SEGMENTAL RETAINING WALLS

By:

Chad Sakai

Vince De Vita

What is a Segmental Retaining Wall (SRW)

- Column of dry-stacked units or blocks.
- Walls are battered or inclined toward the soil being retained (ω).
- Standardized engineering approach produced by National Concrete Masonry Association (NCMA)

Lateral Loads

- Coloumb Theory – Used by NCMA
- Rankine Theory – Used by most engineers
- Double-Wedge Analysis – More sophisticated
- Equivalent Fluid Pressure (EFP) – Given by Geotechnical Engineer
- Psuedo-Static Analysis – Mononobe-Okabe

Types of SRW

- Conventional – Gravity structures that rely solely on their weight to resist destabilizing forces.
- Reinforced – Gravity retaining walls with an expanded width created by a geosynthetic reinforced (infill) soil mass located behind a column of dry-stacked SRW units.

Failure Modes

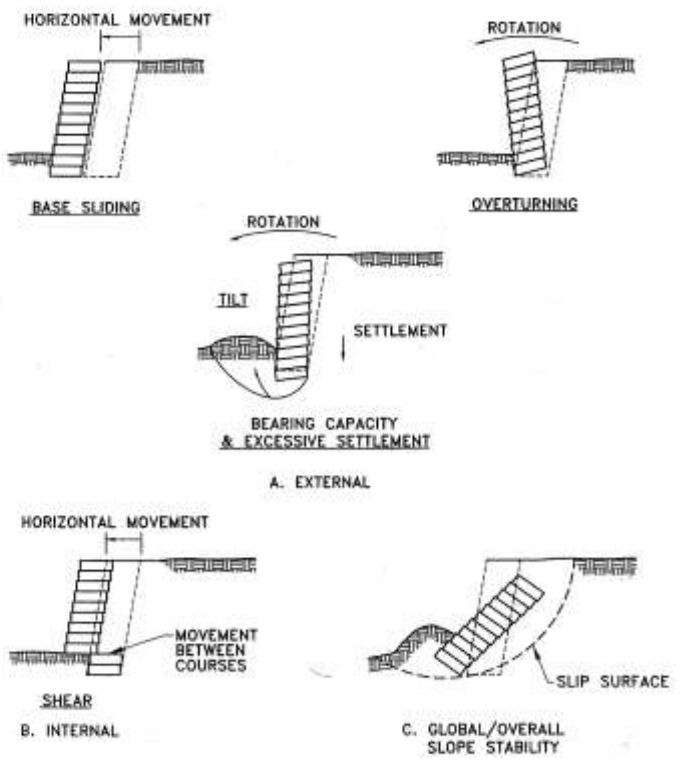


FIGURE 4-1: MAIN MODES OF FAILURE FOR CONVENTIONAL SRWs

- External – Sliding, Over-turning & Settlement
- Internal – Shear
- Global – Overall slope stability

Factors of Safety for Conventional SRW

TABLE 4-1

Recommended Minimum Factors of Safety for Design of Conventional SRWs		
Failure Modes		***FS***
Base Sliding	FS_{sl}	1.5
Overturning	FS_{ot}	1.5
Bearing Capacity	FS_{bc}	2.0
Internal Shear Capacity	FS_{sc}	1.5
Global Stability	FS_{gl}	1.3 - 1.5

Hinge Height (H_h)

- The max. number of SRW units that can be stacked in an isolated column at a batter without toppling.
- Necessary because of the flexible nature of the dry-stack SRW construction and the limited ability of SRW units to transmit moments.
- If H_h is greater than the wall height or is a vertical wall, use $H_h = H$ where H = total height of wall.

Hinge Height (H_h)

