

## Clase No. 9- Fundaciones

### 1. Fundaciones Superficiales.

- Tipos y Usos.
- Capacidad de soporte
- Fórmula de Rotura: efecto del agua, forma de la zapata, correcciones por enterramiento, estratificación del suelo.
- Asentamientos en fundaciones superficiales: tipos de asentamientos, metodologías para la estimación de asentamientos, la constante de balastro, giros de fundación.
- Integración de los conceptos de rotura y asentamientos (giros) admisibles.
- Losas de fundación

## Asentamientos



## Asentamientos máximos permitidos

**Table 14.1 Allowable Settlement**

Type of Movement	Limiting Factor	Maximum Settlement	
Total settlement	Drainage	6-12 in.	
	Access	12-24 in.	
	Probability of nonuniform settlement:		
	Masonry walled structure	1-2 in.	
	Framed structures	2-4 in.	
	Smokestacks, silos, mats	3-12 in.	
Tilting	Stability against overturning	Depends on height and width	
	Tilting of smokestacks, towers	$0.004/l$	
	Rolling of trucks, etc.	$0.01/l$	
	Stacking of goods	$0.01/l$	
	Machine operation-cotton loom	$0.003/l$	
	Machine operation-turbogenerator	$0.0002/l$	
	Crane rails	$0.003/l$	
	Drainage of floors	$0.01-0.02/l$	
	Differential movement	High continuous brick walls	$0.0005-0.001/l$
		One-story brick mill building, wall cracking	$0.001-0.002/l$
Plaster cracking (gypsum)		$0.001/l$	
Reinforced-concrete building frame		$0.0025-0.004/l$	
Reinforced-concrete building curtain walls		$0.003/l$	
Steel frame, continuous		$0.002/l$	
Simple steel frame		$0.005/l$	

From Sowers, 1962.

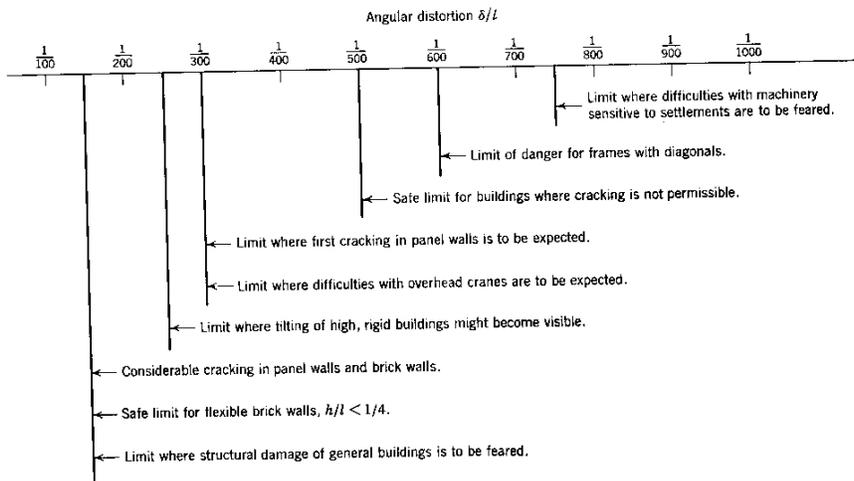
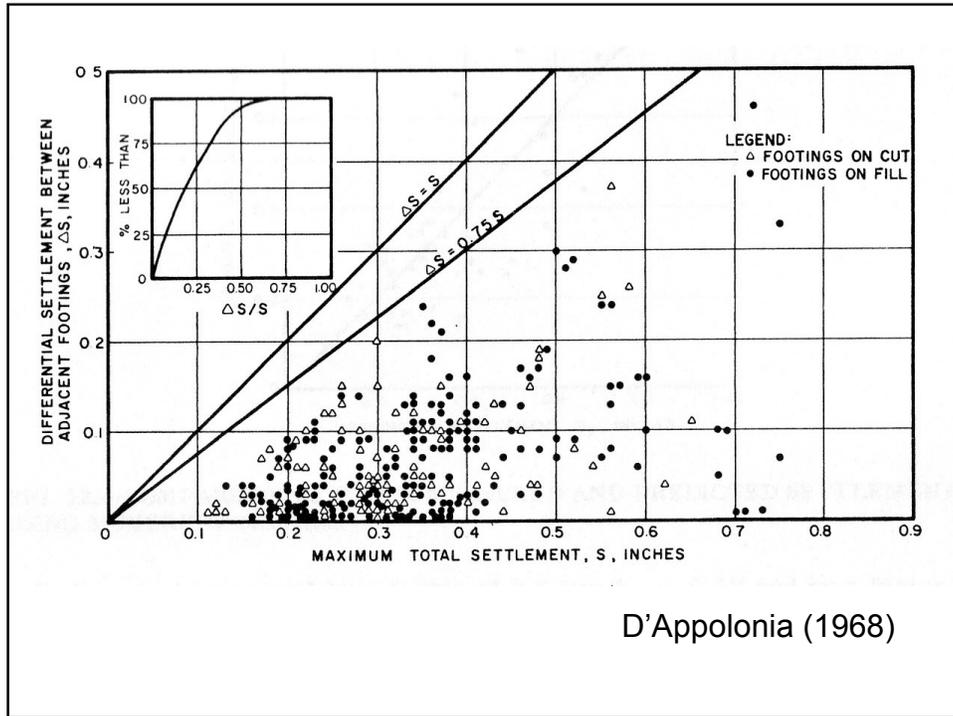
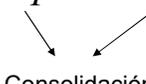


