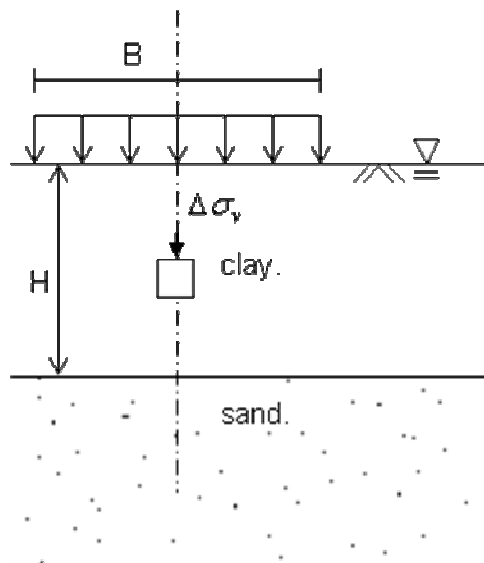
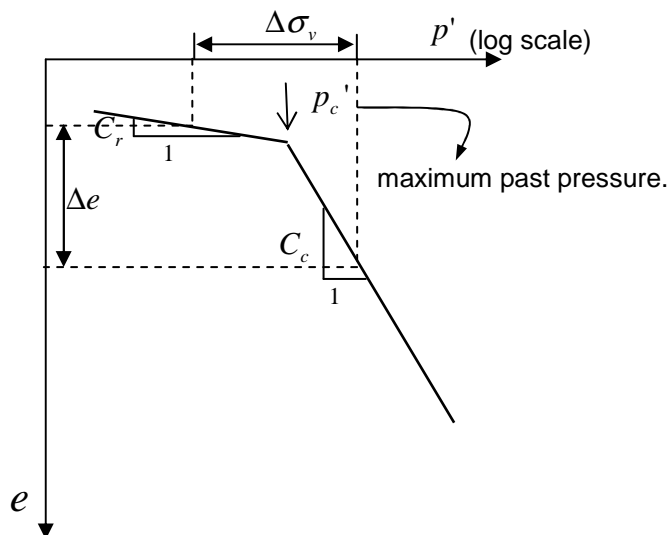


2.3 Rate – Dependent Settlements

- 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 $B/H \geq 1$, then 1-D conditions are approximated under centerline of loading.

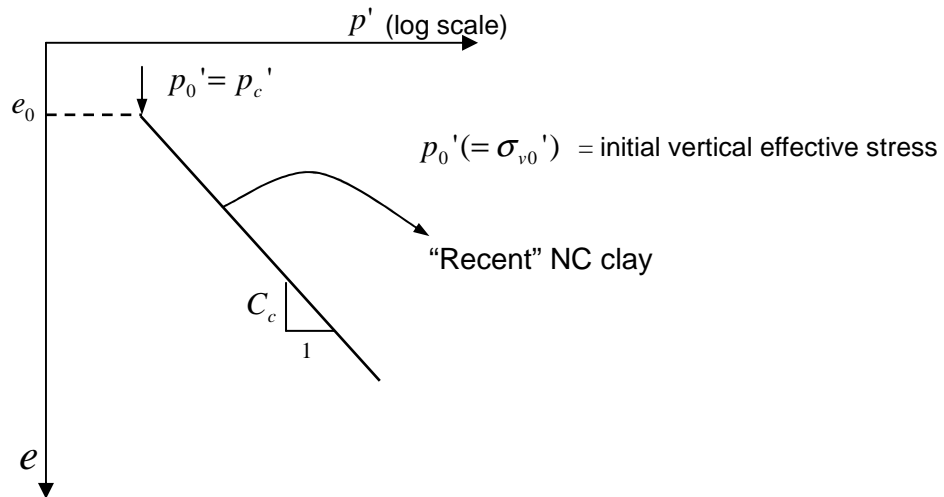


- p_c' \equiv maximum past pressure
- C_c \equiv compression index
- C_r \equiv recompression index

