CHAPTER 3 DESIGN OF CIVIL WORKS

3.1 Construction Material and Their Property

3.1.1 Weight of Material (Dead Load)

The dead loads consist of the weight of the structure considered, including additional materials for construction or other utility services. The following unit weights of construction materials are in principle used in computing the dead load. In case that the actual unit weight of materials is evident, their unit weight is to be used.

No.	Material	Unit Weight	
		(tf/m^3)	(kN/m^3)
1	Concrete - Reinforced Concrete - Prestressed Concrete - Plain/Mass Concrete	 2.50 2.55 2.35	 24.51 25.00 23.04
2	Cement Mortar	2.15	21.08
3	Stone	2.60	25.48
4	Wet Cobble/Rubble Masonry	2.30	22.54
5	Brick Masonry	2.00	19.61
6	Asphalt Concrete Pavement	2.30	22.55
7	Soil	(Refer to 3.2.1 Unit Weight of Soil)	
8	Compacted Gravel	2.00	19.61
9	Structural Steel	7.85	76.96
10	Cast Iron	7.25	71.05
11	Aluminum Alloys	2.80	27.44
12	Lead	11.40	111.76
13	Timber (soft wood)	0.80	7.84
14	Timber (hard wood)	1.10	10.78
15	Water	1.00	9.80

Note : 1kN = 102 kgf

Other materials not listed above table shall be calculated on the basis of their density.

3.1.2 Property of Construction Materials

Concrete

(1) Classification

Concrete is classified according to its compressive strength (28 th day, σ_{bk}) maximum size of aggregates and application as shown in the following table :

Class of Concrete	28 th-day (σ_{bk}) Compressive Strength Mpa	(kgf/cm²)	Max. Size of Aggregate (mm)	Application
A-1 (K – 500)	49.02	(500)	-	Prestressed concrete pile (Ready made product)
A-2 (K – 400)	39.20	(400)	25	Prestressed concrete for bridge girder, Prestressed concrete pile
A-3 (K – 350)	34.30	(350)	25	Prestressed concrete for slab deck of bridge, Precast concrete pile
B (K – 250)	24.51	(250)	25	Reinforced concrete for bridge girder, weir and water gate
C1 (K – 225)	22.05	(225)	25	General use, reinforced concrete members with thickness more than 20 cm
C2 (K - 225)	22.05	(225)	15	Secondary concrete
D (K - 175)	17.15	(175)	40	Plain concrete for structure
E (K - 125)	12.25	(125)	25	Plain concrete for leveling

Note : 1 MPa = 10.2 kgf/cm², (MP_a : mega pascal)
1 kg/cm² = 0.098 MPa

(2) Modulus of Elasticity (Young's Modulus)

Young's Modulus of concrete to be used in calculation of the statically indeterminate force or elastic deformation of a reinforced concrete structure and those for design calculation of presetressed concrete members are given in the table below.

Grade	σ_{bk} (kgf/cm²)	E_c (kgf/cm²)	$n = E_s / E_c$
K - 175	175	215,000	9.77
K - 225	225	245,000	8.57
K - 250	250	255,000	8.24
K - 350	350	295,000	7.12
K - 400	400	310,000	6.77
K - 500	500	330,000	6.36

where :

σ_{bk} : compressive strength of concrete at relevant age (kgf/cm²)
E_c : elasticity of concrete (kgf/cm²)
E_s : modulus of elasticity of steel (=2,100,000 kgf/cm²)
n : ratio of Young' modulus

Ratio of Young' modulus n to be used in calculation of stress of reinforced concrete members is 15 (n = 2,100,000 / 140,000, E_c value is assumed to be 140,000 kgf/cm^2).

(3) Shear Modulus

Shear modulus of concrete is calculated from equation as follows:

$$G_c = E_c / 2.3$$

where, G_c : shear modulus of concrete kgf/cm^2

E_c : Youngs' modulus of concrete kgf/cm^2

Steel

(1) Classification

The major steel materials used in the structural design are generally conform to the standards given in the table below.

Kind of Steel	Description and Code Number		Designation
1. Structural Steel	JIS G3101 or equivalent	Rolled steel for general structure	(SS41, SS50)
	JIS G3106 or equivalent	Rolled steel for welded structure	(SM41,SM50,SM53, SM58)
	JIS G3114 or equivalent	Hot-rolled atmospheric corrosion resisting steel for welded structure	(SMA41, SMA50, SMA58)
2. Steel Bars	SII 0292-80 or equivalent	Steel bars for concrete reinforcement	U-24,U-30
	JIS G3109 or equivalent	Steel bars for prestressed concrete	
3. Steel Pipes	JIS G3444	Carbon steel tubes for general structural purposes	(STK41, STK50)
4. Fasteners	JIS B1186 or equivalent	Sets of high strength hexagon bolt, Hexagon nut and plain washers for friction grip joint	(F8T, F10T)

Note : JIS indicates Japanese Industrial Standard.

Items in parentheses ( ) are a kind of steel under JIS.

(2) Physical Constants of Steel

Physical constants of steel to be used in design calculations are given in the table below.

Kinds of Steel	Value of physical constant
Young's modulus of steel and cast steel	2.1×10^6 (kgf/cm^2)
Young's modulus of wire, steel strand and steel bar for prestressed concrete	2.0×10^6 (kgf/cm^2)
Young's modulus of cast iron	1.1×10^6 (kgf/cm^2)
Shear modulus of steel	8.1×10^5 (kgf/cm^2)
Poason's ratio of steel and cast steel	0.30
Poason's ratio of cast iron	0.25

Reinforcing Steel Bar

Reinforcing steel bars shall be U-24 or U-30 (SII, 0292-80) and conform to SII 0136 (Standar Industri Indonesia) as shown below.

(1) Round Bars

Code No.	Cross Sectional Area (cm^2)	Unit Weight (kg/m)
P6	0.283	0.222
P8	0.503	0.395
P9*	0.636	0.499
P10	0.785	0.617
P12	1.13	0.888
P13	1.33	1.04
P14*	1.54	1.21
P16	2.01	1.58
P18*	2.54	2.00
P19	2.84	2.23
P20*	3.14	2.47
P22	3.80	2.98
P25	4.91	3.85
P28*	6.10	4.83

Note, * : The size is subject to order.

(2) Deformed Bars

Code No.	Cross Sectional Area (cm^2)	Unit Weight (kg/m)
D10	0.785	0.617
D12*	1.130	0.888
D13	1.330	1.040
D14*	1.540	1.210
D16	2.010	1.580
D18*	2.540	2.000
D19	2.840	2.230
D22	3.800	2.980
D25	4.910	3.850
D29	6.610	5.190
D32	8.040	6.310
D36	10.200	7.990

Note * : The size is subject to order.

Steel bars with the standard lengths of 6 m and 12 m are available.

Tendon

(1) Tensile Strength of Wire, Strand and Bar

Material Type	Dia.	Area	Minimum Breaking Load		Maximum Tensile Strength (σ p)	
	mm	mm^2	kN	(kg)	Mpa	(kg/cm^2)
	5.0	19.6	30.4	310	1,550	15,810
Wire	5.0	19.6	33.4	341	1,700	17,340
	7.0	38.5	65.5	668	1,700	17,340
7 Wire Super	9.3	54.7	102.0	1,040	1,860	18,972
Strand	12.7	100.0	184.0	1,877	1,840	18,768
	15.2	143.0	250.0	2,550	1,750	17,850
7 Wire Regular	12.7	94.3	165.0	1,683	1,750	17,850
Strand						
	23.0	415.0	450.0	4,590	1,080	11,016
Bar	29.0	660.0	710.0	7,242	1,080	11,016
	32.0	804.0	870.0	8,874	1,080	11,016
	38.0	1,140.0	1,230.0	12,546	1,080	11,016

(2) Yield Strength of Tendon.

The yield strengths of tendon (σ py) are determined by test results or assumed as follows :

- for wire used in the as-drawn condition .... 0.75 σ p (kg/cm^2)
- for stress relieved wire .... 0.85 σ p (kg/cm^2)
- for all grade of strand and bar tendons .... 0,85 σ p (kg/cm^2)

(3) Modulus Elasticity

The following modulus elasticity of tendon (Ep) is used for structural calculation.

- for stress-relieved wire : 200 x 10^3 Mpa or 2.1 x 10^5 kg/cm^2
- for stress-relieved steel strand : 195 x 10^3 Mpa or 1.9 x 10^5 kg/cm^2
- for cold worked high tensile alloy steel bar : 170 x 10^3 Mpa or 1.7 x 10^5 kg/cm^2

Source : Structural Concrete Design Section 6

3.1.3 Allowable Stress

Concrete

Allowable compressive stress and allowable shear stress of each type of concrete are shown in the following table.

Type of Strength \ Class of Concrete		Strength							
		K-175		K-225		K-250		K-350	
		MP$_a$	kgf/cm^2	MP$_a$	kgf/cm^2	MP$_a$	kgf/cm^2	MP$_a$	kgf/cm^2
Compressive strength (28 th day σ$_{bk}$)		17.15	175	22.05	225	24.51	250	34.31	350
Bending with or without normal stress	Compression	5.88	60	7.35	75	7.84	80	0.33 σ$_{bk}$	
	Tension	0.64	6.5	0.69	7	0.71	7.2	0.48 σ$_{bk}$	
Normal Stresses	Compression	5.88	60	7.35	75	7.84	80	0.33 σ$_{bk}$	
	Tension	0.49	5	0.54	5.5	0.56	5.7	0.36 σ$_{bk}$	
Shear caused by bending or torsion	without shear reinforcement	0.54	5.5	0.64	6.5	0.66	6.7	0.43 σ$_{bk}$	
	with shear reinforcement	1.37	14	1.57	16	1.47	15	1.08 σ$_{bk}$	
Shear caused by combination of bending and torsion	without shear reinforcement	0.69	7	0.78	8	0.83	8.5	0.54 σ$_{bk}$	
	with shear reinforcement	1.76	18	1.96	20	2.06	21	1.35 σ$_{bk}$	

Note : 1 MPa = 10.2 kgf/cm^2
1 kg/cm^2 = 0.098 MPa

Allowable bond stresses of concrete are given in the following table for reinforcement not greater than 32 mm in diameter.

Type of Strength \ Class of Concrete	K-175		K-225		K-250		K350	
	MP$_a$	kgf/cm^2	MP$_a$	kgf/cm^2	MP$_a$	kgf/cm^2	MP$_a$	kgf/cm^2
Round Bar	0.59	6	0.74	7.5	0.79	8.1	1.18	12
Deformed Bar	1.18	12	1.47	15	1.70	17.3	2.36	24

Prestressed Concrete

Allowable stresses of concrete, namely compressive stress, tensile stress, shear stress and diagonal tensile stress are presented in the following table :

Allowable compressive stress of concrete (kgf/cm^2)

Kind of stress \ Compressive strength			300	400	500
Immediately after pre-stressing	Flexure extreme compressive fiber stress	(1) for rectangular section	150	190	210
		(2) for T or box section	140	180	200
	(3) Axial compressive stress		110	145	160
Others	Flexure extreme compressive fiber stress	(4) for rectangular section	120	150	170
		(5) for T or box section	110	140	160
	(6) Axial compressive stress		85	110	135

Allowable tensile stress of concrete (kgf/cm^2)

Kind of stress \ Compressive strength			300	400	500
Flexure extreme tensile fiber stress	(1) Immediately after prestressing		12	15	18
	(2) Principal loads excluding live load and impact		0	0	0
	Principal load and particular load to be regarded as principal load	(3) for floor slab or joint of pre-fabricated segment	0	0	0
		(4) Others	12	15	18
(5) Axial tensile stress			0	0	0

Allowable shear stress and allowable diagonal tensile stress of concrete (kgf/cm^2)

Kind of stress \ Compressive strength		300	400	500
(1) Shear stress		4.5	5.5	6.5
Diagonal tensile stress	(2) When considering only shear force or torsional moment	8	10	12
	(3) When considering shear force and torsional moment simultaneously	11	13	15

Reinforcing Steel Bar

Allowable stresses of reinforcing steel bars are as follows :

Kind of Stress / Steel Grade	SII U-24 or JIS SR-24		SII U-30 or JIS SD-30	
	(Mpa)	(kgf/cm^2)	(Mpa)	(kgf/cm^2)
Allowable tensile stress				
- Above ground elevation	137.25	1,400	176.47	1,800
- Below ground elevation	137.25	1,400	156.86	1,600
Allowable compressive stress	137.25	1,400	176.47	1,800

where,

U-24, U-30 : Indonesian Industrial Standard of steel bars with yield strength of 2,400 and 3,000 kg/cm^2 respectively.

