Part 5 - Structural Forces

Table 5.1: Foundations

Foundation Investigation: _____
Section 1804

Soil Classification: _____
UBC Table 18-I-A

Foundation Pressure: _____
UBC Table 18-I-A

Lateral Pressure:
UBC Table 18-I-A

Expansive Soils: ❒ Yes ❒ No
Section 1803.2, UBC Tables 18-I-B and 18-I-C

Retaining Wall Pressures: _____
Section 1611.6

Hydrostatic Uplift: _____
Section 1611.8

Liquefaction/Strength Loss Evaluation:
Sections 1804.2 ❒ Required ❒ Not Required and 1804.5

Frost Line Depth: _____
Section 1806.1

Foundation Type: _____

Table 5.2: Floor Loads
UBC Table 16-A

Floor Area or Use	Uniform Load	Concentrated Load

Impact Loads:

Special Loads:
UBC Table 16-B

Partition Loads:
Section 1606.2

Live Load Reduction:
Sections 1607.5 and 1607.6

Table 5.3: Roof Loads
UBC Table 16-C

Minimum Roof Live Load: _____
UBC Table 16-C

Roof Snow Load: _____
Per Building Official

Live Load Reduction: _____
Section 1607.6

Snow Load Reduction: _____
Section 1614

Table 5.4: Wind Loads

Wind Speed:
UBC Figure 16-1

Exposure:
Section 1616

Equation:
Section 1620

$P = C_e\, C_q\, q_s\, I_w$
P = Design Wind Pressure

Combined Height, Exposure, and Gust Factor (C_e): _____
UBC Table 16-G

Importance Factor (I_w): _____
UBC Table 16-K

Wind Stagnation Pressure (q_s): _____
UBC Table 16-F

Pressure Coefficient (C_q): _____
UBC Table 16-H

Computed Wind Loads:

Wall Field: _____

Wall Areas of Discontinuity: _____

Roof Field: _____

Roof Areas of Discontinuity: _____

Roof Overhangs: _____

Other Elements: _____

Table 5.5: Seismic Loads

Seismic Zone: ____
UBC Figure 16-2

Zone Factor (Z): ____
UBC Table 16-I

Soil Profile Type (S): _____
UBC Table 16-J

Occupancy Category: (I) ____ **(I_p)** ____
Table 16-K

Vertical Structural Irregularities: _____
UBC Table 16-L

Structural System: (R) ____ **(Ω_o)** ____
UBC Table 16-N

Height Limitations: _____
UBC Table 16-N

Horizontal Force Factor: (a_p) ____ **(R_p)** ____
UBC Table 16-O

Nonbuilding Structure Factor: (R) ____ **(Ω_o)** ____
UBC Table 16-P

Plan Structural Irregularities: _____
UBC Table 16-M

10 FOUNDATIONS AND RETAINING WALLS

Nomenclature

a_v	coefficient of compressibility	ft^2/lbf
A	area	ft^2
B	width or diameter	ft
c	cohesion (undrained shear strength)	lbf/ft^2
c_a	adhesion	lbf/ft^2
C	multiplicative correction factor	–
C_c	compression index	–
C_v	coefficient of consolidation	ft^2/sec
d	depth factor	–
D	depth	ft
e	void ratio	–
f_o	skin friction coefficient	–
F	factor of safety	–
h	depth	ft
H	soil layer thickness or depth	ft
k	permeability coefficient, or a constant	ft/sec,–
k_o	coefficient of earth pressure at rest	–
L	length	ft
M	moment	ft-lbf
N	capacity factor, or number of blows	–, –
N_o	stability number	–
p	pressure	lbf/ft^2
P	load or force	lbf
q	uniform surcharge	lbf/ft, or lbf/ft^2
r	distance (moment arm)	ft
R	force (resistance)	lbf/ft of wall
S	strength or settlement	lbf/ft^2, or ft
SG	specific gravity	–
t	time	various
T_v	time factor	–
U_z	percent of total consolidation	–
w	water content	–
w_l	liquid limit	–
W	weight (mass)	lbm
z	depth	ft

