Appendix 3 Sample of Design Criteria[*1]

1.1 CONVERSION RATIO OF UNITS

The conversion ratio between metric measurement system and foot-pound measurement system is tabulated as follows:

1 inch = 2.54 cm (1 cm = 0.3937 in.)
1 foot = 0.3048 m (1 m = 3.2808 ft.)
1 yard = 0.9144 m (1 m = 1.0936 yd.)
1 rod = 5.029 m (1 m = 0.1988 rd.)
1 mile = 1.6093 km (1 km = 0.6214 mi.)

1 square inch = 6.452 cm^2 (1 cm^2 = 0.1550 sq.in.)
1 square foot = 929.0 cm^2 (1 cm^2 = 0.0011 sq.ft.)
1 square yard = 0.8361 m^2 (1 m^2 = 1.1960 sq.yd.)

1 cubic inch = 16.387 cm^3 (1 cm^3 = 0.0610 cu.in.)
1 cubic foot = 0.0283 m^3 (1 m^3 = 35.3148 cu.ft.)
1 cubic yard = 0.7645 m^3 (1 m^3 = 1.3080 cu.yd.)

1 ounce = 28.35 g (1 g = 0.0353 oz.)
1 pound = 453.59 g (1 kg = 2.2046 lb.)

Note:

[*1]: Source from “Report on Design Criteria”, Baluchaung Hydroelectric Project No.1 Power Station, The Socialist Republic of The Union of Burma, The Electric Power Corporation, February 1986, The New Japan Engineering Consultants, Inc., Japan.

1.2 DESIGN LOADS AND ENGINEERING PROPERTIES OF MATERIALS

Principal design loads which structure must bear are : dead load, earthquake force, wind force, earth pressure, uplift etc. This section deals with these loads and engineering properties used in the detailed design.

1.2.1 Dead Load

Dead load is the self weight of structure including the weight of earth or other materials which covers the structure. Unit weight of various materials commonly used for calculation of load are as follows.

Unit Weight of Materials

(Unit : t/m3)

Materials		Unit Weight
Water		1.0
Steel		7.85
Plain concrete		2.3
Reinforced concrete	(Common)	2.4
"	(Bridge slab)	2.5
Mortar		2.15
Masonry		2.2
Brick layer		1.75

1.2.2 Live Load Acting on the Culvert

In case of structures laid under the ground, vertical distribution of live load is calculated by the following formula.

$$We = \frac{2P(1+i)}{a.b} \qquad \text{(in case } b \geq B\text{)}$$

$$We' = \frac{2P(1+i)}{a} . \frac{2B-b}{B^2} \qquad \text{(in case } b < B\text{)}$$

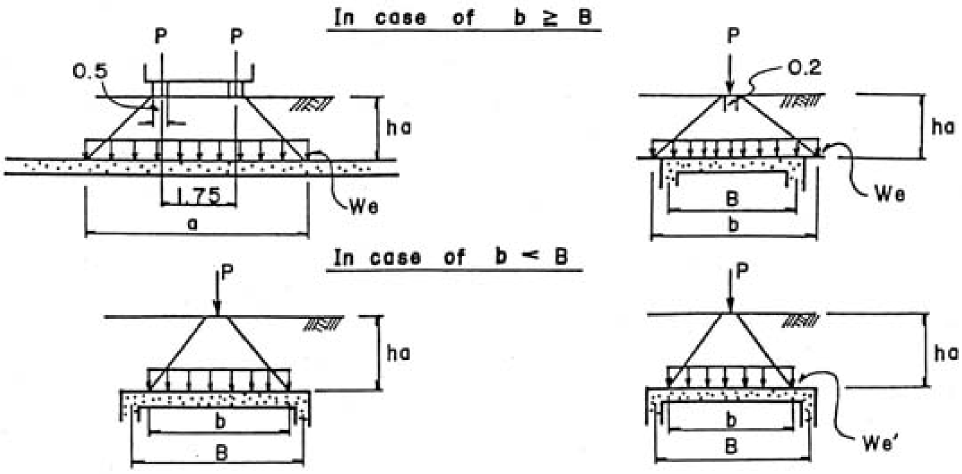
$a = 2ha + 2.25$

$b = 2ha + 0.20$

Where, We : Distributed load (t/m2)
We' : -do- (t/m2)
a : Length of distributed load (m)
b : Width of distributed load (m)
B : Width of structure (m)
P : Rear wheel load of vehicle (t)
ha : Height of earth covering (m)
i : Impact coefficient, which is determined as follows.

