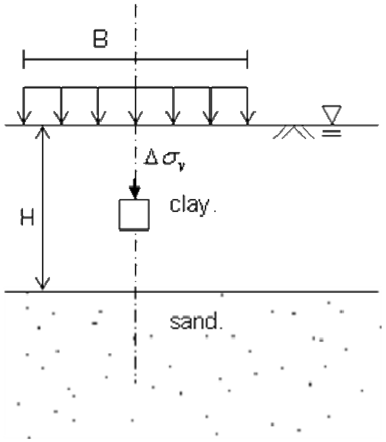
2.3 Rate – Dependent Settlements

- Time – dependent settlement :

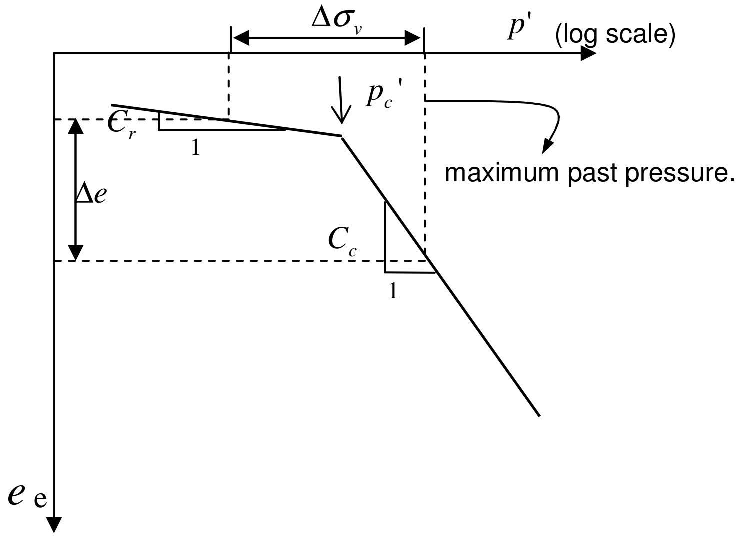
  Primary consolidation : related to dissipation of u_e

  Secondary compression : relevant to drained creep (u_e=0) at constant vertical stress.

- How to compute consolidation settlements (1-D state).



When B/H ≥ 1, then 1-D conditions are approximated under centerline of loading.



