CHAPTER 8 TEMPORARY COFFERDAM

8.1 Temporary Cofferdam

1 Design Condition

1.1 Surcharge Load

	Mark	Unit	Surcharge Load
Normal Case	wt	tf/m^2	1.00
Seismic Case	wt'	tf/m^2	0.50

1.2 Design Seismic Coefficient

Aerial coefficient Kh = 0.10

Underwater coefficient Khx = Kh × γ b / (γ b-1)

γ b : Wet unit weight (tf/m^3)

1.3 Safety Factor

		Normal case	Seismic case
Stability of dam body	Shear deformational failure	1.20	1.20
	Sliding	1.20	1.00
	Bearing capacity	1.20	1.00
Depth of embedment		1.50	1.20
Impermeable effectiveness		3.00	

1.4 Soil Condition

1) Soil Condition at River side

Soil	Depth		Layer width	Unit weight			Cohesion		Resistant angle
	Upper side	Bottom side		Wet	Submerged	Saturation	CO	KX	
	(m)	(m)	(m)	(tf/m^3)	(tf/m^3)	(tf/m^3)	(tf/m^3)		(°)
Sand	1.50	1.00	0.50	1.80	1.00	2.00	0.00	0.00	30.00
Sand	1.00	-1.50	2.50	1.80	1.00	2.00	0.00	0.00	30.00
Cray	-1.50	-10.50	9.00	1.80	0.80	1.80	10.00	0.00	0.00
Sand	-10.50	-20.50	10.00	1.80	1.00	2.00	0.00	0.00	40.00

2) Soil Condition at Land side

Soil	Depth		Layer width	Unit weight			Cohesion		Resistant angle
	Upper side	Bottom side		Wet	Submerged	Saturation	CO	KX	
	(m)	(m)	(m)	(tf/m^3)	(tf/m^3)	(tf/m^3)	(tf/m^3)		(°)
Sand	1.00	-1.50	2.50	1.80	1.00	2.00	0.00	0.00	30.00
Cray	-1.50	-10.50	9.00	1.80	0.80	1.80	10.00	0.00	0.00
Sand	-10.50	-20.50	10.00	1.80	1.00	2.00	0.00	0.00	4.00

3) Soil Condition at dam body

Soil	Depth		Layer width	Unit weight			Cohesion		Resistant angle
	Upper side	Bottom side		Wet	Submerged	Saturation	CO	KX	
	(m)	(m)	(m)	(tf/m³)	(tf/m³)	(tf/m³)	(tf/m³)		(°)
Sand	5.80	1.00	4.80	1.80	1.00	2.00	0.00	0.00	30.00
Sand	1.00	-1.50	2.50	1.80	1.00	2.00	0.00	0.00	30.00
Cray	-1.50	-10.50	9.00	1.80	0.80	1.80	10.00	0.00	0.00
Sand	-10.50	-20.50	10.00	1.80	1.00	2.00	0.00	0.00	40.00

4) Soil filling condition

Item		Mark	Unit	Value
Unit weight	Wet	γ	tf/m³	1.80
	Submerged	γ '	tf/m³	1.00
	Saturation	γ st	tf/m³	2.00
Resistant angle		ϕ	Angle (°)	30.00

1.5 Structural condition

(1).	Dike crown elevation	5.800	(m)
(2).	Design ground elevation	-10.500	(m)
(3).	Wall height at river side	4.300	(m)
(4).	Wall height at land side	4.800	(m)
(5).	Elevation of jointing tie rod	5.500	(m)
(6).	Elevation of excavated surface at land side	0.000	(m)
(7).	Flood plain width at land side	2.000	(m)
(8).	Slope grade at land side	1:2.0	

1.6 Condition of water surface

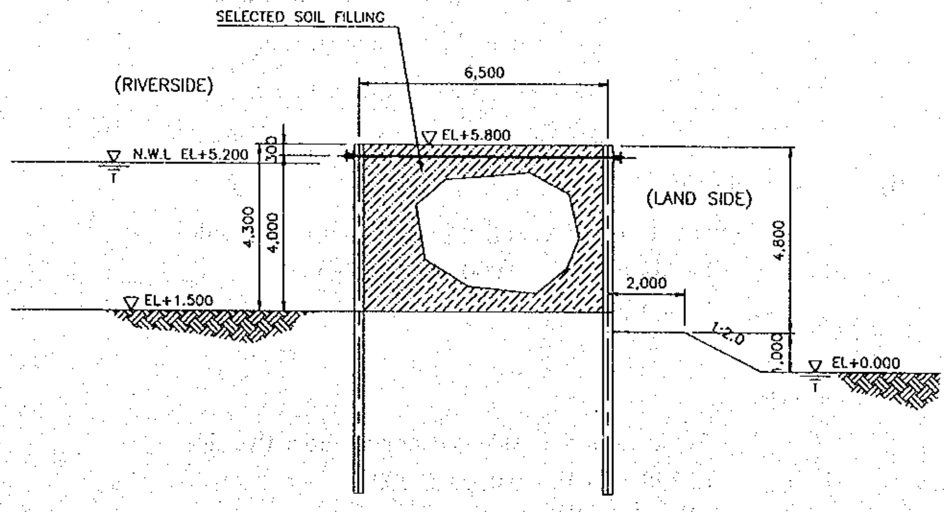
(1).	High water level (HWL)	5.200	(m)
(2).	Mean water level (MWL)	5.200	(m)
(3).	Low water level (LWL) at river side	5.200	(m)
(4).	Low water level (LWL) at land side	0.000	(m)

1.7 Allowable capacity

Allowable capacity of each member is shown as follows.

Member	Mark	Unit	Normal case	Seismic case	Material
Steel sheet pile	σ sa	kgf/cm²	1800.0	2700.0	SY295
Tie rod	σ sa	kgf/cm²	880.0	1320.0	SS400(>40mm)
Waling	σ sa	kgf/cm²	1400.0	2100.0	SS400

1.2 Figure of considering section



2 Consideration of dam body stability

2.1 Consideration of shear deformational failure for sand filling

1) Calculation of dam body width

Dam body width is calculated with following form and it is adopted that dam body width compare normal case and seismic case.

$$F \cdot Md \leqq Mr$$

Where:

F: Safety factor

Md: Deforming moment at design ground (tf-m)

Mr: Resistant moment at design ground (tf-m)

2) Calculation of deforming moment (Md)

$$Md = \begin{array}{l} \frac{1}{6}\times(Pw1\times Hw1^2)+\frac{1}{6}\times(Pa\times La^2)-\frac{1}{6}\times(Pw2\times Hw2^2) \\ -\frac{1}{6}\times(P0\times L0^2)+kh\times B\times\gamma\times h1\times(h1/2+h2) \\ +kh\times B\times\gamma b\times(h2^2/2) \end{array}$$

Where;

$Pw1\times Hw1^2$: Water pressure moment at active side

$Pw2\times Hw2^2$: Water pressure moment passive side

$Pa\times La^2$: Earth pressure moment at active side

Kh:	Aerial seismic coefficient	0.10
γ:	Wet unit weight of sand filling	1.80 tf/m^3
γ b:	Saturation unit weight of sand filling	2.00 tf/m^3
h1:	Wall height above water surface	
h2:	Wall height below water surface	

(i) Normal case

In normal case, river side is changed into active side.

Md = 12.348 + 0.007 – 0.000 – 0.000 + 0.000

= 12.355 (tf·m)

(ii) Seismic case

In seismic case, river side is changed into active side.

Md = 12.348 + 0.010 – 0.000 – 0.000

+ 9.914 + 3.960

= 26.232 (tf·m)

Inertia force

$kh \cdot B \cdot \gamma \cdot h1 \cdot (h2+0.5 \times h1) = 0.10 \times 6.50 \times 1.80 \times 2.332 \times (2.468+0.5 \times 2.332)$

$= 9.914 (tf \cdot m)$

$kh \cdot B \cdot \gamma b \cdot (0.5 \times h2^2) = 0.10 \times 6.50 \times 2.00 \times (0.5 \times 6.093)$

$= 3.960 (tf \cdot m)$

3) Calculation of resistant moment (Mr)

$Mr = 1/6 \cdot \gamma m \cdot (RH^3)$

Normal case $R = 2/3 \cdot V^2 \cdot (3-V \cdot \cos\phi) \cdot \tan\phi \cdot \sin\phi$

Seismic case $R = V^2 \cdot (3-V \cdot \cos\phi) \cdot \sin\phi$

Where;

γ m:	Mean consistency of sand filling (tf/m3)	
	$(\gamma \times h1 + \gamma 1 \times h2) / H$	
B:	Dam body width	6.50 m
H:	Dam body height	4.80 m
V:	B / H	
ϕ:	Resistant angle of sand filling (°)	

(i) Normal case

$Mr = 1/6 \times 1.39 \times 0.645 \times 4.800^3$

$= 16.505 (tf \cdot m)$

$\gamma m = (1.80 \times 2.332 + 1.00 \times 2.468) / 4.80 = 1.39 (tf/m^3)$

$V = 6.50 / 4.800 = 1.35$

$R = 2/3 \times 1.35^2 \times (3-1.35 \times \cos 30.00) \times \tan 30.00 \times \sin 30.00$

