Chapter 8. Stability of Earth Slopes (Fill/Cut)

Outlines

8.1 Infinite slopes

○ Sand slopes
- w/ no seepage
- w/ seepage parallel to slopes

○ Clay slopes
- w/ no seepage
- w/ seepage parallel to slopes

○ Factor of safety

8.2 Slopes of limited height

○ Method of slope stability analysis considering equilibrium of free body as a whole : Friction circle method

○ Method of slices :

- Ordinary method
- Simplified Bishop method

○ Factor of safety

8.1 Infinite slopes

○ Sand slopes w/ no seepage (submerged case)

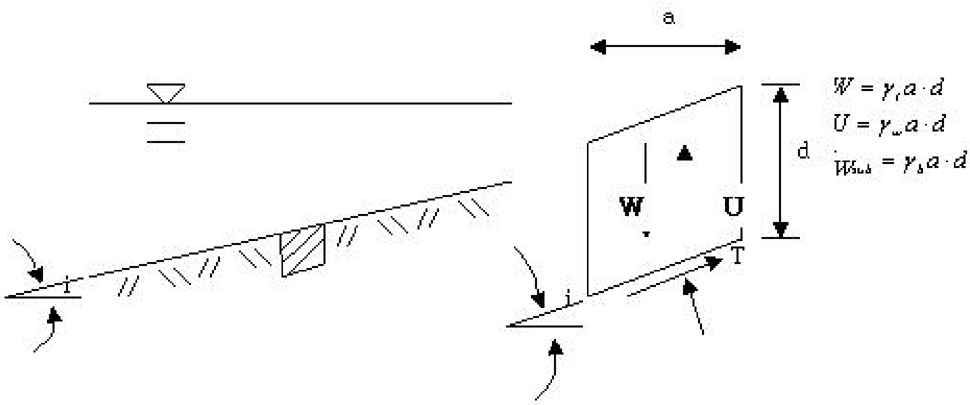


Fig. 1

- If the free body is in equilibrium,

$$\overline{N} = W_{sub} \cdot \cos i \rightarrow \overline{\sigma} = \frac{\overline{N}}{a/\cos i} = \gamma_b \cdot d \cdot \cos^2 i$$

$$T = W_{sub} \cdot \sin i \rightarrow \tau = \frac{T}{a/\cos i} = \gamma_b \cdot d \cdot \cos i \sin i \quad \cdots \text{①}$$

- If full resistance is mobilized,

$$\tau_{max} = \overline{\sigma} \tan\overline{\phi} = \gamma_b \cdot d \cdot \cos^2 i \cdot \tan\overline{\phi}$$

- To maintain stability, $\tau_{max} \geq \tau_{equil}$

i.e., $\gamma_b \cdot d \cdot \cos^2 i \cdot \tan\overline{\phi} \geq \gamma_b \cdot d \cdot \cos i \cdot \sin i$

$\rightarrow \tan\overline{\phi} \geq \tan i$ or $\overline{\phi} \geq i$ (Fig. 3 (a)) ··· ②

