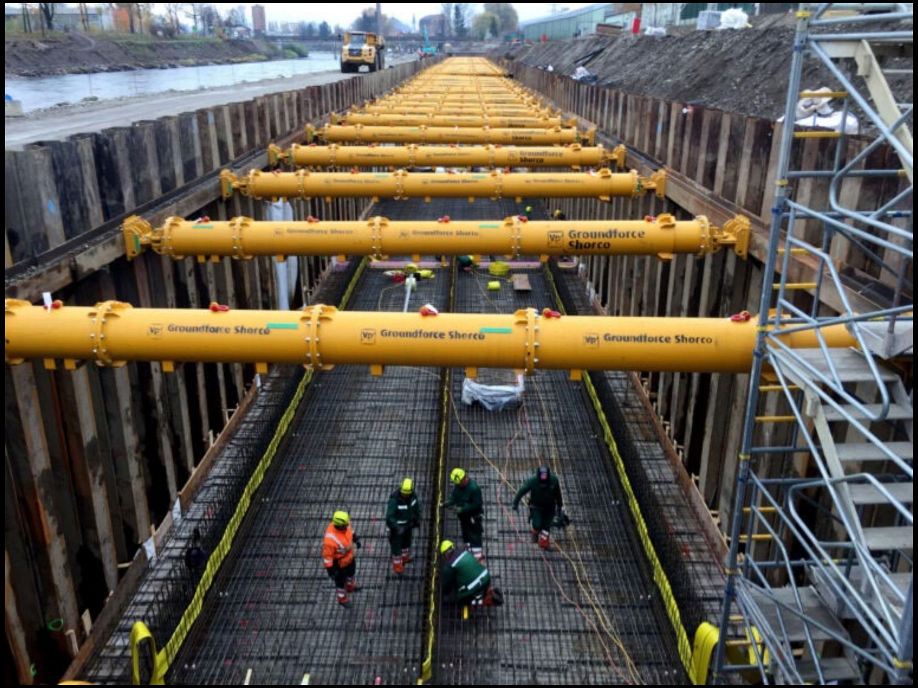
BRACED CUTS

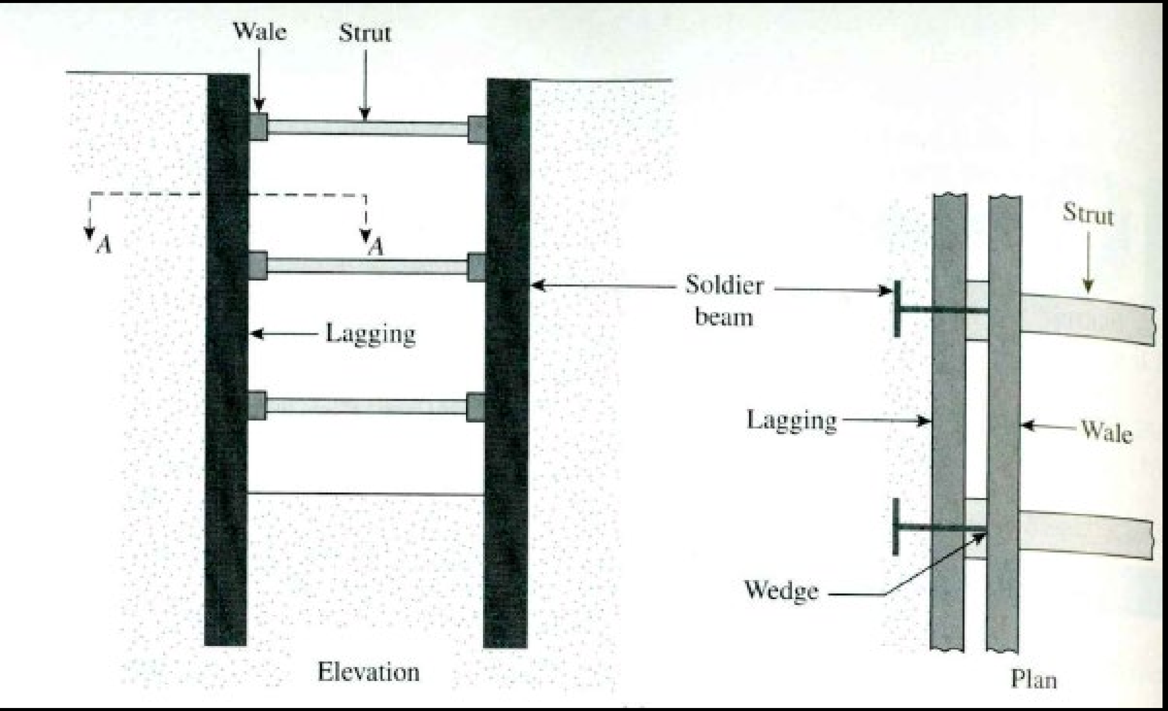
Sometimes construction work requires ground excavations with vertical or near vertical faces.The vertical faces of the cuts need to be protected by temporary bracing systems.

