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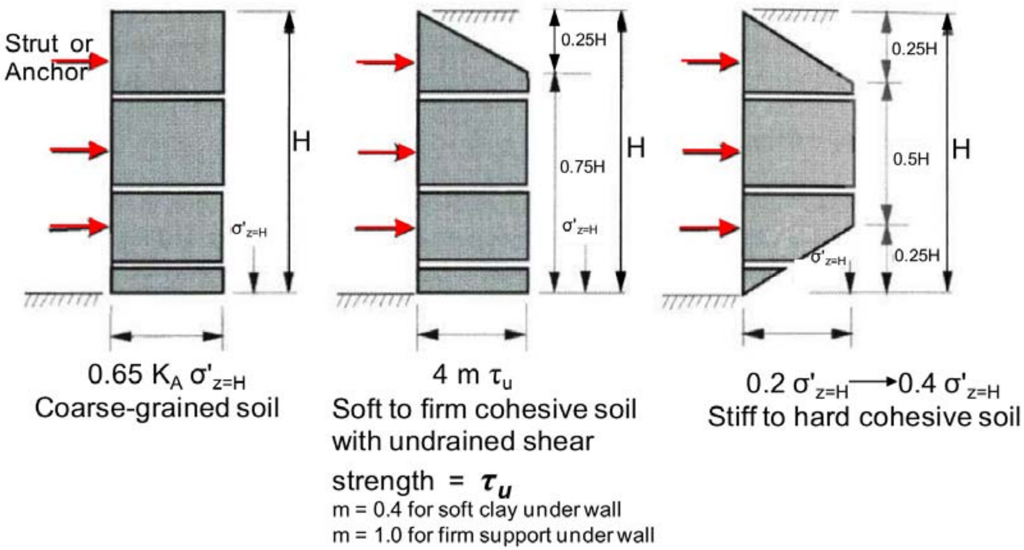
ENCE 4610
Foundation Analysis and Design



Lecture 12

Braced Cuts

Tied Back Walls

Overview of Braced Cuts and Tied Back Excavations

- All of the walls we have looked at up until now have been a single wall with no more than one anchor
- There are situations where either a) we need two facing walls or b) we need more than one anchor or c) both
- Braced cuts are sets of walls (usually sheet pile, but can be slurry) which are used to create a "mechanical ditch" inside of which construction can take place
- Tied back walls have multiple anchors, but the braces are outside of the cut (if any)

History of Braced Excavation Design

- Original work by Terzaghi and Peck on subway braced excavations in 1940's
- Discovered that progressive excavation and placement of braces altered lateral earth pressure profile
- Toe design entirely different from conventional sheet pile walls

- Important considerations in braced excavation design
  - Suitable for walls constructed "progressively"
  - Strictly speaking, brace loads are statically indeterminate
  - Terzaghi and Peck profiles assume hinges at braces for wall beam loading
  - Must consider bottom heave (esp. cohesionless soils, see ENCE 3610) and bearing capacity failure (esp. cohesive soils)

