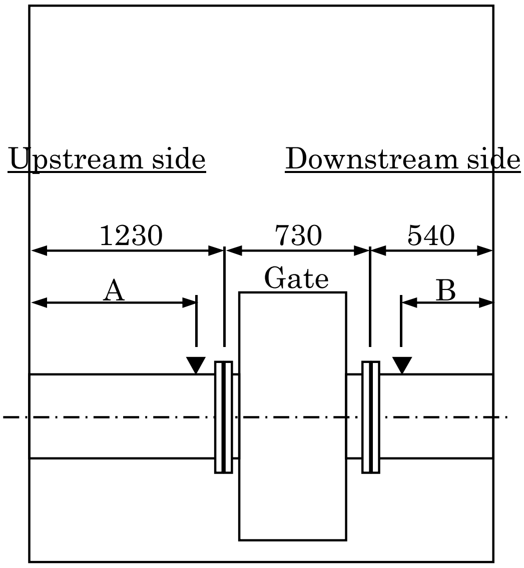
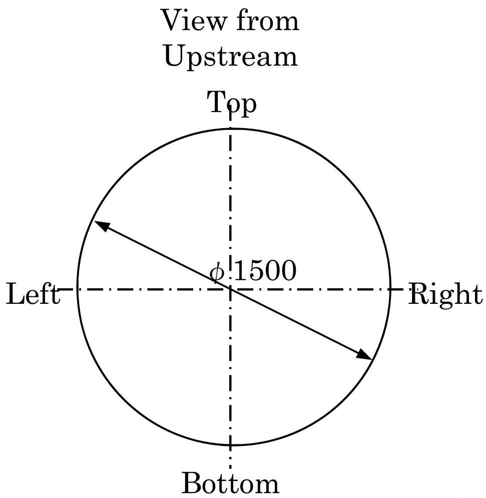
APPENDIX-1 :

Result of measure thickness

Dam Oeste Dam Date 12 May, 2011

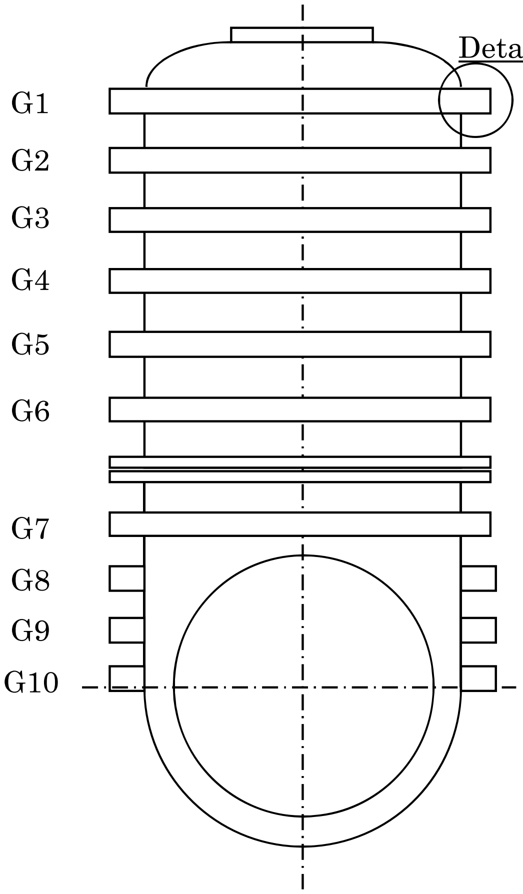




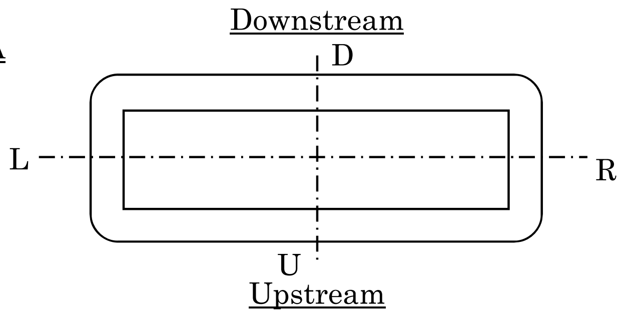
Unit : mm

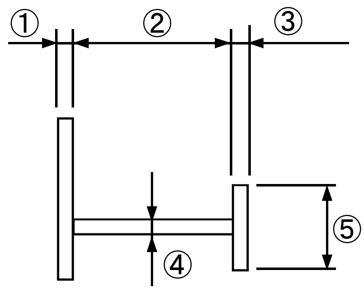
Measurement Location		Position	Result of Measurement						Evaluated thickness
			No.1	No.2	No.3	No.4	No.5	Average	
No.1 unit upstream side	A 1100	Top	5.4	5.4	6.2	6.3	5.7	5.80	5.93
		Left	5.4	5.4	5.4	5.8	6.0	5.60	
		Bottom	5.9	6.5	6.5	6.8	6.2	6.38	
		Right	—	—	—	—	—	—	
No.1 unit Downstream side	B 450	Top	6.4	6.4	7.3	6.2	6.7	6.60	6.51
		Left	6.1	6.2	6.8	6.7	6.2	6.40	
		Bottom	7.1	6.1	6.8	6.8	5.8	6.52	
		Right	—	—	—	—	—	—	

Dam	Oeste Dam	Date	12 May, 2011
Unit No.	No.1 Unit		



Front View





Detail A

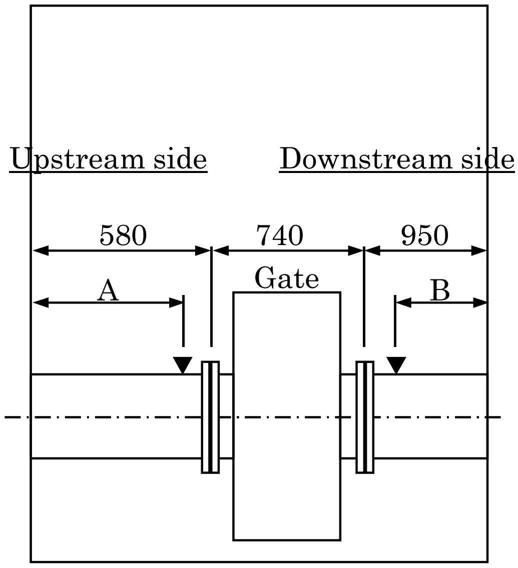
Unit : mm

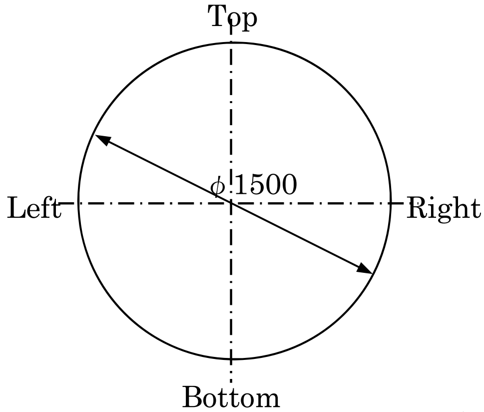
Measurement Location			Result of Measurement						
			No.1	No.2	No.3	No.4	No.5	Average	Design
G1	Right	②	–	–	–	–	–	–	100
		③	20.0	–	–	–	–	20.0	20
		⑤	65.0	–	–	–	–	65.0	60
G2	Right	②	105.0	–	–	–	–	105.0	100
		③	20.0	–	–	–	–	20.0	20
		⑤	65.0	–	–	–	–	65.0	60
G3	Right	①	12.3	12.5	12.2	13.1	12.6	12.5	15
		②	100.0	–	–	–	–	100.0	100
		③	20.0	–	–	–	–	20.0	20
		④	12.7	12.6	13.2	12.7	12.8	12.8	15
		⑤	65.0	–	–	–	–	65.0	60
G4	Right	①	13.1	11.8	11.9	13.1	12.9	12.6	15
		②	100.0	–	–	–	–	100.0	100
		③	20.0	–	–	–	–	20.0	20
		④	12.3	12.8	12.3	13.2	12.8	12.7	15
		⑤	65.0	–	–	–	–	65.0	60
G5	Right	②	100.0	–	–	–	–	100.0	100
		③	20.0	–	–	–	–	20.0	20
		⑤	65.0	–	–	–	–	65.0	60

Unit : mm

Measurement Location			Result of Measurement						
			No.1	No.2	No.3	No.4	No.5	Average	Design
G6	Right	②	100.0	−	−	−	−	100.0	100
		③	20.0	−	−	−	−	20.0	20
		⑤	65.0	−	−	−	−	65.0	60
G7	Right	①	10.5	10.6	10.2	10.1	10.6	10.4	15
		②	95.0	−	−	−	−	95.0	100
		③	20.0	−	−	−	−	20.0	20
		④	13.8	13.5	13.5	13.6	13.5	13.6	15
		⑤	65.0	−	−	−	−	65.0	60
G8	Right	②	100.0	−	−	−	−	100.0	100
		③	20.0	−	−	−	−	20.0	20
		⑤	65.0	−	−	−	−	65.0	60
G9	Right	②	100.0	−	−	−	−	100.0	100
		③	20.0	−	−	−	−	20.0	20
		⑤	65.0	−	−	−	−	65.0	60
G10	Right	②	100.0	−	−	−	−	100.0	100
		③	20.0	−	−	−	−	20.0	20
		⑤	65.0	−	−	−	−	65.0	60

Dam Sul Dam Date 12 May, 2011

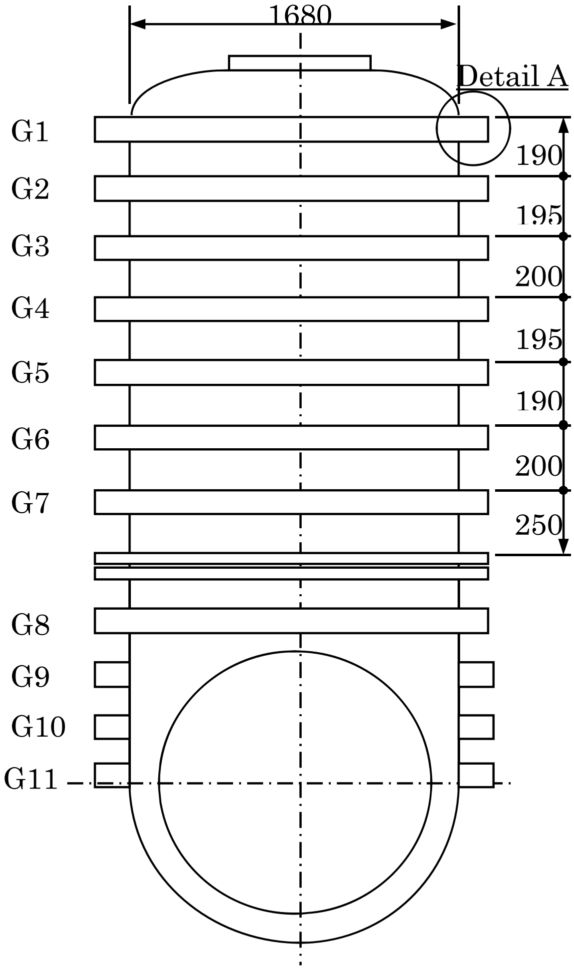




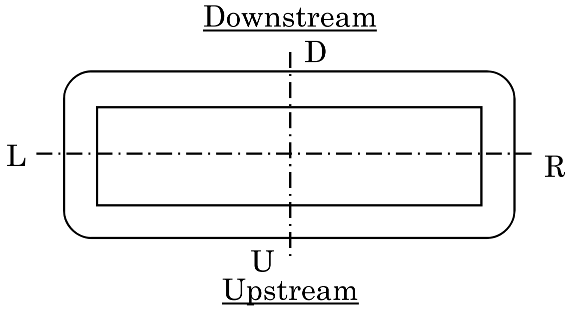
Unit : mm

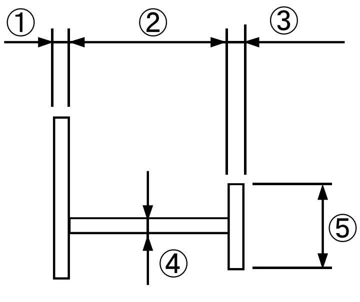
Measurement Location		Position	Result of Measurement						Evaluated thickness
			No.1	No.2	No.3	No.4	No.5	Average	
No. 2 Unit upstream side	A 250	Top	9.4	9.3	9.3	9.2	9.1	9.26	9.17
		Left	9.2	9.2	9.5	9.2	9.2	9.26	
		Bottom	9.2	9.2	8.7	9.2	8.7	9.00	
		Right	—	—	—	—	—	—	
No. 2 Unit Downstream side	B 100	Top	8.6	8.6	8.5	8.8	8.8	8.66	8.66
		Left	—	—	—	—	—	—	
		Bottom	—	—	—	—	—	—	
		Right	—	—	—	—	—	—	

Dam	Sul Dam	Date	12 May, 2011
Unit No.	No.2 Unit		



Front View





Detail A

Unit : mm

Measurement Location			Result of Measurement						
			No.1	No.2	No.3	No.4	No.5	Average	Design
G1	Upstream	①	12.5	12.5	12.6	12.6	12.7	12.58	12.7
		②	122.0	—	—	—	—	122.00	123
		③	26.0	—	—	—	—	26.00	25.4
		④	16.0	16.0	16.5	16.5	16.0	16.20	16
		⑤	100.0	—	—	—	—	100.00	100

APPENDIX-2 :

Structural calculation for control gates (After heightning)

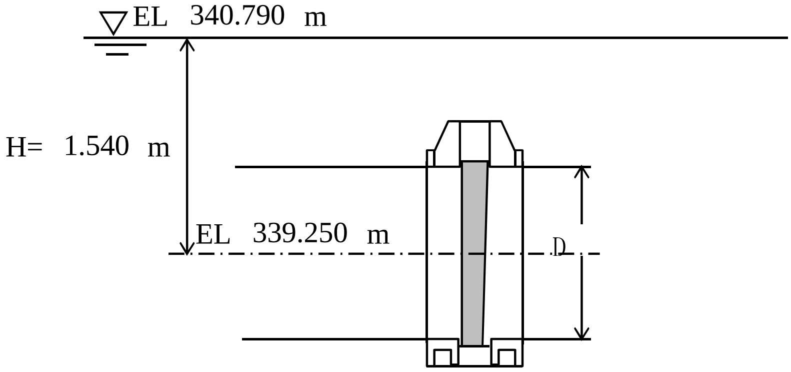
1. Strength Calculation for Control Gate in Oeste Dam (After heightning)

1.1 Design conditions

(1)	Type	Slide gate		
(2)	Quantity	7	sets	
(3)	Gate center elevation	EL.	339.25	m
(4)	Max. water level	EL.	364.65	m （heightning 2.0 m)
(5)	Flood water level	EL.	362.30	m
(6)	Normal water level	EL.	340.79	m
(7)	Diameter	φ	1.50	m
(8)	Seismic intensity		0.05	
(9)	Sealing system	Metal seal at both side of gate leaf		
(10)	Foundation rock elevation	EL.	337.60	m
(11)	Operation device	Hydraulic cylinder		
(12)	Lifting height		1.57	m
(13)	Operating system	Local		
(14)	Allowable stress	ABNT NBR 8883		

1.2 Design load

(1) CCN (Normal water level Only)



D：Diameter = φ1.50 m

Load of normal water level only

$Ps = \gamma o \times H \times A$

$= 9.81 \times 1.54 \times 1.77$

$= 26.69$ kN

Where, Ps ：Hydrostatic load

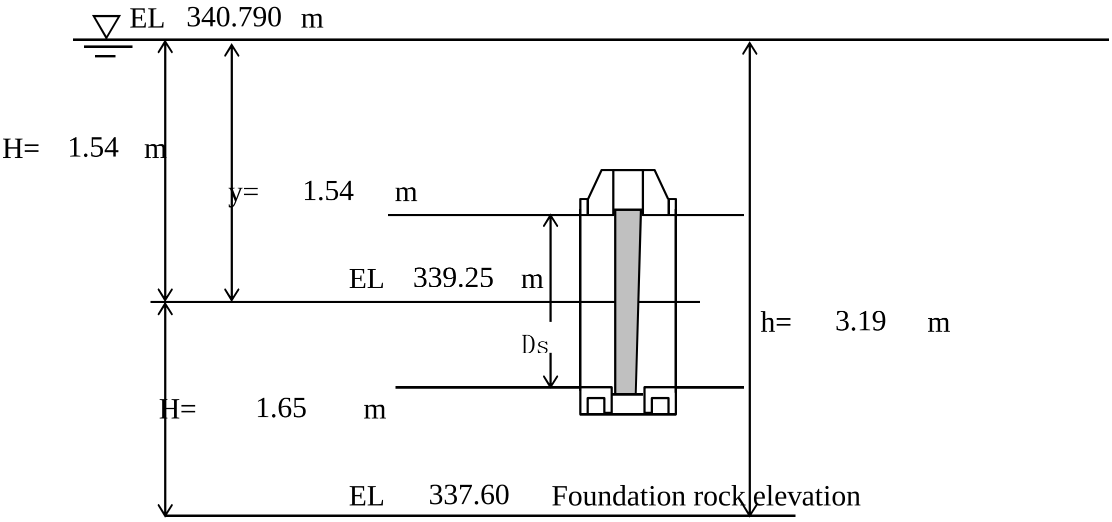
γo ：Specific gravity of water = 9.81 kN/m^3

H ：Design head = 1.54 m

A ：Receiving pressure area $= \pi \cdot Ds^2/4 = \pi \times 1.50^2/4$

$= 1.77$ m^2

(2) CCE1(Normal water level + Dynamic water pressure during earthquake)



a) Hydrostatic load

Ps= γo×H×A

= 9.81 × 1.54 × 1.77

= 26.69 kN

b) Dynamic pressure load during earthquake

$P_d = \gamma o \cdot 7/8 \cdot k \cdot (h \cdot y)^{1/2} \cdot A$

$= 9.81 \times 7/8 \times 0.05 \times 3.19 \times 1.54^{1/2} \times 1.77$

= 1.68 kN

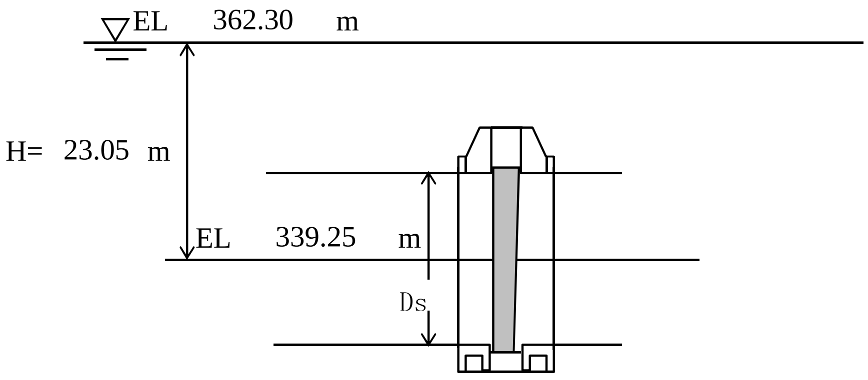
c) Total load

$Pw = Ps + P_d$

= 26.69 ＋ 1.68

= 28.38 kN

(3) CCE2(Flood water level only)

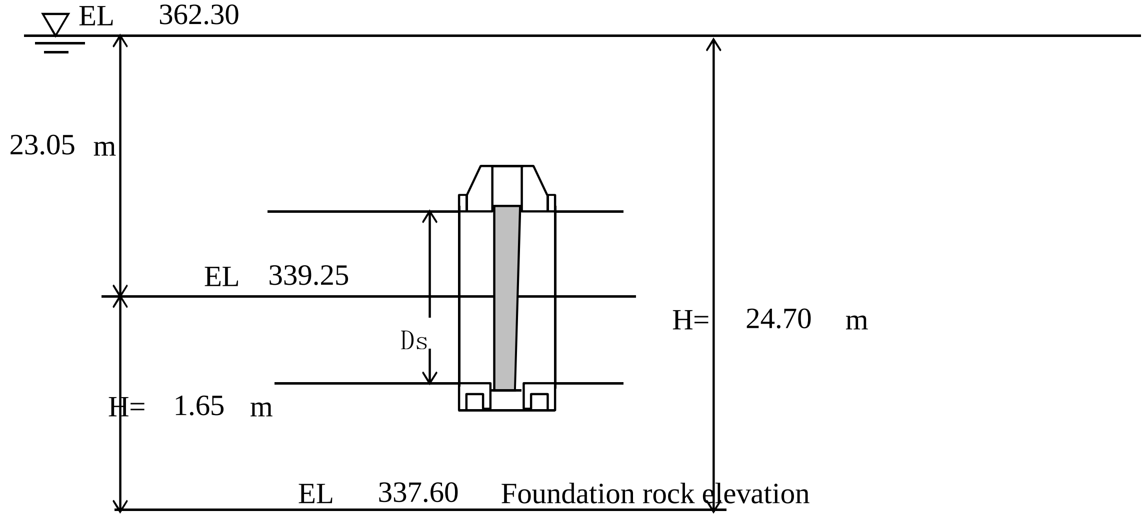


D：Diameter = φ1.50 m

$Ps = \gamma o \times H \times A$
$= 9.81 \times 23.05 \times 1.77$
$= 399.55$ kN

Where, Ps : Hydrostatic load
γo : Specific gravity of water = 9.81 kN/m^3
H : Design head = 23.05 m
A : Receiving pressure area = $\pi \cdot Ds^2/4$ = $\pi \times 1.50^2/4$
= 1.77 m^2

(4) CCL(Flood water level+ Dynamic water pressure during earthquake)

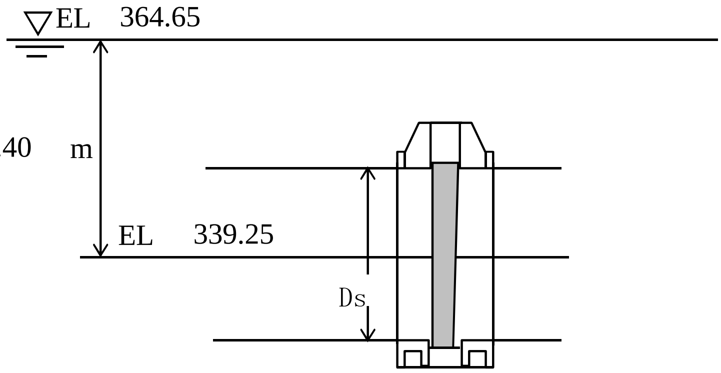


a) Hydrostatic load
$Ps = \gamma o \cdot H \cdot A$
$= 9.81 \times 23.05 \times 1.77$
$= 399.55$ KN

b) Dynamic pressure load during earthquake
$P_d = \gamma o \cdot 7/8 \cdot k \cdot (h \cdot y)^{1/2} \cdot A$
$= 9.81 \times 7/8 \times 0.05 \times 24.70 \times 23.05^{1/2} \times 1.77$
$= 18.10$ kN

c) Total load
$Pw = Ps + P_d$
$= 399.55 + 18.10$
$= 417.65$ kN

(5) Max. water level



D : Diameter = φ1.50 m

Ps= γo×H×A

= 9.81 × 25.40 × 1.77

= 440.29 kN

Where, Ps : Hydrostatic load

γo : Specific gravity of water = 9.81 kN/m^3

H : Design head = 25.40 m

A : Receiving pressure area = $\pi \cdot Ds^2/4$ = π × $1.50^2/4$

= 1.77 m^2

(5) Comparison of loads

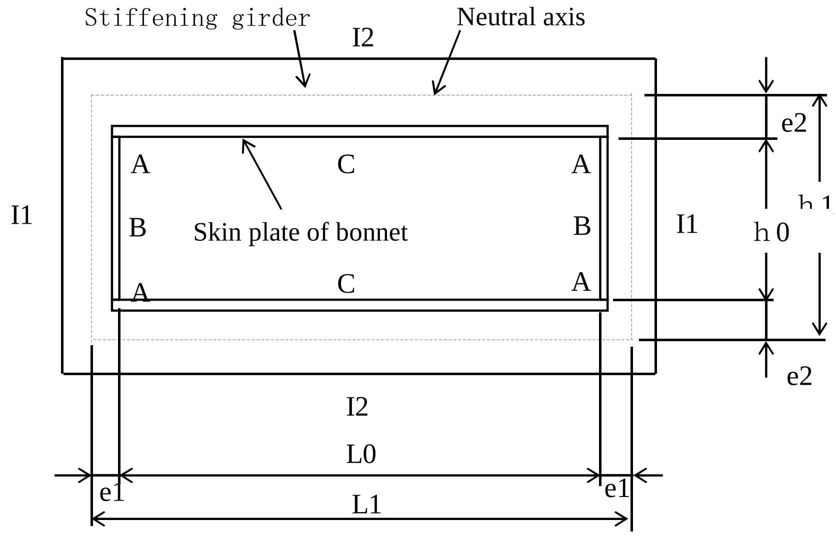
unit : kN

Case / Water level	Coefficient		Hydrostatic load only		Dynamic water pressure	
	Hydrostatic load only	Dynamic water pressure	Actual load	Converted load	Actual load	Converted load
Normal water level	0.50	0.90	26.69	53.39	28.38	31.53
			CCN		CCE1	
Flood water level	0.63	0.90	399.55	634.21	417.65	464.06
			CCE2		CCL	
Max. water level	0.80	—	440.29	550.36	—	—

The strength calculation is made for CCE2 since the maximum converted load acts on the bonnet at CCE2.

1.3 Strength calculation of bonnet

The bonnet is calculated as a box ramen as shown in the model figure below.



Where, L0 : Width of bonnet = 1575 mm

h0 : Depth of bonnet = 315 mm

(1) Internal pressure

pi= γo×H

= 9.81 × 23.05 = 226.121 kN/m^2

= 0.226 N/mm^2

pi : Internal pressure (N/mm^2)

γ0 : Specific gravity of water = 9.81 kN/m^3

H : Design head = 23.05 m

(2) Effective width of skin plate

The effective width is calculated so that the flange of stiffening girder may support the load together with the skin plate.

a) Point A

l/L≦0.02

λ= l

0.02<l/L<0.3

$\lambda=\{1.06-3.2(l/L)+4.5(l/L)^2\}\,l$

0.3≦l/L

λ= 0.15L

b) Point B and C

l/L≦0.05

λ= l

0.05<l/L<0.3

$\lambda=\{1.1-2(l/L)\}\,l$

0.3≦l/L

λ= 0.15L

Where, λ : Effective width of one side of skin plate mm

l : Half of supporting length of skin plate = 315 / 2 = 158 mm

L : Equivalent supporting length

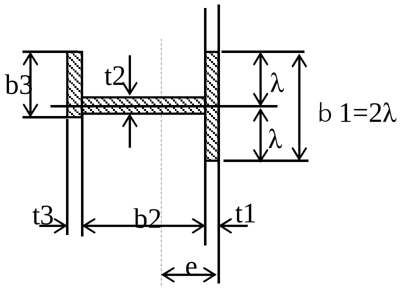
Point A = 0.2 (l0+h0) = 0.2 × (1575 + 315)= 378 mm

Point B = 0.6 h0 = 0.6 × 315 = 189 mm

Point C = 0.6 L0 = 0.6 × 1575 = 945 mm

Position	Effective width of skin plate				
	l mm	Lmm	l/L	λmm	2λmm
Point A	158	378	0.42	57	114
Point B	158	189	0.83	28	56
Point C	158	945	0.17	121	242

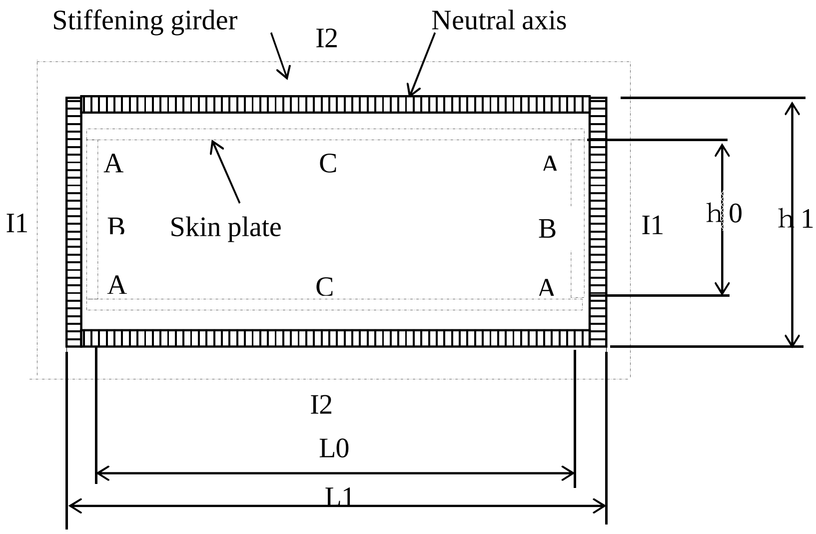
(3) Section properties of stiffening girder



t1 : Thickness of skin plate mm
t2 : Thickness of web mm
t3 : Thickness of flange mm
b1 : Effective width mm
b2 : Width of web mm
b3 : Width of flange mm

Position	Skin plate		Web		Flange		Section properties					
	t1	b1	t2	b2	t3	b3	I (mm^4)	Zi (mm^3)	Zo (mm^3)	A (mm^2)	Aw(mm^2)	e (mm)
A	12.5	114	12.8	100	20	65	10297124	166083	146058	4005	1280	62
B	12.5	56	12.8	100	20	65	7547377	101580	129680	3280	1280	74
C	12.5	242	12.8	100	20	65	13863875	300735	160462	5605	1280	46

(4) Sectional force



1) Acting load

It is assumed that the internal design pressure between the stiffeners acts as the distributed load. The acting load converts into the design load which is calculated by the ratio of an acting axis and a neutral axis.

