27.1	0.0	-23.9	-5.0	55.1	-5.0	
	N	kN	51.6	18.1	51.6	118.0	0.0	129.7	34.9	49.8	34.9	
	S	kN	102.9	-77.7	-102.9	-43.2	37.3	45.5	-117.3	79.9	117.3	
Reinforcing	Required	cm ²	0.00	9.91	0.00	3.36	0.88	1.99	0.81	9.94	0.81	
	Design	cm ²	10.14	10.14	10.14	10.14	10.14	10.14	10.14	10.14	10.14	
	Dia.	mm	13	13	13	13	13	13	13	13	13	
	Pitch	mm	125	125	125	125	125	125	125	125	125	
Concrete Cove		mm	100	100	100	100	100	100	110	110	110	
Stress	Design	σc	N/mm ²	0.76	5.16	0.74	4.27	0.00	3.60	0.34	5.17	0.34
		σs	N/mm ²	7.08	176.13	7.52	74.04	0.00	52.65	-2.35	176.63	-2.35
		τm	N/mm ²	0.412	0.311	0.412	0.216	0.186	0.227	0.404	0.276	0.404
	Allowable	σca	N/mm ²	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
		σsa	N/mm ²	180.00	180.00	180.00	180.00	180.00	180.00	-180.00	180.00	-180.00
		τa	N/mm ²	0.780	0.390	0.780	0.780	0.390	0.780	0.780	0.390	0.780

Source: JICA Study Team

Sectional Force and Reinforcing Schedule (B x H = 2.7m x 2.0m)



Type IV (3@B=3.5m x H=3.0m)

Table A.5.5 Design Result for Box Culvert Type IV (Top Slab)

Schematic Figure			Dimension							Stress Calculation Position							
Member			Top Slab														
Calculation Position			①		②		③		④		⑤		⑥		⑦		
Reinforcing Diagram																	
Sectional Force	M	kN·m	-25.4	59.6	-56.2	51.4	-34.2	18.1	-25.4								
	N	kN	40.6	54.6	54.6	65.3	13.8	10.2	40.6								
	S	kN	105.3	-130.2	-147.7	108.7	-126.2	43.3	-40.4								
Reinforcing	Required	cm ²	4.25	13.01	12.11	10.29	7.85	3.93	4.38								
	Design	cm ²	10.14	15.89	15.89	15.89	15.89	15.89	10.14								
	Dia.	mm	13	16	16	16	16	16	13								
	Pitch	mm	125	125	125	125	125	125	125								
	Concrete Cover	mm	100	100	100	100	100	100	100								
Stress	Design	σ_c	N/mm ²	3.07	6.13	5.78	5.28	3.52	1.86	3.05							
		σ_s	N/mm ²	84.24	149.38	139.65	121.92	92.22	47.69	84.99							
		τ_m	N/mm ²	0.421	0.521	0.591	0.435	0.505	0.173	0.162							
	Allowable	σ_{ca}	N/mm ²	8.00	8.00	8.00	8.00	8.00	8.00	8.00							
		σ_{sa}	N/mm ²	180.00	180.00	180.00	180.00	180.00	180.00	180.00							
		τ_a	N/mm ²	0.780	0.390	0.780	0.390	0.780	0.390	0.780							

Source: JICA Study Team

Table A.5.6 Design Result for Box Culvert Type IV(Bottom Slab)

Schematic Figure			Dimension				Stress Calculation Position			
Member			Bottom Slab							
Calculation Position			⑭	⑮	⑯	⑰	⑱	⑲	⑳	
Reinforcing Diagram										
Sectional Force	M	kN·m	-43.9	46.7	-73.8	30.2	-73.8	40.5	-29.9	
	N	kN	19.3	-3.4	16.0	37.3	16.0	16.0	63.7	
	S	kN	-134.2	-109.6	-121.5	-101.6	-119.9	-102.1	59.9	
Reinforcing	Required	cm ²	8.21	9.95	15.34	4.91	15.18	7.89	4.18	
	Design	cm ²	10.14	10.14	15.89	10.14	15.89	10.14	10.14	
	Dia.	mm	13	13	16	13	16	13	13	
	Pitch	mm	125	125	125	125	125	125	125	
Concrete Cover		mm	110	110	110	110	110	110	110	
Stress	Design	σ_c	N/mm ²	4.27	4.44	5.95	2.82	6.02	3.83	2.73
		σ_s	N/mm ²	148.57	176.91	174.12	91.04	172.63	141.84	74.01
		τ_m	N/mm ²	0.463	0.378	0.419	0.350	0.414	0.352	0.207
	Allwoable	σ_{ca}	N/mm ²	8.00	8.00	8.00	8.00	8.00	8.00	8.00
		σ_{sa}	N/mm ²	180.00	180.00	180.00	180.00	180.00	180.00	180.00
		τ_a	N/mm ²	0.780	0.390	0.780	0.390	0.780	0.390	0.780

