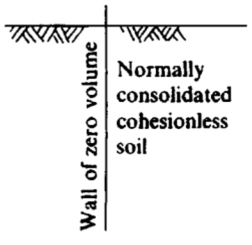
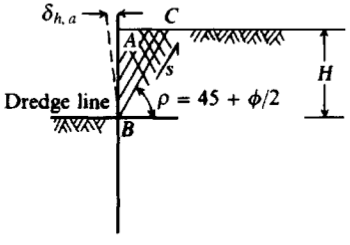
Resumen

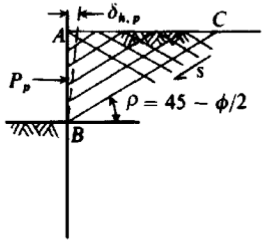
- Empuje en reposo $K=K_0$. Estado elástico, $\delta_h=0$.
- Empuje activo $K=K_A$. Estado plástico, $\delta_h>0$, $\sigma'_h<\sigma'_v$
- Empuje pasivo $K=K_P$. Estado plástico, $\delta_h>0$, $\sigma'_h>\sigma'_v$


Wall of zero volume
Normally consolidated cohesionless soil

(*a*)


$\delta_{h,a}$
C
A
S
H
Dredge line
$\rho = 45 + \phi/2$
B

(*b*) Active case.


$\delta_{h,p}$
A
C
P_p
S
$\rho = 45 - \phi/2$
B

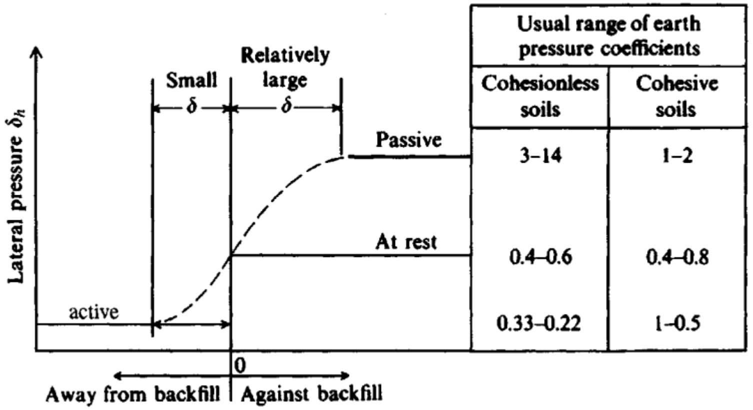
(*c*) Passive case.

$$\sigma'_v = \gamma z \qquad \sigma'_h = K\sigma'_V$$

$$P = \frac{1}{2}\sigma'_h H$$

Resumen

Suelo y condición	Deformación Horizontal, δh
No cohesivo denso	0.001 a 0.002H
No cohesivo suelto	0.002 a 0.004H
Cohesivo firme	0.01 a 0.02H
Cohesivo blando	0.02 a 0.05H

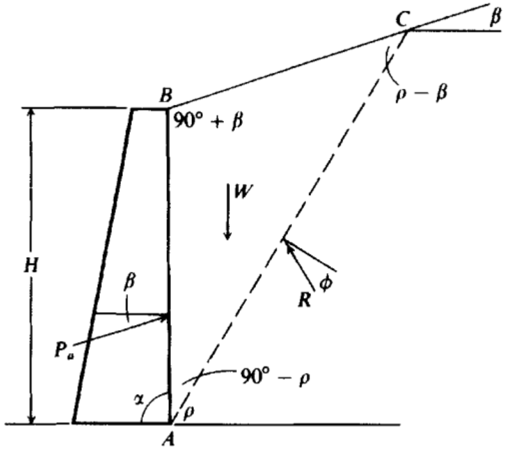

Lateral pressure δ_h
Small
δ
Relatively large
δ
Passive
At rest
active
0
Away from backfill
Against backfill

Usual range of earth pressure coefficients	
Cohesionless soils	Cohesive soils
3–14	1–2
0.4–0.6	0.4–0.8
0.33–0.22	1–0.5