Symbols

ϕ	angle of internal friction	degrees
δ	angle of wall friction	degrees
α	secondary compression index	–
ρ	density	lbm/ft^3
μ	pore pressure	lbf/ft^2
ϵ	eccentricity	ft
η	efficiency	–
β	cut angle	degrees
γ	specific weight	lbf/ft^3

Subscripts

a	allowable
A	active
b	below mudline
c	compressive
f	footing
g	gross
h	horizontal
i	the ith component
n	unconfined
o	at rest
P	passive
q	surcharge
s	shear, or sliding
v	vertical
w	water or water table
γ	density (as a subscript)

1 CONVERSIONS

multiply	by	to obtain
kips	1000	pounds
pounds	5 EE−4	tons
pounds	0.001	kips
pounds/square foot	5 EE−4	$tons/ft^2$
pounds/square inch	0.072	$tons/ft^2$
tons	2000	pounds
tons/square foot	2000	$pounds/ft^2$
tons/square foot	13.889	$pounds/inch^2$
Newtons/square meter	0.021	$pounds/ft^2$

2 DEFINITIONS

Abutment: A retaining wall which also supports a vertical load.

Active pressure: Pressure causing a wall to move away from the soil.

Batter pile: A pile inclined from the vertical.

Bell: An enlarged section at the base of a pile or pier used as an anchor.

Berm: A shelf, ledge, or pile.

Cased hole: An excavation whose sides are lined or sheeted.

Dead load: An inert, inactive load, primarily due to the structure's own weight.

Dredge level: See 'Mud line.'

Freeze (of piles): A large increase in the ultimate capacity (and required driving energy) of a pile after it has been driven some distance.

Grillage: A footing or part of a footing consisting of horizontally laid timbers or steel beams.

Lagging: Heavy planking used to construct walls in excavations and braced cuts.

Live load: The weight of all non-permanent objects in a structure, including people and furniture. Live load does not include seismic or wind loading.

Mud line: The lower surface of an excavation or braced cut.

Passive pressure: A pressure acting to counteract active pressure.

Pier shaft: The part of a pier structure which is supported by the pier foundation.

Ranger: See 'Wale.'

Rip rap: Pieces of broken stone used to protect the sides of waterways from erosion.

Sheeted pit: See 'Cased hole.'

Slickenside: A surface (plane) in stiff clay which is a potential slip plane.

Soldier pile: An upright pile used to hold lagging.

Stringer: See 'Wale.'

Surcharge: A surface loading in addition to the soil load behind a retaining wall.

Wale: A horizontal brace used to hold timbers in place against the sides of an excavation, or to transmit the braced loads to the lagging.

3 COMPARISON OF SAND AND CLAY AS FOUNDATION MATERIALS

Ordinarily, sand makes a good foundation material. It doesn't settle after its initial loading. It drains quickly. However, it behaves poorly in excavations. When sand is fine and saturated, it can become quick, and a major loss in supporting strength occurs.

Care must be taken when distinguishing between "moist" and "saturated" sands. Sand which has been allowed to drain may be "moist" in the normal sense of the word. However, if the water is not captive, pore pressure will not develop, and the sand can be considered dry. However, special considerations are required if the sand is below the water table. Such sand is saturated, not moist.

Clay, on the other hand, is good in excavations, but is poor for foundations. It continues to settle indefinitely. It retains water for a long time, and large volume changes can result when large changes in moisture content occur.

4 GENERAL CONSIDERATIONS FOR FOOTINGS

A *footing* is an enlargement at the base of a load-supporting column designed to transmit forces to the soil. The area of the footing will depend on the load and the soil characteristics. The following types of footings are used.

- spread footing: A footing used to support a single column. This is also known as an *individual column footing* and *isolated footing*.
- continuous footing: A long footing supporting a continuous wall. Also known as *wall footing*.
- combined footing: A footing carrying more than one column.
- cantilever footing: A combined footing that supports a column and an exterior wall or column.

If possible, footings should be designed according to the following general considerations:

- The footing should be located below the frost line and below the level which is affected by moisture content changes.
- Footings need not be any lower than the highest-adequate stratum.
- The centroid of the footing should coincide with the centroid of the applied load.
- Allowable soil pressures should not be exceeded.