$W = pi \cdot b \cdot (2h0+L0)/(2h1+L1)$

$= 0.226 \times 315 \times (2 \times 315 + 1575)/(2 \times 407 + 1724)$

$= 62$ N/mm

Where, W : Converted acting load N/mm

ps : Design internal pressure = 0.226 N/mm^2

b : Width of receiving pressure = 315 mm

h0 : Depth of bonnet = 315 mm

h1 : Length of neutral axis = h0+e = 315 + 2 × 46 = 407 mm

L0 : Width of bonnet = 1575 mm

L1 : Length of neutral axis = L0+2e : 1575 + 2 × 74 = 1724 mm

2) Acting load on each part

[Stiffness ratio]

k = (I2・h1)/(I1・L1)

= (13863875 × 407)/ (7547377 × 1724) = 0.434

n = h1/L1

= 407 / 1724 = 0.236

[Bending moment]

$MA=W \cdot L1^2/12 \cdot \{(1+n^2 \cdot k)/(1+k)\}$

$MB=MA-W \cdot h^2/8$

$MC=MA-W \cdot L1^2/8$

[Axial force]

Section A-B NAB=W・L1/2 （Tensile force）

Section B-C NBC=W・h1/2 （Tensile force）

[Shearing force]

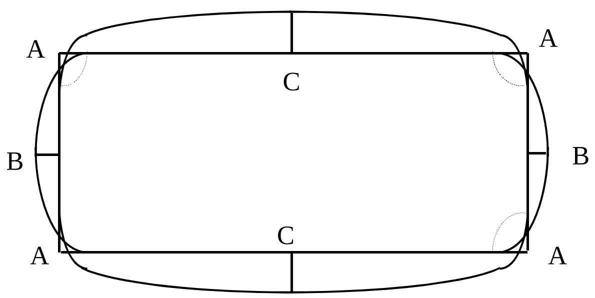
Section A-B SAB=W・h1/2

Section B-C SAC=W・l1/2

[Result of calculation]

MA= 10942410 N-mm MB= 9659805 N-mm

MC= -12037612 N-mm



VA= 0 N

NAB= 53330 N NBC= 12599 N

SAB= 12599 N SBC= 53330 N

(5) Stress of bonnet

1) Stress at "A"

Bending stress

[Bending stress(Inside)]

$\sigma Ai = MA/Zi+NAB/A$

$= 10942410 / 166083 + 53330 / 4005$

$= 65.9 + 13.3 = \underline{79.2\ N/mm^2 < \sigma a = 157.5\ N/mm^2}$

[Bending stress(Outside)]

$\sigma Ao = -MA/Zo+NAB/A$

$= -10942410 / 146058 + 53330 / 4005$

$= -74.9 + 13.3 = \underline{-61.6\ N/mm^2 < \sigma a = 157.5\ N/mm^2}$

Shearing stress

$\tau A = SBC/Aw$

$= 53330 / 1280$

$= \underline{41.7\ N/mm^2 < \tau a = 90.9\ N/mm^2}$

2) Stress at "B"

Bending stress

[Bending stress(Inside)]

$\sigma Bi = MB/Zi+NAB/A$

$= 9659805 / 101580 + 53330 / 3280$

$= 95.1 + 16.3 = \underline{111.4\ N/mm^2 < \sigma a = 157.5\ N/mm^2}$

[Bending stress(Outside)]

$\sigma Bo = -MB/Zo+NAB/A$

$= -9659805 / 129680 + 53330 / 3280$

$= -74.5 + 16.3 = \underline{-58.2\ N/mm^2 < \sigma a = 157.5\ N/mm^2}$

Shearing stress

$\tau B = SAB/Aw$

$= 12599 / 1280$

$= \underline{9.8\ N/mm^2 < \tau a = 90.9\ N/mm^2}$

3) Stress at "C"

Bending stress

[Bending stress(Inside)]

$\sigma Ci = MC/Zi+NBC/A$

$= -12037612 / 300735 + 12599 / 5605$

$= -40.0 + 2.2 = \underline{-37.8\ N/mm^2 < \sigma a = 157.5\ N/mm^2}$

[Bending stress(Outside)]

$\sigma Co = -MC/Zo+NBC/A$

$= 12037612 / 160462 + 12599 / 5605$

$= 75.0 + 2.2 = \underline{77.3\ N/mm^2 < \sigma a = 157.5\ N/mm^2}$

Shearing stress

$\tau C = SBC/Aw$

$= 53330 / 1280$

$= \underline{41.7\ N/mm^2 < \tau a = 90.9\ N/mm^2}$

(6) Allowable stresses

Allowable bending stress

Outside

$\sigma a = 250 \times 0.63 = 157.5$ N/mm^2 Material : A36(ASTM)

Inside

$\sigma a = 250 \times 0.63 = 157.5$ N/mm^2 Material : A36(ASTM)

Coefficient : 0.63

Allowable shearing stress

Outside

$\tau a = 90.9$ N/mm^2 Material : A36(ASTM)

1.4 Operating load

The operating load is summed up the following loads.

(1) Self weight

Gate leaf G1 = 1.6 × 9.81 = 15.7 kN

Rod of cylinder G2 = 0.77 kN

Total load G = 16.47 kN

(2) Friction force of seal plate

$F2 = \mu_2 \cdot P$

$= 0.4 \times 440.290 = 176.12$ kN

Where, μ_2 : Frictional coefficient of metal seal = 0.4

P : Hydrostatic pressure at operation = 440.29 kN

(3) Buoyancy

$F3 = \gamma 0 / W0 \cdot G1$

$= 9.81 / 77.0 \times 15.70 = 2.00$ kN

ここに、 $\gamma 0$: Specific gravity of water = 9.81 kN/m3

W0 : Specific gravity of steel material = 77.01 kN/m3

(4) Friction force of seal in cylinder

$F4 = d \cdot \pi \cdot b \cdot n \cdot \mu_2 \cdot P$

$= 0.090 \times \pi \times 0.006 \times 1 \times 0.7 \times 440.290 = 0.523$ kN

Where, d : Outside diameter of rod = 0.090 m

b : Contact width of V-packing = 0.006 m

n : Quantity of V-packing = 1 piece

μ_2 : Frictional coefficient of V-packing = 0.7

P : Pressure on V-packing = 440.290 kN

(5) Total operating load

(Unit : kN)

Load		Raising		Lowering	
Self weight	G	↓	16.47	↓	16.47
Friction force of seal plate	F2	↓	176.12	↑	176.12
Buoyancy	F3	↑	2.00	↑	2.00
Friction force of seal in cylinder	F4	↓	0.52	↑	0.52
Total load		↓	191.11	↑	162.17

Raising load	Fu	=	191.11	kN	→	200.00	kN
Lowering load	Fd	=	162.17	kN	→	170.00	kN

1.5 Capacity of cylinder

(1) Design conditions

Type of cylinder	Fixed cylinder				
Rated pressure	Raising（Setting pressure of relief valve）	P1	=	21.0	MPa
	Lowering（Setting pressure of relief valve）	P2	=	12.6	MPa
Working pressure	Raising（Effective operating pressure）	P1'	=	18.9	MPa
	Lowering（Effective operating pressure）	P2'	=	11.3	MPa
Operating speed	0.1 m/min				
Operating load	Raising	Wu	=	200.00	kN
	Lowering	Wd	=	170.00	kN
Cylinder	Inside diameter of tube	D	=	160	mm
	Outside diameter of rod	d	=	90	mm
	Cylinder stroke	S	=	1570	mm

(2) Pulling and pushing forces of cylinder

1) Rated pressure

Pulling force (Raising)

$$F_u = \frac{\pi}{4} \times (D^2 - d^2) \times p_1'$$

$$= \frac{\pi}{4} \times (160^2 - 90^2) \times \frac{21.0}{1000}$$

$$= 288.6 \text{ kN}$$

Pushing force (Lowering)

$$F_d = \frac{\pi}{4} \times D^2 \times p_2'$$

$$= \frac{\pi}{4} \times 160^2 \times \frac{12.6}{1000}$$

$$= 253.3 \text{ kN}$$

2) Working pressure

Pulling force (Raising)

$$F_u' = \frac{\pi}{4} \times (D^2 - d^2) \times p_1'$$

$$= \frac{\pi}{4} \times (160^2 - 90^2) \times \frac{18.9}{1000}$$

$$= 259.8 \text{ kN} > W_u = 200 \text{ kN}$$

Pushing force (Lowering)

$$F_d' = \frac{\pi}{4} \times D^2 \times p_2'$$

$$= \frac{\pi}{4} \times 160^2 \times \frac{11.3}{1000}$$

$$= 228.0 \text{ kN} > W_d = 170.00 \text{ kN}$$

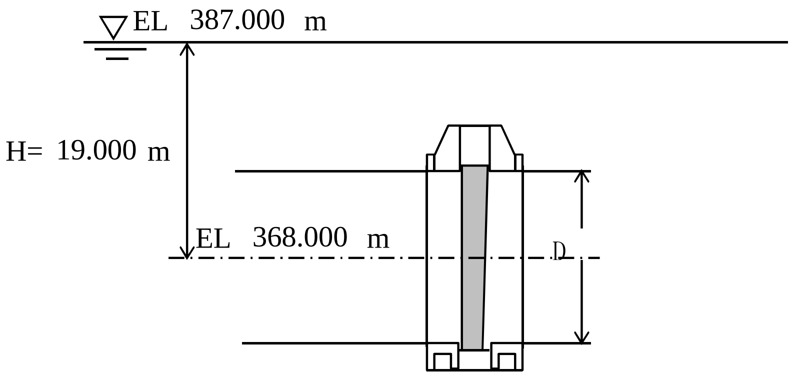
2. Strength Calculation for control gate in Oeste dam (After heightning)

2.1 Design conditions

(1)	Type	Slide gate		
(2)	Quantity	5	sets	
(3)	Gate center elevation	EL.	368.00	m
(4)	Max. water level	EL.	408.00	m （heightning 2.0 m)
(5)	Flood water level	EL.	401.00	m
(6)	Normal water level	EL.	387.00	m
(7)	Diameter	φ	1.50	m
(8)	Seismic intensity		0.05	
(9)	Sealing system	Metal seal at both side of gate leaf		
(10)	Basic grand level	EL.	357.50	m
(11)	Operation device	Hydraulic cylinder		
(12)	Lifting height		1.57	m
(13)	Operating system	Local		
(14)	Allowable stress	ABNT NBR 8883		

2.2 Design head

(1) CCN (Nomal water level Only)



D：Diameter = φ1.50 m

Load of normal water level only

Ps= γo×H×A

= 9.81 × 19.00 × 1.77

= 329.35 kN

Where, Ps ：Hydrostatic load

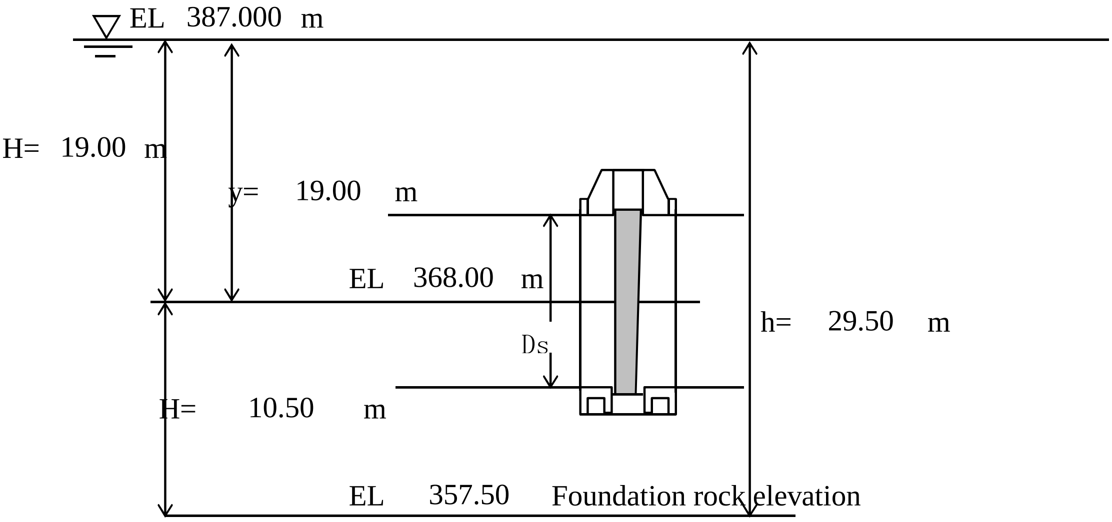
γo ：Specific gravity of water = 9.81 kN/m^3

H ：Design head = 19.00 m

A ：Receiving pressure area = $\pi \cdot Ds^2/4$ = π × $1.50^2/4$

= 1.77 m^2

(2) CCE1(Normal water level + Dynamic water pressure during earthquake)



a) Hydrostatic load

$Ps = \gamma o \times H \times A$

$= 9.81 \times 19.00 \times 1.77$

$= 329.35$ kN

b) Dynamic pressure load during earthquake

$P_d = \gamma o \cdot 7/8 \cdot k \cdot (h \cdot y)^{1/2} \cdot A$

$= 9.81 \times 7/8 \times 0.05 \times 29.50 \times 19.00^{1/2} \times 1.77$

$= 17.95$ kN

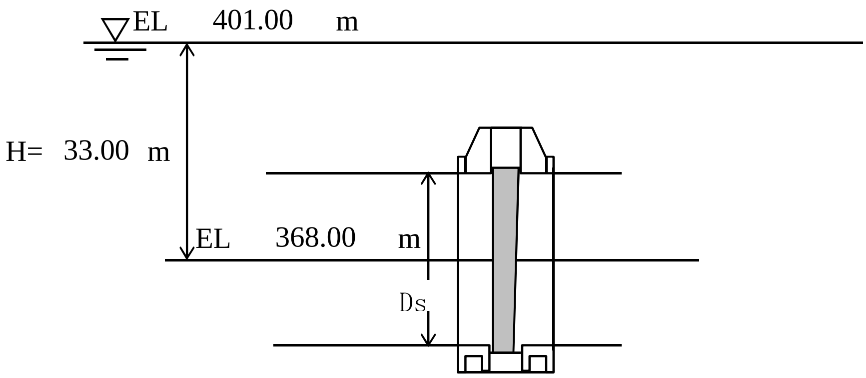
c) Total load

$Pw = Ps + P_d$

$= 329.35 + 17.95$

$= 347.31$ kN

(3) CCE2(Flood water level only)



D: Caliber = φ1.50 m

$Ps = \gamma o \times H \times A$

$= 9.81 \times 33.00 \times 1.77$

$= 572.03$ kN

Where, Ps : Hydrostatic load

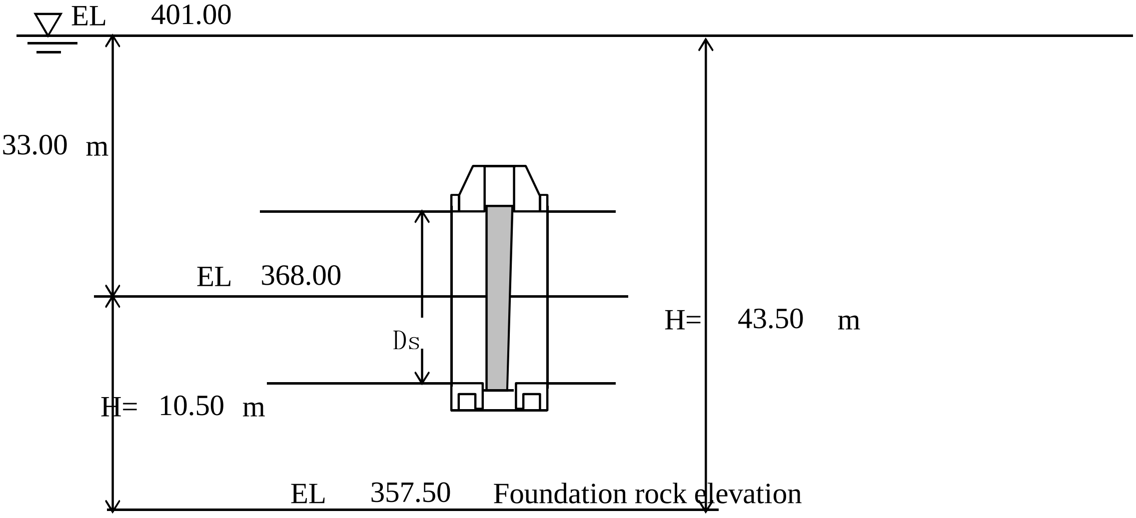
γo : Specific gravity of water = 9.81 kN/m^3

H : Design head = 33.00 m

A : Receiving pressure area $= \pi \cdot Ds^2/4 = \pi \times 1.50^2/4$

$= 1.77$ m^2

(4) CCL(Flood water level+ Dynamic water pressure during earthquake)



a) Hydrostatic load

$Ps = \gamma o \cdot H \cdot A$

$= 9.81 \times 33.00 \times 1.77$

$= 572.03$ KN

b) Dynamic pressure load during earthquake

$P_d = \gamma o \cdot 7/8 \cdot k \cdot (h \cdot y)^{1/2} \cdot A$

$= 9.81 \times 7/8 \times 0.05 \times 43.50 \times 33.00^{1/2} \times 1.77$

$= 28.73$ kN

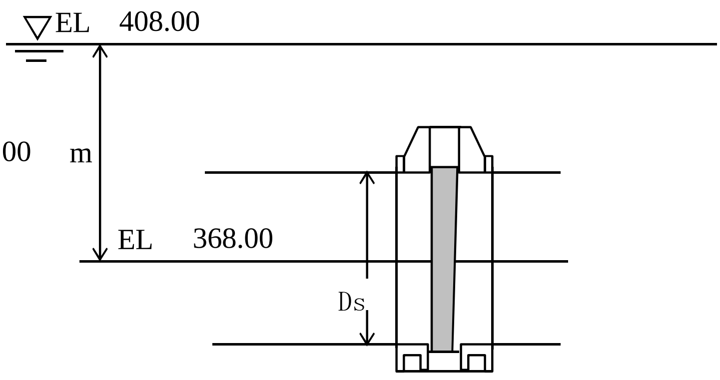
c) Total load

$Pw = Ps + P_d$

$= 572.03 + 28.73$

$= 600.76$ kN

(5) Max. water level



D : Diameter = φ1.50 m

$Ps = \gamma o \times H \times A$

$= 9.81 \times 40.00 \times 1.77$

$= 693.37$ kN

Where, Ps : Hydrostatic load

γo : Specific gravity of water = 9.81 kN/m^3

H : Design head = 40.00 m

A : Receiving pressure area $= \pi \cdot Ds^2/4 = \pi \times 1.50^2/4$

$= 1.77$ m^2

(5) Comparison of loads

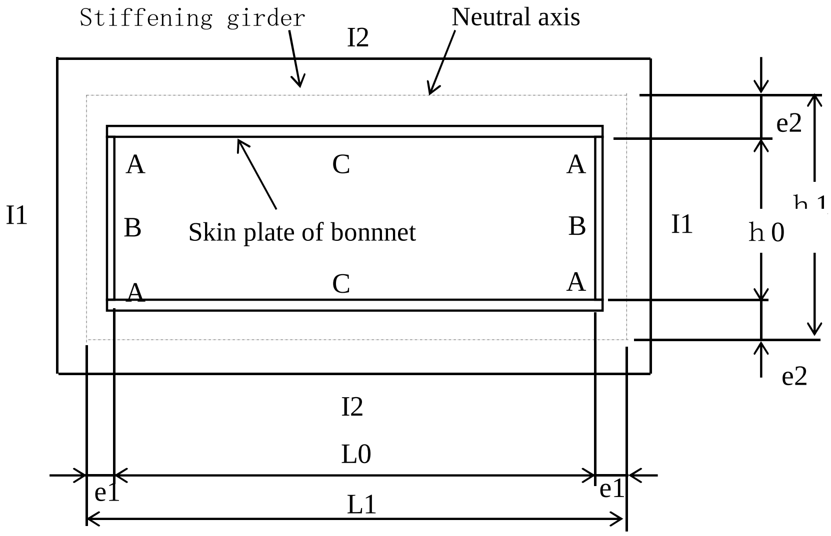
unit : kN

Case / 水 位	Coefficient		Hydrostatic load only		Dynamic water pressure	
	Hydrostatic load only	Dynamic water pressure	Actual load	Converted load	Actual load	Converted load
Normal water level	0.50	0.90	329.35	658.70	347.31	385.90
			CCN		CCE1	
Flood water level	0.63	0.90	572.03	907.99	600.76	667.52
			CCE2		CCL	
Max. water level	0.80	—	693.37	866.71	—	—

Because the load of "CCE2" becomes the maximum, strength of the load of "CCE2" is checked.

2.3 Strength calculation of bonnet

The bonnet is calculated as a box ramen as shown in the model figure below.



Where, L0 : Width of bonnet = 1650 mm

h0 : Depth of bonnet = 315 mm

(1) Internal pressure

pi= γo×H

= 9.81 × 33.00 = 323.73 kN/m^2

= 0.324 N/mm^2

pi : Internal pressure (N/mm^2)

γ0 : Specific gravity of water = 9.81 kN/m^3

H : Design head = 33.00 m

(2) Effective width of skin plate

The effective width is calculated so that the flange of stiffening girder may support the load together with the skin plate.

a) Point of A

l/L≦0.02

λ= l

0.02<l/L<0.3

$\lambda=\{1.06-3.2(l/L)+4.5(l/L)^2\}\,l$

0.3≦l/L

λ= 0.15L

b) Point of B and C

l/L≦0.05

λ= l

0.05<l/L<0.3

$\lambda=\{1.1-2(l/L)\}\,l$

0.3≦l/L

λ= 0.15L

Where, λ : Working width in one side of skinplate mm

l : Half of skin plate at support intervals = 315 / 2 = 158 mm

L : Equivalent support inter

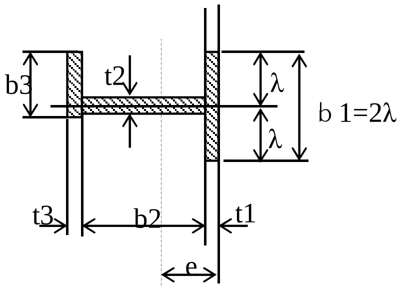
Point A = 0.2 (l0+h0) = 0.2 × (1650 + 315)= 393 mm

Point B = 0.6 h0 = 0.6 × 315 = 189 mm

Point C = 0.6 L0 = 0.6 × 1650 = 990 mm

Position	Effective width of skin plate				
	l mm	Lmm	l/L	λmm	2λmm
Point A	158	393	0.40	59	118
Point B	158	189	0.83	28	56
Point C	825	990	0.83	149	298

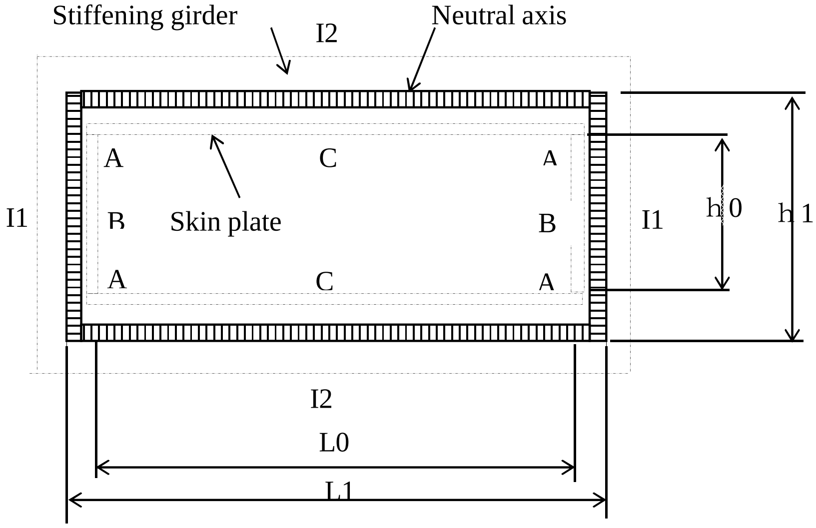
(3) Section properties of stiffening girder



t1 : Thickness of skin plate mm
t2 : Thickness of web mm
t3 : Thickness of flange mm
b1 : Effective width mm
b2 : Width of web mm
b3 : Width of flange mm

Position	Skin plate		Web		Flange		Section properties					
	t1	b1	t2	b2	t3	b3	I (mm^4)	Zi (mm^3)	Zo (mm^3)	A (mm^2)	Aw(mm^2)	e (mm)
A	12.6	118	16.2	122	26	100	22214599	250164	309396	6063	1976.4	89
B	12.6	56	16.2	122	26	100	16102576	159431	270177	5282	1976.4	101
C	12.6	298	16.2	122	26	100	33413694	503218	354710	8331	1976.4	66

(4) Sectional force



1) Acting load

It is assumed that the internal design pressure between the stiffeners acts as the distributed load. The acting load converts into the design load which is calculated by the ratio of an acting axis and a neutral axis.

$W = pi \cdot b \cdot (2h0+L0)/(2h1+L1)$

$= 0.324 \times 315 \times (2 \times 315 + 1650) / (2 \times 448 + 1852)$

$= 85$ N/mm

Where, W : Converted acting load N/mm

ps : Design internal pressure = 0.324 N/mm^2

b : Width of receiving pressure = 315 mm

h0 : Depth of bonnet = 315 mm

h1 : Length of neutral axis = h0+e = 315 + 2 × 66 = 448 mm

L0 : Width of bonnet = 1650 mm

L1 : Length of neutral axis = L0+2e : 1650 + 2 × 101 = 1852 mm

2) Acting load on each part

[Stiffness ratio]

k = (I2・h1)/(I1・L1)

= (33413694 × 448)/ (16102576 × 1852) = 0.502

n = h1/L1

= 448 / 1852 = 0.242

[Bending moment]

$MA=W \cdot L1^2/12 \cdot \{(1+n^2 \cdot k)/(1+k)\}$

$MB=MA-W \cdot h^2/8$

$MC=MA-W \cdot L1^2/8$

[Axial force]

Section A-B NAB=W・L1/2（Tensile force）

Section B-C NBC=W・h1/2（Tensile force）

[Shearing force]

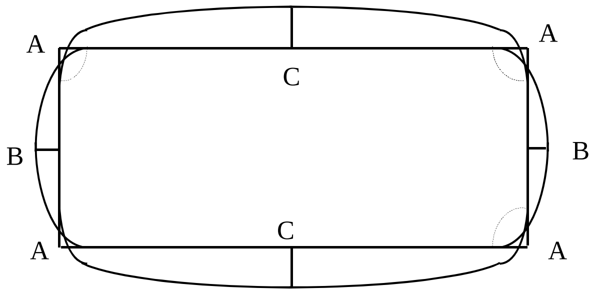
Section A-B SAB=W・h1/2

Section B-C SAC=W・l1/2

[Result of calculation]

MA= 16578259 N-mm MB= 14457199 N-mm

MC= -19701702 N-mm



VA= 0 N

NAB= 78358 N NBC= 18946 N

SAB= 18946 N SBC= 78358 N

(5) Stress of bonnet

1) Stress at "A"

Bending stress

[Bending stress(Inside)]

σAi = MA/Zi+NAB/A

= 16578259 / 250164 + 78358 / 6063

= 66.3 + 12.9 = 79.2 N/mm^2 ＜ σa = 157.5 N/mm^2

[Bending stress(Outside)]

σAo = -MA/Zo+NAB/A

= -16578259 / 309396 + 78358 / 6063

= -53.6 + 12.9 = -40.7 N/mm^2 ＜ σa = 157.5 N/mm^2

Shearing stress

τA = SBC/Aw

= 78358 / 1976

= 39.6 N/mm^2 ＜ τa= 90.9 N/mm^2

2) Stress of "B"

Bending stress

[Bending stress(Inside)]

σAi = MB/Zi+NAB/A

= 14457199 / 159431 + 78358 / 5282

= 90.7 + 14.8 = 105.5 N/mm^2 ＜ σa = 157.5 N/mm^2

[Bending stress(Outside)]

σAo = -MB/Zo+NAB/A

= -14457199 / 270177 + 78358 / 5282

= -53.5 + 14.8 = -38.7 N/mm^2 ＜ σa = 157.5 N/mm^2

Shearing stress

τA = SAB/Aw

= 18946 / 1976

= 9.6 N/mm^2 ＜ τa= 90.9 N/mm^2

3) Stress of "C"

Bending stress

[Bending stress(Inside)]

σAi = MC/Zi+NBC/A

= -19701702 / 503218 + 18946 / 8331

= -39.2 + 2.3 = -36.9 N/mm^2 ＜ σa = 157.5 N/mm^2

[Bending stress(Outside)]

σAo = -MC/Zo+NBC/A

= 19701702 / 354710 + 18946 / 8331

= 55.5 + 2.3 = 57.8 N/mm^2 ＜ σa = 157.5 N/mm^2

Shearing stress

τA = SBC/Aw

= 78358 / 1976

= 39.6 N/mm^2 ＜ τa= 90.9 N/mm^2

(6) Allowable stresses

Allowable bending stress

Outside

$\sigma a = 250 \times 0.63 = 157.5$ N/mm^2 Material：A36(ASTM)

Inside

$\sigma a = 250 \times 0.63 = 157.5$ N/mm^2 Material：A36(ASTM)

Coefficient： 0.63

Allowable shearing stress

Outside

$\tau a = 90.9$ N/mm^2 Material：A36(ASTM)

2.4 Operating load

The operating load is summed up the following loads.