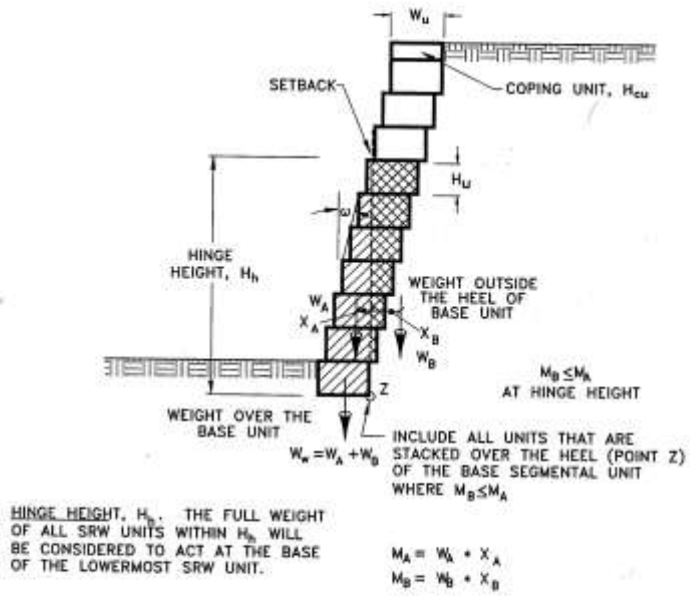


FIGURE 4-2: HINGE HEIGHT FOR SRW DESIGN

$H_h = 2(W_u - G_u)/\tan \omega$

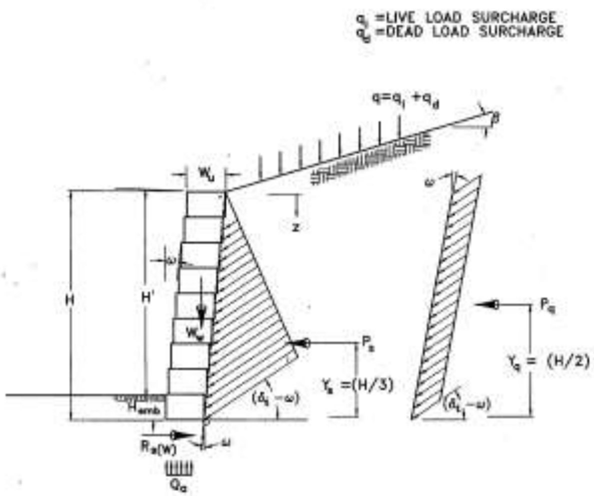
H_u = SRW unit height (ft)

W_u = SRW unit width (ft)

G_u = distance to the C.O.G. of a SRW unit measured from the front of the unit (ft)

H = Total height of wall (ft)

Conventional SRW Free Body Diagram



$P_a=P_s+P_q$

K_a = USING COULOMB EQUATION 3-11 AND REINFORCED (INFILL) SOIL PROPERTIES

$P_s = 0.5K_a\gamma_i H^2\cos(\delta_i-\omega)$

$P_q = K_a qH \cos(\delta_i-\omega)$

FIGURE 4-3: FORCES AND GEOMETRY FOR EXTERNAL STABILITY ANALYSIS OF CONVENTIONAL SINGLE DEPTH SRWs

P_s = Lateral load due to active soil wedge.

P_q = Lateral load due to surcharge.

$P_a = P_s + P_q$

$W_w = H_h\gamma_u W_u$ where γ_u is the unit weight of the segmental units

Sliding

$R_{s(w)} = \mu_b[W_w \tan\phi + c\, W_u]$

μ_b = friction coefficient for base segmental unit on bearing soil.

ϕ = soil internal angle of friction

c = cohesion of soil

- $F.S._{sl} = R_{s(w)} / P_a > 1.5$
- Sliding resistance should be calculated under foundation soil if used.

Over-turning

$M_r = W_w X_w$

$X_w = G_u + 0.5 \{(H_h - H_u) \tan \omega\}$

$M_o = P_s Y_s + P_q Y_q$

- $F.S._{ot} = M_r / M_o > 1.5$
- Moments taken about the toe of the wall.

Bearing Capacity

$Q_{ult} = c_f N_c + 0.5 \gamma_f B_f' N_\gamma + \gamma_f H_{emb} N_q$

N_c, N_γ, and N_q are dimensionless bearing capacity coefficients based on ϕ

$B_f' = B_f - 2e$

$B_f = W_u + 0.5$

$e = [P_s Y_s + P_a Y_a + W_w e_w] / W_w$

$e_w = X_w - 0.5 W_u P_s Y_s$

$Q_a = W_w / B_f'$

- $F.S._{bc} = Q_{ult} > Q_a$
- A portion of the compacted aggregate bearing pad is assumed to act as a conventional continuous footing.

Internal Shear

$V_u = a_u + W_w \tan \lambda_u$

a_u = apparent shear capacity adhesion (lb/ft)

λ_u = apparent peak interface friction angle between SRW units (degrees)