Impact coefficient

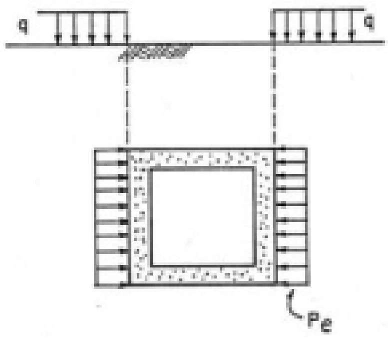
i	ha (m)
20/(50+B)	ha ≦ 0.6
0.3	0.6 < ha ≦ 1.2
0	1.2 < ha

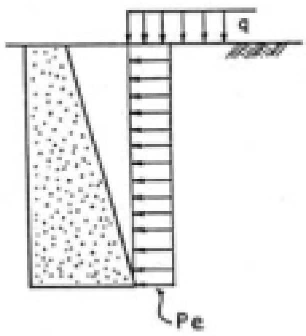


In case of ha < 0.6 m, distributed load should be caluculated by the formula of b ≧ B.

1.2.3 Live Load Acting on the Wall

Live load acting on the wall can be calculated by the following formula regardless of depth of earth covering.





Pe = k.q

where, Pe : Horizontal load due to live load (t/m2)
k : Coefficient of earth pressure
q : Equivalent uniform load (t/m2)

q = W/(L.A)

where, W : Total weight of vehicle (t)
L : Length of vehicle (m)
A : Width of vehicle (m)

1.2.4 Earth Pressure Acting on the Wall

Calculation of earth pressure acting on walls shall be made by the following formula.

$$PV = 1/2 . r . K . H^2$$

where, PV : Earth pressure (t)
r : Unit weight of earth (t/m^3)
H : Height from the ground surface (m)
K : Coefficient of earth pressure

Following coefficients of earth pressure shall be selected and applied for the load of stability or structural analysis in accordance with its applicable condition and extent.

(1) Coefficient of Earth pressure at Rest

$$K_o = 0.5$$

(2) Coefficient of Coulomb's Active Earth Pressure

a) under normal condition

$$K_A = \frac{\cos^2(\phi - \theta)}{\cos^2\theta . \cos(\theta + \delta) \cdot \left[1 + \sqrt{\dfrac{\sin(\phi - \delta) \cdot \sin(\phi - \alpha)}{\cos(\theta + \delta) \cdot \cos(\theta - \alpha)}}\right]^2}$$

where, θ : inclination of the back with the vertical
ϕ : internal friction angle of backfill material
δ : angle of wall friction between the back and backfill material
α : surface slope of backfill with the horizontal

b) under earthquake condition

$$K_{AE} = \frac{\cos^2(\phi-\theta_o-\theta)}{\cos\theta_o \cdot \cos^2\theta \cdot \cos(\delta+\theta+\theta_o) \cdot \left[1+\sqrt{\frac{\sin(\phi+\delta)\sin(\phi-\alpha-\theta_o)}{\cos(\delta+\theta+\theta_o)\ \cos(\theta-\alpha)}}\right]^2}$$

where , $\theta,\phi,\delta,\alpha$: above-mentioned

θ_o : combined angle

$= \tan^{-1} k_h/(1-kv)$

k_h= horizontal component of earthquake coefficient

k_v= vertical component of earthquake coefficient

(3) Coefficient of Rankine's Active Earth Pressure

a) under normal condition

$$K_A = \cos\alpha \cdot \frac{\cos\alpha-\sqrt{\cos^2\alpha-\cos^2\phi}}{\cos\alpha+\sqrt{\cos^2\alpha-\cos^2\phi}}$$