Pressure Distribution for Braced Loads

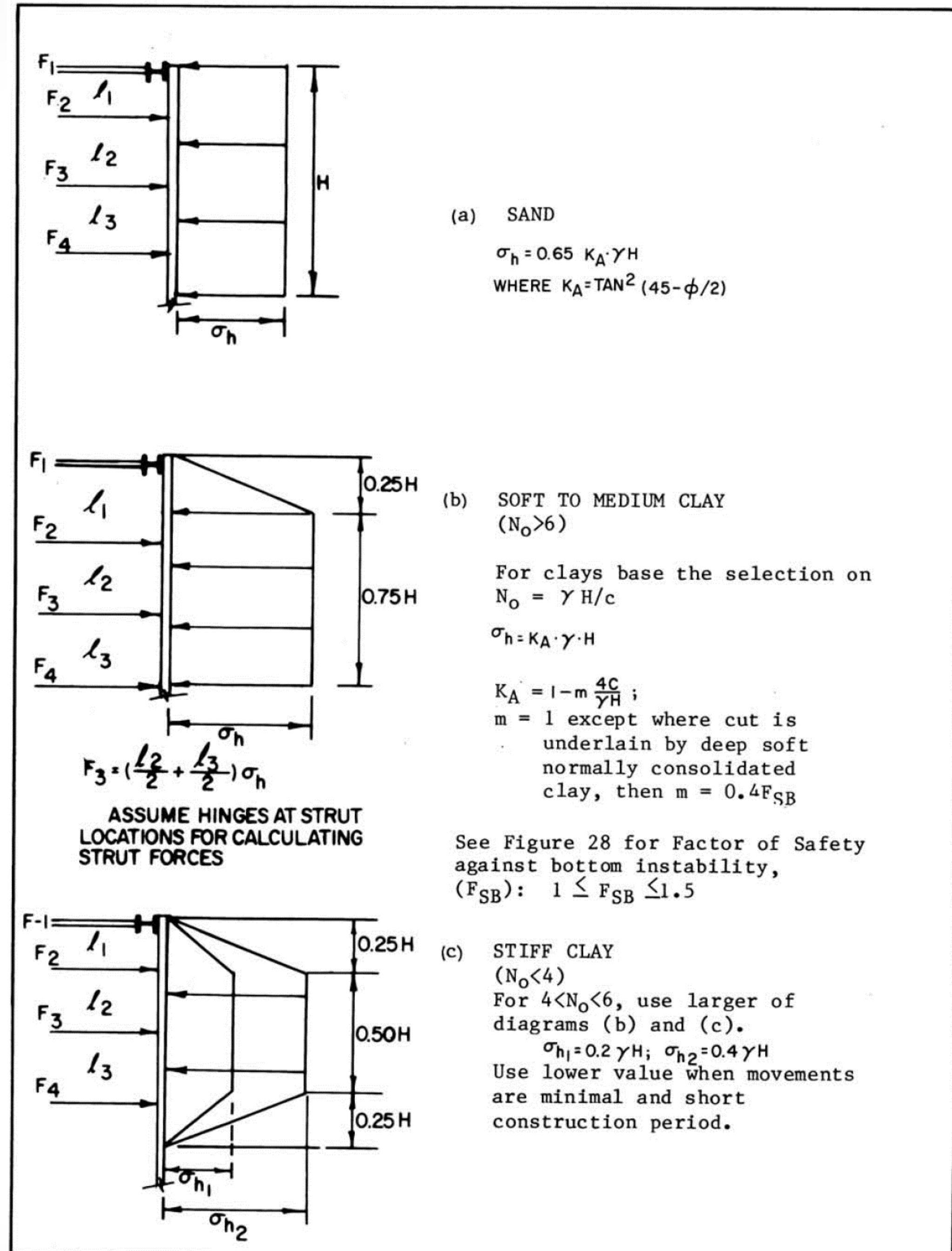
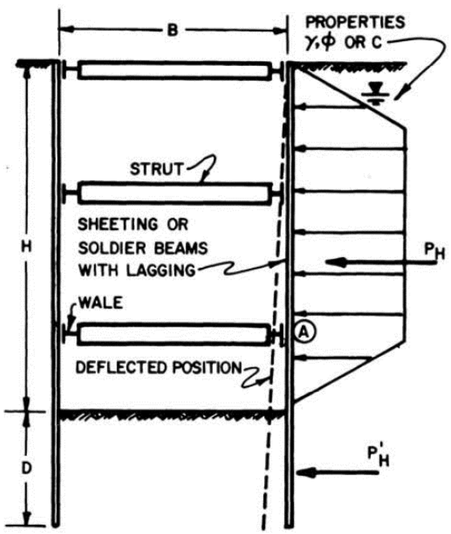


FIGURE 26
Pressure Distribution for Brace Loads in Internally Braced Flexible Walls