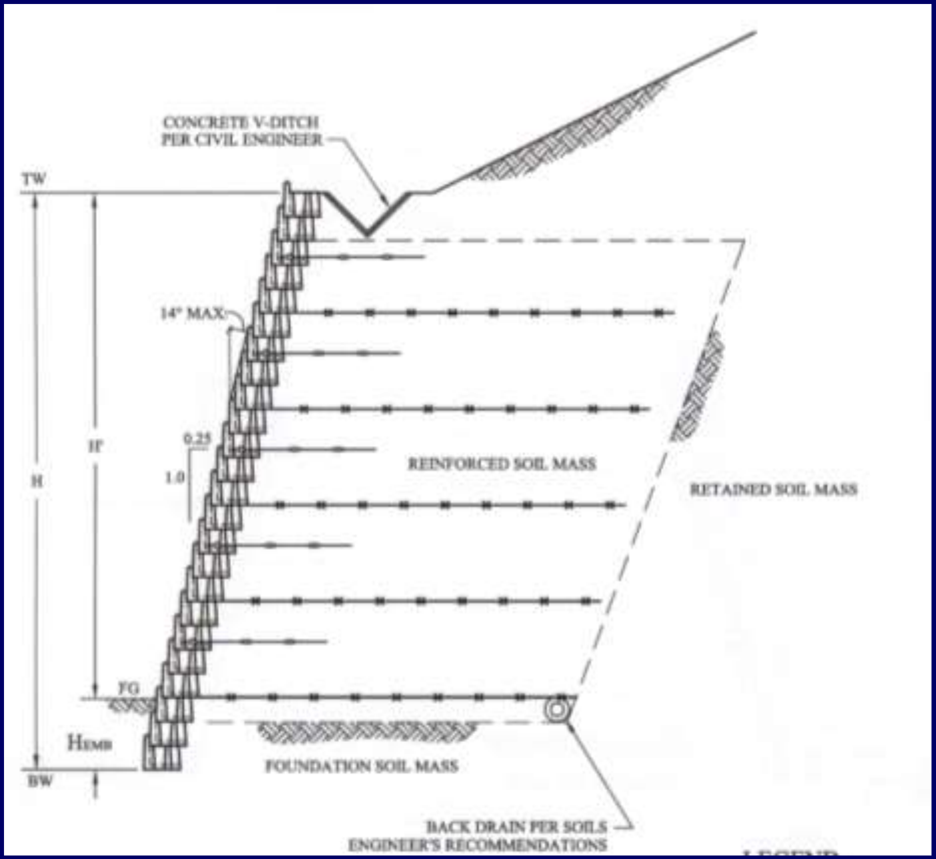
- $F.S._{sc} = V_u / P_a > 1.5$
- Internal sliding analysis should be performed at each SRW unit interface elevation.
- Lower elevation interfaces are typically more critical.

Global Stability

- The general mass movement of a conventional SRW structure and adjacent soil mass.
- A slope stability analysis for potential global stability should be done in any design.