Teoría Rankine

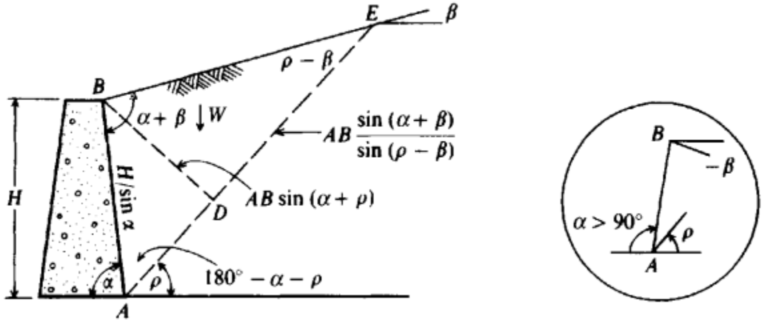
- EMPUJE ACTIVO Y PASIVO
- Suelo es isótropo y homogéneo
- La superficie de ruptura es plana
- El ángulo de fricción es uniforme
- El volumen de falla es cuerpo rígido
- **No hay roce suelo-muro**

$$K_A = \frac{1 - sen\phi}{1 + sen\phi} = \frac{1}{K_P}$$


C
β
ρ − β
B
90° + β
W
H
β
R
φ
P_a
90° − ρ
α
ρ
A

Teoría Coulomb

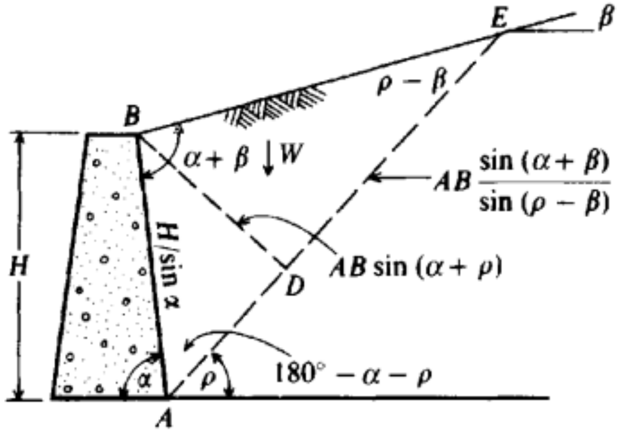
- EMPUJE ACTIVO Y PASIVO
- Suelo es isótropo y homogéneo
- La superficie de ruptura es plana
- El ángulo de fricción es uniforme
- El volumen de falla es cuerpo rígido
- **Hay roce suelo-muro**

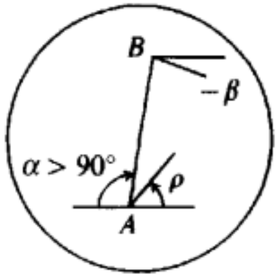

E
β
ρ − β
B
α + β
W
$AB \frac{\sin(\alpha+\beta)}{\sin(\rho-\beta)}$
H
H/sin α
$AB \sin(\alpha+\rho)$
D
α
ρ
180° − α − ρ
A
B
−β
α > 90°
ρ
A

Teoría Coulomb

- EMPUJE ACTIVO

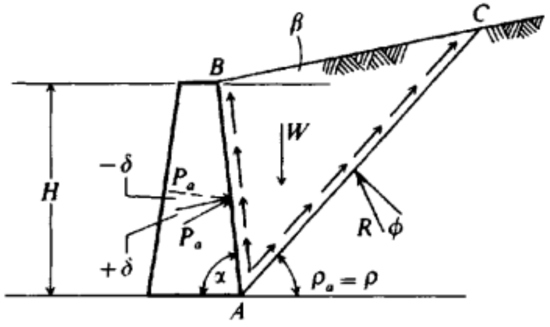
$$W = \gamma A = \frac{\gamma H^2}{2 sen^2\alpha}\left[sen(\alpha+\rho)\frac{sen(\alpha+\beta)}{sen(\alpha-\beta)}\right]$$


E
β
ρ − β
B
α + β
W
AB $\frac{\sin(\alpha+\beta)}{\sin(\rho-\beta)}$
H/sin α
AB sin (α + ρ)
H
D
180° − α − ρ
α
ρ
A