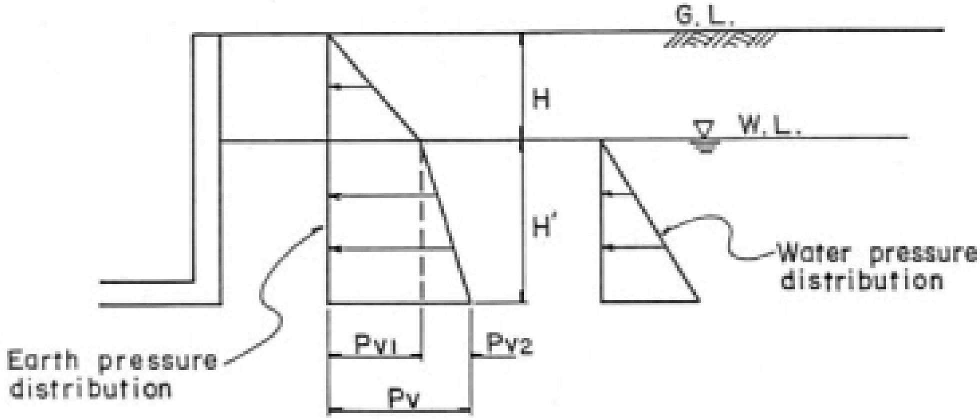
where, α,ϕ: above-mentioned

b) under earthquake condition

$$K_{AE} = \frac{\cos(\theta_o+\alpha)}{\cos^3\theta_o} \cdot \left[\frac{\cos(\theta_o+\alpha)-\sqrt{\cos^2(\theta_o+\alpha)-\cos^2\phi}}{\cos(\theta_o+\alpha)+\sqrt{\cos^2(\theta_o+\alpha)-\cos^2\phi}}\right]$$

where, θ_o,α,ϕ: above-mentioned

In case that a ground water level exists at rather high position, the earth pressure acting on the wall shall be calculated as follows.



$$P_v = P_{v1} + P_{v2}$$
$$= 1/2 \cdot r \cdot K \cdot H^2 + 1/2 \cdot r' \cdot K \cdot H'^2$$

where, r' : Submerged density of earth

= r-1

1.2.5 Hydraulic Pressure

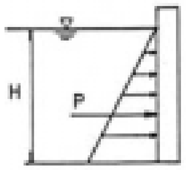
Total hydraulic pressure acting on a plane surface is calculated by the following formula.

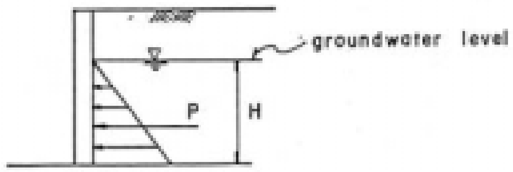
$$P = 1/2.Wo.H^2$$

where, P : Total hydraulic pressure (t)

Wo : Unit weight of water (t/m^3)

H : Water depth (m)





Hydrodynamic pressure due to earthquake acting on a gravity type dam is calculated by Westergaard's formula as follows.

$$P_{max} = \frac{7}{8} W_o \alpha \sqrt{hy}$$

$$P_d = \frac{7}{12} W_o \alpha h^{1/2} y^{3/2}$$

$$Y = \frac{2}{5} y$$

where, P_{max} : Hydrodynamic pressure at water depth y

w_o : Unit weight of water

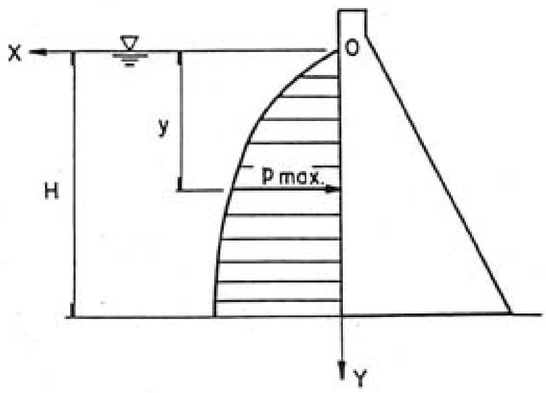
α : Seismic coefficient of dambody in horizontal direction

h : Water depth of the reservoir

y : Water depth

P_d : Total hydrodynamic pressure from the water surface down to the water depth y