$= 0.645$

(ii) Seismic case

Mr = $1/6 \times 1.39 \times 1.675 \times 4.800^3$
= 42.881(tf·m)
γ m = $(1.80 \times 2.332 + 1.00 \times 2.468) / 4.80 = 1.39$ (tf/m³)
V = 6.50 / 4.800 = 1.35
R = $1.35^2 \times (3 - 1.35 \times \cos 30.00) \times \sin 30.00$
= 1.675

4) Summary of calculation results

Item	Normal case	Seismic case
Active water pressure ($1/6 \cdot Pw1 \cdot Hw1^2$)	12.348 (tf·m/m)	12.348 (tf·m/m)
Active earth pressure ($1/6 \cdot Pa \cdot La^2$)	0.007 (tf·m/m)	0.010 (tf·m/m)
Passive water pressure ($1/6 \cdot Pw2 \cdot Hw2^2$)	0.000 (tf·m/m)	0.000 (tf·m/m)
Passive earth pressure ($1/6 \cdot Po \cdot Lo^2$)	0.000 (tf·m/m)	0.000 (tf·m/m)
Other moment	0.000 (tf·m/m)	-
Moment of seismic force	-	13.874 (tf·m/m)
Deforming moment (Total)	12.355 (tf·m/m)	26.232 (tf·m/m)
Resistant moment (Total)	16.505 (tf·m/m)	42.881 (tf·m/m)
Safety factor F = Mr / Md	1.336 ≧ 1.20	1.635 ≧ 1.20

2.2 Consideration of sliding

1) Sliding calculation

Sliding calculation is calculated with following form.

Fs = R/PH

Where;

R: Sliding resistant force $B \times \mu$ (tf/m)

μ: Resistant coefficient

PH: Horizontal force (tf/m)

2) Calculation of sliding resistant force

$\mu = C + (\gamma \cdot h1 + \gamma' \cdot h2) \cdot \tan\phi$

Where;

C: Cohesion 0.00 (tf/m2)

ϕ: Resistant angle 40.00 (°)

(i) Normal case

R = $6.50 \times \{0.00 + (1.80 \times 2.332 + 1.00 \times 13.968) \times \tan 40.00\}$
= 99.076(tf/m)

(ii) Seismic case

$$R = 6.50 \times \{0.00 + (1.80 \times 2.332 + 1.00 \times 13.968) \times \tan 40.00\}$$
$$= 99.076 (tf/m)$$

3) Calculation of seismic force

$$\text{Seismic force} = KH \cdot B \cdot (\gamma \cdot h1 + \gamma b \cdot h2)$$
$$= 0.10 \times 6.50 \times (1.80 \times 2.332 + 2.00 \times 13.968)$$
$$= 20.887 \text{ (tf/m)}$$

4) Summary of calculation results

Item	Normal case	Sesimic case
Active water pressure HPw1 (1/2·Pw1·Hw1)	123.245 (tf/m)	123.245 (tf/m)
Active earth pressure Hpa (1/2·Pa·La)	1.500 (tf/m)	2.130 (tf/m)
Passive water pressure HPw2 (1/2·Pw2·Hw2)	55.125 (tf/m)	55.125 (tf/m)
Passive earth pressure HPp (1/2·Po·Ho)	256.275 (tf/m)	254.696 (tf/m)
Other horizontal force	0.000 (tf/m)	-
Seismic force	-	20.887 (tf/m)
Horizontal force (PH)	0.000 (tf/m)	0.000 (tf/m)
Sliding resistant force (R)	99.076 (tf/m)	99.076 (tf/m)
Safety factor Fs = R / PH	999.99≧1.20	999.999≧1.00

2.3 Consideration of bearing capacity

1) Calculation of bearing capacity

Bearing capacity is calculated with following form.

$$F = Qu / W$$
$$Qu = A'(K \cdot C \cdot Nc + K \cdot r2 \cdot Df \cdot Nq + 0.5 \cdot r1 \cdot B' \cdot Nr)$$

Where;

F: Safety factor

Qu: Ultimate bearing capacity (tf/m)

W: Weight of sand filling (tf/m)

A': Effective surcharge area (m^2)

B': Effective surcharge area for eccentricity (m)

B: Dam body width (m)

e: Eccentric length of load (m) $e = Mb / W$

Mb: Moment having affecting length to ground (tf-m)

K: $K = 1.0$

C: Cohesion

Df: Depth of embedment from existing ground to consideration point (m)

$\gamma 1, \gamma 2$: Wet unit weight (tf/m^3)

Nc,Nq,Nr: Coefficient of bearing capacity

2) Moment (Mb)

Item	Normal case	Seismic case
Active water pressure MPw1(1/6·Pw1·Hw1)	644.982 (tf·m/m)	644.982 (tf·m/m)
Active earth pressure MPa(1/6·Pa·La^2)	15.000 (tf·m/m)	21.297 (tf·m/m)
Passive water pressure MPw2(1/6·Pw2·$Hw2^2$)	192.937 (tf·m/m)	192.937 (tf·m/m)
Passive earth pressure MPp(1/6·Po·Lo^2)	1181.140 (tf·m/m)	1165.670 (tf·m/m)
Other moment	0.000 (tf·m/m)	-
Moment of seismic force	-	168.111 (tf·m/m)
Deforming moment (Mb)	0.000 (tf·m/m)	168.111 (tf·m/m)

(i) Calculation of seismic force

kh·B·γ·h1·(h2+0.5×h1) = 0.10×6.50×1.80×2.332×(13.968+0.5×2.332)
= 41.286(tf·m)

kh·B·γb·(0.5×$h2^2$) = 0.10×6.50×2.00×(0.5×195.116)
= 126.826(tf·m)
= 41.286+126.826=168.111(tf·m)

3) Summary of calculation results

Item		Normal case	Seismic case
Surcharge load	W1	6.500 (tf/m)	3.250 (tf/m)
Weight of sand filling	W2	140.619 (tf/m)	140.619 (tf/m)
Moment	Mb	0.000(tf·m)	168.111(tf·m)
Horizontal force	PH	0.000 (tf/m)	0.000 (tf/m)
Eccentric length	E	0.000 (m)	1.169 (m)
Effective surcharge area	B'	6.500 (m)	4.163 (m)
Synthetic grade angle	tan α	0.000	0.000
Resistant angle	ϕ	40.000 (°)	40.000 (°)
Coefficient of bearing capacity	Nc	72.000	72.000
	Nq	68.000	68.000
	Nr	86.000	86.000
Ultimate bearing capacity	Qu	6899.750 (tf/m)	4000.670 (tf/m)
Safety factor	Fs	46.899≧1.20	27.808≧1.00

(i) Ultimate bearing capacity

Item	Normal case	Seismic case
A' (m^2)	6.500	4.163
C·Nc	0.000×72.000	0.000×72.000
	= 0.000	= 0.000
r2·Df·Nq	1.00×11.500×68.000	1.00×11.500×68.000
	= 782.000	= 782.000
r1·B'·Nr	1.00× 6.500×86.000	1.00× 6.500×86.000
0.5·r1·B·Nr	= 279.500	= 279.500
Qu (tf/m)	6899.750	4000.670

3 Consideration of depth of embedment for sheet pile

3.1 Calculation of depth of embedment for sheet pile

1) Consideration of sheet pile at land side (Normal case)

(i) Calculation of active earth pressure

No	Depth of layer		Layer width	Earth pressure			Affecting length	Moment
	Upper side	Bottom side		Upper side	Bottom side			
	(m)	(m)	(m)			(tf/m)	(m)	(tf·m/m)
1	5.800	5.500	0.300	0.333	0.513	0.127	-0.139	-0.018
2	5.500	3.468	2.032	0.513	1.732	2.282	1.200	2.720
3	3.468	1.500	1.968	1.732	2.388	4.055	3.068	15.161
4	1.500	1.000	0.500	2.388	2.555	1.236	4.253	20.417
5	1.000	0.000	1.000	2.555	2.888	2.722	5.010	34.053
6	0.000	-1.500	1.500	2.888	3.388	4.708	6.270	63.569
7	-1.500	-9.000	7.500	0.000	0.000	0.000	14.500	63.569
8	-9.000	-10.500	1.500	0.000	0.000	0.000	16.000	63.569
9	-10.500	-20.000	10.000	3.776	5.950	48.632	21.373	1102.96

(ii) Calculation of water pressure

No	Depth of layer		Layer width	Water pressure			Affecting length	Moment
	Upper side	Bottom side		Upper side	Bottom side			
	(m)	(m)	(m)			(tf/m)	(m)	(tf·m/m)
1	5.800	5.500	0.300					0.000
2	5.500	3.468	2.032					0.000
3	3.468	1.500	1.968					6.478
4	1.500	1.000	0.500					11.203
5	1.000	0.000	1.000					26.128
6	0.000	-1.500	1.500					41.736
7	-1.500	-9.000	7.500					158.794
8	-9.000	-10.500	1.500					190.010
9	-10.500	-20.500	10.000					464.592