p_c' ≡ maximum past presssure

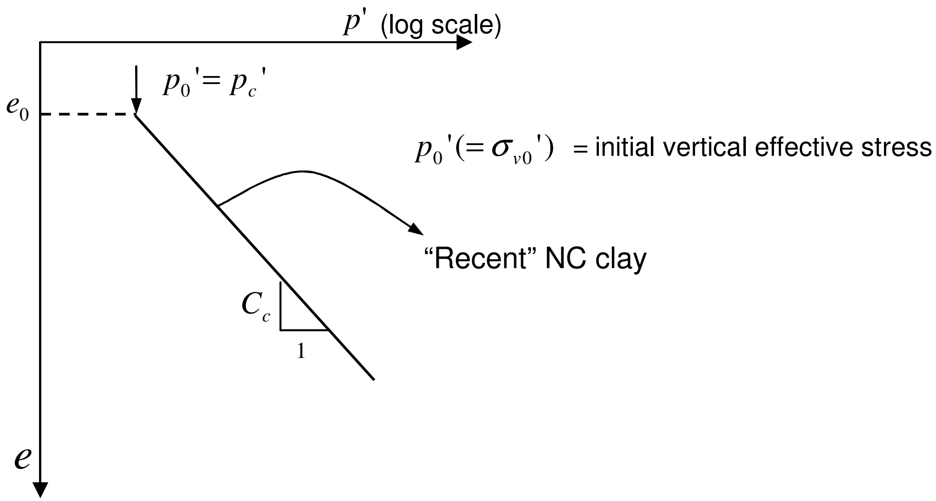
C_c ≡ compression index

C_r ≡ recompression index

$$S = \frac{\Delta e}{1+e_0} H$$

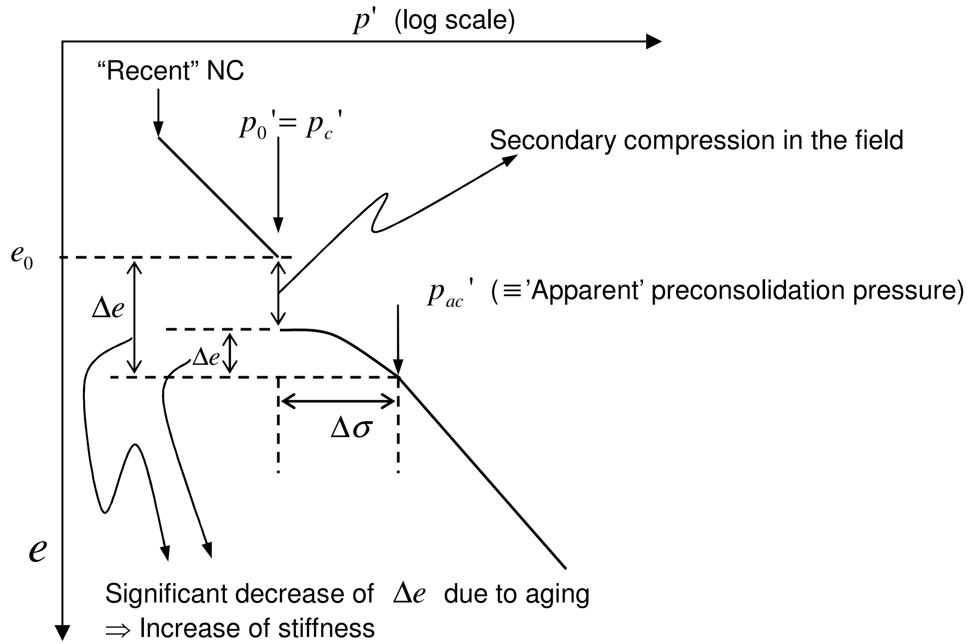
● Preconsolidation Effect

i) Normally Consolidated Clay.



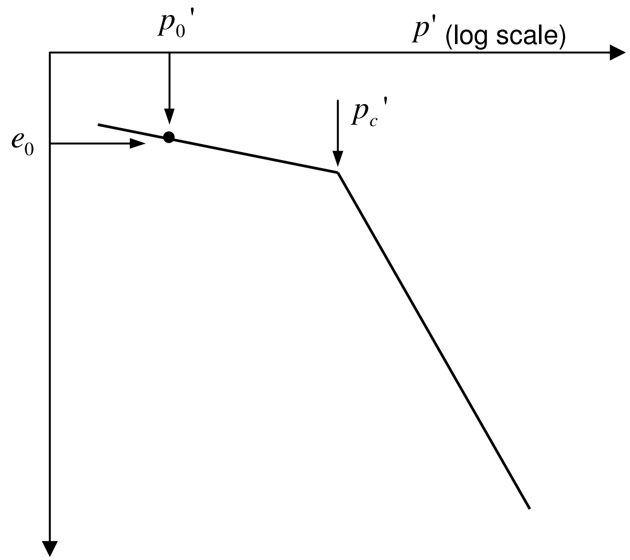
ii) "Aged" Normally Consolidated Clay.

Aged : clay has been subjected to constant p_0' for a significant period of time.



iii) Overconsolidated clay.