SR-24, SD-30 : Japanese Industrial Standard (JIS)

Yield strength : SR-24 or U-24.....s $\geq$ 2,400 kgf/cm^2

SD-30 or U-30.....s $\geq$ 3,000 kgf/cm^2

Structural Steel

Allowable stresses of structural steel members such as H-shape steel beam, steel pipe pile, sheet pile and other steel members are as follows :

Kind of steel	Type of Steel	Tensil Strength (kgf/cm^2)	Shear Strength (kgf/cm^2)
Structural Steel	JIS SS41 or equivalent	1,400	800
Steel Pipe Pile	JIS STK41 or equivalent	1,400	800
Steel Sheet Pile	JIS SY30 or equivalent	1,800	-
Tie Lod	JIS SS41 or equivalent	900 ($\phi \geqq$ 40mm) 800 ($\phi <$ 40mm)	-

Masonry and Brick

The allowable compressive stresses of masonry and brick shall be as follows, Tensile stress shall not be allowed.

Masonry : τ ca = 15 kgf/cm^2

Brick : τ ca = 8 kgf/cm^2

Increase Rate of Allowable Stress

Allowable stresses of the above mentioned materials are increased as shown below.

Loading Combinations	Incremental Coefficient	
	Concrete Structure	Steel Structure
1. P + PP	1.00	1.00
2. P + PP + T	1.15	1.15
3. P + PP + W	1.25	1.25
4. P + PP + T + W	1.35	1.35
5. P + PP + BK	1.25	1.25
6. P + PP + CO	1.50	1.70
7. P' + EQ	1.50	1.50
8. P' + EQ + T	1.65	1.65
9. W	1.20	1.20
10. ER	1.25	1.50
11. Temporary Structural Member	1.25	1.50

where, P : Principal load

PP : Particular load to be regarded as principal load

T : Thermal force

W : Wind load

BK : Breaking force

CO : Collision force

P' : Principal load excluding live load and impact

EQ : Earthquake force

ER : Temporary load and force during construction

3.1.4 Others

Corrosion Thickness of Structural Steel

Steel structural members used for foundation work are designed in consideration of corrosion thickness as shown in the following table.

Kind of Steel Member	Standard Corrosion Thickness (mm)
Steel Pipe Pile	2 mm on outside surface
Steel Sheet Pile	1 mm on one side surface for under ground portion 2 mm on one side surface for the portion in the air and submerged portion
Other Structural Steel Member	1 mm on one side surface for the potion in fresh water 2 mm on one side surface for the portion in sea water

3.2 Loading Criteria

All river structures and road structures related to the river improvement and drainage system improvement are analyzed/designed to carry the following loads and forces and/or their combinations as required :

- Dead loads (refer to 3.1.1)
- Live load and impact/dynamic effect
- Earth pressure
- Hydrostatic force
- Hydrodynamic force
- Buoyancy
- Earthquake load
- Wind pressure
- Thermal Force

Live Load and Impact/Dynamic Effect

(1) Truck Loading on Buried Box Culvert

The truck loading on slab of buried box culvert is obtained by the following :

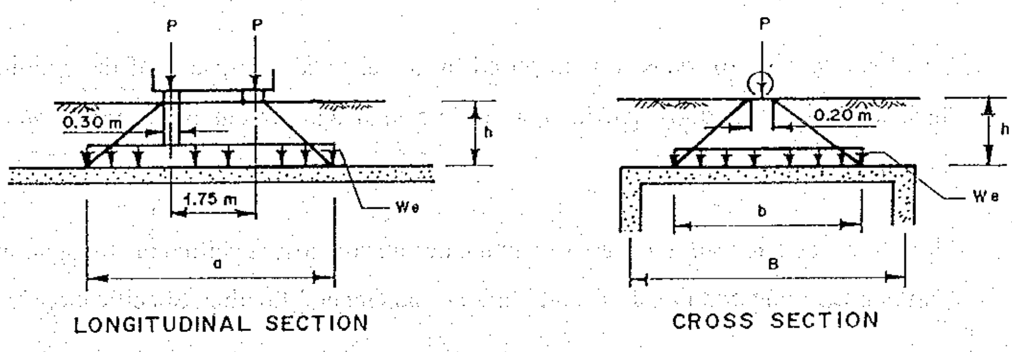
$$We = \frac{2P \cdot (1.0 + i)}{a \cdot b} \qquad \text{.......... } (b \geq B)$$

$$We = \frac{2P \cdot (1.0 + i)}{a} x \frac{2B - b}{B^2} \qquad \text{.......... } (b < B)$$

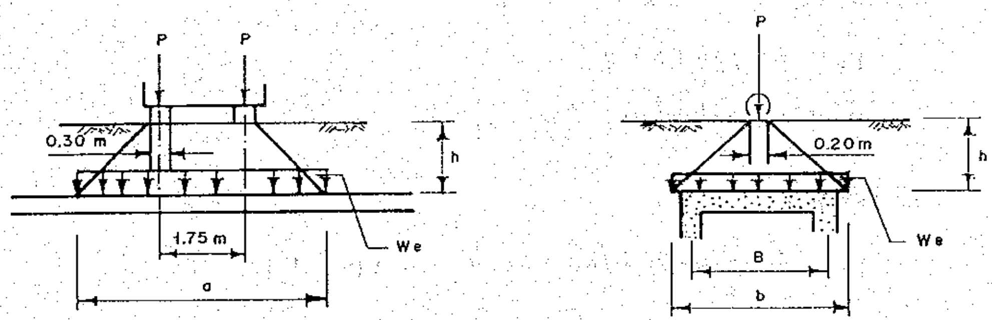
where,

We	:	distributed load (tf/m2)
a	:	width of truck (m) , a = 2.75 m
b	:	width of distributed load, b = 2h + 0.20
B	:	width of structure (m)
P	:	rear wheel load of vehicle (tf)
h	:	height of earth covering above top of slab (m)
i	:	impact coefficient, determined as follows :
		$i = 0.30$ for $h \leq 3.5$ m
		$i = 0.0$ for $h > 3.5$ m

(a) In case when "b" is less than "B"



(b) In case when "b" is equal to or greater than "B"



(2) Live Loads and Surcharge Load on/behind Concrete Structure

(a) Live load on operating decks for intake/drainage gate :

w = 3,060 Pa (0.30 tf/m^2) (Pa : pascal)

(b) Surcharge load on the ground behind retaining wall :

w = 9,800 Pa (1.00 tf/m^2) -- under normal condition

w = 4,900 Pa (0.50 tf/m^2) -- under earthquake condition

(c) Surcharge load on concrete slab during construction :

w = 9,800 Pa (1.00 tf/m^2)

(3) Live Load on Building

Live load consists of loads superimposed by the use and occupancy of the buildings. Such loads include floor live load, roof live load and weight of machines and its dynamic effect, if any.

Floor live load and roof live load used in the design are those specified in "Regulation of National Building and Finishes" and "Indonesian General Loading Specifications".

Earth Pressure

(1) Earth Pressure under the Normal Condition

(a) The earth pressure acting on movable walls is calculated by the following Coulom's formulas :

<u>Sandy Soil</u>

$$p_a = Ka \cdot \gamma \cdot h + Ka \cdot q$$

$$p_p = Kp \cdot \gamma \cdot h + Kp \cdot q$$

<u>Clayey Soil</u>

$$p_a = Ka \cdot \gamma \cdot h - 2C \cdot \sqrt{Ka} + Ka \cdot q \qquad (p_a \geqq 0)$$

$$p_p = Kp \cdot \gamma \cdot h + 2C \cdot \sqrt{Kp} + Kp \cdot q$$

$$Ka = \frac{\cos^2(\phi - \theta)}{\cos^2\theta \cdot \cos(\theta + \delta) \cdot [1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha)}{\cos(\theta + \delta) \cdot \cos(\theta - \alpha)}}]^2}$$

$$Kp = \frac{\cos^2(\phi + \theta)}{\cos^2\theta \cdot \cos(\theta + \delta) \cdot [1 - \sqrt{\frac{\sin(\phi - \delta) \cdot \sin(\phi + \alpha)}{\cos(\theta + \delta) \cdot \cos(\theta - \alpha)}}]^2}$$

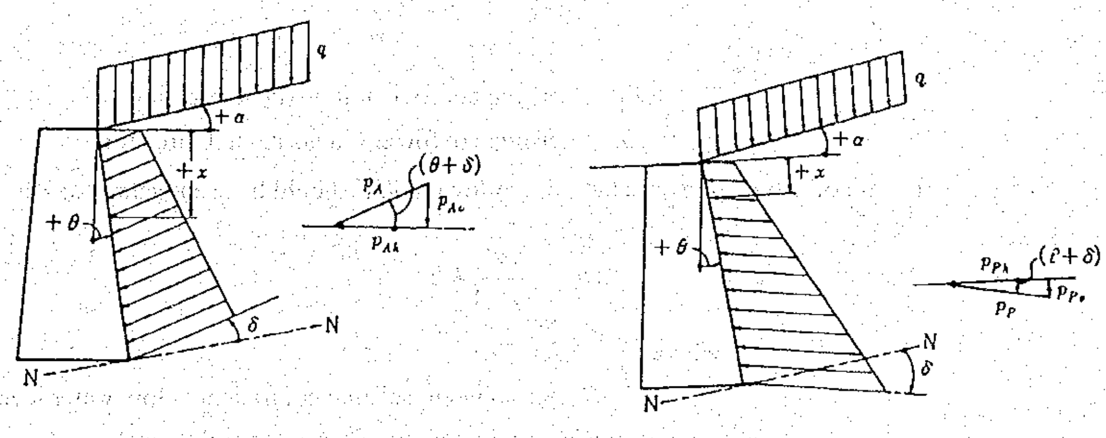
(b) The earth pressure acting on fixed walls is calculated by the following formula :

$$p_s = Ks \cdot (\gamma \cdot h + q)$$

where,

p_a : acting earth pressure (tf/m^2)

p_p	:	passive earth pressure (tf/m^2)
p_s	:	steady earth pressure (tf/m^2)
γ	:	unit weight of soil (tf/m^3)
Ka	:	coefficient of active earth pressure
Kp	:	coefficient of passive earth pressure
Ks	:	coefficient of steady earth pressure (0.5)
h	:	earth depth to acting point of earth pressures p_a, p_p and p_s (m)
c	:	soil cohesion (tf/m^2)
ϕ	:	internal friction angle of soil (degree)
q	:	surcharge in normal condition (tf/m^2)
θ	:	angle between back side surface of wall and vertical plane (degree)
α	:	angle between ground surface and horizontal plane (degree)
δ	:	friction angle of soil to concrete (degree)



N – N face : a face which is perpendicular to the back face of wall

Active Earth Pressure — Passive Earth Pressure

(2) Earth Pressure under the Earthquake Condition

Horizontal earth pressure due to earthquake is calculated by the Mononobe-Okabe's formula based on the Coulomb's theory considering seismic factor.

$$p_{ae} = Kea \cdot \gamma \cdot h - 2C \cdot \sqrt{Kea} + Kea \cdot q'$$

$$p_{pe} = Kep \cdot \gamma \cdot h + 2C \cdot \sqrt{Kep} + Kep \cdot q'$$

$$Kea = \frac{\cos^2(\phi - \theta_0 - \theta)}{\cos\theta_0 \cdot \cos^2\theta \cdot \cos(\theta + \theta_0 + \delta) \cdot [1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha - \theta_0)}{\cos(\theta + \theta_0 + \delta) \cdot \cos(\theta - \alpha)}}]^2}$$

$$Kep = \frac{\cos^2(\phi - \theta_0 + \theta)}{\cos\theta_0 \cdot \cos^2\theta \cdot \cos(\theta - \theta_0 + \delta) \cdot [1 + \sqrt{\frac{\sin(\phi - \delta) \cdot \sin(\phi + \alpha - \theta_0)}{\cos(\theta - \theta_0 + \delta) \cdot \cos(\theta - \alpha)}}]^2}$$

where,

Kea : coefficient of active earth pressure

Kep : coefficient of passive earth pressure

q' : surcharge in seismic case (tf/m^2)

θ_o : angle expressed below (degree)

$$\tan\theta_o = \frac{Kh}{1 - Kv}$$

where,

Kv : seismic coefficient in vertical direction

Kh : seismic coefficient in horizontal direction

In case of submerged structure, the following Kh' should be used instead of Kh.

$$Kh' = \frac{\gamma'}{\gamma' - 1} Kh$$

where,

Kh' : apparent seismic coefficient below water level

γ' : unit weight of saturated soil (tf/m^3)

The others are defined in normal condition.