Design Criteria for Braced Cuts



FLEXIBLE WALL OF NARROW CUT

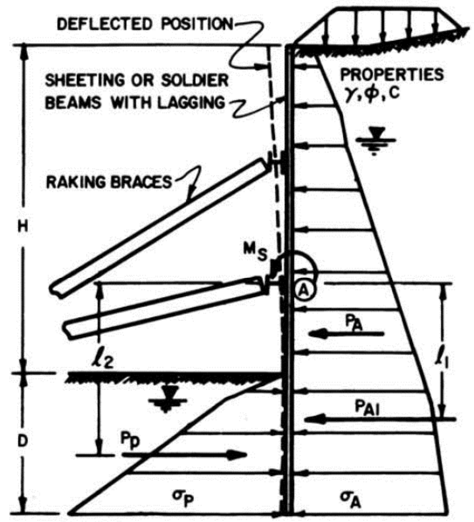
1. COMPUTE PRESSURES ON WALL ABOVE BASE OF CUT BY METHODS OF FIGURE 26. FOR WATER AT BACKFILL SURFACES USE $\gamma = \gamma_{SUB}$ AND ADD PRESSURES FOR UNBALANCED WATER LEVEL. FOR WATER AT BASE OF CUT USE $\gamma = \gamma_T$. INTERPOLATE BETWEEN THESE PRESSURE DIAGRAMS FOR AN INTERMEDIATE WATER LEVEL.

2. DETERMINE STABILITY OF BASE OF CUT BY METHODS OF FIGURE 28. IF BASE IS STABLE, SHEETING TOES IN SEVERAL FEET AND NO FORCE ACTS ON BURIED LENGTH. IF BASE IS UNSTABLE, SHEETING PENETRATES AS SHOWN IN FIGURE 28 AND UNBALANCED FORCE P'_H ACTS ON BURIED LENGTH. IN ANY CASE, PENETRATION MAY BE CONTROLLED BY REQUIREMENT FOR CUT-OFF OF UNDERSEEPAGE.

3. MOMENTS IN SHEETING BETWEEN BRACES = 0.8 x (SIMPLE SPAN MOMENTS), EXCEPT FOR UPPER SPAN WHERE MOMENT = 1.0 x (SIMPLE SPAN MOMENT). MOMENTS IN SHEETING AT POINT Ⓐ IS COMPUTED FOR CANTILEVER SPAN BELOW Ⓐ, INCLUDING UNBALANCED FORCE P'_H.

4. REACTION AT BRACES COMPUTED ASSUMING SIMPLE SPAN BETWEEN BRACES.

FIGURE 27
Design Criteria for Braced Flexible Walls



P_A = RESULTANT ACTIVE PRESSURE
P_{AI} = RESULTANT ACTIVE BELOW POINT Ⓐ

FLEXIBLE WALL WITH RAKING BRACES

1. COMPUTE ACTIVE AND PASSIVE PRESSURES BY METHODS IN SECTION 2. PASSIVE PRESSURES FOR CLEAN, COARSE-GRAINED SOILS INCLUDE WALL FRICTION (δ), TABLE 1. IGNORE WALL FRICTION FOR PASSIVE PRESSURES IN OTHER SOIL TYPES AND FOR ACTIVE PRESSURES IN ALL SOILS.

2. MAXIMUM MOMENTS IN SHEETING AND MAXIMUM LOADS IN BRACES ARE USUALLY OBTAINED AT A CONSTRUCTION STAGE WHEN EXCAVATION FOR A BRACE AND WALE IS COMPLETE AND JUST PRIOR TO PLACING THE BRACE. FOR EACH SUCCESSIVE STAGE OF EXCAVATION COMPUTE SHEETING MOMENTS AND BRACE LOADS BY ASSUMING SIMPLE SPAN BETWEEN LOWEST BRACE THEN IN PLACE AND POINT OF ZERO NET PRESSURE BELOW EXCAVATION.

3. FOR TEMPORARY CONSTRUCTION CONDITIONS, APPLY FACTOR OF SAFETY OF 1.5 TO COMPUTE PASSIVE PRESSURES. TO ALLOW FOR POSSIBLE CONSTRUCTION SURCHARGE AND RIGIDITY OF UPPER BRACE POINT, INCREASE LOAD ON UPPER WALE AND BRACE BY 15% OF COMPUTED VALUE.