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

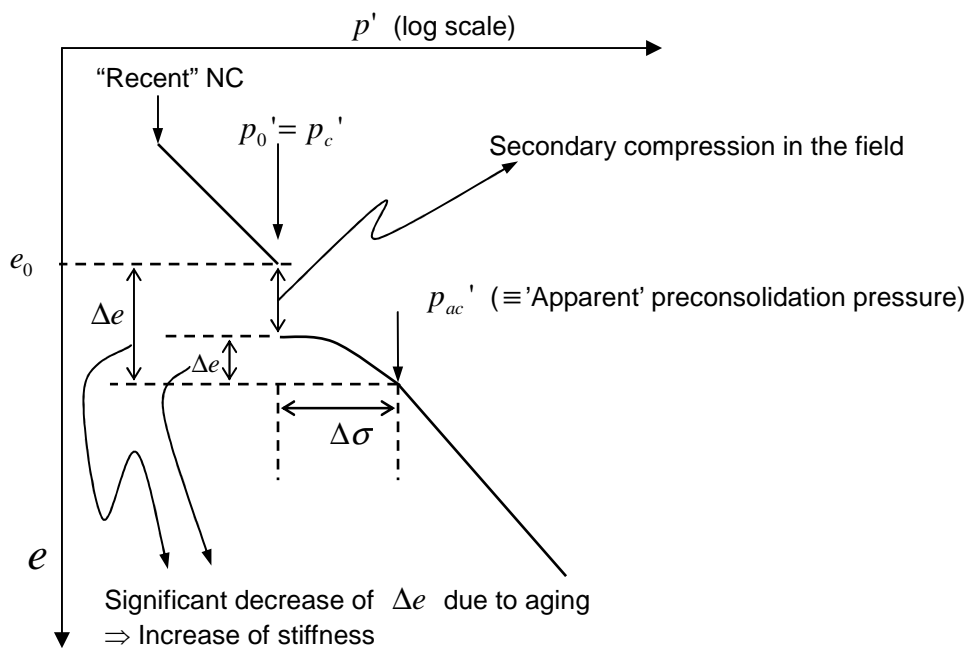
● Preconsolidation Effect

i) Normally Consolidated Clay.



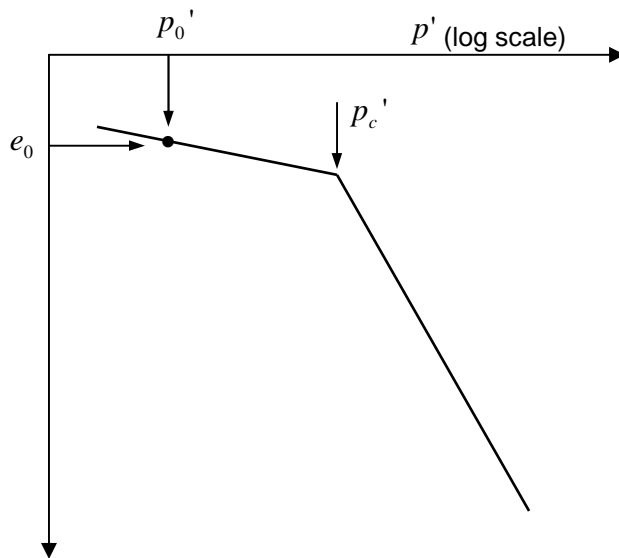
ii) "Aged" Normally Consolidated Clay.