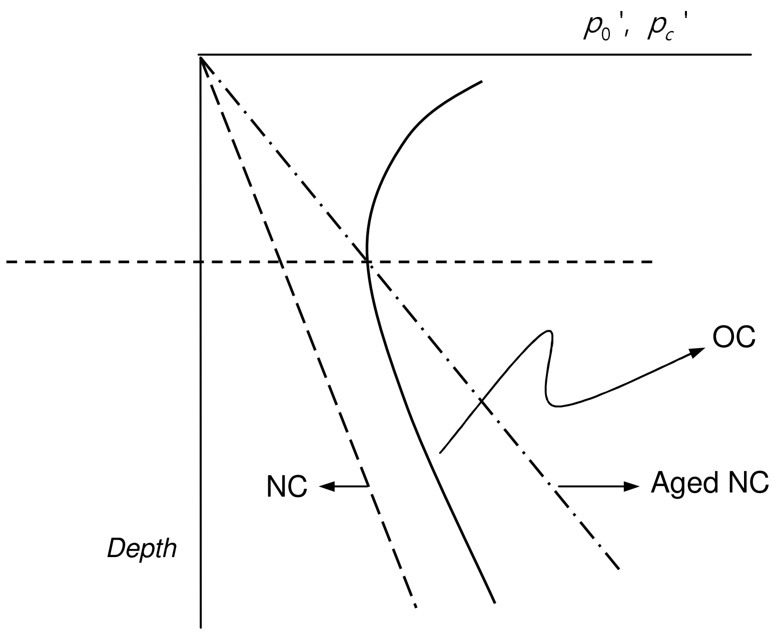
$$p_C' > p_0'$$



∗ To distinguish aged NC soils from OC soils.

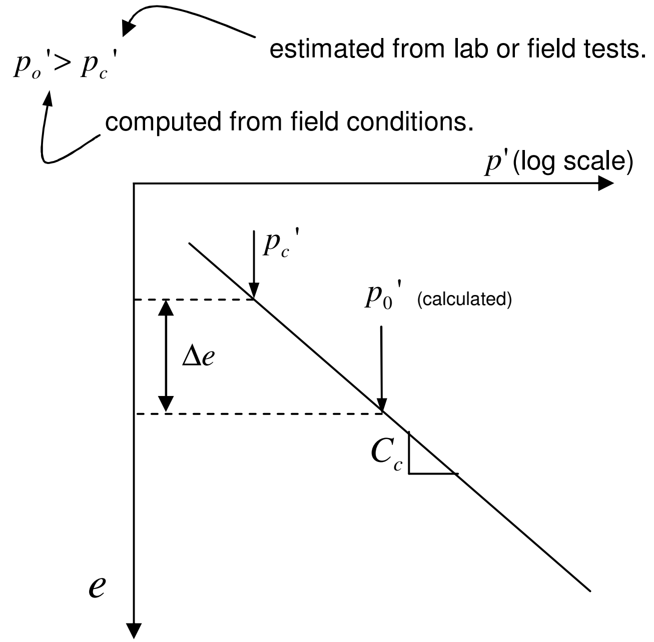
1. Based on geologic history.

2. For an aged deposit, the difference between p_c' and p_0' will increase with depth.



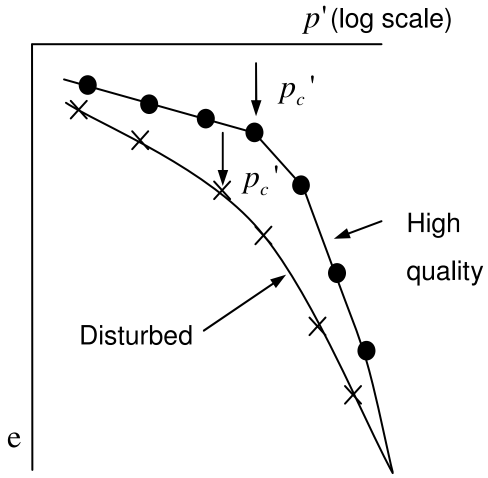
iv) Clay under consolidation.

(u_e is not fully dissipated.)



- Consolidation settlement can be computed, assuming soil layer as a normally consolidated soil with stress increment $p_0^{'} - p_c^{'}$.

● Disturbance Effects



Disturbance.

