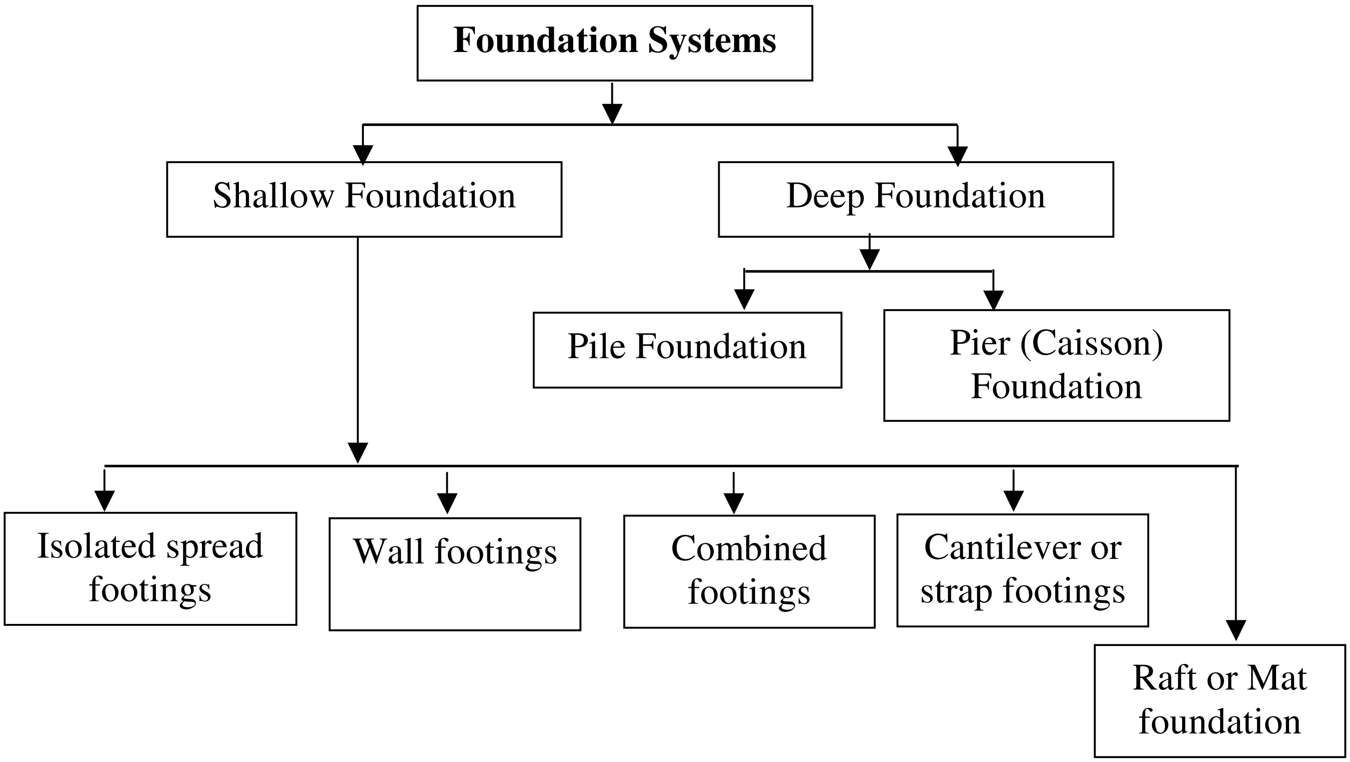
TYPES OF FOUNDATIONS

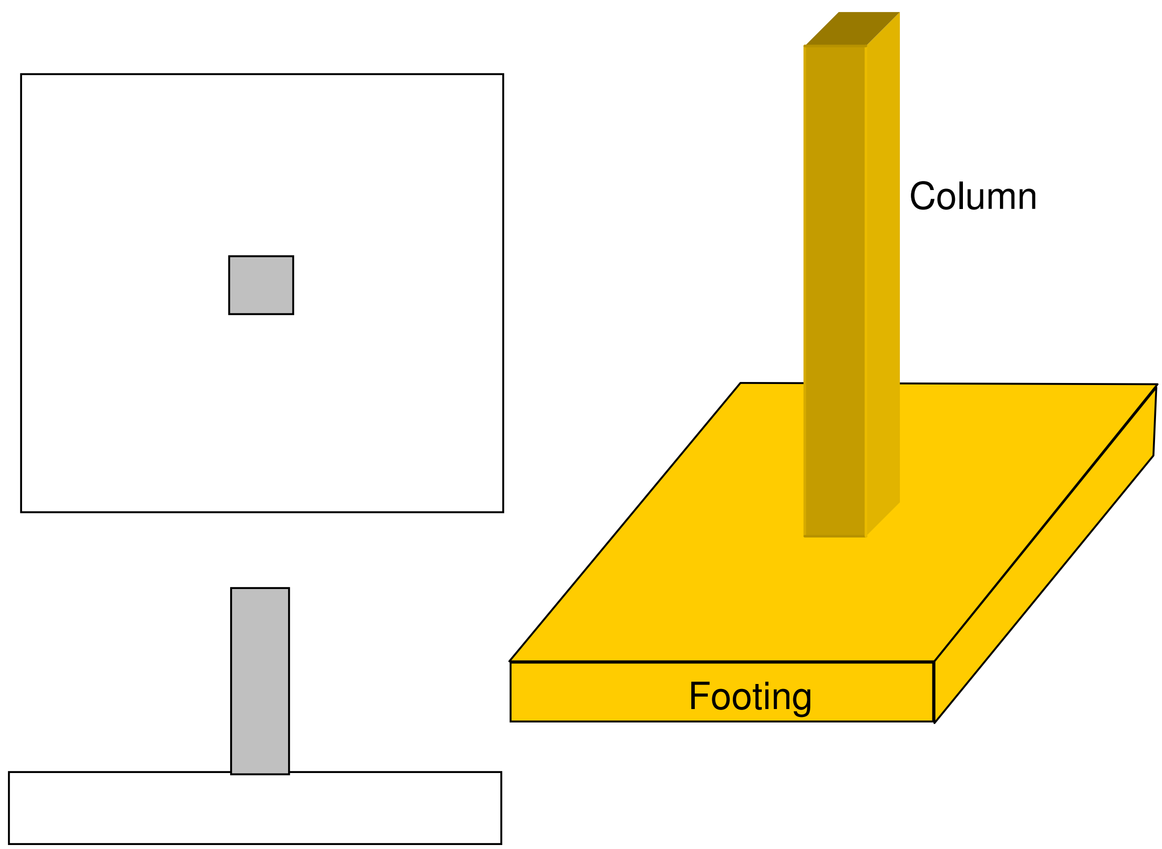


Shallow Foundations – are usually located no more than 6 ft below the lowest finished floor. A shallow foundation system generally used when (1) the soil close the ground surface has sufficient bearing capacity, and (2) underlying weaker strata do not result in undue settlement. The shallow foundations are commonly used most economical foundation systems.

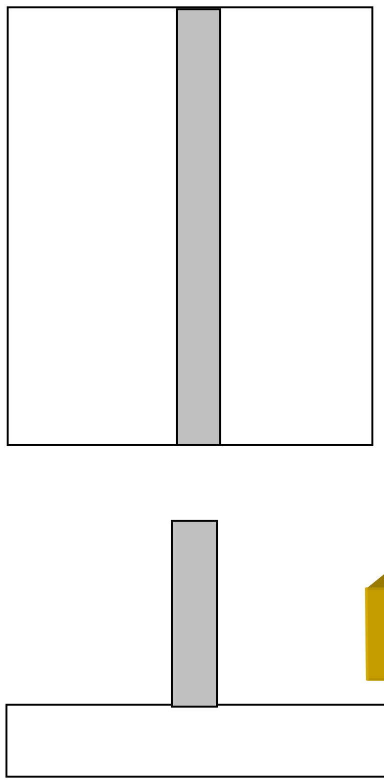
Footings are structural elements, which transfer loads to the soil from columns, walls or lateral loads from earth retaining structures. In order to transfer these loads properly to the soil, footings must be design to

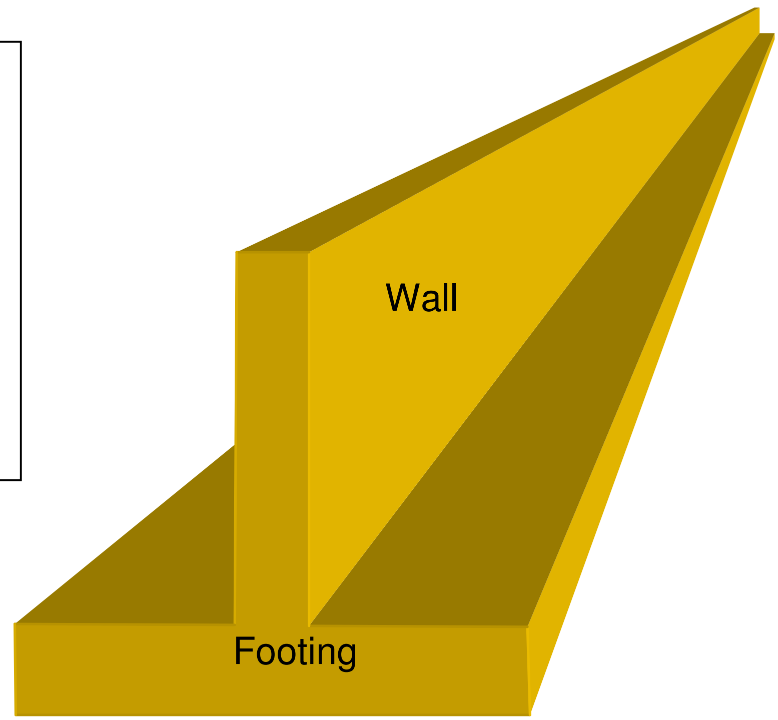
- Prevent excessive settlement
- Minimize differential settlement, and
- Provide adequate safety against overturning and sliding.