(3) Muddy Soil Pressure

Muddy soil pressure due to sedimentation is considered for the design of gated structure. The pressure of muddy soil is estimated as follows :

$$P_e = Ce \cdot W_1 \cdot d$$

where,

Pe : muddy soil pressure at d m from the surface (tf/m^2)

Ce : coefficient of muddy soil pressure (Ce=0.4～0.6)

W_1 : unit weight of muddy soil (tf/m^3) (effective weight 0.8～1.0)

d : depth from the surface (m)

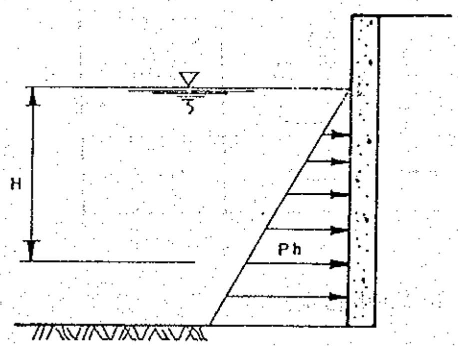
Hydrostatic Force

Hydrostatic pressure acting on the structure is calculated by the following formula :

$$Ph = \gamma_w \cdot H$$

where,

Ph	:	hydrostatic pressure (tf/m^2)
γ_w	:	mass unit weight of water (1.0 tf/m^3)
H	:	depth below the water surface (m)



For a vertical surface, the hydrostatic force acting on a unit meter width of structure is calculated using the following formula :

$$Pf = \gamma_w \cdot H^2/2$$

where,

Pf	:	hydrostatic force (tf/m)
γ_w	:	mass unit weight of water (tf/m^3)
H	:	depth of water (m)

The hydrostatic force Pf acts at a distance of H/3 from the bottom.

Hydrodynamic Force

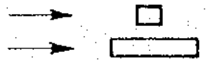
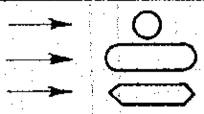
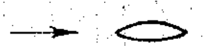
(1) Flowing Water Force

The following formula can be used for estimating the pressure acting on the structures such as bridge/weir piers installed in the stream. The flowing water force P acts at a distance of 0.6H from the water surface.

$$P = K \cdot v^2 \cdot A$$

where,

P	:	flowing water pressure (tf/m^2)
v	:	maximum flow velocity (m/sec)
K	:	coefficient of pier resistance, depends on pier dimension and shall be determined from the table below.
A	:	projective area of pier in vertical direction (m^2)

FLOW DIRECTION / PIER SHAPE	K
	0.07
	0.04
	0.02

(2) Hydrodynamic Force Due to Earthquake

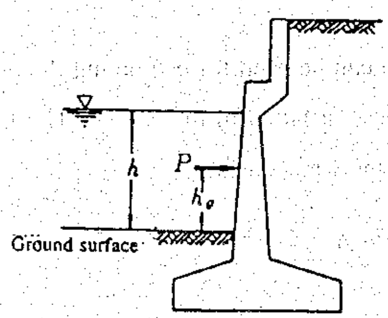
(a) Walls

Hydrodynamic force caused by earthquake acting on wall structure facing water on one side only is calculated based on the following Westergaard formula :

$$P = \frac{7}{12} Kh \cdot W \cdot b \cdot h^2 \quad , \quad hg = 2/5 \cdot h$$

where,

P	:	hydrodynamic force caused by earthquake (tf)
Kh	:	coefficient of horizontal earthquake factor
W	:	unit weight of water (tf/m^3)
b	:	width of wall structure (m)
h	:	water depth (m)
hg	:	hydrodynamic force acting depth from the bottom (m)



(b) Pier

Structures surrounded by water, such as piers which suffer the hydrodynamic force caused by earthquake, is calculated by using following formulas :

$$P = \frac{3}{4} Kh \cdot Wo \cdot Ao \cdot h \cdot \frac{b}{a} \cdot (1 - \frac{b}{4h}) \quad \text{...in case } \frac{b}{h} \leq 2.0$$

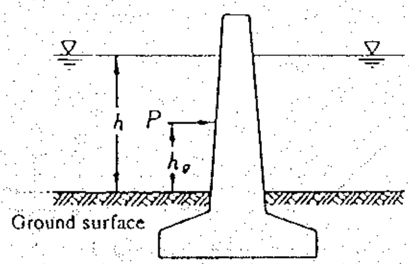
$$P = \frac{3}{4} Kh \cdot Wo \cdot Ao \cdot h \cdot \frac{b}{a} \cdot (0.7 - \frac{b}{10h}) \quad \text{... in case } 2.0 < \frac{b}{h} \leq 4.0$$

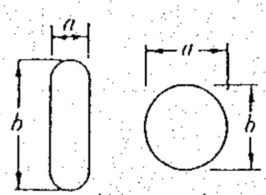
$$P = \frac{9}{40} Kh \cdot Wo \cdot Ao \cdot h \cdot \frac{b}{a} \quad \text{......in case } 4.0 < \frac{b}{h}$$

$$hg = \frac{3}{7} h$$

where,

P : total hydrodynamic pressure during earthquake (tf)
Kh : design horizontal seismic coefficient (same as E in section 3.1.6)
h : water depth (m)
Wo : unit weight of water (tf/m^3)
b : column width perpendicular to the acting direction of hydrodynamic pressure during earthquake (m)
a : column width in acting direction of hydrodynamic pressure (m)
Ao : cross sectional area of a pier (m^2)
hg : hydrodynamic force acting depth from the bottom (m)

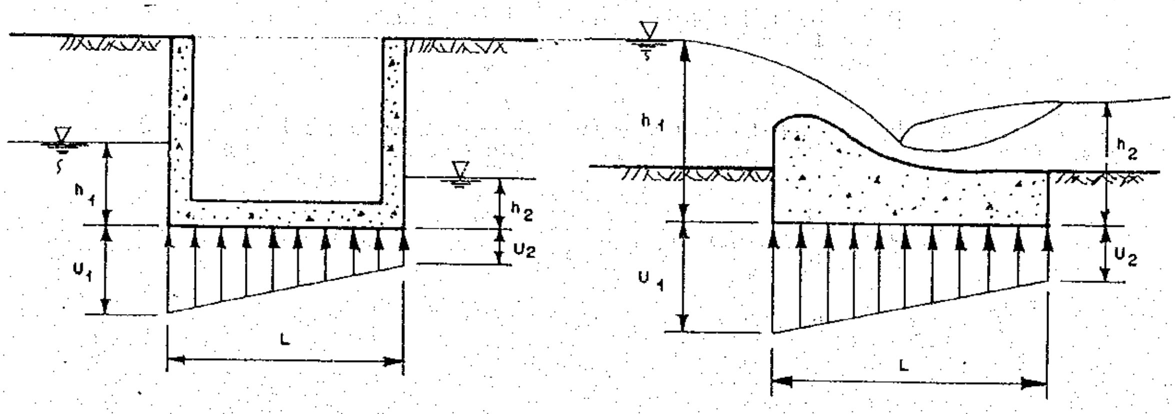




Average section

Buoyancy (Uplift)

Uplift pressure should be considered for the design of structures which are fully or partially submerged. The total buoyancy acting on the structure is calculated as follows :

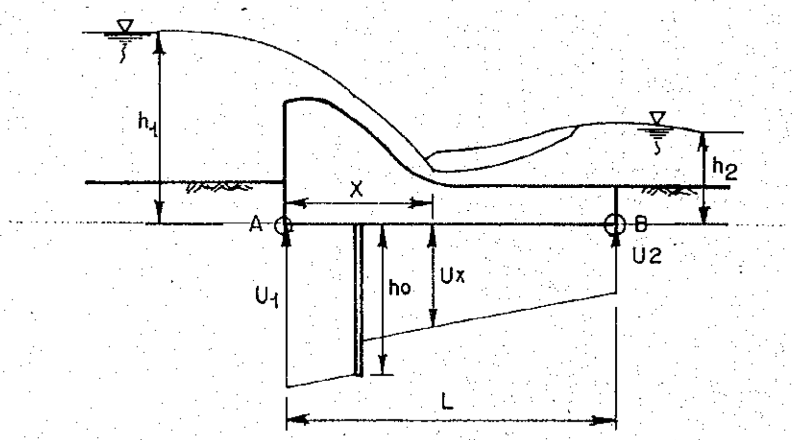


$$U = \frac{1}{2} \cdot (U1 + U2) \cdot L$$

where,

U	:	total uplift (tf/m)
U1	:	buoyancy at upstream side (tf/m^2) (U1 = W· h1)
U2	:	buoyancy at downstream side (tf/m^2) (U2 = W· h2)
L	:	bottom width of structure (m)
W	:	unit weight of water (1.0 tf/m^3)

In case the cut-off wall is installed to reduce the uplift, the uplift pressure should be calculated by using Lane's weighted creep method as follows :



$$Lt = L + 2 \cdot ho/3$$

$$Ux = h1 - (h1 - h2) \cdot \frac{lx}{Lt}$$

where,

Lt	:	total weighted creep length
lx	:	weighted creep length from A to X
Ux	:	uplift pressure at point X

Earthquake Load

The horizontal earthquake load (G) is determined using the following formula.

$$G = E \cdot M$$

where,

G	:	earthquake load
E	:	horizontal earthquake factor
M	:	total dead load

The earthquake factor is calculated using the following equations.

$$E = ad / g$$
$$ad = n (ac \cdot Z)^{m}$$

where,

ad	:	design shock acceleration (cm/s^2)
ac	:	basic shock acceleration as indicated in Table below (cm/s^2)

Return Period (Years)	Basic Acceleration ac (cm/s^2)
20	85
100	160
500	225
1,000	275

g	:	acceleration of gravity (980 cm/s^2)
Z	:	factor depending on geographic position as indicated on Fig. 3.1.
n, m	:	coefficients for soil types as indicated in table below.

Soil Type	n	m
Rock	2.76	0.71
Diluvium	0.87	1.05
Alluvium	1.56	0.89
Soft Alluvium	0.29	1.32

The vertical component of the earthquake load will no be included in the structural analysis.

