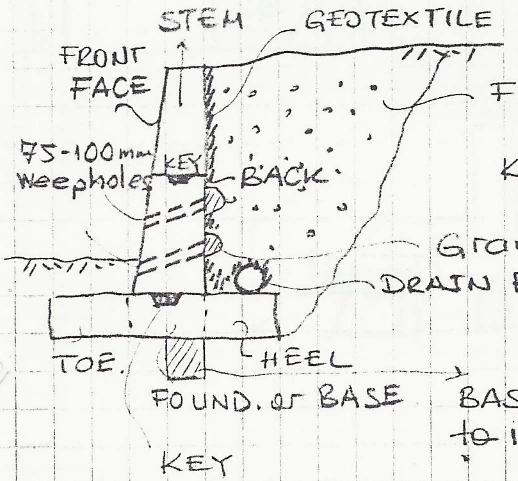
RETAINING WALLS Read. Ass: BOWLES: (12.1 - 12.16)

Common Uses of Retaining Walls Sheet Fig. 11.1

Types : GRAVITY
SEMI-GRAVITY
CANTILEVER Sheet Fig. 11.2
COUNTERFORT
BUTTRESSED
CRIBWALLS
REINFORCED EARTH



FREE-DRAINING BACKFILL

KEY: between successive concrete walls.

Granular material to avoid plugging

DRAIN PIPE

FAILURE In DRAINAGE → may lead to failure in wall.

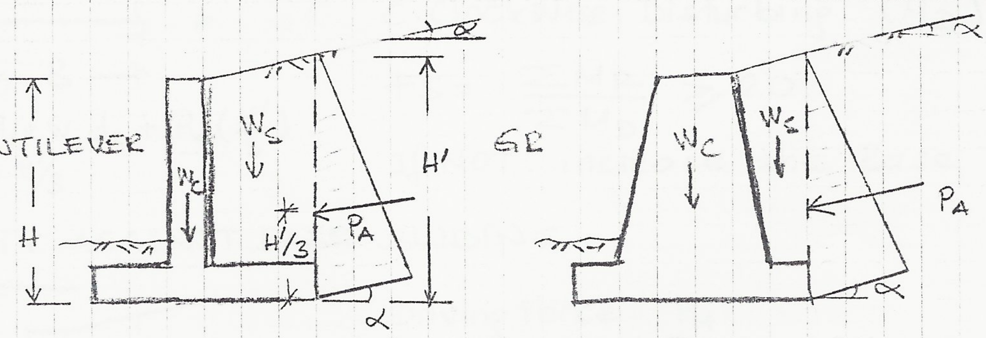
BASE KEY to increase base friction (Usually under the STEM)

DESIGN DIMENSIONS (for preliminary design) Sheet!

LOADS ACTING: Main function is to resist Lateral earth pressures (ACTIVE)

Lateral Earth Pressure Theories: RANKINE → WALL FRICTIONLESS
COULOMB : FRICTION b/w WALL and BACKFILL.

RANKINE:



$P_A = \frac{1}{2} \gamma H'^2 K_A$ $\quad K_A = \cos\alpha \dfrac{\cos\alpha - \sqrt{\cos^2\alpha - \cos^2\phi}}{\cos\alpha + \sqrt{\cos^2\alpha - \cos^2\phi}}$ COHESIONLESS BACKFILL $c=0$

α = backfill slope
ϕ = friction angle of backfill

Note if $\alpha = 0$ → $K_A = \dfrac{1-\sin\phi}{1+\sin\phi}$

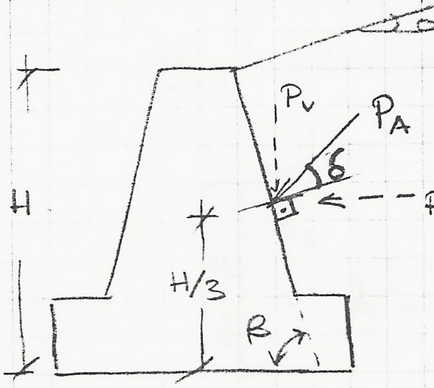
W_c & W_s → included.

P_A is // to backfill slope.

Passive resistance at front face is ignored. (future exc.)

FOR CANTILEVER WALLS → USE RANKINE

COULOMB → usually for Gravity Walls.