Types of Footings

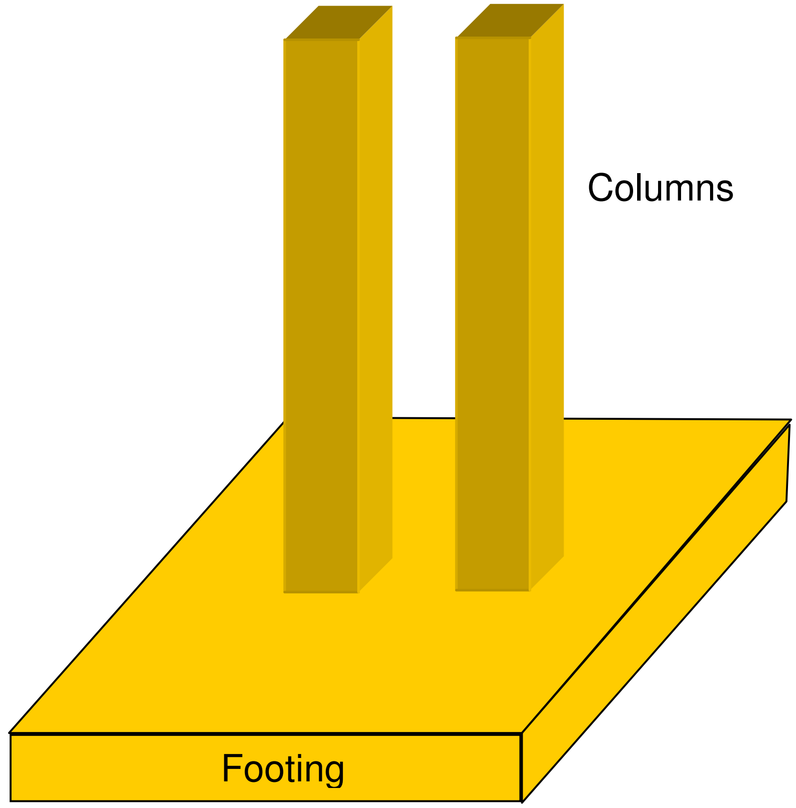


Isolated spread footings under individual columns. These can be square, rectangular, or circular.

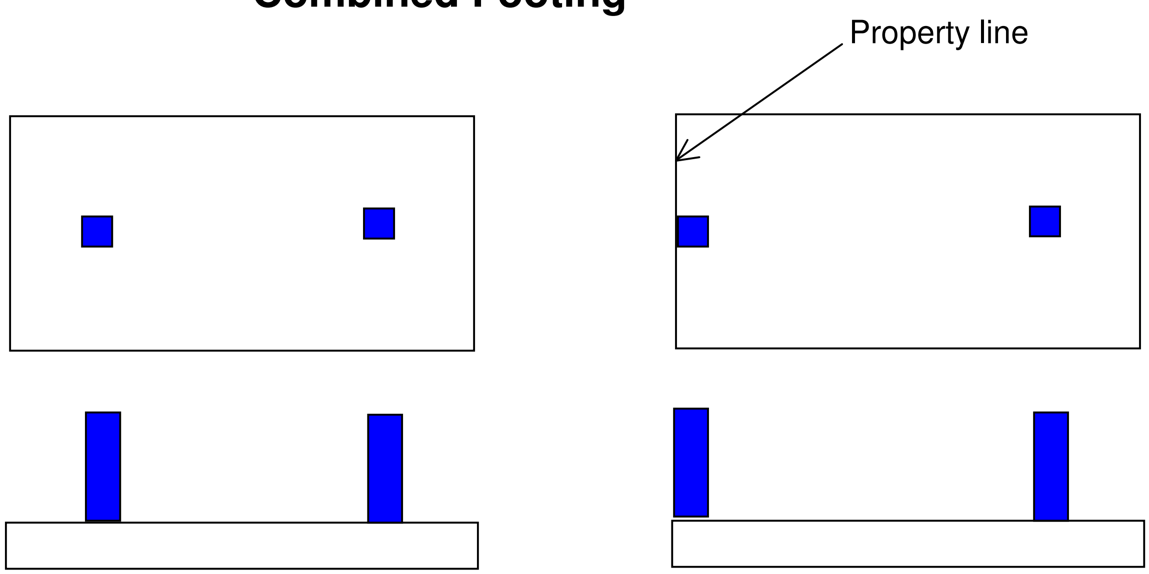




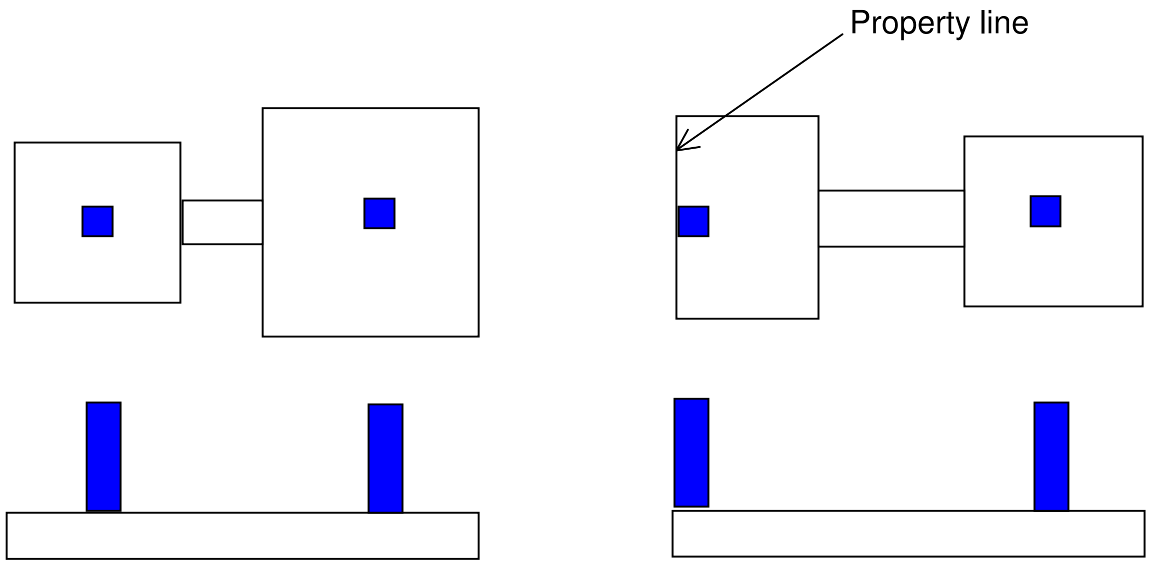
Wall footing is a continuous slab strip along the length of wall.



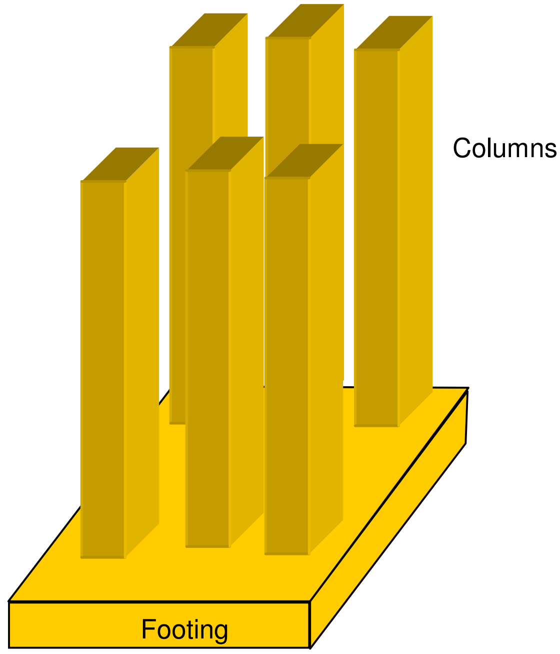
Combined Footing



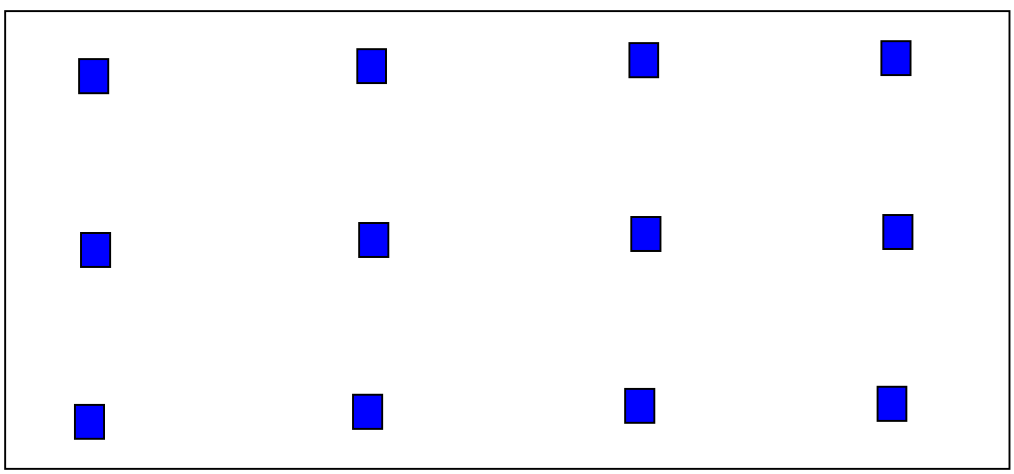
Combined footings support two or more columns. These can be rectangular or trapezoidal plan.