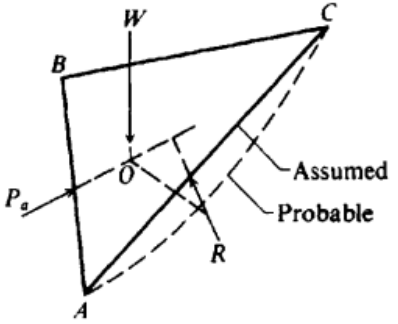


Teoría Coulomb

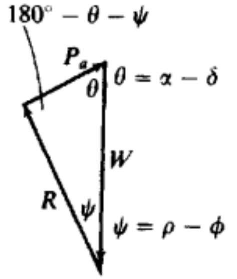
- EMPUJE ACTIVO


β
C
B
W
H
−δ
P_a
P_a
+δ
α
R
φ
A
$\rho_a = \rho$

(*a*) Assumed conditions for failure


W
C
B
O
P_a
Assumed
Probable
R
A

(*b*) Indication that all force vectors may not pass through point *O*; hence static equilibrium is not satisfied


180° − θ − ψ
P_a
θ = α − δ
θ
W
R
ψ
ψ = ρ − φ

(*c*) Force triangle to establish P_a

$$\frac{P_a}{sen(\rho-\phi)} = \frac{W}{sen(180°-\alpha-\rho+\phi+\delta)}$$

$$P_a = \frac{W sen(\rho-\phi)}{sen(180°-\alpha-\rho+\phi+\delta)}$$

$$P_a = \frac{\gamma H^2}{2 sen^2\alpha}\left[sen(\alpha+\rho)\frac{sen(\alpha+\beta)}{sen(\rho-\beta)}\right]\frac{sen(\rho-\phi)}{sen(180°-\alpha-\rho+\phi+\delta)}$$

Teoría Coulomb

- EMPUJE ACTIVO

$$P_a = \frac{\gamma H^2}{2}\frac{sen^2(\alpha+\phi)}{sen^2\alpha sen(\alpha-\delta)\left[1+\sqrt{\frac{sen(\phi+\delta)sen(\phi-\beta)}{sen(\alpha-\delta)sen(\alpha+\beta)}}\right]^2}$$

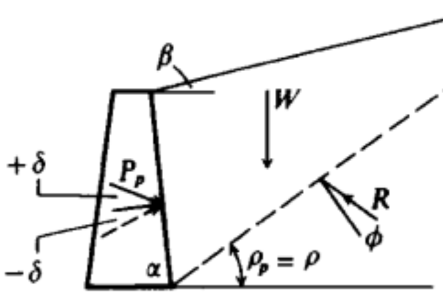
Para $\beta = \delta = 0$ y $\alpha = 90^\circ$

$$P_a = \frac{\gamma H^2}{2}\frac{(1-sen\phi)}{(1+sen\phi)}$$

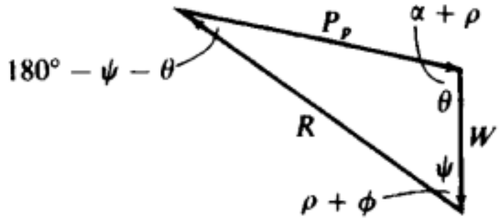
$$K_A = \frac{sen^2(\alpha+\phi)}{sen^2\alpha sen(\alpha-\delta)\left[1+\sqrt{\frac{sen(\phi+\delta)sen(\phi-\beta)}{sen(\alpha-\delta)sen(\alpha+\beta)}}\right]^2}$$

Teoría Coulomb

- EMPUJE PASIVO



(*a*) Failure wedge and forces acting on it for passive earth pressure



(*b*) Force polygon for graphical computation of passive earth force, note $\rho_p = \rho_a$ of Fig. 11-5

$$W = \frac{\gamma H^2}{2} sen(\alpha + \rho) \frac{sen(\alpha + \beta)}{sen(\rho - \beta}$$

$$P_p = \frac{W sen(\rho + \phi)}{sen(180° - \alpha - \rho - \phi - \delta)}$$

$$P_P = \frac{\gamma H^2}{2} \frac{sen^2(\alpha - \phi)}{sen^2 \alpha \, sen(\alpha + \delta) \left[1 - \sqrt{\frac{sen(\phi + \delta) sen(\phi + \beta)}{sen(\alpha + \delta) sen(\alpha + \beta)}} \right]^2}$$