Y : Distance between the acting point of P_d and the water depth y



1.2.6 Uplift

The uplift is caused by the seepage pressure in the foundation rock or soils. The total uplift acting on the structure is calculated as follows.

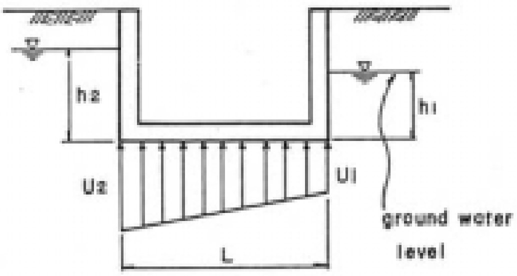
$U = 1/2.(U_1+U_2).L$

where, U : Total uplift (t/m)

U_1 : Uplift at right side (t/m^2) ($U_1=h_1$)

U_2 : Uplift at left side (t/m^2) ($U_2=h_2$)

L : Bottom width of structure (m)



1.2.7 Earthquake Force

Earthquake force acting on the structure is calculated by the following formula.

$K=Kh.G$

where, K : Horizontal force (t)

G : Dead load of structure (t)

Kh: Earthquake coefficient =0.15

1.2.8 Wind Load

on flat surface		150 kg/cm^2
on cylindrical surface		100 kg/cm^2
on lattice member	the windward	150 kg/cm^2
	the leeward	75 kg/cm^2

1.2.9 Physical Properties of Soil

Physical properties of backfill materials are as follows. As to the physical properties of embankment material, refer to section, 2.2.7 of Part II.

Physical properties	Unit	Backfill Material	
		Free drain	Random
1. Wet density	t/m^3	2.0	1.8
2. Saturated density	t/m^3	2.0	2.0
3. Submerged density		1.0	1.0
4. Internal friction angle	Degree	30	25
5. Cohesion	t/m^2	0	0

1.2.10 Bearing Capacity of Foundation

The bearing capacity of foundation for structures is estimated from N-value, which is obtained from the penetration test and soil test.

(a) Bearing capacity of sand foundation

Bearing capacity of sand foundation can be estimated from Fig. I-1 which is prepared based on Peck-Henson-Thornburn formula. The figure shows the relations between N-value and bearing capacity in accordance with the depth of penetration and the width of footing under the conditions of (i) existence of groundwater and (ii) non-existence of groundwater.

(b) Bearing capacity of clay foundation

Bearing capacity of clay foundation can be estimated from Table I-1 which is prepared based on Terzaghi-Peck formula. In using this table to obtain "qa" (Allowable bearing capacity), it is advised that "qu" (Unconfined compression strength) should be used in place of N-value, if "qu" has been estimated already as the result of the unconfined compression test. Because the relation between "qa" and N-value cannot be decided clearly.

(c) Bearing capacity of rock foundation

Bearing capacity of rock foundation can be estimated from Table I-2 which is prepared in Design Standard No.9, Bureau of Reclamation, USA.

1.2.11 Pile foundation

A pile foundation can be chosen among several different types of piles such as wood, cast-in-place concrete, pre-cast reinforced concrete, and steel. The final choice should be made in due consideration of cost and features of the works.

In general, wood piles are used in case that the pile length is less than 10 m and the safe design load is less than 10 tons, whereas the concrete piles are used in case the pile length is less than 20 m. Steel piles are used in severer conditions.