Source: JICA Study Team

Table A.5.7 Design Result for Box Culvert Type IV (Wall)

Schematic Figure			Dimension				Stress Calculation Position						
Member			Side Wall(Left)		Side Wall(Right)		Inside Wall(Left)		Inside Wall(Right)				
Calculation Position			⑧	⑨	⑩	⑪	⑫	⑬	top edge	bottom edge	top edge	bottom edge	
Reinforcing Diagram													
Sectional Force	M	kN·m	-27.1	7.9	-60.7	-27.1	7.9	-30.0	-58.9	-32.3	-40.2	-12.3	
	N	kN	49.0	64.7	151.7	49.0	64.7	53.8	238.5	234.8	217.2	107.7	
	S	kN	-48.8	81.0	92.0	37.7	-46.8	-53.8	41.6	41.6	30.2	30.2	
Reinforcing	Required	cm ²	4.50	0.90	9.74	4.50	0.00	5.04	18.28	2.79	3.93	0.81	
	Design	cm ²	10.14	10.14	10.14	10.14	10.14	10.14	22.92	22.92	22.92	22.92	
	Dia.	mm	13	13	13	13	13	13	19	19	19	19	
	Pitch	mm	125	125	125	125	125	125	125	125	125	125	
Concrete Cover		mm	100	100	100	100	100	100	100	100	100	100	
Stress	Design	σ_c	N/mm ²	3.23	0.69	7.06	3.23	0.69	3.57	7.52	3.86	4.99	1.42
		σ_s	N/mm ²	87.53	-4.74	173.99	87.53	-4.74	96.98	90.00	27.23	49.34	-7.19
		τ_m	N/mm ²	0.195	0.324	0.368	0.151	0.187	0.215	0.208	0.208	0.151	0.151
	Allwoable	σ_{ca}	N/mm ²	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
		σ_{sa}	N/mm ²	180.00	-180.00	180.00	180.00	-180.00	180.00	180.00	180.00	180.00	-180.00
		τ_a	N/mm ²	0.780	0.390	0.780	0.780	0.390	0.780	0.780	0.780	0.780	0.780

Source: JICA Study Team

Sectional Force and Reinforcing Schedule (B x H = 3@3.5m x 3.0m)

Moment Diagram	Main Reinforcing	Concrete Cover

Type V (B=5.5m x H=3.0m)

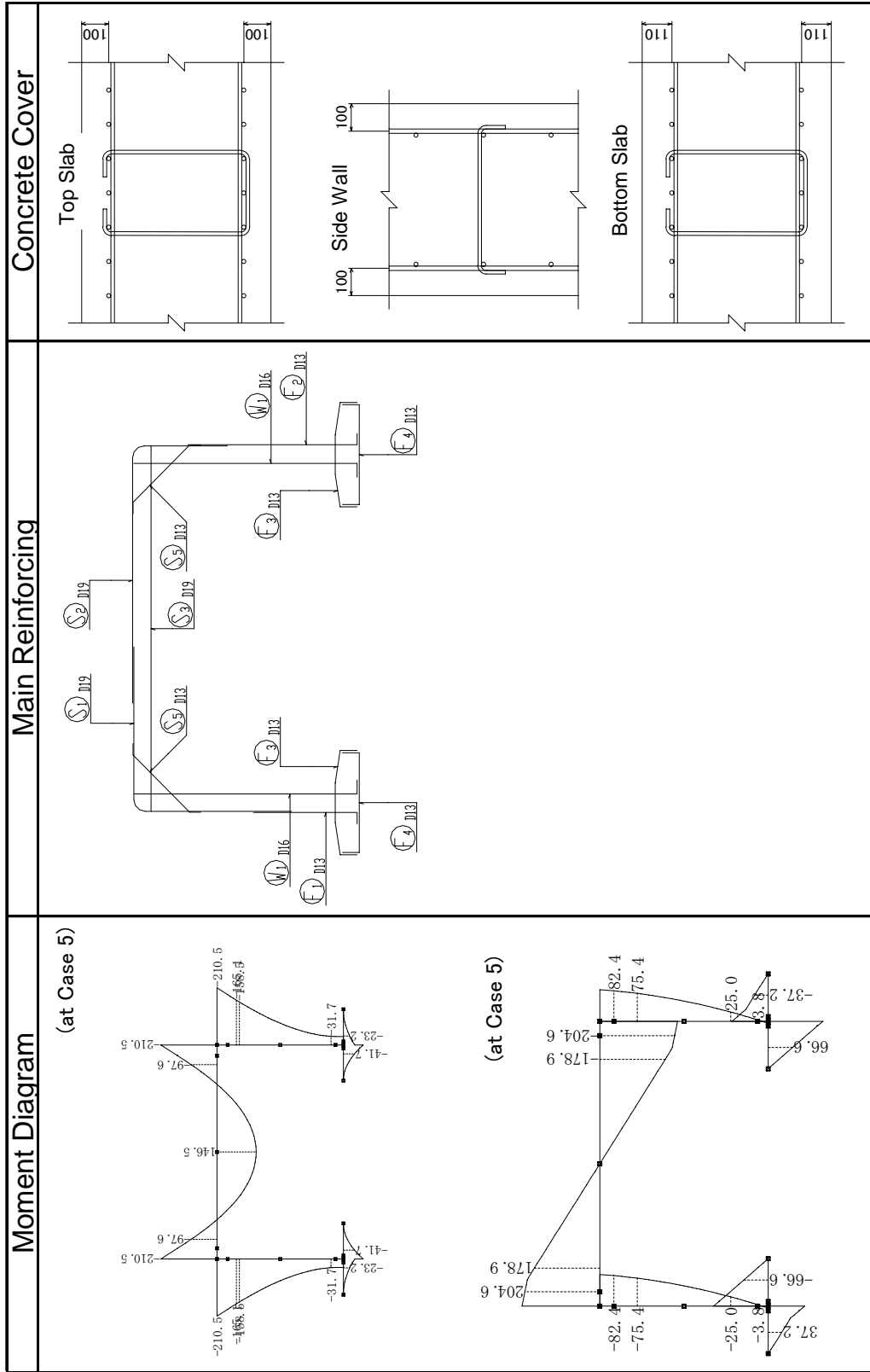
Table A.5.8 Design Result for Portal Culvert Type V