Teoría Coulomb

- EMPUJE PASIVO

Para $\beta = \delta = 0$ y $\alpha = 90°$

$$P_P = \frac{\gamma H^2}{2}\frac{(1+sen\phi)}{(1-sen\phi)}$$

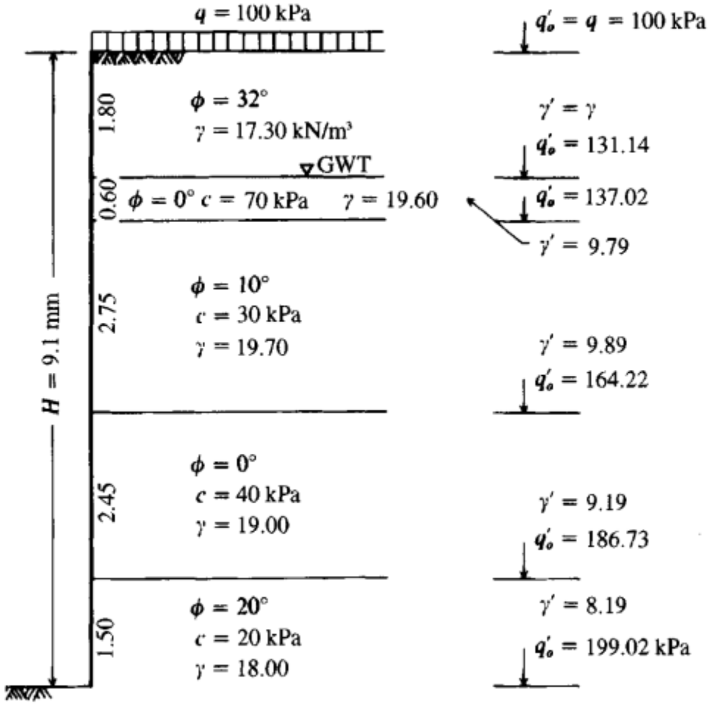
$$K_P = \frac{sen^2(\alpha-\phi)}{sen^2\alpha sen(\alpha+\delta)\left[1+\sqrt{\frac{sen(\phi+\delta)sen(\phi+\beta)}{sen(\alpha+\delta)sen(\alpha+\beta)}}\right]^2}$$

Teoría Coulomb

Ángulo de fricción muro-suelo δ

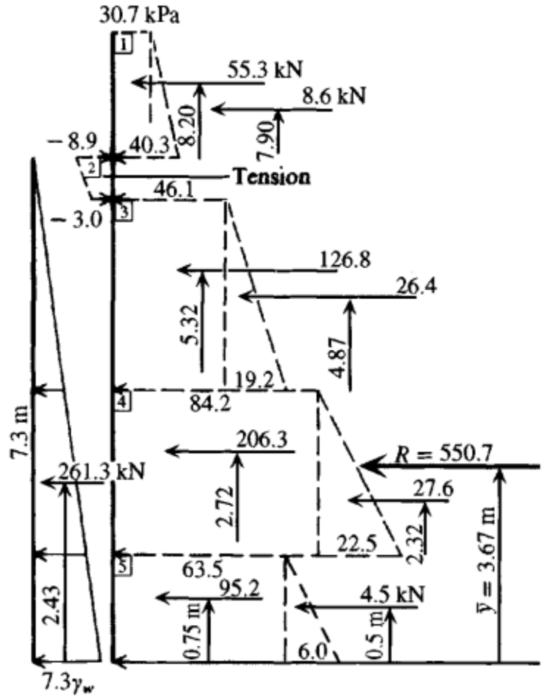
Interface de Materiales	Ángulo de Fricción δ
Muro hormigonado:	
Gravas limpias	22-26
Arenas limpias	17-22
Arena Limosa y/o arcillosa	17
Muro hormigonado contra:	
Gravas, arenas, limos, arcillas	ϕ
Madera	14-16

Ejemplo de Cálculo



q = 100 kPa
1.80
φ = 32°
γ = 17.30 kN/m³
GWT
0.60
φ = 0° c = 70 kPa γ = 19.60
2.75
φ = 10°
c = 30 kPa
γ = 19.70
H = 9.1 mm
2.45
φ = 0°
c = 40 kPa
γ = 19.00
1.50
φ = 20°
c = 20 kPa
γ = 18.00
q'ₒ = q = 100 kPa
γ' = γ
q'ₒ = 131.14
q'ₒ = 137.02
γ' = 9.79
γ' = 9.89
q'ₒ = 164.22
γ' = 9.19
q'ₒ = 186.73
γ' = 8.19
q'ₒ = 199.02 kPa