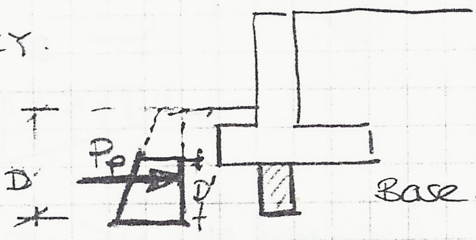


$$P_A = \frac{1}{2}\gamma H^2 K_A$$

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

Note: W_s above the heel is ignored!

BASE KEY.



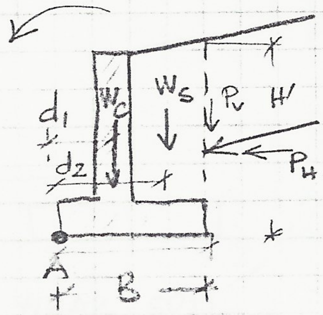
$$P_P = \frac{1}{2}\gamma_2 D'^2 K_P + 2c_2 D' \sqrt{K_P}$$

Base soil: $c_2 \phi_2, \gamma_2$

USE RANKINE $K_P = \dfrac{1+\sin\phi_2}{1-\sin\phi_2}$

STABILITY CHECKS: (DESIGN)

1. SAFETY AGAINST OVERTURNING.



Consider forces W_c, W_s, P_V, P_H

Take moment w.r.t A (TOE)

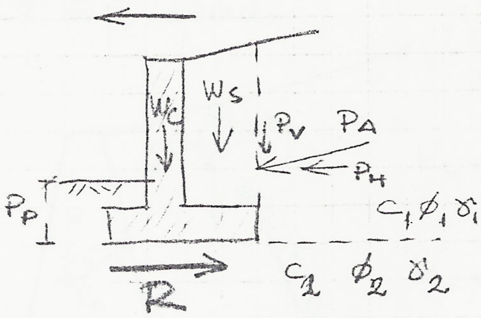
Clockwise: Resisting (M_R) (W_c, W_s, P_V)
C.Clockwise: Disturbing (M_D) (P_H)

$$FS = \frac{\Sigma M_R}{\Sigma M_D} \geq 2.0.$$

If NOT: increase the Base B

$\Sigma M_R = W_c d_1 + W_s d_2 + P_V \left(\frac{H'}{3}\right)$
$\Sigma M_D = P_H \times H'/3$

2. SAFETY AGAINST BASE SLIDING:



Driving Force P_H
Ignore P_P

Resisting Force: R.

$$R = c_2 B + \Sigma V \tan\phi_2 + P_P.$$

$$FS = \frac{c_2^* B + (\Sigma V)\tan\phi_2^* + P_P}{P_H = P_A\cos\alpha} \geq 1.5$$

If base key: $P_P = \frac{1}{2}\gamma_2 D'^2 K_P + 2c_2 D'\sqrt{K_P}$ ϕ_2

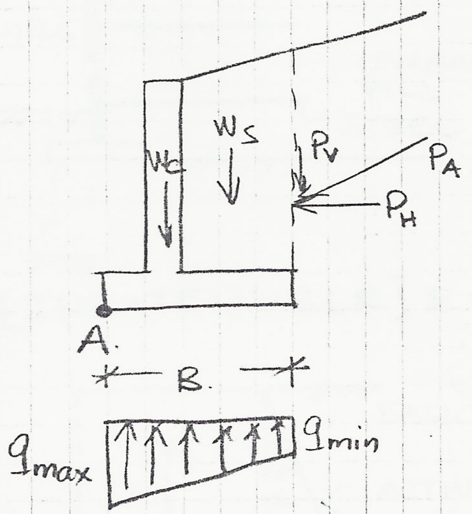
Use Reduced c_2 an ϕ_2. ($\phi^*_{design} = (0.5-0.67)\phi_2$, $c^*_{design} = (0.5-0.67)c_2$)

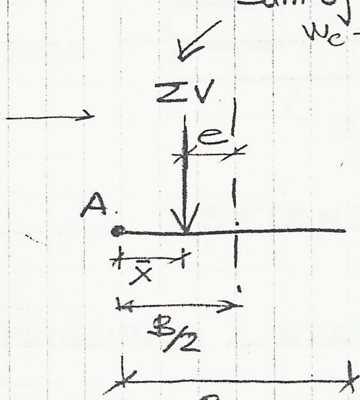
If not: increase B or provide key

3. BASE PRESSURES (bearing capacity failure)

q_{all} : allowable bearing capacity of foundation soil.