4. REQUIRED PENETRATION OF SHEETING BELOW FINAL SUBGRADE GENERALLY IS CONTROLLED BY CONDITIONS AT COMPLETION OF EXCAVATION. PENETRATION REQUIRED IS DETERMINED BY EQUILIBRIUM OF FREE ENDED SPAN BELOW POINT Ⓐ. ASSUMING FIXITY AT POINT Ⓐ:

$$P_{AI}\,\ell_1 - \frac{P_P}{F_S}\,\ell_2 - M_S = 0$$

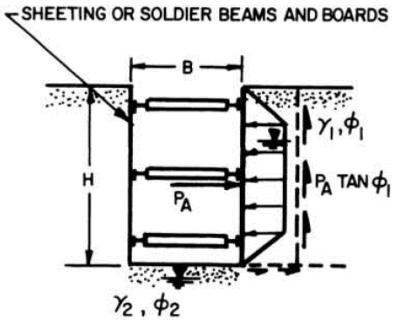
M_S = ALLOWABLE MOMENT IN SHEETING

5. CHECK POSITIVE MOMENTS IN SPAN BELOW POINT Ⓐ FOR THIS FINAL LOADING CONDITION.

FIGURE 27 (continued)
Design Criteria for Braced Flexible Walls

Base Stability for Braced Cuts

CUT IN COHESIONLESS SOIL



STABILITY IS INDEPENDENT OF H AND B, BUT VARIES WITH γ, ϕ AND SEEPAGE CONDITION.

SAFETY FACTOR, $F_S = 2N_{\gamma 2} \left(\frac{\gamma_2}{\gamma_1}\right) K_A \tan \phi$

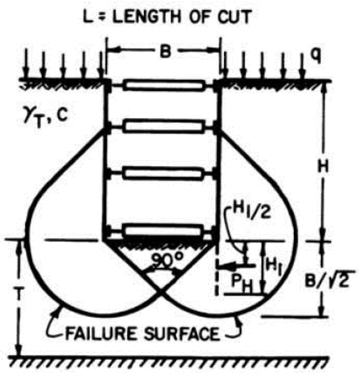
$N_{\gamma 2}$ = BEARING CAPACITY FACTOR, FIGURE 1, CHAPTER 4

IF GROUNDWATER IS AT A DEPTH OF (B) OR MORE BELOW BASE OF CUT:
γ_1 AND γ_2 ARE TAKEN AS MOIST UNIT WEIGHT

IF GROUNDWATER IS STATIC AT BASE OF CUT:
γ_1 = MOIST WEIGHT, γ_2 = SUBMERGED WEIGHT.

IF SEEPAGE IS MOVING UPWARD TO BASE OF CUT:
γ_2 = (SATURATED UNIT WEIGHT) − (UPLIFT PRESSURE)

CUT IN CLAY, DEPTH OF CLAY UNLIMITED ($T > 0.7B$)



IF SHEETING TERMINATES AT BASE OF CUT:

SAFETY FACTOR, $F_S = \frac{N_C\, C}{\gamma_T H + q}$

N_C = BEARING CAPACITY FACTOR, FIGURE 2, CHAPTER 5 WHICH DEPENDS ON DIMENSIONS OF THE EXCAVATION: B, L AND H (USE H = Z).

C = UNDRAINED SHEAR STRENGTH OF CLAY IN FAILURE ZONE BENEATH AND SURROUNDING BASE OF CUT.

q = SURFACE SURCHARGE.

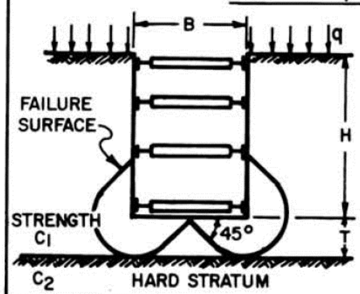
IF SAFETY FACTOR IS LESS THAN 1.5, SHEETING MUST BE CARRIED BELOW BASE OF CUT TO INSURE STABILITY.