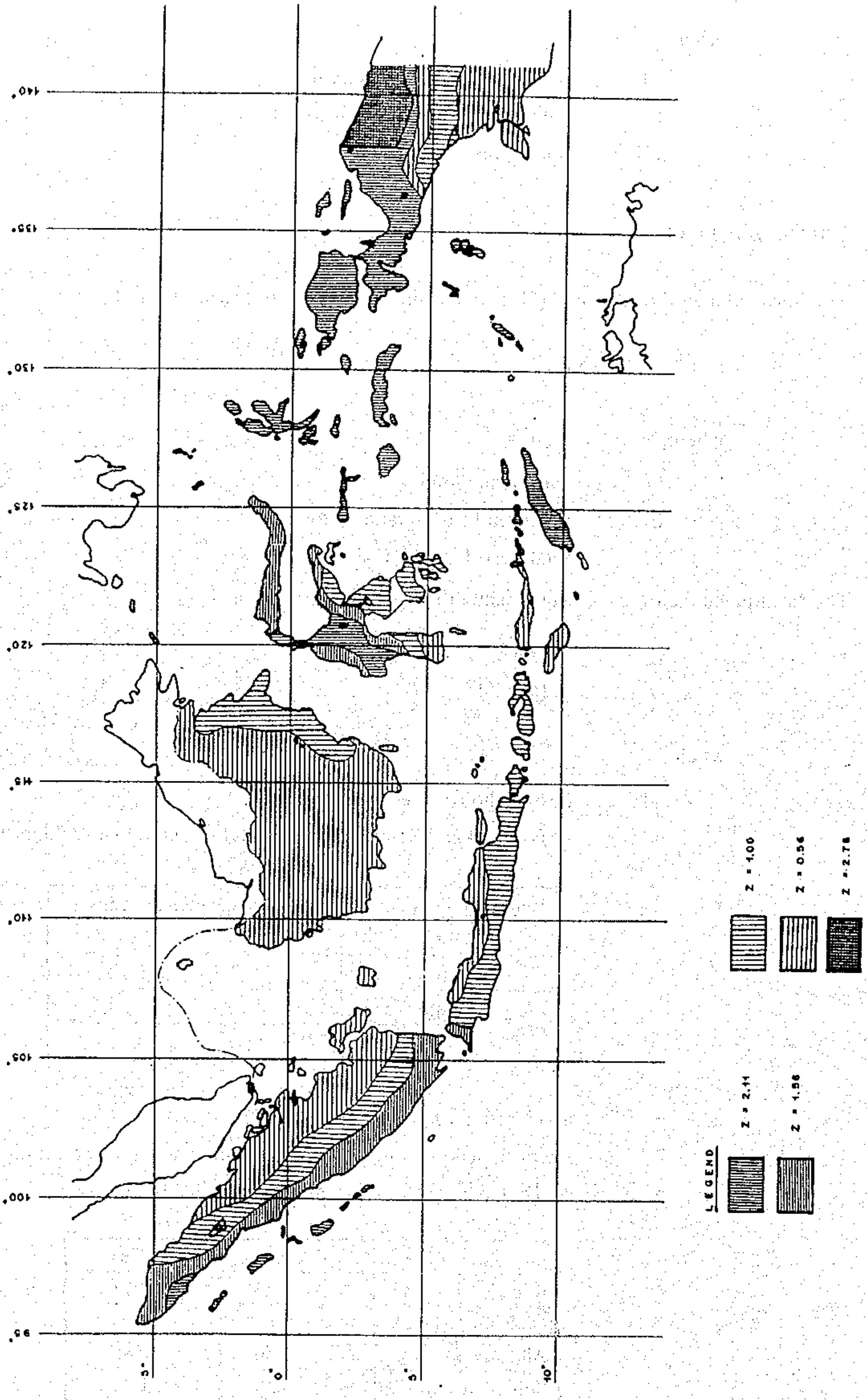


Fig. 3.1 Geographic Position and Factor Z

Wind Pressure

Wind pressure should be determined from the following formula as indicated by MPW SNI-1727-1989-F.

$$Pa = V^2 / 16$$

where,

Pa : wind pressure (kg/m^2)

V : wind velocity (km/hr)

Design wind velocities adopted are equal to or greater than 40 km/hr. A safety factor of between 1.2 and 1.5 is recommended.

Thermal Force

Thermal force caused by the temperature change is considered for the design of indeterminate concrete structures. The assumed ambient temperature for design purpose is thirty (30) degree, and structures are designed for a variation of minimum 15℃ to maximum 40℃. The coefficients of liner expansion of 1.0×1.0^{-5} and 1.2×1.0^{-5} are used for concrete member and steel member, respectively.

3.3 Coefficient/Property of Soil

Coefficients of soil which are used in stability analysis of foundation are determined by the following manners.

Unit Weight of Soil

Unit weight of soil shall be determined by results of laboratory tests, but if there is no data available at hand, the following standards of unit weight may be used.

(Unit : tf/m^3)

Type of Soil		Wet		Submerged	
		Loose	Compacted	Loose	Compacted
Natural Foundation	Sand or gravel	1.8	2.0	0.9	1.0
	Sandy soil	1.7	1.9	0.8	0.9
	Clayey soil	1.4	1.8	0.6	0.8
Embankment	Sand or gravel	2.0			1.0
	Sandy soil	1.9			0.9
	Clayey soil	1.8			0.8

Cohesion of Cohesive Soil

Cohesion of cohesive soil shall be determined by tri-axial test or unconfined compression test. When using unconfined compression test, the following formula can be used to estimate the cohesion of soft clay.

$$C = qu / 2$$

where,

C : cohesion (tf/m^2)

qu : unconfined compression strength (tf/m^2)

If there is no data available, cohesion can be estimated by using "N" value as follows :

$$C = qu/2 = \frac{N}{8} \approx \frac{N}{11} \quad \text{(for soft clay, N < 10)}$$

$$C = (0.6 \sim 1.0) . N \quad \text{(for hard clay, N > =10)}$$

Internal Friction Angle of Cohesionless Soil

The internal friction angle of cohesionless soil shall be determined either by direct shear test, unconfined compression test or tri-axial test, but for sandy soil or if there is no data available, it can be estimated by the following formula.

$$\phi = 15 + \sqrt{15.N} \leq 45^\circ \quad \text{(for N > 5)}$$

where,

ϕ : internal friction angle (degree)

N : "N" value by standard penetration test

Modulus of Deformation

Modulus of deformation shall be determined based on the unconfined compression test or trio-axial test, but if there is no data available, it can be estimated from "N" value of standard penetration test as follows :

$$Eo = 28 \cdot N$$

where,

Eo : modulus of deformation (kgf/cm^2)

N : "N" value of standard penetration test

Coefficient of Lateral Reaction of Foundation Ground

For the design of pile foundation, coefficient of lateral reaction of soil can be estimated by using the following method.

$$K = K_0 \cdot y^{-1/2}$$

where,

K : coefficient of lateral reaction of soil (kgf/cm^3)
y : standard lateral displacement of pile (y=1 cm)
K_0 : standard coefficient of lateral reaction of soil (kgf/cm^3)

K_0 is given by the following formula.

$$K_0 = \alpha \cdot E_0 \cdot D^{-3/4}$$

where,

α : coefficient given by the table below
E_0 : modulus of deformation of soil for design (kgf/cm^2), which is given by soil test or equation as shown in the table below.
D : outer diameter of pile (cm)

Relation between E_0 and α

Modulus of Deformation E_0 (kgf/cm^2)	Value of α
E_0 value of soil observed by horizontal loading test in boring hole	0.8
E_0 value of soil given by unconfined or triaxial compressive test	0.8
E_0 value of soil given by the equation $E_0 = 28 \cdot N$	0.2

Compression Index

Compression index of soil or foundation ground shall be determined by compression test, but if there is no data available, it can be estimated by the following formulas.

$$Cc = 0.009\,(LL - 10) \quad \text{or}$$

$$Cc = 0.0054\,(2.6\,W - 35)$$

where,

Cc : compression index
LL : liquid limit (%)
W : natural water content (%)

Permeability

Permeability of soil or foundation ground shall be determined based on the permeability test in site or in the laboratory, but it can also be estimated by "Creager's Method" or the following "Hazen's formula".

$$k = C\,(0.7 + 0.03\,t)\,D_{10}^{2}$$

where,

k	:	coefficient of permeability (cm/sec)
D_{10}	:	diameter of soil particles passing 10% by weight (cm)
t	:	temperature (^{0}C)
C	:	coefficient (46 ~ 150)

D_{10} (mm)	K (cm/s)	Soil Classification
0.005	3.00×10^{-6}	Coarse Clay
0.01	1.05×10^{-5}	Fine Silt
0.02	4.00×10^{-5}	
0.05	2.80×10^{-4}	Coarse Silt
0.06	4.60×10^{-4}	
0.10	1.75×10^{-3}	Very Fine Grain Sand
0.12	2.60×10^{-3}	
0.25	1.40×10^{-2}	Fine Grain Sand
0.30	2.20×10^{-2}	
0.50	7.50×10^{-2}	Middle Grain Sand
0.60	1.10×10^{-1}	
1.00	3.60×10^{-1}	Coarse Sand

Source : Creager's Method

3.4 Structural Stability

The proposed structures shall be designed to meet the following requirements of stability.

Spread Foundation

The structures with direct foundation should be safe against sliding, overturning, failure of foundation ground and uplift.

(1) Sliding

The factor of safety against sliding is determined using the following formula:

$$SF = \frac{C.A + \sum(V - U).\tan\phi}{\sum H}$$

where,

H	:	total horizontal forces
V	:	vertical forces
U	:	uplift forces
\	:	coefficient of internal friction of ground
C	:	cohesion value
A	:	structure base area
SF	:	safety factor given in the following
		SF $\geq$ 1.5 (under normal condition)
		SF $\geq$ 1.2 (under earthquake condition)

The values of cohesion and internal friction of the foundation of structure contact should be determined using appropriate geotechnical laboratory testing and evaluation.

(2) Overturning

All forces acting on part of the structure above any horizontal plane should fall within the middle third of the structure base.

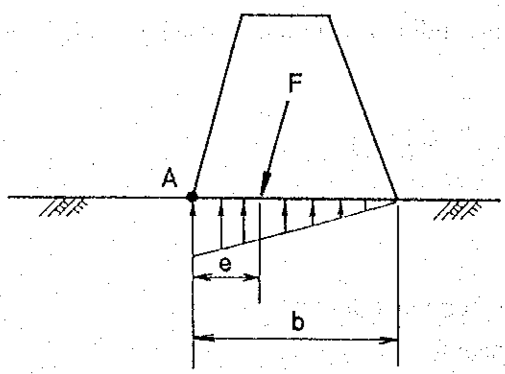
For this purpose, the following condition should be satisfied :

$$e = \frac{b}{2} - \frac{M}{N} < \frac{b}{6} \quad \text{(under the normal condition)}$$

$$e = \frac{b}{2} - \frac{M}{N} < \frac{b}{3} \quad \text{(under the earthquake condition)}$$

where,

b	:	width of base (m)
M	:	total moment about point A (tf . m)
N	:	total vertical forces (tf)
e	:	eccentricity (m)



(3) Bearing Capacity of Spread Foundation

The maximum principal stress in the spread foundation must be kept within allowable soil bearing capacity which is derived from the following :

$$Qa = \frac{Qu}{SF}$$

where,

Qa : allowable soil bearing capacity
Qu : ultimate soil bearing capacity
SF = 3 (under the normal condition)
SF = 2 (under the earthquake condition)

The ultimate soil bearing capacity of a foundation ground is calculated by the following formula :

$$Qu = A' \{\alpha \cdot k \cdot c \cdot Nc + k \cdot q \cdot Nq + 1/2 \cdot \gamma_i \cdot \beta \cdot B' \cdot N\gamma\}$$

where,

Qu : ultimate bearing capacity
A' : effective loading area on footing (refer to figure below)
α, β : coefficient depending on shape of footing as shown in the following table.