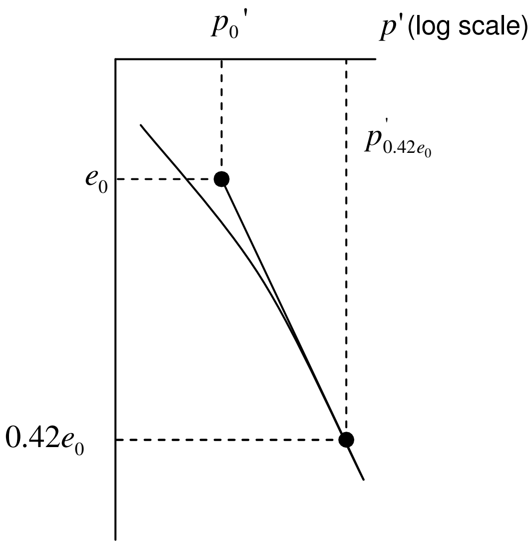
→ flattens out e-log p' curve.

→ masks p_c' (lowers it).

→ gives higher estimation of settlement.

- To "correct" the curve from disturbance, Schmertmann recommended a "field" e - log p' curve.

① If we have a NC soil.



Steps.

i) Estimate $e_{o(field)}$.

ii) Calculate p_0' and $(0.42)e_o$.

iii) Connect (e_o, p_0') and ($0.42e_o$, $p'_{0.42e_o}$) in the consolidation curve. ⇒ Use this line to compute consolidation settlement.

② OC soil (or aged NC soil).

Run test with unload – reload cycle at $0.42e_o$. (or at least at $p' > p'_c$).

i) Estimate e_o.

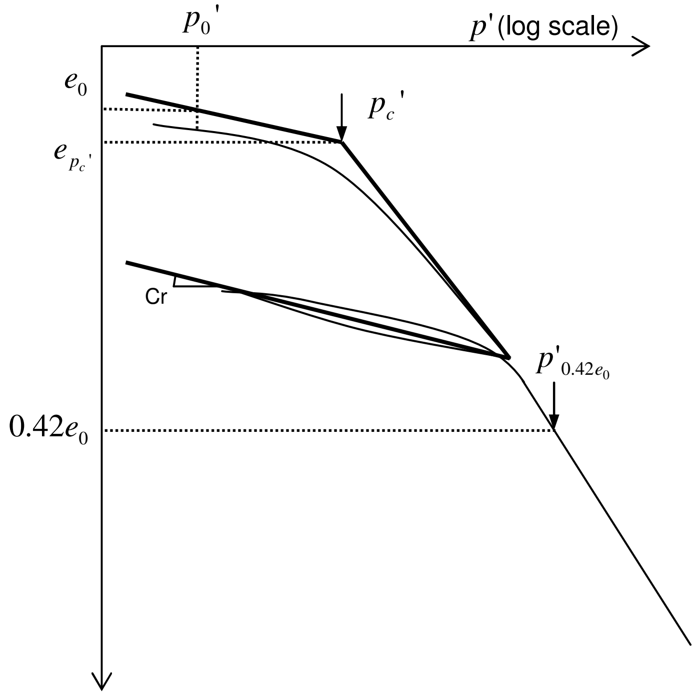
ii) Calculate p_0' and $0.42e_o$.

iii) Obtain p_c' from Cassagrande construction.

iv) Find C_r from unload – reload cycle.

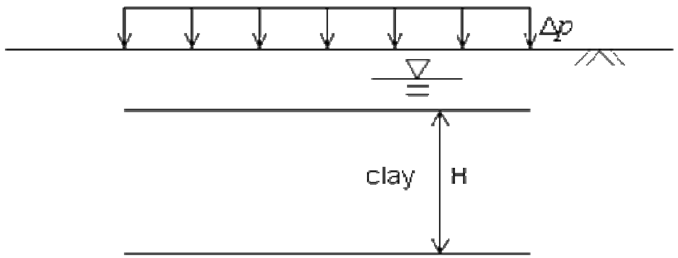
v) Draw line parallel to C_r line from unload – reload through (e_o', p_0'). (⇒ Gives $e_{p_c'}$ at $p' = p_c'$.)

vi) Connect ($e_{p_c'}$, p_c') and ($0.42e_o$, $p'_{0.42e_o}$).