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



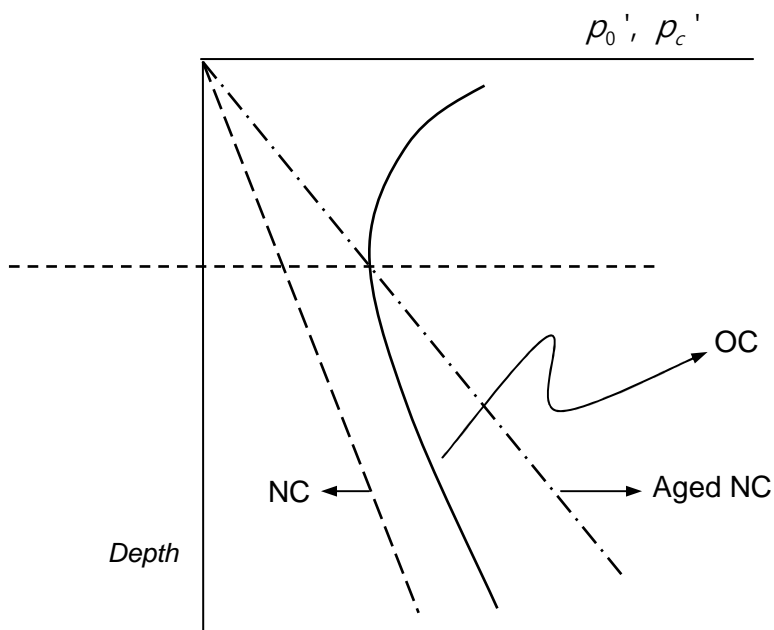
iii) Overconsolidated clay.

$$p_c' > p_0'$$



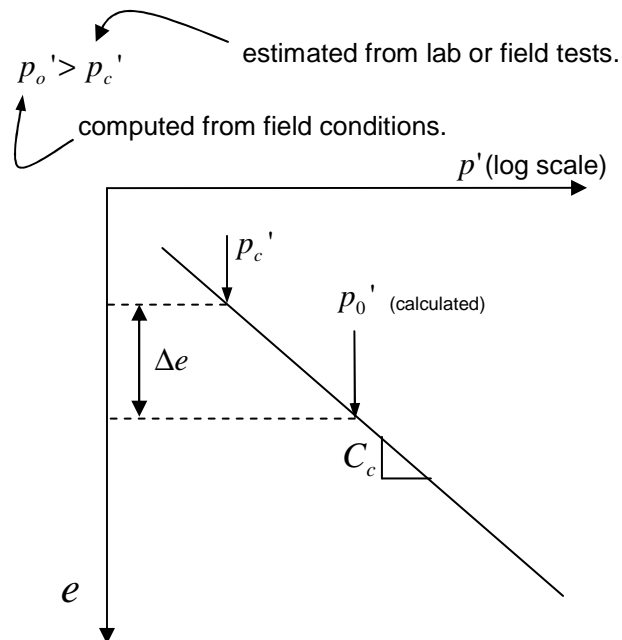
* To distinguish aged NC soils from OC soils.

1. Based on geologic history.
2. For an aged deposit, the difference between p_c' and p_0' will increase with depth.



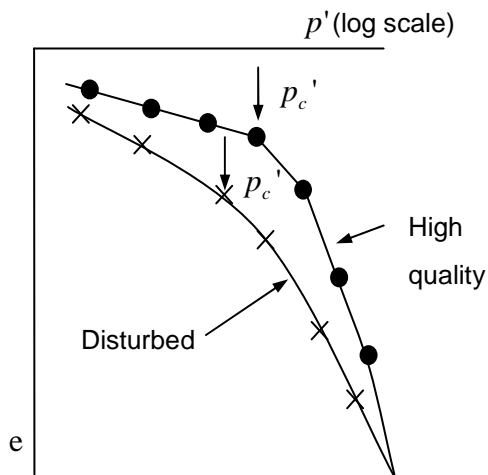
iv) Clay under consolidation.

(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

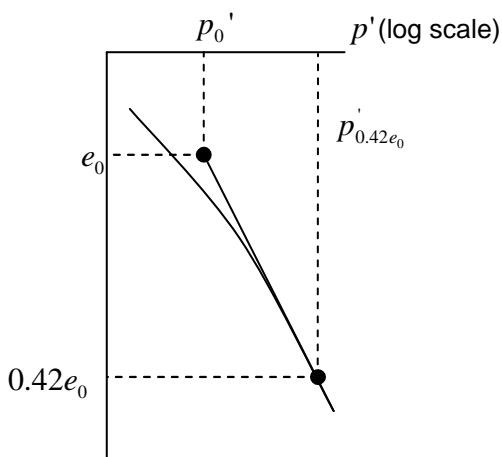


Disturbance.

