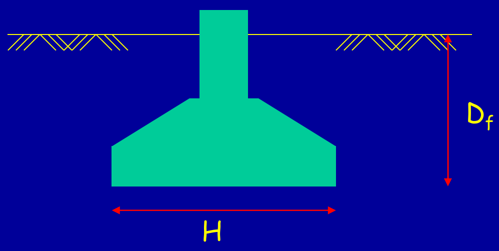
BEARING CAPACITY



Assoc. Prof. Derin Ural

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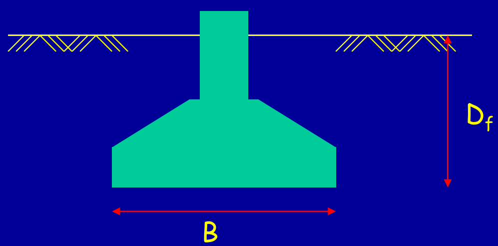
BEARING CAPACITY

The function of the foundation of structures is to transfer the load throughout the soil without overstressing the soil.
Overstressing can result in either **excessive settlement** or **shear failure** of soil. Therefore, in designing foundations the bearing capacity of soils must be evaluated.

A footing is a relatively small slab giving separate support to a part of a structure. An individual footing (also called a "pad foundation")supports a single column.



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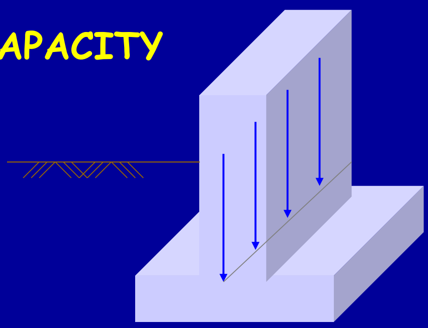
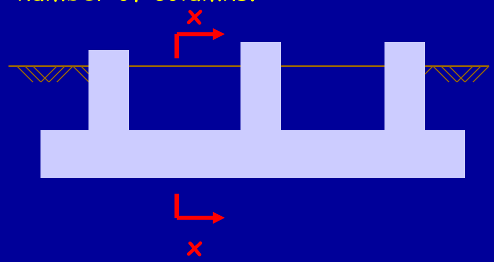
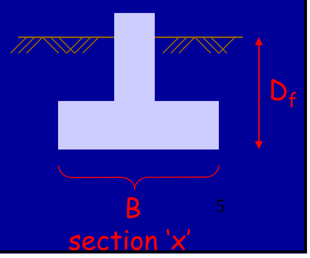
BEARING CAPACITY

A strip footing (also known as "continuous footing") supports a load bearing wall or group of columns.



Combined Footing supports a number of columns.



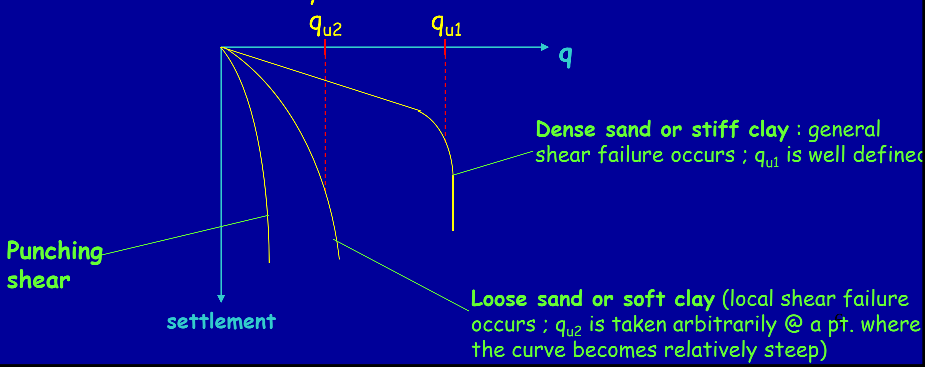


BEARING CAPACITY

*A raft (or mat) foundation is a relatively large slab supporting the structure as a whole .

*A shallow foundation is one whose depth 'D_f' below the ground surface is not greater than the width 'B' . *(i.e. pile & drilled shaft)*

*Ultimate Bearing Capacity (q_f)is the least (gross) pressure that will cause shear failure in the vicinity of the foundation.