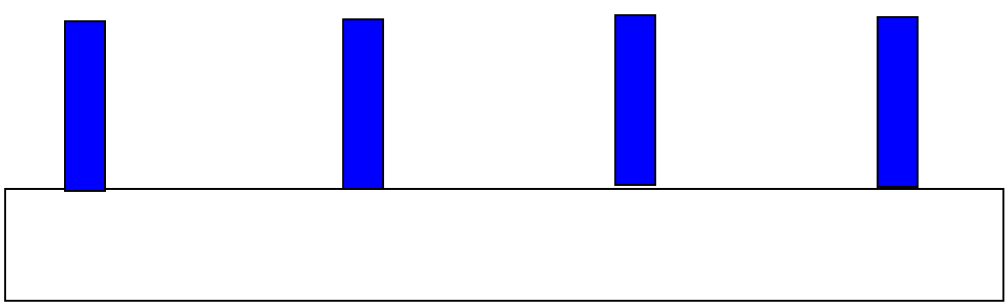


Cantilever or strap footings: These are similar to combined footings, except that the footings under columns are built independently, and are joined by strap beam.



Mat or Raft





Raft or Mat foundation: This is a large continuous footing supporting all the columns of the structure. This is used when soil conditions are poor but piles are not used.

Deep Foundations – The shallow foundations may not be economical or even possible when the soil bearing capacity near the surface is too low. In those cases deep foundations are used to transfer loads to a stronger layer, which may be located at a significant depth below the ground surface. The load is transferred through skin friction and end bearing (Figure below).