Reinforced Soil Segmented Retaining Walls

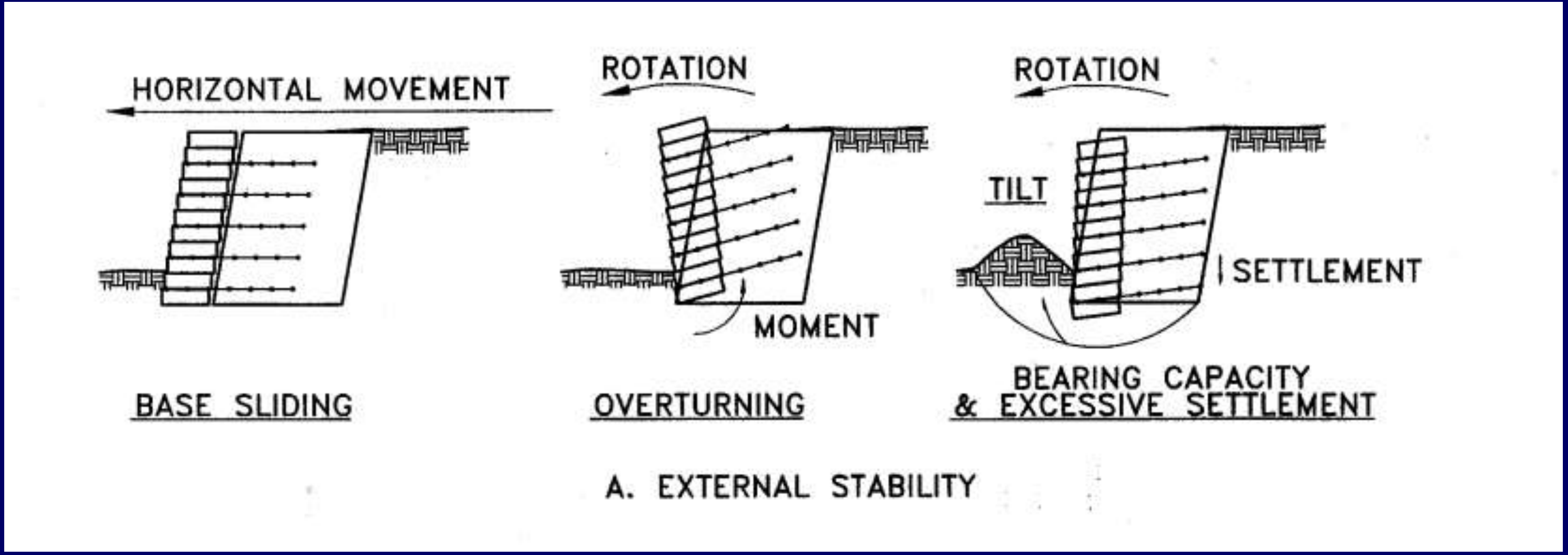
SRW Typical Section



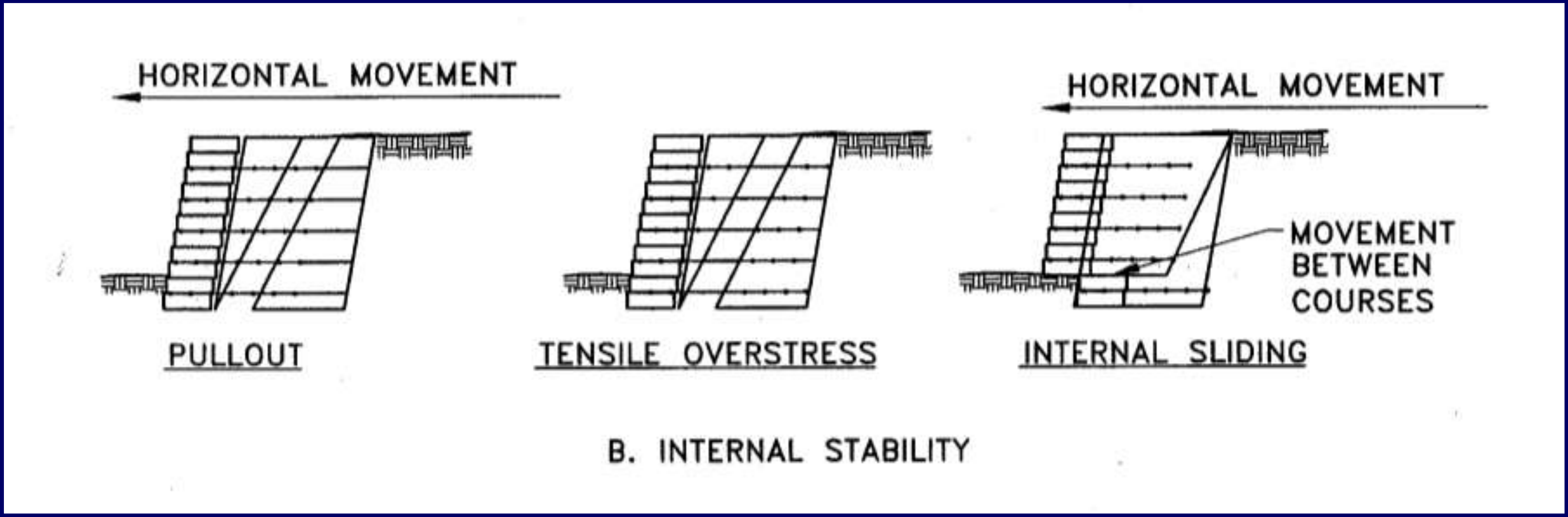
Design Overview

- Four General Classifications of Failure
  - External Stability
  - Internal Stability
  - Local Facing Stability
  - Global/Overall Stability