Member		Dimension			Stress Calculation Position						
		Schematic Figure			Stress Calculation Position						
Schematic Figure											
Member		Top Slab			Side Wall			Bottom Footing			
Calculation Position		①	②	③	④	⑤	⑥	⑦	⑧		
Reinforcing Diagram											
Sectional Force	M	kN·m	-103.0	146.5	-103.0	-165.1	-158.5	-31.7	-23.2	-41.7	
	N	kN	75.7	85.5	75.7	216.0	217	249.1	0	0	
	S	kN	204.6	178.9	-204.6	-82.4	-75.4	22.8	37.2	-66.6	
Reinforcing	Required	cm ²	13.53	20.59	13.53	19.66	18.51	0	2.69	4.94	
	Design	cm ²	22.92	22.92	22.92	22.92	22.92	13.136			
	Dia.	mm	19	19	19	19	19	13	13	13	
	Pitch	mm	125	125	125	125	125	125	125	125	
Concrete Cove		mm	10	10	10	10	10	10	11	11	
Stress	Design	σc	N/mm ²	4.22	5.80	4.22	6.66	6.39	1.21	0.95	1.71
		σs	N/mm ²	110.29	163.05	110.29	156.66	148.39	-13.35	50.36	90.5
		τm	N/mm ²	0.512	0.447*	0.512	0.206	0.188	0.057	0.084	0.15
	Allowable	σca	N/mm ²	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
		σsa	N/mm ²	180.00	180.00	180.00	180.00	180.00	180.00	180.00	180.00
ta	N/mm ²	0.780	0.390	0.780	0.780	0.390	0.780	3.029	3.041		

*note: see check by stirrup in Appendices.

Source: JICA Study Team

Sectional Force and Reinforcing Schedule (B x H = 5.0m x 3.0m)



Structural Calculation of Pipe Culverts

Pipe Culvert Design (910mm)

1.Design Conditions

(1) Type of Pipe Culvert	RC Pipe Culvert
(2) Pipe Diameter	910mm
(3) Unit Weight of Backfill Material	18kN/m ³
(4) Live Loading	A-Loading
(5) Effective Support Angle	180degree
(6) Concrete Design	
Compressive Strength	24N/mm ²
Allowable Stress	8N/mm ²
(7) Reinforcing Steel	
Yeild Strength	295N/mm ²
Allowable Bending Compressive Stress	180N/mm ²
(8) Earth Fill Height	0.6m
(9) Unit Length	1m

2.Loading

- (1) Dead Load by Earth back fill (Standard Installation Type)

$$q_d = Cc \cdot \gamma \cdot Bc \text{ (kN/m}^2 \text{ (kgf/m}^2\text{))}$$

$$Cc = \frac{\exp\left(k \cdot \frac{h}{Bc}\right) - 1}{K}$$

where:

γ (unit weight of soil)

Cc (coefficient of vertical earth pressure)

Bc (pipe outside diameter)

K (Coefficient: when sandy soil 0.4 cohesive soil :0.8)

h (Earth Fill Height)