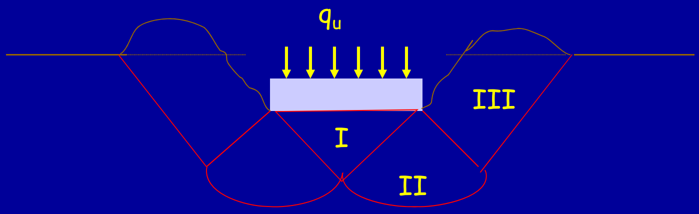


BEARING CAPACITY

TYPES OF SHEAR FAILURE

When uniform load q is applied, soil settles. If $q=q_f$; bearing capacity failure occurs.

(1) General Shear Failure : Zone I is pushed downwards, then II and III are pushed sideways then upwards. Failure takes place by sliding, tilting of foundation is possible.



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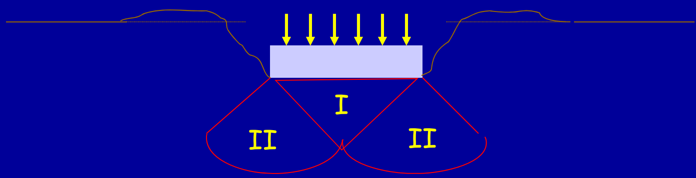
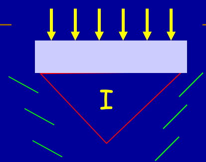
BEARING CAPACITY

(2) Local Shear Failure : Zone I moves downward (below footing). The slip surfaces end somewhere inside the soil ; (some signs of bulging at surface are seen.) No tilting, only slight heaving occurs.



(3) Punching Shear: Zone I moves downward relatively large settlements occur, and q_u is not well defined.
There is no heaving nor tilting of the footing .



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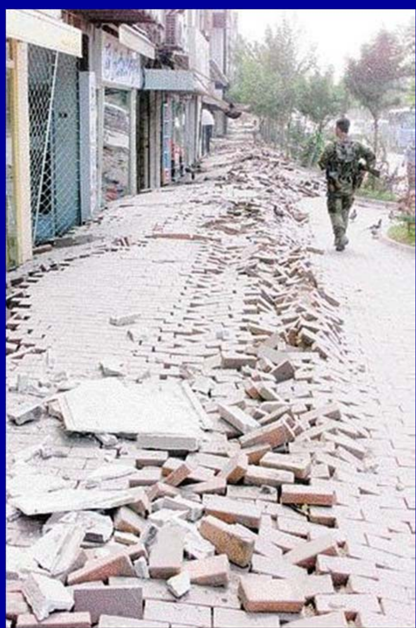

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BEARING CAPACITY

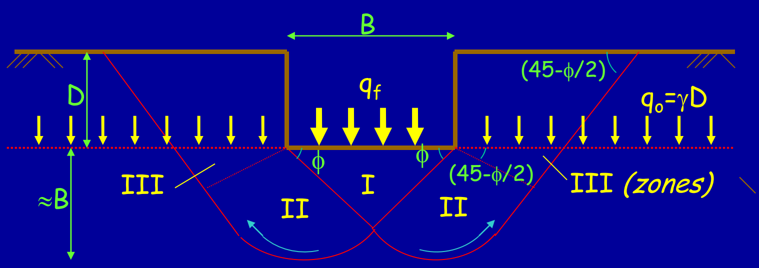
Safe Bearing Capacity is the value of gross pressure that can be applied without danger of shear failure.

Allowable Bearing Capacity (q_a) is the maximum (net) pressure which may be applied to the soil such that:

1. F.S. against shear failure of supporting soil is adequate (FS=2 or 3)
2. The total and differential settlements are within permissible limits.

BEARING CAPACITY

TERZAGHI's Bearing Capacity Formulae for Shallow Foundations



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BEARING CAPACITY

Note : I Active Rankine zone if base of footing is assumed as smooth, Elastic zone if base of footing is assumed as rough

II Zones of Radial Shear

III Passive Rankine Zone

Shear strength of a soil between the ground surface and Depth D is neglected. This soil is taken as a surcharge ; $q_0=\gamma D$.