(1) Self weight

Gate leaf G1 = 2.5 × 9.81 = 24.53 kN

Rod of cylinder G2 = 0.77 kN

Total load G = 25.30 kN

(2) Seal friction

$F2 = \mu_2 \cdot P$

= 0.4 × 693.371 = 277.35 kN

Where, μ_2 ：Frictional coefficient of metal seal = 0.4

P ：Hydrostatic pressure at operation = 693.37 kN

(3) Buoyancy

$F3 = \gamma 0 / W0 \cdot G1$

= 9.81 / 77.0 × 24.53 = 3.12 kN

ここに、 $\gamma 0$ ：Specific gravity of water = 9.81 kN/m3

W0 ：Specific gravity of steel material = 77.01 kN/m3

(4) Friction force of seal in cylinder

$F4 = d \cdot \pi \cdot b \cdot n \cdot \mu_2 \cdot P$

= 0.090 × π × 0.006 × 1 × 0.7 × 693.371 = 0.823 kN

Where, d ：Rod outside diameter = 0.090 m

b ：Width of contact of V-packing = 0.006 m

n ：Quantity of V-paccking = 1 piece

μ_2 ：Frictional coefficient of V-packing = 0.7

P ：Pressure on V-packing = 693.371 kN

(5) Total operating load

(Unit：kN)

Load		Raising	Lowering
Self weight	G	↓ 25.30	↓ 25.30
Seal friction	F2	↓ 277.35	↑ 277.35
Buoyancy	F3	↑ 3.12	↑ 3.12
Friction force of seal in cylinder	F4	↓ 0.82	↑ 0.82
Total load		↓ 300.34	↑ 256.00

Raising load	Fu	=	300.34	kN	→	310.00	kN
Lowerring load	Fd	=	256.00	kN	→	260.00	kN

2.5 Capacity of cylinder

(1) Design conditions

Type of hoist	Fixed cylinder				
Rated pressure	Raising（Setting pressure of relief valve）	P1	=	16.0	MPa
	Lowering（Setting pressure of relief valve）	P2	=	9.6	MPa
Working pressure	Raising（Effective operating pressure）	P1'	=	14.4	MPa
	Lowering（Effective operating pressure）	P2'	=	8.6	MPa
Operating speed	0.1 m/min				
Operating load	Raising	Wu	=	310.00	kN
	Lowerring	Wd	=	260.00	kN
Cylinder	Inside diameter of tube	D	=	200	mm
	Outside diameter of rod	d	=	100	mm
	Cylinder stroke	S	=	1570	mm

(2) Power to push and power to pull

1）Rated pressure

Pulling force (Raising)

$$F_u = \frac{\pi}{4} \times (D^2 - d^2) \times p_1'$$

$$= \frac{\pi}{4} \times (200^2 - 100^2) \times \frac{16.0}{1000}$$

$$= 377 \text{ kN}$$

Pushing force (Lowering)

$$F_d = \frac{\pi}{4} \times D^2 \times p_2'$$

$$= \frac{\pi}{4} \times 200^2 \times \frac{9.6}{1000}$$

$$= 301.6 \text{ kN}$$

2）Working pressure

Pulling force (Raising)

$$F_u' = \frac{\pi}{4} \times (D^2 - d^2) \times p_1'$$

$$= \frac{\pi}{4} \times (200^2 - 100^2) \times \frac{14.4}{1000}$$

$$= 339.3 \text{ kN} > W_u = 310 \text{ kN}$$

Pushing force (Lowering)

$$F_d' = \frac{\pi}{4} \times D^2 \times p_2'$$

$$= \frac{\pi}{4} \times 200^2 \times \frac{8.6}{1000}$$

$$= 271.4 \text{ kN} > W_d = 260.00 \text{ kN}$$

APPENDIX-3 :

Structural calculation for control gates (Before heightning)

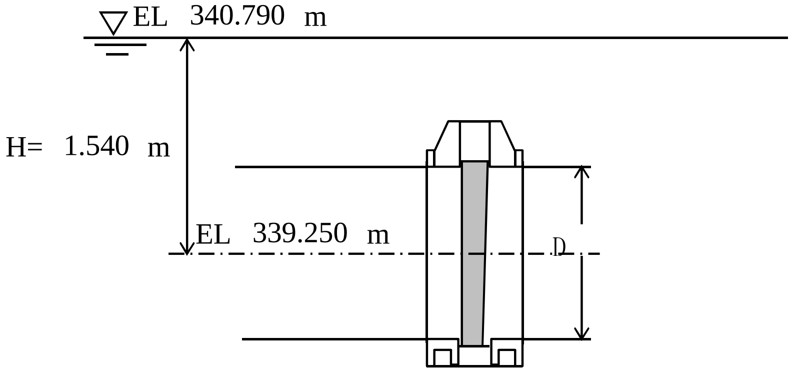
1. Strength Calculation for Control Gate in Oeste Dam (Before heightning)

1.1 Design conditions

(1)	Type	Slide gate
(2)	Quantity	7 sets
(3)	Gate center elevation	EL. 339.25 m
(4)	Max. water level	EL. 362.65 m （heightning 0.0 m)
(5)	Flood water level	EL. 360.30 m
(6)	Normal water level	EL. 340.79 m
(7)	Diameter	φ 1.50 m
(8)	Seismic intensity	0.05
(9)	Sealing system	Metal seal at both side of gate leaf
(10)	Foundation rock elevation	EL. 337.60 m
(11)	Operation device	Hydraulic cylinder
(12)	Lifting height	1.57 m
(13)	Operating system	Local
(14)	Allowable stress	ABNT NBR 8883

1.2 Design load

(1) CCN (Normal water level Only)



D：Diameter = φ1.50 m

Load of normal water level only

Ps= γo×H×A

= 9.81 × 1.54 × 1.77

= 26.69 kN

Where, Ps ：Hydrostatic load

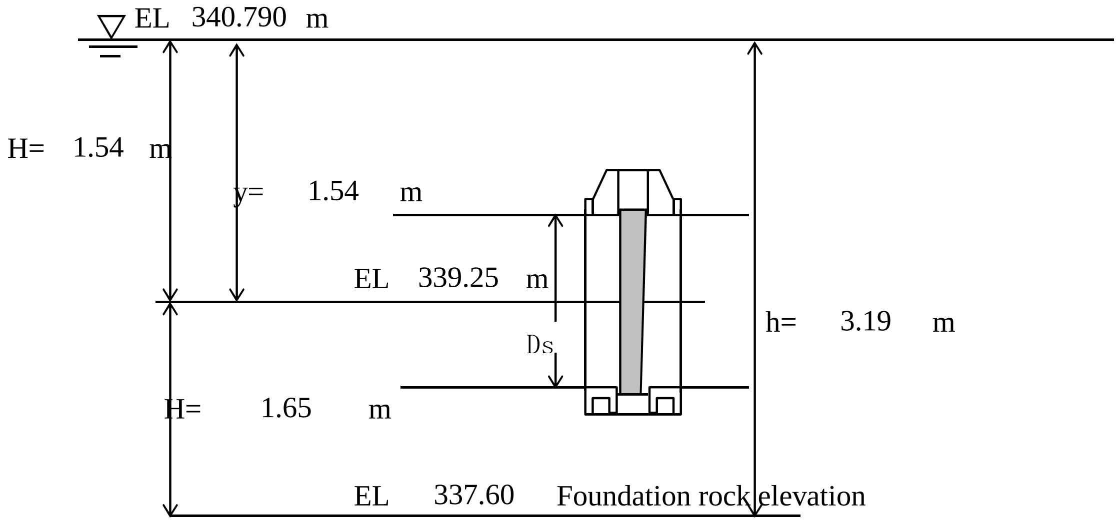
γo ：Specific gravity of water = 9.81 kN/m^3

H ：Design head = 1.54 m

A ：Receiving pressure area = $\pi \cdot Ds^2/4$ = π × $1.50^2/4$

= 1.77 m^2

(2) CCE1(Normal water level + Dynamic water pressure during earthquake)



a) Hydrostatic load

$Ps = \gamma o \times H \times A$

$= 9.81 \times 1.54 \times 1.77$

$= 26.69$ kN

b) Dynamic pressure load during earthquake

$P_d = \gamma o \cdot 7/8 \cdot k \cdot (h \cdot y)^{1/2} \cdot A$

$= 9.81 \times 7/8 \times 0.05 \times 3.19 \times 1.54^{1/2} \times 1.77$

$= 1.68$ kN

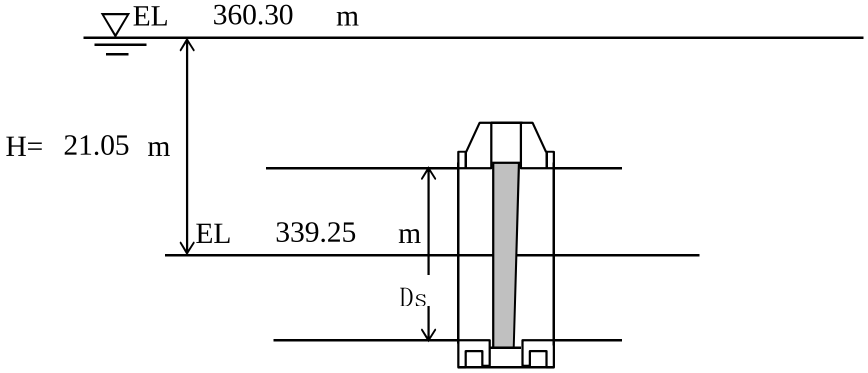
c) Total load

$Pw = Ps + P_d$

$= 26.69 + 1.68$

$= 28.38$ kN

(3) CCE2(Flood water level only)



D：Diameter = φ1.50 m

$Ps = \gamma o \times H \times A$

$= 9.81 \times 21.05 \times 1.77$

$= 364.89$ kN

Where, Ps : Hydrostatic load

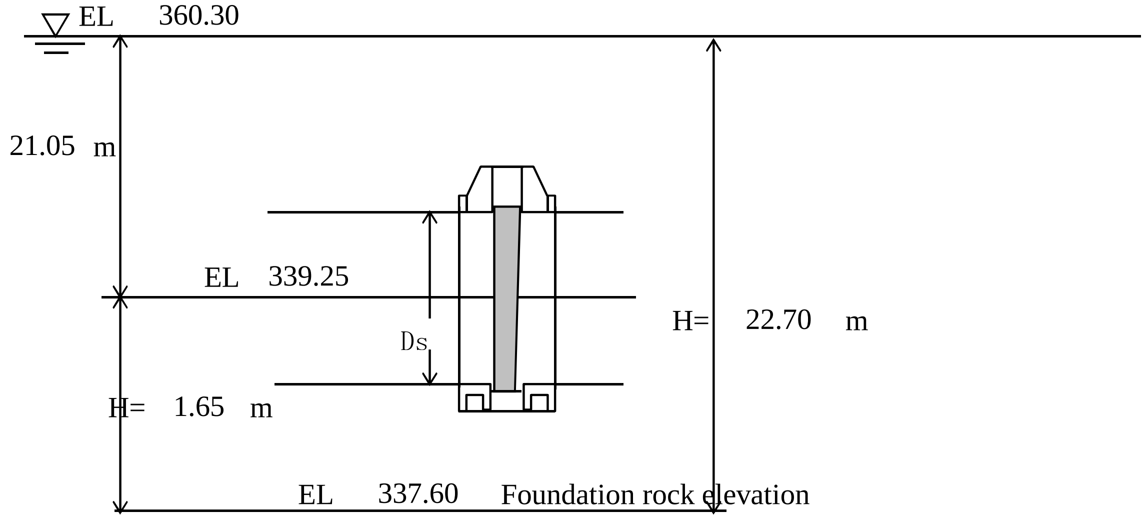
γo : Specific gravity of water = 9.81 kN/m^3

H : Design head = 21.05 m

A : Receiving pressure area $= \pi \cdot Ds^2/4 = \pi \times 1.50^2/4$

$= 1.77$ m^2

(4) CCL(Flood water level+ Dynamic water pressure during earthquake)



a) Hydrostatic load

$Ps = \gamma o \cdot H \cdot A$

$= 9.81 \times 21.05 \times 1.77$

$= 364.89$ KN

b) Dynamic pressure load during earthquake

$P_d = \gamma o \cdot 7/8 \cdot k \cdot (h \cdot y)^{1/2} \cdot A$

$= 9.81 \times 7/8 \times 0.05 \times 22.70 \times 21.05^{1/2} \times 1.77$

$= 16.58$ kN

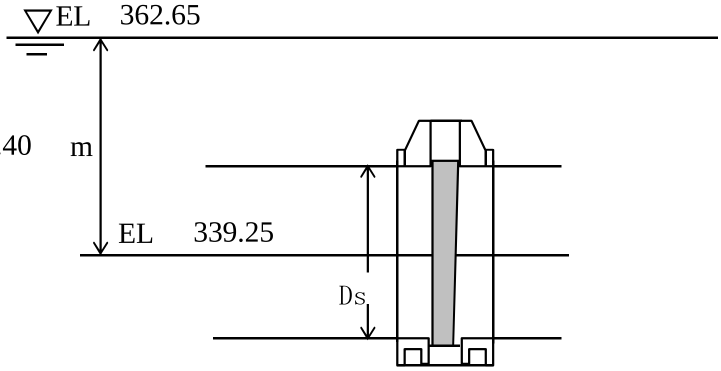
c) Total load

$Pw = Ps + P_d$

$= 364.89 + 16.58$

$= 381.46$ kN

(5) Max. water level



D : Diameter = φ1.50 m

$Ps = \gamma o \times H \times A$

$= 9.81 \times 23.40 \times 1.77$

$= 405.62$ kN

Where,
- Ps : Hydrostatic load
- γo : Specific gravity of water = 9.81 kN/m^3
- H : Design head = 23.40 m
- A : Receiving pressure area = $\pi \cdot Ds^2/4 = \pi \times 1.50^2/4$ = 1.77 m^2

(5) Comparison of loads

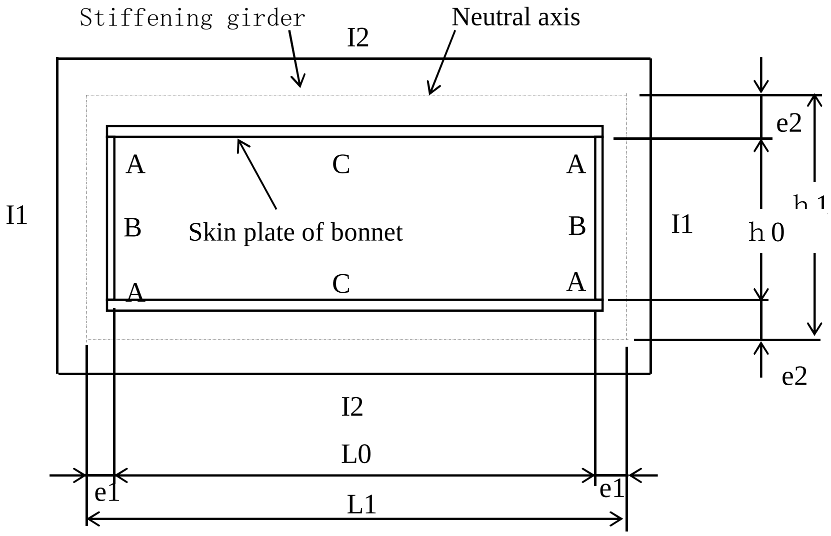
unit : kN

Case / Water level	Coefficient		Hydrostatic load only		Dynamic water pressure	
	Hydrostatic load only	Dynamic water pressure	Actual load	Converted load	Actual load	Converted load
Normal water level	0.50	0.90	26.69	53.39	28.38	31.53
			CCN		CCE1	
Flood water level	0.63	0.90	364.89	579.18	381.46	423.85
			CCE2		CCL	
Max. water level	0.80	—	405.62	507.03	—	—

The strength calculation is made for CCE2 since the maximum converted load acts on the bonnet at CCE2.

1.3 Strength calculation of bonnet

The bonnet is calculated as a box ramen as shown in the model figure below.



Where, L0 : Width of bonnet = 1575 mm

h0 : Depth of bonnet = 315 mm

(1) Internal pressure

pi= γo×H

= 9.81 × 21.05 = 206.501 kN/m^2

= 0.207 N/mm^2

pi : Internal pressure (N/mm^2)

γ0 : Specific gravity of water = 9.81 kN/m^3

H : Design head = 21.05 m

(2) Effective width of skin plate

The effective width is calculated so that the flange of stiffening girder may support the load together with the skin plate.

a) Point A

l/L≦0.02

λ= l

0.02<l/L<0.3

$\lambda=\{1.06-3.2(l/L)+4.5(l/L)^2\}\, l$

0.3≦l/L

λ= 0.15L

b) Point B and C

l/L≦0.05

λ= l

0.05<l/L<0.3

$\lambda=\{1.1-2(l/L)\}\, l$

0.3≦l/L

λ= 0.15L

Where, λ : Effective width of one side of skin plate mm

l : Half of supporting length of skin plate = 315 / 2 = 158 mm

L : Equivalent supporting length

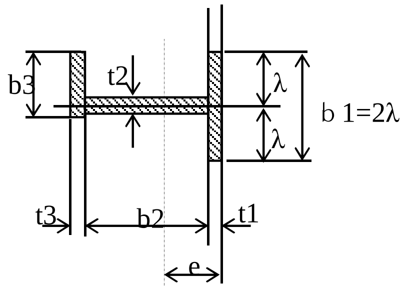
Point A = 0.2 (l0+h0) = 0.2 × (1575 + 315)= 378 mm

Point B = 0.6 h0 = 0.6 × 315 = 189 mm

Point C = 0.6 L0 = 0.6 × 1575 = 945 mm

Position	Effective width of skin plate				
	l mm	Lmm	l/L	λmm	2λmm
Point A	158	378	0.42	57	114
Point B	158	189	0.83	28	56
Point C	158	945	0.17	121	242

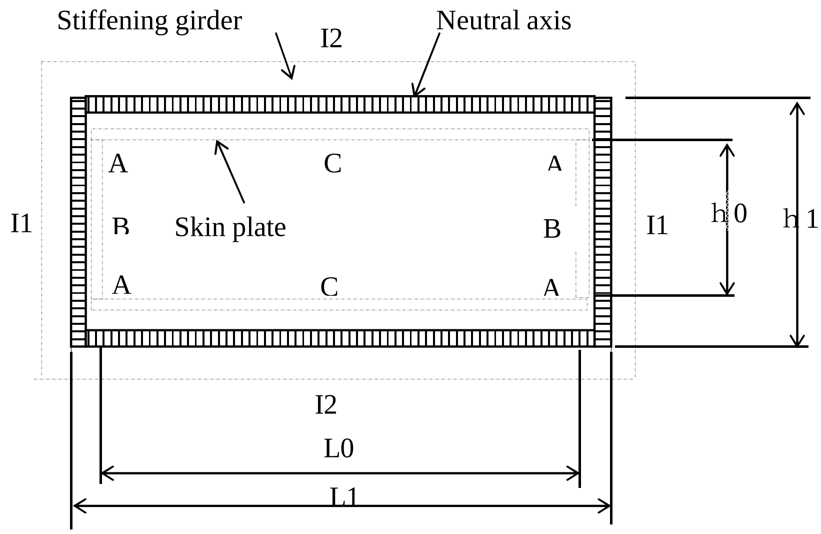
(3) Section properties of stiffening girder



t1 : Thickness of skin plate mm
t2 : Thickness of web mm
t3 : Thickness of flange mm
b1 : Effective width mm
b2 : Width of web mm
b3 : Width of flange mm

Position	Skin plate		Web		Flange		Section properties					
	t1	b1	t2	b2	t3	b3	I (mm^4)	Zi (mm^3)	Zo (mm^3)	A (mm^2)	Aw(mm^2)	e (mm)
A	12.5	114	12.8	100	20	65	10297124	166083	146058	4005	1280	62
B	12.5	56	12.8	100	20	65	7547377	101580	129680	3280	1280	74
C	12.5	242	12.8	100	20	65	13863875	300735	160462	5605	1280	46

(4) Sectional force



1) Acting load

It is assumed that the internal design pressure between the stiffeners acts as the distributed load. The acting load converts into the design load which is calculated by the ratio of an acting axis and a neutral axis.

$W = pi \cdot b \cdot (2h0+L0)/(2h1+L1)$

$= 0.207 \times 315 \times (2 \times 315 + 1575) / (2 \times 407 + 1724)$

$= 57$ N/mm

Where, W : Converted acting load N/mm

ps : Design internal pressure = 0.207 N/mm^2

b : Width of receiving pressure = 315 mm

h0 : Depth of bonnet = 315 mm

h1 : Length of neutral axis = h0+e = 315 + 2 × 46 = 407 mm

L0 : Width of bonnet = 1575 mm

L1 : Length of neutral axis = L0+2e : 1575 + 2 × 74 = 1724 mm

2) Acting load on each part

[Stiffness ratio]

k = (I2・h1)/(I1・L1)

= (13863875 × 407)/ (7547377 × 1724) = 0.434

n = h1/L1

= 407 / 1724 = 0.236

[Bending moment]

$MA=W\cdot L1^2/12\cdot\{(1+n^2\cdot k)/(1+k)\}$

$MB=MA-W\cdot h^2/8$

$MC=MA-W\cdot L1^2/8$

[Axial force]

Section A-B NAB=W・L1/2（Tensile force）

Section B-C NBC=W・h1/2（Tensile force）

[Shearing force]

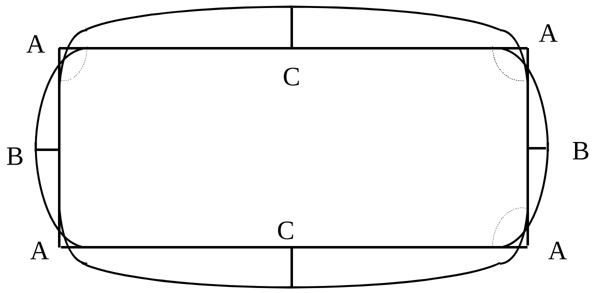
Section A-B SAB=W・h1/2

Section B-C SAC=W・l1/2

[Result of calculation]

MA= 9992960 N-mm MB= 8821644 N-mm

MC= -10993134 N-mm



VA= 0 N

NAB= 48703 N NBC= 11506 N

SAB= 11506 N SBC= 48703 N

(5) Stress of bonnet

1) Stress at "A"

Bending stress

[Bending stress(Inside)]

σAi = MA/Zi+NAB/A

= 9992960 / 166083 + 48703 / 4005

= 60.2 + 12.2 = 72.3 N/mm^2 < σa = 157.5 N/mm^2

[Bending stress(Outside)]

σAo = -MA/Zo+NAB/A

= -9992960 / 146058 + 48703 / 4005

= -68.4 + 12.2 = -56.3 N/mm^2 < σa = 157.5 N/mm^2

Shearing stress

τA = SBC/Aw

= 48703 / 1280

= 38.0 N/mm^2 < τa= 90.9 N/mm^2

2) Stress at "B"

Bending stress

[Bending stress(Inside)]

σBi = MB/Zi+NAB/A

= 8821644 / 101580 + 48703 / 3280

= 86.8 + 14.8 = 101.7 N/mm^2 < σa = 157.5 N/mm^2

[Bending stress(Outside)]

σBo = -MB/Zo+NAB/A

= -8821644 / 129680 + 48703 / 3280

= -68.0 + 14.8 = -53.2 N/mm^2 < σa = 157.5 N/mm^2

Shearing stress

τB = SAB/Aw

= 11506 / 1280

= 9.0 N/mm^2 < τa= 90.9 N/mm^2

3) Stress at "C"

Bending stress

[Bending stress(Inside)]

σCi = MC/Zi+NBC/A

= -10993134 / 300735 + 11506 / 5605

= -36.6 + 2.1 = -34.5 N/mm^2 < σa = 157.5 N/mm^2

[Bending stress(Outside)]

σCo = -MC/Zo+NBC/A

= 10993134 / 160462 + 11506 / 5605

= 68.5 + 2.1 = 70.6 N/mm^2 < σa = 157.5 N/mm^2

Shearing stress

τC = SBC/Aw

= 48703 / 1280

= 38.0 N/mm^2 < τa= 90.9 N/mm^2

(6) Allowable stresses

Allowable bending stress

Outside

$\sigma a = 250 \times 0.63 = 157.5$ N/mm^2 Material：A36(ASTM)

Inside

$\sigma a = 250 \times 0.63 = 157.5$ N/mm^2 Material：A36(ASTM)

Coefficient： 0.63

Allowable shearing stress

Outside

$\tau a = 90.9$ N/mm^2 Material：A36(ASTM)

1.4 Operating load

The operating load is summed up the following loads.

(1) Self weight

Gate leaf G1 = 1.5 × 9.81 = 14.72 kN

Rod of cylinder G2 = 0.77 kN

Total load G = 15.49 kN

(2) Friction force of seal plate

$F2 = \mu_2 \cdot P$

$= 0.4 \times 405.622 = 162.25$ kN

Where, μ_2 ：Frictional coefficient of metal seal = 0.4

P ：Hydrostatic pressure at operation = 405.62 kN

(3) Buoyancy

$F3 = \gamma 0 / W0 \cdot G1$

$= 9.81 / 77.0 \times 14.72 = 1.87$ kN

ここに、 $\gamma 0$ ：Specific gravity of water = 9.81 kN/m3

W0 ：Specific gravity of steel material = 77.01 kN/m3

(4) Friction force of seal in cylinder

$F4 = d \cdot \pi \cdot b \cdot n \cdot \mu_2 \cdot P$

$= 0.090 \times \pi \times 0.006 \times 1 \times 0.7 \times 405.622 = 0.482$ kN

Where, d ：Outside diameter of rod = 0.090 m

b ：Contact width of V-packing = 0.006 m

n ：Quantity of V-packing = 1 piece

μ_2 ：Frictional coefficient of V-packing = 0.7

P ：Pressure on V-packing = 405.622 kN

(5) Total operating load

(Unit：kN)

Load		Raising	Lowering
Self weight	G	↓ 15.49	↓ 15.49
Friction force of seal plate	F2	↓ 162.25	↑ 162.25
Buoyancy	F3	↑ 1.87	↑ 1.87
Friction force of seal in cylinder	F4	↓ 0.48	↑ 0.48
Total load		↓ 176.34	↑ 149.12

Raising load	Fu	=	176.34	kN	→	180.00	kN
Lowering load	Fd	=	149.12	kN	→	150.00	kN

1.5 Capacity of cylinder

(1) Design conditions

Type of cylinder	Fixed cylinder				
Rated pressure	Raising（Setting pressure of relief valve）	P1	=	21.0	MPa
	Lowering（Setting pressure of relief valve）	P2	=	12.6	MPa
Working pressure	Raising（Effective operating pressure）	P1'	=	18.9	MPa
	Lowering（Effective operating pressure）	P2'	=	11.3	MPa
Operating speed	0.1 m/min				
Operating load	Raising	Wu	=	180.00	kN
	Lowering	Wd	=	150.00	kN
Cylinder	Inside diameter of tube	D	=	160	mm
	Outside diameter of rod	d	=	90	mm
	Cylinder stroke	S	=	1570	mm

(2) Pulling and pushing forces of cylinder

1）Rated pressure

Pulling force (Raising)

$$F_u = \frac{\pi}{4} \times (D^2 - d^2) \times p_1'$$

$$= \frac{\pi}{4} \times (160^2 - 90^2) \times \frac{21.0}{1000}$$

$$= 288.6 \text{ kN}$$

Pushing force (Lowering)

$$F_d = \frac{\pi}{4} \times D^2 \times p_2'$$

$$= \frac{\pi}{4} \times 160^2 \times \frac{12.6}{1000}$$

$$= 253.3 \text{ kN}$$

2）Working pressure

Pulling force (Raising)

$$F_u' = \frac{\pi}{4} \times (D^2 - d^2) \times p_1'$$

$$= \frac{\pi}{4} \times (160^2 - 90^2) \times \frac{18.9}{1000}$$

$$= 259.8 \text{ kN} > W_u = 180 \text{ kN}$$

Pushing force (Lowering)

$$F_d' = \frac{\pi}{4} \times D^2 \times p_2'$$

$$= \frac{\pi}{4} \times 160^2 \times \frac{11.3}{1000}$$

$$= 228.0 \text{ kN} > W_d = 150.00 \text{ kN}$$

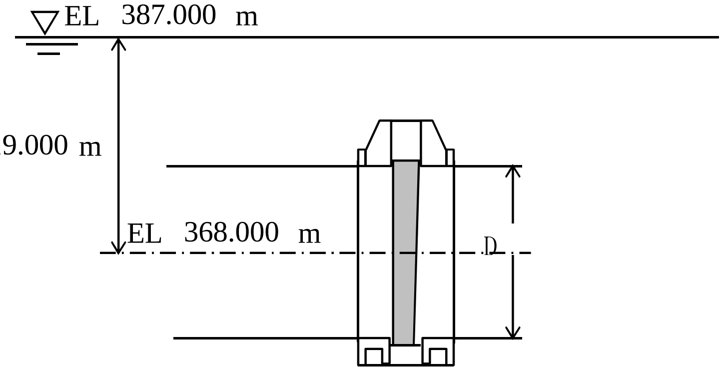
2. Strength Calculation for control gate in Oeste dam (Before heightning)

2.1 Design conditions

(1)	Type	Slide gate		
(2)	Quantity	5	sets	
(3)	Gate center elevation	EL.	368.00	m
(4)	Max. water level	EL.	408.00	m （heightning 0.0 m)
(5)	Flood water level	EL.	399.00	m
(6)	Normal water level	EL.	387.00	m
(7)	Diameter	φ	1.50	m
(8)	Seismic intensity		0.05	
(9)	Sealing system	Metal seal at both side of gate leaf		
(10)	Basic grand level	EL.	357.50	m
(11)	Operation device	Hydraulic cylinder		
(12)	Lifting height		1.57	m
(13)	Operating system	Local		
(14)	Allowable stress	ABNT NBR 8883		

2.2 Design head

(1) CCN (Nomal water level Only)