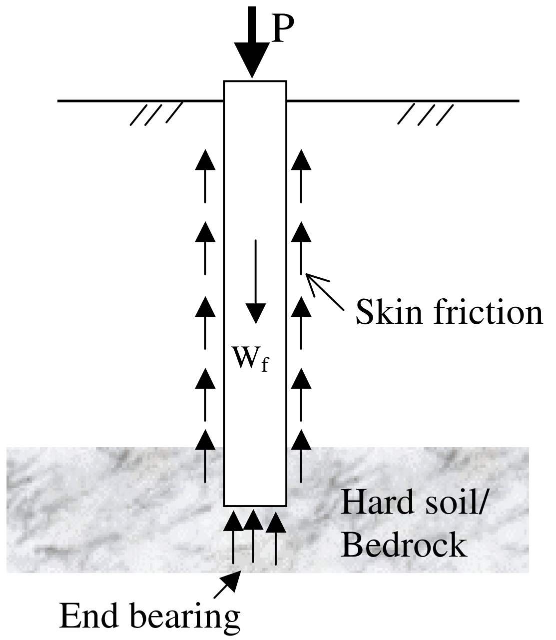


Fig. 1(a) Axial Compressive Load transfer in deep foundations

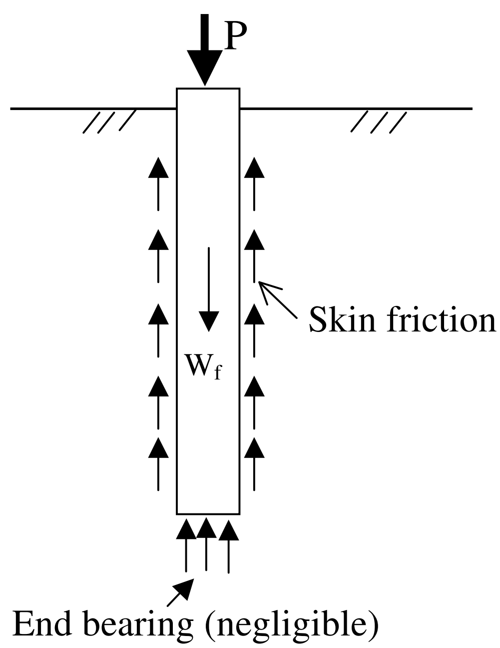


Fig. 1(b) Axial Compressive Load transfer in deep foundations

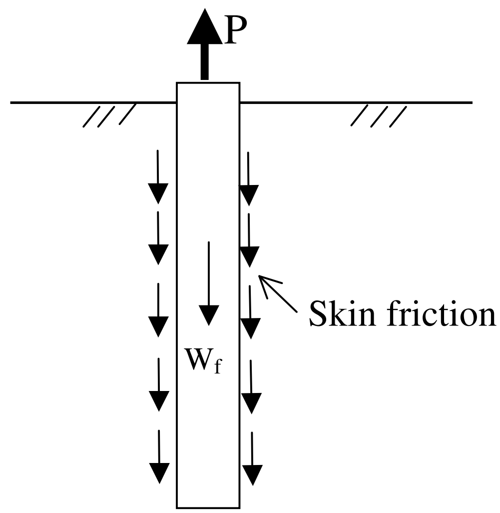


Fig. 2 Axial Tension Load transfer in deep foundations

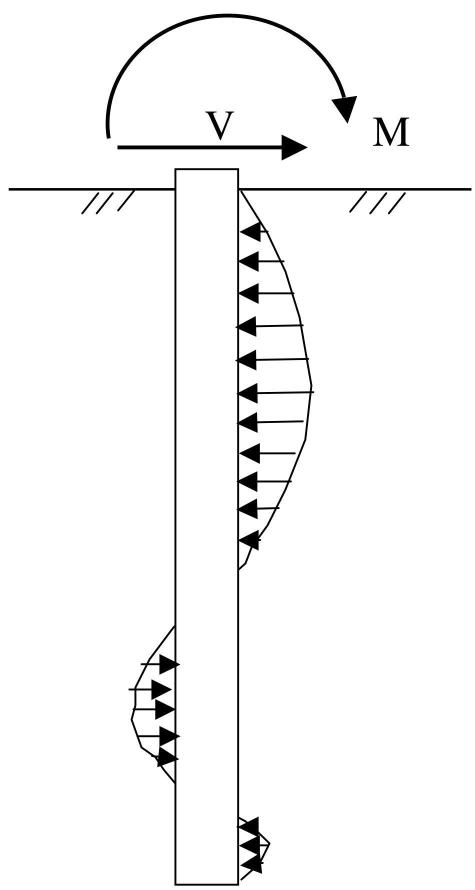


Fig. 3 Lateral Load transfer in deep foundations

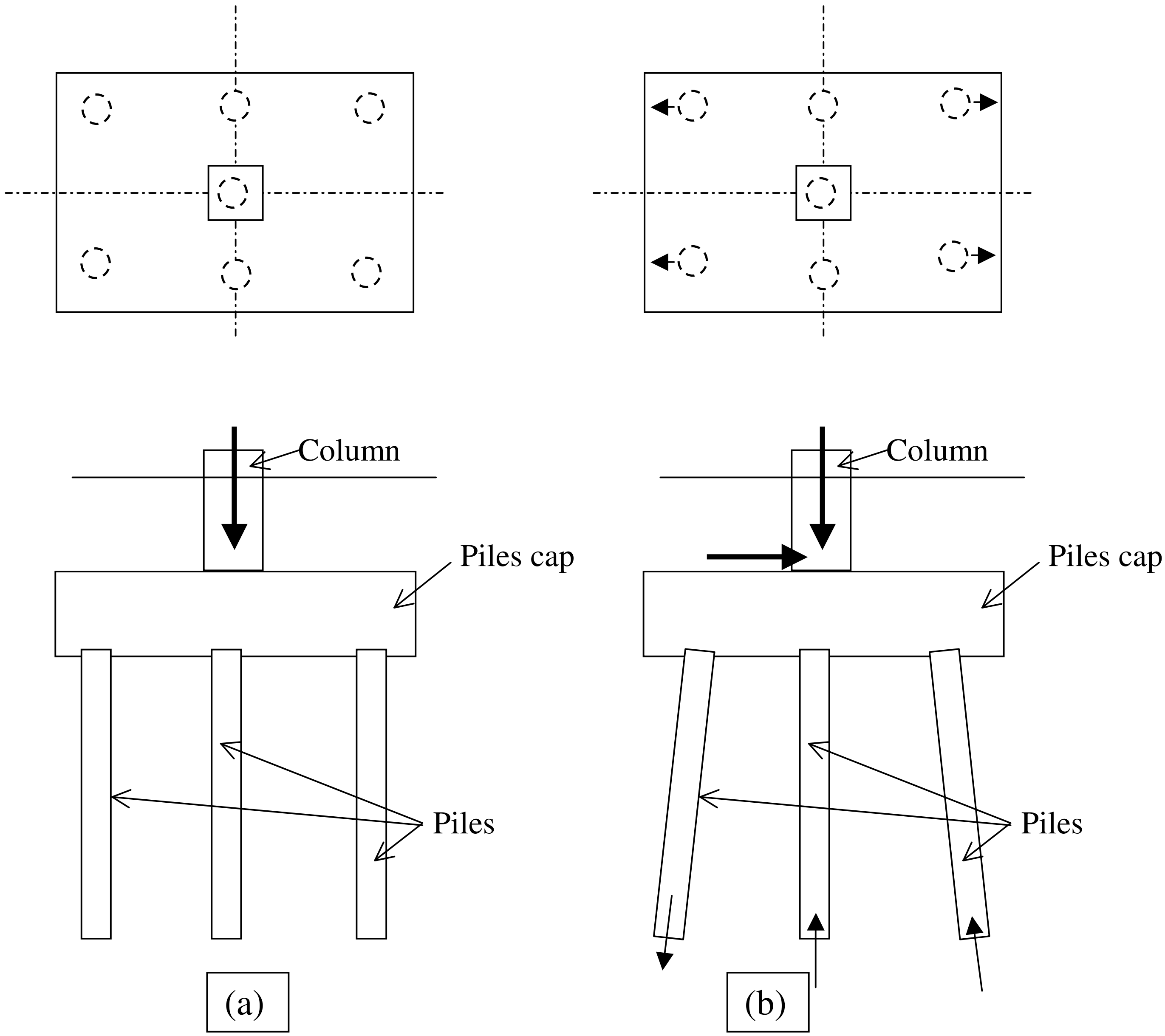
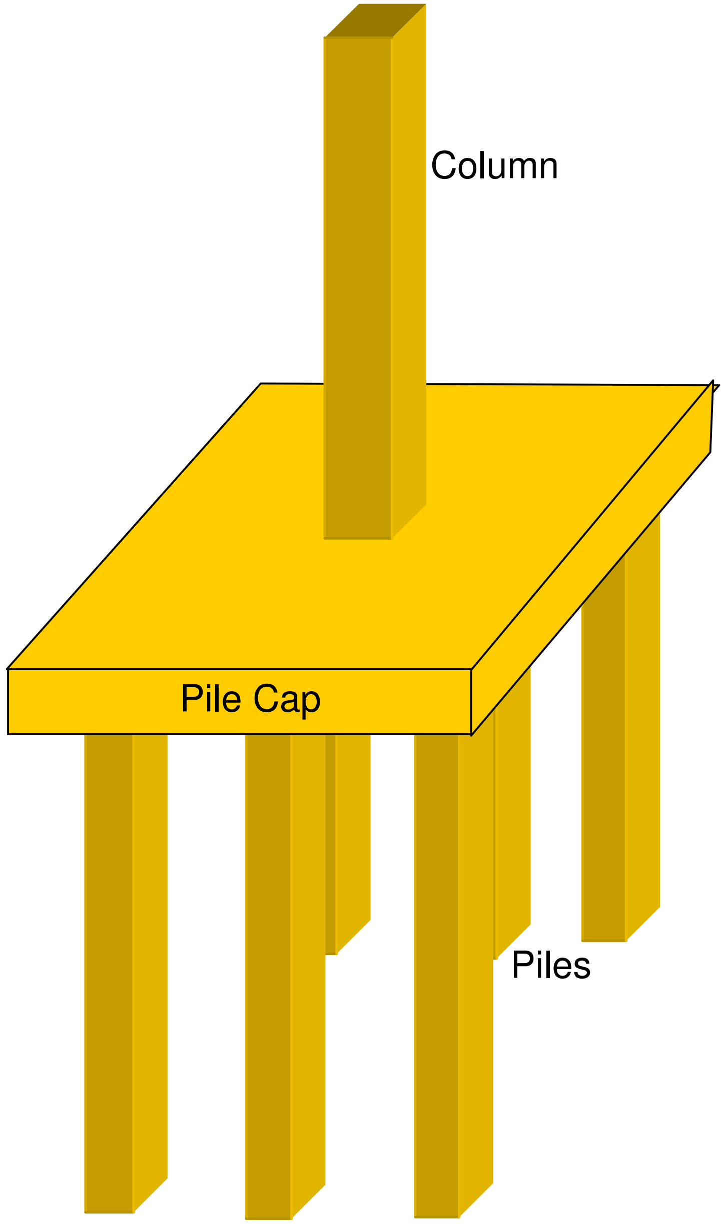
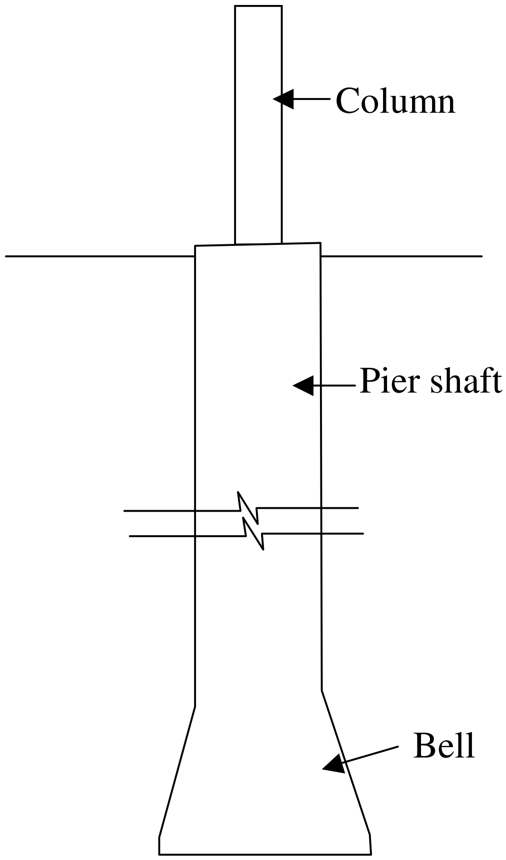


Fig. Pile Foundation- (a) Vertical Piles; (b) Battered Piles



Pile Foundation



Pier Foundation (Caisson)

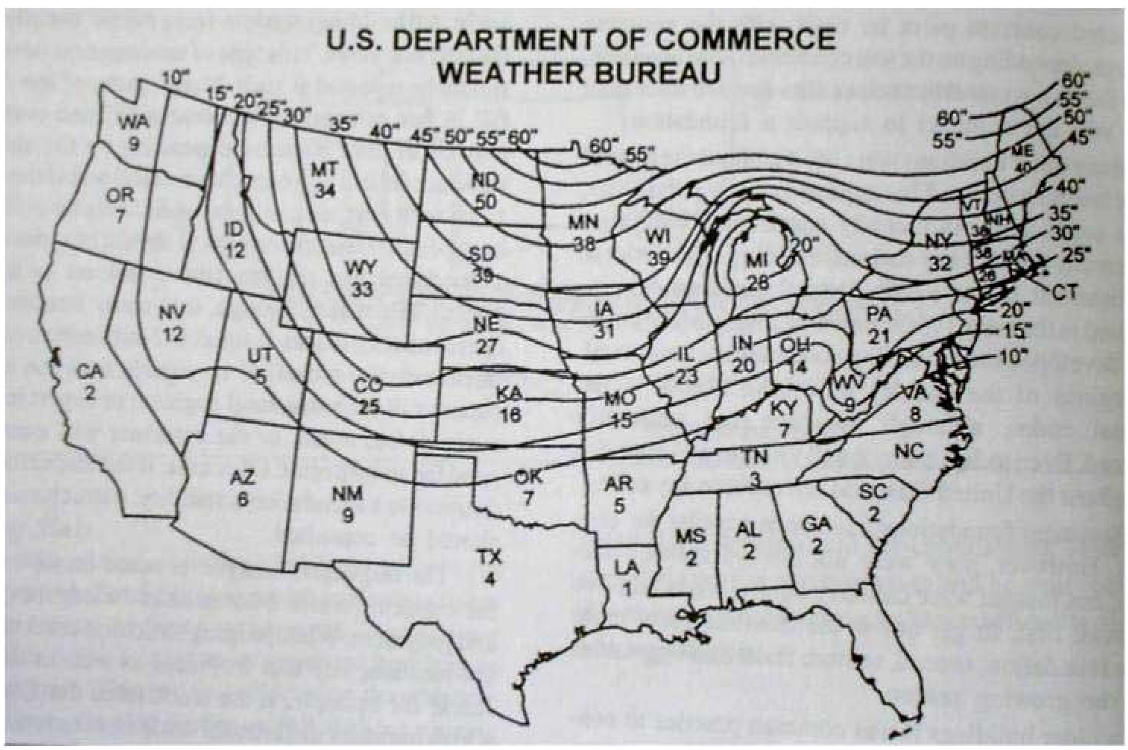
Soil properties and parameters, and Foundation Systems

Frost Depth (Frost Line or Freezing Depth) —is the depth to which the groundwater in soil is expected to freeze due to temperature drop.

The frost line varies by latitude; it is deeper closer to the poles.
It ranges in the United States from about zero to six feet.
Below that frost depth the temperature varies, but is always above 0 °C (32 °F).

In Arctic and Antarctic locations the freezing depth is so deep that it becomes year-round permafrost, and the term "thaw depth" is used instead.

[Reference: http://en.wikipedia.org/wiki/Frost_line]



Frost Depth in USA

Frost heaving is an upwards swelling of soil during freezing conditions caused by an increasing presence of ice as it grows towards the surface.

- Ice growth requires a water supply that delivers water to the freezing front via capillary action in certain soils.
- The weight of overlying soil restrains vertical growth of the ice and can promote the formation of lens-shaped areas of ice within the soil.
- Yet the force of one or more growing ice lenses is sufficient to lift a layer of soil, as much as 30 cm or more.
- The soil through which water passes to feed the formation of ice lenses must be sufficiently porous to allow capillary action, yet not so porous as to break capillary continuity. Such soil is referred to as "frost susceptible".
- Differential frost heaving can crack pavements—contributing to springtime pothole formation—and damage building foundations.

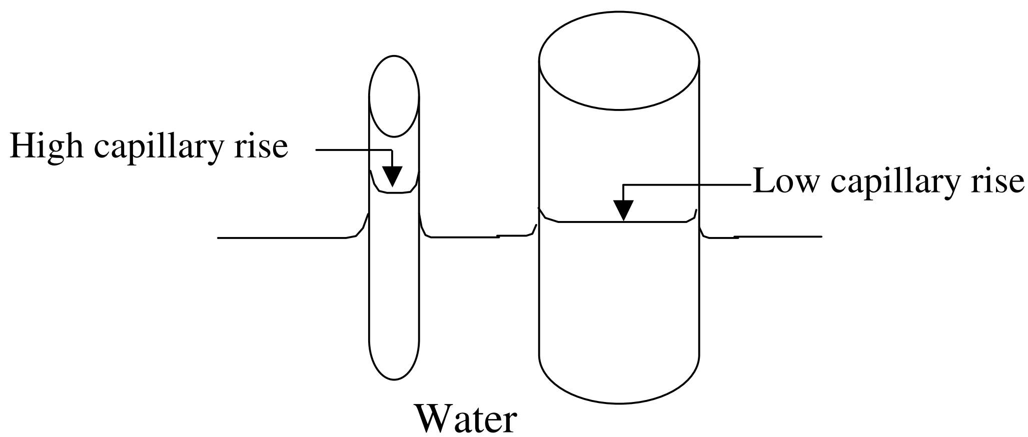
[Reference: http://en.wikipedia.org/wiki/Frost_heaving]

Capillary action (capillarity, capillary motion, or wicking) is the ability of a liquid to flow in narrow spaces without the assistance of, and in opposition to, external forces like gravity.