Terzaghi's approximate theory yields the following equations:

For a Strip footing:

$$q_u = \frac{1}{2}\gamma B N_\gamma + c N_c + \gamma D N_q \quad [1]$$

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BEARING CAPACITY

Where : q_u : Ultimate bearing capacity

N_γ : Bearing capacity factor due to weight of soil with zero surcharge

N_c : Bearing capacity factor due to cohesion of soil, assuming soil to be weightless & surcharge as zero

N_q : Bearing capacity factor due to surcharge pressure, $q_0=\gamma D$ an horizontal plane at foundation base level , assuming soil below foundation as weightless

Values of N_γ,N_c, N_q depend on ϕ alone and are given in textbooks.

For a **square** footing , side B

$$q_u = 0{,}4\gamma BN_\gamma + 1{,}3cN_c + \gamma DN_q \qquad [2]$$

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BEARING CAPACITY

For a **circular** footing with diameter B :

$$q_u = 0{,}3\gamma BN_\gamma + 1{,}3cN_c + \gamma DN_q \qquad [3]$$

Note: For **rectangular** footing (L*B) use linear interpolation between strip footing (B/L=0) and square footing (B/L=1,0)

$N_{c\ rect} = N_{c\ strip}$ (1+0,2B/L)

$N_{\gamma\ rect} = N_{\gamma\ strip}$ (1-0,2B/L)

$N_{q\ rect} = N_{q\ strip}$

*For the same soil conditions, for different foundation shapes, we have different q_f values

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BEARING CAPACITY

*Factor of safety (FS) wrt shear failure is defined in terms of the net ultimate bearing capacity , q_{nf} :

$$\therefore \quad Fs = \frac{q_{nf}}{q_n} = \frac{q_u - \gamma D}{q - \gamma D} \qquad [4]$$

where :

q_n : net foundation pressure
q : total gross foundation pressure
q_{gross} : total weight of structure / base area of structure

FS is generally not less than 3

$q_n = q_u - q$ (where $q = \gamma D_f$)
$q_{gross} = c_d N_c + q N_q + 1/2 \gamma B N_\gamma$

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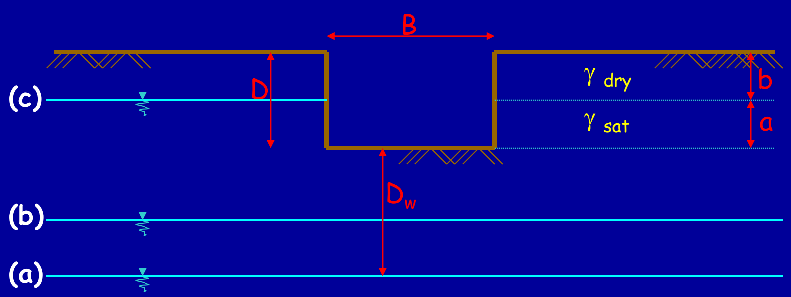
BEARING CAPACITY

*Effect of water table on the bearing capacity of a **strip footing** *(on sand)*



$$q_u = \frac{1}{2}\gamma B N_\gamma + c N_c + \gamma D N_q$$

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BEARING CAPACITY

(a) If depth D_w of water table below base of footing not less than B, Then net ultimate bearing capacity $q_{nf}=q_u-\gamma D$

0

$$q_{nf} = cN_c + \gamma D(N_q - 1) + 0{,}5\gamma B N_\gamma \qquad [5]$$

(b) If $0<D_w<B$

0

$$q_{nf} = cN_c + \gamma D(N_q - 1) + 0{,}5\gamma_{sub} B N_\gamma \qquad [6]$$

(c) W.T. between foundation level & ground surface (ie , $0 > D_w > -D$)

0

$$q_{nf} = cN_c + P_0'(N_q - 1) + 0{,}5\gamma_{sub} B N_\gamma \qquad [7]$$

p_0' :initial effective overburden pressure @foundation level.