D：Diameter = φ1.50 m

Load of normal water level only

Ps= γo×H×A

= 9.81 × 19.00 × 1.77

= 329.35 kN

Where, Ps ：Hydrostatic load

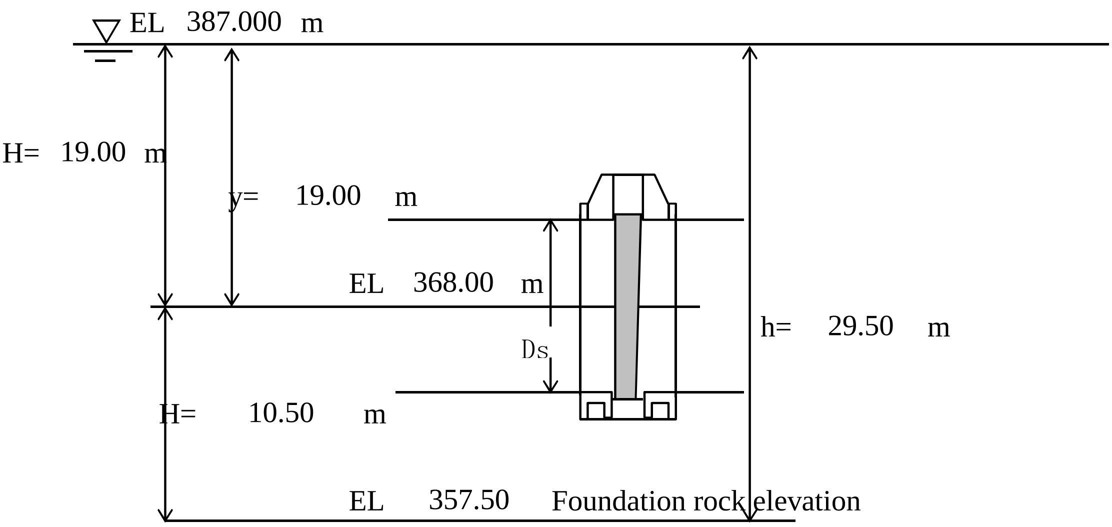
γo ：Specific gravity of water = 9.81 kN/m^3

H ：Design head = 19.00 m

A ：Receiving pressure area = $\pi \cdot Ds^2/4$ = π × $1.50^2/4$

= 1.77 m^2

(2) CCE1(Normal water level + Dynamic water pressure during earthquake)



a) Hydrostatic load

Ps= γo×H×A

= 9.81 × 19.00 × 1.77

= 329.35 kN

b) Dynamic pressure load during earthquake

$P_d = \gamma o \cdot 7/8 \cdot k \cdot (h \cdot y)^{1/2} \cdot A$

$= 9.81 \times 7/8 \times 0.05 \times 29.50 \times 19.00^{1/2} \times 1.77$

= 17.95 kN

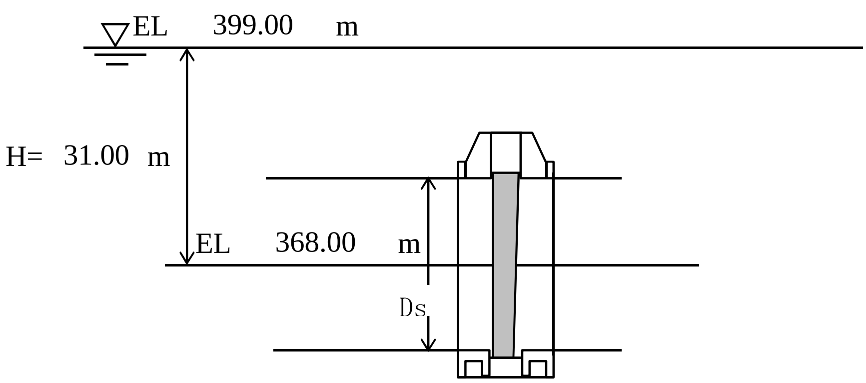
c) Total load

$Pw = Ps + P_d$

= 329.35 ＋ 17.95

= 347.31 kN

(3) CCE2(Flood water level only)



D：Caliber = φ1.50 m

$Ps = \gamma o \times H \times A$

$= 9.81 \times 31.00 \times 1.77$

$= 537.36$ kN

Where, Ps : Hydrostatic load

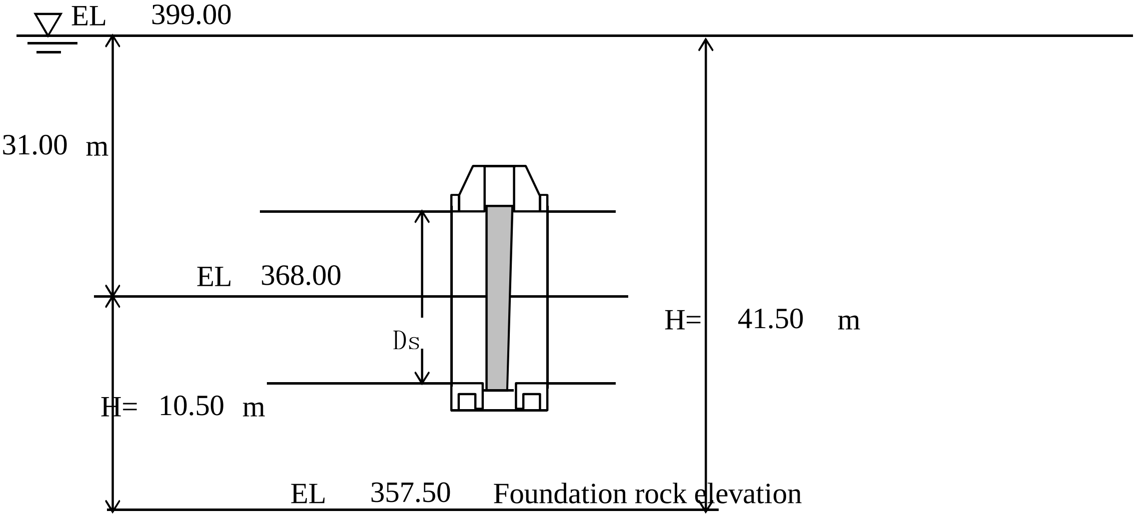
γo : Specific gravity of water = 9.81 kN/m^3

H : Design head = 31.00 m

A : Receiving pressure area $= \pi \cdot Ds^2/4 = \pi \times 1.50^2/4$

$= 1.77$ m^2

(4) CCL(Flood water level+ Dynamic water pressure during earthquake)



a) Hydrostatic load

$Ps = \gamma o \cdot H \cdot A$

$= 9.81 \times 31.00 \times 1.77$

$= 537.36$ KN

b) Dynamic pressure load during earthquake

$P_d = \gamma o \cdot 7/8 \cdot k \cdot (h \cdot y)^{1/2} \cdot A$

$= 9.81 \times 7/8 \times 0.05 \times 41.50 \times 31.00^{1/2} \times 1.77$

$= 27.20$ kN

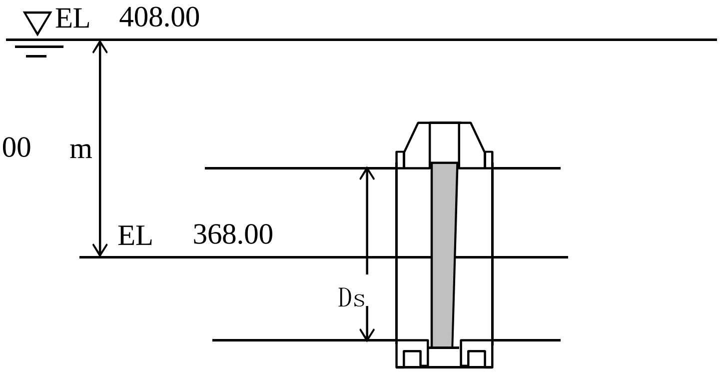
c) Total load

$Pw = Ps + P_d$

$= 537.36 + 27.20$

$= 564.56$ kN

(5) Max. water level



D : Diameter = φ1.50 m

$Ps = \gamma o \times H \times A$

$= 9.81 \times 40.00 \times 1.77$

$= 693.37$ kN

Where, Ps : Hydrostatic load

γo : Specific gravity of water = 9.81 kN/m^3

H : Design head = 40.00 m

A : Receiving pressure area $= \pi \cdot Ds^2/4 = \pi \times 1.50^2/4$

$= 1.77$ m^2

(5) Comparison of loads

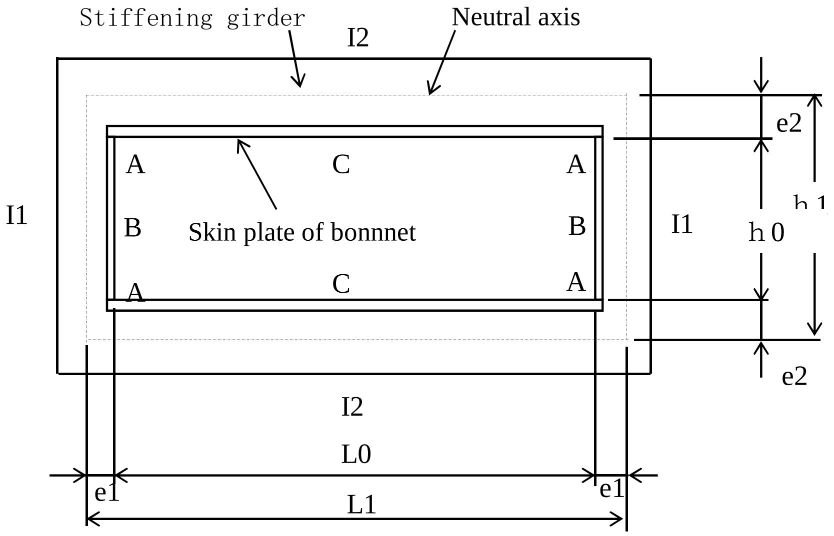
unit : kN

Case / 水 位	Coefficient		Hydrostatic load only		Dynamic water pressure	
	Hydrostatic load only	Dynamic water pressure	Actual load	Converted load	Actual load	Converted load
Normal water level	0.50	0.90	329.35	658.70	347.31	385.90
			CCN		CCE1	
Flood water level	0.63	0.90	537.36	852.96	564.56	627.29
			CCE2		CCL	
Max. water level	0.80	—	693.37	866.71	—	—

Because the load of "CCE2" becomes the maximum, strength of the load of "CCE2" is checked.

2.3 Strength calculation of bonnet

The bonnet is calculated as a box ramen as shown in the model figure below.



Where, L0 : Width of bonnet = 1650 mm

h0 : Depth of bonnet = 315 mm

(1) Internal pressure

pi= γo×H

= 9.81 × 31.00 = 304.11 kN/m^2

= 0.304 N/mm^2

pi : Internal pressure (N/mm^2)

γ0 : Specific gravity of water = 9.81 kN/m^3

H : Design head = 31.00 m

(2) Effective width of skin plate

The effective width is calculated so that the flange of stiffening girder may support the load together with the skin plate.

a) Point of A

l/L≦0.02

λ= l

0.02<l/L<0.3

$\lambda=\{1.06-3.2(l/L)+4.5(l/L)^2\}\ l$

0.3≦l/L

λ= 0.15L

b) Point of B and C

l/L≦0.05

λ= l

0.05<l/L<0.3

λ={1.1-2(l/L)} l

0.3≦l/L

λ= 0.15L

Where, λ : Working width in one side of skinplate mm

l : Half of skin plate at support intervals = 315 / 2 = 158 mm

L : Equivalent support inter

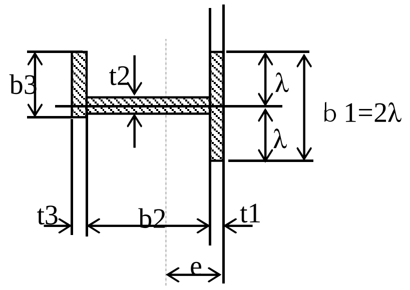
Point A = 0.2 (l0+h0) = 0.2 × (1650 + 315)= 393 mm

Point B = 0.6 h0 = 0.6 × 315 = 189 mm

Point C = 0.6 L0 = 0.6 × 1650 = 990 mm

Position	Effective width of skin plate				
	l mm	Lmm	l/L	λmm	2λmm
Point A	158	393	0.40	59	118
Point B	158	189	0.83	28	56
Point C	825	990	0.83	149	298

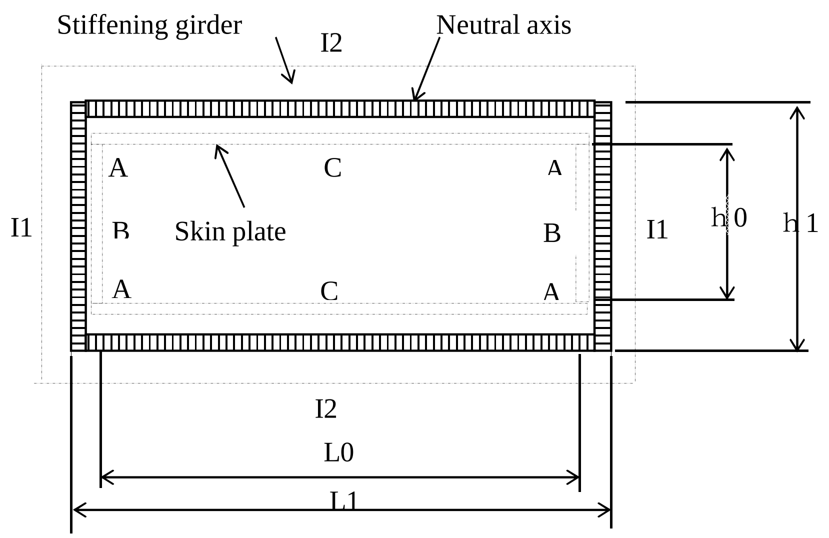
(3) Section properties of stiffening girder



t1 : Thickness of skin plate mm
t2 : Thickness of web mm
t3 : Thickness of flange mm
b1 : Effective width mm
b2 : Width of web mm
b3 : Width of flange mm

Position	Skin plate		Web		Flange		Section properties					
	t1	b1	t2	b2	t3	b3	I (mm^4)	Zi (mm^3)	Zo (mm^3)	A (mm^2)	Aw(mm^2)	e (mm)
A	12.6	118	16.2	122	26	100	22214599	250164	309396	6063	1976.4	89
B	12.6	56	16.2	122	26	100	16102576	159431	270177	5282	1976.4	101
C	12.6	298	16.2	122	26	100	33413694	503218	354710	8331	1976.4	66

(4) Sectional force



1) Acting load

It is assumed that the internal design pressure between the stiffeners acts as the distributed load. The acting load converts into the design load which is calculated by the ratio of an acting axis and a neutral axis.

$W = pi \cdot b \cdot (2h0+L0)/(2h1+L1)$

$= 0.304 \times 315 \times (2 \times 315 + 1650) / (2 \times 448 + 1852)$

$= 79$ N/mm

Where, W : Converted acting load N/mm

ps : Design internal pressure = 0.304 N/mm^2

b : Width of receiving pressure = 315 mm

h0 : Depth of bonnet = 315 mm

h1 : Length of neutral axis = h0+e = 315 + 2 × 66 = 448 mm

L0 : Width of bonnet = 1650 mm

L1 : Length of neutral axis = L0+2e : 1650 + 2 × 101 = 1852 mm

2) Acting load on each part

[Stiffness ratio]

k = (I2・h1)/(I1・L1)

= (33413694 × 448)/ (16102576 × 1852) = 0.502

n = h1/L1

= 448 / 1852 = 0.242

[Bending moment]

$MA=W \cdot L1^2/12 \cdot \{(1+n^2 \cdot k)/(1+k)\}$

$MB=MA-W \cdot h^2/8$

$MC=MA-W \cdot L1^2/8$

[Axial force]

Section A-B NAB=W・L1/2（Tensile force）

Section B-C NBC=W・h1/2（Tensile force）

[Shearing force]

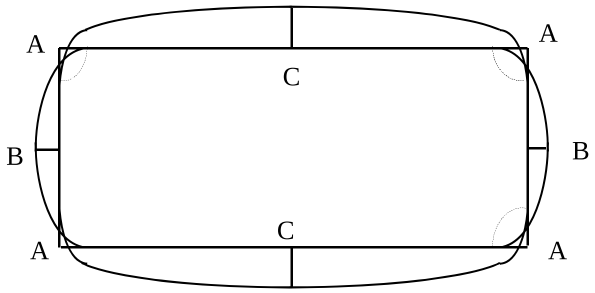
Section A-B SAB=W・h1/2

Section B-C SAC=W・l1/2

[Result of calculation]

MA= 15573516 N-mm MB= 13581005 N-mm

MC= -18507660 N-mm



VA= 0 N

NAB= 73609 N NBC= 17798 N

SAB= 17798 N SBC= 73609 N

(5) Stress of bonnet

1) Stress at "A"

Bending stress

[Bending stress(Inside)]

σAi = MA/Zi+NAB/A

= 15573516 / 250164 + 73609 / 6063

= 62.3 + 12.1 = 74.4 N/mm^2 ＜ σa = 157.5 N/mm^2

[Bending stress(Outside)]

σAo = -MA/Zo+NAB/A

= -15573516 / 309396 + 73609 / 6063

= -50.3 + 12.1 = -38.2 N/mm^2 ＜ σa = 157.5 N/mm^2

Shearing stress

τA = SBC/Aw

= 73609 / 1976

= 37.2 N/mm^2 ＜ τa= 90.9 N/mm^2

2) Stress of "B"

Bending stress

[Bending stress(Inside)]

σAi = MB/Zi+NAB/A

= 13581005 / 159431 + 73609 / 5282

= 85.2 + 13.9 = 99.1 N/mm^2 ＜ σa = 157.5 N/mm^2

[Bending stress(Outside)]

σAo = -MB/Zo+NAB/A

= -13581005 / 270177 + 73609 / 5282

= -50.3 + 13.9 = -36.3 N/mm^2 ＜ σa = 157.5 N/mm^2

Shearing stress

τA = SAB/Aw

= 17798 / 1976

= 9.0 N/mm^2 ＜ τa= 90.9 N/mm^2

3) Stress of "C"

Bending stress

[Bending stress(Inside)]

σAi = MC/Zi+NBC/A

= -18507660 / 503218 + 17798 / 8331

= -36.8 + 2.1 = -34.6 N/mm^2 ＜ σa = 157.5 N/mm^2

[Bending stress(Outside)]

σAo = -MC/Zo+NBC/A

= 18507660 / 354710 + 17798 / 8331

= 52.2 + 2.1 = 54.3 N/mm^2 ＜ σa = 157.5 N/mm^2

Shearing stress

τA = SBC/Aw

= 73609 / 1976

= 37.2 N/mm^2 ＜ τa= 90.9 N/mm^2

(6) Allowable stresses

Allowable bending stress

Outside

$\sigma a = 250 \times 0.63 = 157.5$ N/mm^2 Material : A36(ASTM)

Inside

$\sigma a = 250 \times 0.63 = 157.5$ N/mm^2 Material : A36(ASTM)

Coefficient : 0.63

Allowable shearing stress

Outside

$\tau a = 90.9$ N/mm^2 Material : A36(ASTM)

2.4 Operating load

The operating load is summed up the following loads.

(1) Self weight

Gate leaf G1 = 2.5 × 9.81 = 24.53 kN

Rod of cylinder G2 = 0.77 kN

Total load G = 25.30 kN

(2) Seal friction

$F2 = \mu_2 \cdot P$

$= 0.4 \times 693.371 = 277.35$ kN

Where, μ_2 : Frictional coefficient of metal seal = 0.4

P : Hydrostatic pressure at operation = 693.37 kN

(3) Buoyancy

$F3 = \gamma 0 / W0 \cdot G1$

$= 9.81 / 77.0 \times 24.53 = 3.12$ kN

ここに、 $\gamma 0$: Specific gravity of water = 9.81 kN/m3

W0 : Specific gravity of steel material = 77.01 kN/m3

(4) Friction force of seal in cylinder

$F4 = d \cdot \pi \cdot b \cdot n \cdot \mu_2 \cdot P$

$= 0.090 \times \pi \times 0.006 \times 1 \times 0.7 \times 693.371 = 0.823$ kN

Where, d : Rod outside diameter = 0.090 m

b : Width of contact of V-packing = 0.006 m

n : Quantity of V-paccking = 1 piece

μ_2 : Frictional coefficient of V-packing = 0.7

P : Pressure on V-packing = 693.371 kN

(5) Total operating load

(Unit : kN)

Load		Raising	Lowering
Self weight	G	↓ 25.30	↓ 25.30
Seal friction	F2	↓ 277.35	↑ 277.35
Buoyancy	F3	↑ 3.12	↑ 3.12
Friction force of seal in cylinder	F4	↓ 0.82	↑ 0.82
Total load		↓ 300.34	↑ 256.00

Raising load	Fu	=	300.34	kN	→	310.00	kN
Lowerring load	Fd	=	256.00	kN	→	260.00	kN

2.5 Capacity of cylinder

(1) Design conditions

Type of hoist	Fixed cylinder				
Rated pressure	Raising（Setting pressure of relief valve）	P1	=	16.0	MPa
	Lowering（Setting pressure of relief valve）	P2	=	9.6	MPa
Working pressure	Raising（Effective operating pressure）	P1'	=	14.4	MPa
	Lowering（Effective operating pressure）	P2'	=	8.6	MPa
Operating speed	0.1 m/min				
Operating load	Raising	Wu	=	310.00	kN
	Lowerring	Wd	=	260.00	kN
Cylinder	Inside diameter of tube	D	=	200	mm
	Outside diameter of rod	d	=	100	mm
	Cylinder stroke	S	=	1570	mm

(2) Power to push and power to pull

1) Rated pressure

Pulling force (Raising)

$$F_u = \frac{\pi}{4} \times (D^2 - d^2) \times p_1'$$

$$= \frac{\pi}{4} \times (200^2 - 100^2) \times \frac{16.0}{1000}$$

$$= 377 \text{ kN}$$

Pushing force (Lowering)

$$F_d = \frac{\pi}{4} \times D^2 \times p_2'$$

$$= \frac{\pi}{4} \times 200^2 \times \frac{9.6}{1000}$$

$$= 301.6 \text{ kN}$$

2) Working pressure

Pulling force (Raising)

$$F_u' = \frac{\pi}{4} \times (D^2 - d^2) \times p_1'$$

$$= \frac{\pi}{4} \times (200^2 - 100^2) \times \frac{14.4}{1000}$$

$$= 339.3 \text{ kN} > W_u = 310 \text{ kN}$$

Pushing force (Lowering)

$$F_d' = \frac{\pi}{4} \times D^2 \times p_2'$$

$$= \frac{\pi}{4} \times 200^2 \times \frac{8.6}{1000}$$

$$= 271.4 \text{ kN} > W_d = 260.00 \text{ kN}$$

APPENDIX-4 :

Structural calculation for conduit pipes (After heightning)

1. Strength Calculation for Conduit Pipe in Oeste Dam (After heightning)

1.1 Design Conditions

(1)	Type	Circular section embedded steel pipe (Exposed pipe at control gate chamber)
(2)	Quantity	7 lanes
(3)	Diameter	1500 mm
(4)	Pipe center elevation	EL. 339.25 m
(5)	Max. water level	EL. 364.65 m （heightning 2.0 m ）
(6)	Flood water level	EL. 362.30 m
(7)	Normal water level	EL. 341.50 m
(8)	Material	ASTM A36(equivalent to SS400 of JIS G3101）
(9)	Allowable stress	ABNT NBR 8883:2008
(10)	Young's modulus	Es= 206 kN/mm^2

1.2 Allowable Stress

Material	Yield point σ_y (N/mm^2)	ABNT NBR 8883	Allowable stress CCN σa (N/mm^2)	CCE σa (N/mm^2)	CCL σa (N/mm^2)
A36	250	Safety factor	0.50	0.63	0.80
		Allowable stress	125.0	157.5	200.0

1.3 Strength Calculation for Conduit Pipe

$$\sigma_1 = \frac{P \times D}{2 \times t} \ (N/mm^2)$$

Where,

D : Internal diameter(mm)

P : Hydraulic pressure(MPa)

t : Shell thickness(mm)

Location	Case	D (mm)	t (mm)	H (m)	P (MPa)	σ_1 (N/mm^2)	Allowable stress (N/mm^2)
Upstream	Max. water level	1500.0	5.93	25.40	0.249	31.5	200.0
	Flood water level	1500.0	5.93	23.05	0.226	28.6	157.5
	Normal water level	1500.0	5.93	2.25	0.022	2.8	125.0
Downstream	Max. water level	1500.0	6.51	25.40	0.249	28.7	200.0
	Flood water level	1500.0	6.51	23.05	0.226	26.1	157.5
	Normal water level	1500.0	6.51	2.25	0.022	2.5	125.0

2. Strength Calculation for Conduit Pipe in Sul dam (After heightning)

2.1 design conditions

(1)	Type	Circular section embedded steel pipe (Exposed pipe at control gate chamber)
(2)	Quantity	5 lanes
(3)	Diameter	φ 1500 mm
(4)	Pipe center elevation	EL. 368.00 m
(5)	Max. water level	EL. 408.00 m （heightning 2.0 m)
(6)	Flood water level	EL. 401.00 m
(7)	Normal water level	EL. 387.00 m
(8)	Material	ASTM A36(equivalent to SS400 of JIS G3101）
(9)	Allowable stress	ABNT NBR 8883:2008
(10)	Young's modulus	Es= 206 kN/mm^2

2.2 Allowable Stress

Material	Yield point σ_y (N/mm^2)	ABNT NBR 8883	Arrowed stress CCN σa (N/mm^2)	Arrowed stress CCE σa (N/mm^2)	Arrowed stress CCL σa (N/mm^2)
A36	250	Safety factor	0.50	0.63	0.80
		Allowable stress	125.0	157.5	200.0

2.3 Strength Calculation for Conduit Pipe

$$\sigma_1 = \frac{P \times D}{2 \times t} \ (N/mm^2)$$

Where,

D : Internal diameter(mm)

P : Hydraulic pressure(MPa)

t : Shell thickness(mm)

Location	Case	D (mm)	t (mm)	H (m)	P (MPa)	σ_1 (N/mm^2)	Allowable stress (N/mm^2)
Upstream	Max. water level	1500.0	9.17	40.00	0.392	32.1	200.0
	Flood water level	1500.0	9.17	33.00	0.324	26.5	157.5
	Normal water level	1500.0	9.17	19.00	0.186	15.2	125.0
Downstream	Max. water level	1500.0	8.66	40.00	0.392	34.0	200.0
	Flood water level	1500.0	8.66	33.00	0.324	28.0	157.5
	Normal water level	1500.0	8.66	19.00	0.186	16.1	125.0

APPENDIX-5 :

Structural calculation for conduit pipes (Before heightning)

1. Strength Calculation for Conduit Pipe in Oeste Dam (Before heightning)

1.1 Design Conditions

(1)	Type	Circular section embedded steel pipe (Exposed pipe at control gate chamber)
(2)	Quantity	7 lanes
(3)	Diameter	1500 mm
(4)	Pipe center elevation	EL. 339.25 m
(5)	Max. water level	EL. 362.65 m （heightning 0.0 m)
(6)	Flood water level	EL. 360.30 m
(7)	Normal water level	EL. 341.50 m
(8)	Material	ASTM A36(equivalent to SS400 of JIS G3101）
(9)	Allowable stress	ABNT NBR 8883:2008
(10)	Young's modulus	Es= 206 kN/mm^2

1.2 Allowable Stress

Material	Yield point σ_y (N/mm^2)	ABNT NBR 8883	Allowable stress CCN σa (N/mm^2)	CCE σa (N/mm^2)	CCL σa (N/mm^2)
A36	250	Safety factor	0.50	0.63	0.80
		Allowable stress	125.0	157.5	200.0

1.3 Strength Calculation for Conduit Pipe

$$\sigma_1 = \frac{P \times D}{2 \times t} \ (N/mm^2)$$

Where,

D : Internal diameter(mm)

P : Hydraulic pressure(MPa)

t : Shell thickness(mm)

Location	Case	D (mm)	t (mm)	H (m)	P (MPa)	σ_1 (N/mm^2)	Allowable stress (N/mm^2)
Upstream	Max. water level	1500.0	5.93	23.40	0.230	29.0	200.0
	Flood water level	1500.0	5.93	21.05	0.207	26.1	157.5
	Normal water level	1500.0	5.93	2.25	0.022	2.8	125.0
Downstream	Max. water level	1500.0	6.51	23.40	0.230	26.4	200.0
	Flood water level	1500.0	6.51	21.05	0.207	23.8	157.5
	Normal water level	1500.0	6.51	2.25	0.022	2.5	125.0

2. Strength Calculation for Conduit Pipe in Sul dam (Before heightning)

2.1 design conditions

(1)	Type	Circular section embedded steel pipe (Exposed pipe at control gate chamber)
(2)	Quantity	5 lanes
(3)	Diameter	φ 1500 mm
(4)	Pipe center elevation	EL. 368.00 m
(5)	Max. water level	EL. 408.00 m （heightning 0.0 m)
(6)	Flood water level	EL. 399.00 m
(7)	Normal water level	EL. 387.00 m
(8)	Material	ASTM A36(equivalent to SS400 of JIS G3101）
(9)	Allowable stress	ABNT NBR 8883:2008
(10)	Young's modulus	Es= 206 kN/mm^2

2.2 Allowable Stress

Material	Yield point σ_y (N/mm^2)	ABNT NBR 8883	Arrowed stress		
			CCN σa (N/mm^2)	CCE σa (N/mm^2)	CCL σa (N/mm^2)
A36	250	Safety factor	0.50	0.63	0.80
		Allowable stress	125.0	157.5	200.0

2.3 Strength Calculation for Conduit Pipe

$$\sigma_1 = \frac{P \times D}{2 \times t} \ (N/mm^2)$$

Where,

D : Internal diameter(mm)

P : Hydraulic pressure(MPa)

t : Shell thickness(mm)

Location	Case	D (mm)	t (mm)	H (m)	P (MPa)	σ_1 (N/mm^2)	Allowable stress (N/mm^2)
Upstream	Max. water level	1500.0	9.17	40.00	0.392	32.1	200.0
	Flood water level	1500.0	9.17	31.00	0.304	24.9	157.5
	Normal water level	1500.0	9.17	19.00	0.186	15.2	125.0
Downstream	Max. water level	1500.0	8.66	40.00	0.392	34.0	200.0
	Flood water level	1500.0	8.66	31.00	0.304	26.3	157.5
	Normal water level	1500.0	8.66	19.00	0.186	16.1	125.0

APPENDIX-6 :

Stability Analysis of Oeste dam

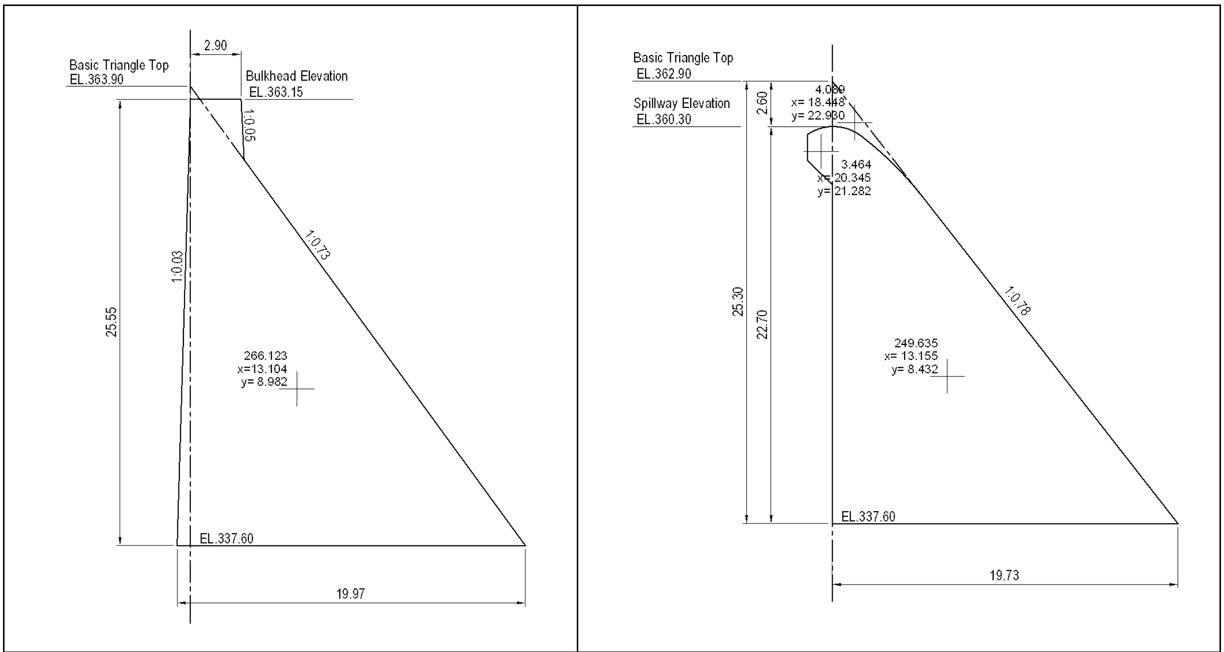
(1) Existing

1) Design Condition

Design condition of Dam stability analysis is considered as shown in the table 1 below.