Fig. 14.8 Limiting angular distortions (From Bjerrum, 1963a).



## Asentamiento en fundaciones superficiales

$$\rho = \rho_e + \rho_p + \rho_s$$


Consolidación

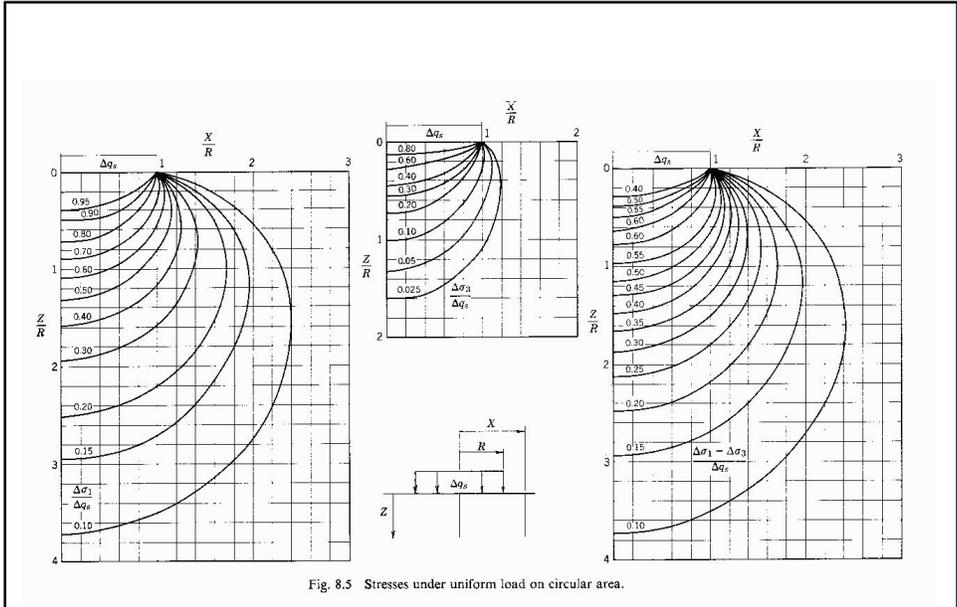
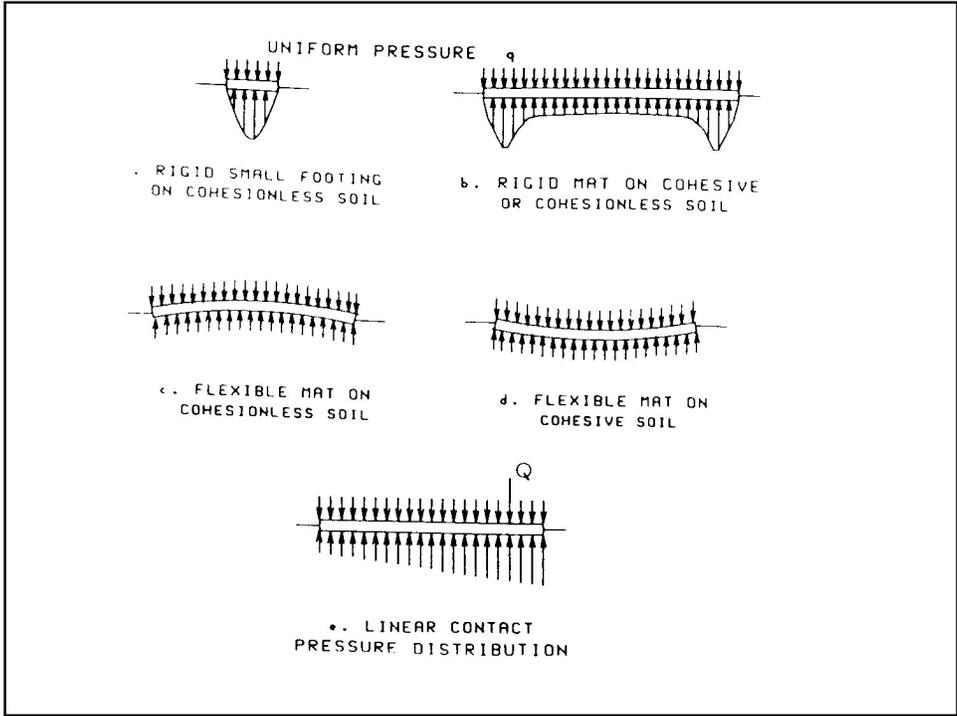
$\rho_e$