There are two types braced cut commonly used in construction work;

- Use soldier beam
- Use sheet pile

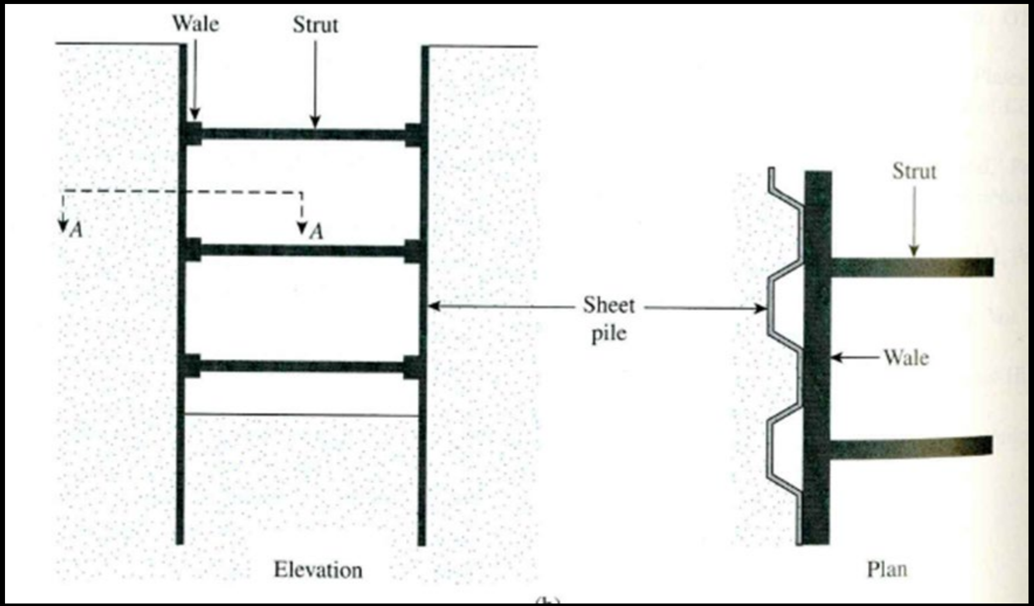


TYPES of BRACED CUTS



Construction of braced cuts using soldier beam;

- Soldier beams driven into the soil before excavation.
- Laggings which are horizontal timber planks are placed between soldier beams as the excavation proceeds.
- When the excavation reaches desired depth; wales and struts (horizontal steel beams) are installed.



Construction of braced cuts using interlocking sheet pile;

- Interlocking sheet piles are driven into the soil before excavation.

- Wales and struts are inserted immeadiately after excavation reaches the appropriate depth.

PRESSURE ENVELOPE for BRACED CUT DESIGN

To design braced excavations (i.e., to select wales, struts, sheet piles, and soldier beams), an engineer must estimate the lateral earth pressure to which the braced cuts will be subjected.

Variation of lateral pressure with depth is a function of several factors;

- type of soil,
- the experience of the construction crew,
- the type of construction equipment used etc.

For that reason, empirical pressure envelopes developed from field observations are used for the design of braced cuts

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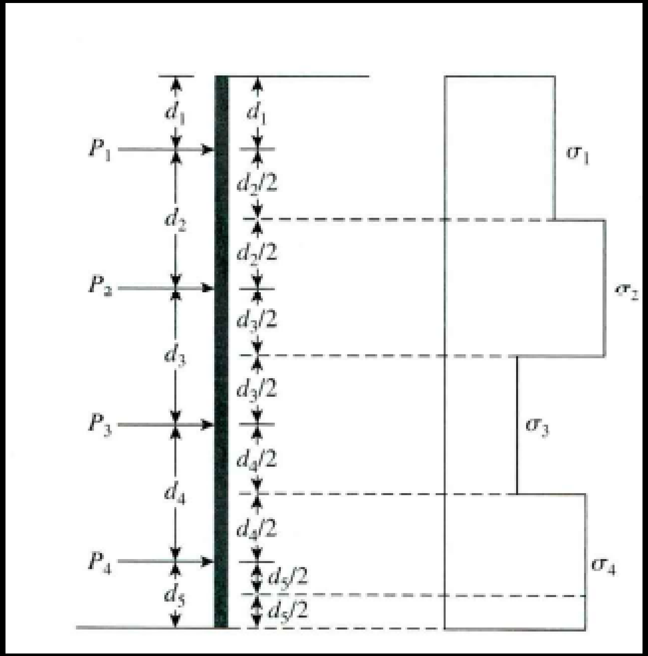
The braced cuts should be designed using apparent pressure diagrams that are envelopes of all the pressure diagrams determined from measured strut loads in the field

