Lateral Earth Pressures & Retaining Structures

• Rankine’s Theory
  – Vertical, Frictionless Wall
• Coulomb’s Theory
  – Inclined Wall with Friction

Retaining Structures

• Cantilever Walls
• Mechanically Stabilized Earth (MSE)
• Penetration Walls
• Gravity Walls

Retaining Wall Design

• Earth Pressures
• Groundwater Effects
• Surcharge Loadings
• Overall Stability Concerns
  – Overturning
  – Sliding
  – Bearing Capacity
Lateral Earth Pressure Theory

At-Rest Earth Pressure Distribution

Groundwater Effects

Figure 11.2

Figure 11.3
Soil Wedges at Failure

Fig 11.6

Rankine’s Active Earth Pressure Theory (Fig 11.4)

$K_a = \tan^2(45 - \phi'/2)$

Rankine’s Passive Earth Pressure Theory (Fig 11.5)

$K_p = \tan^2(45 + \phi'/2)$
Retaining Wall Example

\[ \gamma = 16 \text{ kN/m}^3 \]
\[ \phi' = 36^\circ \]
\[ C' = 0 \]

\[ Ka = \tan^2(45 - 36/2) = 0.26 \]
\[ Pa = 0.5(16)(6^2)(0.26) = 74.9 \text{ kN/m} \]
\[ X = 6/3 = 2 \text{ m} \]
\[ Mo = 74.9(2) = 149.8 \text{ kN-m/m} \]

Active & Passive Soil Forces

\[ P_a = 0.5 \gamma H^2 K_a \]

Surcharge Effects

\[ P_{a1} = qK_a H; X_1 = H/2 \]
\[ P_{a2} = 0.5 \gamma H^2 K_a; X_2 = H/3 \]
\[ Pa = P_{a1} + P_{a2} \]
\[ X = (P_{a1}X_1 + P_{a2}X_2) / Pa \]
Sloping Backfill

\[ P_a = 0.5 \gamma H^2 K_a \]
\[ K_a = f_n (\phi', \alpha, c') \]
See Tables 11.2, 11.3, 11.4

Retaining Walls with Friction
Coulomb’s Theory

\[ K_a = f_n (\phi', \delta', \alpha, \theta) \]
See Tables 11.5, 11.6, 11.7

Stability Checks (Ch 13)

✓ Overturning About Toe
  \[ FS_O = \Sigma M_R / \Sigma M_O \]

✓ Sliding Along Base
  \[ FS_{SL} = \Sigma F_R / \Sigma F_D \]

✓ Bearing Capacity
  \[ FS_{BC} = q_s / q_{max} \]
Stability Checks

\[ \Sigma M_B = P_a \frac{H}{3} \]

\[ \Sigma F_H = P_a \]

\[ \Sigma M_R = \Sigma (V_i x_i) + P_a D_f/3 \]

\[ \Sigma F_R = \Sigma V \tan \delta + B k_c + P_p \]
Example Problem

\[ K_p = \tan^2(45 - \frac{\phi}{2}) = \tan^2(30) = 0.333 \]

\[ P_p = 0.5 (18 \text{ kN/m}^3) (6.7 \text{ m})^2 (0.333) = 134.67 \text{ kN/m} \]

\[ M_{03} = 134.67 \text{ kN/m (6.7/3 m)} = 300.76 \text{ kN-m/m} \]
\[ K_p = \tan^2(45 + \phi/2) = \tan^2(60) = 3 \{1/\text{Ka}\} \]

\[ P_p = 0.5 \times (18 \text{ kN/m}^3) \times (2 \text{ m})^2 \times (3) = 108 \text{ kN/m} \]

\[ \Sigma F_R = \Sigma V \tan \delta + B_k c_k + P_p = 443.2 \tan(16) + 3.9 \times 0.67 \times 40 + 108 = 339.6 \text{ kN/m} \]

\[ \Sigma M_R = 942.2 + P_p \times (D_f/3) = 942.2 + 108 \times (2/3) = 1014.2 \text{ kN-m/m} \]

### Stability Checks

\[ F_{SSL} = \frac{\Sigma F_R}{\Sigma F_D} = \frac{339.6}{134.67} = 2.52 \quad > \quad 1.5 \quad \text{OK} \]

\[ F_{SO} = \frac{\Sigma M_R}{\Sigma M_D} = \frac{1014.2}{300.76} = 3.37 \quad > \quad 2 \quad \text{OK} \]

**Without Pp and Soil Block 4**

\[ F_{SSL} = \frac{\Sigma F_R}{\Sigma F_D} = \frac{226.9}{134.67} = 1.68 \quad > \quad 1.5 \quad \text{OK} \]

\[ F_{SO} = \frac{\Sigma M_R}{\Sigma M_D} = \frac{936.47}{300.76} = 3.11 \quad > \quad 2 \quad \text{OK} \]

### Bearing Capacity Check

\[ FS = \frac{q_{u}}{q_{max}} \]
Anchored Penetration Walls
Free-Earth Support

Dredge Line

F
Pa
Pp