Categoría A -> Mediciones in-situ

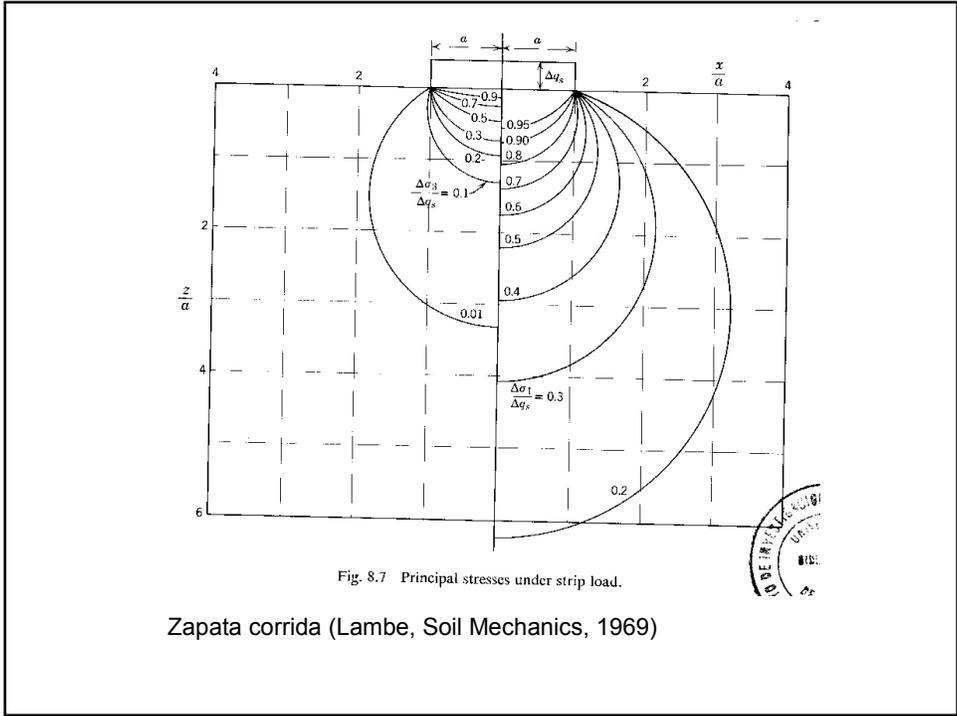
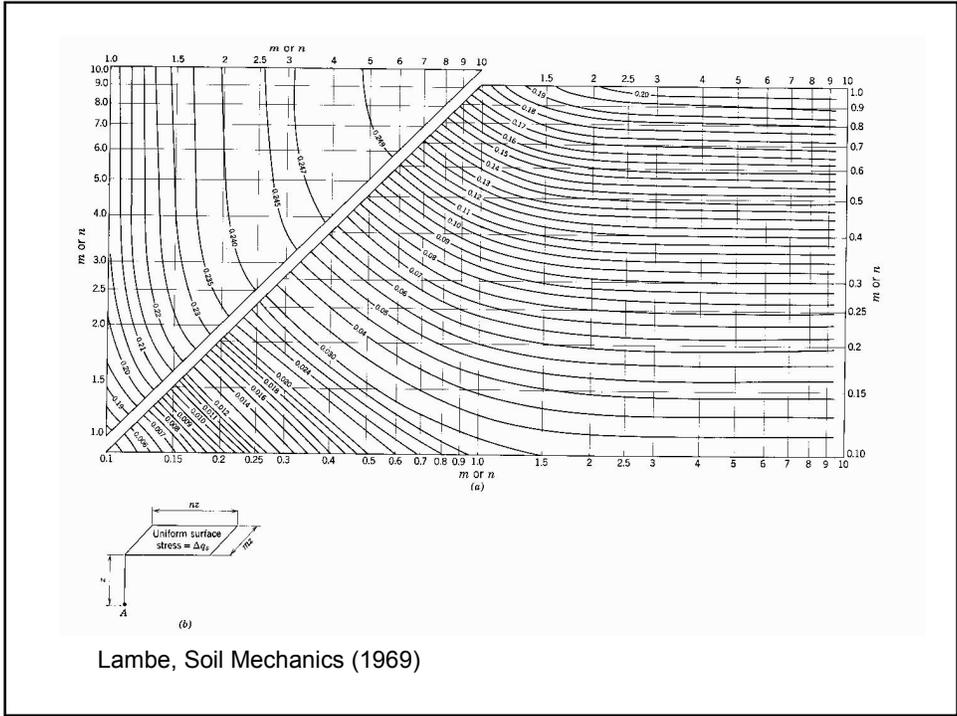
Categoría B -> Uso de la teoría  
de la elasticidad

## Cálculo de tensiones inducidas

- Teoría de la elasticidad
  - Comportamiento elástico;
  - Espacio homogéneo y semi-infinito
  - Pequeñas deformaciones
- Gráficos



(Lambe, Soil Mechanics, 1969)



## Cálculo de asentamientos instantáneos

- Basados en la teoría de la elasticidad

$$\rho_{ins} = \frac{q' B (1 - \nu^2) I_p}{E}$$

$q'$ : intensidad de la presión efectiva de contacto

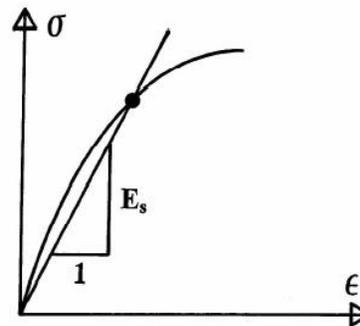
$B$ : ancho de la fundación

$\nu$ : coeficiente de Poisson

$E$ : módulo de deformación

$I_p$ : factor de influencia para el desplazamiento vertical

**Assumed Elastic Behavior:**  
Immediate deformations and/or settlements are calculated as linear elastic using closed-form solutions for elastic boundary value problems with an "elastic" modulus estimated from a stress-strain curve