- 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 $e_{o(\text{field})}$.
- ii) Calculate p_0' and $(0.42)e_0$.
- iii) Connect (e_0, p_0') and $(0.42e_0,$

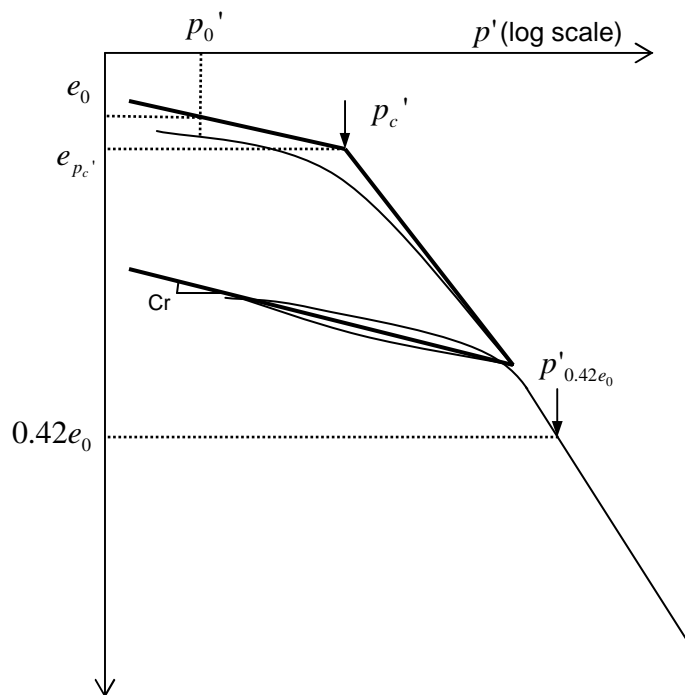
$p'_{0.42e_0})$ in the consolidation curve.

⇒ Use this line to compute consolidation settlement.

② OC soil (or aged NC soil).

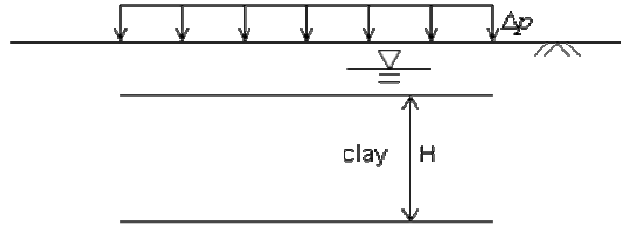
Run test with unload – reload cycle at $0.42e_0$. (or at least at $p' > p'_c$).

- i) Estimate e_0 .
- ii) Calculate p_0' and $0.42e_0$.
- 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_0', p_0') . (\Rightarrow Gives $e_{p'_c}$ at $p' = p'_c$.)
- vi) Connect $(e_{p'_c}, p'_c)$ and $(0.42e_0, p'_{0.42e_0})$.