$$\sigma_1 = \frac{P_1}{(s)\left(d_1 + \frac{d_2}{2}\right)}$$

$$\sigma_2 = \frac{P_2}{(s)\left(\frac{d_2}{2} + \frac{d_3}{2}\right)}$$

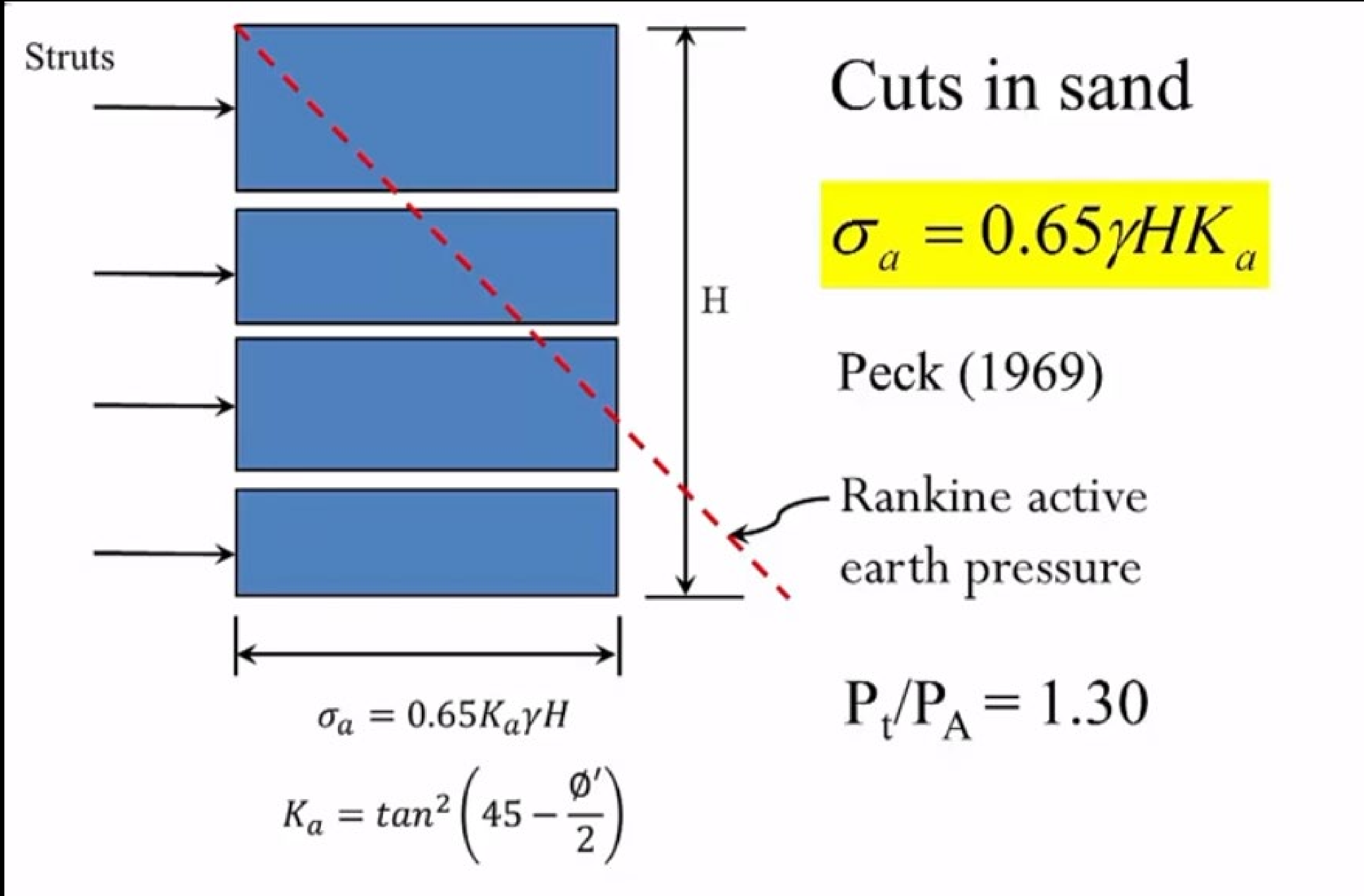
$$\sigma_3 = \frac{P_3}{(s)\left(\frac{d_3}{2} + \frac{d_4}{2}\right)}$$

$$\sigma_4 = \frac{P_4}{(s)\left(\frac{d_4}{2} + \frac{d_5}{2}\right)}$$



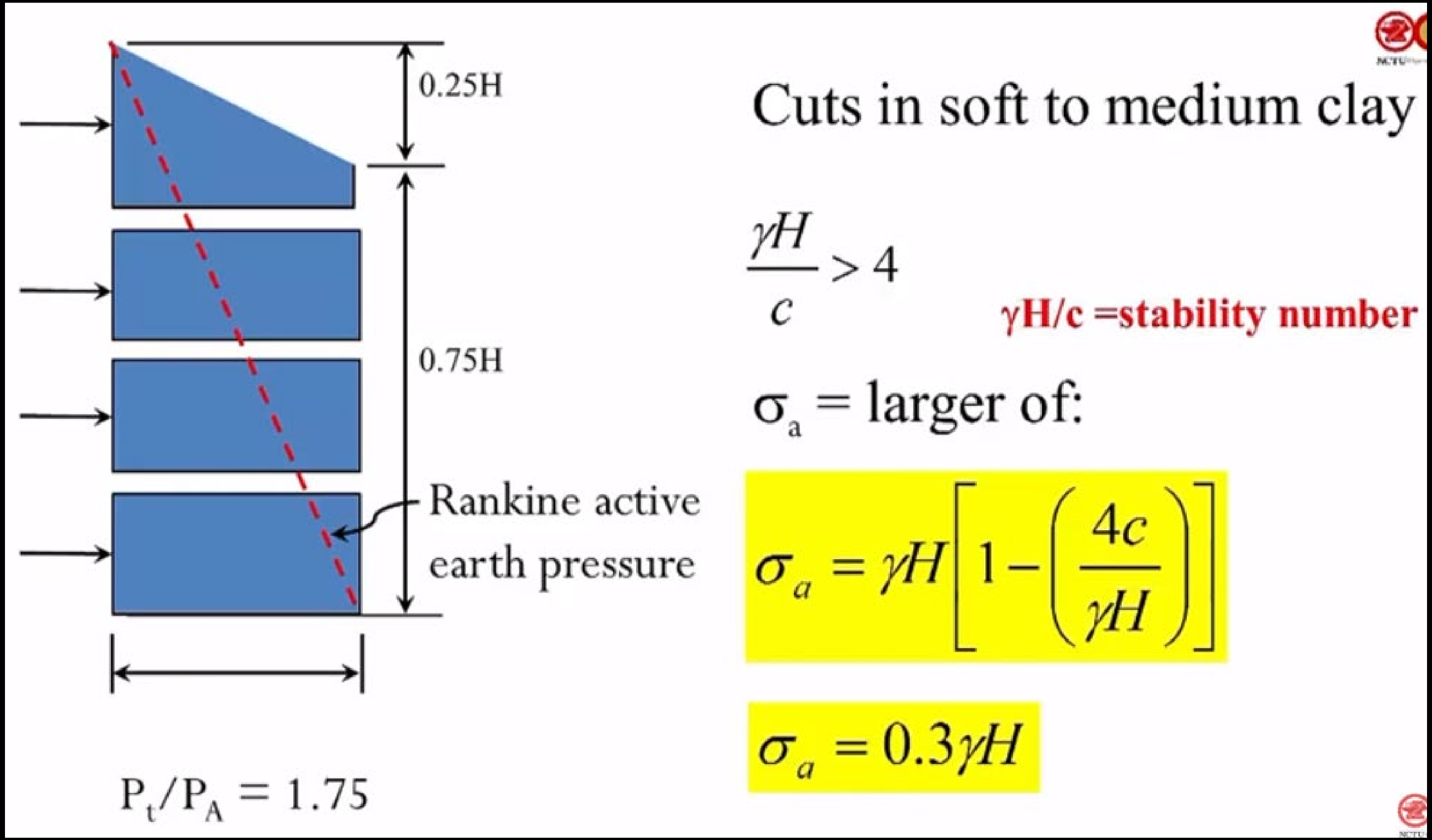
Using the procedure just described for strut loads observed from the Berlin subway cut, Munich subway cut, and New York subway cut, Peck (1969) provided the envelope of apparent-lateral-pressure diagrams for design of cuts in sand.