If the diameter of the tube is sufficiently small, then the combination of surface tension caused by cohesion within the liquid and adhesive forces between the liquid and the tube act to lift the liquid (Figure).

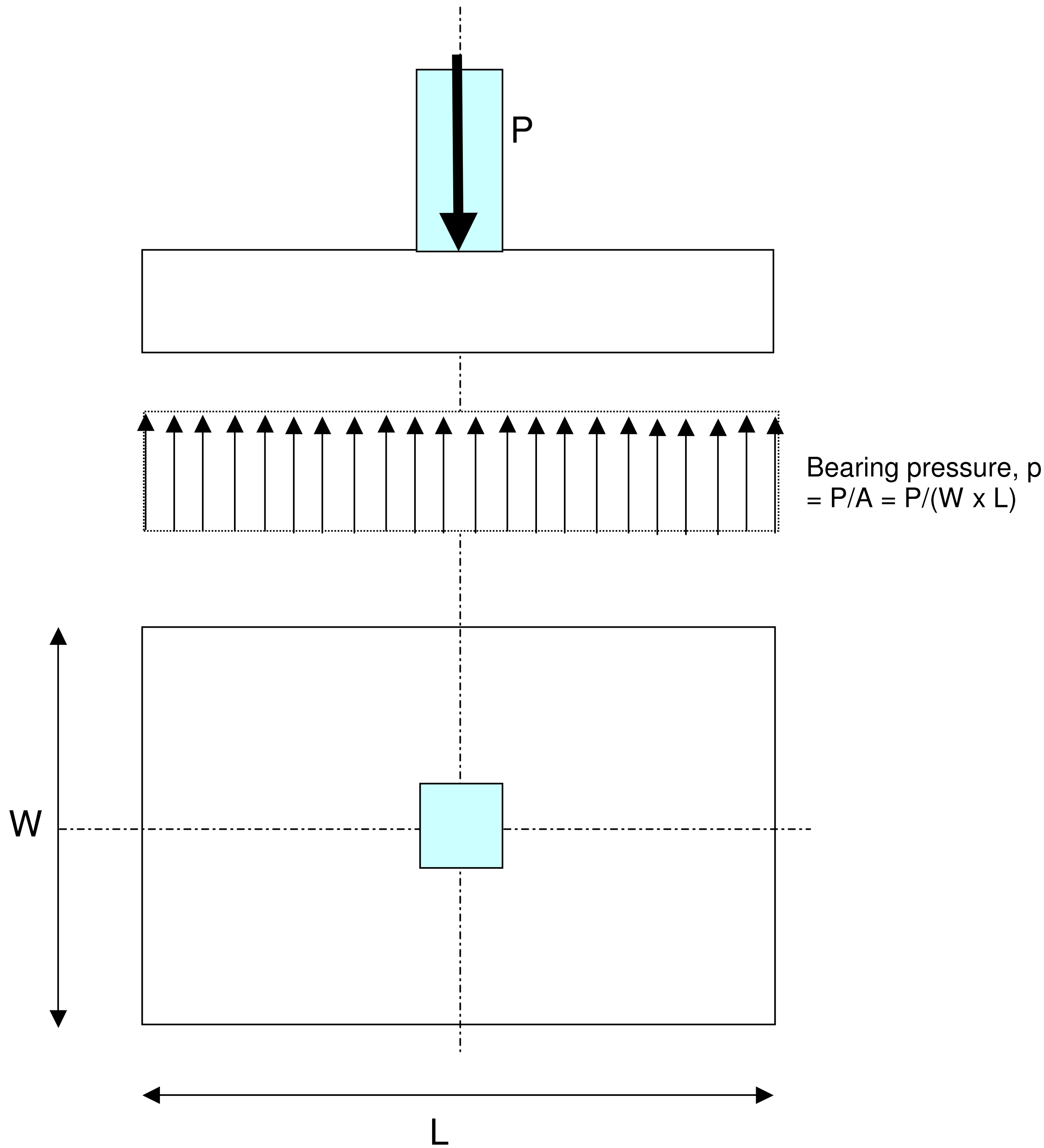
The capillary action is due to the pressure of cohesion and adhesion, which cause the liquid to work against gravity.

[Reference: http://en.wikipedia.org/wiki/Capillary_action]



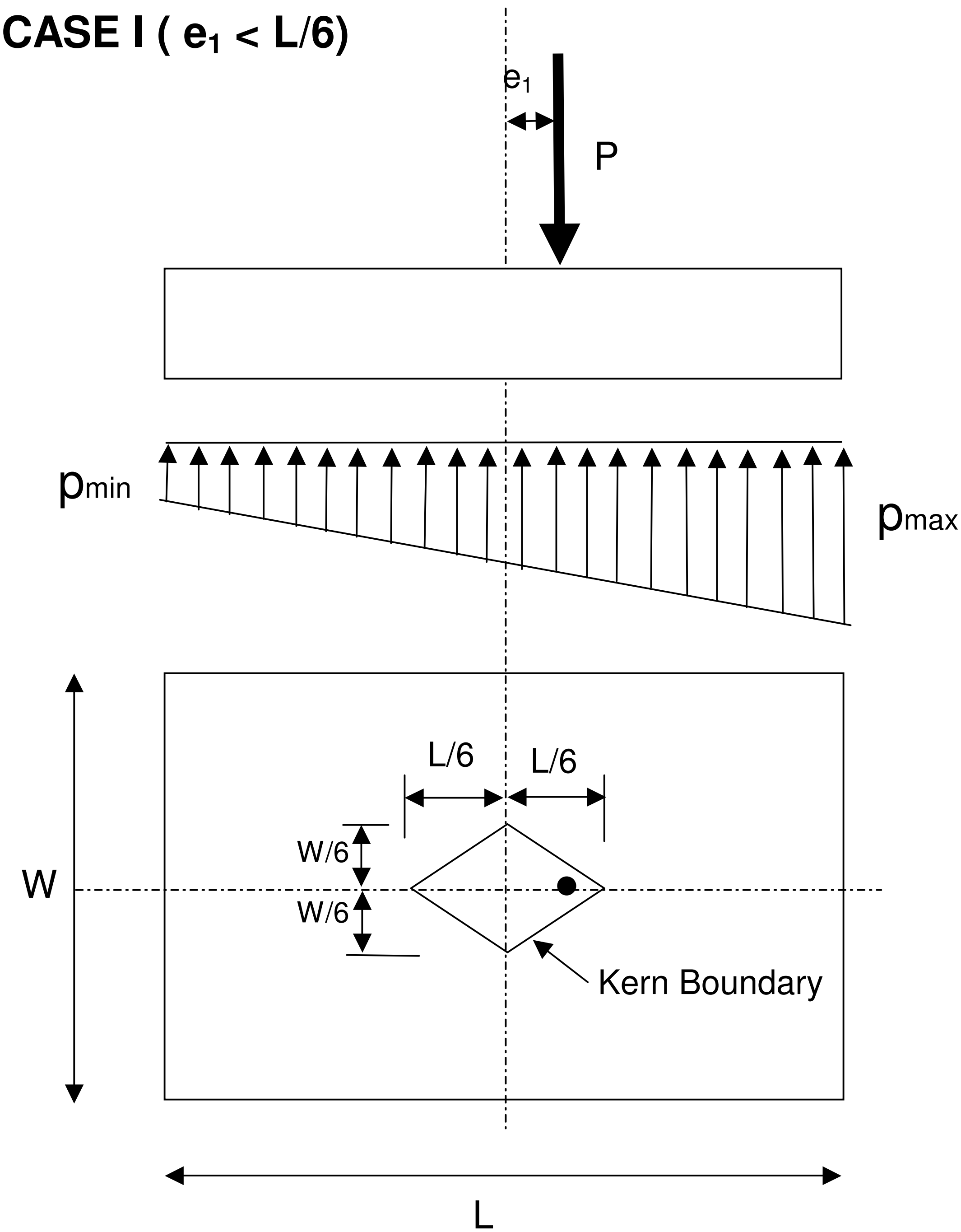
Soil Bearing Pressure at base of Footings