(iii) Calculation of passive earth pressure

No	Depth of layer		Layer width	Earth pressure			Affecting length	Moment
	Upper side	Bottom side		Upper side	Bottom side			
	(m)	(m)	(m)			(tf/m)	(m)	(tf·m/m)
5	1.000	0.000	1.000	0.000	5.400	2.700	5.167	13.950
6	0.000	-1.500	1.500	5.400	9.900	11.475	6.324	86.513
7	-1.500	-9.000	7.500	23.300	29.300	197.250	10.893	2235.07
8	-9.000	-10.500	1.500	29.300	30.500	44.850	15.255	2919.26
9	-10.500	-20.500	10.000	48.289	94.278	712.830	21.538	18271.9

(iv) Moment and safety factor around jointing tie rod

No	Depth of layer		Moment of active earth pressure	Moment of active water pressure	Moment of passive earth pressure	Safety factor
	Upper side	Bottom side	Ma	Mw	Mp	F
	(m)	(m)	(tf·m/m)	(tf·m/m)	(tf·m/m)	Mp/(Ma+Mw)
1	5.800	5.500	-0.018	0.000	-	-
2	5.500	3.468	2.720	0.000	-	-
3	3.468	1.500	15.161	6.478	-	-
4	1.500	1.000	20.417	11.230	-	-
5	1.000	0.000	34.053	26.128	13.950	0.232
6	0.000	-1.500	63.569	41.736	86.513	0.822
7	-1.500	-9.000	63.569	158.794	2235.070	10.051
8	-9.000	-10.500	63.569	190.010	2919.260	11.512
9	-10.500	-20.500	1102.960	464.592	18271.900	11.656

(v) Balance equation at 7th layer

Item	$A \cdot Z^3$ +	$B \cdot Z^2$ +	$C \cdot Z$ +	D
	A	B	C	D
Moment of active earth pressure (Ma)	0.000	0.000	0.000	63.569
Moment of water pressure (Mw)	0.000	0.578	11.272	41.736
Moment of passive earth pressure (Mp)	0.267	14.450	163.100	86.513
Safety factor	1.50			
Fs×(Ma + Mw) – Mp	-0.267	-13.538	-146.192	71.445
Result of cubic equation	0.468			
Depth of embedment from ground	2.968 (m)			
Original length of sheet pile	7.768 (m)			
Adopted length of sheet pile	9.000 (m)			

3.2 Consideration of sheet pile at land side (Seismic case)

(i) Calculation of active earth pressure

No	Depth of layer		Layer width	Earth pressure			Affecting length	Moment
	Upper side	Bottom side		Upper side	Bottom side			
	(m)	(m)	(m)			(tf/m)	(m)	(tf·m/m)
1	5.800	5.500	0.300	0.198	0.412	0.092	-0.132	-0.012
2	5.500	3.468	2.032	0.412	1.863	2.311	1.232	2.835
3	3.468	1.500	1.968	2.223	3.154	5.291	3.073	19.094
4	1.500	1.000	0.500	3.154	3.391	1.636	4.253	26.054
5	1.000	0.000	1.000	3.391	3.864	3.628	5.011	44.232
6	0.000	-1.500	1.500	3.864	4.574	6.329	6.271	83.920
7	-1.500	-9.000	7.500	0.000	0.000	0.000	14.500	83.920
8	-9.000	-10.500	1.500	0.000	0.000	0.000	16.000	83.920
9	-10.500	-20.000	10.000	5.539	8.824	71.817	21.381	1619.44

(ii) Calculation of water pressure

No	Depth of layer		Layer width	Water pressure			Affecting length	Moment
	Upper side	Bottom side		Upper side	Bottom side			
	(m)	(m)	(m)			(tf/m)	(m)	(tf·m/m)
1	5.800	5.500	0.300					0.000
2	5.500	3.468	2.032					0.000
3	3.468	1.500	1.968					6.478
4	1.500	1.000	0.500					11.203
5	1.000	0.000	1.000					26.128
6	0.000	-1.500	1.500					41.736
7	-1.500	-9.000	7.500					158.794
8	-9.000	-10.500	1.500					190.010
9	-10.500	-20.500	10.000					464.592

(iii) Calculation of passive earth pressure

No	Depth of layer		Layer width	Earth pressure			Affecting length	Moment
	Upper side	Bottom side		Upper side	Bottom side			
	(m)	(m)	(m)			(tf/m)	(m)	(tf·m/m)
5	1.000	0.000	1.000	0.000	5.078	2.539	5.167	13.119
6	0.000	-1.500	1.500	4.732	8.676	10.056	6.324	76.711
7	-1.500	-9.000	7.500	23.300	29.300	197.250	10.893	2225.27
8	-9.000	-10.500	1.500	29.300	30.500	44.850	15.255	2909.46
9	-10.500	-20.500	10.000	43.599	85.121	643.601	21.538	16771.1

(iv) Moment and safety factor around jointing tie rod

No	Depth of layer		Moment of active earth pressure	Moment of active water pressure	Moment of passive earth pressure	Safety factor
	Upper side	Bottom side				F
			Ma	Mw	Mp	Mp/(Ma+Mw)
	(m)	(m)	(tf·m/m)	(tf·m/m)	(tf·m/m)	
1	5.800	5.500	-0.012	0.000	-	-
2	5.500	3.468	2.835	0.000	-	-
3	3.468	1.500	19.094	6.478	-	-
4	1.500	1.000	26.054	11.203	-	-
5	1.000	0.000	44.232	26.128	13.119	0.186
6	0.000	-1.500	83.920	41.736	76.711	0.610
7	-1.500	-9.000	83.920	158.794	2225.270	9.168
8	-9.000	-10.500	83.920	190.010	2909.460	10.621
9	-10.500	-20.500	1619.440	464.592	16771.100	8.047

(v) Balance equation at 7th layer

Item	A·Z³ +	B·Z² +	C·Z +	D
	A	B	C	D
Moment of active earth pressure (Ma)	0.000	0.000	0.000	83.920
Moment of water pressure (Mw)	0.000	0.578	11.272	41.736
Moment of passive earth pressure (Mp)	0.267	14.450	163.100	76.711
Safety factor	1.20			
Fs×(Ma + Mw) – Mp	-0.267	-13.756	-149.573	74.076
Result of cubic equation	0.474			
Depth of embedment from ground	2.974 (m)			
Original length of sheet pile	7.774 (m)			
Adopted length of sheet pile	9.000 (m)			

3.3 Consideration of sheet pile at river side (Normal case)

(i) Calculation of active earth pressure

No	Depth of layer		Layer width	Earth pressure			Affecting length	Moment
	Upper side	Bottom side		Upper side	Bottom side			
	(m)	(m)	(m)			(tf/m)	(m)	(tf·m/m)
1	5.800	5.500	0.300	0.333	0.513	0.127	-0.139	-0.018
2	5.500	5.200	0.300	0.513	0.693	0.181	0.157	0.011
3	5.200	3.468	1.732	0.693	1.732	2.101	1.290	2.720
4	3.468	1.500	1.968	1.732	2.388	4.055	3.068	15.161
5	1.500	1.000	0.500	2.388	2.555	1.236	4.253	20.417
6	1.000	-1.500	2.500	2.555	3.388	7.429	5.808	63.570
7	-1.500	-8.500	7.000	0.000	0.000	0.000	14.000	63.570
8	-8.500	-10.500	2.000	0.000	0.000	0.000	16.000	63.570
9	-10.500	-20.500	10.000	3.776	5.950	48.632	21.373	1102.96

(ii) Calculation of water pressure

No	Depth of layer		Layer width	Water pressure			Affecting length	Moment
	Upper side	Bottom side		Upper side	Bottom side			
	(m)	(m)	(m)			(tf/m)	(m)	(tf·m/m)
1	5.800	5.500	0.300					0.000
2	5.500	5.200	0.300					0.000
3	5.200	3.468	1.732					2.182
4	3.468	1.500	1.968					12.460
5	1.500	1.000	0.500					16.139
6	1.000	-1.500	2.500					41.031
7	-1.500	-8.500	7.000					168.304
8	-8.500	-10.500	2.000					220.252
9	-10.500	-20.500	10.000					387.640

(iii) Calculation of passive earth pressure

No	Depth of layer		Layer width	Earth pressure			Affecting length	Moment
	Upper side	Bottom side		Upper side	Bottom side			
	(m)	(m)	(m)			(tf/m)	(m)	(tf·m/m)
5	1.500	0.000	0.500	0.000	1.500	0.375	4.333	1.625
6	1.000	-1.500	2.500	1.500	9.000	13.125	6.048	81.000
7	-1.500	-8.500	7.000	23.000	28.600	180.600	10.627	2000.17
8	-8.500	-10.500	2.000	28.600	30.200	58.800	15.009	2882.70
9	-10.500	-20.500	10.000	46.909	92.898	699.035	21.548	17945.7