Table 1 Design condition of Existing

		Bulkhead section	Spillway section
Elevation of Top of Dam	EL.m	363.150	-----
Basic triangle Top Elevation	EL.m	363.900	362.900
Upstream Slope	1:n	0.030	-----
Downstream Slope	1:n	0.730	0.780
Upper surface of the downstream slope	1:n	0.030	-----
Dam base elevation	EL.m	337.600	337.600
Crest width of non-overflow section	m	2.900	-----
Reservoir sediment level	EL.m	338.500	←
Reservoir water level [CCN]	EL.m	340.790	←
[CCE]	EL.m	362.650	←
[CCL]	EL.m	360.300	←
Downstream water level [CCN]	EL.m	340.090	←
[CCE]	EL.m	347.740	←
[CCL]	EL.m	341.950	←
Unit weight of concrete dams	kN/m^3	23.5	←
Weight of sediment in the water	kN/m^3	8.5	←
Unit weight of water	kN/m^3	10.0	←
Seismic Coefficient: Horizontal (kh)	---	0.050	←
Seismic Coefficient: Vertical (kv)	---	0.030	←
Coefficient of earth pressure (Rankine coefficient of earth pressure)	---	0.40	←
Uplift pressure coefficient	---	1/3	←
Shear strength of foundation	kN/m^2	1,000.0	←
Friction angle of foundation	deg	38.00	←
Internal friction coefficient	---	0.78	←



Bulkhead section	Spillway section

Fig 1 Typical section of Existing

2) Stability Analysis of Existing dam

[Bulkhead section]

- CCN: Normal water

Resume of Acting Force and Moment

[CCN : Normal water]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	6,251.14		13.103		81,905.56		
W/O Dead Load							
Seismic							
W/O Seismic							
U/S Water weight	1.53		19.934		30.50		
D/S Water weight	22.63		0.605		13.70		
U/S Water Pressure		50.88		1.063		54.09	
D/S Water Pressure		-31.00		0.830		-25.73	
Dynamic Water Pressure							
Earth Pressure	0.10		19.957		2.00		
Soil weight		1.38		0.300		0.41	
Uplift	-520.43		10.132		-5,272.78		
Total	5,754.97	21.26			76,678.98	28.77	

Control of Stability [CCN]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{76,650.21}{5,754.97} = 13.319 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{19.966}{2} - 13.319 = |-3.336 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{6,275.40}{520.43} = 12.058 \quad > 1.30 \ldots \text{-OK-}$$

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{76,678.98}{28.77} = 2,665.241 \quad > 1.50 \ldots \text{-OK-}$$

- Safety factor due to sliding

V=	5,754.97	kN	FSD-φ	1.50
H=	21.26	kN	FSD-c	3.00
L=	19.966	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{5,754.97*0.78}{1.50} = 2,992.58$$

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*19.966}{3.00} = 6,655.33$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{2,992.58+6,655.33}{21.26} = 453.806 \quad > 1.0 \ldots \text{-OK-}$$

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{5,754.97}{19.966} \times \left(1.0 \pm \frac{6\times3.336}{19.966}\right)$$

vertical stress of upstream = 577.220 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = -0.729 kN/㎡ ＜ 0 kN/㎡ (Tensile force occur) but downstream side -OK-

- CCE: Maximum Flood water

Resume of Acting Force and Moment

[CCE : Maximum Flood water]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	6,251.14		13.103		81,905.56		
W/O Dead Load							
Seismic							→
W/O Seismic							→
U/S Water weight	94.13		19.716		1,855.82		
D/S Water weight	375.29		2.467		926.03		
U/S Water Pressure		3,137.51		8.350		26,198.21	
D/S Water Pressure		-514.10		3.380		-1,737.66	
Dynamic Water Pressure							
Earth Pressure	0.10		19.957		2.00		
Soil weight		1.38		0.300		0.41	
Uplift	-2,520.64		10.638		-26,813.31		
Total	4,200.02	2,624.79			57,876.10	24,460.96	

Control of Stability [CCE]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{33,415.14}{4,200.02} = 7.956 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{19.966}{2} - 7.956 = |2.027 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{6,720.66}{2,520.64} = 2.666$$

> 1.10 … -OK-

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{57,876.10}{24,460.96} = 2.366$$

> 1.20 … -OK-

- Safety factor due to sliding

V=	4,200.02	kN	FSD-φ	1.10
H=	2,624.79	kN	FSD-c	1.50
L=	19.966	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{4,200.02*0.78}{1.10} = 2,978.20$$

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*19.966}{1.50} = 13,310.67$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{2,978.20+13,310.67}{2,624.79} = 6.206$$

> 1.0 … -OK-

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{4,200.02}{19.966} \times \left(1.0 \pm \frac{6 \times 2.027}{19.966}\right)$$

vertical stress of upstream = 82.221 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = 338.507 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur) -OK-

- CCL: Flood water + Seismic

Resume of Acting Force and Moment

[CCL : Flood water + Seismic]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	6,251.14		13.103		81,905.56		
W/O Dead Load							
Seismic	-187.53	312.56	13.103	8.977	-2,457.17	2,805.86	
W/O Seismic							
U/S Water weight	77.29		19.739		1,525.59		
D/S Water weight	69.07		1.059		73.18		
U/S Water Pressure		2,576.45		7.567		19,496.00	
D/S Water Pressure		-94.61		1.450		-137.18	
Dynamic Water Pressure		150.29		9.080		1,364.63	
Earth Pressure	0.10		19.957		2.00		
Soil weight		1.38		0.300		0.41	
Uplift	-1,479.11		11.357		-16,797.51		
Total	4,730.96	2,946.07			64,251.65	23,529.72	

Control of Stability [CCL]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{40{,}721.93}{4{,}730.96} = 8.608 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{19.966}{2} - 8.608 = |1.375 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{6{,}210.07}{1{,}479.11} = 4.199 \quad > 1.10 \ldots \text{-OK-}$$

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{64{,}251.65}{23{,}529.72} = 2.731 \quad > 1.10 \ldots \text{-OK-}$$

- Safety factor due to sliding

V=	4,730.96	kN	FSD-φ	1.10
H=	2,946.07	kN	FSD-c	1.30
L=	19.966	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{4{,}730.96 * 0.78}{1.10} = 3{,}354.68$$

$$\frac{c \cdot l}{FSD_c} = \frac{1{,}000.0 * 19.966}{1.30} = 15{,}358.46$$

$$FSD = \frac{\dfrac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \dfrac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{3{,}354.68 + 15{,}358.46}{2{,}946.07} = 6.352 \quad > 1.0 \ldots \text{-OK-}$$

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{4{,}730.96}{19.966} \times \left(1.0 \pm \frac{6 \times 1.375}{19.966}\right)$$

vertical stress of upstream = 139.043 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = 334.870 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur) -OK-

- CCC: Construction

Resume of Acting Force and Moment

[CCC : Construction]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	6,251.14		13.103		81,905.56		
W/O Dead Load							
Seismic							
W/O Seismic							
U/S Water weight							
D/S Water weight							
U/S Water Pressure							
D/S Water Pressure							
Dynamic Water Pressure							
Earth Pressure							
Soil weight							
Uplift							
Total	6,251.14				81,905.56		

Control of Stability [CCC]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{81,905.56}{6,251.14} = 13.102 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{19.966}{2} - 13.102 = |-3.119 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{6,251.14}{0.00} = \infty$$

> 1.20 … -OK-

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{81,905.56}{0.00} = \infty$$

> 1.30 … -OK-

- Safety factor due to sliding

V=	6,251.14	kN	FSD-φ	1.30
H=	0.00	kN	FSD-c	2.00
L=	19.966	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{6,251.14*0.78}{1.30} = 3,750.68$$

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*19.966}{2.00} = 9,983.00$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{3,750.68+9,983.00}{0.00} = \infty$$

> 1.0 … -OK-

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{6,251.14}{19.966} \times \left(1.0 \pm \frac{6\times3.119}{19.966}\right)$$

vertical stress of upstream = 606.568 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = 19.626 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur) -OK-

[Spillway section]

- CCN: Normal water

Resume of Acting Force and Moment

[CCN : Normal water]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	5,866.42		13.156		77,178.62		
W/O Dead Load	-14.69		7.934		-116.55		
Seismic							
W/O Seismic							
U/S Water weight							
D/S Water weight	24.18		0.647		15.64		
U/S Water Pressure		50.88		1.063		54.09	
D/S Water Pressure		-31.00		0.830		-25.73	
Dynamic Water Pressure							
Earth Pressure							
Soil weight		1.38		0.300		0.41	
Uplift	-514.40		10.014		-5,151.20		
Total	5,361.51	21.26			71,926.51	28.77	

Control of Stability [CCN]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{71,897.74}{5,361.51} \quad =13.410 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{19.734}{2} \quad - 13.410 \quad =|-3.543 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{5,875.91}{514.40} \quad =11.423$$

> 1.30 … -OK-

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{71,926.51}{28.77} \quad =2,500.052$$

> 1.50 … -OK-

- Safety factor due to sliding 48

V=	5,361.51	kN	FSD-φ	1.50
H=	21.26	kN	FSD-c	3.00
L=	19.734	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_{\phi}} = \frac{5,361.51*0.78}{1.50} \quad =2,787.99$$

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*19.734}{3.00} \quad =6,578.00$$

$$FSD = \frac{\dfrac{\Sigma V \cdot \tan\phi}{FSD_{\phi}} + \dfrac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{2,787.99+6,578.00}{21.26} \quad =440.545$$

> 1.0 … -OK-

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{5,361.51}{19.734} \times (1.0 \pm \frac{6 \times 3.543}{19.734})$$

vertical stress of upstream = 564.360 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = -20.982 kN/㎡ ＜ 0 kN/㎡ (Tensile force occur) but downstream side -OK-

- CCE: Maximum flood water

Resume of Acting Force and Moment

[CCE : Maximum Flood water]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	5,866.42		13.156		77,178.62		
W/O Dead Load	-14.69		7.934		-116.55		
Seismic							
W/O Seismic							
U/S Water weight							
D/S Water weight	401.00		2.637		1,057.44		
U/S Water Pressure		3,137.51		8.350		26,198.21	
D/S Water Pressure		-514.10		3.380		-1,737.66	
Dynamic Water Pressure							
Earth Pressure							
Soil weight		1.38		0.300		0.41	
Uplift	-2,491.42		10.514		-26,194.79		
Total	3,761.31	2,624.79			51,924.72	24,460.96	

Control of Stability [CCE]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{27,463.76}{3,761.31} = 7.302 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{19.734}{2} - 7.302 = |2.565 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{6,252.73}{2,491.42} = 2.510$$

> 1.10 … -OK-

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{51,924.72}{24,460.96} = 2.123$$

> 1.20 … -OK-

- Safety factor due to sliding 49

V=	3,761.31	kN	FSD-φ	1.10
H=	2,624.79	kN	FSD-c	1.50
L=	19.734	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{3,761.31*0.78}{1.10} = 2,667.11$$

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*19.734}{1.50} = 13,156.00$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{2,667.11+13,156.00}{2,624.79} = 6.028$$

> 1.0 … -OK-

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{3,761.31}{19.734} \times (1.0 \pm \frac{6 \times 2.565}{19.734})$$

vertical stress of upstream = 41.956 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = 339.245 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur) -OK-

- CCL: Flood water + Seismic

Resume of Acting Force and Moment

[CCL : Flood water + Seismic]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	5,866.42		13.156		77,178.62		
W/O Dead Load	-14.69		7.934		-116.55		
Seismic	-175.99	293.32	13.156	8.433	-2,315.36	2,473.67	
W/O Seismic	0.44	-0.73	7.934	32.047	3.50	-23.54	
U/S Water weight							
D/S Water weight	73.80		1.132		83.54		
U/S Water Pressure		2,576.45		7.567		19,496.00	
D/S Water Pressure		-94.61		1.450		-137.18	
Dynamic Water Pressure		150.29		9.080		1,364.63	
Earth Pressure							
Soil weight		1.38		0.300		0.41	
Uplift	-1,461.96		11.225		-16,410.50		
Total	4,288.02	2,926.10			58,423.25	23,173.99	

Control of Stability [CCL]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{35,249.26}{4,288.02} \quad =8.220 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{19.734}{2} \quad - 8.220 \quad =|1.647 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{5,749.98}{1,461.96} \quad =3.933 \quad > 1.10 \ldots \text{-OK-}$$

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{58,423.25}{23,173.99} \quad =2.521 \quad > 1.10 \ldots \text{-OK-}$$

- Safety factor due to sliding

				50
V=	4,288.02	kN	FSD-φ	1.10
H=	2,926.10	kN	FSD-c	1.30
L=	19.734	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{4,288.02*0.78}{1.10} \quad =3,040.60$$

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*19.734}{1.30} \quad =15,180.00$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{3,040.60+15,180.00}{2,926.10} \quad =6.227 \quad > 1.0 \ldots \text{-OK-}$$

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{4,288.02}{19.734} \quad \times(1.0\pm \quad \frac{6\times1.647}{19.734})$$

vertical stress of upstream = 108.480 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = 326.101 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur) -OK-

- CCC: Construction

Resume of Acting Force and Moment

[CCC : Construction]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	5,866.42		13.156		77,178.62		
W/O Dead Load	-14.69		7.934		-116.55		
Seismic							
W/O Seismic							
U/S Water weight							
D/S Water weight							
U/S Water Pressure							
D/S Water Pressure							
Dynamic Water Pressure							
Earth Pressure							
Soil weight							
Uplift							
Total	5,851.73				77,062.07		

Control of Stability [CCC]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{77{,}062.07}{5{,}851.73} \quad = 13.169 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{19.734}{2} - 13.169 \quad = |-3.302 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{5{,}851.73}{0.00} = \infty \quad > 1.20 \ldots \text{-OK-}$$

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{77{,}062.07}{0.00} = \infty \quad > 1.30 \ldots \text{-OK-}$$

- Safety factor due to sliding

				51
V=	5,851.73	kN	FSD-φ	1.30
H=	0.00	kN	FSD-c	2.00
L=	19.734	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{5{,}851.73*0.78}{1.30} \quad = 3{,}511.04$$

$$\frac{c \cdot l}{FSD_c} = \frac{1{,}000.0*19.734}{2.00} \quad = 9{,}867.00$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{3{,}511.04+9{,}867.00}{0.00} = \infty \quad > 1.0 \ldots \text{-OK-}$$

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{5{,}851.73}{19.734} \times \left(1.0 \pm \frac{6 \times 3.302}{19.734}\right)$$

vertical stress of upstream = 594.233 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = -1.172 kN/㎡ ＜ 0 kN/㎡ (Tensile force occur) but downstream side -OK-

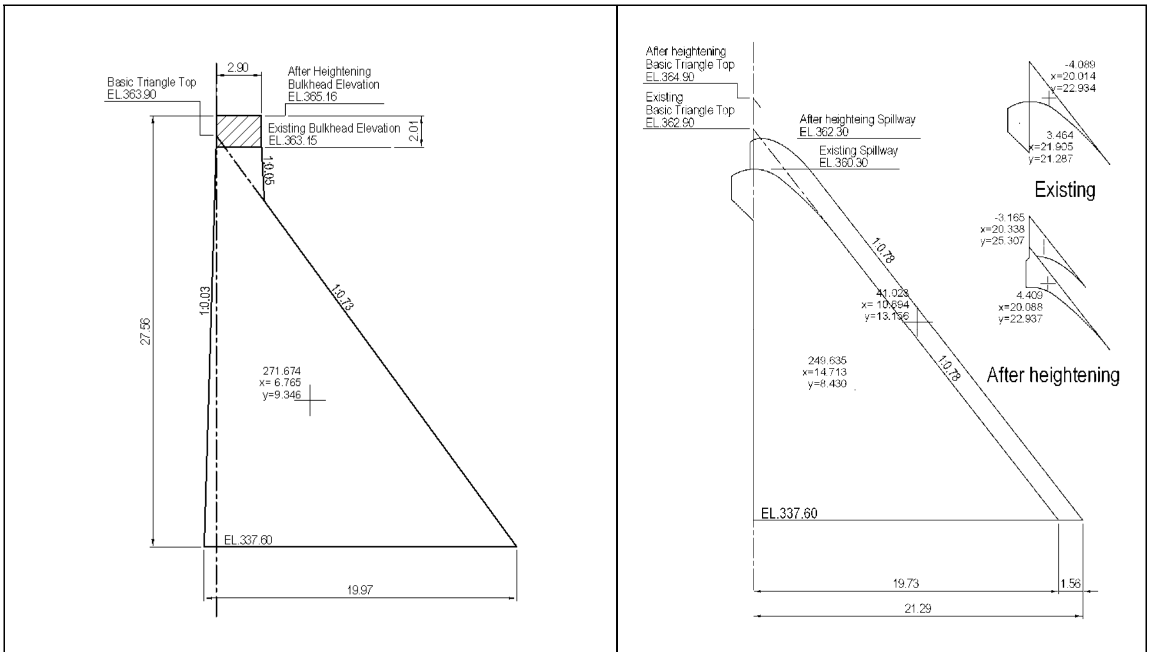
(2) After heightening

1) Design Condition

Design condition of Dam stability analysis is considered as shown in the table 2 below.

Table 2 Design condition of After heightening

		Bulkhead section	Spillway section
Elevation of Top of Dam	EL.m	365.160	-----
Basic triangle Top Elevation	EL.m	363.900	364.900
Upstream Slope	1:n	0.030	-----
Downstream Slope	1:n	0.730	0.780
Upper surface of the downstream slope	1:n	-----	-----
Dam base elevation	EL.m	337.600	337.600
Crest width of non-overflow section	m	2.900	-----
Reservoir sediment level	EL.m	338.500	←
Reservoir water level [CCN]	EL.m	340.790	←
[CCE]	EL.m	364.660	←
[CCL]	EL.m	362.300	←
Downstream water level [CCN]	EL.m	340.090	←
[CCE]	EL.m	347.740	←
[CCL]	EL.m	342.060	←
Unit weight of concrete dams	kN/m^3	23.5	←
Weight of sediment in the water	kN/m^3	8.5	←
Unit weight of water	kN/m^3	10.0	←
Seismic Coefficient: Horizontal (kh)	---	0.050	←
Seismic Coefficient: Vertical (kv)	---	0.030	←
Coefficient of earth pressure (Rankine coefficient of earth pressure)	---	0.40	←
Uplift pressure coefficient	---	1/3	←
Downstream cover thickness	m	-----	1.83
Concrete mat elevation (Top point)	EL.m	342.500	-----
Concrete mat length (Base point)	m	1.000	-----
Shear strength of foundation	kN/m^2	1,000.0	←
Friction angle of foundation	deg	38.00	←
Internal friction coefficient	---	0.78	←



Determinatimg Bulkhead Section	Determinatimg Spillway section

Fig 2 After heightening Bulkhead section

2) Stability Analysis of after heightening

[Bulkhead section]

- CCN: Normal water

Resume of Acting Force and Moment

[CCN : Normal water]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	6,384.34		13.201		84,276.48		
Mat section							
W/O Dead Load							
Seismic							
Seismic of mat							
W/O Seismic							
U/S Water weight	1.53		19.934		30.50		
D/S Water weight	22.63		19.360		438.12		
U/S Water Pressure		50.88		1.063		54.09	
D/S Water Pressure		-31.00		0.830		-25.73	
Dynamic Water Pressure							
Earth Pressure	0.10		19.957		2.00		
Soil weight		1.38		0.300		0.41	
Uplift	-520.43		10.132		-5,272.78		
Total	5,888.17	21.26			79,474.32	28.77	

Control of Stability [CCN]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{79,445.55}{5,888.17} \quad =13.492 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{19.966}{2} \quad - 13.492 \quad =|-3.509 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{6,408.60}{520.43} \quad =12.314 \quad > 1.30 \ldots \text{-OK-}$$

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{79,474.32}{28.77} \quad =2,762.403 \quad > 1.50 \ldots \text{-OK-}$$

- Safety factor due to sliding

V=	5,888.17	kN	FSD-φ	1.50
H=	21.26	kN	FSD-c	3.00
L=	19.966	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{5,888.17*0.78}{1.50} \quad =3,061.85$$

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*19.966}{3.00} \quad =6,655.33$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{3,061.85+6,655.33}{21.26} \quad =457.064 \quad > 1.0 \ldots \text{-OK-}$$

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{5,888.17}{19.966} \quad \times(1.0\pm \quad \frac{6\times 3.509}{19.966})$$

vertical stress of upstream = 605.913 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = -16.079 kN/㎡ ＜ 0 kN/㎡ (Tensile force occur) but downstream side -OK-

- CCE: Maximum flood water

Resume of Acting Force and Moment

[CCE : Maximum Flood water]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	6,384.34		13.201		84,276.48		
Mat section							
W/O Dead Load							
Seismic							
Seismic of mat							
W/O Seismic							
U/S Water weight	109.50		19.697		2,156.77		
D/S Water weight	375.29		17.498		6,566.82		
U/S Water Pressure		3,661.22		9.020		33,024.20	
D/S Water Pressure		-514.10		3.380		-1,737.66	
Dynamic Water Pressure							
Earth Pressure	0.10		19.957		2.00		
Soil weight		1.38		0.300		0.41	
Uplift	-2,587.53		10.707		-27,703.39		
Total	4,281.70	3,148.50			65,298.68	31,286.95	

Control of Stability [CCE]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{34,011.73}{4,281.70} = 7.944 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{19.966}{2} - 7.944 = |2.039 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{6,869.23}{2,587.53} = 2.655$$

> 1.10 … -OK-

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{65,298.68}{31,286.95} = 2.087$$

> 1.20 … -OK-

- Safety factor due to sliding

V=	4,281.70	kN	FSD-φ	1.10
H=	3,148.50	kN	FSD-c	1.50
L=	19.966	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{4,281.70*0.78}{1.10} = 3,036.11$$

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*19.966}{1.50} = 13,310.67$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{3,036.11+13,310.67}{3,148.50} = 5.192$$

> 1.0 … -OK-

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{4,281.70}{19.966} \times \left(1.0 \pm \frac{6 \times 2.039}{19.966}\right)$$

vertical stress of upstream = 83.046 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = 345.864 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur) -OK-

- CCL: Flood water + Seismic

Resume of Acting Force and Moment

[CCL : Flood water + Seismic]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	6,384.34		13.201		84,276.48		
Mat section							
W/O Dead Load							
Seismic	-191.53	319.22	13.201	9.346	-2,528.29	2,983.40	→
Seismic of mat							→
W/O Seismic							→
U/S Water weight	91.51		19.719		1,804.44		
D/S Water weight	72.60		18.881		1,370.76		
U/S Water Pressure		3,050.45		8.233		25,114.35	
D/S Water Pressure		-99.46		1.487		-147.90	
Dynamic Water Pressure		177.94		9.880		1,758.05	
Earth Pressure	0.10		19.957		2.00		
Soil weight		1.38		0.300		0.41	
Uplift	-1,563.96		11.416		-17,853.39		
Total	4,793.06	3,449.53			67,072.00	29,708.31	

Control of Stability [CCL]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{37{,}363.69}{4{,}793.06} = 7.795 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{19.966}{2} - 7.795 = |2.188 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{6{,}357.02}{1{,}563.96} = 4.065$$

> 1.10 … -OK-

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{67{,}072.00}{29{,}708.31} = 2.258$$

> 1.10 … -OK-

- Safety factor due to sliding

V=	4,793.06	kN	FSD-φ	1.10
H=	3,449.53	kN	FSD-c	1.30
L=	19.966	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{4{,}793.06*0.78}{1.10} = 3{,}398.72$$

$$\frac{c \cdot l}{FSD_c} = \frac{1{,}000.0*19.966}{1.30} = 15{,}358.46$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{3{,}398.72+15{,}358.46}{3{,}449.53} = 5.438$$

> 1.0 … -OK-

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{4{,}793.06}{19.966} \times (1.0 \pm \frac{6\times2.188}{19.966})$$

vertical stress of upstream = 82.215 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = 397.919 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur) -OK-

- CCC: Construction

Resume of Acting Force and Moment

[CCC : Construction]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	6,384.34		13.201		84,276.48		
Mat section							
W/O Dead Load							
Seismic							
Seismic of mat							
W/O Seismic							
U/S Water weight							
D/S Water weight							
U/S Water Pressure							
D/S Water Pressure							
Dynamic Water Pressure							
Earth Pressure							
Soil weight							
Uplift							
Total	6,384.34				84,276.48		

Control of Stability [CCC]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{84,276.48}{6,384.34} = 13.200 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{19.966}{2} - 13.200 = |-3.217 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{6,384.34}{0.00} = \infty \quad > 1.20 \text{ … -OK-}$$

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{84,276.48}{0.00} = \infty \quad > 1.30 \text{ … -OK-}$$

- Safety factor due to sliding

V=	6,384.34	kN	FSD-φ	1.30
H=	0.00	kN	FSD-c	2.00
L=	19.966	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{6,384.34*0.78}{1.30} = 3,830.60$$

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*19.966}{2.00} = 9,983.00$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{3,830.60+9,983.00}{0.00} = \infty \quad > 1.0 \text{ … -OK-}$$

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{6,384.34}{19.966} \times (1.0 \pm \frac{6 \times 3.217}{19.966})$$

vertical stress of upstream = 628.911 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = 10.627 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur) -OK-

[Spillway section]

- CCC: Construction

Resume of Acting Force and Moment

[CCC : Construction]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	5,851.74		13.169		77,061.56		
Seismic					0.00	0.00	
U/S Water pressure,weight	0.00	45.00	19.734	1.000	0.00	45.00	
D/S Water pressure,weight					0.00	0.00	
Dynamic Water Pressure					0.00	0.00	
Earth Pressure	0.00		19.734		0.00	0.00	
Soil weight		1.38		0.300	0.00	0.41	
Uplift	-98.67	0.00	13.156	0.000	-1,298.10	0.00	
Total	5,753.07	46.38			75,763.46	45.41	

Control of Stability [CCC]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{75,718.05}{5,753.07} = 13.161 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{19.734}{2} - 13.161 = |-3.294 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{5,851.74}{98.67} = 59.306$$ > 1.20 … -OK-

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{75,763.46}{45.41} = 1,668.431$$ > 1.30 … -OK-

- Safety factor due to sliding

V=	5,753.07	kN	FSD-φ	1.30
H=	46.38	kN	FSD-c	2.00
L=	19.734	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{5,753.07*0.78}{1.30} = 3,451.84$$

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*19.734}{2.00} = 9,867.00$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{3,451.84+9,867.00}{46.38} = 287.168$$ > 1.0 … -OK-

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{5,753.07}{19.734} \times \left(1.0 \pm \frac{6 \times 3.294}{19.734}\right)$$

vertical stress of upstream = 583.505 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = -0.443 kN/㎡ ＜ 0 kN/㎡ (Tensile force occur)

but downstream side -OK-

- CCN: Normal water

Resume of Acting Force and Moment

[CCN : Normal water]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	993.39		11.287		11,212.39		
Seismic							
U/S Water pressure,weight	0.00	31.05	21.294	1.730	0.00	53.72	
D/S Water pressure,weight	24.96	32.00	0.658	0.843	16.42	26.99	
Dynamic Water Pressure							
Earth Pressure							
Soil weight							
Uplift	-488.69	0.00	10.179	0.000	-4,974.15	0.00	
Total	529.66	63.05			6,254.66	80.71	

	V(kN)	U(kN)	H(kN)	Me(kN.m)	Mt(kN.m)
[CCC]	5,851.74	-98.67	46.38	75,763.46	45.41
[CCN]	1,018.35	-488.69	63.05	6,254.66	80.71
	6,870.09	-587.36	109.43	82,018.12	126.12