Cuts in sand;

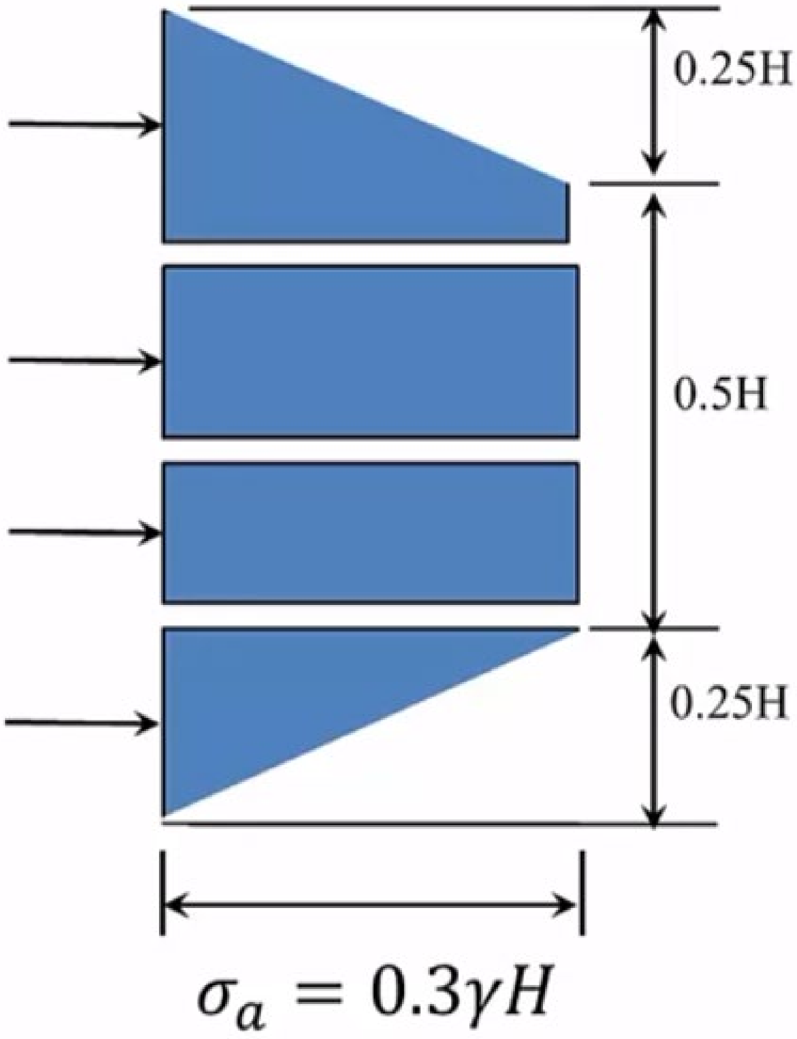


In a similar manner, Peck (1969) also provided the envelopes of apparent-lateral-pressure diagrams for cuts in soft to medium clay and in stiff clay.

Cuts in soft to medium clay;



Cuts in stiff clay;