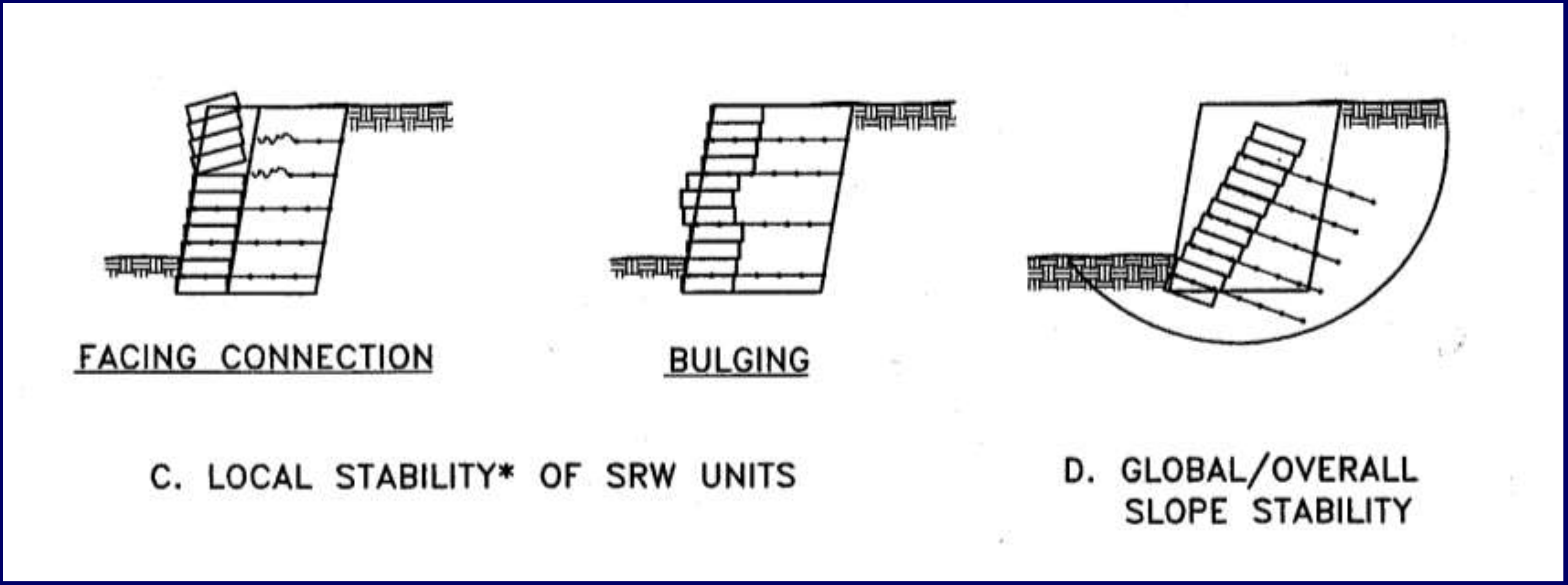
External Stability



Internal Stability



Local and Global Stability

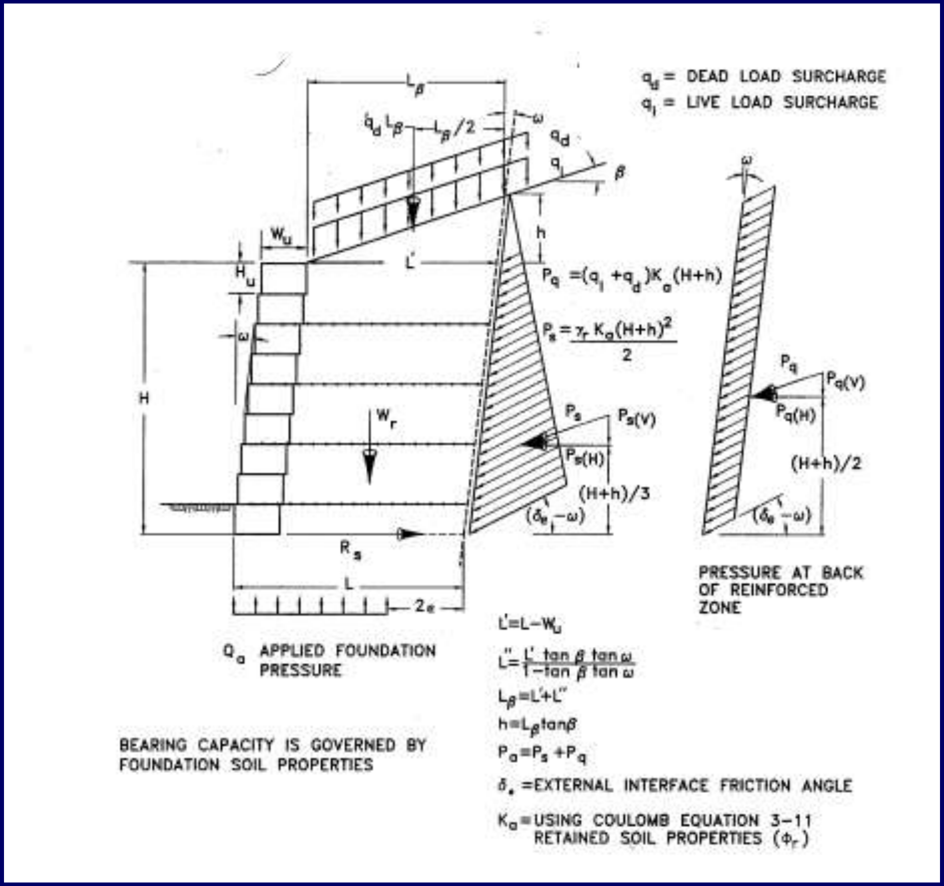


Recommended Minimum Safety Factors

Recommended Minimum Factors of Safety and Design Criteria for Reinforced Soil SRWs

<u>Failure Modes</u>		
Base Sliding	FS_{sl}	1.5
Overturning	FS_{ot}	2.0
Bearing Capacity	FS_{bc}	2.0
Global Stability	FS_{gl}	1.3 - 1.5
Tensile Overstress	Fs_{to}	1.0
Pullout	FS_{po}	1.5
Facing Shear Capacity	FS_{sc}	1.5
Connection	FS_{cs}	1.5
<u>Design Criteria</u>		
Uncertainties	FS_{UNC}	1.5
Facing shear (serviceability criterion)		0.75 inch
Connection (serviceability criterion)(Note 3)		0.75 inch
Minimum Base Width	L	0.6H
Minimum Wall Embedment (Note 5)	H_{emb}	0.5 foot
Minimum Anchorage Length	L_a	1.0 foot