**Example:**

$$S = q \cdot B \cdot \left( \frac{1 - \nu^2}{E_s} \right) \cdot I_w$$

Labels for the equation:

- $S$ : Settlement
- $q$ : Bearing Pressure
- $B$ : Width of Foundation
- $\left( \frac{1 - \nu^2}{E_s} \right)$ : "Elastic" Properties
- $I_w$ : Shape Factor for Foundation (based on small scale tests)

## Coeficiente de Poisson, $\nu$

- Normalmente considerado 0.25 a 0.3, aunque puede ser menor si se considera el comportamiento del suelo en la zona elástica.
- En condiciones No-drenadas es teóricamente igual a 0.5

$$G = \frac{E}{2(1 + \nu)}$$

G: Módulo de corte

E: Módulo de Young

**TABLE 2-7**  
**Values or value ranges for Poisson's ratio  $\mu$**

Type of soil	$\mu$
Clay, saturated	0.4–0.5
Clay, unsaturated	0.1–0.3
Sandy clay	0.2–0.3
Silt	0.3–0.35
Sand, gravelly sand	–0.1–1.00
commonly used	0.3–0.4
Rock	0.1–0.4 (depends somewhat on type of rock)
Loess	0.1–0.3
Ice	0.36
Concrete	0.15
Steel	0.33

Bowles (1996)

$\mu$	Soil type
0.4–0.5	Most clay soils
0.45–0.50	Saturated clay soils
0.3–0.4	Cohesionless—medium and dense
0.2–0.35	Cohesionless—loose to medium

## Factor de Influencia, $I_p$

Forma	Flexible			Rígida	
	Centro	Esquina	Promedio		
Circular	1.00	0.64	0.89	0.79	
Cuadrada	1.122	0.561	0.946	0.82	
Rectangular	L/B = 1.5	1.358	0.679	1.148	1.06
	2.0	1.532	0.766	1.300	1.20
	3.0	1.783	0.892	1.527	1.42
	4.0	1.964	0.982	1.694	1.58
	5.0	2.105	1.052	1.826	1.70
	10.0	2.540	1.270	2.246	2.10
	100.0	4.010	2.005	3.693	3.47

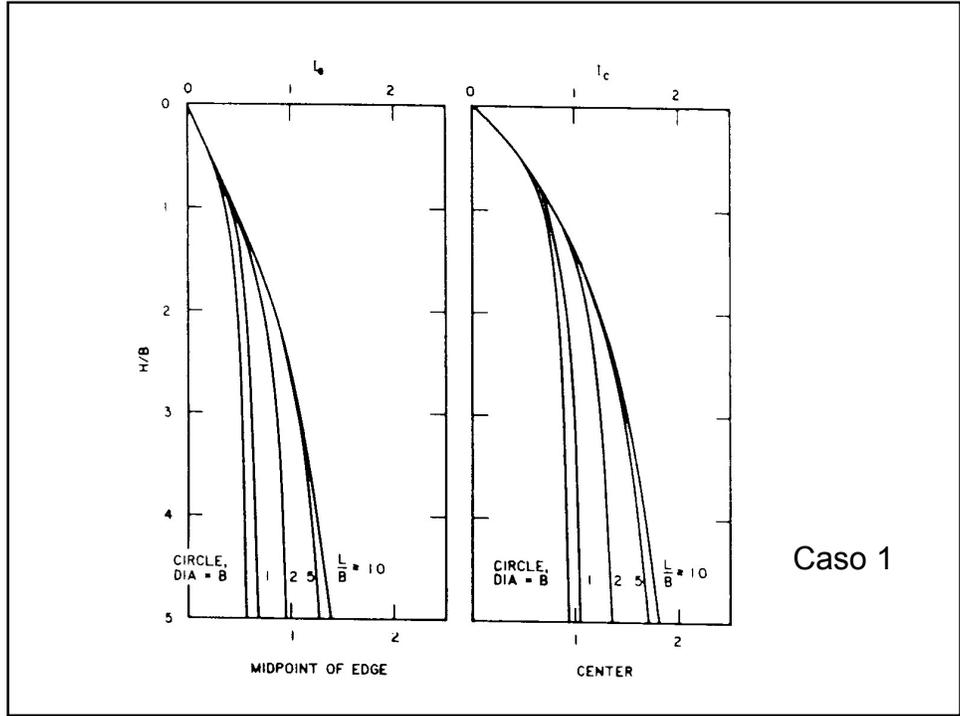
Whitlow (1994)