$P_0'=\gamma_{dry}b+(\gamma_{sat}-\gamma_w)a$

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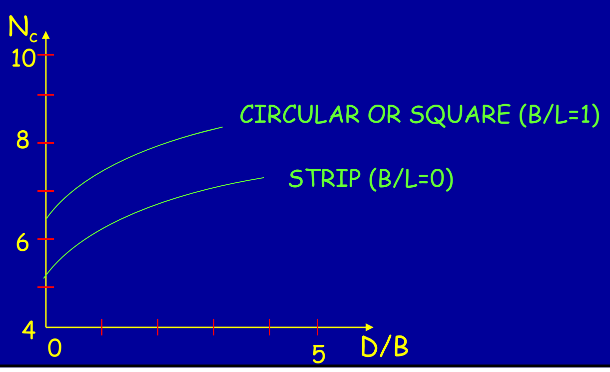
BEARING CAPACITY

Skempton's Method for Determining N_c :

For saturated , undrained clays (ϕ_u=0) ; the ultimate bearing capacity of a foundation footing is :

$$q_u=c_uN_c+\gamma D$$

where : N_c :dependent on shape of footing and B/L , D/B



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BEARING CAPACITY

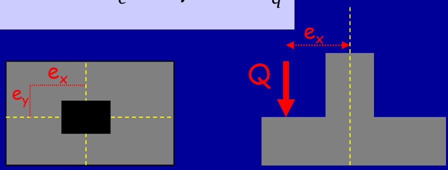
For a rectangular footing with dimensions B*L ;

$N_{c\ rectangle} = N_{c\ square}$ * [0,84+0,16 B*L]

Eccentric Loading (Meyerhof) :
If footing has eccentric loading, with eccentricity 'e' ; then :

$$q_u = \frac{1}{2}\gamma B' N_\gamma + cN_c + \gamma D N_q$$

where : $B' = B - 2e_x$
$L' = L - 2e_y$



resultant load is uniformly distributed over B' & ultimate footing load , $P_{ult} = q_f(B'L')$

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BEARING CAPACITY

Inclined Loading:

If angle of inclination of resultant load is 'α' to the vertical, then bearing capacity factors (N_γ, N_c & N_q) need to be multiplied by :

$$i_\gamma = \left(1 - \frac{\alpha}{\phi}\right)^2$$

$$i_c = i_q = \left(1 - \frac{\alpha}{90^\circ}\right)^2$$

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BEARING CAPACITY

If foundation is on :

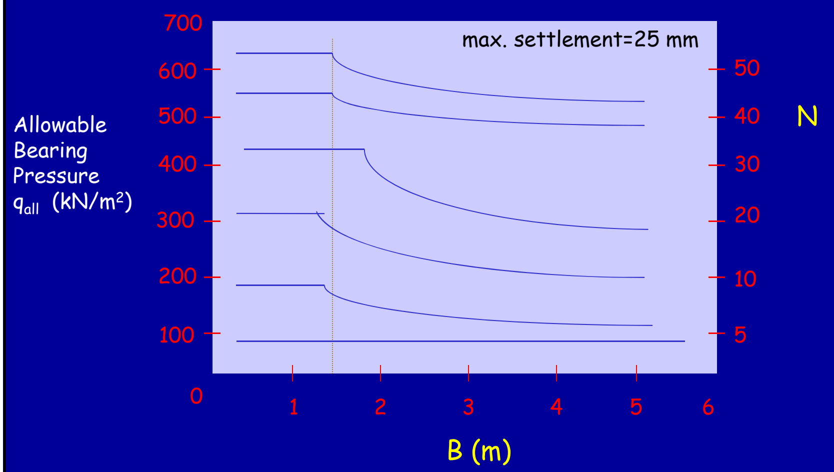
⇒ **sand & gravels** :calculations are made in terms of effective stresses. The c term (2^{nd} term) in equation 'q_u' can be omitted. ϕ can be determined from empirical studies (wrt SPT, CPT).

⇒ clays : Assuming ϕ (angle of shearing resistance) is zero , the 1^{st} & 3^{rd} term in equation 'q_u' are omitted.

⇒ silts : Calculations for q_u should be made separately for undrained (ϕ=0) and drained (c', ϕ') conditions. Use engineering judgement to decide which values to use for design.