Cuts in stiff clay

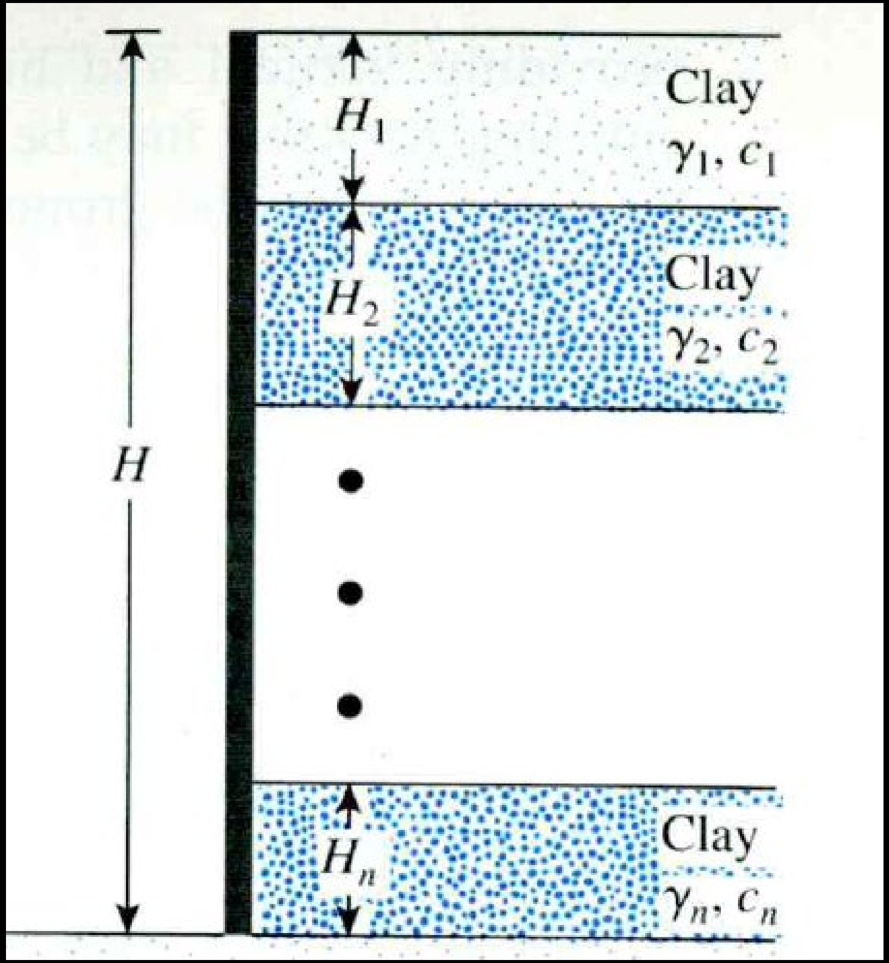
$$\frac{\gamma H}{c} \leq 4$$

$$\sigma_a = 0.2\gamma H \ to \ 0.4\gamma H$$

$$P_A \leq 0$$

When several clay layers are encountered in the cut, the average undrained cohesion becomes;

$$c_{av} = \frac{1}{H}(c_1 H_1 + c_2 H_2 + \cdots + c_n H_n)$$



where;
c1, c2.....cn: undrained cohesion in layers
H1,H2.....Hn: thickness of layer

The average unit weight ;

$$\gamma_a = \frac{1}{H}(\gamma_1 H_1 + \gamma_2 H_2 + \gamma_3 H_3 + \cdots + \gamma_n H_n)$$

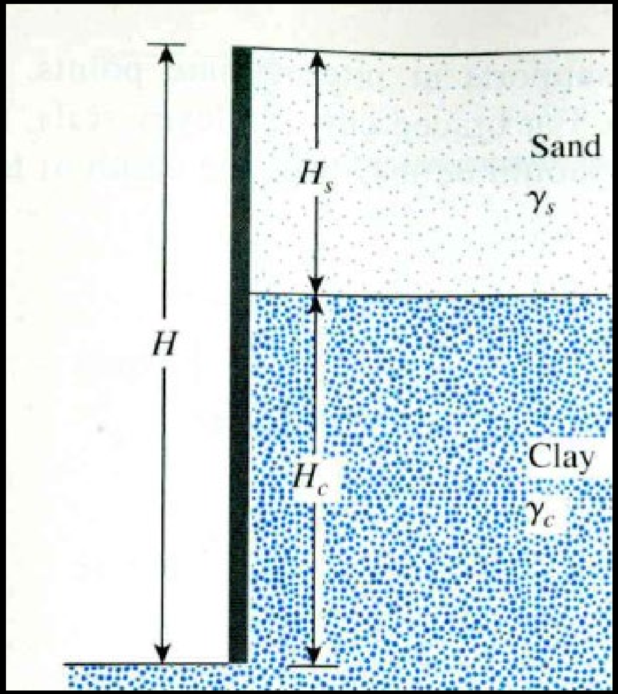
where;
γ1,γ2,……. γn: unit weight of the clay layers
H1,H2.....Hn: thickness of layer

Sometimes, layers of both sand and clay are encountered when a braced cut is being constructed.In this case, Peck (1943) proposed that an equivalent value of cohesion should be determined according to the formula

$$c_{av} = \frac{1}{2H}[\gamma_s K_s H_s^2 \tan \phi'_s + (H - H_s)n' q_u]$$

where

H = total height of the cut
γ_s = unit weight of sand
H_s = height of the sand layer
K_s = a lateral earth pressure coefficient for the sand layer (≈ 1)
ϕ'_s = effective angle of friction of sand
q_u = unconfined compression strength of clay
n' = a coefficient of progressive failure (ranging from 0.5 to 1.0; average value 0.75)



Once the average values of cohesion and unit weight are determined, the pressure envelopes in clay can be used to design the cuts.