The following formula is used to estimate the safe design load per pile.

$$Ra = Ru/n = (Ruf + Rup)/n$$

where, Ra : Safe design load per pile (ton)
Ru : Ultimate bearing capacity (")
Ruf : Bearing capacity due to surface friction (")
Rup : Bearing capacity due to point resistance (")
n : Safety factor (3 for normal condition and 2 for earthquake)

For estimating the ultimate bearing capacity, various theoretical formulae have been used. But, the results usually give wide discrepancies due to many assumptions involved. In this project, the Terzaghi's formula will be used since it gives good results in case of shallow piles in rather clayey soils. The formula is given below.

$$(Ruf + Rup) = U.1.f + q.A$$
$$= 2\pi r.1.f + \pi \cdot r^2.q \text{ (in case of round pile)}$$
$$q = 1.3.C.Nc + r.1.Ng + 0.6.r.\gamma.Nr$$

where, U : Length of periphery (m)
l : Length of pile (m)
f : Surface friction between pile and soil (t/m^2)
q : Point bearing capacity (ton)
A : Area of pile tip (m^2)
r : Radius of pile (m)
C : Cohesion (t/m^2)

Nc: Bearing capacity factor
(Refer to Fig. I-2)
Ng: Bearing capacity factor
(Refer to Fig. I-2)
γ : Unit weight of soil (t/m^2)
Nr: Bearing capacity factor
(Refer to Fig. I-2)

The cohesion can be estimated in relation with N-value as shown below.

<u>N Value and Cohesion</u>

(Unit : t/m^2)

N-Value	Consistency	Cohesion, C
>30	Hard	20
15-30	Very stiff	12
8-15	Stiff	6
4- 8	Medium	3
2- 4	Soft	1.5
< 2	Very soft	0

1.2.12 Requirement of Concrete and Reinforced Concrete

(1) Modulus of Elasticity

a. Modulus of elasticity used for area and stress calculation of reinforced concrete

	Modulus of elasticity (kg/cm^2)
Reinforcing Steel (E^s)	2.1×10^6
Concrete (E^c)	1.4×10^5
Ratio of Moduli	$n = E^s/E^c = 15$

b. Modulus of elasticity used for calculation of statically indeterminate forces and elastic deformations

σ_{28} (kg/cm^2)	E^c ($10^5 kg/cm^2$)	G^c ($10^5 kg/cm^2$)	ν	n
210	2.55	1.11	1/6	≒10
180	2.40	1.04	1/6	≒10

where, σ_{28} = Compressive strength of 28-day age
G^c = Modulus of rigidity
ν = Poisson's ratio
n = Ratio of moduli
Ec/Gc = 2.3

(2) Allowable Stress

Reinforced Concrete

(Unit: kg/cm^2)

	σ^{28} (kg/cm^2)	
	210	180
(A) Flexure		
Compressive fiber stress,	70	60
Tensile fiber stress	0	0
(B) Shear		
Beams without web reinf't	4.2	4.0
slabs without shear reinf't	8.5	8.0
Beams and slab with diagonal tension reinf't	19.0	18.0
(C) Bond		
Deformed bar	15.0	14.0
Round bar	7.5	7.0
(D) Bearing		
Load on full area	60.0	50.0
Load on partial area	$\sigma ca = (0.25+0.05A/A')\cdot\sigma^{28}$ but $\sigma ca \leqq 0.5\sigma^{28}$	

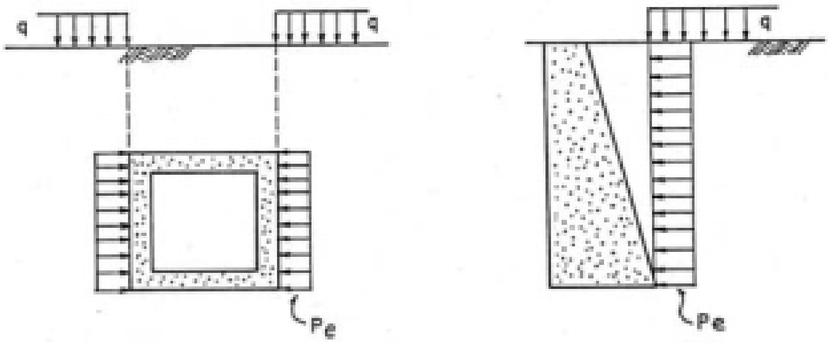
where, A = full area of concrete

A'= loaded area

In case of ha < 0.6 m, distributed load should be caluculated by the formula of b ≥ B.