BEARING CAPACITY

Design Methods by Terzaghi & Peck (sand)



BEARING CAPACITY

-max settlement SHOULD NOT EXCEED 25 mm.
-Applicable when w.t. > 2B below footing
-If sand at foundation is saturated, then pressure obtained from chart should be reduced by ,

$$\frac{1}{2} \quad \text{if} \quad D/B = 0$$
$$\frac{1}{3} \quad \text{if} \quad D/B = 1$$

-Correction for depth of w.t. :

$$c_w = 0{,}5 + 0{,}5 D_w/(D+B)$$

if settlement ≠25 mm

$$q_{all} = (q_a)_{chart} * c_w * settl./25$$

- *For raft foundations, 50 mm settlement is allowable, therefore values from chart should be* *doubled.*

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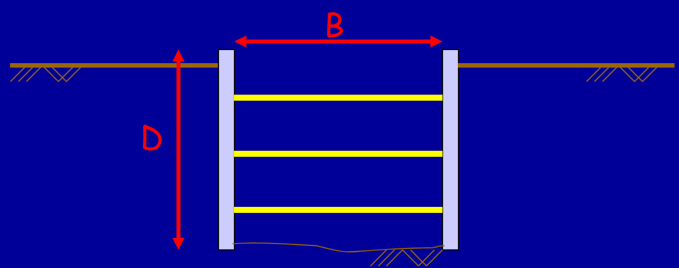
BEARING CAPACITY

Base Failure : (Skempton)

-Sides of excavations are strutted or anchored such that horizontal displacements are prevented.

-Soil is unloaded as excavation proceeds.



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BEARING CAPACITY

The depth of failure is :

$$D_c = \frac{c_u N_c}{\gamma} \qquad (q_f=0)$$

where c_u : immediately below or next to base of excavation

FS against base failure is :

$$F = \frac{c_u N_c}{\gamma D}$$

If there is surcharge pressure on surface next to excavation
⇒ add to denominator.

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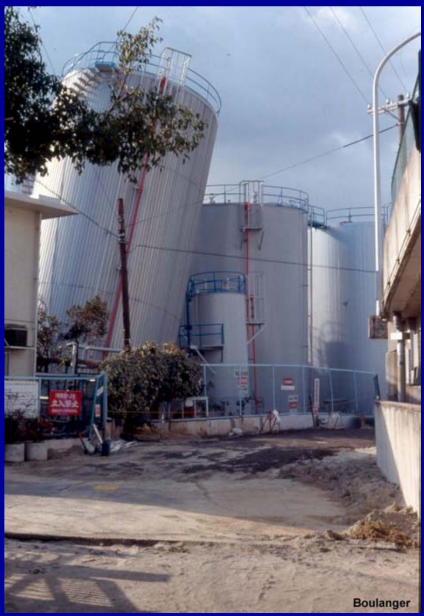

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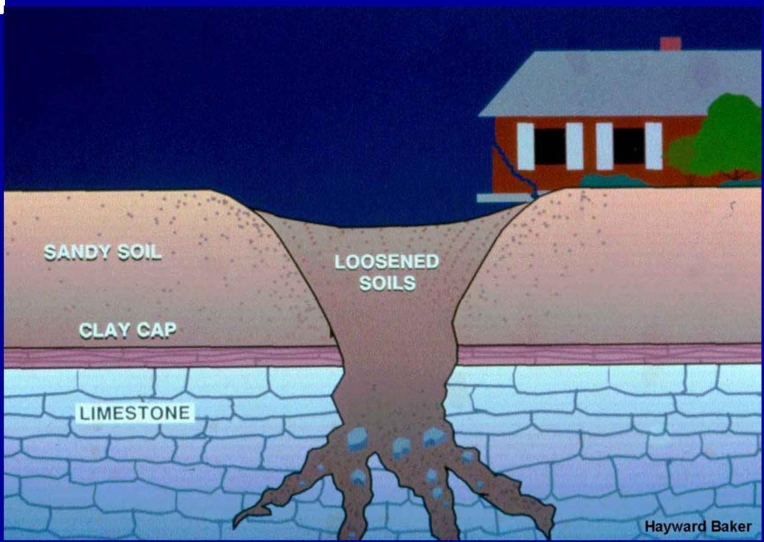
SANDY SOIL
LOOSENED SOILS
CLAY CAP
LIMESTONE
Hayward Baker

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