● 1-D settlement

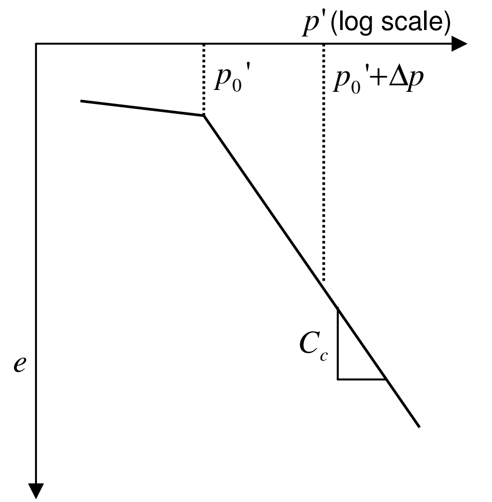
$$S = \frac{\Delta e}{1+e_0} H$$



If field corrected curve is plotted, consolidation settlements, S_c can be computed with C_c, C_r and p'_c, as below ;

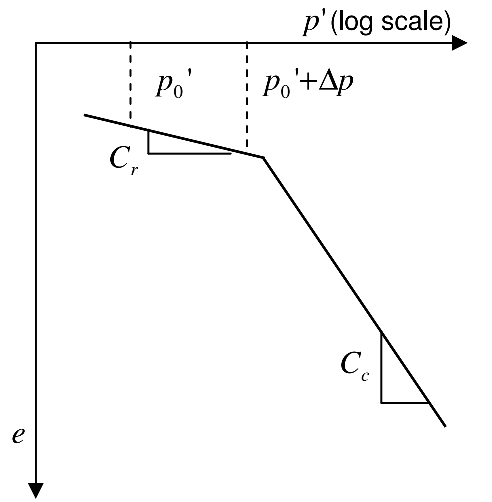
For NC,

$$S_c = \frac{C_c}{1+e_0} H \log \frac{p'_0 + \Delta p}{p'_0}$$



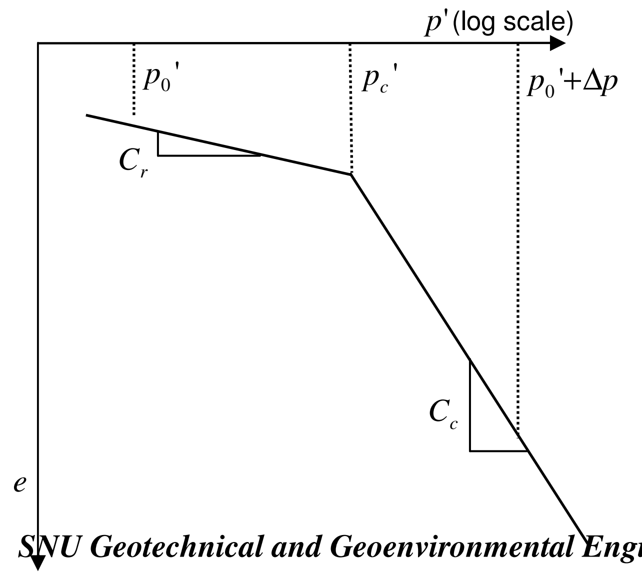
For OC, and $p'_0 + \Delta p \le p'_c$,

$$S_c = \frac{C_r}{1+e_0} H \log \frac{p'_0 + \Delta p}{p'_0}$$



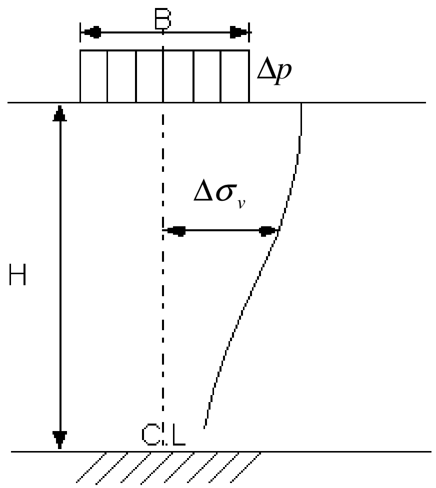
For OC, and $p'_0 + \Delta p > p'_c$,

$$S_c = \frac{C_r}{1+e_0} H \log \frac{p'_C}{p'_0} + \frac{C_c}{1+e_{p'_C}} H \log \frac{p'_0 + \Delta p}{p'_C}$$



● What about loads of limited extent?