## Corrección de Perloff

$$\rho_{ins} = \frac{q' B (1 - \nu^2) I_p \alpha}{E_s}$$

Caso 1: Capa superior 1 es más compresible que la capa 2 que puede ser una arcilla dura, arena densa o roca.

Caso 2: Capa inferior 2 es más compresible que capa superior



**Factors for Estimating Immediate Settlement in Cohesive Soil: Correction Factor  $\alpha$  at the Center of a Circular Uniformly Loaded Area of Width  $B$  on an Elastic Layer of Modulus  $E_1$ , of Depth  $H$  Underlain by a Less Stiff Elastic Material of Modulus  $E_2$  of Infinite Depth**

$H/B$	$E_1/E_2$				
	1	2	5	10	100
0	1.000	1.000	1.000	1.000	1.000
0.1	1.000	0.972	0.943	0.923	0.760
0.25	1.000	0.885	0.779	0.699	0.431
0.5	1.000	0.747	0.566	0.463	0.228
1.0	1.000	0.627	0.399	0.287	0.121
2.5	1.000	0.550	0.274	0.175	0.058
5	1.000	0.525	0.238	0.136	0.036
$\infty$	1.000	0.500	0.200	0.100	0.010

Reprinted from D.M. Burmister, 1965, "Influence Diagrams for Stresses and Displacements in a Two-Layer Pavement System for Airfields," Contract NBY 13009, Department of the Navy, Washington, D.C. (item 7).

Caso 2

## Módulo de deformación, E

- Módulo de elasticidad ???
  - Módulo de deformación o módulo secante
- Normalmente se determina a través de ensayos triaxiales (muestras representativas) o de ensayos insitu.
- En suelos varía con el nivel de tensión de confinamiento

**TABLE 2-8**  
**Value range<sup>a</sup> for the static stress-strain modulus  $E_s$  for selected soils (see also Table 5-6)**

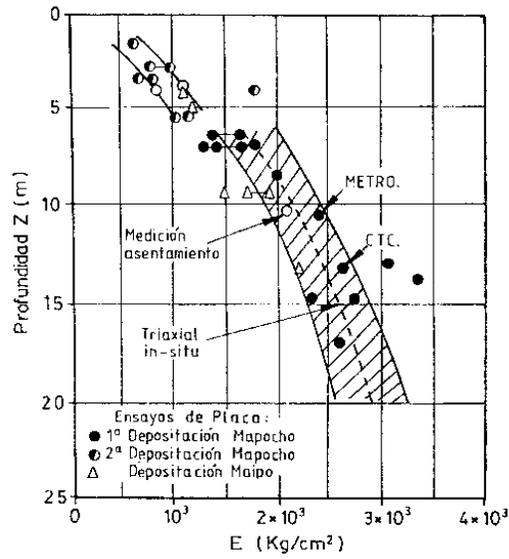
Field values depend on stress history, water content, density, and age of deposit

Soil	$E_s$ , MPa
Clay	
Very soft	2-15
Soft	5-25
Medium	15-50
Hard	50-100
Sandy	25-250
Glacial till	
Loose	10-150
Dense	150-720
Very dense	500-1440
Loess	15-60
Sand	
Silty	5-20
Loose	10-25
Dense	50-81
Sand and gravel	
Loose	50-150
Dense	100-200
Shale	150-5000
Silt	2-20

Bowles (1996)

<sup>a</sup>Value range is too large to use an "average" value for design.