● 1-D settlement

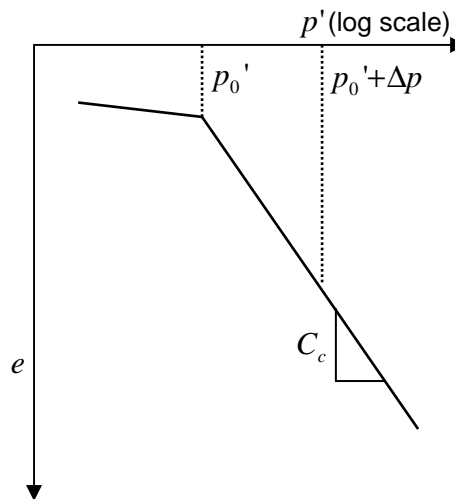
$$S = \frac{\Delta e}{1 + e_0} H$$



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

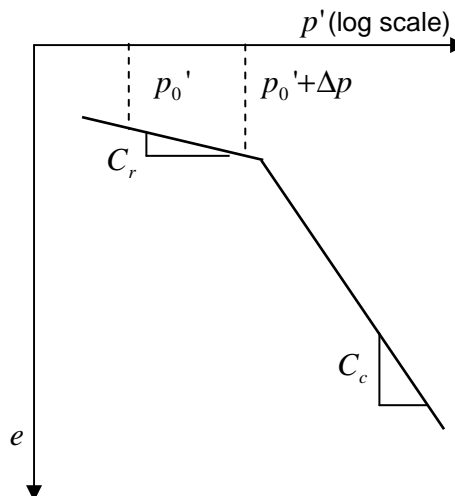
For NC,

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



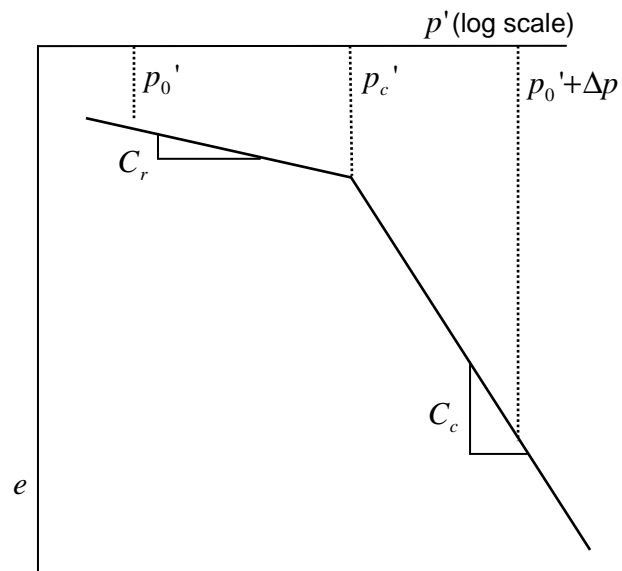
For OC, and $p'_0 + \Delta p \leq p'_c$,

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



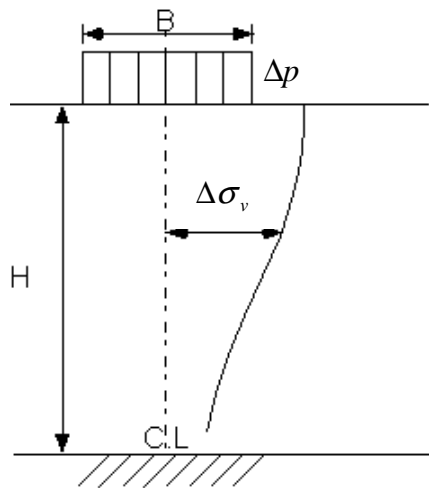
For OC, and $p'_0 + \Delta p > p'_c$,

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



● What about loads of limited extent?