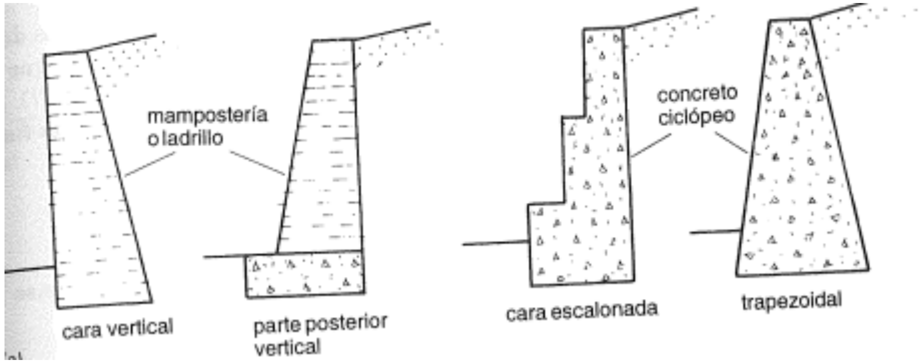
(*a*) Soil profile.

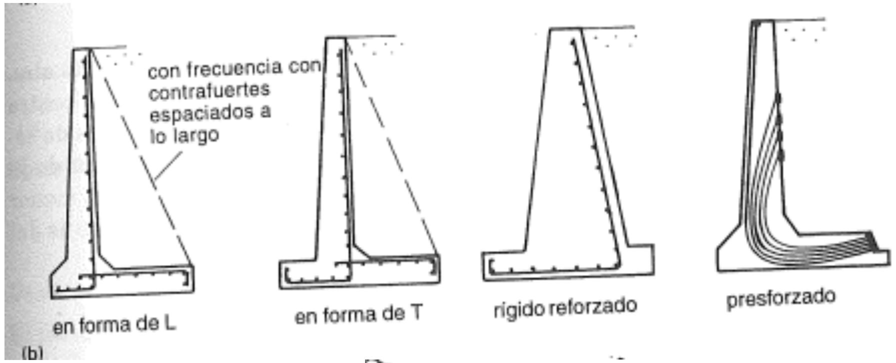


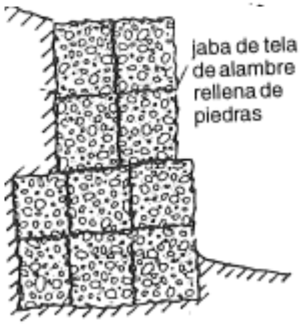
30.7 kPa
1
55.3 kN
8.6 kN
8.20
7.90
−8.9
40.3
2
Tension
46.1
3
−3.0
126.8
26.4
5.32
4.87
19.2
4
84.2
7.3 m
206.3
R = 550.7
261.3 kN
27.6
2.72
2.32
ȳ = 3.67 m
22.5
5
63.5
95.2
4.5 kN
2.43
0.75 m
0.5 m
6.0
7.3γw

(*b*) Pressure profile.

Cálculo de Equilibrio


mampostería
o ladrillo
concreto
ciclópeo
cara vertical
parte posterior
vertical
cara escalonada
trapezoidal


con frecuencia con
contrafuertes
espaciados a
lo largo
en forma de L
en forma de T
rígido reforzado
presforzado
(b)


jaba de tela
de alambre
rellena de
piedras

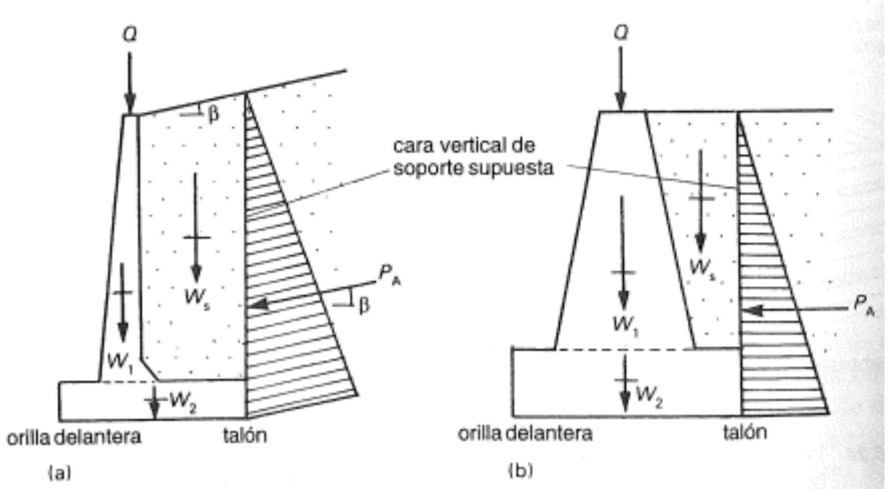
Cálculo de Equilibrio

- VOLCAMIENTO

Cálculo de empujes y equilibrio

$$\sum F_H = R \qquad \sum \mathrm{F}_{\mathrm{Hi}} h_i = R h_r$$

$$FS_{volc} = \frac{\sum (\mathrm{Momentos} W_i + Q_i + etc)}{\sum (\mathrm{Momentos\ P_A} + etc)} > 2.0$$