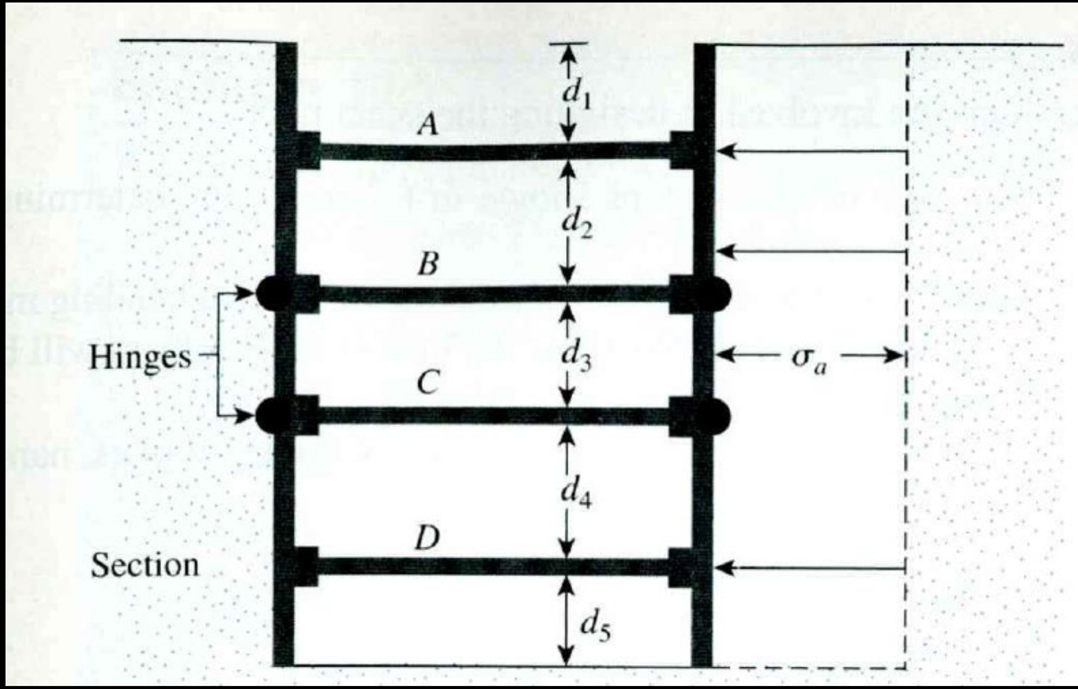
When using the pressure envelopes just described, keep the following points in mind:

- They apply to excavations having depths greater than about 6 m.
- They are based on the assumption that the water table is below the bottom of the cut.
- Sand is assumed to be drained with zero pore water pressure.
- Clay is assumed to be undrained and pore water pressure is not considered.

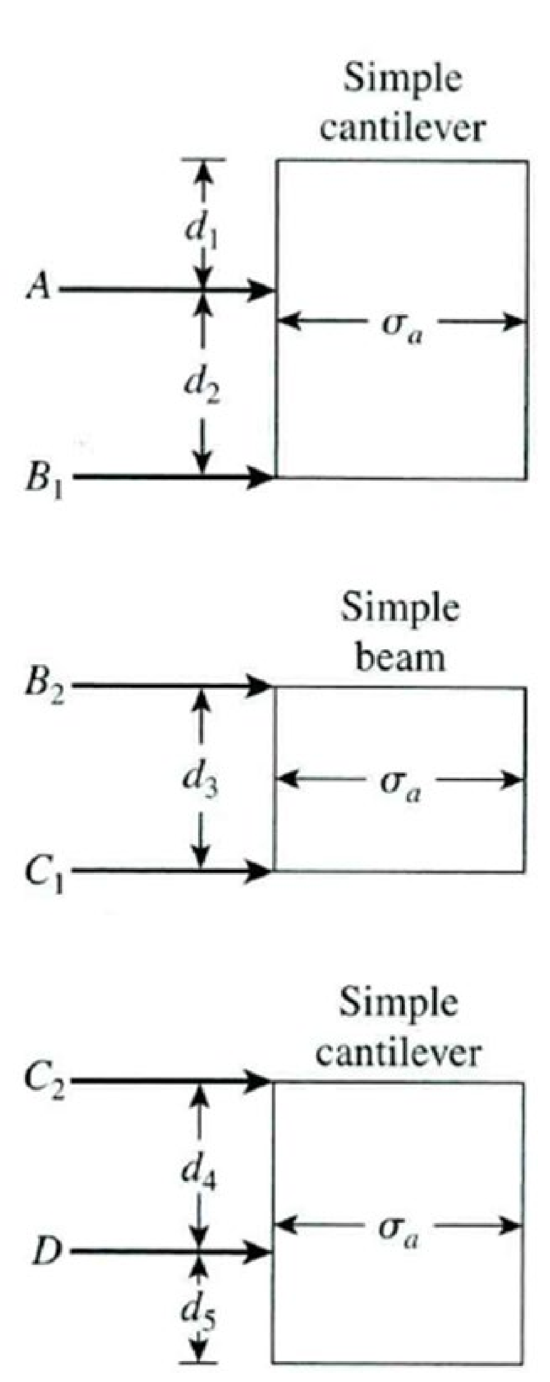
DESIGN of VARIOUS COMPONENTS of BRACED CUT

Strut

Step 1. Draw the pressure envelope for the braced cut.show the proposed strut levels.The strut levels are marked A, B, C, and D. The sheet piles (or soldier beams) are assumed to be hinged at the strut levels, except for the top and bottom ones.



Step 2.Determine the reactions (A,B1,B2,C1,C2,D) for the two simple cantilever beams (top and bottom) and all the simple beams between.



Step 3. The strut loads in the figure may be calculated via the formulas

$$P_A = (A)(s)$$

$$P_B = (B_1 + B_2)(s)$$

$$P_C = (C_1 + C_2)(s)$$

$$P_D = (D)(s)$$

Step 4. Knowing the strut loads at each level and the intermediate bracing conditions allows selection of the proper sections from the steel construction manual.