$B/H < 1 \rightarrow$ not 1-D

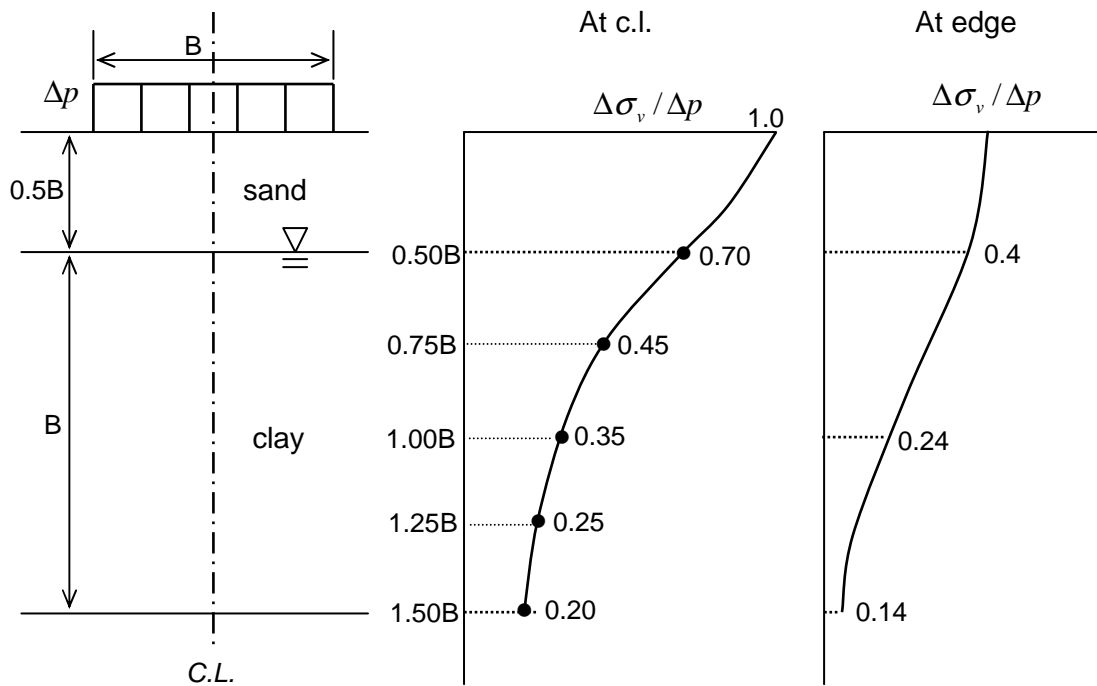


- i) $\Delta p \neq \Delta \sigma_v$
- ii) $\Delta \sigma_v \neq \Delta u$
- iii) $\epsilon_{lateral} \neq 0$

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

\rightarrow using Boussinesq distributions.

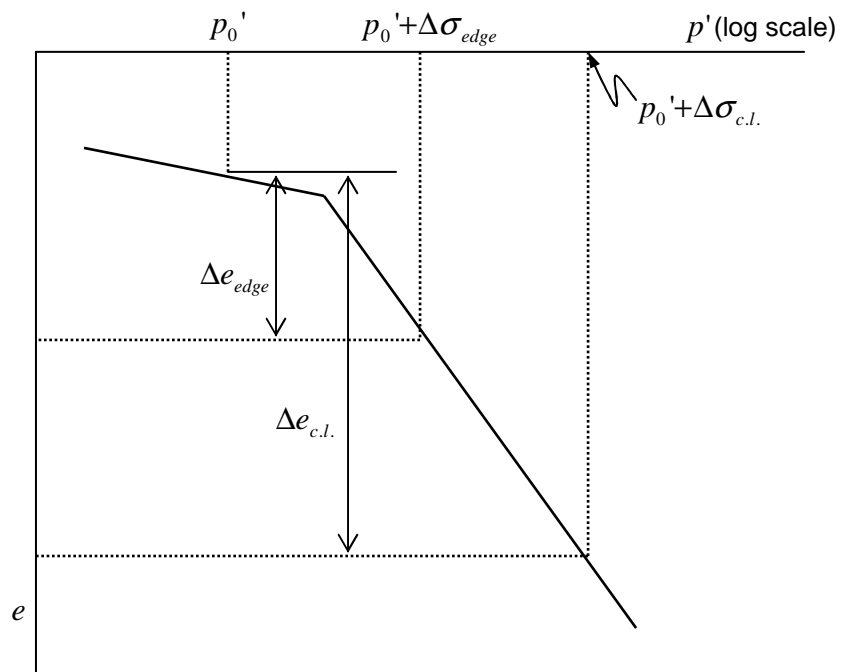
Ex) circular footing.