# Grava de Santiago



Ortigosa&Kort (1997)

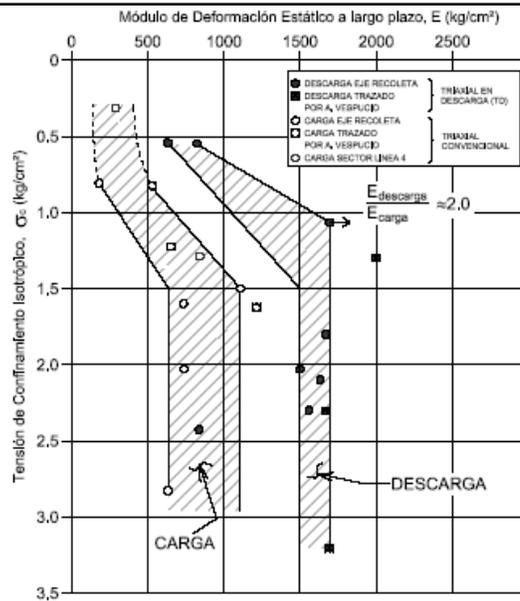


FIG.30 MODULOS DE DEFORMACIÓN ESTÁTICOS EN CARGA Y EN DESCARGA DRENADA PARA FS = 3.0 EN SUELOS FINOS CON HUMEDAD NATURAL

## Capacidad de soporte en suelos estratificados

- 1. Suelos finos
  - 1.A. Estrato superior más débil que los restantes estratos
  - 1.B. Estrato superior más resistente que los restantes estratos
- 2. Suelos No-cohesivos
  - 2.A. Estrato superior más débil que los restantes estratos
  - 2.B. Estrato superior más resistente que los restantes estratos
- 3. Suelos no-cohesivos con suelos finos

Ejemplo 1.A. Arcilla sobre estrato más competente

$$q_{ult} = Su \cdot N_{cH} + \gamma_{sat} \cdot D_f$$

B/H	$N_{cH}$ (Skempton)
< 2	$N_c$
2-7	$N_c + ((B/2H) - 1)$
> 7	7.6

## Ejemplo caso 1.B. Arcilla resistente sobre arcilla blanda

$$q_{ult} = S_u^1 \cdot N_c^* + \gamma_{sat} D_f$$

● Brown and Meyerhof, 1969)

Zapata corrida

$$N_c^* = \frac{3d}{2B} + 5.14 \frac{S_u^2}{S_u^1} \leq 5.14$$

d: distancia desde el sello de fundación a la capa de Suelo 2

Zapata circular

$$N_c^* = \frac{3d}{B} + 6.05 \frac{S_u^2}{S_u^1} \leq 6.05$$

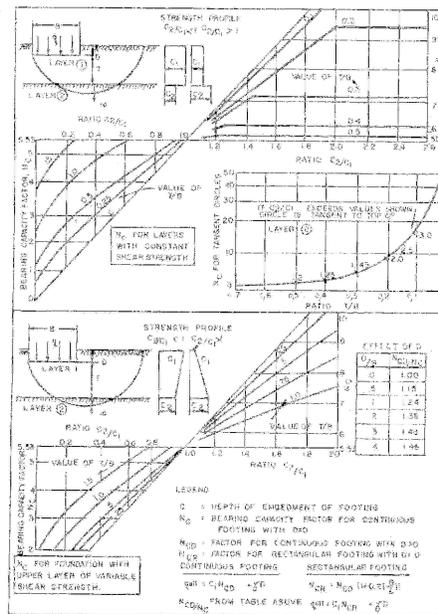


FIGURE 11.5  
Ultimate Bearing Capacity on Two Layer Cohesive Soil ( $c_u = 0$ )