B/H < 1 → not 1-D



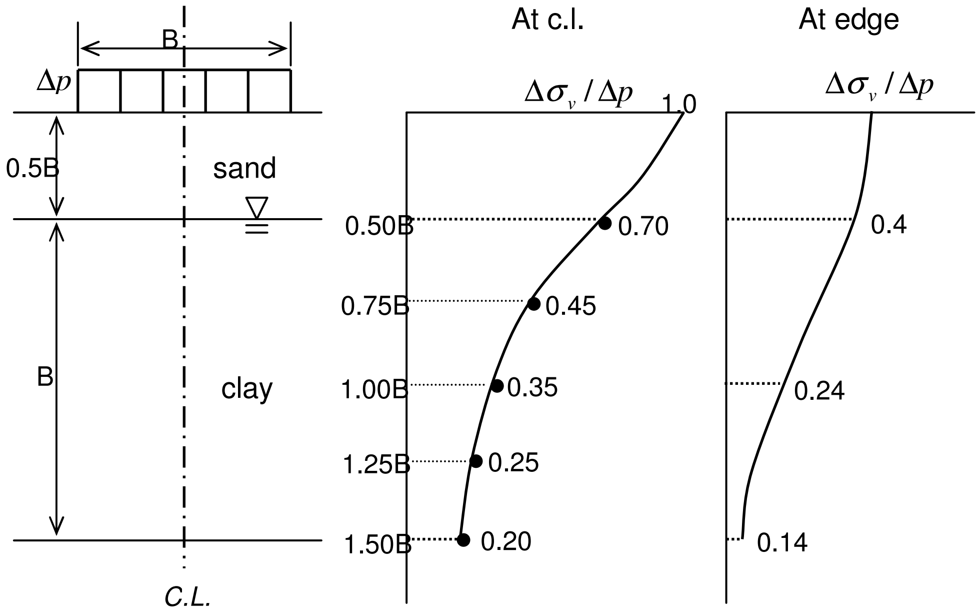
i) $\Delta p \neq \Delta\sigma_v$

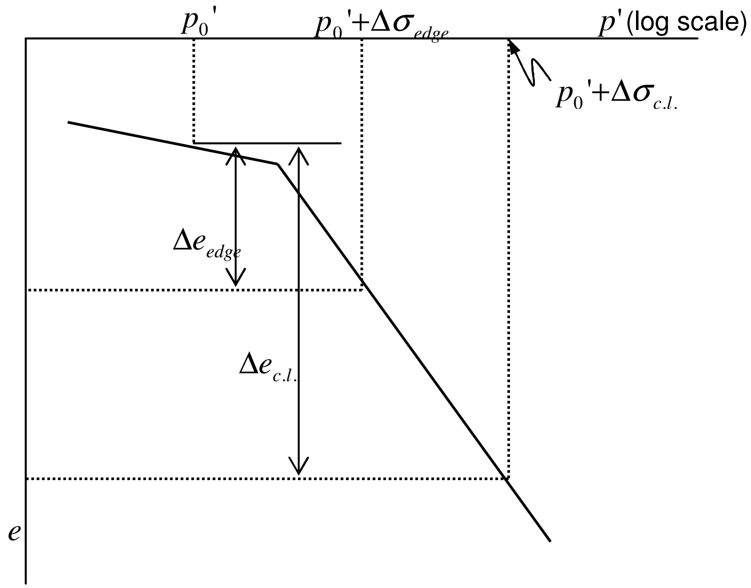
ii) $\Delta\sigma_v \neq \Delta u$

iii) $\varepsilon_{lateral} \neq 0$

i) $\underline{\Delta p \neq \Delta\sigma_v}$ $\rightarrow$ using Bousinesque distributions.

Ex) circular footing.





$$\left(\frac{\Delta\sigma_v}{\Delta p}\right)_{c.l.} = \frac{1}{4}\left(\frac{0.7+0.45}{2} + \frac{0.45+0.35}{2} + \frac{0.35+0.25}{2} + \frac{0.25+0.20}{2}\right) = 0.375$$

$$\left(\frac{\Delta\sigma_v}{\Delta p}\right)_{edge} = 0.225$$