Control of Stability [CCN]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{6,173.95}{529.66} = 11.656 \text{ m}$$

- Safety factor due to Lifting

$$e = \frac{B}{2} - x = \frac{21.294}{2} - 11.656 = |-1.009 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{6,870.09}{587.36} = 11.697 \quad > 1.30 \ldots \text{-OK-}$$

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{82,018.12}{126.12} = 650.318 \quad > 1.50 \ldots \text{-OK-}$$

- Safety factor due to sliding

V=	6,282.73	kN	FSD-φ	1.50
H=	109.43	kN	FSD-c	3.00
L=	21.294	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{6,282.73*0.78}{1.50} = 3,267.02$$

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*21.294}{3.00} = 7,098.00$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{3,267.02+7,098.00}{109.43} = 94.714 \quad > 1.0 \ldots \text{-OK-}$$

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{529.66}{21.294} \times \left(1.0 \pm \frac{6\times1.009}{21.294}\right)$$

(Stress during to construction)

vertical stress of upstream =	31.95 kN/㎡ +	583.51 kN/㎡	= 615.46	kN/㎡	≧ 0 kN/㎡
Existing dam downstream part (-)=	18.83 kN/㎡ +	-0.44 kN/㎡	= 18.39	kN/㎡	≧ 0 kN/㎡
Existing dam downstream part (+)=	(17.79-31.95)×19.734/21.294+31.95		= 18.83	kN/㎡	≧ 0 kN/㎡
vertical stress of downstream =			= 17.79	kN/㎡	≧ 0 kN/㎡

-OK-

- CCE: Maximum flood water

Resume of Acting Force and Moment

[CCE : Maximum Flood water]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	993.39		11.287		11,212.39		
Seismic							
U/S Water pressure,weight	0.00	3,616.22	21.294	9.120	0.00	32,979.93	
D/S Water pressure,weight	401.00	514.10	2.636	3.380	1,057.19	1,737.65	
Dynamic Water Pressure							
Earth Pressure							
Soil weight							
Uplift	-2,661.03	0.00	11.297	0.000	-30,061.67	0.00	
Total	-1,266.65	4,130.32			-17,792.09	34,717.58	

	V(kN)	U(kN)	H(kN)	Me(kN.m)	Mt(kN.m)
[CCC]	5,851.74	-98.67	46.38	75,763.46	45.41
[CCE]	1,394.39	-2,661.03	4,130.32	-17,792.09	34,717.58
	7,246.13	-2,759.70	4,176.70	57,971.37	34,762.99

Control of Stability [CCE]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{-52,509.67}{-1,266.65}$$ =41.456 m

41.45555

- Safety factor due to Lifting

$$e = \frac{B}{2} - x = \frac{21.294}{2}$$ - 41.456 =|-30.809 m|

-30.8085481

1.1

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{7,246.13}{2,759.70}$$ =2.626 > 1.10 … -OK-

1.2

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{57,971.37}{34,762.99}$$ =1.668 > 1.20 … -OK-

- Safety factor due to sliding

53

V=	4,486.42	kN	FSD-φ	1.10
H=	4,176.70	kN	FSD-c	1.50
L=	21.294	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{4,486.42*0.78}{1.10}$$ =3,181.28

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*21.294}{1.50}$$ =14,196.00

$$FSD = \frac{\dfrac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \dfrac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{3,181.28+14,196.00}{4,176.70}$$ =4.161 > 1.0 … -OK-

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{-1,266.65}{21.294} \times \left(1.0 \pm \frac{6\times30.809}{21.294}\right)$$

(Stress during to construction)

vertical stress of upstream =	-575.88	kN/㎡ +	583.51 kN/㎡	= 7.63	kN/㎡	≧ 0 kN/㎡
Existing dam downstream part (-)=	381.25	kN/㎡ +	-0.44 kN/㎡	= 380.81	kN/㎡	≧ 0 kN/㎡
Existing dam downstream part (+)=	(456.91-575.88)×19.734/21.294-575.88			= 381.25	kN/㎡	≧ 0 kN/㎡
vertical stress of downstream =				= 456.91	kN/㎡	≧ 0 kN/㎡

-OK-

- CCL: Flood water + Seismic

Resume of Acting Force and Moment

[CCL : Flood water + Seismic]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	993.39		11.287		11,212.39		
Seismic	-205.35	342.26	14.229	9.084	-2,921.93	3,109.09	→
U/S Water pressure,weight	0.00	3,005.45	21.294	8.340	0.00	25,065.45	
D/S Water pressure,weight	84.33	108.11	1.209	1.550	101.95	167.57	
Dynamic Water Pressure	0.00	177.94	21.294	9.880	0.00	1,758.05	
Earth Pressure							
Soil weight							
Uplift	-1,603.08	0.00	11.972	0.000	-19,191.84	0.00	
Total	-730.71	3,633.76			-10,799.43	30,100.16	

	V(kN)	U(kN)	H(kN)	Me(kN.m)	Mt(kN.m)
[CCC]	5,851.74	-98.67	46.38	75,763.46	45.41
[CCL]	872.37	-1,603.08	3,633.76	-10,799.43	30,100.16
	6,724.11	-1,701.75	3,680.14	64,964.03	30,145.57

Control of Stability [CCL]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{-40,899.59}{730.7} = -55.972 \text{ m}$$

- Safety factor due to Lifting

$$e = \frac{B}{2} - x = \frac{21.294}{2} - 55.972 = |-45.325 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{6,724.11}{1,701.75} = 3.951 \quad > 1.10 \ldots \text{-OK-}$$

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{64,964.03}{30,145.57} = 2.155 \quad > 1.10 \ldots \text{-OK-}$$

- Safety factor due to sliding

V=	5,022.36 kN		FSD-φ	1.10
H=	3,680.14 kN		FSD-c	1.30
L=	21.294 m		tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{5,022.36*0.78}{1.10} = 3,561.31$$

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*21.294}{1.30} = 16,380.00$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{3,561.31+16,380.00}{3,680.14} = 5.419 \quad > 1.0 \ldots \text{-OK-}$$

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{-730.71}{21.294} \times \left(1.0 \pm \frac{6 \times 45.325}{21.294}\right)$$

(Stress during to construction)

vertical stress of upstream =	-472.51 kN/㎡ + 583.51 kN/㎡	= 111.00	kN/㎡	≧ 0 kN/㎡
Existing dam downstream part (-)=	339.68 kN/㎡ + -0.44 kN/㎡	= 339.24	kN/㎡	≧ 0 kN/㎡
Existing dam downstream part (+)=	(403.88-472.51)×19.734/21.294-472.51	= 339.68	kN/㎡	≧ 0 kN/㎡
vertical stress of downstream =		= 403.88	kN/㎡	≧ 0 kN/㎡

-OK-

APPENDIX-7 :

Stability Analysis of Sul dam

(1) Design condition

Design condition of Dam Spillway stability analysis is considered as shown in the table 1 below.

Table 1 Design condition of Existing

		Existing	After heightening
Elevation of Top of Dam	EL.m	399.000	401.000
Upstream Slope	1:n	0.030	←
Downstream Slope	1:n	1.100	←
Dam base elevation	EL.m	383.800	383.800
Reservoir sediment level	EL.m	394.510	←
Reservoir water level [CCN]	EL.m	383.800	←
[CCE]	EL.m	406.000	408.000
[CCL]	EL.m	399.000	401.000
Unit weight of concrete dams	kN/m^3	23.5	←
Weight of sediment in the water	kN/m^3	8.5	←
Unit weight of water	kN/m^3	10.0	←
Seismic Coefficient: Horizontal (kh)	---	0.050	←
Seismic Coefficient: Vertical (kv)	---	0.030	←
Coefficient of earth pressure (Rankine coefficient of earth pressure)	---	0.40	←
Uplift pressure coefficient	---	1/3	←
Shear strength of foundation	kN/m^2	1,000.0	←
Friction angle of foundation	deg	38.00	←
Internal friction coefficient	---	0.78	←

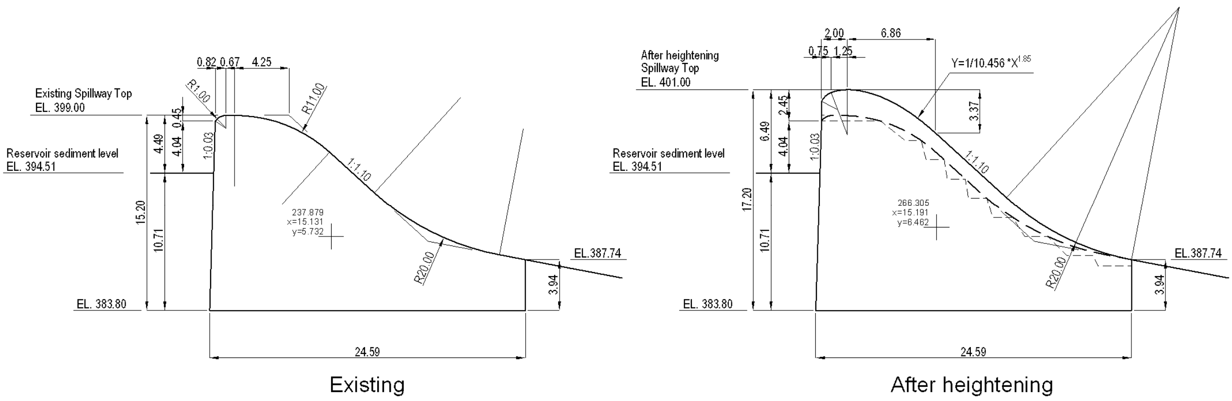


Fig 1 Typical section of Existing

(2) Stability Analysis

1) Existing dam

- CCN: Normal water

Resume of Acting Force and Moment

[CCN : Normal water]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	5,590.16		15.131		84,584.66		
Seismic							
U/S Water Pressure							
Dynamic Water Pressure							
Earth Pressure		401.46		3.570		1,433.23	
Uplift							
Total	5,590.16	401.46			84,584.66	1,433.23	

Control of Stability [CCN]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{83,151.43}{5,590.16} \quad =14.875 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{24.590}{2} \quad - 14.875 \quad =|-2.580 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{5,590.16}{0.00} \quad = \infty \quad > 1.30 \ldots \text{-OK-}$$

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{84,584.66}{1,433.23} \quad =59.017 \quad > 1.50 \ldots \text{-OK-}$$

- Safety factor due to sliding

V=	5,590.16	kN	FSD-φ	1.50
H=	401.46	kN	FSD-c	3.00
L=	24.590	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{5,590.16*0.78}{1.50} \quad =2,906.88$$

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*24.590}{3.00} \quad =8,196.67$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{2,906.88+8,196.67}{401.46} \quad =27.658 \quad > 1.0 \ldots \text{-OK-}$$

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{5,590.16}{24.590} \quad \times (1.0 \pm \quad \frac{6 \times 2.580}{24.590})$$

vertical stress of upstream = 370.447 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = 84.222 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur) -OK-

- CCE: Maximum flood water

Resume of Acting Force and Moment

[CCE : Maximum Flood water]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	5,590.16		15.131		84,584.66		
Seismic							
U/S Water Pressure		2,219.20		6.281		13,939.41	
Dynamic Water Pressure							
Earth Pressure		195.00		3.570		696.14	
Uplift	-909.83		16.393		-14,915.15		
Total	4,680.33	2,414.20			69,669.51	14,635.55	

Control of Stability [CCE]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{55,033.96}{4,680.33} = 11.759 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{24.590}{2} - 11.759 = |0.536 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{5,590.16}{909.83} = 6.144 \quad > 1.10 \ldots \text{-OK-}$$

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{69,669.51}{14,635.55} = 4.760 \quad > 1.20 \ldots \text{-OK-}$$

- Safety factor due to sliding

V=	4,680.33	kN	FSD-φ	1.10
H=	2,414.20	kN	FSD-c	1.50
L=	24.590	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{4,680.33*0.78}{1.10} = 3,318.78$$

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*24.590}{1.50} = 16,393.33$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{3,318.78+16,393.33}{2,414.20} = 8.165 \quad > 1.0 \ldots \text{-OK-}$$

- Safety factor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{4,680.33}{24.590} \times (1.0 \pm \frac{6\times0.536}{24.590})$$

vertical stress of upstream = 165.442 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = 215.227 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur) -OK-

- CCL: Flood water + Seismic

Resume of Acting Force and Moment

[CCL : Flood water + Seismic]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	5,590.16		15.131		84,584.66		
Seismic	-167.70	279.51	15.131	5.732	-2,537.54	1,602.14	
U/S Water Pressure		1,155.20		5.067		5,853.01	
Dynamic Water Pressure		67.39		6.080		409.71	
Earth Pressure		195.00		3.570		696.14	
Uplift	-622.95		16.393		-10,212.17		
Total	4,799.51	1,697.09			71,834.95	8,561.00	

Control of Stability [CCL]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{63,273.95}{4,799.51} = 13.183 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{24.590}{2} - 13.183 = |-0.888 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{5,422.45}{622.95} = 8.705$$

> 1.10 … -OK-

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{71,834.95}{8,561.00} = 8.391$$

> 1.10 … -OK-

- Safety factor due to sliding

V=	4,799.51	kN	FSD-φ	1.10
H=	1,697.09	kN	FSD-c	1.30
L=	24.590	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{4,799.51*0.78}{1.10} = 3,403.29$$

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*24.590}{1.30} = 18,915.38$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{3,403.29+18,915.38}{1,697.09} = 13.151$$

> 1.0 … -OK-

ctor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{4,799.51}{24.590} \times (1.0 \pm \frac{6\times0.888}{24.590})$$

vertical stress of upstream = 237.472 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = 152.891 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur) -OK-

2) After heightening of dam

- CCN: Normal water

Resume of Acting Force and Moment

[CCN : Normal water]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	6,258.17		15.192		95,074.08		
Seismic							
U/S Water Pressure							
Dynamic Water Pressure							
Earth Pressure		401.46		3.570		1,433.23	
Uplift							
Total	6,258.17	401.46			95,074.08	1,433.23	

Control of Stability [CCN]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{93,640.85}{6,258.17} = 14.963 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{24.590}{2} - 14.963 = |-2.668 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{6,258.17}{0.00} = \infty$$

> 1.30 … -OK-

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{95,074.08}{1,433.23} = 66.336$$

> 1.50 … -OK-

- Safety factor due to sliding

V=	6,258.17	kN	FSD-φ	1.50
H=	401.46	kN	FSD-c	3.00
L=	24.590	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{6,258.17*0.78}{1.50} = 3,254.25$$

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*24.590}{3.00} = 8,196.67$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{3,254.25+8,196.67}{401.46} = 28.523$$

> 1.0 … -OK-

ctor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{6,258.17}{24.590} \times (1.0 \pm \frac{6\times2.668}{24.590})$$

vertical stress of upstream = 420.179 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = 88.822 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur) -OK-

- CCE: Maximum flood water

Resume of Acting Force and Moment

[CCE : Maximum Flood water]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	6,258.17		15.192		95,074.08		
Seismic							
U/S Water Pressure		2,683.20		7.020		18,835.15	
Dynamic Water Pressure							
Earth Pressure		195.00		3.570		696.14	
Uplift	-991.80		16.393		-16,258.85		
Total	5,266.37	2,878.20			78,815.23	19,531.29	

Control of Stability [CCE]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{59{,}283.94}{5{,}266.37} \quad = 11.257 \text{ m}$$

- Excentricity

$$e = \frac{B}{2} - x = \frac{24.590}{2} - 11.257 \quad = |1.038 \text{ m}|$$

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{6{,}258.17}{991.80} \quad = 6.310 \quad > 1.10 \ldots \text{-OK-}$$

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{78{,}815.23}{19{,}531.29} \quad = 4.035 \quad > 1.20 \ldots \text{-OK-}$$

- Safety factor due to sliding

V=	5,266.37	kN	FSD-φ	1.10
H=	2,878.20	kN	FSD-c	1.50
L=	24.590	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{5{,}266.37*0.78}{1.10} \quad = 3{,}734.34$$

$$\frac{c \cdot l}{FSD_c} = \frac{1{,}000.0*24.590}{1.50} \quad = 16{,}393.33$$

$$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{3{,}734.34+16{,}393.33}{2{,}878.20} \quad = 6.993 \quad > 1.0 \ldots \text{-OK-}$$

ctor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{5{,}266.37}{24.590} \times (1.0 \pm \frac{6 \times 1.038}{24.590})$$

vertical stress of upstream = 159.924 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = 268.410 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur) -OK-

- CCL: Flood water + Seismic

Resume of Acting Force and Moment

[CCL : Flood water + Seismic]

---	V(kN)	H(kN)	X(m)	Y(m)	Me(kN.m)	Mt(kN.m)	Remark
Dead load	6,258.17		15.192		95,074.08		
Seismic	-187.75	312.91	15.192	6.462	-2,852.22	2,022.01	
U/S Water Pressure		1,479.20		5.733		8,480.75	
Dynamic Water Pressure		86.29		6.880		593.65	
Earth Pressure		195.00		3.570		696.14	
Uplift	-704.91		16.393		-11,555.88		
Total	5,365.51	2,073.39			80,665.98	11,792.55	

Control of Stability [CCL]

- Barycentric position

$$x = \frac{Mx + My}{V} = \frac{68,873.43}{5,365.51}$$ =12.836 m

- Excentricity

$$e = \frac{B}{2} - x = \frac{24.590}{2}$$ - 12.836 =|-0.541 m|

- Safety factor due to Lifting

$$FSF = \frac{\Sigma V}{\Sigma U} = \frac{6,070.42}{704.91}$$ =8.612 > 1.10 … -OK-

- Safety factor due to overturning

$$FST = \frac{\Sigma Me}{\Sigma Mt} = \frac{80,665.98}{11,792.55}$$ =6.840 > 1.10 … -OK-

- Safety factor due to sliding

V=	5,365.51	kN	FSD-φ	1.10
H=	2,073.39	kN	FSD-c	1.30
L=	24.590	m	tanφ	0.78

$$\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} = \frac{5,365.51*0.78}{1.10}$$ =3,804.63

$$\frac{c \cdot l}{FSD_c} = \frac{1,000.0*24.590}{1.30}$$ =18,915.38

F$\scriptstyle S$ $$FSD = \frac{\frac{\Sigma V \cdot \tan\phi}{FSD_\phi} + \frac{c \cdot l}{FSD_c}}{\Sigma H} = \frac{3,804.63+18,915.38}{2,073.39}$$ =10.958 > 1.0 … -OK-

ctor due to bearing power

$$q = \frac{V}{B} \times \left(1 \pm \frac{6 \times e}{B}\right) = \frac{5,365.51}{24.590} \times \left(1.0 \pm \frac{6\times0.541}{24.590}\right)$$

vertical stress of upstream = 247.002 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur)

vertical stress of downstream = 189.396 kN/㎡ ≧ 0 kN/㎡ (Tensile force not occur) -OK-

Supporting Report (H)
Economic Evaluation

PREPARATORY SURVEY
FOR
THE PROJECT ON DISASTER PREVENTION
AND
MITIGATION MEASURES FOR THE ITAJAI RIVER BASIN

FINAL REPORT

VOLUME III : SUPPORTING REPORT
ANNEX H: ECONOMIC EVALUATION

Table of Contents

<u>**Table**</u>

Page

Figure

CHAPTER 1 METHODOLOGY OF ECONOMIC EVALUATION

1.1 Evaluation Criteria

In economical and financial evaluations, the followings criteria were applied;

– Applied price for the cost and benefit estimation is of a base of year 2010.

– The evaluation will be made for whole program for each return period of 5, 10, 25 and 50 years.

– The evaluation period is of 50 years.

– The evaluations will be carried out as a total program of the mitigation measure for disasters of flood, flashflood and prevention / alert / alarm.

– The evaluation will be carried out the financial and economical point of view. In the financial evaluation, the market price will be applied and for the economical evaluation, the discounted price excluded the taxes and the compensations fees, will be applied.

– In an evaluation, the concept of the Net Present Value (NPV), Internal Rate of Return (IRR), and Benefit/Cost Ratio (B/C) will be used.

– As a discount rate for the estimation of NPV and B/C, the commonly used rate of 12%, rate calculated from the Certificate of Interbanking Deposit's Rate and the rate of the long term Interest (TJLP) in last 9 years will be utilized.

– The estimated benefit values for each safety level will be calculated by statistic method, on the basis of the registered disaster's damages value published by the State Government. The medium annual benefit will be considered multiplying the probabilities of each inundation and the damages caused by each safety level. Besides this, also, the benefit from land valorizations with improvement of safety level will be possible. However, this kind of benefit, in this evaluation, will not be considered.

– The values used as bases of damages estimation for each safety level were of flood damages registered at October, 2001 and November, 2008.

– The flood at October, 2001 was considered equivalent to the one of 7 years Safety level, and the flood of November, 2008 was considered as of 50 years of Safety level.

1.2 Tax

The taxes included in a cost are as followings items;

Table 1.2.1 Rate of Tax

Tax	Tax objective	Rate
Federal Tax		
Physical Person Income Tax IRPF.	Percentage for each salary	7.5%、15%、22%、27,5%
Judicial Person Income Tax IRPJ.	Companies Profit	15% / 25%
Industries Product Tax (IPI)	Charged for the industrialized products, national and foreigners. The field of incidence of the tax includes all of the products with index allocation, although, it reduce to zero, observed the dispositions contained in the	Related in the Table of Incidence of IPI (TIPI)

Tax	Tax objective	Rate
	respective complementally notes, excluded those that corresponds the (no-taxed) notation "NT."	
Import Tax (II)	Imported Product	Goods, import origin, volumes
Financial Operation Tax (IOF)	Tax about Operations of Credit, Exchange and security, or relative to Titles and real estate values	
State Tax		
Tax for Circulated Good and Services (ICMS)	Tax about relative operations to the circulation of goods and services rendered of interstate transport, inter municipal and of communication.	17% a 25%
Tax for Properties of Vehicles Terrestrial (IPVA)	On the Property of Vehicle	Type of vehicles
Municipal Tax		
Tax for Services (ISS)	rendered service (cleaning of properties, safety, building site, labor supply)	3% a 5%
Social Contribution		
Contribution for the Social Security Finance(COFINS)		3% a 7.6%
Social Integration Program (PIS PASEP)	Totality of the incomes gained by the legal entity	065 - 1.65%
Social Contribution over net Profit (CSLL)	Conceited profit will correspond the: 12% of the gross revenue in the activities commercial, industrial, services hospitalizes and of transport	9%
Others Contribution		
National Institution of Social Security (INSS)	Executed by discount in the payroll, before the employee of the company to receive the total value of salary.	Salaried ; 11% Employer ; 20%
Grantee Fond for Working period (FGTS)	Executed by discount in the payroll, before the employee of the company to receive the total value of salary.	2% or 8% In the rescission of the labor agreement - 40%

Source: JICA Study Team, http://www.receita.fazenda.gov.br/

1.3 Conversion Rate (Economic Evaluation)

The applied price for the economical evaluation is considered using a conversion rate. The rates of applied conversions are the following ones:

Table 1.3.1 Applied Tax rate in a Construction works

Item	Rate	Total Tax	Conversion Rate	weighted value	Considered Tax
Salary	15%+11%+20%+8.8% =54.8%	93.7%	0.52	30%	IRPF, INSS, FGTS
Materials	20%	50.2%	0.67	20%	ICMS
Fuel	107%	159.0%	0.39	20%	ICMS, PIS, COFINS, IRPJ, CSLL
Machineries	47%+20%+3%=70%	112.7%	0.47	20%	IPI, ICMS, IPVA
Imported	47%+30%+20%+3%=100%	150.3%	0.40	10%	IPI, II, ICMS, IPVA

Machineries					
Administration	1.5%+5%+7.6%+1.65%+9% +0.38% =25.13%				IRPJ, ISS, COFINS, CSLL, PIS
Weighted			0.50		

Source: JICA Study Team

According to the table above, the taxation of taxes in the works can be estimated in 50%. In this study, the conversion rate for the estimation of economical price, the conversion value of 0.5 is used.

1.4 Discount Rate

The discount rate applied for the financial evaluation is considered the rate of Certificate of Inerbanking Deposit (CDI) and for the economical evaluation, the Tax of Interest the Long term was considered. The annual medium taxes of the considered respective years are the following ones:

Table 1.4.1 Tax of CDI & TJLP

Year	**CDI**	**TJLP**
2009	9.88%	6.00%
2008	12.38%	6.00%
2007	11.81%	6.50%
2006	15.04%	9.00% - 6.85%
2005	19.00%	9.75%
2004	16.16%	10.00% - 9.75%
2003	23.26%	11.00%- 12.00%
2002	19.10%	9.50% - 10.00%
2001	17.27%	9.25% - 10.00%

Source: Dados de BACEN http://www.portalbrasil.net/indices_cdi.htm

On the base of the indicated rate above, the discounts rate used are the following ones

Table 1.4.2 Discount Rate

	Financial Evaluation	**Economical Evaluation**
Discount rate (1)	10.0 %	6.0%
Discount rate (2)	23.0 %	12.0 %
Referred Discount Rate	12.0 %	12.0 %

Source: JICA Study Team

The discount rate (1) is the value when the economy of Brazil is stable. The discount rate (2) is the value for the economy of Brazil is in situation of high interest rate.

CHAPTER 2 ECONOMIC & FINANCIAL EVALUATION FOR MASTER PLAN

2.1 Cost

The measures required for the mitigations of the disasters are the following ones:

Table 2.1.1 Cost for each return period

		5 year	10 year	25 year	50 year
Flood Mitigation Measure	Direct Cost	99,000	155,000	399,000	831,000
	Land Compensation	72,000	296,000	435,000	779,000
	Engineering	7,000	12,000	37,000	80,000
	Administration	3,000	10,000	20,000	41,000
	Physical Contingency	14,000	43,000	86,000	170,000
	Price Escalation	8,000	24,000	47,000	94,000
	Subtotal	202,000	541,000	1,025,000	1,996,000
Land Slide Mitigations Measures	Direct Cost	42,000	42,000	42,000	42,000
	Engineering	4,200	4,200	4,200	4,200
	Administration	1,500	1,500	1,500	1,500
	Physical Contingency	4,200	4,200	4,200	4,200
	Price Escalation	2,100	2,100	2,100	2,100
	Subtotal	54,000	54,000	54,000	54,000
Flood Prevention and Alert	Equipment	2,400	2,400	2,400	2,400
	Inventory Study	900	900	900	900
	Training	300	300	300	300
	Engendering	400	400	400	400
	Subtotal	4,000	4,000	4,000	4,000
Land Slide Preventi on and	Installation and Equipments	2,300	2,300	2,300	2.300
	Program	1,700	1,700	1,700	1.700
	Subtotal	4,000	4,000	4,000	4.000
Total		264.000	603,000	1,087,000	2,058,000

Source: JICA Study Team

2.1.1 Cost in a Market Price

(1) Cost for each return period

As presupposition for the evaluation, the following financial schedule was applied for each Return period.

The annual Cost for each Return period is considered the following ones;

Table 2.1.2 Annual Cost for Return Period

TR	Total cost	1st year	2nd year	3 rd year	4th year	5tj year
5 year	264,000	88,000	88,000	88,000		
10 year	603,000	201,000	201,000	201,000		
25 year	1,087,000	271,750	271,750	271,750	271,750	
50 year	2,058,000	411,600	411,600	411,600	411,600	411,600

Source: JICA Study Team

(2) Maintenance Cost

The maintenance cost for Return period is considered 5% of the total construction cost;

Table 2.1.3 Maintenance Cost (R$ Thousand)

	Total Cost	Maintenance Cost
5 year	264,000	13,200
10 year	603,000	30,200
25 year	1,087,000	54,400
50 year	2,058,000	102,900

Source: JICA Study Team

2.1.2 Economic Cost – Economic Values

(1) Economic cost for each return period

The economic cost to be applied for the economical evaluation is considered discounting the taxes and the lands compensations cost of the works at market prices. The schedule of cost application is considered in the following;

Table 2.2.4 Application of annual cost in economic price

	Total de Works	1st year	2nd year	3rd year	4th year	5th year
5 year	91,000	30,333	30,333	30,333		
10 year	141,000	47,000	47,000	47,000		
25 year	303,000	75,750	75,750	75,750	75,750	
50 year	594,000	118,800	118,800	118,800	118,800	118,800

Source: JICA Study Team

(2) Maintenance cost

The maintenance cost is considered 5% of the total construction cost;

Table 2.1.5 Estimated Operational Cost (R$ Thousand)

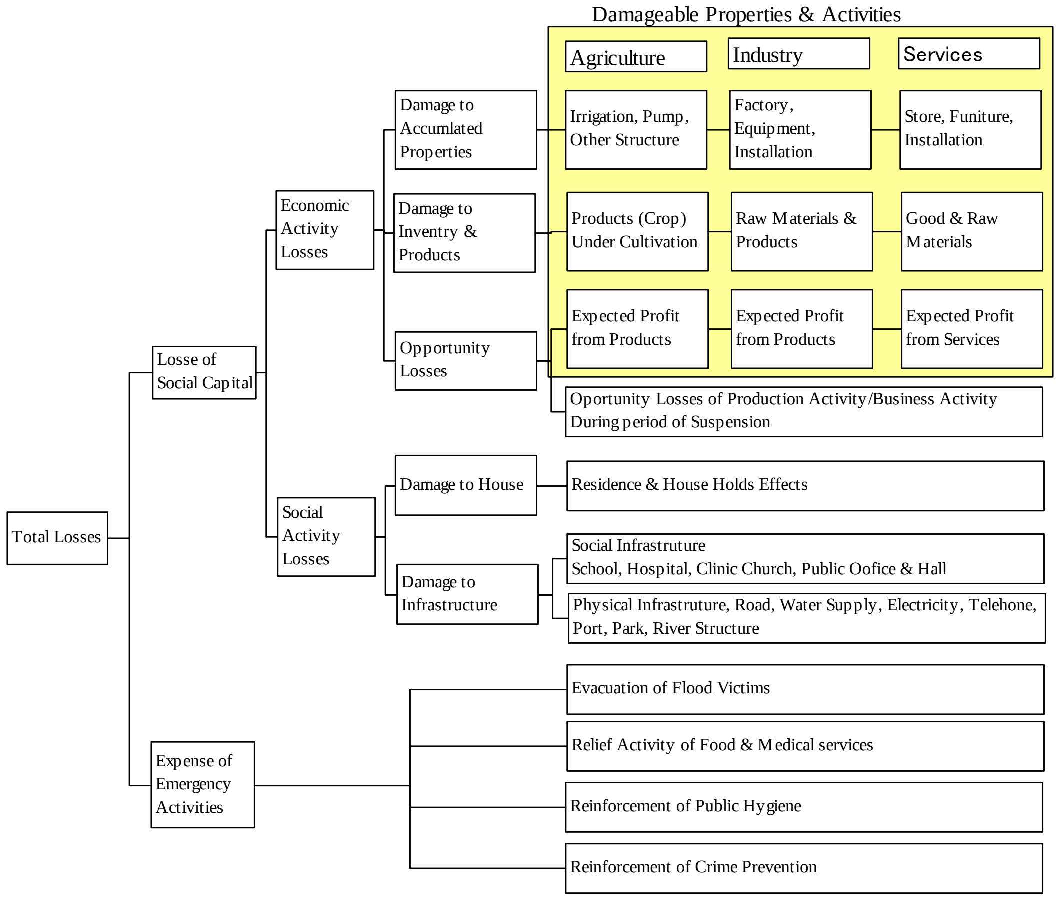
	Total Cost	Operational Cost
5 year	91,000	4,600
10 year	141,000	7,100
25 year	303,000	15,200
50 year	594,000	29,700

Source: JICA Study Team

2.2 Benefit

2.2.1 Accounting Method of Benefit

In this Study, as a benefit, the estimated damages that will be caused by disasters for each return period as the effect of the adopted measures are considered. The damages caused by the disasters are considered the following ones:



Source: JICA Study Team

Figure 2.2.1 Concept of loss in a Disaster

The mentioned losses will be minimized by the implementation of the measures for inundations. With this concept, the benefits of the measures were considered, classified as

– Emergency Expenses

– Cost of Works of Reconstructions

– Losses in the Economical Activities (Agricultural section, Trade, Industry and Transport)

Besides the listed benefits, the possibility of land valorization exists with the improvement of safety's degree, however, this valorization was not considered.