Shape of Footing	α	β
Excessively long rectangle	1.0	1.0
Circle or square	1.3	0.6
Rectangle or ellipse	1 + 0.3 B'/L'	1 - 0.4 B'/L'

c : cohesion of foundation ground (tf/m^2)

q : ground surface surcharge (tf/m^2)

$q = \gamma \cdot Df$

γ_i : unit weight of soil of ground foundation (tf/m^3)

B', L' : width and length of effective loading area as shown in the figure below (m)

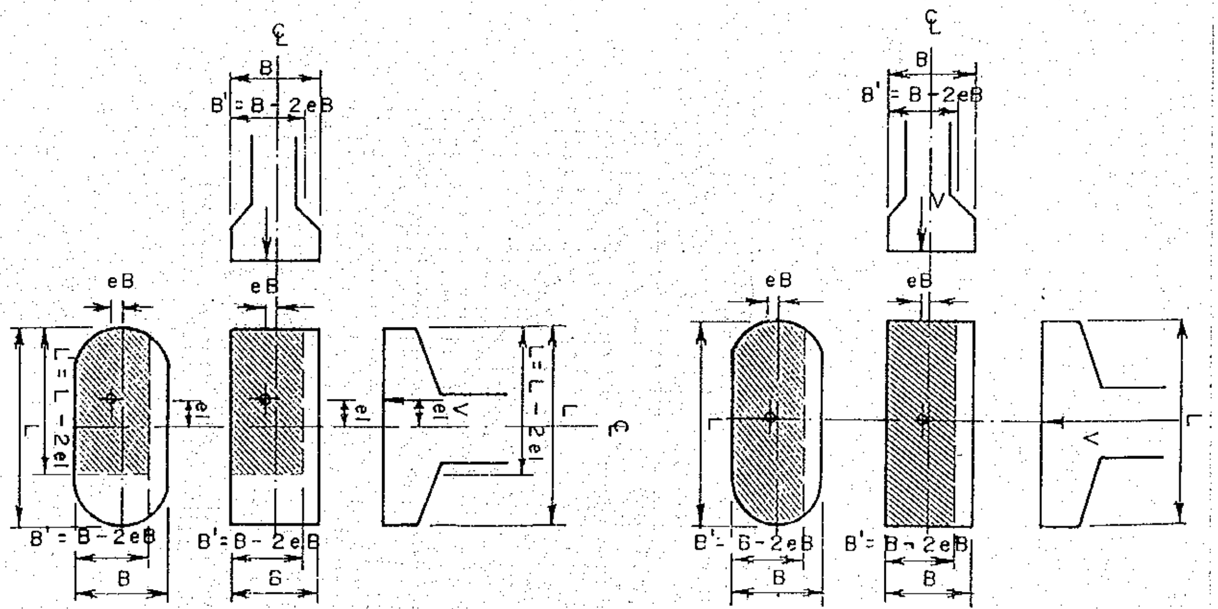
e : distance from entrance of footing to acting point of resultant force on footing illustrated in figures below (m)

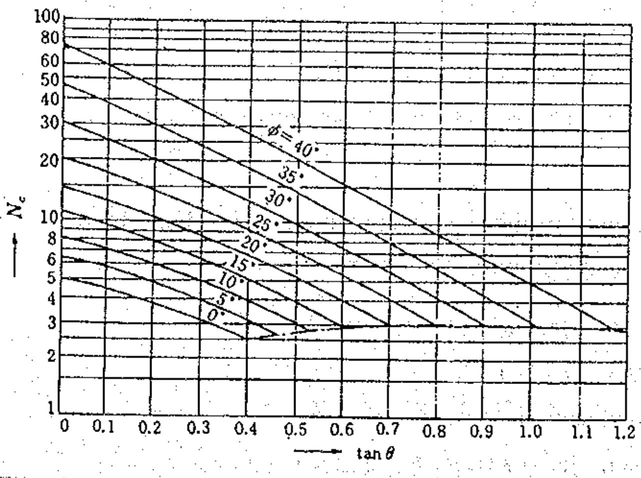
Df : depth from ground surface to bottom of footing (m)

k : coefficient ($1 + 0.3 \cdot Df'/B'$)

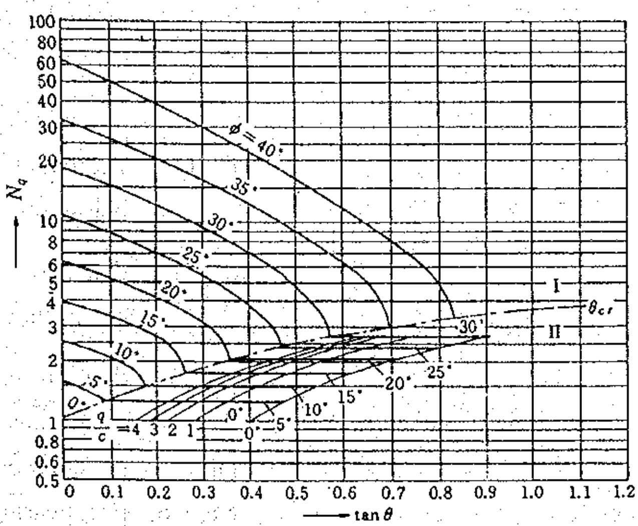
Df : structure embedded depth into base

Nc, Nq, Nr : bearing capacity factors (refer to Fig. 3.2)

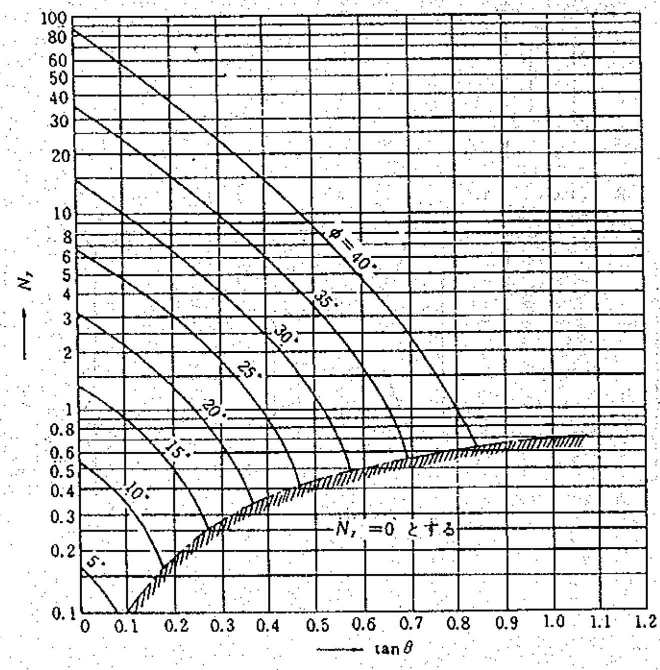




Graph for Bearing Capacity Factor Nc



Graph for Bearing Capacity Factor Nq



Graph for Bearing Capacity Factor Nr

Fig. 3.2 Bearing Capacity Factor for Spread Foundation

(4) Uplift

Adequate resistance against uplift shall be provided to prevent the structure from becoming buoyant. The factor of safety against uplift is determined as follows :

$$SF = \frac{\Sigma V}{\Sigma U}$$

where,

SF : safety factor (SF shall be more than 4/3.)
V : vertical force resisting uplift
U : uplift forces

Pile Foundation

(1) Allowable Compressive Bearing Capacity

The allowable axial compressive bearing capacity is calculated by the following formula :

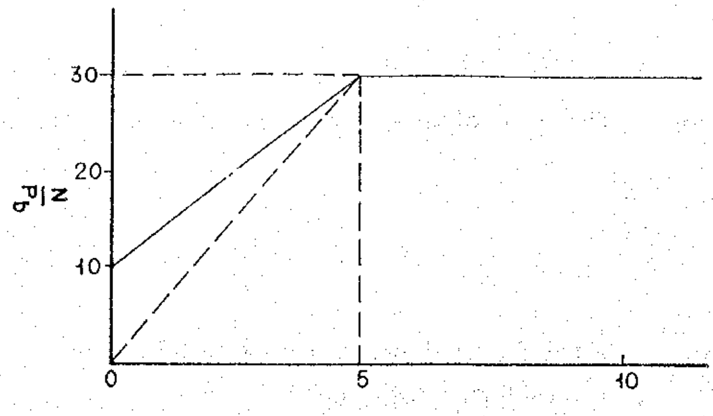
$$Ra = \{q_d \cdot A + U\,\Sigma\,(li \cdot fi)\} / SF$$

where,

Ra : allowable bearing capacity of pile (tf)
q_d : ultimate bearing capacity per unit area at pile tip (tf/m^2)
A : area of pile tip (m^2)
U : circumferential length of pile (m)
li : stratum depth (m)
fi : maximum skin friction of stratum (tf/m^2)
SF : safety factor given in the following table;

Loading Condition	Safety Factor	
	Bearing Pile	Friction Pile
Normal Condition	3	4
Earthquake Condition	2	3

In case of driven piles, the ultimate bearing capacity per unit area at the pile tip is estimated by using the following chart : (This chart is applied for the bearing stratum such as clayey soil, sandy soil and gravel).



(embedded length)/Pile diameter

where,

N : "N" value by standard penetration test

(2) Allowable Axial Pull-out Capacity

The allowable axial pull-out capacity of a pile is determined by the following formula :

$$Pa = Pu / SF + w$$

where,

Pa : allowable axial pull-out capacity at pile head (tf)

Pu : ultimate axial pull-out capacity of pile determined by ground conditions as follows (tf);

$Pu = U \sum (li \cdot fi)$

w : effective weight of pile (tf)

SF : safety factor adopted as follows;

SF = 6 (under the normal condition)

SF = 3 (under the earthquake condition)

(3) Allowable Lateral Bearing Capacity

The allowable lateral bearing capacity of a pile is calculated by the following formula :

(a) For the pile whose head is embedded into ground

$$Ha = \frac{k \cdot D}{\beta} \delta a$$

(b) For the pile whose head is protruding above ground

$$Ha = \frac{4 \cdot E \cdot I \cdot \beta^3}{1 + \beta \cdot h}$$

where,

Ha : allowable lateral bearing capacity of pile (kgf)
k : coefficient of lateral reaction of foundation ground (kgf/cm^3)
D : pile diameter (cm)
E : coefficient of elasticity of pile body (kgf/cm^2)
I : moment of inertia of cross section of pile body (cm^4)
h : length of protruding part of pile (cm)
β : characteristic value of pile (cm^{-1})

$$\beta = \sqrt[4]{\frac{k \cdot D}{4 \cdot E \cdot I}}$$

δa : allowable displacement of pile (cm)
δa = 1.0 cm (under normal condition)
δa = 1.5 cm (under earthquake condition)

(4) Allowable Displacement

Displacement of foundation structure is divided into three (3) categories, namely horizontal displacement, vertical displacement and an angle of inclination. For the design of foundation structures, allowable displacements are determined as follows:

Kind of Displacement	Normal Case	Seismic Case
Horizontal Displacement	10 mm	15mm
Vertical Displacement	10 - 20 mm	10 - 20 mm
Angle of Inclination	1/500 ～1/1000 radian	1/500 ～1/1000 radian

(5) Axial Spring Constant

The axial spring constant of a pile (Kv) can be estimated by using the following formula:

$$Kv = a \times \frac{Ap \cdot Ep}{l}$$

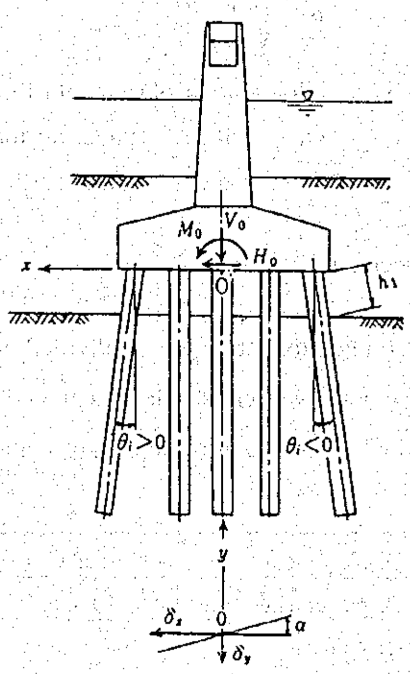
a = $0.014 \cdot (l / D) + 0.78$ (for steel pipe pile)
$0.013 \cdot (l / D) + 0.61$ (for prestressed concrete pile)
$0.031 \cdot (l / D) - 0.15$ (for cast in place pile)

where,

Kv	:	axial spring constant of pile (kg.cm)
Ap	:	net section area of pile (cm^2)
Ep	:	modulus of elasticity of pile (cm^2)
l	:	pile length (cm)

(6) Pile Reaction and Displacement of Footing

The reaction of the pile and the deformation of the footing are calculated by the deformation method described below. However when the entire pile foundation is comparatively stiff, a simplified deformation method may be used.