FORCE ON BURIED LENGTH:

IF $H_1 > \frac{2}{3} \frac{B}{\sqrt{2}}$, $P_H = .7\,(\gamma_T HB - 1.4\,CH - \pi CB)$

IF $H_1 < \frac{2}{3} \frac{B}{\sqrt{2}}$, $P_H = 1.5 H_1 (\gamma_T H - \frac{1.4 CH}{B} - \pi C)$

CUT IN CLAY, DEPTH OF CLAY LIMITED BY HARD STRATUM ($T \leq 0.7B$)



SHEETING TERMINATES AT BASE OF CUT. SAFETY FACTOR:

CONTINUOUS EXCAVATION; $F_S = N_{CD} \frac{C_1}{\gamma_T H + q}$

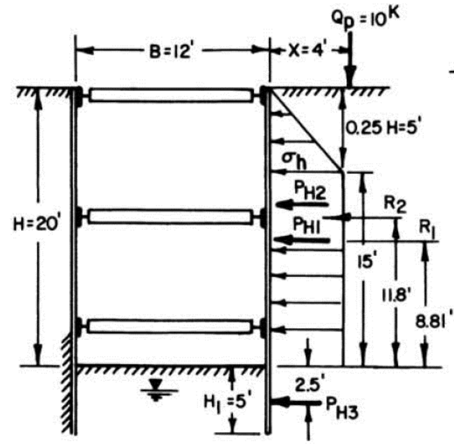
RECTANGULAR EXCAVATION; $F_S = N_{CR} \frac{C_1}{\gamma_T H + q}$

N_{CD} AND N_{CR} = BEARING CAPACITY FACTORS.
FIGURE 5 CHAPTER 4, WHICH DEPEND ON DIMENSIONS OF THE EXCAVATION: B, L AND H, (USE H = Z)

NOTE: IN EACH CASE FRICTION AND ADHESION ON BACK OF SHEETING IS DISREGARDED.
CLAY IS ASSUMED TO HAVE A UNIFORM SHEAR STRENGTH = C THROUGHOUT FAILURE ZONE.

FIGURE 28
Stability of Base for Braced Cut

Braced Cuts Example



GIVEN CONDITIONS:

EXCAVATION IN SILTY CLAY.
$C = 400$ PSF, $\phi = 0$, $\gamma_T = 120$ PCF
LENGTH OF EXCAVATION, L = 80'

DETERMINE: PRESSURES ON WALL. FORCE ON BURIED LENGTH OF SHEETING AND STABILITY OF BASE OF CUT.

STABILITY OF BASE OF CUT (SEE FIGURE 28)

$F_{SB} = \dfrac{N_C C}{\gamma_T H + q}$, q = 0 (NO UNIFORM SURCHARGE)

FOR N_C, (FIGURE 2, CHAPTER 5) $\dfrac{H}{B} = \dfrac{Z}{B} = \dfrac{20}{12} = 1.67$,

$\dfrac{B}{L} = \dfrac{12}{80} = 0.15$, $N_{CC} = 6.9$

$N_{CR} = N_{CC}(1 + 0.2\ B/L) = 6.9(1 + 0.2(0.15)) = 7.1$

$F_S = \dfrac{7.1 \times 400}{120 \times 20 + 0} = 1.18 < 1.5$

DRIVE SHEETING BELOW BOTTOM OF EXCAVATION

PRESSURE ON WALL FROM SURROUNDING SOIL (SEE FIGURE 26)

$K_A = 1 - m\dfrac{4C}{\gamma H}$: $m = 0.4\ F_{SB} = 0.4 \times 1.18 = 0.47$

$= 1 - (0.47)\left(\dfrac{4 \times 400}{120 \times 20}\right) = 0.69$

$\sigma_h = K_A \gamma H = 0.69 \times 0.12 \times 20 = 1.66$ KSF

$P_{H1} = \dfrac{(15+20)(1.66)}{2} = 29.05$ KIPS

LOCATION OF RESULTANT:

$R_1 = \dfrac{1.66 \times 5/2 \times (15 + 5/3) + 1.66 \times 15 \times 15/2}{29.05} = 8.81'$

PRESSURES ON WALL FROM SURCHARGE (SEE FIGURE 11)