(iv) Moment and safety factor around jointing tie rod

No	Depth of layer		Moment of active earth pressure	Moment of active water pressure	Moment of passive earth pressure	Safety factor
	Upper side	Bottom side	Ma	Mw	Mp	F
	(m)	(m)	(tf·m/m)	(tf·m/m)	(tf·m/m)	Mp/(Ma+Mw)
1	5.800	5.500	-0.018	0.000	-	-
2	5.500	5.200	0.011	0.000	-	-
3	5.200	3.468	2.720	2.182	-	-
4	3.468	1.500	15.161	12.460	-	-
5	1.500	1.000	20.417	16.139	1.625	0.870
6	1.000	-1.500	63.570	41.031	81.000	1.920
7	-1.500	-8.500	63.570	168.304	2000.170	4.112
8	-8.500	-10.500	63.570	220.252	2882.700	48.812
9	-10.500	-20.500	1102.960	387.640	17945.700	16.622

(v) Balance equation at 7th layer

Item	$A \cdot Z^3$ + A	$B \cdot Z^2$ + B	$C \cdot Z$ + C	D D
Moment of active earth pressure (Ma)	0.111	2.028	11.498	20.417
Moment of water pressure (Mw)	0.000	0.866	7.792	16.139
Moment of passive earth pressure (Mp)	1.000	7.500	6.750	1.625
Safety factor	1.50			
Fs×(Ma + Mw) – Mp	-0.833	-5.325	2.705	12.861
Result of cubic equation	1.607			
Depth of embedment from ground	2.107 (m)			
Original length of sheet pile	6.407 (m)			
Adopted length of sheet pile	9.000 (m)			

3.4 Consideration of sheet pile at river side (Seismic case)

(i) Calculation of active earth pressure

No	Depth of layer		Layer width	Earth pressure			Affecting length	Moment
	Upper side	Bottom side		Upper side	Bottom side			
	(m)	(m)	(m)			(tf/m)	(m)	(tf·m/m)
1	5.800	5.500	0.300	0.198	0.412	0.092	-0.132	-0.012
2	5.500	5.200	0.300	0.412	0.627	0.156	0.160	0.013
3	5.200	3.468	1.732	0.627	1.863	2.156	1.309	2.835
4	3.468	1.500	1.968	2.223	3.154	5.291	3.073	19.094
5	1.500	1.000	0.500	3.154	3.391	1.636	4.253	26.054
6	1.000	-1.500	2.500	3.391	4.574	9.957	5.812	83.921
7	-1.500	-8.500	7.000	0.000	0.000	0.000	14.000	83.921
8	-8.500	-10.500	2.000	0.000	0.000	0.000	16.000	83.921
9	-10.500	-20.500	10.000	5.539	8.824	71.817	21.381	1619.44

(ii) Calculation of water pressure

No	Depth of layer		Layer width	Water pressure			Affecting length	Moment
	Upper side	Bottom side		Upper side	Bottom side			
	(m)	(m)	(m)			(tf/m)	(m)	(tf·m/m)
1	5.800	5.500	0.300					0.000
2	5.500	5.200	0.300					0.000
3	5.200	3.468	1.732					2.182
4	3.468	1.500	1.968					12.460
5	1.500	1.000	0.500					16.139
6	1.000	-1.500	2.500					41.031
7	-1.500	-8.500	7.000					168.304
8	-8.500	-10.500	2.000					220.252
9	-10.500	-20.500	10.000					387.640

(iii) Calculation of passive earth pressure

No	Depth of layer		Layer width	Earth pressure			Affecting length	Moment
	Upper side	Bottom side		Upper side	Bottom side			
	(m)	(m)	(m)			(tf/m)	(m)	(tf·m/m)
5	1.500	1.000	0.500	0.000	1.315	0.329	4.333	1.424
6	1.000	-1.500	2.500	1.315	7.887	11.503	6.048	70.987
7	-1.500	-8.500	7.000	23.000	28.600	180.600	10.627	1990.15
8	-8.500	-10.500	2.000	28.600	30.200	58.800	15.009	2872.69
9	-10.500	-20.500	10.000	42.353	83.876	631.144	21.548	16472.7

(iv) Moment and safety factor around jointing tie rod

No	Depth of layer		Moment of active earth pressure	Moment of active water pressure	Moment of passive earth pressure	Safety factor
	Upper side	Bottom side	Ma	Mw	Mp	F
	(m)	(m)	(tf·m/m)	(tf·m/m)	(tf·m/m)	Mp/(Ma+Mw)
1	5.800	5.500	-0.012	0.000	-	-
2	5.500	5.200	0.013	0.000	-	-
3	5.200	3.468	2.835	2.182	-	-
4	3.468	1.500	19.094	12.460	-	-
5	1.500	1.000	26.054	16.139	1.424	0.674
6	1.000	-1.500	83.921	41.031	70.987	1.335
7	-1.500	-8.500	83.921	168.304	1990.150	25.720
8	-8.500	-10.500	83.921	220.252	2872.690	36.856
9	-10.500	-20.500	1619.440	387.640	16472.700	10.411

(v) Balance equation at 7th layer

Item	$A \cdot Z^3$ + A	$B \cdot Z^2$ + B	$C \cdot Z$ + C	D D
Moment of active earth pressure (Ma)	0.158	2.760	15.260	26.054
Moment of water pressure (Mw)	0.000	0.866	7.792	16.139
Moment of passive earth pressure (Mp)	0.876	6.573	5.916	1.424
Safety factor	1.20			
Fs×(Ma + Mw) – Mp	-0.687	-4.126	4.640	13.701
Result of cubic equation	2.044			
Depth of embedment from ground	2.544 (m)			
Original length of sheet pile	6.844 (m)			
Adopted length of sheet pile	9.000 (m)			

4 Stress Calculation of Sheet Pile

Balance point that depend on active pressure and passive pressure is estimated fulcurm.

In structural calculation of sheet pile, sheet pile is regarded as simple beam between tie rod joint and estimated fulcrum

(i) Stress calculation of sheet pile

$$Z = Mmax / \sigma a$$

Where;

Z:	Section modulus	(cm^3/m)
Mmax:	Maximum bending moment	(kgf·cm/m)
Σ a:	Allowable stress	(kgf/cm)

(ii) Maximum bending moment

$$AX2 + BX + C = 0$$

$$A = 0.5 \cdot (Pi2 - Pi1) / (Zi2 - Zi1)$$

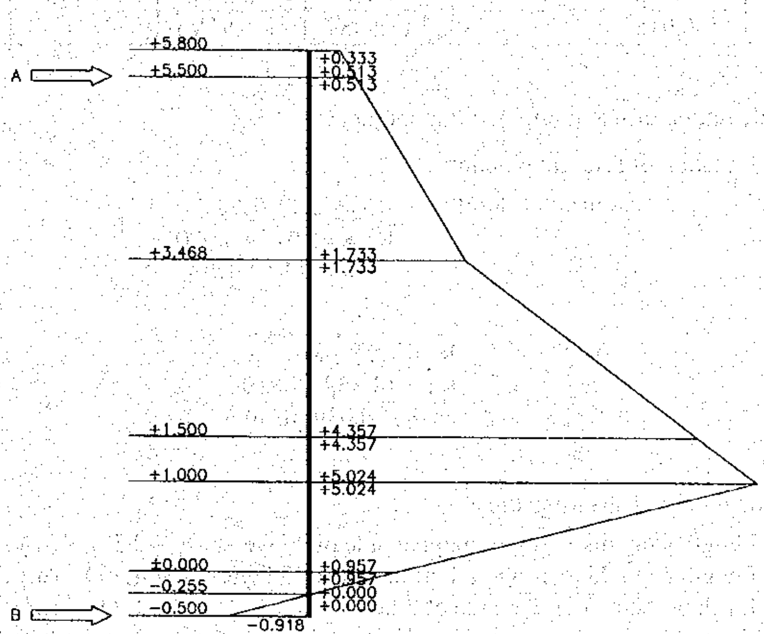
$$B = Pi1$$

$$C = \Sigma pi - Ra$$

Where;

Zi1:	Length form dike crown to Upper side of i layer	(m)
Zi2:	Length from dike crown to bottom side of I layer	(m)
Pi1:	Earth pressure until upper side of i layer	(tf/m^2)
Pi2:	Earth pressure until bottom side of i layer	(tf/m^2)
Σ pi:	Total earth pressure	(tf/m^2)

4.1 In case of land side sheet pile (Normal case)



(i) Earth pressure for calculation

No	Layer depth	Active earth pressure	Water pressure	Passive earth pressure	Earth pressure for calculation
	(m)	Pa(tf/m²)	Pw(tf/m²)	Pp(tf/m²)	Pa+Pw-Pp(tf/m²)
1	5.800	0.333	0.000		0.333
	5.500	0.513	0.000		0.513
2	5.500	0.513	0.000		0.513
	3.468	1.732	0.000		1.733
3	3.468	1.732	0.000		1.733
	1.500	2.388	1.968		4.357
4	1.500	2.388	1.968		4.357
	1.000	2.555	2.468		5.024
5	1.000	2.555	2.468	0.000	5.024
	0.000	2.888	3.468	5.400	0.957
6	0.000	2.888	3.468	5.400	0.957
	-0.255	2.973	3.192	6.165	0.000
7	-0.255	2.973	3.192	6.165	0.000
	-0.500	3.055	2.926	6.900	-0.918