1.8
0.61
1.2
0.8
0.6

$$q_d = \boxed{1.33}$$

- (2) Live Load
A-Loading

$$ql = \frac{111 \text{ kN} \cdot (1 + i)}{2.638 (0.254 + 2h)}$$

where:

i (impact coefficient)

0.3

h (Earth Fill Height)

0.6

ql=

37.6

 kN/m

3 Design of Culvert

- (1) Maximum Bending Moment

$$M = k(qd + ql)r^2 \text{ (kN} \cdot \text{m(kgf} \cdot \text{m))}$$

k (coefficient for effective support angle:refer to the following table)

Foundation Type	Support Angle	K
Sandy Soil	60°	0.378
	90°	0.314
	120°	0.275
Concrete	90°	0.303
	120°	0.243
	180°	0.220

K=

0.314

r=

0.555

case 1 (A-Loading)

M= 3.767 kNm

(2) Reinforcement

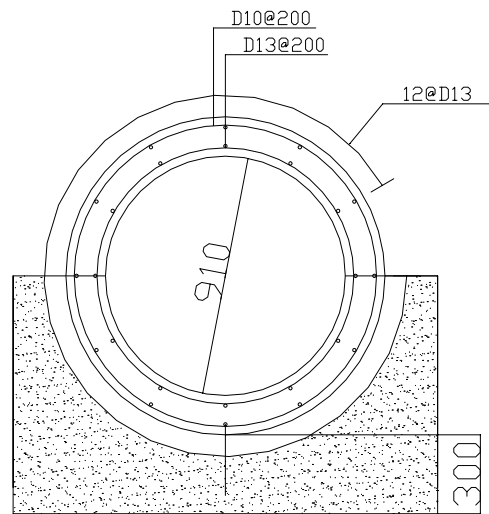
Reinforce Arrangement	D10@200 (3.567cm ² /m)
Wall Thickness	100mm

(Bending Stress)

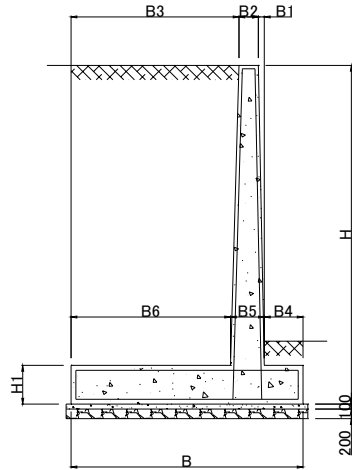
σ_c (N/mm ²)	5.5	< 8N/mm ²
σ_s (N/mm ²)	162.2	< 180N/mm ²
σ_s' (N/mm ²)	22	< 180N/mm ²

(Resistant Moment)

Mr(kN.m)	5.724	>	3.767 kNm (OK)
----------	-------	---	----------------



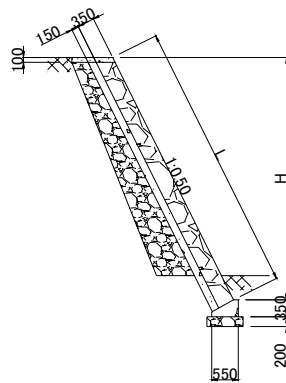
Structural Calculation of Retaining Wall



RC T-Shaped	Unit	B	B1	B2	B3	B4	B5	B6	H1
H=7.00m	mm	4,800	124	400	3,476	800	700	3,300	800
H=6.00m	mm	4,000	106	400	2,894	600	600	2,800	700
H=5.00m	mm	3,400	88	350	2,362	600	500	2,300	600
H=4.00m	mm	2,800	70	350	1,980	400	500	1,900	500

Source: JICA Study Team

Figure A.5.22 Typical Structural Detail for T-Shaped Retaining Wall

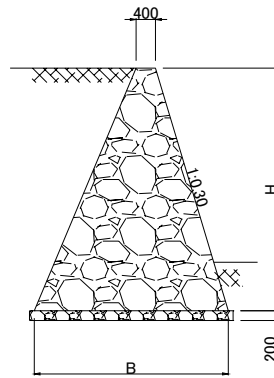


Stone Masonry (Learning)	Unit	L
H=5.00m	mm	5,590

H=4.50m	mm	5,031
H=4.00m	mm	4,473
H=3.50m	mm	3,913
H=3.00m	mm	3,354

Source: JICA Study Team

Figure A.5.23 Typical Structural Detail for Stone Masonry (Learning)



Stone Masonry (Gravity)	Unit	B
H=5.00m	mm	4,000
H=4.00m	mm	3,250
H=3.00m	mm	2,400

Source: JICA Study Team

Figure A.5.24 Typical Structural Detail for Stone Masonry (Gravity)