1.2.3 Live Load Acting on the Wall

Live load acting on the wall can be calculated by the following formula regardless of depth of earth covering.



Pe = k.q

where, Pe : Horizontal load due to live load (t/m2)

k : Coefficient of earth pressure

q : Equivalent uniform load (t/m2)

q = W/(L.A)

where, W : Total weight of vehicle (t)

L : Length of vehicle (m)

A : Width of vehicle (m)

(3) Increase in Allowable Stress

Under short term loading condition, allowable stresses designated can be increased by the following percentages;

Load Condition	Thermal stress not considered	Thermal stress considered
Normal	0%	15%
Design flood	25%	40%
Earthquake	50%	65%
Wind	20%	35%
Under construction	25%	40%
Grouting operation	50%	65%

If combination of short term loading is applied, an allowable stress can be increased up the the sum of increment, but the maximum increment is limited to 100% for the allowable stress of concrete and 65% for steel.

Note = This provision is applied for stress analysis but is not for stability analysis.

(4) Linear Expansion Coefficient

The following linear expansion coefficients of concrete and reinforcing bar are adopted for the short term loading condition of temperature change.

$\alpha = 1.0 \times 10^{-5}$/1 degree centigrade (1°c)

Thermal change

$\Delta t = \pm 15$°c (for normal structure)

$\Delta t = \pm 10$°c (for massive structure of which the minimum dimension is larger than 70 cm.)

(5) Reinforcing Bar Requirement

The size and weight of round and deformed steel bars are tabulated below, which shall be used for reinforcement of concrete.

Nominal size	Diameter (mm)	Area (cm^2)	Perimeter (cm)	Weight (kg/m)
(Round bar)				
ϕ 6	6	0.2827	1.885	0.222
ϕ 9	9	0.6362	2.827	0.499
ϕ 13	13	1.327	4.084	1.04
ϕ 16	16	2.011	5.027	1.58
ϕ 19	19	2.835	5.969	2.23
ϕ 22	22	3.801	6.911	2.98
(Deformed bar)				
D 13	12.7	1.267	4.0	0.995
D 16	15.9	1.986	5.0	1.56
D 19	19.1	2.865	6.0	2.25
D 22	22.2	3.871	7.0	3.04
D 25	25.4	5.067	8.0	3.98
D 29	28.6	6.424	9.0	5.04
D 32	31.8	7.942	10.0	6.23

1.2.13 Safety Factor Requirement

Loading Condition	Weir and Important Structure ∠1		Anchor block ∠2		Wall ∠2	∠3
	Slide	Overturn	Slide	Overturn	Slide	Overturn
Normal	4.0	M.T.∠4	1.2	M.T.	2.0	1.5
Extreme	4.0	M.T.	1.2	M.T.	1.5	1.2

∠1 : $S.F. = \frac{f\Sigma V + cA}{\Sigma H}$

∠2 : $S.F. = \frac{f\Sigma H}{\Sigma H}$

∠3 : $S.F. = \frac{\text{Resisting moment}}{\text{Overturning moment}}$

∠4 : M.T. = middle third

where , S.F. : factor of safety
f : friction coefficient
ΣV : sum of vertical forces
ΣH : sum of horizontal forces
c : cohesion or unit shearing resistance
A : area of base

1.2.14 Friction Coefficient

Material	Friction Coefficient
Concrete to concrete	0.70

Concrete to hard rock	0.65
Concrete to soft rock	0.50
Concrete to earth or sand and gravel	0.30

1.2.15 Roughness Coefficient

Roughness coefficient of different materials, which is listed below, shall be used for the hydraulic analysis on Manning's formula.