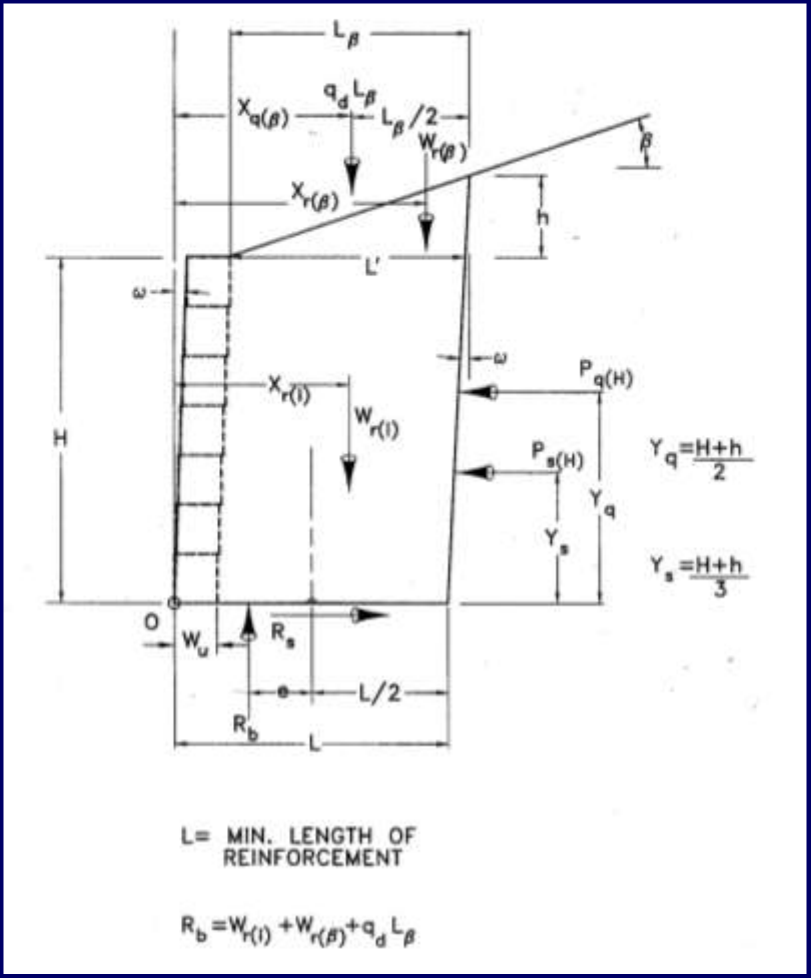
Forces and Wall Geometry



External Stability Calculations

- Select trial reinforcement length, L
  ¾ H is a good starting estimate
- Calculate the active soil forces and surcharge forces
  $Ps_{(H)} = 0.5Ka\gamma_r(H+h)^2 \cos(\delta_e - \omega)$
  $Pa_{(H)} = Ps_{(H)} + Pq_{(H)}$

External Stability Calculations



External Stability Calculations

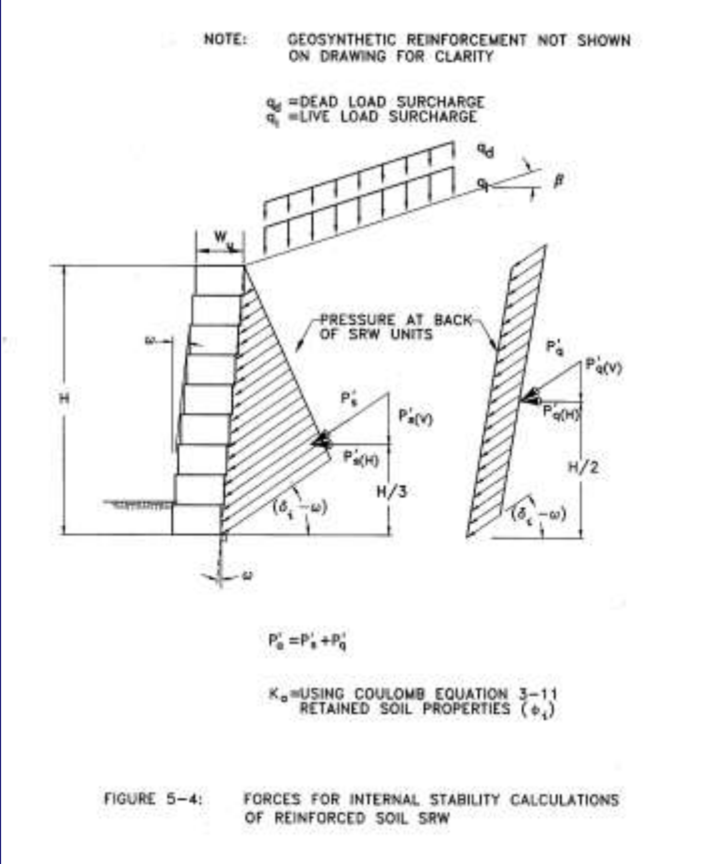
- Calculate Base Sliding
  $Rs = Cds(q_d L_\beta + W_{ri} + W_{r\beta})\tan \phi_i$
  (Cds is typically equal to 1.0)
  $FS_{sl} = Rs/Pa_{(H)}$ (Shall not be less than 1.5)
- Calculate Overturning
  $Fs_{ot} = Mr/Mo$ (Should not be less than 2.0)
- Calculate Bearing Capacity
  $Fs_{bc} = Q_{ult}/Q_a$ (Should not be less than 2.0)