The human damages by death and wounded, were not considered as a benefit, due to the accountancy difficulties.

The emergencies expenses are those applied in the public calamities, rescue, expenses with shelters, health, feeding, etc.

The expenses of the reconstructions are those expenses with the works of reconstructions in the affected areas for the catastrophe, as ports, highways, electrification, sanitation, school, hospital, etc.

The economical losses were estimated for the differences among the normality time and with disaster. The items considered to estimate the economical loss were of agricultural production, service and transport. The economical losses in the agricultural production were estimated for lost cereals for the disaster. The economical losses in the industry, transport and services were estimated with base in the data of ICMS.

The details of the estimates of economical losses are suitable in the section 3.4. For the benefits, for each Return period, the inundation of the October of 2001 was used as equivalent to 7 years of Return period and the inundation of November of 2008, equivalent to 50 years of Return period.

2.2.2 Benefit at market price

(1) Emergencies Expenses and reconstruction cost

The expenses and the costs of reconstructions in the inundations of October of 2001 and of November of 2008 were the following ones:

Table2.2.1 Emergencies Expenses and reconstruction cost (R$ millions)

	Flood at 2001 (1)	Flood at 2008 (2)
Emergencies Expenses	12.6	656.5
Reconstruction Cost		2,065.8
Total		
2001/2008 Conversion Rate	2.78	1
Values at year 2008	34.9	2,065.8

Source: (1) Plano de Recursos Hídricos da Bacia Hidrográfica do Rio Itajaí 2010, elaborado pela JICA Study Team

(2) Relatório "Reconstrução das Áreas Afetadas Catástrofe Novembro/2008" Gov. SC novembro de 2009.

The estimated value of the agricultural section was calculated with base in the data of production of rice. The estimated values in time of normality and time of disaster:

Table 2.2.2 Estimated economic loss values in a Agricultural sector (R$ thousand)

	Flood 2001			Flood 2008		
	2000	2001	2002	2008	2009	Difference
Blumenau	67	68	67	140	140	0
Brusque	95	202	293	630	630	0
Gaspar	6,912	7,168	7,654	13,940	8,500	(5,440)
Ilhota	3,640	3,120	6,119	13,312	5,857	(7,455)
Itajaí	3,360	4,742	5,824	9,660	6,048	(3,612)
Subtotal of 5 municipalities	14,074	15,300	19,957	37,682	21,175	(16,507)
Medium of 2000 & 2002		17,016				
Estimated loss		(1,716)				(16,507)
Values 2009		(4,770)				(16,507)

Source: JICA Study Team

(3) Economical loss in Services and Transports

The economical losses in the services and transports were estimated using the data of variations of ICMS.

Table 2.2.3 Economic Loss (R$ thousand)

	Flood of year 2001			Flood of year 2008		
	2000	2001	2002	Real	Without flood	
Blumenau	178,604	173,034	185,664	292,980	451,285	
Brusque	44,489	42,867	44,276	90,124	140,728	
Ilhota	313	424	442	476	1,132	
Itajaí	62,180	76,397	164,634	366,299	575,301	
Subtotal of 4 cities	301,955	309,209	410,748	749,880	1,168,447	
Mediums of 2000 & 2002		356,352				
Economic Loss		(23,789)			(418,567)	
Price in 2009		(66,135)				

Source: JICA Study Team

(4) Estimated Economic Loss

The economical losses considered by the inundations of October of 2001 (Return period 7 years) and of November of 2008 (Return period 50 years) can be estimate in accordance:

Table2.2.4 Economic Loss by Flood (Unit; R$ millions)

Return Period	Emergencies Expenses & Reconstruction	Agriculture	ICMS	Service	Total	PIB Basin
7 year	34.9	4.4	66.1	661.3	700.7	34,110
50 year	2,722.3	19.5	418.0	4.180.0	6.921.8	34,110

Source: JICA Study Team

(5) Estimated Economic loss for each Return period

The estimates of the economical losses for each Return period are indicated the following:

Table 2.2.5 Estimation of Economic Loss (R$ millions)

Return Period	Emergencies Expenses & Reconstruction	Agriculture	ICMS	Service	Total	PIB Basin	%
2 year	2.2	1.7	20.4	204.1	208.0	34,110.0	0.6%
5 year	16.6	3.5	48.2	482.1	502.1	34,110.0	1.5%
7 year	34.9	4.4	66.1	661.0	700.3	34,110.0	2.1%
10 year	76.9	5.8	92.4	923.7	1,006.4	34,110.0	3.0%
25 year	585.9	11.6	218.2	2,181.8	2,779.3	34,110.0	8.1%
50 year	2,721.8	19.5	418.0	4,180.4	6,921.7	34,110.0	20.3%
100 year	12,643.9	32.9	801.0	8,009.6	20,686.4	34,110.0	60.6%

Source: JICA Study Team

(6) Expected Annual value of economical losses by the interventions for each Return period

The expected annual Value of the economical losses for the interventions for each Return period was esteemed considering the probabilities of occurrences for each Return period. The expected annual value of the economical losses is the following ones:

Table2.2.6 Expected Annual values by Mitigation of Economic Loss (unit; R$ millions)

Return Period	Flood Economic Loss	5 year	10 year	25 year	50 year	100 year
2	208.0	67.8	62.9	61.0	60.1	59.7
5	502.1	75.4	69.9	67.9	66.9	66.4
10	1,006.4		73.6	71.4	70.4	69.9
25	2,779.3			81.3	80.1	79.5
50	6,921.7				100.7	100.0
100	20,686.4					150.1
Annual Expected Values of the mitigation of Economic Loss		143.2	206.3	281.5	378.1	525.5

Source: JICA Study Team

(7) Annual value of emergencies expenses and cost of reconstructions in the implementations of the interventions for the possible inundations

The annual Value in emergencies expenses and cost of reconstructions in the implementations of the interventions for the possible inundations was esteemed considering the probabilities of occurrences of inundations for each Time of Return. The expected annual value of the emergencies expenses and cost of reconstructions the following ones:

Table 2.2.7 Emergencies Expenses and Reconstruction Cost in a Implementation of measure for possible flood (Unit; R$ millions)

Return Period	Emergencies Expenses & Reconstruction	5 year	10 year	25 year	50 year
1	0.0				
2	2.2				
5	16.6	2.2			
10	76.9	5.4	5.4		
25	585.9	16.9	16.9	16.9	
50	2,721.8	39.6	39.6	39.6	39,6
Annual Expected Values of the mitigation of Economic Loss		64.1	61.9	56.5	39.6

Source: JICA Study Team

2.2.3 Economic Benefit

(1) Estimates of the Economical Losses for each Return Period（in economical value）

The Estimated value of the losses in economical value for each Return period was converted using the conversion factor above described (13.1). The economical losses for each Return period are considered the following ones:

Tables2.2.8 Estimated Economic loss without tax and without compensation (R$ millions)

Return Period	Emergencies Expenses & Reconstruction	Agriculture	ICMS	Service	Total	PIB Basin	%
Conversion Factor	0,5	0,8	1	0.5		0.8	
2 year	0.0	0.0	0.0	0.0	0.0	27,288.0	0.0%
5 year	1.1	1.4	20.4	102.0	104.5	27,288.0	0.4%
7 year	8.3	2.8	48.2	241.0	252.1	27,288.0	0.9%
10 year	17.5	3.6	66.1	330.5	351.5	27,288.0	1.3%
25 year	38.5	4.7	92.4	461.8	504.9	27,288.0	1.9%
50 year	293.0	9.3	218.2	1,090.9	1,393.1	27,288.0	5.1%
100 year	1,360.9	15.6	418.0	2,090.2	3,466.7	27,288.0	12.7%

Source: JICA Study Team

(2) Expected annual value of the mitigations of the economical losses for the interventions for each Return period (Price without tax and without compensation)

The value annual expectation of the mitigations of the economical losses for the interventions for each Return period was estimated considering the probabilities of occurrences for each Return period. The value annual expectation of the mitigations of the economical losses is the following:

Table 2.2.9 Expected Annual values of the Mitigation measure of Economic loss

(unit: R$ millions)

	Flood Economic Loss	5 year	10 year	25 year	50 year	100 year
2	104.5	34.1	31.6	30.7	30.2	30,0
5	252.1	37.9	35.1	34.1	33.6	33,3
10	504.9		36.9	35.8	35.3	35,0
25	1,393.1			40.7	40.1	39,8
50	3,466.7				50.4	50,1
100	16,675.0					121,0
Annual Expected Values of the mitigation of Economic Loss		71.9	103.6	141.3	189.7	309.3

Source: JICA Study Team

(3) Annual value required for emergencies expenses and cost of reconstructions in the implementations of the interventions for possible inundations (without tax and without compensation)

The annual Value required for emergencies expenses and cost of reconstructions in the implementations of the interventions for the possible inundations was estimated considering the probabilities of occurrences of inundations for each Return period. The expected annual value of the expenses emergencies and cost of reconstructions the following ones:

Table 2.2.10 Emergencies Expenses and Reconstruction Cost in a Implementation of measure for possible flood

(Unit; R$ millions)

	Emergencies Expenses & Reconstruction	5 year	10 year	25 year	50 year
1	0.0				
2	104.5				
5	252.1	1.1			
10	504.9	2.7	2.7		
25	1,393.1	8.4	8.4	8.4	
50	3,466.7	19.8	19.8	19.8	19,8
Annual Expected Values of the mitigation of Economic Loss		32.0	30.9	28.2	19.8

Source: JICA Study Team

2.3 Financial and Economical Evaluation

2.3.1 Financial Evaluation

(1) Cash Flow for 5 years safety level

The cash flow of the Master Plan for 5 years safety level is as follow;

Table 2.3.1 Cash flow (5 years safety level Plan) **Unit (R$ million)**

Year	Cost	Maintenance Cost	Emergencies Expense	Benefit	Balance
1	88.0				-88.0
2	88.0				-88.0
3	88.0				-88.0
4		13.2	37.7	143.2	92.3
5		13.2	37.7	143.2	92.3
6		13.2	37.7		-50.9
7		13.2	37.7	143.2	92.3
8		13.2	37.7	143.2	92.3
9		13.2	37.7	143.2	92.3
10		13.2	37.7	143.2	92.3
11		13.2	37.7		-50.9
12		13.2	37.7	143.2	92.3
13		13.2	37.7	143.2	92.3
14		13.2	37.7	143.2	92.3
15		13.2	37.7	143.2	92.3
16		13.2	37.7		-50.9
17		13.2	37.7	143.2	92.3
18		13.2	37.7	143.2	92.3
19		13.2	37.7	143.2	92.3
20		13.2	37.7	143.2	92.3
21		13.2	37.7		-50.9
22		13.2	37.7	143.2	92.3
23		13.2	37.7	143.2	92.3
24		13.2	37.7	143.2	92.3
25		13.2	37.7	143.2	92.3
26		13.2	37.7		-50.9
27		13.2	37.7	143.2	92.3
28		13.2	37.7	143.2	92.3
29		13.2	37.7	143.2	92.3
30		13.2	37.7	143.2	92.3
31		13.2	37.7		-50.9
32		13.2	37.7	143.2	92.3
33		13.2	37.7	143.2	92.3
34		13.2	37.7	143.2	92.3
35		13.2	37.7	143.2	92.3
36		13.2	37.7		-50.9
37		13.2	37.7	143.2	92.3
38		13.2	37.7	143.2	92.3
39		13.2	37.7	143.2	92.3
40		13.2	37.7	143.2	92.3
41		13.2	37.7		-50.9
42		13.2	37.7	143.2	92.3
43		13.2	37.7	143.2	92.3
44		13.2	37.7	143.2	92.3
45		13.2	37.7	143.2	92.3
46		13.2	37.7		-50.9
47		13.2	37.7	143.2	92.3
48		13.2	37.7	143.2	92.3
49		13.2	37.7	143.2	92.3
50		13.2	37.7	143.2	92.3

Source: JICA Study Team

(2) Cash Flow for 10 years safety level

The cash flow of the Master Plan for 10 years safety level is as follow;

Table 2.3.2 Cash flow (10 years safety level Plan)

Unit (R$ million)

Year	Cost	Maintenance Cost	Emergencies Expense	Benefit	Balance
1	201.0				-201.0
2	201.0				-201.0
3	201.0				-201.0
4		30.2	36.4	206.3	176.2
5		30.2	36.4	206.3	176.2
6		30.2	36.4	206.3	176.2
7		30.2	36.4	206.3	176.2
8		30.2	36.4	206.3	176.2
9		30.2	36.4	206.3	176.2
10		30.2	36.4	206.3	176.2
11		30.2	36.4		-30.2
12		30.2	36.4	206.3	176.2
13		30.2	36.4	206.3	176.2
14		30.2	36.4	206.3	176.2
15		30.2	36.4	206.3	176.2
16		30.2	36.4	206.3	176.2
17		30.2	36.4	206.3	176.2
18		30.2	36.4	206.3	176.2
19		30.2	36.4	206.3	176.2
20		30.2	36.4	206.3	176.2
21		30.2	36.4		-30.2
22		30.2	36.4	206.3	176.2
23		30.2	36.4	206.3	176.2
24		30.2	36.4	206.3	176.2
25		30.2	36.4	206.3	176.2
26		30.2	36.4	206.3	176.2
27		30.2	36.4	206.3	176.2
28		30.2	36.4	206.3	176.2
29		30.2	36.4	206.3	176.2
30		30.2	36.4	206.3	176.2
31		30.2	36.4		-30.2
32		30.2	36.4	206.3	176.2
33		30.2	36.4	206.3	176.2
34		30.2	36.4	206.3	176.2
35		30.2	36.4	206.3	176.2
36		30.2	36.4	206.3	176.2
37		30.2	36.4	206.3	176.2
38		30.2	36.4	206.3	176.2
39		30.2	36.4	206.3	176.2
40		30.2	36.4	206.3	176.2
41		30.2	36.4		-30.2
42		30.2	36.4	206.3	176.2
43		30.2	36.4	206.3	176.2
44		30.2	36.4	206.3	176.2
45		30.2	36.4	206.3	176.2
46		30.2	36.4	206.3	176.2
47		30.2	36.4	206.3	176.2
48		30.2	36.4	206.3	176.2
49		30.2	36.4	206.3	176.2
50		30.2	36.4	206.3	176.2

(3) Cash Flow for 25 years safety level

The cash flow of the Master Plan for 25 years safety level is as follow;

Table 2.3.3 Cash flow (25 years safety level Plan)

Unit (R$ million)

Year	Cost	Maintenance Cost	Emergencies Expense	Benefit	Balance
1	271.8				-271.8
2	271.8				-271.8
3	271.8				-271.8
4	271.8	30.2	36.4	206.3	-95.6
5		54.4	33.2	281.5	227.2
6		54.4	33.2	281.5	227.2
7		54.4	33.2	281.5	227.2
8		54.4	33.2	281.5	227.2
9		54.4	33.2	281.5	227.2
10		54.4	33.2	281.5	227.2
11		54.4	33.2	281.5	227.2
12		54.4	33.2	281.5	227.2
13		54.4	33.2	281.5	227.2
14		54.4	33.2	281.5	227.2
15		54.4	33.2	281.5	227.2
16		54.4	33.2	281.5	227.2
17		54.4	33.2	281.5	227.2
18		54.4	33.2	281.5	227.2
19		54.4	33.2	281.5	227.2
20		54.4	33.2	281.5	227.2
21		54.4	33.2	281.5	227.2
22		54.4	33.2	281.5	227.2
23		54.4	33.2	281.5	227.2
24		54.4	33.2	281.5	227.2
25		54.4	33.2	281.5	227.2
26		54.4	33.2		-54.4
27		54.4	33.2	281.5	227.2
28		54.4	33.2	281.5	227.2
29		54.4	33.2	281.5	227.2
30		54.4	33.2	281.5	227.2
31		54.4	33.2	281.5	227.2
32		54.4	33.2	281.5	227.2
33		54.4	33.2	281.5	227.2
34		54.4	33.2	281.5	227.2
35		54.4	33.2	281.5	227.2
36		54.4	33.2	281.5	227.2
37		54.4	33.2	281.5	227.2
38		54.4	33.2	281.5	227.2
39		54.4	33.2	281.5	227.2
40		54.4	33.2	281.5	227.2
41		54.4	33.2	281.5	227.2
42		54.4	33.2	281.5	227.2
43		54.4	33.2	281.5	227.2
44		54.4	33.2	281.5	227.2
45		54.4	33.2	281.5	227.2
46		54.4	33.2	281.5	227.2
47		54.4	33.2	281.5	227.2
48		54.4	33.2	281.5	227.2
49		54.4	33.2	281.5	227.2
50		54.4	33.2	281.5	227.2

(4) Cash Flow for 50 years safety level

The cash flow of the Master Plan for 50 years safety level is as follow;

Table 2.3.4 Cash flow (50 years safety level Plan)

Unit (R$ million)

Year	Cost	Maintenance Cost	Emergencies Expense	Benefit	Balance
1	411.6				-411.6
2	411.6				-411.6
3	411.6				-411.6
4	411.6	30.2	36.4	206.3	-235.4
5	411.6	54.4	33.2	281.5	-184.4
6		102.9	23.3	378.1	275.2
7		102.9	23.3	378.1	275.2
8		102.9	23.3	378.1	275.2
9		102.9	23.3	378.1	275.2
10		102.9	23.3	378.1	275.2
11		102.9	23.3	378.1	275.2
12		102.9	23.3	378.1	275.2
13		102.9	23.3	378.1	275.2
14		102.9	23.3	378.1	275.2
15		102.9	23.3	378.1	275.2
16		102.9	23.3	378.1	275.2
17		102.9	23.3	378.1	275.2
18		102.9	23.3	378.1	275.2
19		102.9	23.3	378.1	275.2
20		102.9	23.3	378.1	275.2
21		102.9	23.3	378.1	275.2
22		102.9	23.3	378.1	275.2
23		102.9	23.3	378.1	275.2
24		102.9	23.3	378.1	275.2
25		102.9	23.3	378.1	275.2
26		102.9	23.3	378.1	275.2
27		102.9	23.3	378.1	275.2
28		102.9	23.3	378.1	275.2
29		102.9	23.3	378.1	275.2
30		102.9	23.3	378.1	275.2
31		102.9	23.3	378.1	275.2
32		102.9	23.3	378.1	275.2
33		102.9	23.3	378.1	275.2
34		102.9	23.3	378.1	275.2
35		102.9	23.3	378.1	275.2
36		102.9	23.3	378.1	275.2
37		102.9	23.3	378.1	275.2
38		102.9	23.3	378.1	275.2
39		102.9	23.3	378.1	275.2
40		102.9	23.3	378.1	275.2
41		102.9	23.3	378.1	275.2
42		102.9	23.3	378.1	275.2
43		102.9	23.3	378.1	275.2
44		102.9	23.3	378.1	275.2
45		102.9	23.3	378.1	275.2
46		102.9	23.3	378.1	275.2
47		102.9	23.3	378.1	275.2
48		102.9	23.3	378.1	275.2
49		102.9	23.3	378.1	275.2
50		102.9	23.3	378.1	275.2

(5) Results of financial evaluation

The results of the financial evaluations are the following ones:

Table 2.3.5 Results of Financial Evaluation

Evaluation Index		**5 years**	**10 years**	**25 years**	**50 years**
	FIRR	20.1%	22.2%	18.1%	12.4%
Discount Rate 10%	B/C	1.43	1.43	1.35	1.08
	FNPV(^106)	282.4	465.7	570.6	218.4
Discount Rate 23%	B/C	0.91	0.82	0.72	0.55
	FNPV(^106)	-31.2	-125.4	-291.7	-780.9
Discount Rate 12%	B/C	1.33	1.29	1.20	0.95
	FNPV(^106)	187.0	286.5	302.7	-112.8

Source: JICA Study Team

The result of the evaluation for the indicator FIRR (Financial Internal Rate of Return), is indicated 20.1% in the intervention in Return period 10 years, and 12.4% in the intervention of Return period 50 years.

In the cost-benefit (B/C) ratio with the discount rate of 10%/year, the indicator shows positive results. But, with the discount rate of 23%/year, the indicator shows low profitability. However, the discount rate of 23%/year is considered very high in a current economical scenery of Brazil.

In the relationship of Net Present Value (NPV), with the discount rate of 23%/year the result is shown negative. However, if taking in consideration the last tendencies of CDI, having varied among 10%/year to 12%/year, the possibility of the high rate to return is low. Considering these circumstances, it is considered viable the implementation of the interventions presented in this report with the Return period 50 years. Besides, to be considered the valorizations of the lands with less disaster risk, the economical viability would be getting better abruptly.

2.3.2 Economic Evaluation

(1) Cash Flow for 5 years safety level

The cash flow of the Master Plan for 5 years safety level is as follow;

Table 2.3.6 Cash flow at economic price (5 years safety level Plan)

Unit (R$ million)

Year	Cost	Maintenance Cost	Emergencies Expense	Benefit	Balance
1	30.3				-30.3
2	30.3				-30.3
3	30.3				-30.3
4		4.6	18.8	71.9	48.5
5		4.6	18.8	71.9	48.5
6		4.6	18.8		-23.4
7		4.6	18.8	71.9	48.5
8		4.6	18.8	71.9	48.5
9		4.6	18.8	71.9	48.5
10		4.6	18.8	71.9	48.5
11		4.6	18.8		-23.4
12		4.6	18.8	71.9	48.5
13		4.6	18.8	71.9	48.5
14		4.6	18.8	71.9	48.5
15		4.6	18.8	71.9	48.5
16		4.6	18.8		-23.4
17		4.6	18.8	71.9	48.5
18		4.6	18.8	71.9	48.5
19		4.6	18.8	71.9	48.5
20		4.6	18.8	71.9	48.5
21		4.6	18.8		-23.4
22		4.6	18.8	71.9	48.5
23		4.6	18.8	71.9	48.5
24		4.6	18.8	71.9	48.5
25		4.6	18.8	71.9	48.5
26		4.6	18.8		-23.4
27		4.6	18.8	71.9	48.5
28		4.6	18.8	71.9	48.5
29		4.6	18.8	71.9	48.5
30		4.6	18.8	71.9	48.5
31		4.6	18.8		-23.4
32		4.6	18.8	71.9	48.5
33		4.6	18.8	71.9	48.5
34		4.6	18.8	71.9	48.5
35		4.6	18.8	71.9	48.5
36		4.6	18.8		-23.4
37		4.6	18.8	71.9	48.5
38		4.6	18.8	71.9	48.5
39		4.6	18.8	71.9	48.5
40		4.6	18.8	71.9	48.5
41		4.6	18.8		-23.4
42		4.6	18.8	71.9	48.5
43		4.6	18.8	71.9	48.5
44		4.6	18.8	71.9	48.5
45		4.6	18.8	71.9	48.5
46		4.6	18.8		-23.4
47		4.6	18.8	71.9	48.5
48		4.6	18.8	71.9	48.5
49		4.6	18.8	71.9	48.5
50		4.6	18.8	71.9	48.5

(2) Cash Flow for 10 years safety level

The cash flow of the Master Plan for 10 years safety level is as follow;

Table 2.3.7 Cash flow at economic price (10 years safety level Plan)

Unit (R$ million)

Year	Cost	Maintenance Cost	Emergencies Expense	Benefit	Balance
1	47.0				-47.0
2	47.0				-47.0
3	47.0				-47.0
4		7.1	18.2	103.6	78.3
5		7.1	18.2	103.6	78.3
6		7.1	18.2	103.6	78.3
7		7.1	18.2	103.6	78.3
8		7.1	18.2	103.6	78.3
9		7.1	18.2	103.6	78.3
10		7.1	18.2	103.6	78.3
11		7.1	18.2		-25.2
12		7.1	18.2	103.6	78.3
13		7.1	18.2	103.6	78.3
14		7.1	18.2	103.6	78.3
15		7.1	18.2	103.6	78.3
16		7.1	18.2	103.6	78.3
17		7.1	18.2	103.6	78.3
18		7.1	18.2	103.6	78.3
19		7.1	18.2	103.6	78.3
20		7.1	18.2	103.6	78.3
21		7.1	18.2		-25.2
22		7.1	18.2	103.6	78.3
23		7.1	18.2	103.6	78.3
24		7.1	18.2	103.6	78.3
25		7.1	18.2	103.6	78.3
26		7.1	18.2	103.6	78.3
27		7.1	18.2	103.6	78.3
28		7.1	18.2	103.6	78.3
29		7.1	18.2	103.6	78.3
30		7.1	18.2	103.6	78.3
31		7.1	18.2		-25.2
32		7.1	18.2	103.6	78.3
33		7.1	18.2	103.6	78.3
34		7.1	18.2	103.6	78.3
35		7.1	18.2	103.6	78.3
36		7.1	18.2	103.6	78.3
37		7.1	18.2	103.6	78.3
38		7.1	18.2	103.6	78.3
39		7.1	18.2	103.6	78.3
40		7.1	18.2	103.6	78.3
41		7.1	18.2		-25.2
42		7.1	18.2	103.6	78.3
43		7.1	18.2	103.6	78.3
44		7.1	18.2	103.6	78.3
45		7.1	18.2	103.6	78.3
46		7.1	18.2	103.6	78.3
47		7.1	18.2	103.6	78.3
48		7.1	18.2	103.6	78.3
49		7.1	18.2	103.6	78.3
50		7.1	18.2	103.6	78.3

(3) Cash Flow for 25 years safety level

The cash flow of the Master Plan for 25 years safety level is as follow;

Table 2.3.8 Cash flow at economic price (25 years safety level Plan)

Unit (R$ million)

Year	Cost	Maintenance Cost	Emergencies Expense	Benefit	Balance
1	75.8				-75.8
2	75.8				-75.8
3	75.8				-75.8
4	75.8	7.1	18.2	103.6	2.6
5		15.2	16.6	141.3	109.5
6		15.2	16.6	141.3	109.5
7		15.2	16.6	141.3	109.5
8		15.2	16.6	141.3	109.5
9		15.2	16.6	141.3	109.5
10		15.2	16.6	141.3	109.5
11		15.2	16.6	141.3	109.5
12		15.2	16.6	141.3	109.5
13		15.2	16.6	141.3	109.5
14		15.2	16.6	141.3	109.5
15		15.2	16.6	141.3	109.5
16		15.2	16.6	141.3	109.5
17		15.2	16.6	141.3	109.5
18		15.2	16.6	141.3	109.5
19		15.2	16.6	141.3	109.5
20		15.2	16.6	141.3	109.5
21		15.2	16.6	141.3	109.5
22		15.2	16.6	141.3	109.5
23		15.2	16.6	141.3	109.5
24		15.2	16.6	141.3	109.5
25		15.2	16.6	141.3	109.5
26		15.2	16.6		-31.8
27		15.2	16.6	141.3	109.5
28		15.2	16.6	141.3	109.5
29		15.2	16.6	141.3	109.5
30		15.2	16.6	141.3	109.5
31		15.2	16.6	141.3	109.5
32		15.2	16.6	141.3	109.5
33		15.2	16.6	141.3	109.5
34		15.2	16.6	141.3	109.5
35		15.2	16.6	141.3	109.5
36		15.2	16.6	141.3	109.5
37		15.2	16.6	141.3	109.5
38		15.2	16.6	141.3	109.5
39		15.2	16.6	141.3	109.5
40		15.2	16.6	141.3	109.5
41		15.2	16.6	141.3	109.5
42		15.2	16.6	141.3	109.5
43		15.2	16.6	141.3	109.5
44		15.2	16.6	141.3	109.5
45		15.2	16.6	141.3	109.5
46		15.2	16.6	141.3	109.5
47		15.2	16.6	141.3	109.5
48		15.2	16.6	141.3	109.5
49		15.2	16.6	141.3	109.5
50		15.2	16.6	141.3	109.5

(4) Cash Flow for 50 years safety level

The cash flow of the Master Plan for 50 years safety level is as follow;

Table 2.3.9 Cash flow at economic price (50 years safety level Plan)

Unit (R$ million)

Year	Cost	Maintenance Cost	Emergencies Expense	Benefit	Balance
1	118.8				-118.8
2	118.8				-118.8
3	118.8				-118.8
4	118.8	7.1	18.2	103.6	-40.5
5	118.8	15.2	16.6	141.3	-9.3
6		29.7	11.6	189.7	148.3
7		29.7	11.6	189.7	148.3
8		29.7	11.6	189.7	148.3
9		29.7	11.6	189.7	148.3
10		29.7	11.6	189.7	148.3
11		29.7	11.6	189.7	148.3
12		29.7	11.6	189.7	148.3
13		29.7	11.6	189.7	148.3
14		29.7	11.6	189.7	148.3
15		29.7	11.6	189.7	148.3
16		29.7	11.6	189.7	148.3
17		29.7	11.6	189.7	148.3
18		29.7	11.6	189.7	148.3
19		29.7	11.6	189.7	148.3
20		29.7	11.6	189.7	148.3
21		29.7	11.6	189.7	148.3
22		29.7	11.6	189.7	148.3
23		29.7	11.6	189.7	148.3
24		29.7	11.6	189.7	148.3
25		29.7	11.6	189.7	148.3
26		29.7	11.6	189.7	148.3
27		29.7	11.6	189.7	148.3
28		29.7	11.6	189.7	148.3
29		29.7	11.6	189.7	148.3
30		29.7	11.6	189.7	148.3
31		29.7	11.6	189.7	148.3
32		29.7	11.6	189.7	148.3
33		29.7	11.6	189.7	148.3
34		29.7	11.6	189.7	148.3
35		29.7	11.6	189.7	148.3
36		29.7	11.6	189.7	148.3
37		29.7	11.6	189.7	148.3
38		29.7	11.6	189.7	148.3
39		29.7	11.6	189.7	148.3
40		29.7	11.6	189.7	148.3
41		29.7	11.6	189.7	148.3
42		29.7	11.6	189.7	148.3
43		29.7	11.6	189.7	148.3
44		29.7	11.6	189.7	148.3
45		29.7	11.6	189.7	148.3
46		29.7	11.6	189.7	148.3
47		29.7	11.6	189.7	148.3
48		29.7	11.6	189.7	148.3
49		29.7	11.6	189.7	148.3
50		29.7	11.6	189.7	148.3

The Economical Evaluation takes place converting to the economical price that discounts the taxes. The results of the economical evaluations are the following ones:

Table 2.3.10 Results of the Economic Evaluation

Evaluation Index		**5 years**	**10 years**	**25 years**	**50 years**
Economic IRR		29.2%	37.5%	28.7%	21.2%
Discount Rate 6%	B/C	1.95	2.73	2.61	2.24
	ENPV(^106)	390.4	1,087.9	1,332.3	1,427.9
Discount Rate 10%	B/C	1.72	2.34	2.07	1.65
	ENPV(^106)	197.5	596.6	658.3	582.2
Discount Rate 12%	B/C	1.62	2.17	1.85	1.43
	ENPV(^106)	145.6	463.1	477.8	362.4

Source: JICA Study Team

The results of the evaluation without tax and of compensation show the positive indicators in all of the aspects. These results indicate high economical viability of the implementations of the interventions presented in this report.