Surface material	Roughness coefficient
Steel	0.012
Concrete lining without aquatic insect	0.014
" with aquatic insect	0.019
Masonry	0.020
Earth canal without weeds	0.030
Natural channel or diversion channel	0.035

1.2.16 Slope of Cut and Embankment

Slopes of open cut, embankment and others shall be designated to confirm the following requirements. They can be modified if otherwise specified in the drawing or directed by the Engineer.

(1) Slope of Open Cut

Material	Slope	Description
Rock	1 : 0.5	for permanent slopes regardless of slope protection
	1 : 0.3	for temporary or backfilled slopes
Weathered Rock	1 : 0.5	for permanent slopes with slope protection
	1 : 0.8	for permanent slopes without slope protection
	1 : 0.5	for temporary or backfilled slopes
Common	1 : 1.5	for permanent slopes
	1 : 0.5	for temporary or backfilled slopes less than 5m in excavation height.
	1 : 1.0	for temporary or backfilled slopes more than 5 m in excavation height.

A berm of one point five (1.5) m in width shall be provided at every seven point five (7.5) m high interval in cut slopes.

(2) Slope of Embankment

Material	Slope
Selected	1 : 1.8
Random	1 : 2.0

A berm of two (2) m in width shall be provided at every five (5.0) m high interval in embankment slopes.

Table I-1 ALLOWABLE BEARING CAPACITY OF CLAYS

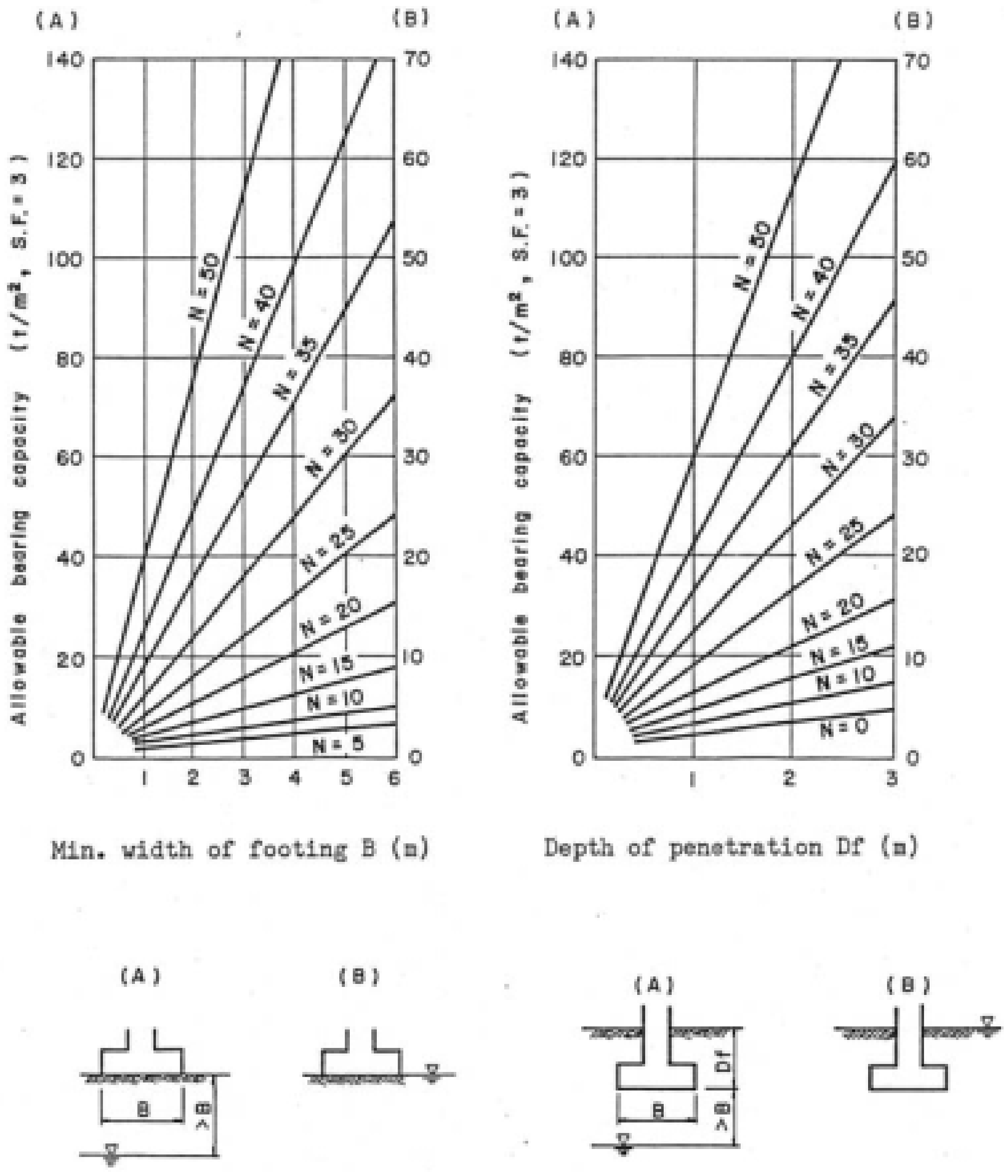
Consistency of clays	N-value	qu (kg/cm^2)	qd (t/m^2)	qds (t/m^2)	qa (t/m^2)		qa' (t/m^2)	
					square	continuous	square	continuous
very soft	below 2	below 0.25	below 7.1	below 9.2	below 3.0	below 2.2	below 4.5	below 3.2
soft	2 - 4	0.25 - 0.5	7.1 - 14.2	9.2 - 18.5	3.0 - 6.0	2.2 - 4.5	4.5 - 9.0	3.2 - 6.5
median	4 - 8	0.5 - 1.0	14.2 - 28.5	18.5 - 37	6.0 - 12	4.5 - 9.0	9.0 - 18	6.5 - 13
stiff	8 - 15	1.0 - 2.0	28.5 - 57	37 - 74	12 - 24	9.0 - 18	18 - 36	13 - 26
very stiff	15 - 30	2.0 - 4.0	57 - 114	74 - 148	24 - 48	18 - 36	36 - 72	26 - 52
hard	above 30	above 4.0	above 114	above 148	above 48	above 36	above 72	above 52