○ sand slopes w/ seepage parallel to slopes

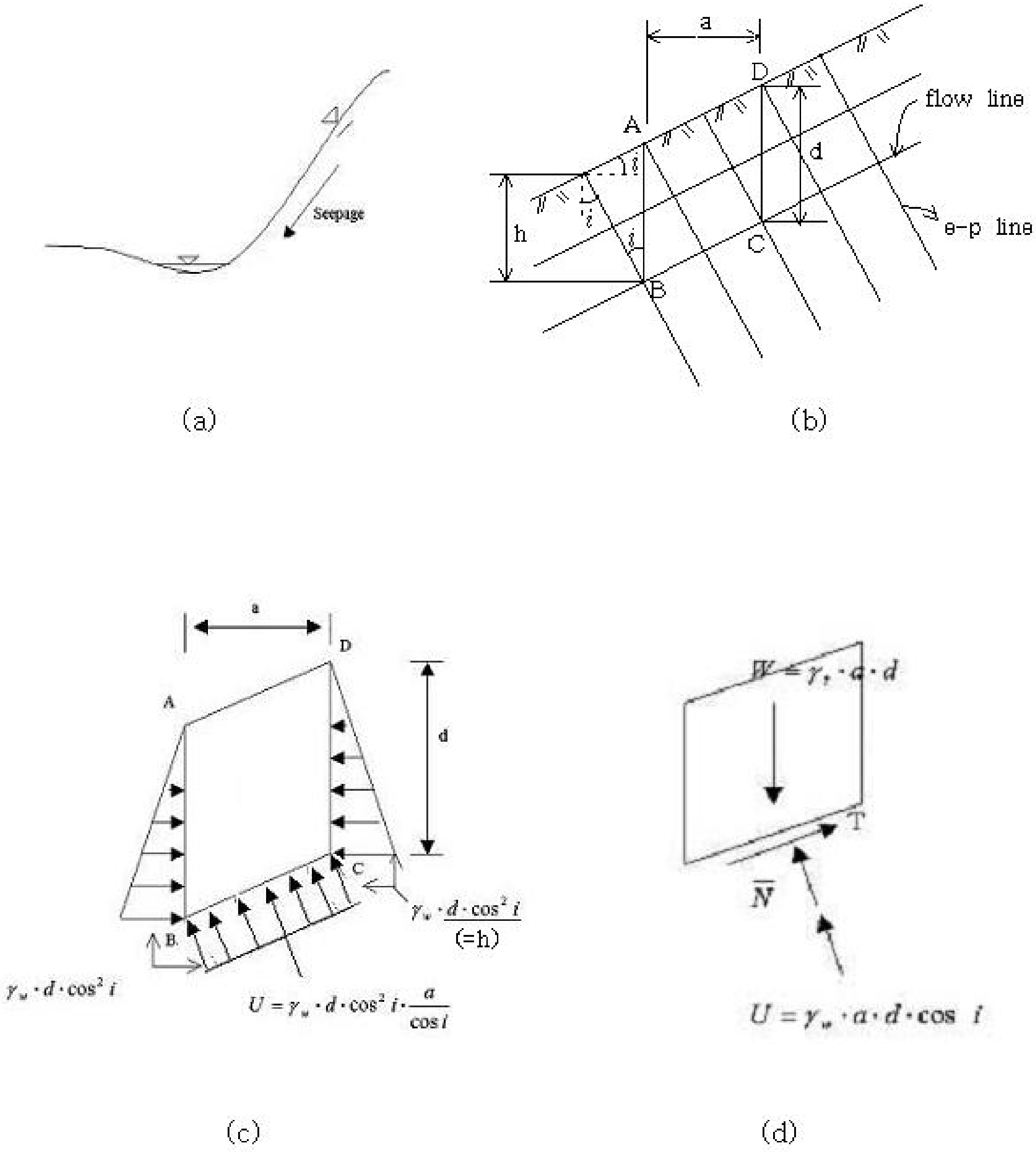


Fig. 2

- For the equilibrium,

$$\bar{\sigma} = \frac{\bar{N}}{a/\cos i} = \gamma_b \cdot d \cdot \cos^2 i$$

$$\tau = \frac{T}{a/\cos i} = \gamma_t \cdot d \cdot \cos i \cdot \sin i \quad \cdots ③$$

- The maximum shearing resistance at the bottom,

$$\tau_{max} = \bar{\sigma} \tan\phi = \gamma_b \cdot d \cdot \cos^2 i \cdot \tan\bar{\phi}$$

- To maintain stability,

$$\tau_{max} \geq \tau_{equil} \rightarrow \frac{\gamma_b}{\gamma_t} tan\bar{\phi} \geq \tan i \rightarrow \frac{\gamma_t}{\gamma_b} tan\ i < \tan\bar{\phi}$$

i.e, $\bar{\phi} \geq \tan^{-1}((\frac{\gamma_t}{\gamma_b})\tan i)$ (Fig. 3 (a)) ··· ④