Internal Stability Calculations

- Calculate Internal Soil Force

  $P's_{(H)} = 0.5Ka_{(int)*}(\gamma_i)(H)2\cos(\delta_i-\omega)$

  $P'a_{(H)} = P's_{(H)} + P'q_{(H)}$



Internal Stability Calculations

- Determine the Long-term design strength of the reinforcement

  $Ta = Tult/(RD_D*Rd_{ID}*RF_{CR}*FS_{UNC})$

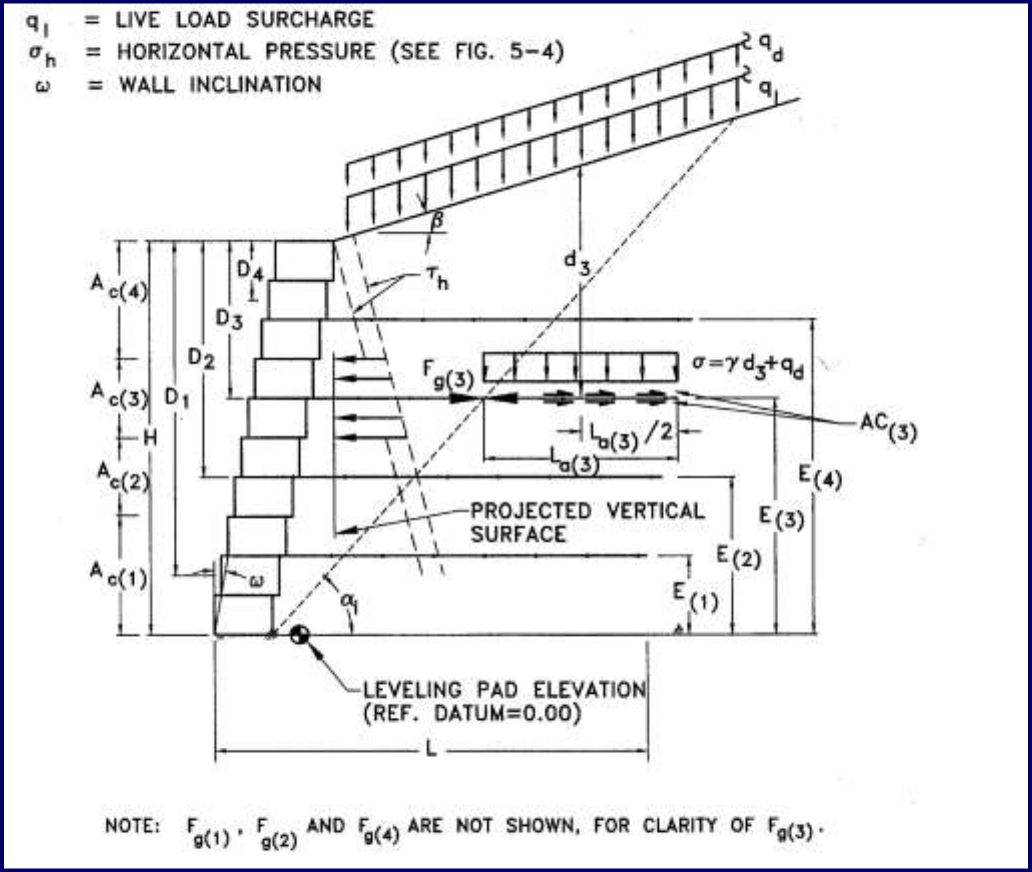
- Calculate Quantity and Location of Reinforcement
  - Number of Reinforcement Layers
  - Vertical Spacing of Reinforcement Layers
  - Applied Tensile Load

Grid Reinforcement

Internal Stability Calculations

- Calculate Pullout of Reinforcement
  - Anchorage Capacity of the Reinforcement
  - Anchorage Length of the Reinforcement
  - Depth of Overburden on Anchorage Length

Internal Stability Calculations

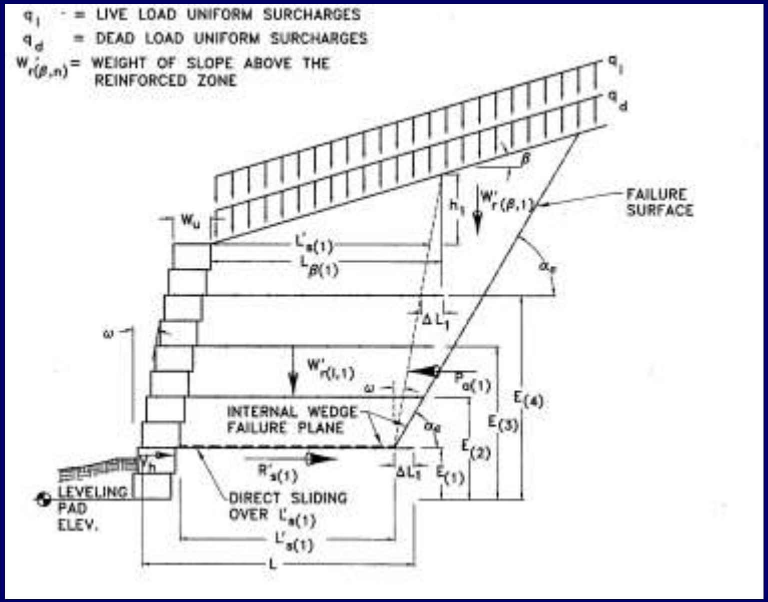


Internal Stability Calculations

- Internal Sliding Failure

$R'_{s(n)} = C_{ds}(q_d L_{\beta(n)} + W'_{r(i,n)} + W'_{r(\beta,n)})*\tan\phi_i$