(ii) Moment and load around jointing tie rod

No	Earth pressure for calculation Upper side	Bottom side	Area for calculation	Total earth pressure	Affecting length	Moment	Total moment
	(tf/m²)	(tf/m²)	(tf/m)	(tf/m)	(m)	(tf·m)	(tf·m)
1	0.333	0.513	0.127	0.127	-0.139	-0.018	-0.018
2	0.513	1.733	2.282	2.409	1.200	2.738	2.720
3	1.733	4.357	5.992	8.401	3.157	18.919	21.639
4	4.357	5.024	2.345	10.746	4.256	9.980	31.620
5	5.024	0.957	2.990	13.736	4.887	14.612	46.232
6	0.957	0.000	0.122	13.858	5.585	0.682	46.913
7	0.000	-0.918		13.858	5.918		46.913

(iii) Calculation of maximum bending moment

a) Calculation of fulcrum reaction

At estimated fulcrum $Rb = \Sigma PL/L$

$Rb = 46.913 / 6.000$

$= 7.819$ (tf/m)

At tie rod $Ra = \Sigma P - Rb$

$Ra = 13.858 / 7.819$

$= 6.039$ (tf/m)

b) Calculation of shearing stress

Zi1:	Length from dike crown to upper side of 3 layer	2.332	(m)
Zi2:	Length from dike crown to bottom side of 3 layer	4.300	(m)
Pi1:	Earth pressure at upper side of 3 layer	1.733	(tf/m²)
Pi2:	Earth pressure at bottom side of 3 layer	4.357	(tf/m²)
Σpi:	Total earth pressure until 2 layer	2.409	(tf/m²)

$AX^2 + BX + C = 0$

$A = 0.5 \cdot (Pi2 - Pi1) / (Zi2 - Zi1)$

$= 0.5 \cdot (4.375 - 1.733) / (4.300 - 2.332)$

$= 0.667$

$B = Pi1 = 1.733$

$C = \Sigma pi - Ra$

$= 2.409 - 6.039$

$= -3.630$

Result of quadratic equation

$X = 1.372$ (m)

c) Maximum bending moment (Mmax)

Mmax	$= M1 - M2 - M3$
M1	$= Ra (X + Zi1 - Zs)$
M2	$= \Sigma Pj (X + Zi1 - Zs - Lj)$
M3	$= PiX \cdot (1/3) \cdot (2 \cdot Pi1 + PiX) / (Pi1 + PiX)$
M1	$= 6.039 \cdot (1.372 + 2.332 - 0.300) = 20.555$
M2	$= 5.478$
PiX	$= Pi1 + \{(Pi2 - Pi1) / (Zi2 - Zi1)\} \cdot X$
	$= 1.733 + \{(4.357 - 1.733) / (4.300 - 2.332)\} \cdot 1.372$
	$= 3.561$
Pix	$= 0.5 \cdot (Pi1 + PiX) \cdot X$
	$= 0.5 \cdot (1.733 + 3.561) \cdot 1.372 = 3.630$
M3	$= 3.630 \cdot (1.372 / 3) \cdot \{(2 \cdot 1.733 + 3.561) / (1.733 + 3.561)\}$
	$= 2.203$
Mmax	$= 12.874$ (tf·m/m)

(iv) Stress calculation of sheet pile

a) Stress calculation of sheet pile

Necessary section modulus and bending stress is calculated with following formula.

$Zr = M / (\sigma sa \times 0.60)$

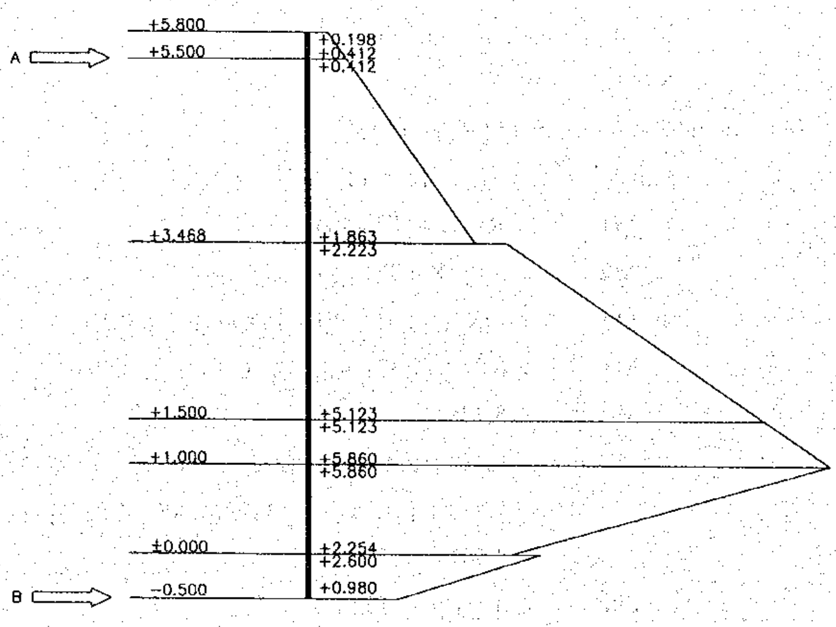
$\sigma s = M / (Z \times 0.60)$

M	Bending moment	(kgf·cm/m)
σ s	Allowable stress	(kgf/cm^2)
Z	Section modulus of sheet pile	(cm^3/m)
0.60	Joint coefficient	

b) Summary of calculation results

Item		Value	
Bending moment		12.874	(tf·m/m)
Necessary section modulus	Zr	1192	(cm³)
Adopted sheet pile		Type-III	
Allowable stress	σ sa	1800	(kgf/cm²)
Section modulus	Z	1340	(cm³)
Bending stress	σ s	1601	(kgf/cm²)

4.2 In case of land side sheet pile (Sesimic case)



(i) Earth pressure for calculation

No	Layer depth	Active earth pressure	Water pressure	Passive earth pressure	Earth pressure for calculation
	(m)	Pa(tf/m²)	Pw(tf/m²)	Pp(tf/m²)	Pa+Pw-Pp(tf/m²)
1	5.800	0.198	0.000		0.198
	5.500	0.412	0.000		0.412
2	5.500	0.412	0.000		0.412
	3.468	1.863	0.000		1.863
3	3.468	2.223	0.000		2.223
	1.500	3.154	1.968		5.123
4	1.500	3.154	1.968		5.123
	1.000	3.391	2.468		5.860
5	1.000	3.391	2.468	0.000	5.860
	0.000	3.864	3.468	5.078	2.254
6	0.000	3.864	3.468	4.732	2.600
	-0.500	4.101	2.926	6.047	0.980

(ii) Moment and load around jointing tie rod

No	Earth pressure for calculation		Area for calculation	Total earth pressure	Affecting length	Moment	Total moment
	Upper side	Bottom side					
	(tf/m²)	(tf/m²)	(tf/m)	(tf/m)	(m)	(tf·m)	(tf·m)
1	0.198	0.412	0.092	0.092	-0.132	-0.012	-0.012
2	0.412	1.863	2.312	2.403	1.232	2.848	2.836
3	2.223	5.123	7.229	9.632	3.145	22.737	25.573
4	5.123	5.860	2.746	12.378	4.256	11.684	37.257
5	5.860	2.254	4.057	16.435	4.926	19.984	57.241
6	2.600	0.980	0.895	17.330	5.712	5.114	62.355

(iii) Calculation of maximum bending moment

a) Calculation of fulcrum reaction

At estimated fulcrum $Rb = \Sigma PL/L$

$Rb = 62.355 / 6.000$

$= 10.392$ (tf/m)

At tie rod $Ra = \Sigma P - Rb$

$Ra = 17.330 / 10.392$

$= 6.937$ (tf/m)

b) Calculation of shearing stress

Zi1:	Length from dike crown to upper side of 3 layer	2.332	(m)
Zi2:	Length from dike crown to bottom side of 3 layer	4.300	(m)
Pi1:	Earth pressure at upper side of 3 layer	2.223	(tf/m²)
Pi2:	Earth pressure at bottom side of 3 layer	5.123	(tf/m²)
Σ pi:	Total earth pressure until 2 layer	2.403	(tf/m²)

$AX^2 + BX + C = 0$

$A = 0.5 \cdot (Pi2 - Pi1) / (Zi2 - Zi1)$

$= 0.5 \cdot (5.123 - 2.223) / (4.300 - 2.332)$

$= 0.737$

$B = Pi1 = 2.223$

$C = \Sigma pi - Ra$

$= 2.403 - 6.937$

$= -4.534$

Result of quadratic equation

$X = 1.395$ (m)

c) Maximum bending moment (Mmax)

$Mmax = M1 - M2 - M3$

$M1 = Ra (X + Zi1 - Zs)$

$M2 = \Sigma Pj (X + Zi1 - Zs - Lj)$

M3 = PiX·(1/3)·(2·Pi1 + PiX) / (Pi1 + PiX)

M1 = 6.937·(1.395 + 2.332 - 0.300)

= 23.772

M2 = 5.400

PiX = Pi1 + {(Pi2 - Pi1) / (Zi2 - Zi1)}·X

= 2.223 + {(5.123 - 2.223) / (4.300 - 2.332)}·1.395

= 4.278

Pix = 0.5·(Pi1 + PiX)·X

= 0.5·(2.223 + 4.278)·1.395

= 4.534

M3 = 4.534·(1.395 / 3)·{(2·2.223 + 4.278) / (2.223 + 4.278)}

= 2.829

Mmax = 15.543 (tf·m/m)

(iv) Stress calculation of sheet pile

a) Stress calculation of sheet pile

Necessary section modulus and bending stress is calculated with following formula.