Sheet Pile

The following steps are involved in designing the sheet piles:

Step 1.For each of the sections, determine the maximum bending moment.
Step 2. Determine the maximum value of the maximum bending moments Mmax obtained in Step 1.
Step 3. Obtain the required section modulus of the sheet piles, namely,

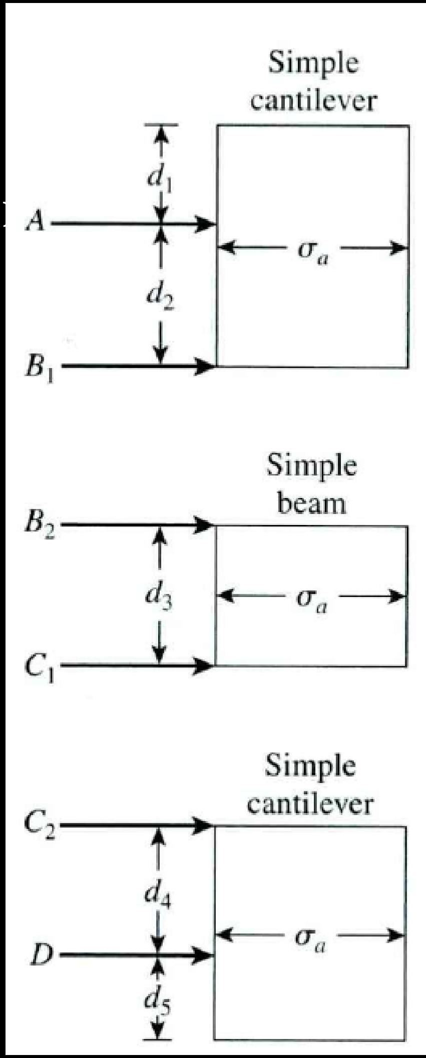
$$S = \frac{M_{\max}}{\sigma_{\text{all}}}$$

Step 4. Choose a sheet pile having a section modulus greater than or equal to the required section modulus from a table

Wale

Wales may be treated as continuous horizontal members if they are spliced properly.

Conservatively, they may also be treated as though they are pinned at the struts.
The maximum moments for the wales (assuming that they are pinned at the struts) a



At level A, $M_{\max} = \frac{(A)(s^2)}{8}$

At level B, $M_{\max} = \frac{(B_1 + B_2)s^2}{8}$

At level C, $M_{\max} = \frac{(C_1 + C_2)s^2}{8}$

and

At level D, $M_{\max} = \frac{(D)(s^2)}{8}$

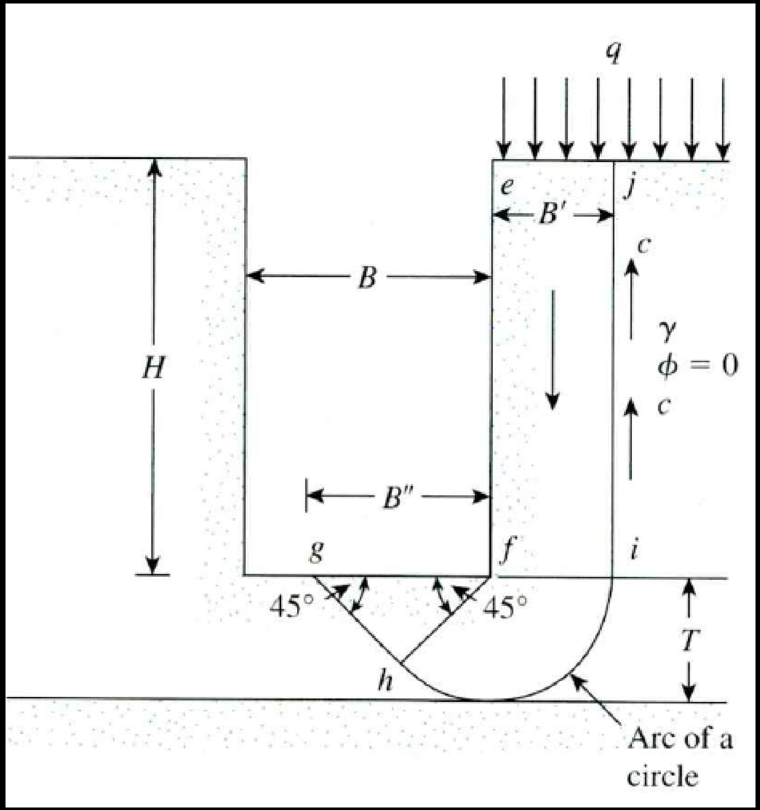
where A,B1,B2,C1,C2,D are the reactions under the struts per unit length of the wall

determine the section modulus of the wales:

$$S = \frac{M_{\max}}{\sigma_{\text{all}}}$$

BOTTOM HEAVE OF A CUT IN CLAY

Braced cuts in clay may become unstable as a result of heaving of the bottom of the excavation.
Terzaghi (1943) analyzed the factor of safety of long braced excavations against bottom heave.
The failure surface for such a case in a homogeneous soil is shown in Figure.
In the figure, the following notations are used: B=width of the cut, H=depth of the cut, T=thickness of the clay below the base of excavation, and q=surcharge adjacent to the excavation.