$$\begin{bmatrix} Axx & Axy & Ax\alpha \\ Ayx & Ayy & Ay\alpha \\ A\alpha x & A\alpha y & A\alpha\alpha \end{bmatrix} \cdot \begin{bmatrix} \delta x \\ \delta y \\ \alpha \end{bmatrix} = \begin{bmatrix} Ho \\ Vo \\ Mo \end{bmatrix}$$

where,

$$Axx = \sum_i (K1 \cdot \cos^2\theta_i + K_v \cdot \sin^2\theta_i)$$

$$Axy = Ayx = \sum_i (K_v - K1) \cdot \sin\theta \cdot \cos \cdot \theta_i$$

$$Ax\alpha = A\alpha x = \sum_i \{(K_v - K1) \cdot X_i \cdot \sin\theta_i \cdot \cos\ \theta_i - K2 \cdot \cos\theta\}$$

$$Ayy = \sum_i (K_v \cdot \cos^2\theta_i + K1 \cdot \sin^2\theta_i)$$

$$Ay\alpha = A\alpha y = \sum_i \{(K_v \cdot \cos^2\theta_i + K1 \cdot \sin^2\theta_i) \cdot X_i + K2 \cdot \sin\theta_i\}$$

$$A\alpha\alpha = \sum_i \{(K_v \cdot \cos^2\theta_i + K1 \cdot \sin^2\theta_i) \cdot X_i^2 + (K2 + K3) \cdot X_i \cdot \sin\theta_i + K4\}$$

$$\delta x_i = \delta x \cdot \cos\theta_i - (\delta y + \alpha x_i)\sin\theta_i$$

$$\delta y_i = \delta x \cdot \sin\theta_i + (\delta y + \alpha x_i)\cos\theta_i$$

$$PN_i = K_v \cdot \delta y_i$$

$$PH_i = K1 \cdot \delta x_i - K2 \cdot \alpha$$

$$Mt_i = -K3 \cdot \delta x_i + K4 \cdot \alpha$$

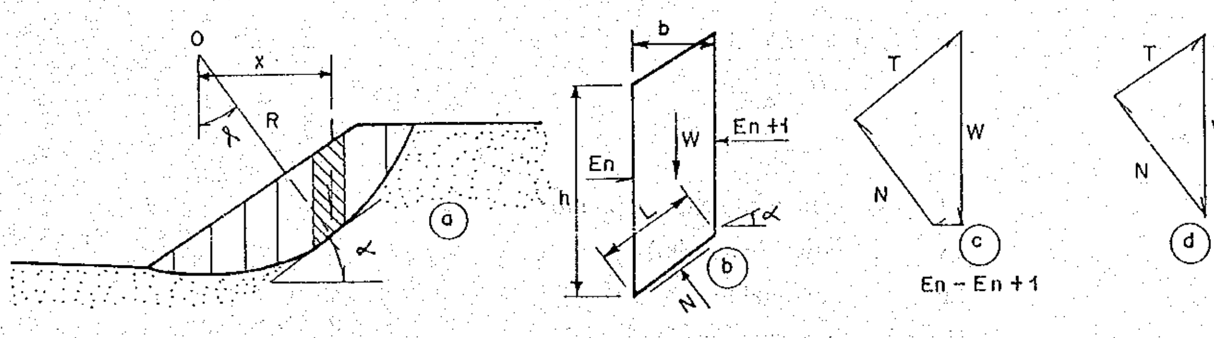
where,

Ho	:	horizontal load acting above the base of footing (ton)
Vo	:	vertical load acting above the base of footing (ton)
Mo	:	moment of the external force around the original "O" (t.m)
δx	:	horizontal displacement of the origin "O" (m)
δy	:	vertical displacement of the origin "O" (m)
α	:	angle of rotation of footing (radial)
Kv	:	axial forces induce the unit axial deflection at the cap of the pile (t/m)
Xi	:	horizontal distance of i-th pile from "O"
θi	:	butt angle of I-th pile (deg)
h	:	length of pile above design ground surface (m)

K1,K2,K3 and K4 : coefficients

Safety Against Slope Failure

The safety factor against slope failure is derived from the slip-circle method described below.



$$SF = \frac{\sum\{C.L + (N - U - Ne).\tan\theta\}}{\sum(T + Te)}$$

where,

SF	:	safety factor (SF≧1.2 - under the normal condition, SF≧1.0 - under the earthquake condition)
N	:	normal forces acting on slip circle of each slice (tf/m)
T	:	tangential force acting on slip circle of each slice (tf/m)
U	:	pore pressure acting on slip circle of each slice (tf/m)
Ne	:	normal force of seismic forces acting on slip circle of each slice (tf/m)
Te	:	tangential force of seismic forces acting on slip circle of each slice (tf/m)
θ	:	angle of internal friction of materials on slip circle of each slice (degree)
C	:	cohesion of material on slip circle of each slice (tf/m)
L	:	arch length of slip circle of each slice (m)

Piping

Hydraulic structures should be designed to resist piping failure at the downstream toe of the structure. The potential for failure due to piping can be assessed by the following empirical methods.

- Bligh's method
- Lane's method (weighted creep ratio)
- Koshla's method

Of these methods, Lane's method can be used for low head hydraulic structures. The equation of Lane's method is given as follows.

$$Cl = \frac{\sum Lv + \sum Lh / 3}{H}$$

where,

Cl	:	actual weighted creep ratio
Lv	:	vertical length (m)
Lh	:	horizontal lengths (m)
H	:	differential head in (m)

The calculated value of the weighted creep ratio should not exceed the minimum recommended values provided in the table below.

Material	Weighted Creep Ratio
Very fine sand or silt	8.5
Fine sand	7.0
Medium sand	6.0
Coarse sand	5.0
Fine gravel	4.0
Medium gravel	3.5
Coarse gravel including cobbles	3.0
Boulders with some cobbles and gravel	2.5
Soft clay	3.0
Medium clay	2.0
Hard clay	1.8
Very hard clay	1.6

Consolidation Settlement

Consolidation settlement is examined on the basis of the results of soil investigation by using Tergaghi's Consolidation Theory as described below :

$$Sc = \frac{e1 - e2}{1 + e1} H$$

$$= mv \cdot H \cdot \Delta p$$

$$= \frac{av}{1 + e1} H . \Delta p$$

where,

Sc	:	total consolidation settlement (cm)
e1, e2	:	initial void ratio and void ratio after embankment
H	:	thickness of compressive stratum (cm)
mv	:	coefficient of volume compressibility (cm^2/kgf)
Δ p	:	increased compressive stress (kgf/cm^2)
av	:	coefficient of compressibility (cm^2/kgf)

3.5 Case of Stability Analysis

Stability analysis will be performed for the cases mentioned below.

(1) Gated Weir

Figs. 3.3 and 3.4 show the loading conditions for the cases of stability analysis of the proposed Simongan Weir. The weir will be designed to satisfy the stability mentioned in the previous section for all the cases shown in Figs 3.3 to 3.4.

The notations in the figures indicate as follows :

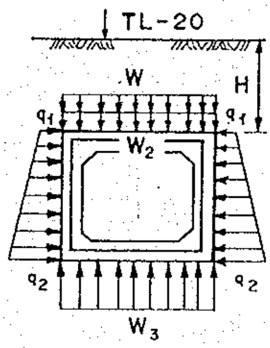
P_1 : Static hydraulic pressure in the upstream channel
P_2 : Static hydraulic pressure in the downstream channel
P_3 : Static hydraulic pressure in front of pier
P_4 : Static hydraulic pressure in back side of pier
P_0 : Flowing water force in the upstream channel
P_d : Hydrodynamic force due to earthquake
P_a : Wave pressure in the downstream
V_0 : Weight of the weir including gates and bridge
V_1 : Weight of water on the floor in the upstream
V_2 : Weight of water on the floor in the downstream
$V_{1,2}$: Total weight of water on the whole floor
V_3 : Weight of water and soil on the floor slab in the back side of pier
V_4 : Weight of soil on the floor slab in the back side of pier
W_1 : Wind pressure acting on gate pier, column, operation deck and room, and maintenance bridge
W_2 : Wind pressure acting on gate pier, column, operation deck and room
W_3 : Wind pressure acting on gates
E : Earth pressure acting on the pier from the back side
E : Earth pressure acting on the pier from the back side
E' : Earth pressure acting on the pier from the back side in seismic case
E'' : Muddy soil pressure acting on the pier in the upstream

(2) Box Culvert

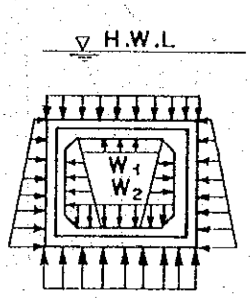
Stability of box culvert is checked for cross sectional and longitudinal directions, and loading conditions are shown in the following figure :

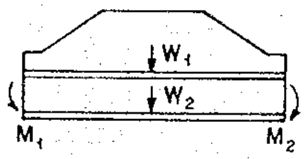
Cross sectional direction | Longitudinal direction

Case-1



Case-2





The notations in the figures indicate as follows :

Case-1

W_1 : Weight of soil + Truck loading

W_2 : Weight of upper slab concrete

W_3 : $W_1 + W_2$ + Weight of side wall

q_1 : Strength of earth pressure at upper end

q_2 : Strength of earth pressure at lower end

Case-2

W_1 : Water pressure acting on upper slab inside the box

W_2 : Water pressure acting on lower slab inside the box

The loads acting on the outside surface of box culvert are the same as those of Case-1.

Longitudinal direction

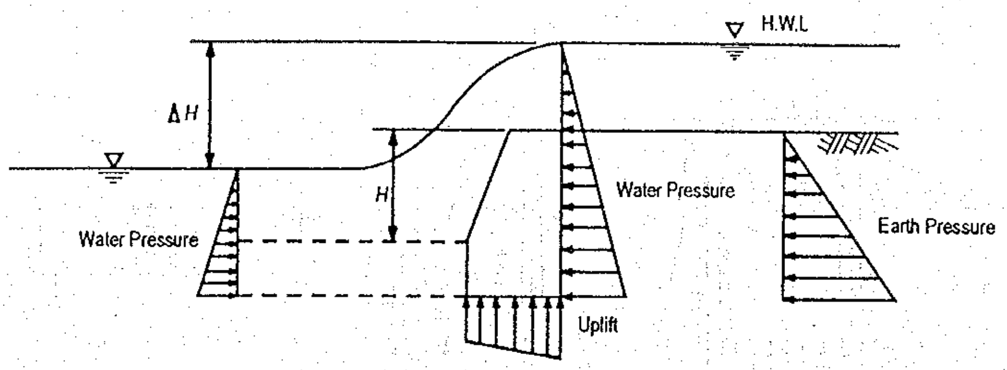
W_1 : Weight of soil + Truck loading

W_2 : Weight of box culvert + weight of water inside the culvert

M_1 M_2 : Edge moments due to gate piers and others

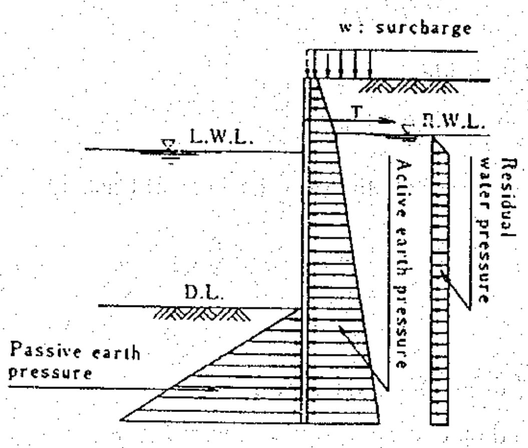
(3) Ground Sill

Ground sills or hydraulic drop structures are designed to ensure the stability against sliding, overturning and bearing capacity of foundation as well as piping under the loading condition as shown below :

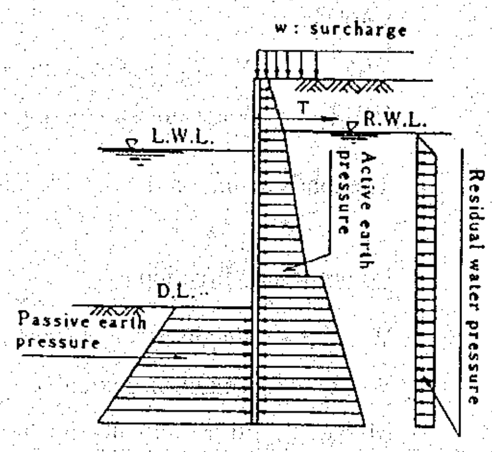


(4) Sheet Pile Wall

Sheet pile walls used for river bank protection are designed to satisfy the allowable stresses and displacement of the structure. External forces acting on sheet pile walls which should be taken into consideration in the design are earth pressure, residual water pressure, surcharge on the ground surface, seismic force as shown in the following drawing:



Earth Pressure of Sandy Soil

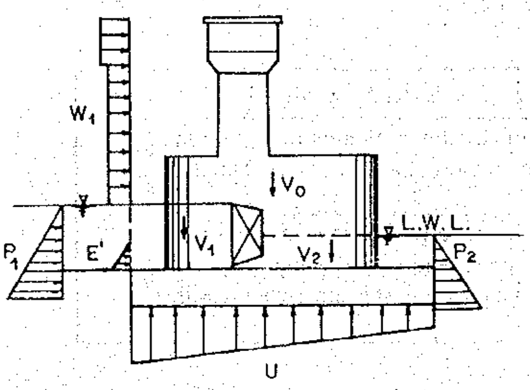
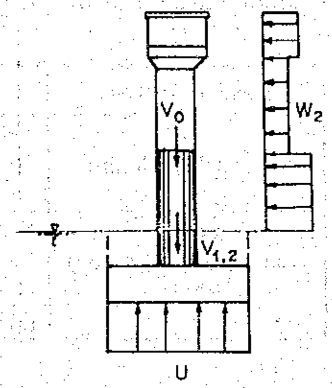