Zr = M / (σ sa × 0.60)

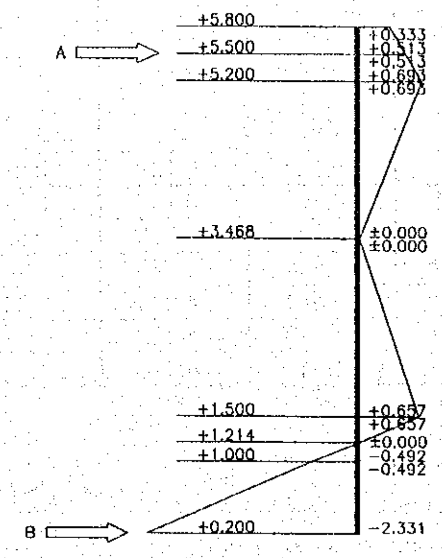
σ s = M / (Z × 0.60)

M	Bending moment	(kgf·cm/m)
σ s	Allowable stress	(kgf/cm^2)
Z	Section modulus of sheet pile	(cm^3/m)
0.60	Joint coefficient	

b) Summary of calculation results

Item		Value	
Bending moment		15.543	(tf·m/m)
Necessary section modulus	Zr	959	(cm^3)
Adopted sheet pile		Type-III	
Allowable stress	σ sa	2700	(kgf/cm^2)
Section modulus	Z	1340	(cm^3)
Bending stress	σ s	1933	(kgf/cm^2)

4.3 Incase of river side sheet pile (Normal case)



(i) Earth pressure for calculation

No	Layer depth	Active earth pressure	Water pressure	Passive earth pressure	Earth pressure for calculation
	(m)	Pa(tf/m²)	Pw(tf/m²)	Pp(tf/m²)	Pa+Pw-Pp(tf/m²)
1	5.800	0.333	0.000		0.333
	5.500	0.513	0.000		0.513
2	5.500	0.513	0.000		0.513
	5.200	0.693	0.000		0.693
3	5.200	0.693	0.000		0.693
	3.468	1.732	1.732		0.000
4	3.468	1.732	1.732		0.000
	1.500	2.388	1.732		0.657
5	1.500	2.338	1.732	0.000	0.657
	1.214	2.484	1.626	0.857	0.000
6	1.214	2.484	1.626	0.857	0.000
	1.000	2.555	1.547	1.500	-0.492
7	1.000	2.555	1.547	1.500	-0.492
	0.200	2.822	1.253	3.900	-2.331

(ii) Moment and load around jointing tie rod

No	Earth pressure for calculation Upper side	Earth pressure for calculation Bottom side	Area for calculation	Total earth pressure	Affecting length	Moment	Total moment
	(tf/m²)	(tf/m²)	(tf/m)	(tf/m)	(m)	(tf·m)	(tf·m)
1	0.333	0.513	0.127	0.127	-0.139	-0.018	-0.018
2	0.513	0.693	0.181	0.308	0.157	0.028	0.011
3	0.693	0.000	0.601	0.909	0.878	0.527	0.538
4	0.000	0.657	0.647	1.556	3.343	2.163	2.701
5	0.657	0.000	0.094	1.649	4.095	0.348	3.085
6	0.000	-0.492		1.649	4.429		3.085
7	-0.492	-2.331		1.649	4.978		3.085

(iii) Calculation of maximum bending moment

a) Calculation of fulcrum reaction

At estimated fulcrum $Rb = \Sigma PL/L$

$Rb = 3.085 / 5.300$

$= 0.582$ (tf/m)

At tie rod $Ra = \Sigma P - Rb$

$Ra = 1.649 / 0.582$

$= 1.067$ (tf/m)

b) Calculation of shearing stress

Zi1:	Length from dike crown to upper side of 3 layer	2.332	(m)
Zi2:	Length from dike crown to bottom side of 3 layer	4.300	(m)
Pi1:	Earth pressure at upper side of 3 layer	0.000	(tf/m²)
Pi2:	Earth pressure at bottom side of 3 layer	0.657	(tf/m²)
Σ pi:	Total earth pressure until 2 layer	0.909	(tf/m²)

$AX^2 + BX + C = 0$

$A = 0.5 \cdot (Pi2 - Pi1) / (Zi2 - Zi1)$

$= 0.5 \cdot (0.657 - 0.000) / (4.300 - 2.332)$

$= 0.167$

$B = Pi1 = 0.001$

$C = \Sigma pi - Ra$

$= 0.909 - 1.067$

$= -0.159$

Result of quadratic equation

$X = 0.974$ (m)

c) Maximum bending moment (Mmax)

$Mmax = M1 - M2 - M3$

$M1 = Ra (X + Zi1 - Zs)$

M2 = ΣPj (X + Zi1 - Zs - Lj)

M3 = PiX·(1/3)·(2·Pi1 + PiX) / (Pi1 + PiX)

M1 = 1.067·(0.974 + 2.332 - 0.300)

= 3.208

M2 = 2.193

PiX = Pi1 + {(Pi2 - Pi1) / (Zi2 - Zi1)}·X

= 0.000 + {(0.657 - 0.000) / (4.300 - 2.332)}·0.974

= 0.325

Pix = 0.5·(Pi1 + PiX)·X

= 0.5·(0.000 + 0.325)·0.974

= 0.158

M3 = 0.158·(0.974 / 3)·{(2·0.000 + 0.325) / (0.000 + 0.325)}

= 0.051

Mmax = 0.963 (tf·m/m)

(iv) Stress calculation of sheet pile

a) Stress calculation of sheet pile

Necessary section modulus and bending stress is calculated with following formula.

Zr = M / (σ sa × 0.60)

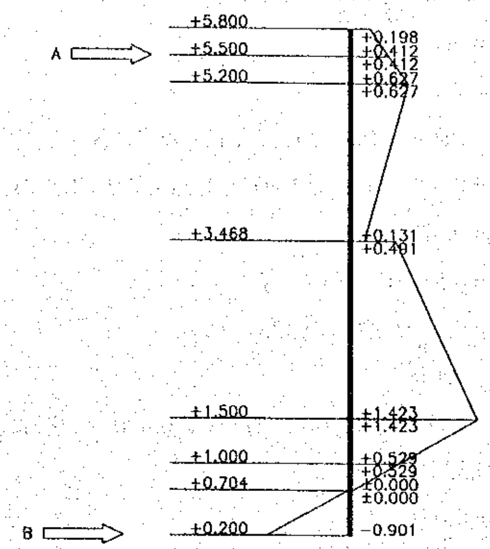
σ s = M / (Z × 0.60)

M	Bending moment	(kgf·cm/m)
σ s	Allowable stress	(kgf/cm^2)
Z	Section modulus of sheet pile	(cm^3/m)
0.60	Joint coefficient	

b) Summary of calculation results

Item		Value	
Bending moment		0.963	(tf·m/m)
Necessary section modulus	Zr	89	(cm^3)
Adopted sheet pile		Type-III	
Allowable stress	σ sa	1800	(kgf/cm^2)
Section modulus	Z	1340	(cm^3)
Bending stress	σ s	120	(kgf/cm^2)

4.4 In case of river side sheet pile (Seismic case)



(i) Earth pressure for calculation

No	Layer depth	Active earth pressure	Water pressure	Passive earth pressure	Earth pressure for calculation
	(m)	Pa(tf/m²)	Pw(tf/m²)	Pp(tf/m²)	Pa+Pw-Pp(tf/m²)
1	5.800	0.198	0.000		0.198
	5.500	0.412	0.000		0.412
2	5.500	0.412	0.000		0.412
	5.200	0.627	0.000		0.627
3	5.200	0.627	0.000		0.627
	3.468	1.863	1.732		0.131
4	3.468	2.223	1.732		0.491
	1.500	3.154	1.732		1.423
5	1.500	3.154	1.732	0.000	1.423
	1.000	3.391	1.547	1.315	0.529
6	1.000	3.391	1.547	1.315	0.529
	0.704	3.531	1.438	2.093	0.000
7	0.704	3.531	1.438	2.093	0.000
	0.200	3.770	1.253	3.418	-0.901

(ii) Moment and load around jointing tie rod

No	Earth pressure for calculation Upper side	Bottom side	Area for calculation	Total earth pressure	Affecting length	Moment	Total moment
	(tf/m²)	(tf/m²)	(tf/m)	(tf/m)	(m)	(tf·m)	(tf·m)
1	0.198	0.412	0.092	0.092	-0.132	-0.012	-0.012
2	0.412	0.627	0.156	0.247	0.160	0.025	0.013
3	0.627	0.131	0.656	0.903	0.977	0.641	0.653
4	0.491	1.423	1.883	2.787	3.176	5.981	6.635
5	1.423	0.529	0.488	3.275	4.212	2.055	8.690
6	0.529	0.000		3.275	4.599		8.690
7	0.000	-0.901		3.275	5.132		8.690