A. Concentrically Loaded Footing

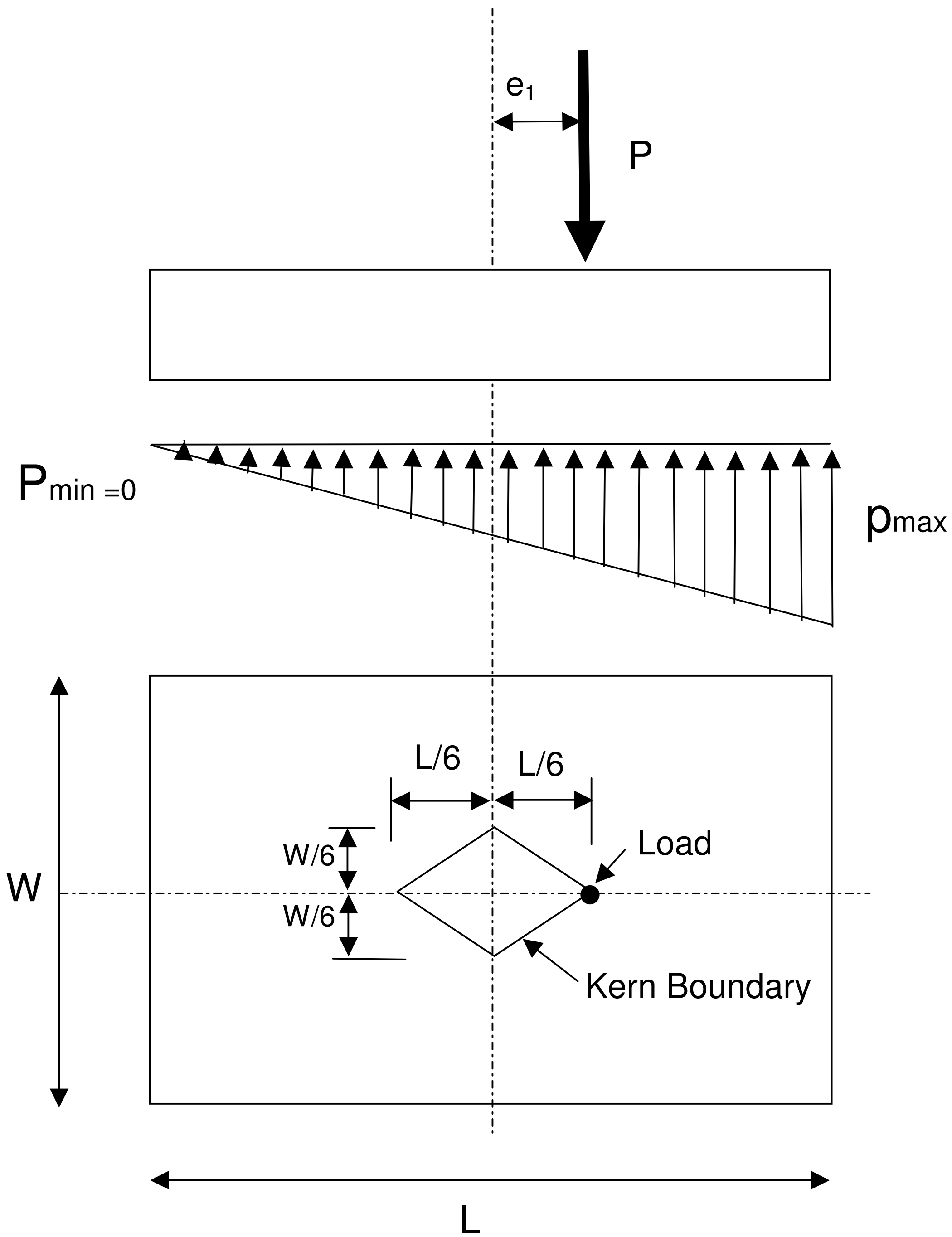


B. Eccentric load on Footings

CASE I ($e_1 < L/6$)



CASE II ($e_1 = L/6$)



CASE I ($e_1 < L/6$)
Direct Stress > Bending Stress

p_{min} = Direct Stress – Bending Stress
p_{max} = Direct Stress + Bending Stress

$p_{min} = (P/A) - (M \cdot c / I)$
$p_{max} = (P/A) + (M \cdot c / I)$

where
$A = W \times L$
$M = P \times e_1$
$c = L/2$
$I = W \times L^3 / 12$
$c/I = (L/2) \times 12/(W \times L^3) = 6/(W \times L^2)$

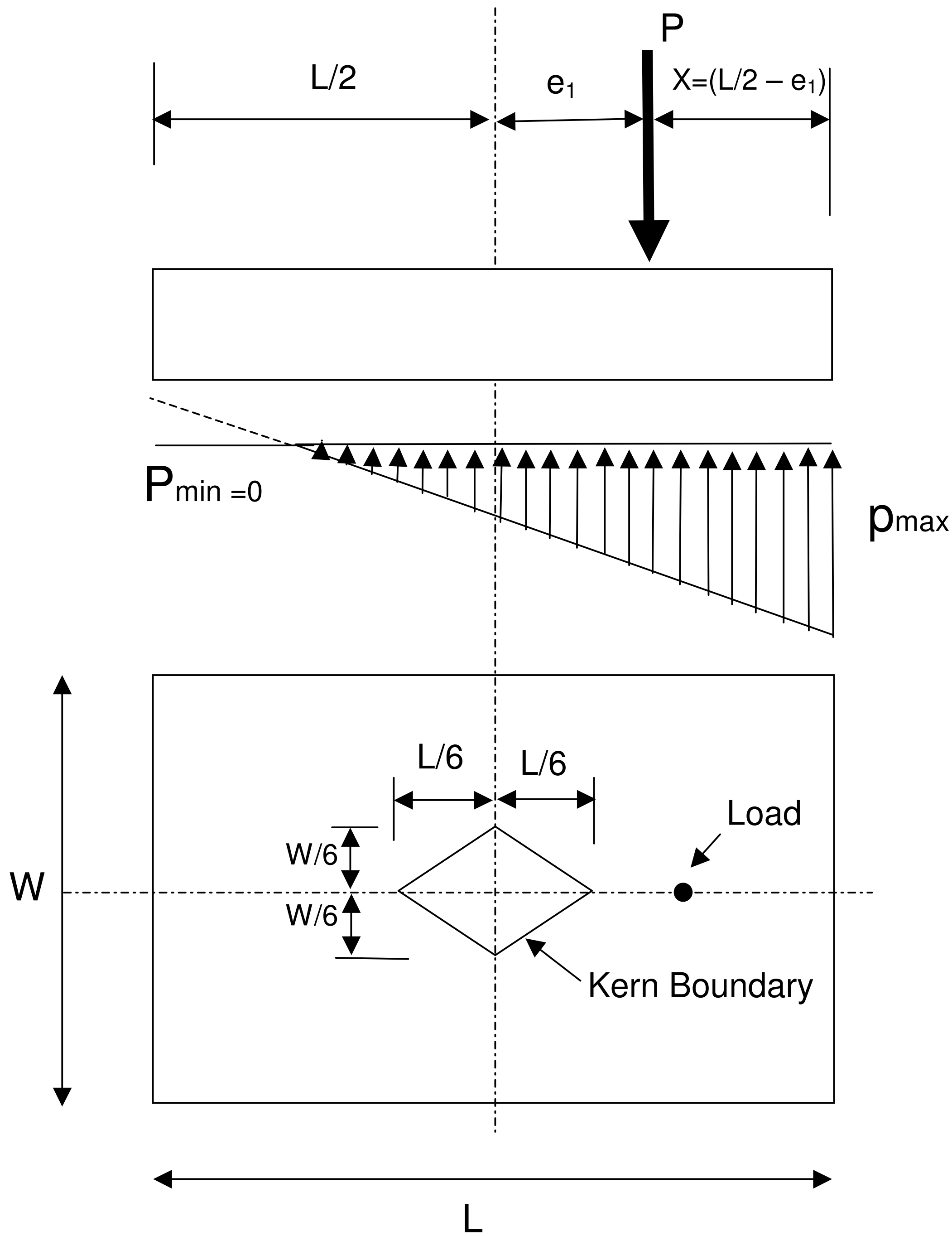
Therefore,
$p_{min} = P/(W \times L) - 6(P \times e_1) / (W \times L^2)$
$p_{max} = P/(W \times L) + 6(P \times e_1) / (W \times L^2)$

CASE II ($e_1 = L/6$)
Direct Stress = Bending Stress

$(P/A) = (M \cdot c / I)$
$P/(W \times L) = 6(P \times e_1) / (W \times L^2)$
Therefore, $\mathbf{e_1 = L/6}$

$\mathbf{p_{min} = 0}$
$\mathbf{p_{max} = P/(W \times L) + 6(P \times L/6) / (W \times L^2)}$
$\mathbf{= 2P/(W \times L)}$

CASE III ($e_1 > L/6$)



CASE III ($e_1 > L/6$)

As shown above, as the load, P acts outside of the kern boundary, tensile stress results at the left side.

For p_{max} less than allowable soil bearing capacity, no uplift is expected at the left end of the footing, and the center of gravity of the triangular bearing stress distribution coincides with the point of action of load, P.

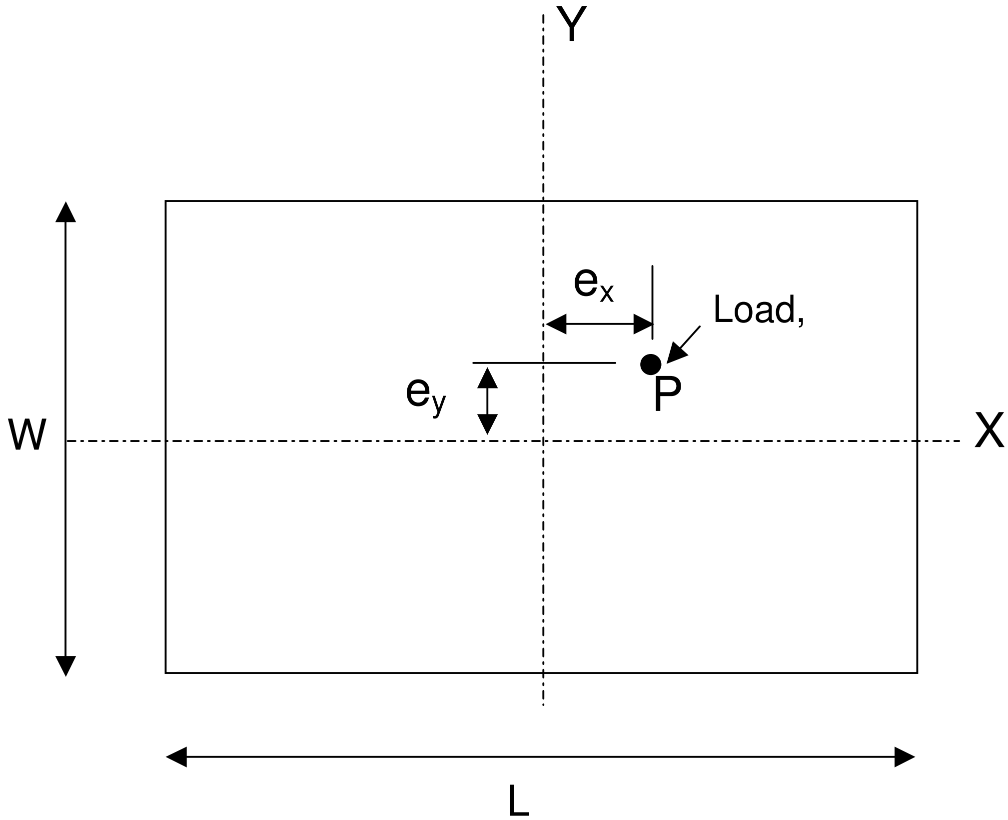
Downward Load = Area of upward triangular stress block x width