Earth Pressure of Cohesive soil

(5) Pump Station

The major components of a pump station are pump station building, discharge pipe and tank, inlet works, outlet works, water gate. The proposed pump station building consists of pile foundation works, water sink portion and pump house. Stability analysis for pump station building will be performed on condition that the structure is supported by foundation piles for the following two (2) cases:

Case of Analysis	Loads to be considered
Case-1 (Normal condition)	Self weight of structures, Weight of equipment, Hydro-static pressure, Earth pressure, Uplift
Case-2 (Earthquake condition)	Self weight of structures, Weight of equipment, Seismic load on structures and equipment Hydro-dinamic pressure, seismic earth pressure, uplift

<table>
<tr><th>Flowing Direction</th><th>Perpendicular to Flowing Direction</th></tr>
<tr><td colspan="2">Normal Condition, Water Level : Design Storage Water Level for Upstream</td></tr>
<tr><td>
</td><td>
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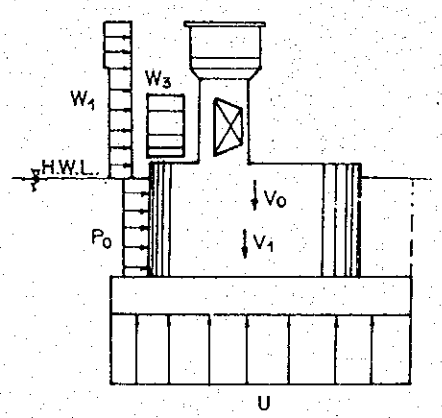
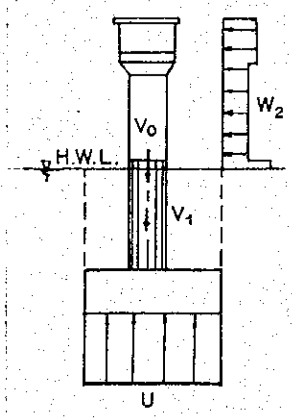
<tr><td>
</td><td>
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Fig. 3.3 (1/2) Loading Conditions for Center Piers of Weir

<table>
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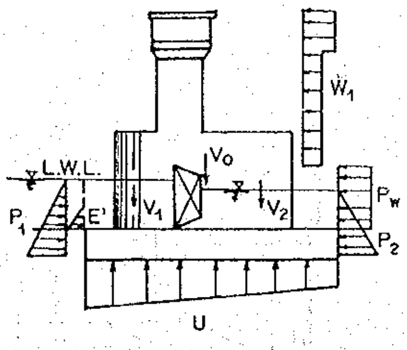
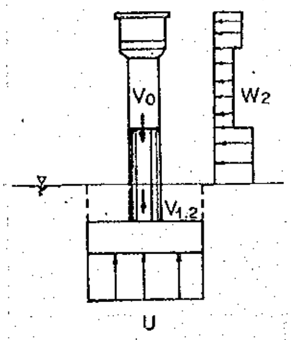
<tr><td colspan="2">Normal Condition, Water Level : Height Tide for Downstream</td></tr>
<tr><td>
</td><td>
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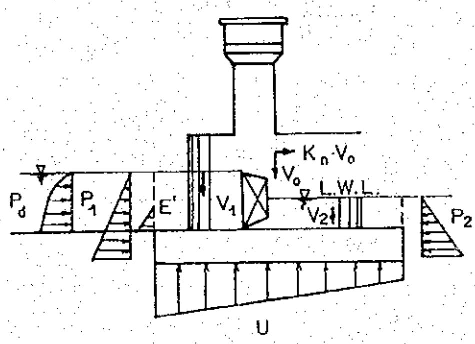
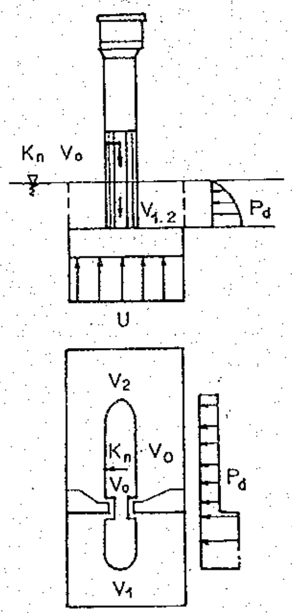
<tr><td colspan="2">Earthquake Condition, Water Level : Design Storage Water Level for Upstream</td></tr>
<tr><td>
</td><td>
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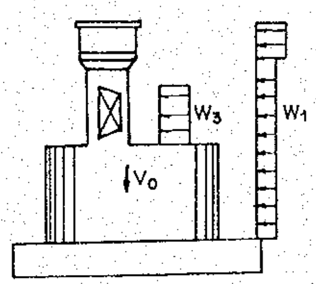
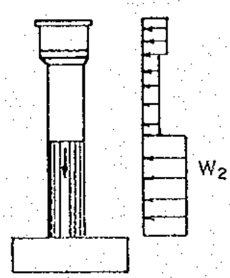
<tr><td>
</td><td>
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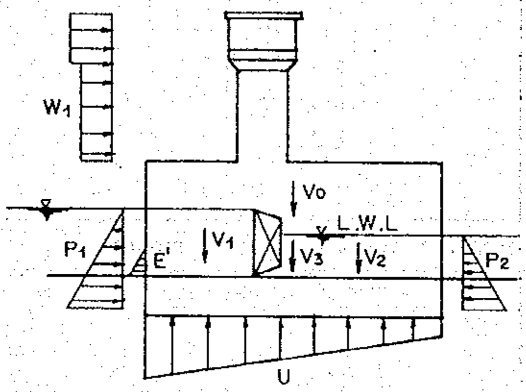
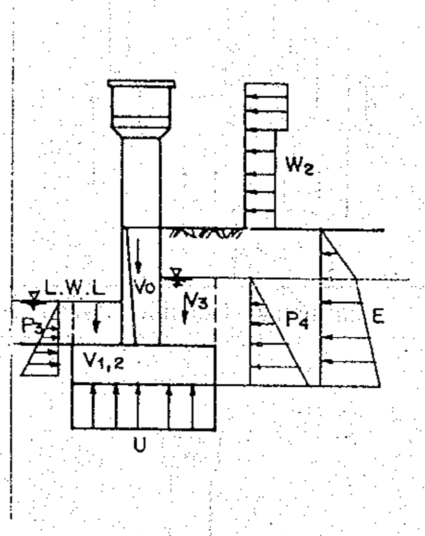
Fig. 3.3 (2/2) Loading Conditions for Center Piers of Weir

Flowing Direction	Perpendicular to Flowing Direction
Normal Condition, Water Level : Design Storage Water Level for Upstream	





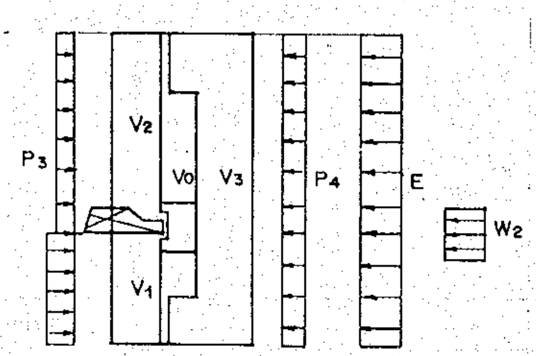
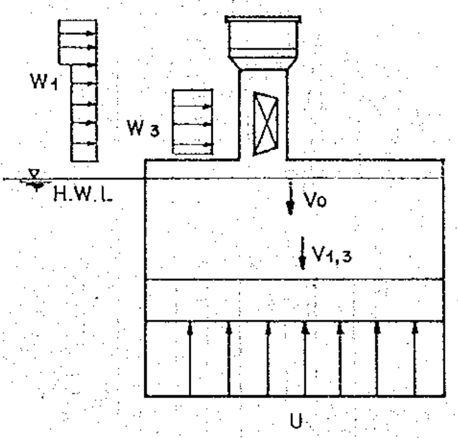
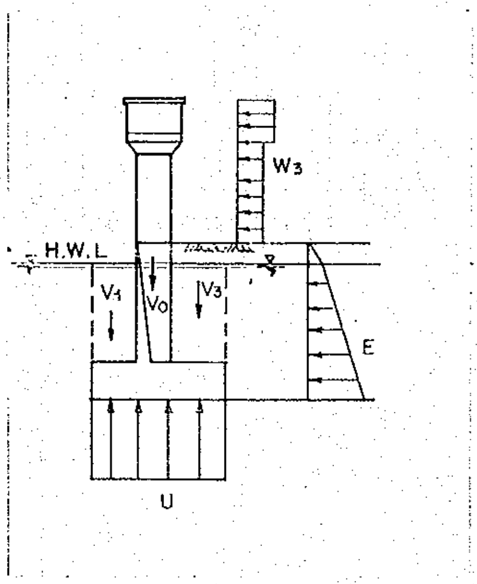


Fig. 3.4 (1/4) Loading Conditions for Side Piers of Weir

Flowing Direction	Perpendicular to Flowing Direction
Normal Condition, Water Level : Design Storage Water Level for Upstream	





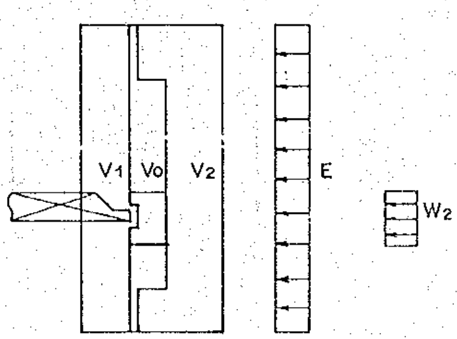


Fig. 3.4 (2/4) Loading Conditions for Side Piers of Weir

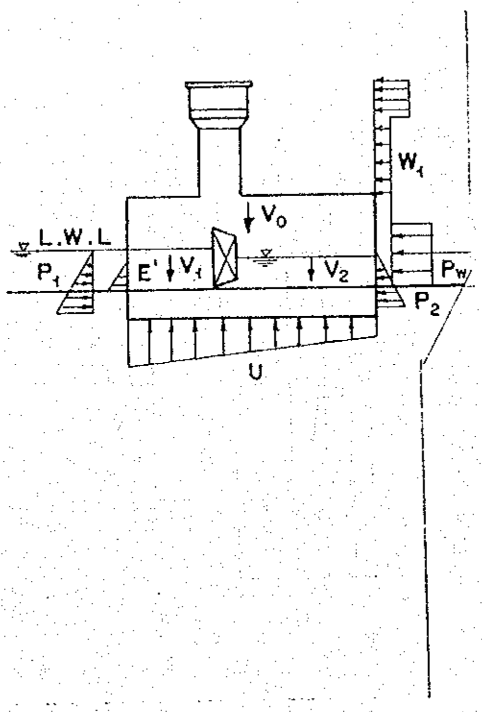
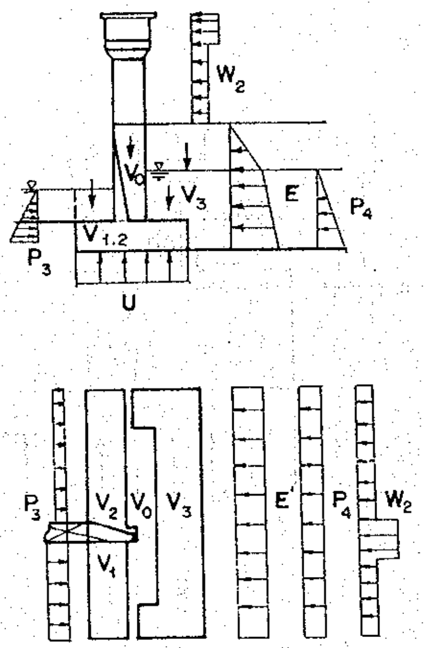
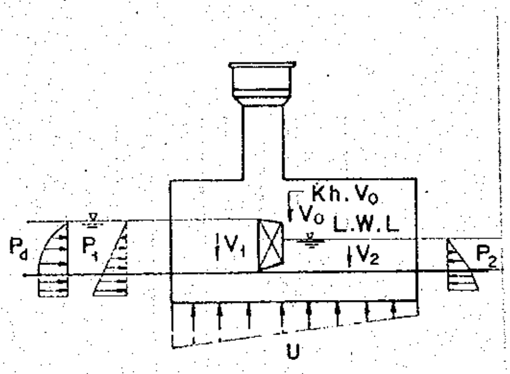
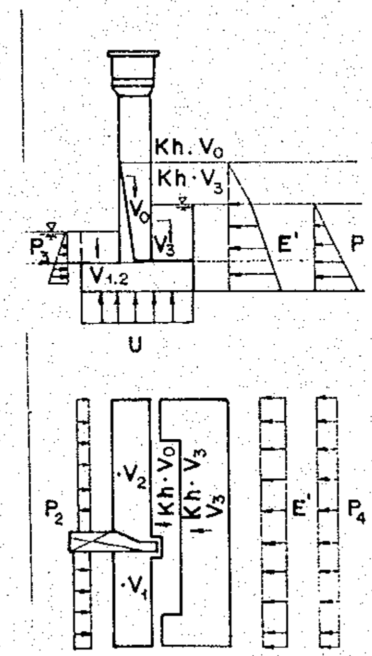
Flowing Direction	Perpendicular to Flowing Direction
Normal Condition, Water Level : High Tide for Downstream	
	