(iii) Calculation of maximum bending moment

a) Calculation of fulcrum reaction

At estimated fulcrum $Rb = \Sigma PL/L$

$Rb = 8.690 / 5.300$

$= 1.640$ (tf/m)

At tie rod $Ra = \Sigma P - Rb$

$Ra = 3.275 / 1.640$

$= 1.635$ (tf/m)

b) Calculation of shearing stress

Zi1:	Length from dike crown to upper side of 3 layer	2.332	(m)
Zi2:	Length from dike crown to bottom side of 3 layer	4.300	(m)
Pi1:	Earth pressure at upper side of 3 layer	0.491	(tf/m²)
Pi2:	Earth pressure at bottom side of 3 layer	1.423	(tf/m²)
Σ pi:	Total earth pressure until 2 layer	0.903	(tf/m²)

$AX^2 + BX + C = 0$

$A = 0.5 \cdot (Pi2 - Pi1) / (Zi2 - Zi1)$

$= 0.5 \cdot (1.423 - 0.491) / (4.300 - 2.332)$

$= 0.237$

$B = Pi1 = 0.491$

$C = \Sigma pi - Ra$

$= 0.903 - 1.635$

$= -0.732$

Result of quadratic equation

$X = 1.004$ (m)

c) Maximum bending moment (Mmax)

$$\begin{aligned}
Mmax &= M1 - M2 - M3 \\
M1 &= Ra\,(X + Zi1 - Zs) \\
M2 &= \Sigma Pj\,(X + Zi1 - Zs - Lj) \\
M3 &= PiX \cdot (1/3) \cdot (2 \cdot Pi1 + PiX) / (Pi1 + PiX) \\
M1 &= 1.635 \cdot (1.004 + 2.332 - 0.300) \\
&= 4.964 \\
M2 &= 2.089 \\
PiX &= Pi1 + \{(Pi2 - Pi1) / (Zi2 - Zi1)\} \cdot X \\
&= 0.491 + \{(1.423 - 0.491) / (4.300 - 2.332)\} \cdot 1.004 \\
&= 0.967 \\
Pix &= 0.5 \cdot (Pi1 + PiX) \cdot X \\
&= 0.5 \cdot (0.491 + 0.967) \cdot 1.004 \\
&= 0.732 \\
M3 &= 0.732 \cdot (1.004 / 3) \cdot \{(2 \cdot 0.491 + 0.967) / (0.491 + 0.967)\} \\
&= 0.327 \\
Mmax &= 2.548\ (tf \cdot m/m)
\end{aligned}$$

(iv) Stress calculation of sheet pile

a) Stress calculation of sheet pile

Necessary section modulus and bending stress is calculated with following formula.

$$Zr = M / (\sigma sa \times 0.60)$$

$$\sigma s = M / (Z \times 0.60)$$

M	Bending moment	(kgf·cm/m)
σ s	Allowable stress	(kgf/cm^2)
Z	Section modulus of sheet pile	(cm^3/m)
0.60	Joint coefficient	

b) Summary of calculation results

Item		Value	
Bending moment		2.548	(tf·m/m)
Necessary section modulus	Zr	157	(cm^3)
Adopted sheet pile		Type-III	
Allowable stress	σ sa	2700	(kgf/cm^2)
Section modulus	Z	1340	(cm^3)
Bending stress	σ s	317	(kgf/cm^2)

4.5 Consideration of tie rod

(i) Load affecting tie rod

Load affecting tie rod is equal to fulcrum reaction of tie rod.

		At land side		At river side	
		Normal case	Seismic case	Normal case	Seismic case
Fulcrum reaction	Ra(tf/m)	6.039	6.937	1.067	1.635

Therefore;

Pe (Normal case) = 6.039 (tf/m)
Pe (Seismic case) = 6.937 (tf/m)

(ii) Tension calculation of tie rod

Tension stress affecting tie rod is calculated with following formula.

$$T = Pe \cdot L \cdot 1000$$

Where;

T:	Tension stress	(kgf)
Pe:	Fulcrum reaction	(tf/m)
L:	Installed interval	(m)

a) Normal case

$$T = 6.039 \times 2.00 \times 1000$$
$$= 12078.80 \text{ (kgf)}$$

b) Seismic case

$$T = 6.937 \times 2.00 \times 1000$$
$$= 13874.40 \text{ (kgf)}$$

(iii) Stress calculation of tie rod

Section area of tie rod is calculated with following formula.

$$A = T / \sigma a$$

Where;

A:	Section area	(cm^2)
T:	Tension stress	(kgf)
σ a:	Allowable stress	(kgf/cm^2)

Item		Normal case	Seismic case
Tension stress	(kgf)	12078.80	13874.40
Allowable strength	(kgf/cm^2)	880	1320
Section area	(cm^2)	13.73	10.51
Necessary diameter	(mm)	41.80	36.60

Therefore, it is adopted that diameter of tie rod is 42.0 mm.

(iv) Summary of calculation results

Material of tie rod	Normal case			Seismic case		
	Allowable strength	Necessary section area	Necessary diameter	Allowable strength	Necessary section area	Necessary diameter
	(kgf/cm^2)	(cm^2)	(mm)	(kgf/cm^2)	(cm^2)	(mm)
SS400(<40mm)	960	12.58	40.1	1440	9.64	35.1
SS400(>40mm)	880	13.73	41.8	1320	10.51	36.6
SS490(<40mm)	1120	10.78	37.1	1680	8.26	32.5
SS490(>40mm)	1040	11.61	38.5	1560	8.89	33.7
High tension steel 390	1600	7.55	31.0	2400	5.78	27.2
High tension steel 440	1800	6.71	29.3	2700	5.14	25.6

4.6 Consideration of waling

(i) Calculation of bending moment

Bending moment is calculated with following formula.

$M = T \cdot L / 4$

Where;

M: Bending moment (tf·m)
T: Tension stress (tf)
L: Horizontal interval (m)

a) Normal case

$M = (12.08 \cdot 2.00) / 4$
$= 6.04$ (tf·m)

b) Seismic case

$M = (13.87 \cdot 2.00) / 4$
$= 6.94$ (tf·m)

(ii) Stress calculation

Stress calculation of waling is calculated with following formulas.

(Section modulus)

$Zr = M / \sigma sa$

(Bending strength)

$\sigma s = M / Z$

Where;

M: Bending moment (tf·m)
σ sa: Allowable strength (kgf/cm^2)
Z: Section modulus (cm^3)

It is adopted that waling member is 2[200×90×8×13.5.

Item		Normal case	Seismic case
Tension stress	(tf)	12.08	12.87
Horizontal interval	(m)	2.00	2.00
Bending moment	(tf·m)	6.04	6.94
Allowable stress	(kgf/cm^2)	1400.00	2100.00
Section modulus	(cm^3)	498.0	
Bending strength	(kgf/cm^2)	1212.73	1393.01
Necessary section modulus	(cm^3)	431.39	330.34

(iii) Summary of calculation results

Waling member					Section modulus (cm^3)	Evaluation	
						Normal case	Seismic case
1	2[100×	50×	5	×7.5	75.2	(×)	(×)
2	2[125×	65×	6	×8	135.6	(×)	(×)
3	2[150×	75×	6.5	×10	230.0	(×)	(×)
4	2[150×	75×	9	×12.5	280.0	(×)	(×)
5	2[180×	75×	7	×10.5	306.0	(×)	(×)
6	2[200×	80×	7.5	×11	390.0	(×)	(○)
7	2[200×	90×	8	×13.5	498.0	(○)	(○)
8	2[250×	90×	9	×13	668.0	(○)	(○)
9	2[250×	90×	11	×14.5	748.0	(○)	(○)
10	2[300×	90×	9	×13	858.0	(○)	(○)
11	2[300×	90×	10	×15.5	988.0	(○)	(○)
12	2[300×	90×	12	×16	1050.0	(○)	(○)
13	2[380×	100×	10.5	×16	1526.0	(○)	(○)
14	2[380×	100×	13	×16.5	1646.0	(○)	(○)
15	2[380×	100×	13	×20	1852.0	(○)	(○)

5 Consideration of impermeable effectiveness

5.1 Calculation formula

$$F1 = L1 / h1$$

$$F2 = L2 / h2$$

Where;

Fi : Safety factor (3.00)
L1 : Vertical seepage length (m)
L2 : Horizontal seepage length (m)
h1 : Height from HWL to ground level
h1 = 5.200 - (1.000)
= 4.200 (m)
h2 : Height form HWL to excavation level
h2 = 5.200 - (0.000)
= 5.200 (m)

5.2 Calculation of impermeable effectiveness

$L1 = D1 + LL1 + D2$

Where;

D1	:	Installed length of river side sheet pile	4.70 (m)
D2	:	Installed length of land side sheet pile	4.20 (m)
LL1	:	$\sqrt{BB^2 + DD^2}$	(m)
BB	:	Dam body width	(m)
DD	:	Gap between river side sheet pile length and land side sheet pile length	(m)
LL1	=	$\sqrt{6.50^2 + 0.00^2}$	
	=	6.50 (m)	