sum of vertical forces.
$W_c + W_s + P_v$





$$\bar{x} = \frac{\Sigma M_R - \Sigma M_D}{\Sigma V}$$

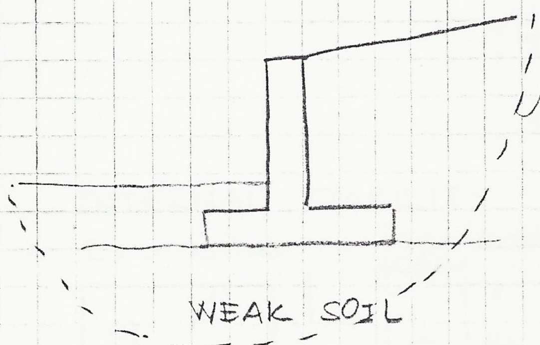
$$e = \frac{B}{2} - \bar{x}$$

$$q_{\substack{max \\ min}} = \frac{\Sigma V}{B \times 1}\left(1 \mp \frac{6e}{B}\right)$$

$q_{min} > 0$ (No tension)

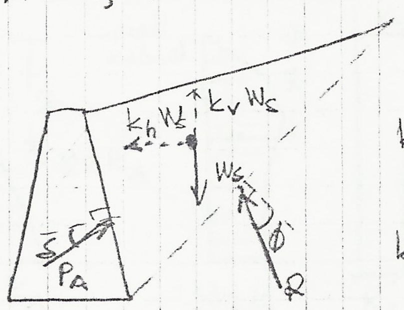
$q_{max} < q_{all}$

4. DEEP SEATED SHEAR FAILURE



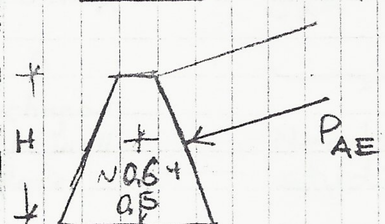
5. CHECK FOR SETTLEMENTS (conventional)
6. REINFORCEMENT DESIGN
7. EQ Loads

Coulomb Failure Wedge & Loads
[MONONOBE-OKABE solution]
Add EQ. Forces



$$k_h = \frac{\text{horizontal EQ. accel. comp}}{\text{accel. due to gravity, g.}}$$

$$k_v = \frac{\text{vertical EQ accel. comp}}{g}$$

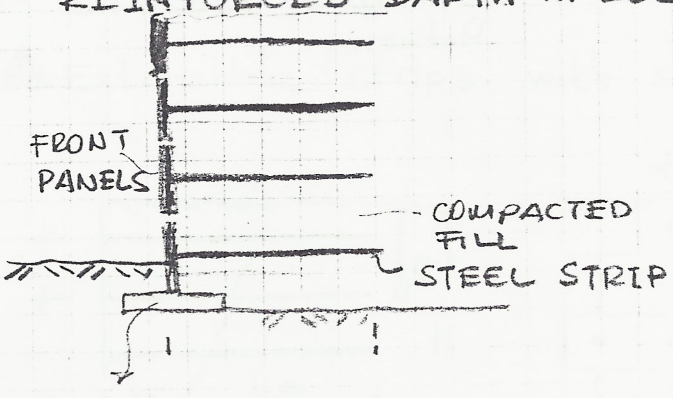


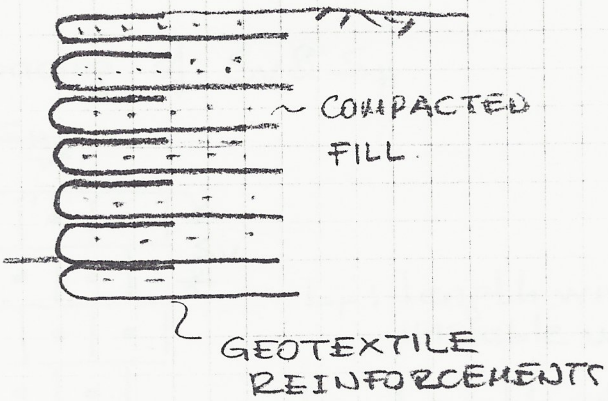
$$P_{AE} = \frac{1}{2}\gamma H^2 (1 - k_v) K_{AE}$$

$$K_{AE} = \frac{\sin^2(\phi + \beta - \theta')}{\cos\theta' \sin^2\beta \sin(\beta - \theta' - \delta)\left[1 + \sqrt{\frac{\sin(\phi+\delta)\sin(\phi - \theta' - \alpha)}{\sin(\beta - \delta - \theta')\sin(\alpha + \beta)}}\right]^2}$$