- Below-grade footings should be equipped with a drainage system.
- Footings on fill over loose sand should be densified with piles.
- If possible, footings should be placed in excavations made in compacted fill. They should not be put in place prior to compaction.
- Size footings to the nearest 3″ above or equal to the theoretical size.

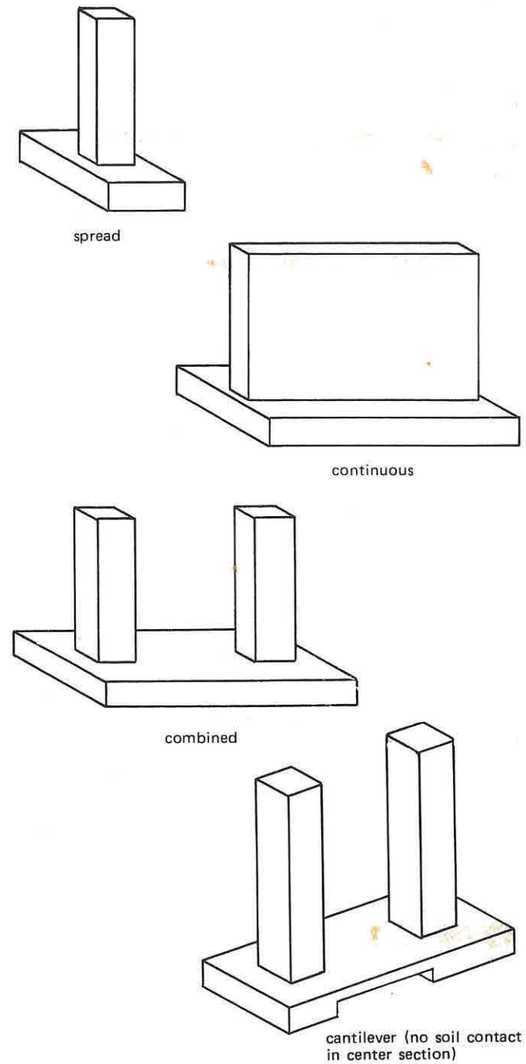

Figure 10.1 Types of Footings

5 ALLOWABLE SOIL PRESSURES

When data from soil tests are unavailable, table 10.1 can be used for preliminary calculations.

Table 10.1
Typical Allowable Soil Bearing Pressures[1]

type of soil	allowable pressure
massive crystalline bedrock	4000 lbf/ft^2
sedimentary and foliated rock	2000
sandy gravel and/or gravel (GW and GP)	2000
sand, silty sand, clayey sand, silty gravel, and clayey gravel (SW, SP, SM, SC, GM, GC)	1500
clay, sandy clay, silty clay, and clayey silt (CL, ML, MH, and CH)	1000

6 GENERAL FOOTING DESIGN EQUATION

The *gross* (or *ultimate*) *bearing capacity* or *gross pressure* for a soil is given by equation 10.1, which is known as the *Terzaghi-Meyerhoff equation*. The equation is good for both sandy and clayey soils. It is specifically valid for continuous wall footings. (p_q is a surface surcharge.)

$$p_g = \frac{1}{2}\gamma B N_\gamma + c N_c + (p_q + \gamma D_f) N_q \qquad 10.1$$

Various researchers have made improvements on this theory, leading to somewhat different terms and sophistication in evaluating N_γ, N_c, and N_q.[2] However, the general form remains valid for design, with corrections for various footing geometries.

Figure 10.2 and table 10.3 can be used to evaluate the capacity factors N_γ, N_c, and N_q in equation 10.1.

Table 10.2
N_c Bearing Capacity Factor Multipliers for Various Values of B/L
(See figure 10.3)

B/L	multiplier
1 (square)	1.25
0.5	1.12
0.2	1.05
0.0	1.00
1 (circular)	1.20

[1] As in the definition of p_a, the term 'allowable' implies that a factor of safety has already been applied.

[2] Differences in reported values of N_γ, N_c, and N_q may also be due to the different units used by researchers.