$L1 = 4.70 + 6.50 + 4.20$

$= 15.40$ (m)

$F1 = 15.40 / 4.20$

$= 3.67$ ....O.K

$L2 = D1 + LL1 + LL2$

Whrere;

LL2	:	Height from bottom of land side sheet pile to excavation surface	(m)
LL2	=	$\sqrt{MB^2 + DE^2}$	
MB	:	Flood plain width	(m)
DE	:	Height from bottom of sheet pile to excavation surface	(m)
	=	$\sqrt{4.00^2 + 3.20^2}$	
	=	5.12 (m)	

$L2 = 4.70 + 6.50 + 5.12$

$= 16.32$ (m)

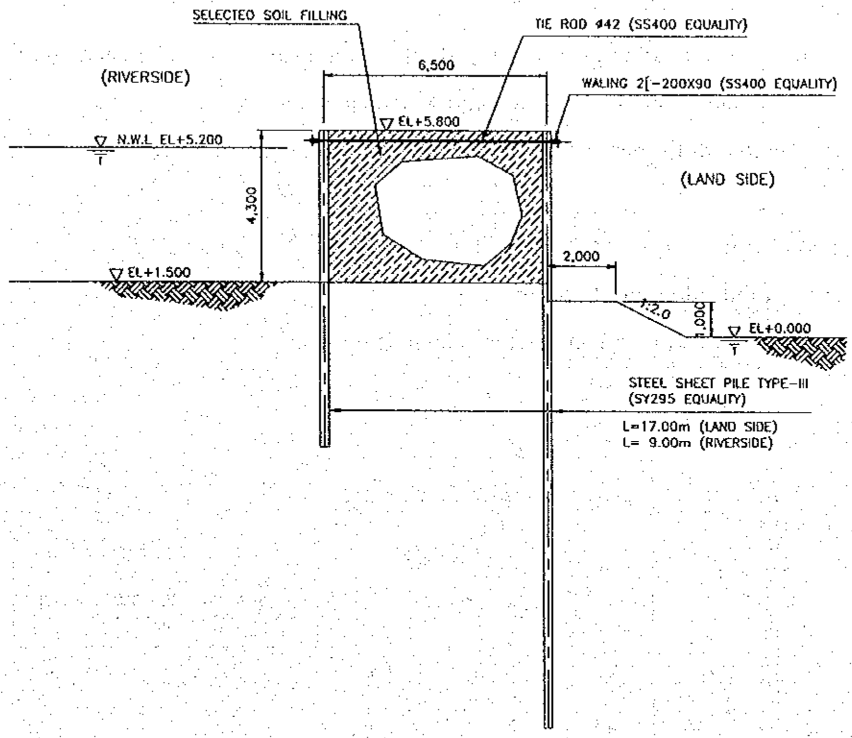
$F1 = 16.32 / 5.20$

$= 3.14$ ....O.K

Therefore, it is adopted that sheet pile length for impermeable effectiveness is 17.00 m.

$L = L2 + 0.30 \text{ m} = 16.62 \fallingdotseq 17.00 \text{ m}$

Standard cross section of temporary cofferdam is shown as follows.



STANDARD CROSS SECTION OF TEMPORARY COFFERDAM

8.2 Consideration of Discharge Capacity

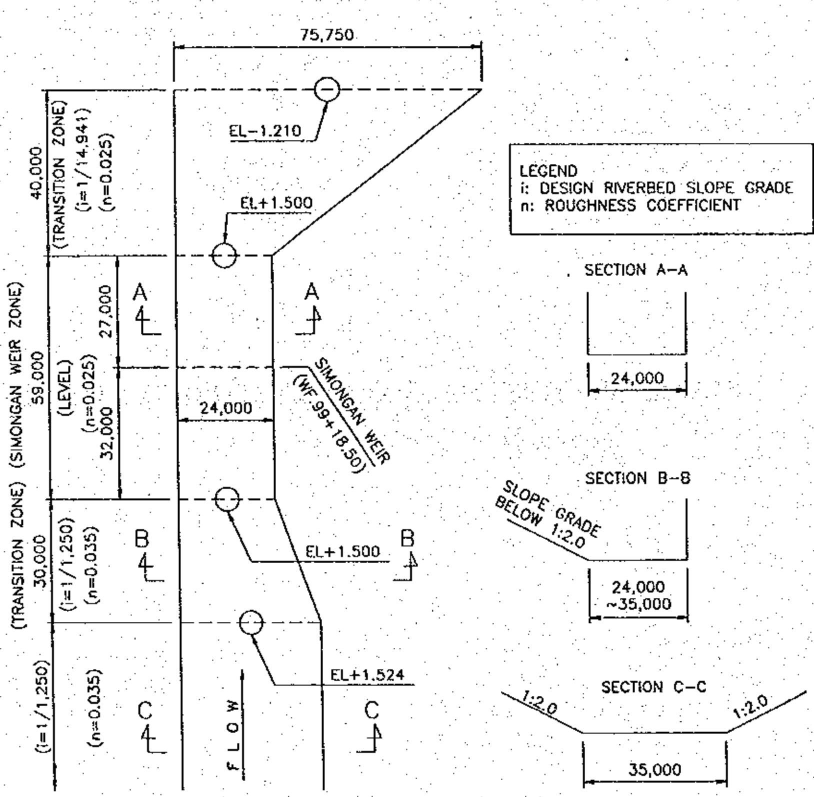
In case of temporary work, discharge capacity is calculated with temporary cofferdam around Simongan weir at second stage.

Method of discharge capacity calculation adopts non-uniform flow.

1 Design condition

a) Configuration of section

Figure of estimated channel is shown as follows.



b) Design dike crown elevation of temporary cofferdam

Design dike crown elevation of temporary cofferdam is adopted as follows.

Design dike crown elevation = N.W.L + freeboard

EL+5.800 m = EL+5.200m + 0.60 m

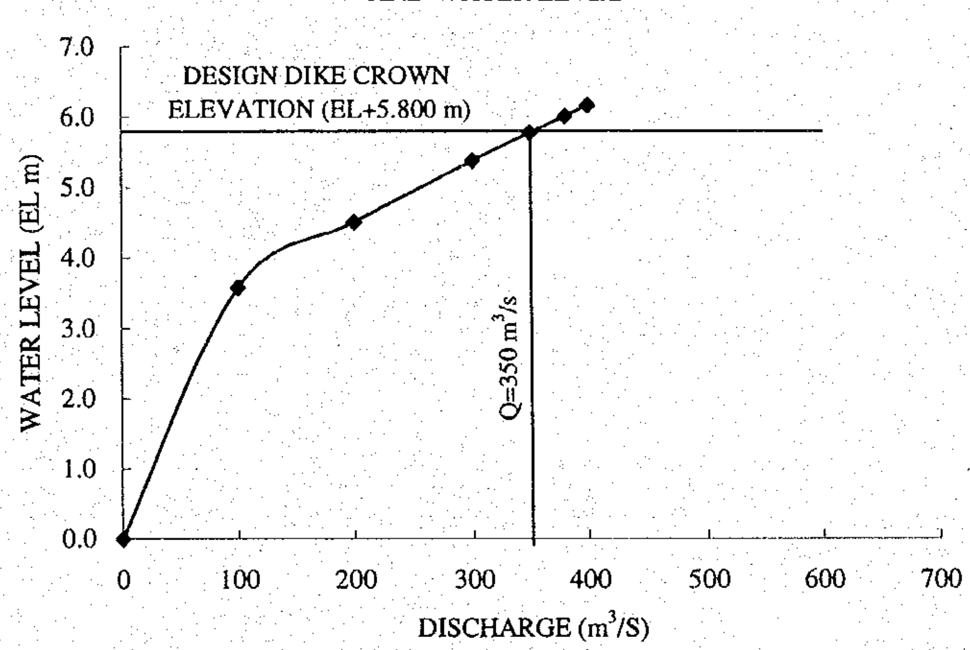
Decision point of water level is most upstream temporary cofferdam (WF.99+80.50), because dike crown elevation of temporary cofferdam is level.

2 Result of Discharge Capacity

In case of each discharge, results of water elevation and flowing velocity are shown as follows.

Discharge	Water level	Velocity of flowing	Remarks
Q = 100 m^3/s	EL+3.476 m	1.316 m/s	Below dike crown
Q = 200 m^3/s	EL+4.511 m	1.634 m/s	- ditto -
Q = 300 m^3/s	EL+5.381 m	1.821 m/s	- ditto -
Q = 350 m^3/s	EL+5.780 m	1.890 m/s	- ditto -
Q = 380 m^3/s	EL+6.011 m	1.926 m/s	Above dike crown
Q = 400 m^3/s	EL+6.162 m	1.948 m/s	- ditto -

RELATION BETWEEN DISCHARGE AND WATER LEVEL



Result of calculation at table and graph says that allowable discharge capacity with temporary cofferdam is below 350 m^3/s, in case of above 350 m^3/s, flowing water across temporary cofferdam.

The discharge of 350 m^3/s is regarded as about 2 – year return period flood.

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