qu : Unconfined compression strength (kg/cm^2)
qd : Ultimate bearing capacity of continuous footing (t/m^2)
qds: Ultimate bearing capacity of square footing (t/m^2)
qa : Long term allowable bearing capacity (t/m^2, S.F.= 3)
qa': Short term allowable bearing capacity (t/m^2, S.F.= 2)

Table I-2 ALLOWABLE FOUNDATION LOADINGS

Class	Material	Allowable bearing value (Tons per sq.ft.)
1	Massive bedrock without laminations, such as granite rocks, gneiss, trap rock, felsite, and thoroughly cemented conglomerates, all in sound condition, (sound condition allows some cracks)	100 (1,076 t/m^2)
2	Laminated rocks, such as slate and schist in sound condition (some cracks allowed) ...	35 (377 t/m^2)
3	Shale in sound condition (some cracks allowed)	10 (108 t/m^2)
4	Residual deposits of shattered or broken bedrock of any kind except shale	10 (108 t/m^2)
5	Hardpan	10 (108 t/m^2)
6	Gravel, sand-gravel mixtures, compact	5 (54 t/m^2)
7	Gravel, sand-gravel mixtures, loose; sand, coarse, compact	4 (43 t/m^2)
8	Sand, coarse, loose; sand, fine, compact ...	3 (32 t/m^2)
9	Sand, fine, loose	1 (11 t/m^2)
10	Hard clay	6 (65 t/m^2)
11	Medium clay	4 (43 t/m^2)
12	Soft clay	1 (11 t/m^2)

Fig. I-1 ALLOWABLE BEARING CAPACITY OF SAND FOUNDATION



(a) Allowable bearing capacity without penetration

(b) Additional amount of allowable bearing capacity with the depth of penetration

Fig.I-2 BEARING-CAPACITY FACTOR