ii) $\underline{\Delta\sigma_v \neq \Delta u}$ (Skempton – Bjerrum Appoach.)

($\Delta\sigma_v = \Delta u$ $\rightarrow$ conventional.)

$\Delta u = \Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3)$ $\leftarrow$ For saturated soil.

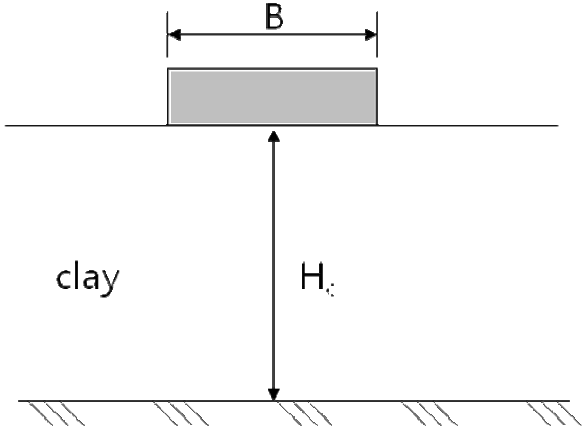
$$S_{conv} = \int_0^z \frac{\Delta e}{1+e_0} dz, \qquad (a_v = \frac{\Delta e}{\Delta u})$$

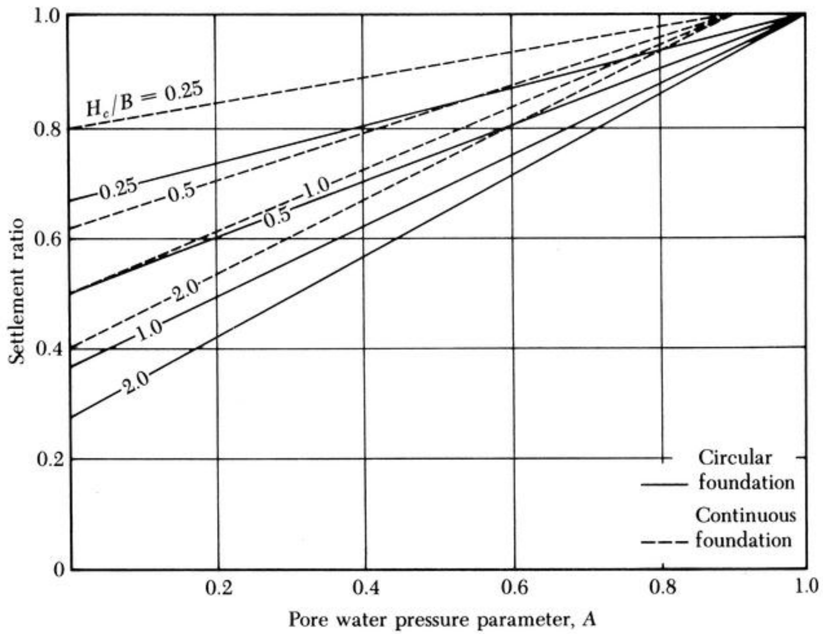
$$= \int_0^z \frac{a_v \Delta u}{1+e_0} dz \quad = \frac{a_v}{1+e_0}\int_0^z \Delta\sigma_v dz \quad = \frac{a_v}{1+e_0}\int_0^z \Delta\sigma_1 dz$$