Earthquake Condition, Water Level : Design Storage Water Level for Upstream	
	

Fig. 3.4 (3/4) Loading Conditions for Side Piers of Weir

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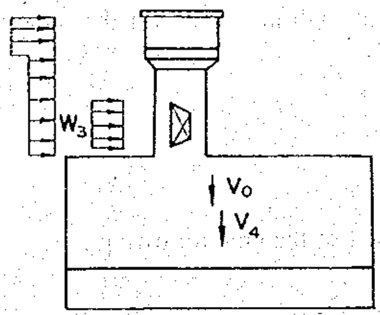

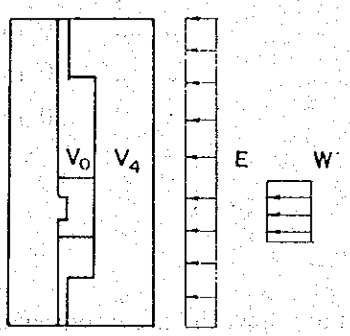

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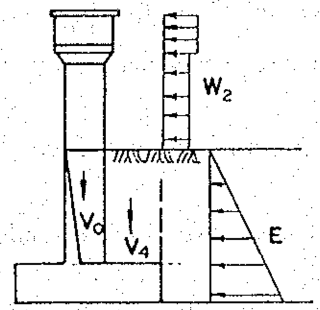

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Fig. 3.4 (4/4) Loading Conditions for Side Piers of Weir

3.6 Details in Designing

3.6.1 Reinforced Concrete

(1) Minimum Thickness of Structural Member

The minimum thickness of the reinforced concrete member shall be 25 cm for double-layer and 20 cm for single-layer reinforcement, but shall be 30 cm for the riverwork structures subjecting to river current.

(2) Minimum Concrete Cover

Protective cover for steel reinforcement shall not be less than the following :

- Important concrete footing and slab exposed to soil .... 100 mm
  (Lower side of footing supported by pile foundation) 150 mm
- Common concrete footing and slab exposed to soil .... 75 mm
- Structures exposed to weather or back-filled soil
  or flowing water .... 50 mm
- Not exposed to earth or weather
  - Beam .... 50 mm
  - Slab .... 30 mm
  - Column .... 30 mm

(3) Fillet/Haunch

Fillet/Haunch is used to increase the strength or to relieve the stress concentration at the corner where the maximum stress is anticipated to yield. The size of fillet provided at the inside corners of a box culvert or at the base of vertical wall is shown as follows :

Size of Fillet/Haunch (cm)	Span of Box (cm)	Height of wall (cm)
5 x 5	less than 100	-
7.5 x 7.5	100 to 150	0 to 250
10 x 10	150 to 250	250 to 400
15 x 15	more than 250	more than 400

3.6.2 Reinforcing Steel Bar

(1) Bar Spacing

The minimum space of the reinforcing steel bars shall satisfy the following requirements.

- four (4) cm of net spacing or wider,
- four-thirds (4/3) of the maximum size of the coarse aggregate or wider, and
- the same as the size of the bar diameter or wider.

The maximum space of the bar arrangement for slab shall be,

- two times of the slab thickness but 30 cm intervals in space or narrower for the section where the maximum bending moment occurs, and
- three times of the slab thickness but 40 cm intervals or narrower in space for the other section.

(2) Lap Splice and Embedding Length

For tensile bar, the length of lap splice and embedment shall be the length obtained from the following formula or thirty times of the bar diameter or longer.

with hook : $$L = \frac{\phi . \sigma sa}{6 . \tau oa} \geq 30\ \phi$$

without hook : $$L = \frac{\phi . \sigma sa}{4 . \tau oa} \geq 30\ \phi$$

where,

L : length of lap joint (cm)
ϕ : diameter of reinforcing bar (cm)
σsa : allowable tensile stress of bar (kgf/cm^2)
τoa : allowable bond stress of concrete (kgf/cm^2)

When deformed bars are used, the joints may be without hook. For compressive bar, the length of the lap splice and embedment shall be eighty percents (80%) of the length obtained from above formula or twenty (20) times of the bar diameter or longer.

(3) Hook and Bend of Reinforcements

The hooks of reinforcements shall be specified as below.

(i) The hook of round bar shall be 180 degree bend.

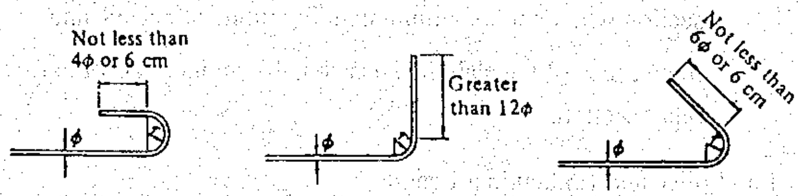
(ii) The hook of deformed bar shall be either 180 degree bend, 90 degree bend or 135 degree bend.

(iii) The hook of reinforcement shall be extended from the end of bend beyond the following length.

(a) 180 degree bend — Four (4) times the diameter of the reinforcement or 6 cm , whichever is greater.

(b) 90 degree bend — Twelve (12) times the diameter of the reinforcement.

(c) 135 degree bend — Six (6) times the diameter of reinforcement or 6 cm, whichever is greater.



(a) 180-degree bend (b) 90-degree bend (c) 135-degree bend

φ : Diameter of reinforcement (cm)

γ : Bend radius (cm)

(4) Anchorage of Reinforcements

The ends of reinforcements shall be anchored sufficiently in concrete by any method specified below. However, round bar used as tension reinforcements shall be anchored by hook.

(a) The reinforcements are buried in concrete and anchored by bond between the reinforcements and concrete.

(b) The reinforcements are buried in concrete and are anchored by means of hook.

(c) The reinforcements are anchored mechanically by means of anchor plate.

(5) Minimum reinforcement requirement for crack control and temperature and shrinkage

For crack control small bars at close spacing are provided. In general the maximum bar spacing shall be not greater than 300 mm. The following bar spacing will be adopted.

(i) When the steel bars of D10 or φ 9 are used, spacing distance = 12.5 cm.

(ii) When the steel basr of D13 or φ 13 are used, spacing distance = 25.0 cm.

3.6.3 Joints

(1) Construction Joint

Construction joints shall be provided where necessary for the practical placement of concrete. Reinforcement shall be continuously through the construction joints. As a rule, the location and the structural details of these joints need not be shown in the design drawing but be shown in the construction drawings. The location of these joints is to be determined from the type and the scale of structures or the construction conditions.

(2) Expansion Joint

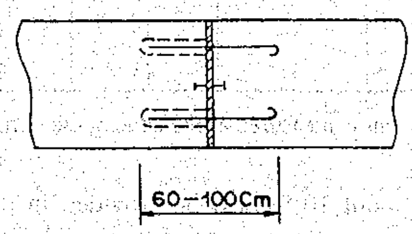
Expansion joints are used to prevent cracks caused by the expansion of the concrete. In general, they are used for the structure which is exposed to the ground surface at the portion where the shape of structure varies. The void of the joint is usually filled with a rubber or elastic filler.

(3) Contraction Joint

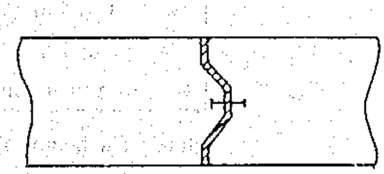
Contraction joints are used to prevent the development of cracks caused by contraction of concrete. The location and structural details of these joints shall be shown in the design drawing. The location of these joints shall be determined from the type of structure, conditions of foundation and construction. Usually, the interval of these joints for the road and river structures are as follows :

- Compressibility foundation (earth) : 10.0 ~ 15.0 m
  (for plain concrete structure) 10.0 m or less
- Non-compressibility foundation (rock) : 15.0 ~ 20.0 m
  (for plain concrete structure) 15.0 m or less

In addition to these joints, the bottom collar and dowel bars as shown in the following figures shall be provided so as to prevent the occurrence of non-uniform subsidence, or the movement of structures due to earthquake.



Dowel Bar Type Jointing



Key Type Jointing

3.6.4 Earthwork

(1) Embankment

(a) Embankment for River Dikes

River dikes will be provided in accordance with the design criteria presented in the definitive plan report. The major points are summarized as follows:

- Freeboard and Top of Dike Width

Design Discharge (m^3/s)	Freeboard (m)	Top of dike width (m)
Less than 200	0.5	3.0
200 to 500	0.8	3.0
500 to 2,000	1.0	4.0
More than 2,000	1.2 or more	5.0 or more

- Minimum side slopes are 1 : 2 (vertical to horizontal).

- Flatter slopes or berms are required based on the results of stability calculation.

- Extra embankment is considered for the expected settlements of earth dike body itself and consolidation of subsurface layer after construction in order to keep the design dike crown elevation. The extra embankment is, in principle, made based on the standard shown in the table below. In case a large settlement is anticipated due to the consolidation, the extra embankment is determined based on the estimation or calculation results of settlement.

Unit : cm

Embankment Material	Common Soil		Sand or Gravel	
Material of Sub-surface Layer	Common Soil	Sand or Gravel	Common Soil	Sandy Soil
Height of Dike				
Less than 3 m	20	15	15	10
3 to 5 m	30	25	25	20
5 to 7 m	40	35	35	30
More than 7 m	50	45	45	40

Note : The height of extra embankment is measured at the edge of dike crown.

- On the dike crown a slope of about 10 % will be provided in the cross sectional direction for drainage purpose.

(b) Embankment/Fill for Road

The basic standards of road fill are described below.

- The gradient of fill slopes are determined based on the filling materials and height of fills as shown in the following table.

Filling Material	Height of fill (m)	Slope ratio
Sand with good grading, gravel and sand mixed with gravel	Less than 5	1:1.5 to 1:1.8
	5 to 15	1:1.8 to 1:1.8
Sand with poor grading	Less than 10	1:1.8 to 1:2.o
Rock masses	Less than 10	1:1.5 to 1:1.8
	10 to 20	1:1.8 to 1:2.0
Sandy soil, hard clayey soil and hard clay	Less than 5	1:1.5 to 1:1.8
	5 to 10	1:1.8 to 1:2.0
Soft clayey soil	Less than 5	1:1.8 to 1:2.0

Where, 1 : N means 1 vertical to N horizontal.

(2) Excavation

Open cut excavation is basically made with the cut slopes mentioned below.

Sub-Grade Material	Slope Gradient	
	Permanently Exposed	Temporarily Exposed
Hard rock	1 : 0.5	1 : 0.3
Soft rock	1 : 1.0	1 : 0.5
Common Material	1 : 1.5	1 : 1.0
Riverbed Material	1 : 1.5	1 : 1.0

Where, 1 : N means 1 vertical to N horizontal.