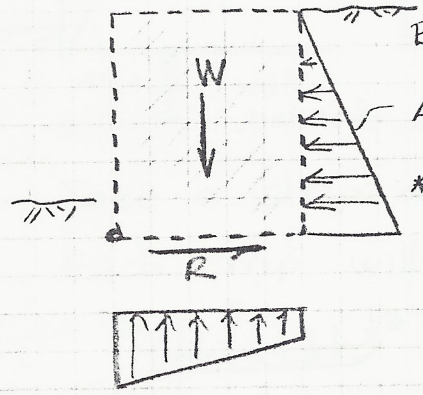
$$\theta' = \tan^{-1}\left[\frac{k_h}{1 - k_v}\right]$$

REINFORCED EARTH WALLS:





[INEXTENSIBLE] R.F. [EXTENSIBLE] RF



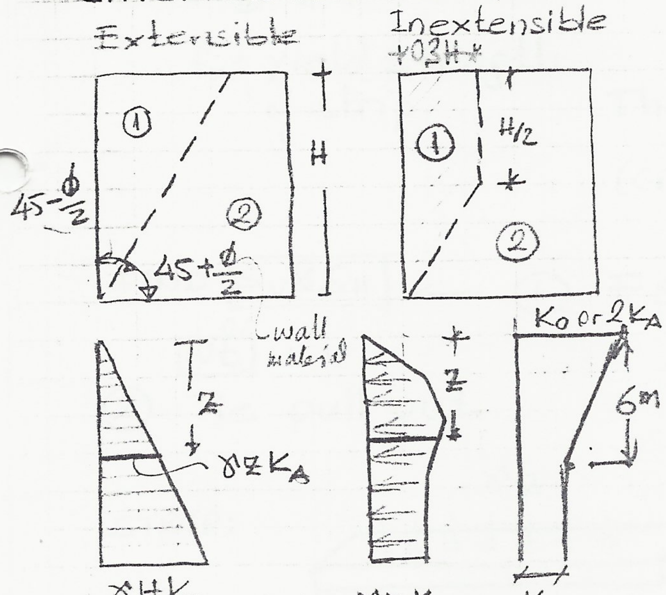
BASIC PRINCIPLE: A GRAVITY WALL

ACTIVE EARTH PRESSURE. (ϕ: natural soil)

* EXTERNAL STABILITY: Same as ordinary retaining walls

- overturning
- Base sliding
- Base pressures
- Deep seated shear failure
- settlements

INTERNAL STABILITY



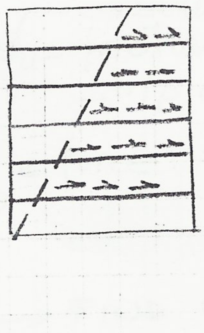
Acting on the wall face.

Needs further studies

① UNSTABLE WEDGE

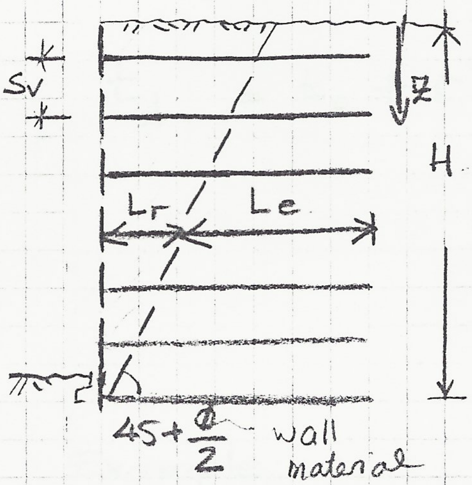
② STABLE WEDGE

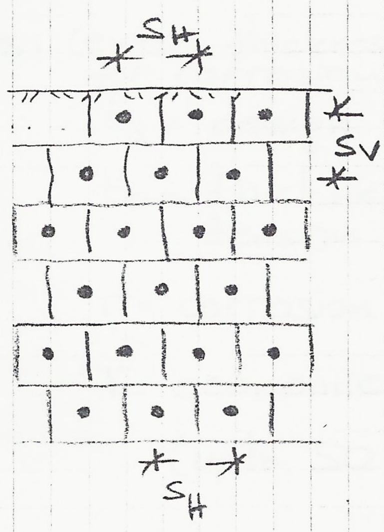
Unstable wedge is hold by tensile forces in the reinforcement. Tensile force is provided by friction b/w soil and reinforcement



SIMPLEST CASE

Extensible ~~strips~~ metal strips with spacing of S_V & S_H.