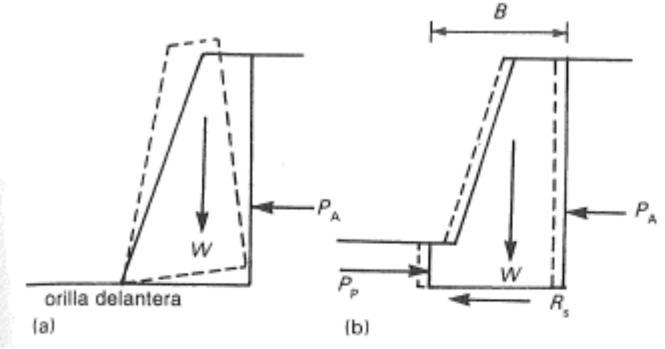

Q
β
W_s
P_A
β
W_1
W_2
orilla delantera
talón
(a)
Q
cara vertical de
soporte supuesta
W_s
W_1
P_A
W_2
orilla delantera
talón
(b)

Cálculo de Equilibrio

- DESLIZAMIENTO

$$R_S = V \tan\delta$$

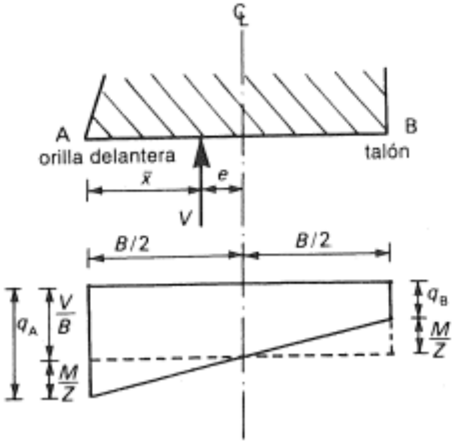
$$FS_{volc} = \frac{R_s}{P_A} > 2.0$$



B
P_A
W
orilla delantera
(a)
P_A
W
P_P
R_s
(b)

Cálculo de Equilibrio

- TENSIONES DE CONTACTO


℄
A
orilla delantera
B
talón
$\bar{x}$
e
V
B/2
B/2
q_A
$\frac{V}{B}$
$\frac{M}{Z}$
q_B
$\frac{M}{Z}$

$$q_A = \frac{V}{B} + \frac{M}{Z} \quad \text{y} \quad q_B = \frac{V}{B} - \frac{M}{Z}$$

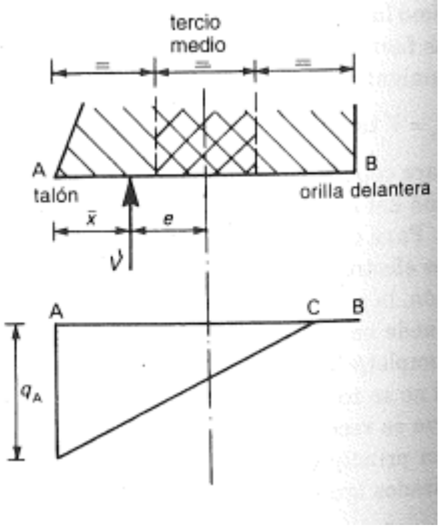
$$M = Ve \quad \text{y} \quad Z = \frac{1 \times B^2}{6}$$

$$q_A = \frac{V}{B} + \frac{6Ve}{B^2} \quad \text{y} \quad q_B = \frac{V}{B} - \frac{6Ve}{B^2}$$

$Si:$

$$\text{e} > {}^{\text{B}}\!/_{6} \Rightarrow q_A = \frac{2V}{3\bar{x}}$$

q_A Menor a la máxima tensión admisible del suelo.


tercio medio
=
=
=
A
talón
B
orilla delantera
$\bar{x}$
e
V
A
C
B
q_A