2.3.3 Total evaluation

The Itajaí basin shows a positive tendency of development, especially in the areas of mouth of the river Itajaí, with great attractiveness to new investments. Every year, the need to structure this area of strategic importance for the State is big, mainly in what refers to the prevention of disasters.

In the results of the evaluations high economical viability is shown, even with the implementations aiming at the Return period 50 years.

CHAPTER 3 FEASIBILITY STUDY PROJECT EVALUATION

3.1 Methodology of Economic Evaluation

The economical evaluation in this Feasibility Study was carried out for the following projects;

Table-3.1.1 Evaluated Project

Project	Outlook of Project
Water storage in paddy fields	Paddy fields ridge heightening (5,000ha)
Change of current dam operation method and heightening of the dam（Oeste）	Heightening of dam (2 m)
Change of current dam operation method and heightening of the dam（Sul）	2 m de Heightening of dam
Utilization of the existing hydropower generation dam for flood control	2 Dam
Installation of floodgate and improving Itajai Mirim River in Itajai City	2 nos、0.95km
Strengthening the existing flood forecasting and warning system	1 Unit
Installation of early warning system for land slide and flush flood	1Unit

Source; JICA survey team

The evaluation period is of 50 years. The benefits are considered that the differences between the potential value of disasters that can be caused by the existent infrastructures and the potential value to be mitigated with the implantation of the project proposed as a mitigation measure. The reaches of disasters were estimated through hydrological simulation of each flood in safety level and it was transformed to values. The benefit is accounted with base in the damages record caused by flood damages history. The accountancies of the damages for each "flood safety level" is considered through the registered data and statistical data published in the State. The annual medium benefit is considered multiplying the probabilities of each flood and the damages caused by each safety level. Besides this, there is benefit of valorizations of the lands through improvement of safety. However, this benefit, in this evaluation, was not considered.

3.2 Cost and Benefit

3.2.1 Cost

The Cost proposed by the in this FS Study are the following ones; The details of project costs are indicated in Chapter 10.

Table3.2.1 Proposed Project Cost

Unit；R$ 1,000

Item		Direct Cost（Loan）	Administration Expenses	Expropriation	Subtotal
I. Direct Cost of Measure					
(1) Basin Storage Measures	Water storage in paddy fields	18,000	3,600		21,600
	Heightening of dams（Oeste）	27,200	800	1,110	29,110
	Heightening of dams（Sul）	22,500	700		23,200
(2) River Improvement Measures	Floodgates in Itajaí Mirim River (Upper stream)	17,800	500	10	18,310
	Floodgates in Itajaí Mirim River (Lower stream)	14,000	400		14,400
(3) Structural Measures for Sediment Disaster Prevention		25,800	800	50	26,650

(4) Strengthening of the Existing Flood Forecasting and Warning System (FFWS)	4,000	120		4,120
(5) Formation of Early Warning System for Sediment Disaster and Flash Flood	4,000	120		4,120
II. Subtotal	133,300	7,040	1,170	141,510
III. Engineering Services	25,100	750		25,850
IV. II+III	158,400	7,790	1,170	167,360
V. Physical Contingency (10％ of IV)	15,800			15,800
VI. Price Escalation	19,700		70	19,770
VII. Project Cost	**193,900**	**7,790**	**1,240**	**202,930**

Source; JICA survey team

3.2.2 Benefit

As the result of the implementations of the measure proposed in this FS Study, it is foreseen to obtain the following benefits;

Table 3.2.2 Expected Impact of the Project

Item	**Results of Measure**
Water storage in paddy fields	Increase of rice production (10%)
Heightening of the dam（Oeste） Heightening of the dam（Sul）	Flood disaster mitigation in Taio city (10 years safety level) Flood disaster mitigation in Rio do Sul (4 years safety level)
Utilization of the existing hydropower generation dam for flood control	Flood disaster mitigation in Timbó city (10 years safety level)
Installation of floodgate and improving Itajai Mirim River in Itajai City	Flood disaster mitigation in Itajaí City (25 years safety level) Mitigation of Economic loss in Itajaí city
Strengthening the existing flood forecasting and warning system & Installation of Early Warning system for Landslide and Flush flood	Mitigation of scarified (Injured and death)

Source; JICA survey team

The benefits counted in the proposed project in this FS study were estimated in the following forms;

(1) Increase of rice production

The impact of the Project "Water storage in paddy fields" will be obtained in the increase of the productivities and of improvement of the quality of the products through the improvement of the paddy fields infrastructures. The expected value of the benefit were estimated the value of R$ 2,5000,000 / year.

(2) Benefit of the Project “Change of current dam operation method and heightening of the dam”

The impact of the disaster mitigations was estimated through the hydrological calculations for each beneficiary main city though the basin storage measure.

The present situation of flood damage for main beneficiary city are ahown in followings;

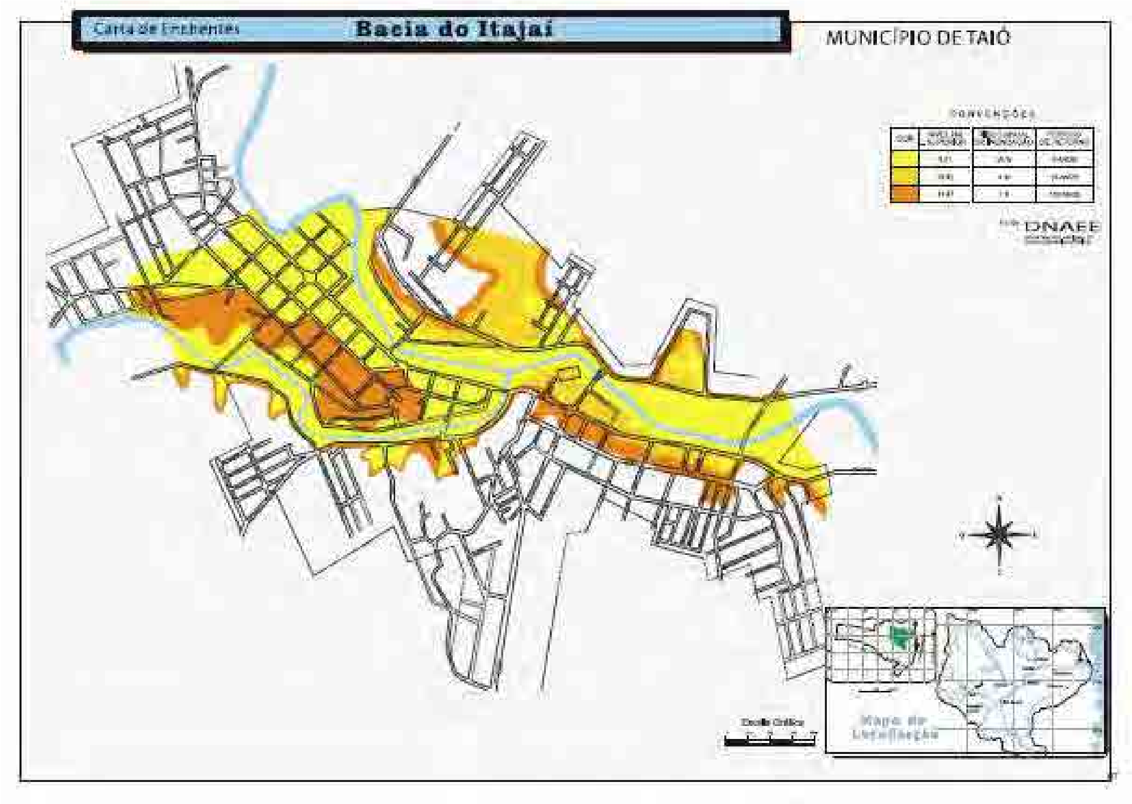


Fig 3.2.1 Present situation of flood damage of Taio city

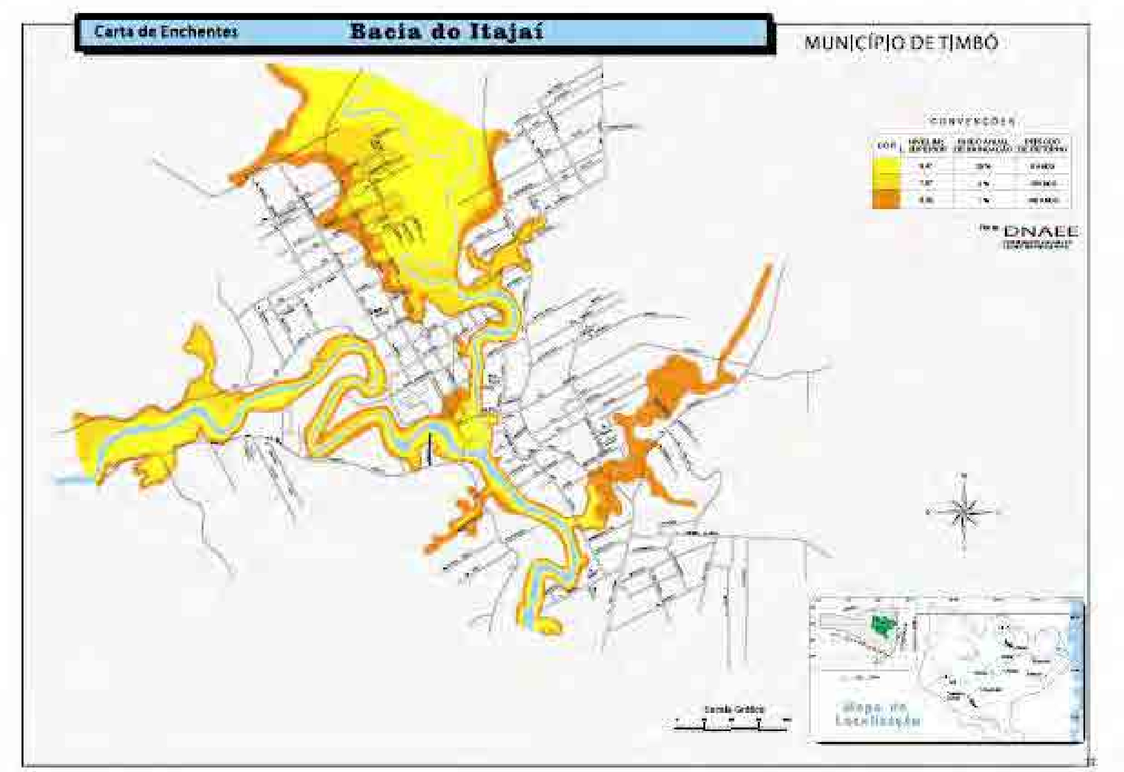


Figure 3.2.2 Present situation of Flood damage at Timbo City

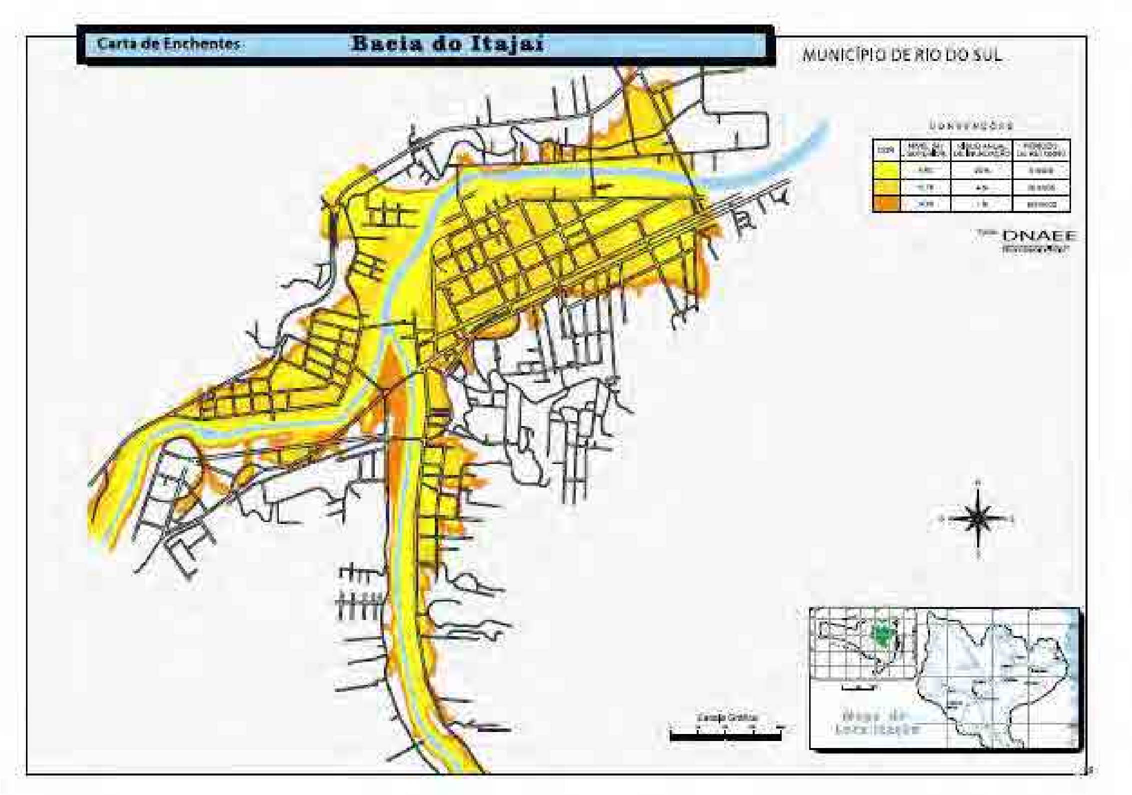


Figure 3.2.3 Present Situation of Flood Damage at Rio do Sul City

The results of the estimated impact of disaster mitigation were the following ones;

Table3.2.3 Benefit by flood mitigation measure

City	Number of housing	Number of affected housing（Estimate）			
		5year	10 year	25 year	50 year
Taio （present）	2,541	250	300	400	500
Taio （with project）		-	250	350	500
Timbo (present)	8,297	150	200	250	300
Timbo （with project）		-	-	200	300
Rio do Sul	15,504	100	500	1,000	1,500
Rio do Sul (with project)		50	480	1,000	1,500
Total		500	1,000	1,650	2,300
With project		50	730	1,550	2,300
Effect of project		450	270	100	0
Annual Benefit（R$1,000）		9,000	10,400	2,000	
Beneficio anual esperado（R$1,000）		1,800	970	248	20
Total de beneficio esperado（R$1,000）					3,038

Source; JICA survey team

The disaster value was estimated, presupposing of R$ 20.0000 value of disasters for each housing affected by flood disaster. The numbers of affected housing for the flood were calculated for each safety level, being used the existent reports in this theme.

(3) Benefit by disaster mitigation in the Itajaí City

In case of the Itajaí city, being used the detailed topographical maps, it was estimated the reaches of the flood for each safety level.

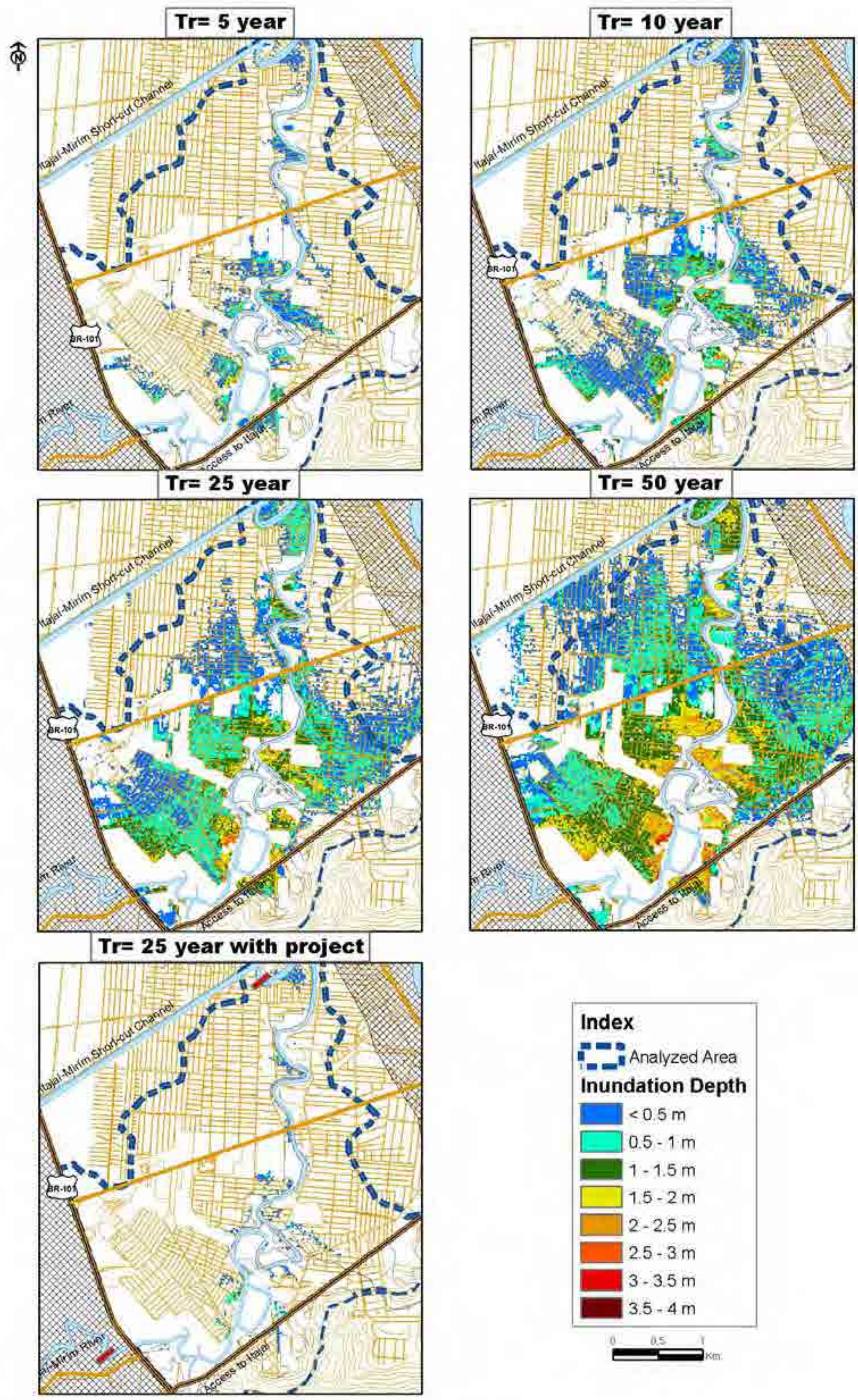


Figure 3.2.4 Present situation of Flood damage and impact of project at Itajai City

The results of the flood simulations for each safety level are;

Table 3.2.4 Benefit by Installation of Flood Gate at Itajaí City

		5 year	10 year	25 year	50 year
Number of affected housing	< 0.5m	512	1,552	1,632	1,596
	>0.5	232	940	2,637	3,911
	Subtotal	744	2,492	4,269	5,506
Economic gain (R$ 1,000)	< 0.5m	2,562	7,759	8,161	7,978
	>0.5	4,633	18,795	52,732	78,214
	Subtotal	7,196	26,555	60,894	86,193
Annual expected gain(R$ 1000)		1,439	968	687	253
Total benefit (R$ 1000)					3,347

Source; JICA survey team

2) Benefit by mitigation of economic loss by flood

The economical flood damages by this project was estimated through the existent companies number (% of itajai City) in a beneficiary area protected by floodgate installation, in the preposition that this portion of companies contribute the economy in a same percentage. The economical amount was estimated from the sequential data of ICMS of Itajai City. The results of the estimation are as follows;

Table 3.2.5 Benefit by Economic Loss of Itajaí City

		5 year	10 year	25 year	50 year
ICMS (R$ 1,000,000)	Decrease of ICMS	11.8	19.3	36.8	59.9
	Economic Decrease	118.0	193.0	368.0	599.0
Benefit Annual		23.6	3.75	3.5	2.31
	Annual Expected Benefit				33.16

Source; JICA survey team

(4) Benefit by structure measure of landslide

The benefit originated by structure measure of landslide was estimated as follows;

Table3.2.6 Benefit of the Structure measure of landslide

No. of priority order	Site	Potential annual loss (R$ x 103/year)	Total cost (direct and indirect) (R$ x 103)	Benefit: decrease in potential annual loss (R$ x 103/year)
1	Road SC 302 Taio-Passo Manso-5	1,255	551	1,062
2	Road SC470 Gaspar River Bank	1,095	2,810	581
3	Blumenau -Av Pres Castelo Branco	1,021	3,883	654
4	Road SC418 Blumenau - Pomerode	989	2,522	841
5	Road SC474 Blumenau-Massaranduba 2	907	5,077	641
6	Road Gaspar - Luiz Alves, Gaspar 9	774	4,664	653
7	Road Gaspar - Luiz Alves, Luiz Alves 6	700	1,974	591
8	Road SC470 Gaspar Bypass	689	3,772	402
9	Road SC477 Benedito Novo - Doutor Pedrinho 1	680	1,399	575
10	Road SC418 Pomerode- Jaragua do Sul 1	651	1,187	553
11	Road Gaspar - Luiz Alves, Luiz Alves 4	629	5,078	532
12	Road SC474 Blumenau - Massaranduba 1	601	702	425
13	Road SC 302 Taio - Passo Manso 4	526	1,599	446
Total of the 13 risk sites		10,516	35,219	7,956

Source: JICA Survey Team

(5) Benefit of Alarm/alert system

The benefit of the installation of the alarm/alert system for flood and early warning system of landslide and flashflood can be estimated as follows, in accordance with the disaster happened November of 2008:

Table 3.2.7 Disaster in Human resources by the Disaster November 2008

	Injured	Death
2008/11 Flood	4,637	89
With project	-	-

Source：AVADAMs enviados pelos munincipios á Defesa Civil de Santa Catarina, nos dias 24 e 25 de novembro de 2008.

But, in this study, the values were not counted by the difficulties.

(6) Expected Annual Benefit of the Project

The annual expected benefit of the project was estimated as follows;

Table 3.2.8 Project Benefit

	Annual Benefit(R$ 1,000,000)				
Project Impact	**After Project**	**1st year**	**2do year**	**3do year**	**4th year**
Increase of rice production (10%)	2.5			0.83	1.67
Flood Disaster mitigation in the Taio, Timbó e Rio do Sul	3.0			1.01	2.03
Flood disaster mitigation in the Itajaí City	3.4				1.67
Flood disaster mitigation in economic loss in the Itajaí City	33.2				16.58
Structure measure for landslide	8.0			2.65	5.30
Annual Benefit	58.6	0.00	0.00	7.33	32.92

Source; JICA survey team

3.3 Project Evaluation

3.3.1 Cash Flow

The cash flow of the Project is as follow;

Table 3.3.1 Cash flow of FS Project

Unit (R$ million)

Year	Cost	Maintenance Cost	Emergencies Expense	Benefit	Balance
1	26.5				-26.5
2	57.5				-57.5
3	65.1			4.4	-60.7
4	18.3	8.4	1.6	27.0	-1.2
5		8.4	1.6	49.7	39.7
6		8.4	1.6	49.7	39.7
7		8.4	1.6	49.7	39.7
8		8.4	1.6	49.7	39.7
9		8.4	1.6	49.7	39.7
10		8.4	1.6	49.7	39.7
11		8.4	1.6		-10.0
12		8.4	1.6	49.7	39.7
13		8.4	1.6	49.7	39.7
14		8.4	1.6	49.7	39.7
15		8.4	1.6	49.7	39.7
16		8.4	1.6	49.7	39.7
17		8.4	1.6	49.7	39.7
18		8.4	1.6	49.7	39.7
19		8.4	1.6	49.7	39.7
20		8.4	1.6	49.7	39.7
21		8.4	1.6		-10.0
22		8.4	1.6	49.7	39.7
23		8.4	1.6	49.7	39.7
24		8.4	1.6	49.7	39.7
25		8.4	1.6	49.7	39.7
26		8.4	1.6	49.7	39.7
27		8.4	1.6	49.7	39.7
28		8.4	1.6	49.7	39.7
29		8.4	1.6	49.7	39.7
30		8.4	1.6	49.7	39.7
31		8.4	1.6		-10.0
32		8.4	1.6	49.7	39.7
33		8.4	1.6	49.7	39.7
34		8.4	1.6	49.7	39.7
35		8.4	1.6	49.7	39.7
36		8.4	1.6	49.7	39.7
37		8.4	1.6	49.7	39.7
38		8.4	1.6	49.7	39.7
39		8.4	1.6	49.7	39.7
40		8.4	1.6	49.7	39.7
41		8.4	1.6		-10.0
42		8.4	1.6	49.7	39.7
43		8.4	1.6	49.7	39.7
44		8.4	1.6	49.7	39.7
45		8.4	1.6	49.7	39.7
46		8.4	1.6	49.7	39.7
47		8.4	1.6	49.7	39.7
48		8.4	1.6	49.7	39.7
49		8.4	1.6	49.7	39.7
50		8.4	1.6	49.7	39.7

3.3.2 Results of evaluation

The results of the economic evaluation are as follows;

Table 3.3.2 Results of Evaluation

Evaluation Index		Indicator
IRR		18.3%
Discount rate（10%）	B/C	1.44
	NPV(^106)	94.5
Discount Rate（23%）	B/C	0.71
	NPV(^106)	- 41.7
Discount Rate（12%）	B/C	1.27
	NPV(^106)	51.8

Source; JICA survey team

The result of the evaluation by the indicator IRR (Internal Rate of Return), is indicated 18.3% in the measure. In the cost-benefit (B/C) relationship with the discount rate of 10%/year, the indicator shows positive results. But, with the discount rate of 23%/year, the indicator shows low profitability. However, the discount rate of 23%/year is considered very high in the current Brazilian economical scenery. In the relationship of the Net Present value (NPV), with the discount rate of 23%/year, the result is shown negative. However, if taking in consideration the last tendencies of CDI, having varied among 10%/year to 12%/year, the possibility of the high rate to return is low. Besides, to be considered the valorizations of the lands with less disaster risk, the economical feasibility would be getting better abruptly.

It is necessary to implement the proposed projects gradually in the Master plan, due to that this proposed projects form one part of the Master plan.

3.4 Total Evaluation

This Project, starting from the flood in the November of 2008, with the consensus of taking the preventive measures for the flood, were formulated the Master plan and were selected the priority projects for the FS Study.

The economical importance in the basin is being more and more significant inside of the economical scenery of the State, with the tendencies of new investments, especially in the Itajai Port area. As well as it exists big quantities of investments more and more inside of the basin, it needs to assure the protections of the installed goods, through the disasters mitigation measure. It is notable that the economical activity in the lower Itajaí basin had 5 times of economical growth in the 8 years of periods (from 1999 to 2008), being significant that the needs to protect the basin from disaster are more and more important.