$= i^*$

or $i \leq \tan^{-1}(\frac{\gamma_b}{\gamma_t} tan\bar{\phi})$ ··· ④'

예제8.1 사질토인 사면 흙의 유효내부마찰각($\bar{\phi}$)은 45이다. 사면 내에 침투가 없는 경우와 사면과 평행하게 침투가 있는 경우 각각에 대하여 안정한 최대 사면각을 산정하라. 단, 포화단위중량(γ_t)은 $1.8 t/m^3$이고 수중단위중량(γ_b)은 $0.8\ t/m^3$이다.

(풀이)

침투가 없는 경우 : $i \leq \phi$ (Eq. ②)

$\therefore\ i_{max} = 45°$

침투가 사면과 평행한 경우 : $\tan i \leq \frac{\gamma_b}{\gamma_t} \cdot \tan\bar{\phi}$ (Eq. ④)

즉, $\tan i \leq \frac{0.8}{1.8} \cdot \tan\ 45°$

$\therefore\ i_{max} = 23.7°$

○ Clay Slopes

- For the equilibrium, τ_{equil} can be expressed same as eqs. ① and ③ depending upon the occurrence of seepage thru the slopes.

i.e.,

w/ no seepage : $(\tau_{equil})_{ns} = \gamma_b \cdot d \cdot \cos i \cdot \sin i$

w/ seepage : $(\tau_{equil})_s = \gamma_t \cdot d \cdot \cos i \cdot \sin i$

- These can be rewritten as a function of $\bar{\sigma}$ as the following

$$(\tau_{equil})_{ns} = \bar{\sigma} \cdot \tan i, \quad (\tau_{equil})_s = \bar{\sigma} \cdot \frac{\gamma_t}{\gamma_b} \cdot \tan i$$

($\because \bar{\sigma} = \gamma_b \cdot d \cdot cos^2 i$, always)

- These relations between τ and $\bar{\sigma}$ can be plotted by dotted lines in the $\tau - \bar{\sigma}$ planes. (Fig. 3. (b))

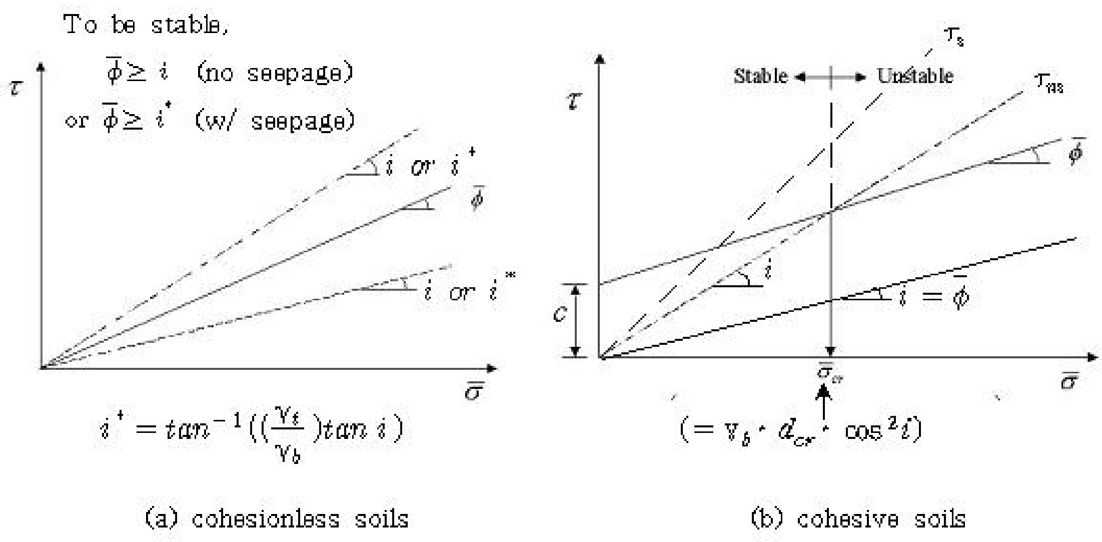


Fig. 3

- To maintain stabilities,

w/ no seepage : $\bar{c} + \bar{\sigma} \cdot \tan \bar{\Phi} \geq \bar{\sigma} \cdot \tan i$