$P = ½ (p_{max}) (3X)W$

$P = 3/2 (p_{max}) (L/2 – e_1) W$

$$P_{max} = 2P / [3W(L/2 – e_1)]$$

C. Biaxial loading of Footing



Biaxial Loading (Eccentricity about two axes):

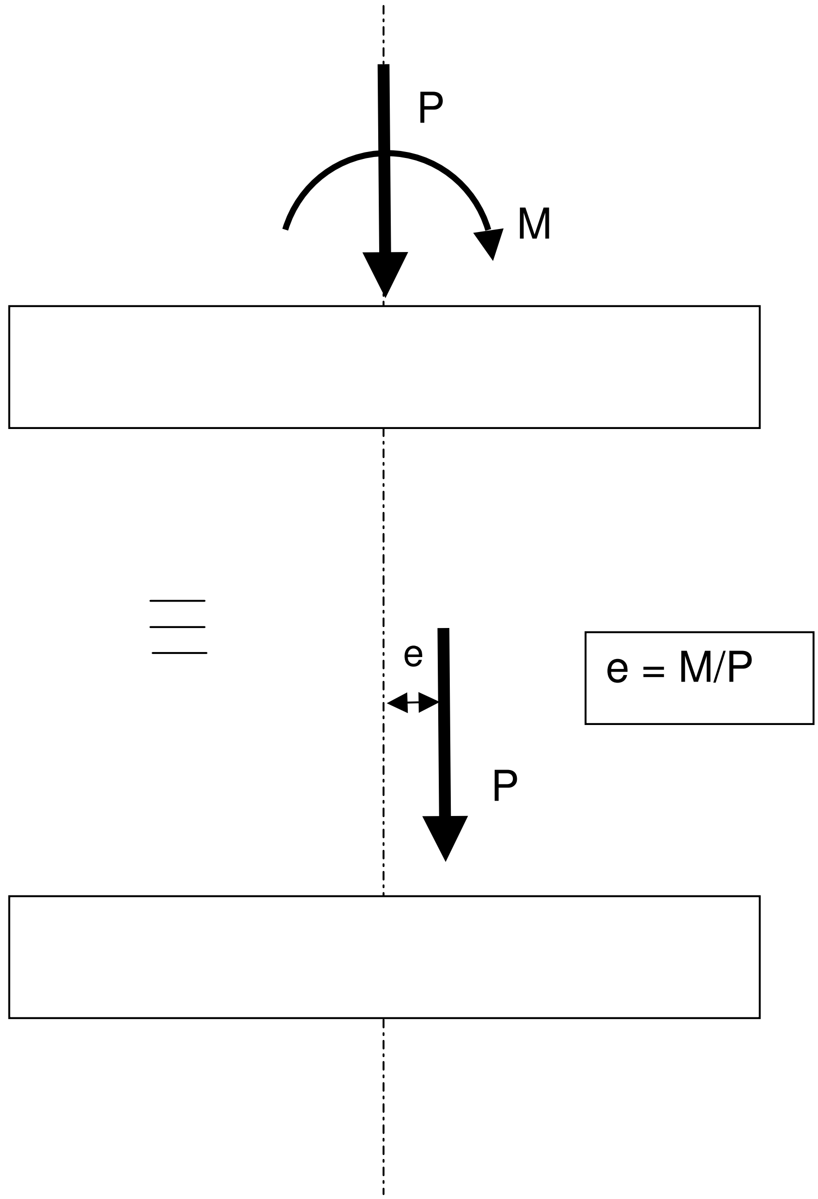
Bearing Stresses at the corners of the footing are –

$$p = P/(W.L) \pm (P.\ e_x\ .\ C_x)/I_y \pm (P.\ e_y\ .\ C_y)/I_x$$

where

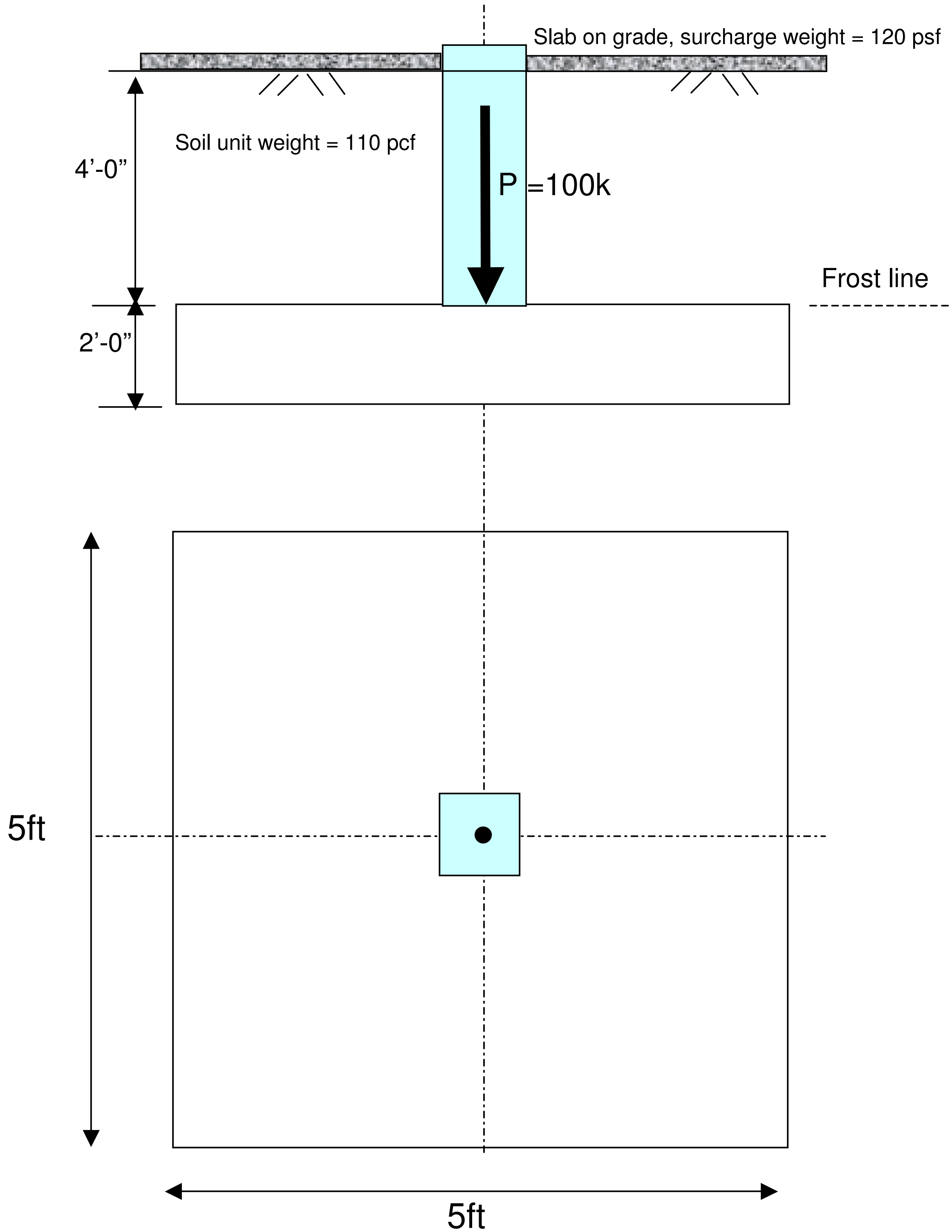
$C_x = L/2$; $C_y = W/2$;

$I_x = L.\ W^3/12$; $I_y = W.\ L^3/12$


P
M
e
P
e = M/P

EXAMPLE 1:

A reinforced concrete footing (Fig 1) supports a 12"x12" column reaction P=100 kips at the top of footing. Based on the soil test, allowable bearing capacity of soil is 5 ksf. Check the adequacy of the footing based on bearing pressure.



Solution:

Since the footing is concentrically loaded, soil bearing pressure is considered uniformly distributed assuming the footing is rigid.