$m = \dfrac{X}{H} = \dfrac{4}{20} = 0.2$

$P_{H2} = .78\dfrac{Q_p}{H} = .78\dfrac{10}{20} = .39$ KIP

LOCATION OF RESULTANT:

$R_2 = .59H = .59 \times 20 = 11.8'$

FORCE ON BURIED LENGTH OF SHEETING: (SEE FIGURE 28)

ASSUME $H_1 = 5 < \dfrac{2}{3}\dfrac{B}{\sqrt{2}}$, FOR T > 0.7B RESULTANT FORCE P_{H3}:

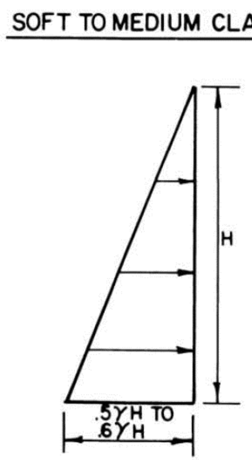
$P_{H3} = 1.5\ H_1\left(\gamma_T H - \dfrac{1.4CH}{B} - \pi C\right)$

$P_{H3} = 1.5 \times 5\left(0.12 \times 20 - \dfrac{1.4 \times .4 \times 20}{12} - 3.14 \times 4\right) = 1.6$ KIP

NOTE: ALL COMPUTATIONS ARE PER LINEAR FOOT OF WALL.

FIGURE 30
Example of Analysis of Pressures on Flexible Wall of Narrow Cut
In Clay - Undrained Conditions

Tied Back Walls Pressure Distribution



Compute pressure based on at-rest conditions with K_o from 0.5 to 0.6. In normally consolidated clays excessive prestressing should not be permitted because of the potential for induced consolidation. Use design procedure as in Figure 26.

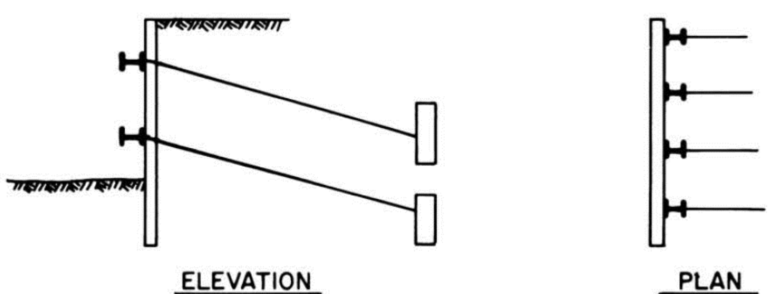
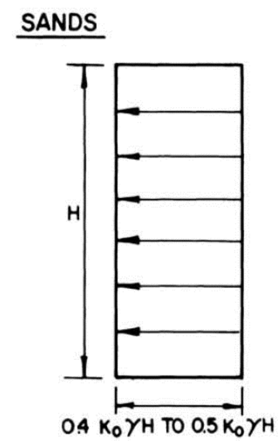
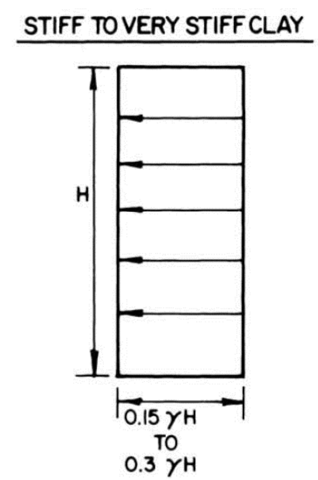


FIGURE 29
Pressure Distribution for Tied-Back Walls



Where deformations are critical and tie-backs are prestressed to 100% of desig load, compute pressure based on at-rest conditions. Use K_o = 0.4 for dense sand, and K_o = 0.5 for loose sand.



Use pressure ordinate to produce the same force as for braced excavation. 0.3 is applicable for stability number of about 4, and 0.15 is applicable when stability number is less than 4. Use design procedure as in Figure 26.

FIGURE 29 (continued)
Pressure Distribution for Tied-Back Walls

Questions