7-11-5

## Ejemplo 2.B y 3. Suelo no-cohesivo sobre suelo blando

### ● Perloff (1975)

- Distribución de tensiones 2V:1H
- Considerar la menor capacidad de soporte

## Ejemplo Caso 3. Arena densa sobre arcilla blanda

### ● Hanna and Meyerhof (1980)

Wall Footing:

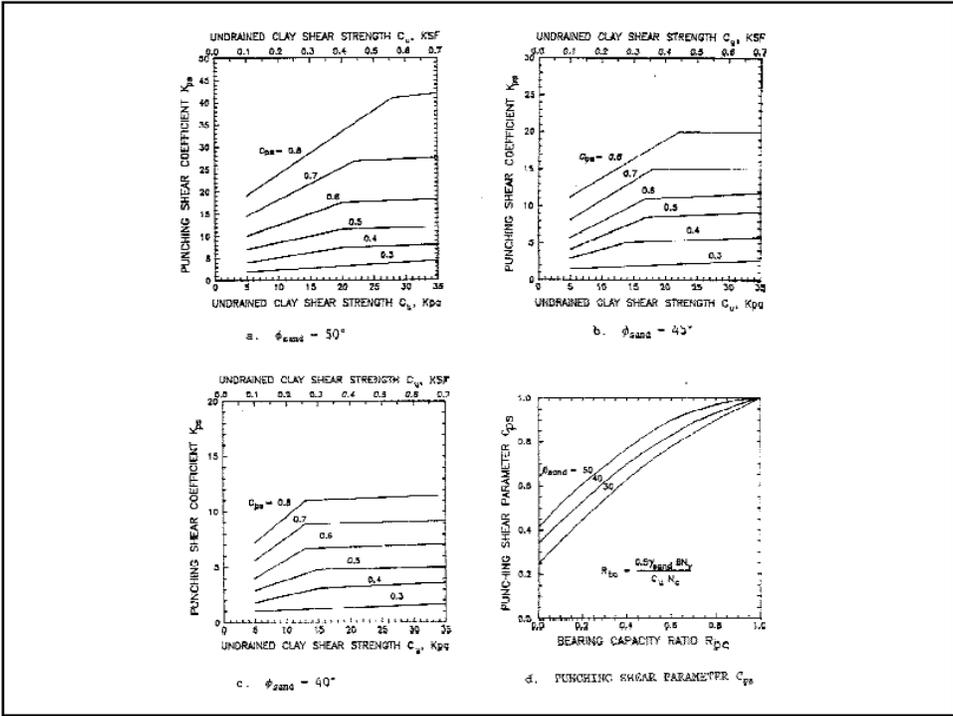
$$q_u = q_{u,b} + \frac{2\gamma_{sand}H_c^2}{B} \left(1 + \frac{2D}{H_c}\right) K_{ps} \tan\phi_{sand} - \gamma_{sand}H_c \leq q_{ut}$$

Circular Footing:

$$q_u = q_{u,b} + \frac{2\gamma_{sand}H_c^2}{B} \left(1 + \frac{2D}{H_c}\right) S_s K_{ps} \tan\phi_{sand} - \gamma_{sand}H_c \leq q_{ut}$$

where

- $q_{u,b}$  = ultimate bearing capacity on a very thick bed of the bottom soft clay layer, ksf
- $\gamma_{sand}$  = wet unit weight of the upper dense sand, kips/ft<sup>3</sup>
- $H_c$  = depth below footing base to soft clay, ft
- $D$  = depth of footing base below ground surface, ft
- $K_{ps}$  = punching shear coefficient, Figure 4-2a, 4-2b, and 4-2c
- $\phi_{sand}$  = angle of internal friction of upper dense sand, degrees
- $S_s$  = shape factor
- $q_{ut}$  = ultimate bearing capacity of upper dense sand, ksf



# Caso General