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

$$= 0.375$$

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



ii) $\Delta\sigma_v \neq \Delta u$ (Skempton – Bjerrum Approach.)

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

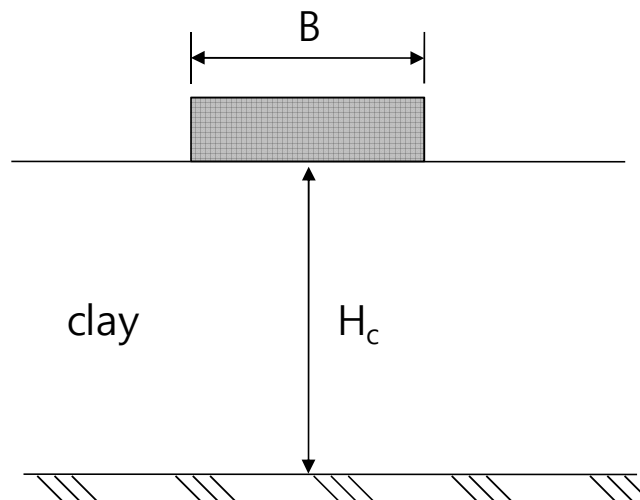
$\Delta u = \Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3) \leftarrow$ For saturated soil.

$$\begin{aligned}
 S_{conv} &= \int_0^z \frac{\Delta e}{1 + e_0} dz, & (a_v = \frac{\Delta e}{\Delta u}) \\
 &= \int_0^z \frac{a_v \Delta u}{1 + e_0} dz \\
 &= \frac{a_v}{1 + e_0} \int_0^z \Delta \sigma_v dz, \\
 &= \frac{a_v}{1 + e_0} \int_0^z \Delta \sigma_1 dz \\
 S_{S-B} &= \frac{a_v}{1 + e_0} \int_0^z [\Delta \sigma_3 + A(\Delta \sigma_1 - \Delta \sigma_3)] dz
 \end{aligned}$$

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).