w/ seepage : $\bar{c} + \bar{\sigma} \cdot \tan \bar{\Phi} \geq \bar{\sigma} \cdot \frac{\gamma_t}{\gamma_b} \cdot \tan i$

- Substitute the expression of $\bar{\sigma}$ and arrange for the depths of soil cover, d.

w/ no seepage : $d_{cr} \leq \frac{\bar{c}}{\gamma_b} \cdot \frac{1}{\cos^2 i\,(\tan i - \tan \bar{\Phi})}$

w/ seepage : $d_{cr} \leq \frac{\bar{c}}{\gamma_t} \cdot \frac{1}{\cos^2 i\,(\tan i - (\frac{\gamma_b}{\gamma_t}) \tan \bar{\Phi})}$

○ Factor of Safety

$$FS = \frac{\text{shear strength along the shearing (sliding) surface}}{\text{shear stress mobilized under the equilibrium}}$$

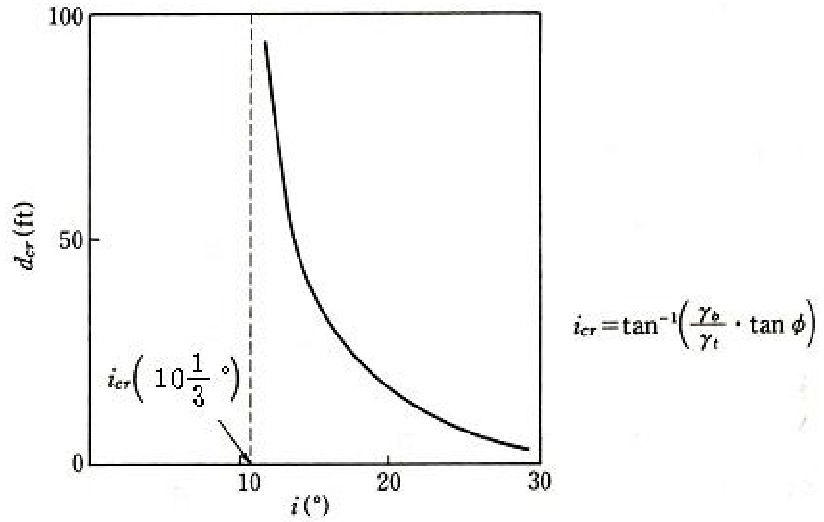
예제 8.2 다음과 같은 강도정수와 단위중량을 갖는 점성토 지반에 투수가 사면과 평행하게 일어날 때 안정을 유지할 수 있는 토층의 두께를 사면 기울기 i의 함수로 나타내고, 이 토층의 한계두께와 사면의 기울기 i의 관계를 그래프로 도시하라. 단, $c=100$ psf, $\phi=20°$, $\gamma_t=124.8$ pcf 이다.

풀이 식 (8-16)으로부터

$$\underset{(d_{cr}=)}{d} \le \frac{c}{\gamma_t} \cdot \frac{1}{\cos^2 i[\tan i-(\gamma_b/\gamma_t)\tan\phi]}$$

$$=\frac{100}{124.8}\frac{1}{\cos^2 i[\tan i-(62.4/124.8)\tan 20°]}$$

$$\fallingdotseq 0.8\cdot\frac{1}{\cos^2 i[\tan i-0.812]}$$



(그림 예 8.2)