L_r: length within unstable wedge

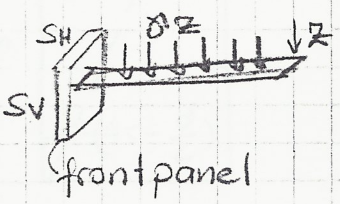
L_e: Length within stable wedge

$L = L_r + L_e$

$(L_r)_{max} = H \tan(45 - \frac{\phi}{2})$

Take a strip at depth "z":

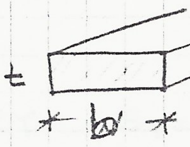
Each strip will support an area of $S_V \times S_H$.



Active pressure on strip = Tension in strip.

$T = (\gamma z K_A) S_V S_H$

$T_{max} = \gamma H K_A S_V S_H$



f_y: yield strength of strip.

Each strip can resist a tension of

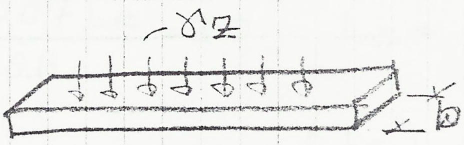
$T_{all} = b t f_y$

Then FS against Tie Break (or tension failure):

FIND $\boxed{S_V \& S_H}$ or $\boxed{wt}$ ← ① $FS_b = \dfrac{b t f_y}{\gamma H K_A S_V S_H} \cong 3.0$ → required

② Tie pull out

STRIP:



Available friction:

$F = 2 b L_e \gamma z \tan\phi_u$ → both sides

ϕ_u = friction angle b/w strip and soil

Tie force: $T = \gamma z K_A S_V S_H$

$FS_p = \dfrac{2 b L_e \cancel{\gamma z} \tan\phi_u}{\cancel{\gamma z} K_A S_V S_H} \cong 3.0$

$FS_p = \dfrac{2 b L_e \tan\phi_u}{K_A S_V S_H} \cong 3.0$ → FIND required L_e

$L = L_e + H \tan\left(45 - \frac{\phi}{2}\right)$ → Design length.

Corrosion Effects: (extra thickness must be provided for corrosion effects)

$t_d = t_o + rT$

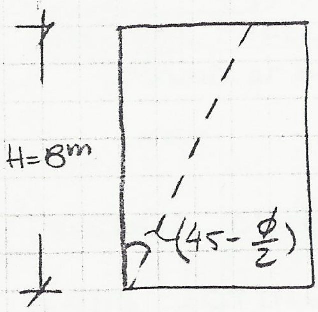
t_d = design thickness

t_o = thickness required to resist tension

r = corrosion rate ≅ 0,025–0,05 mm/year

T = economic life of structure (upto 50 year)

Example:



$\gamma = 20\ kN/m^3$

$\phi = 40° \rightarrow K_A = \frac{1-\sin\phi}{1+\sin\phi} \cong 0{,}22$

$\phi_u = 25°$

$f_y = 2400\ kg/cm^2 = 2.4\times10^5\ kPa.$

$r = 0{,}025\ mm/yr.$

$T = 50$ years.

$(F_S)_b = 3.0$
$(FS)_p = 3.0$ } Required.

TRY: $S_V = 0.5m$, $S_H = 1.0m$ $W = 75mm$.

$$FS_b = \frac{w\,t\,f_y}{\gamma H K_A S_V S_H} = \frac{0{,}075\times t\times 2{,}4\times10^5}{20\times8\times0{,}22\times0{,}5\times1.0} = 3.0$$

$$\frac{1.8\cdot10^4\,t}{17.6} = 3.0$$

$$t = \frac{3\times17.6}{1.8\times10^4} = 29{,}3\times10^{-4}$$

$t \cong 3mm.$

$$t_d = 3 + 0{,}025\times50 = 4.25mm$$

$$FS_p = \frac{2\,W\,L_e \tan\phi_u}{K_A S_V S_H} = \frac{2\times0{,}075\times L_e \tan25°}{0{,}22\times0{,}5\times1.0} = 3.0$$

$$FS_p = \frac{0{,}07\,L_e}{0{,}11} = 3.0 \qquad L_e = \frac{3\times0{,}11}{0{,}07} = 4.7m.$$

$$(L_r)_{max} = 8\times\tan\left(45 - \frac{40}{2}\right) = 3.7m$$

$$L = 4.7 + 3.7 = \boxed{8.4m} \text{ max length.}$$