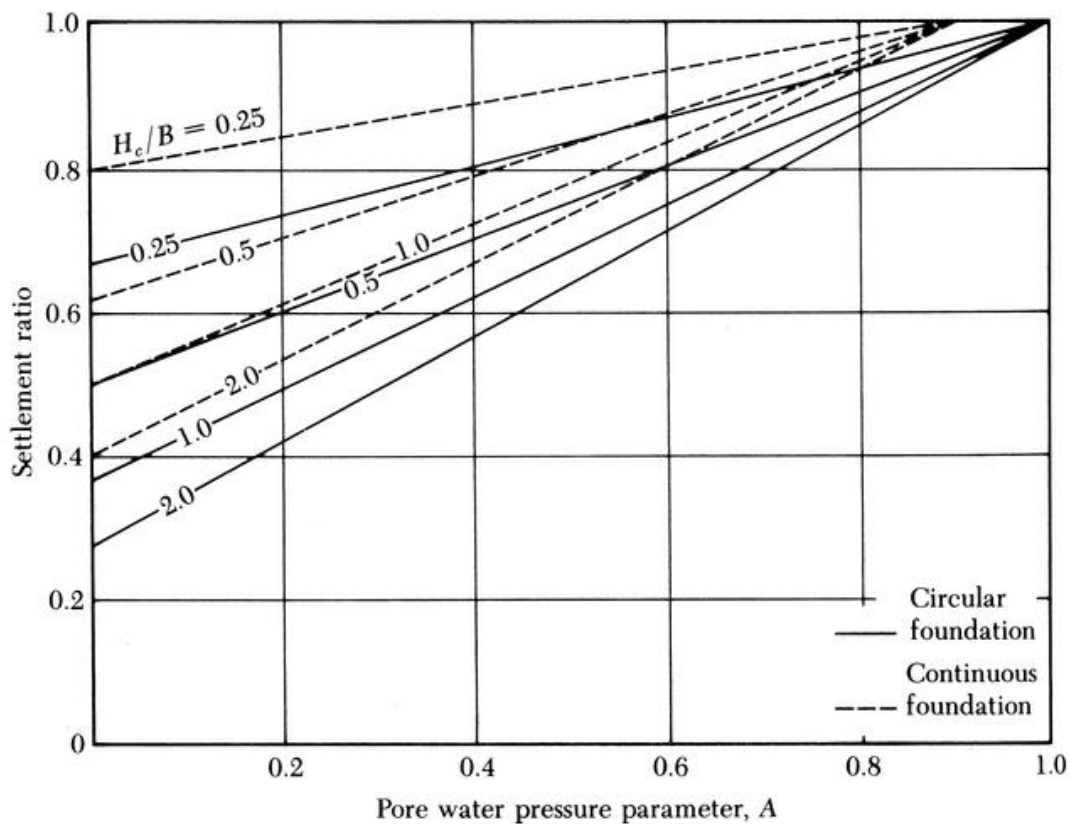
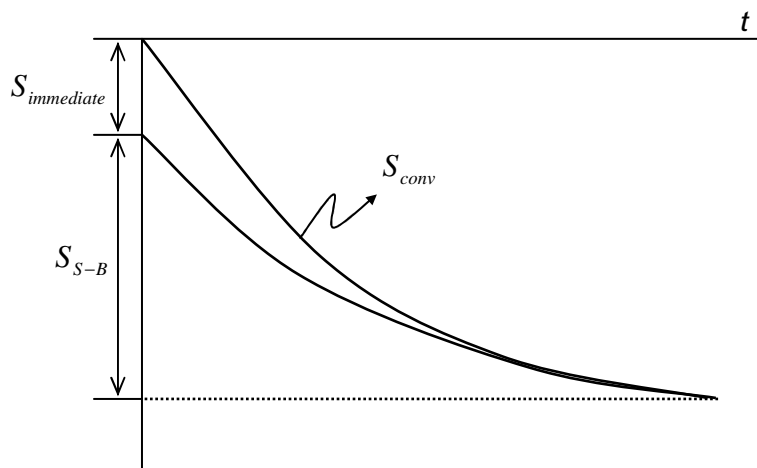


Fig. 2-25 Settlement ratios for circular (K_{cir}) and continuous (K_{str}) foundations

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

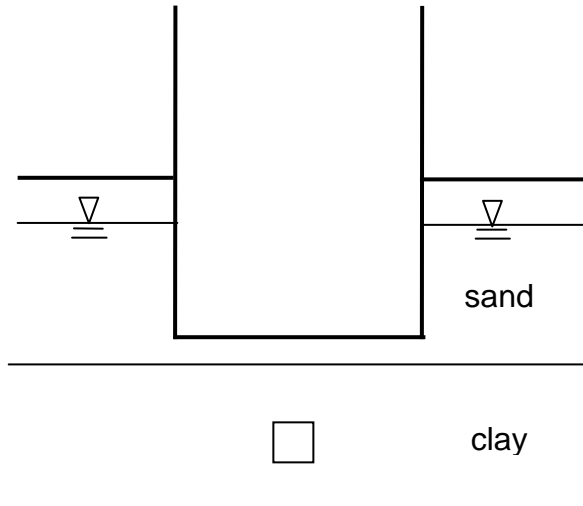
- 1) If S_{conv} is computed only, we get a reasonable estimate of the magnitude of total settlement ($=S_{consolidation} + S_{immediate}$) in field, but not rate of settlements.
- 2) If only magnitude of settlements are needed, then use $S_{conventional}$ and do not add immediate component.



- iii) $\epsilon_{lateral} \neq 0$ (Lateral strain effect).
→ use stress path method.

* Comments) Settlement should be estimated based on loading history of the ground induced by structure construction.

Ex)



- Sequence.
- ①. Excavation.
 - ②. Dewatering.
 - ③. Constructing structure.
 - ④. Grading.
 - ⑤. Turn off dewatering system.