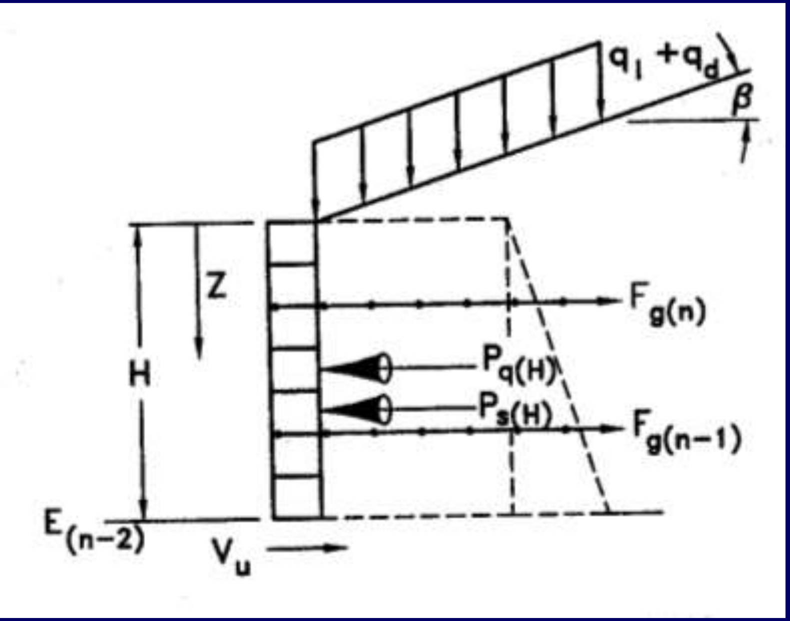
Internal Sliding for Reinforced Soil SRW



Local Stability of SRW Units

- Local Stability
  - Facing Connection Strength
  - Resistance to Bulging
  - Maximum Unreinf. SRW Heights

Free Body Diagram for Bulging



Advantages/Disadvantage of SRW

Advantages:

- Cheaper
- Retains higher heights
- Open assembly allows for vegetation

Disadvantages:

- Batter of wall results in less working space
- More failure modes
- No redundancy
- Sensitve to future construction in backfill

Figure 4 - Settlement near drainage fill / reinforced soil interface due to poor compaction. Note linear crack in pavement and leaning of fence (photo inset)

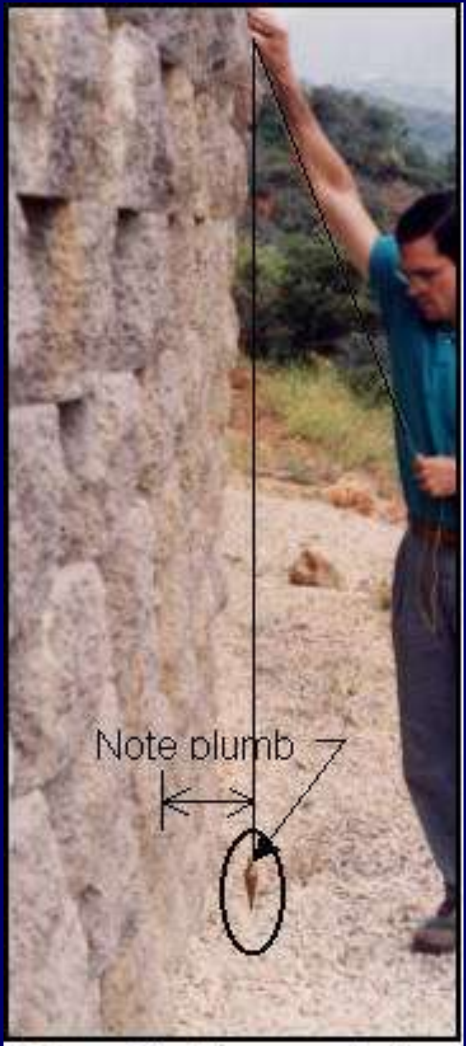


Figure 5 - Reverse batter of wall face due to compaction stresses and near-face traffic loads pushing facia unit outward

La Jolla Serena

La Jolla Serena

La Jolla Serena

Movement at Top of Wall

Bulging at Center of Wall

La Jolla Serena

Cracks in Pavement