$$S_{S-B} = \frac{a_v}{1+e_0}\int_0^z \left[\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3)\right] dz$$

Correction Factor, $K = \frac{S_{S-B}}{S_{conv}} = A + \left[\frac{(1-A)\int_0^z \Delta\sigma_3 dz}{\int_0^z \Delta\sigma_1 dz} \right]$

K is a function of A & H_c/B (+ footing shape).



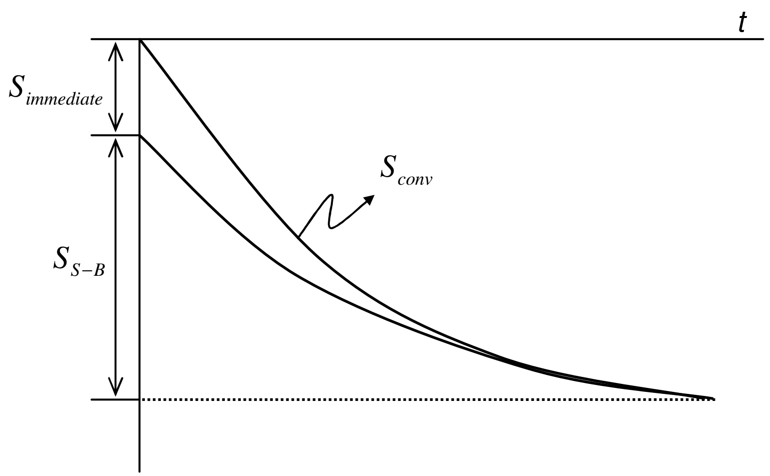


Settlement ratios for circular (K_{cir}) and continuous (K_{str}) foundations

- Comments. (H. B. Seed (1964))

1) If S_{conv} is computed only, we get a reasonable estimate of the magnitude of total settlement (=$S_{consoliation}$ + $S_{immediate}$) in field, but not rate of settlements.

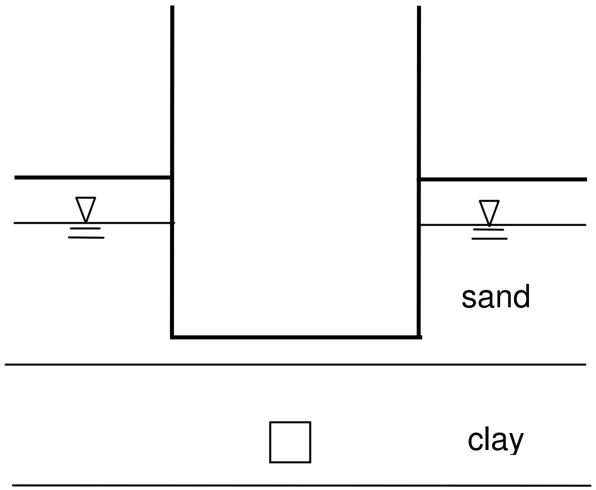
2) If only magnitude of settlements are needed, then use $S_{conventional}$ and do not add immediate component.



iii) $\varepsilon_{lateral} \neq 0$ (Lateral strain effect).

$\rightarrow$ use stress path method.

Ex)



Sequence.

① Excavation.
② Dewatering.

③ Constructing structure.
④ Grading.
⑤ Turn off dewatering system.