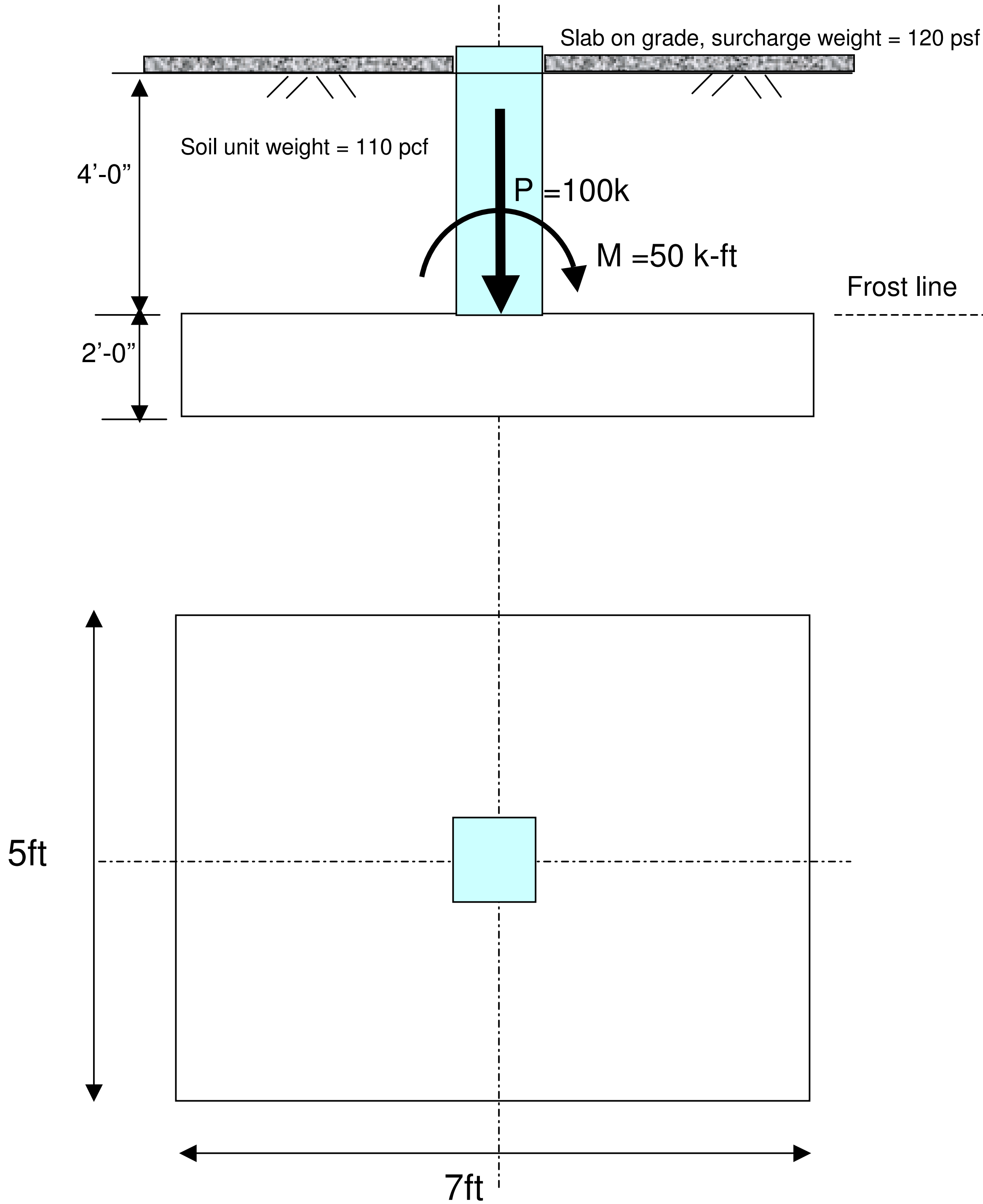
Column load	= 100 k
Footing weight (5x5x2)x150/1000	= 7.5 k
Soil weight [(5x5) - (1x1)]x4x110/1000	= 10.56 k
Slab on grade surcharge weight [(5x5)-(1x1)]x120/1000	= 2.88

Total weight on soil	=120.94 k

Soil pressure p = 120.94/(5x5) = 4.84 ksf < allowable bearing pressure 5 ksf. **OK**

EXAMPLE 2:

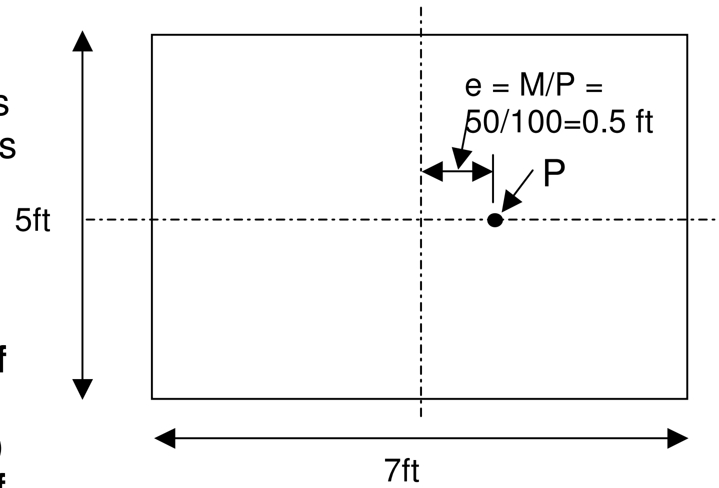
A reinforced concrete footing (Fig 2) supports a 12"x12" column reaction P=100 kips at the top of footing. Based on the soil test, allowable bearing capacity of soil is 5 ksf. Check the adequacy of the footing based on bearing pressure.



Solution:

Eccentricity, e=M/P = 50/100 = 0.5 ft < (L/6 =7/6 = 1.1667 ft)

CASE I (e_1 < L/6)
Direct Stress > Bending Stress



p_{min} = Direct Stress – Bending Stress
p_{max} = Direct Stress + Bending Stress

Therefore,
$p_{min} = P/(W \times L) - 6(P \times e_1)/(W \times L^2)$
$= 100/(5x7) - 6(100x0.5)/(5x7^2)$
$= 2.8571 - 1.2245 =$ **1.6326 ksf**

$p_{max} = P/(W \times L) + 6(P \times e_1)/(W \times L^2)$
$= 2.8571 + 1.2245 =$ **4.0816 ksf**

Calculate net allowable bearing pressure, q_{net} :

Footing weight (5x7x2)x150/1000 = 10.5 k
Soil weight [(5x7) - (1x1)]x4x110/1000 = 14.96 k
Slab on grade surcharge weight [(5x7)-(1x1)]x120/1000 = 4.08 k

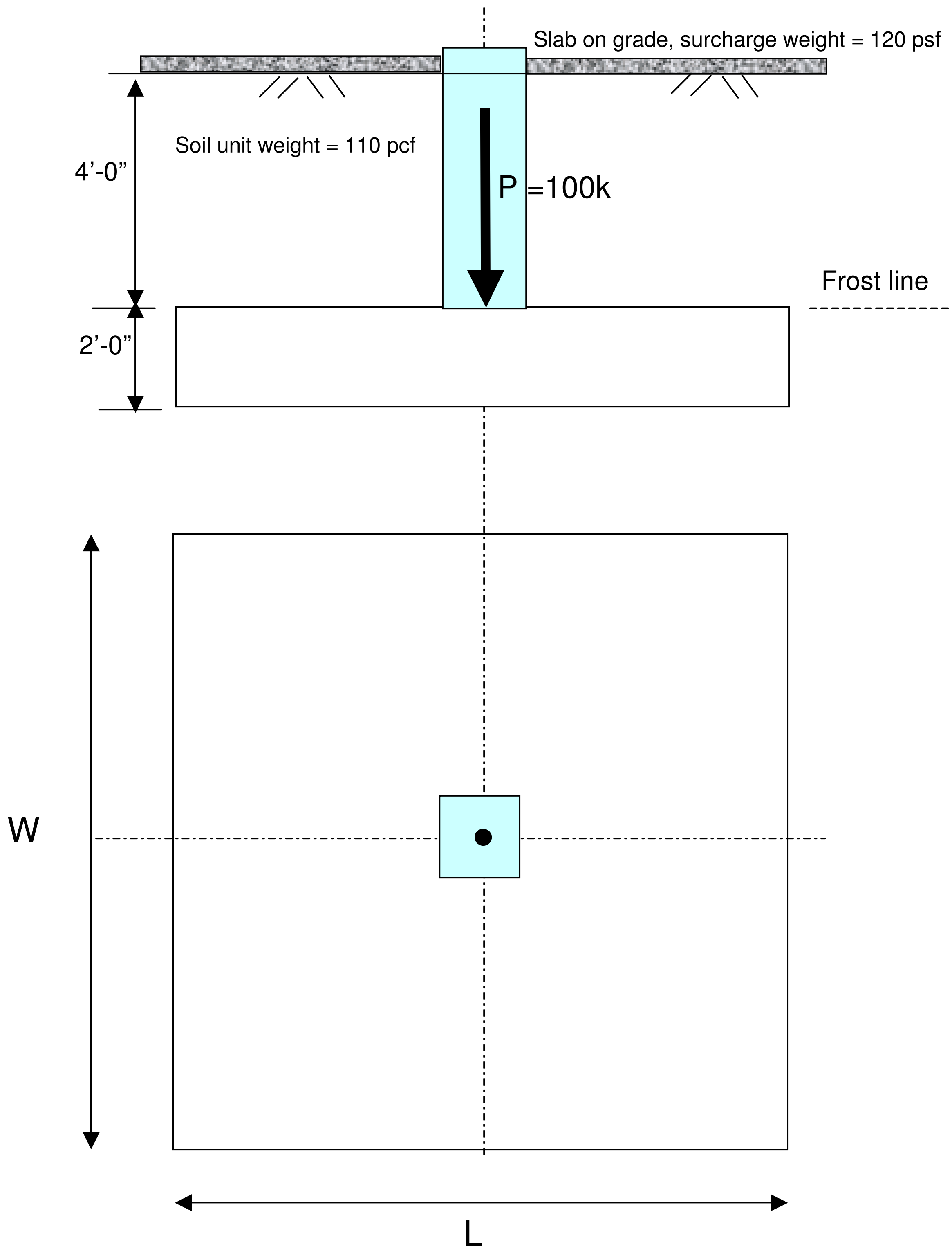
\-
Total weight on soil = 29.54 k

Net allowable bearing pressure, q_{net} = 5 –[29.54/(5x7)] =4.156 ksf

p_{max} = 4.0816 < **q_{net} = 4.156 ksf OK.**

<u>EXAMPLE 3:</u>

A reinforced concrete footing (Fig 3) supports a 12"x12" column reaction P=100 kips at the top of footing. Based on the soil test, allowable bearing capacity of soil is 5 ksf. <u>Determine the size of the footing.</u>



Solution:

Since the footing is concentrically loaded, soil bearing pressure is considered uniformly distributed assuming the footing is rigid.

At the bottom of footing:

Net allowable bearing pressure,

q_{net} = 5 –[110x4/1000] –[150x2/1000] – [120/1000]=4.14 ksf

Required minimum area of footing = P/q_{net} = 100/4.14 = 24.15 sqft.

Use a square footing, 5 ft X 5 ft.