$$q_{\text{ult}} = cN_c$$

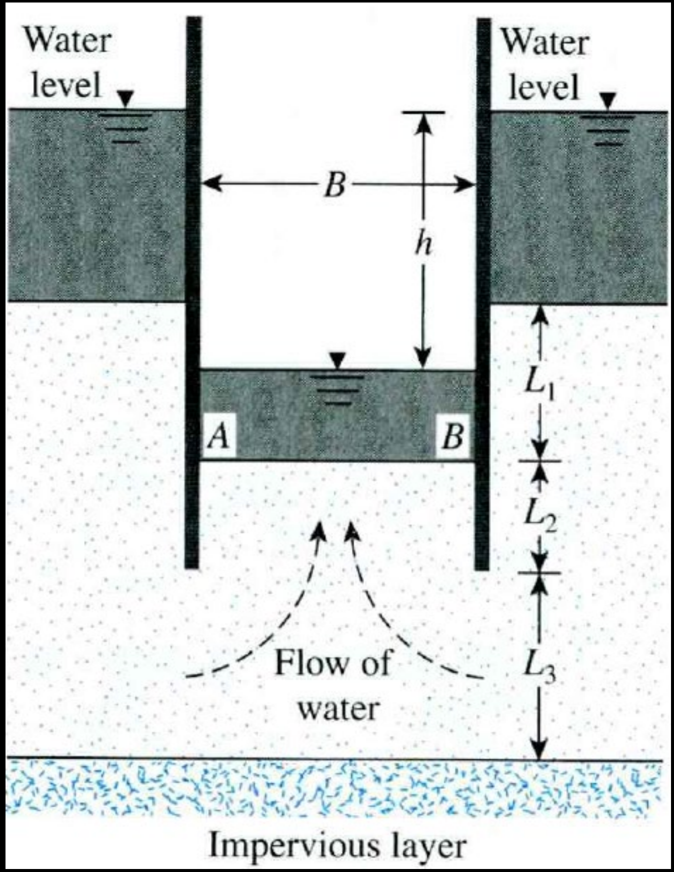
$$q = \gamma H + q - \frac{cH}{B'}$$

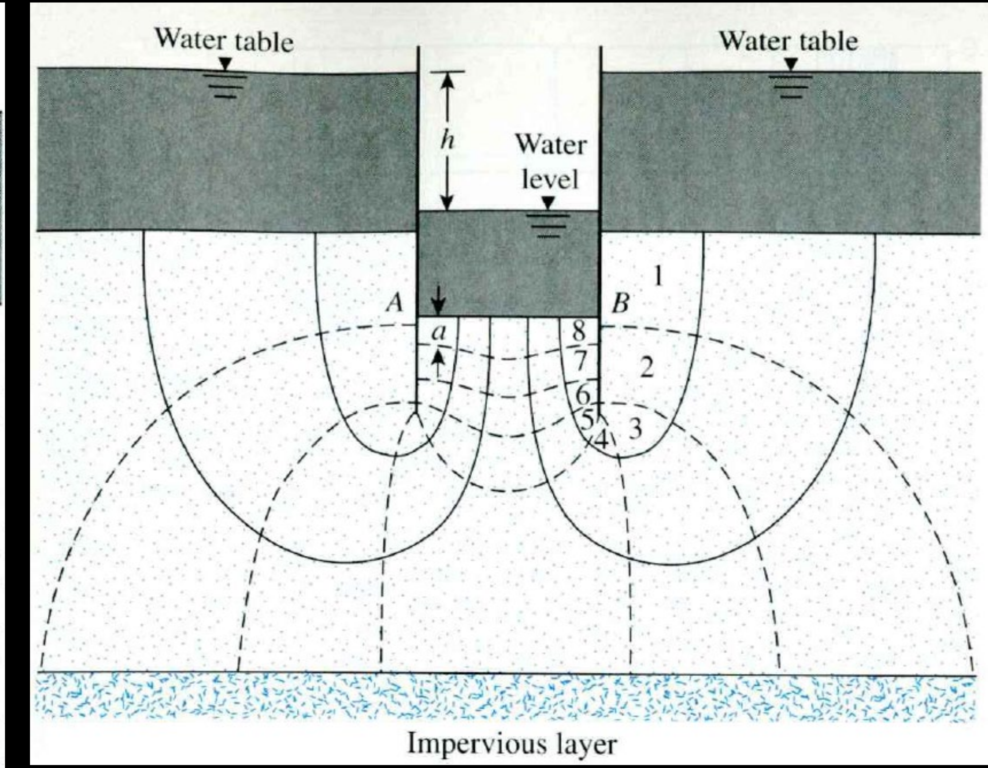
$$FS = \frac{q_{\text{ult}}}{q} = \frac{cN_c}{\gamma H + q - \dfrac{cH}{B'}} = \frac{cN_c}{\left(\gamma + \dfrac{q}{H} - \dfrac{c}{B'}\right)H}$$

$$FS = \frac{cN_c\left(1 + 0.2\dfrac{B'}{L}\right)}{\left(\gamma + \dfrac{q}{H} - \dfrac{c}{B'}\right)H}$$

STABILITY OF BOTTOM OF A CUT IN SAND

The bottom of a cut in sand is generally stable.
When the water table is encountered, the bottom of the cut is stable as long as the water level inside the excavation is higher than the groundwater level.
In case dewatering is needed, the factor of safety against piping should be checked.





$$i_{\max(\text{exit})} = \frac{\frac{h}{N_d}}{a} = \frac{h}{N_d a}$$

$$FS = \frac{i_{cr}}{i_{\max(\text{exit})}}$$

$$i_{cr} = \frac{G_s - 1}{e + 1}$$

REFERENCE;
DAS, PRINCIPLES of FOUNDATION ENGINEERING