Prof. J. N. Mandal

Department of civil engineering, IIT Bombay, Powai, Mumbai 400076, India.
Tel. 022-25767328
email: cejnm@civil.iitb.ac.in

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
Module - 6
LECTURE - 33
Geosynthetics for reinforced soil retaining walls
Recap of previous lecture.....

- Excel program for mechanically stabilized reinforced soil retaining wall

- Geotextile or geogrid wrap-around-faced mechanically stabilized earth (MSE) walls
  - General
  - Wrap-around face construction details
  - Design of geotextile wrap-around-faced wall (partly covered)
### Detailed calculations:

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<th>Spacing S_v (m)</th>
<th>( L_e ) (m)</th>
<th>( L_{emin} ) (m)</th>
<th>( L_R ) (m)</th>
<th>( L ) (m)</th>
<th>( L_{obtained} ) (m)</th>
<th>( L_o ) (m)</th>
<th>( L_o(min) ) (m)</th>
<th>( L_{total} ) (m)</th>
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Final arrangement of reinforcements

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External Stability

Step 1: Stability against Sliding

Earth pressure behind the wall due to existing backfill, $P_a = 0.5 K_a \gamma_b H^2$

$K_a = \frac{1 - \sin \phi_b}{1 + \sin \phi_b}$

$K_a = \frac{1 - \sin 35^\circ}{1 + \sin 35^\circ} = 0.271$

$\gamma_b = 17 \text{ KN/m}^3 \text{ (given)}$

$H = 5 \text{ m (given)}$

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\[ P_a = 0.5 \times 0.271 \times 17 \times 5^2 = 57.59 \text{ kPa} \]

Vertical component of earth pressure
\( (P_{av}) = 57.59 \sin 35^\circ = 33.030 \text{ kN/m} \)

Horizontal component of earth pressure
\( (P_{ah}) = 57.59 \cos 35^\circ = 47.171 \text{ kN/m} \)

Weight of the reinforced soil body \( (W) \)
\[
= (W_3 + W_2 + W_1) \\
= (6 \times 0.3 \times 2 + 4 \times 0.45 \times 3 + 2 \times 0.7 \times 4) \times 17 \\
= 248.200 \text{ kN/m}
\]
Driving force due to backfill soil = $P_{ah}$

Driving force due to surcharge = $q \times K_a \times H$

**Total Driving Force ($F_D$)**

$$= P_{ah} + q \times K_a \times H$$
$$= (47.171 + 15 \times 0.271 \times 5) \text{ kN/m}$$
$$= 47.171 + 20.325 = 67.496 \text{ kN/m}$$

**Total Resisting Force ($F_R$)**

$$= c_a L_{bottom} + (W + P_{av}) \tan \delta_f$$
$$= 17.6 \times 2 + (248.2 + 33.03) \times \tan 14.25^\circ$$
$$= 106.632 \text{ kN/m}$$

$$F_{sliding} = \frac{F_R}{F_D} = \frac{106.632}{67.496} = 1.58 > 1.5 \quad (\text{OK})$$

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Step 2: Overturning Stability

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Overturning moment due to backfill
\[ = P_{ah} \times \frac{H}{3} \]
\[ = 47.171 \times 5/3 = 78.618 \text{ (KN-m)/m} \]

Overturning moment due to surcharge loading
\[ = K_a \times q \times H \times \frac{H}{2} \]
\[ = 0.271 \times 15 \times 5 \times 5/2 \]
\[ = 50.8125 \text{ (kN-m)/m} \]

Total overturning moment (Mov)
\[ = 78.618 + 50.8125 \]
\[ = 129.43 \text{ (kN-m)/m} \]
Resisting moment due to weight of reinforced soil

\[ W \cdot x = W_3 x_3 + W_2 x_2 + W_1 x_1 \]

\( X = \) distance of point of application of the weight of reinforced zone from the toe of wall

\[ x_3 = \frac{2}{2} = 1 \text{ m} \]
\[ W_3 = 17 \times 1.8 \times 2 = 61.2 \text{ kN/m} \]

\[ x_2 = \frac{3}{2} = 1.5 \text{ m} \]
\[ W_2 = 17 \times 1.8 \times 3 = 91.8 \text{ kN/m} \]

\[ x_1 = \frac{4}{2} = 2 \text{ m} \]
\[ W_1 = 17 \times 1.4 \times 4 = 95.2 \text{ kN/m} \]
Hence, Resisting moment due to weight of reinforced soil
= \(W_3x_3 + W_2x_2 + W_1x_1\)
= \(61.2 \times 1 + 91.8 \times 1.5 + 95.2 \times 2\)
= 389.3 kN-m/m

Resisting Moment due to Earth Pressure
= \(P_{av} \times L\)
= 33.03 \times 4
= 132.12 (kN-m)/m

Total resisting moment (\(M_r\))
= 389.3 + 132.12
= 521.42 (kN-m)/m

\[FS_{overturning} = \frac{M_r}{M_{ov}} = \frac{521.42}{129.43} = 4.03 > 2.5\] (OK)
Step 3: Check for bearing capacity

Ultimate bearing capacity of the foundation soil ($P_{ult}$)

$$P_{ult} = c_f N_c + 0.5 \gamma_f L_{bottom} N_\gamma$$

$$= 22 \times 12.9 + 0.5 \times 18 \times 2 \times 2.5$$

$$= 328.8 \text{ kN/m}^2$$

For angle of internal friction ($\phi_f$) = 15°

$N_c = 12.9$, $N_q = 4.4$, $N_\gamma = 2.5$ (Bowles, 1982)

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Total vertical pressure over the foundation soil,
\[ q_{\text{act}} = \gamma_r \times H + q = 17 \times 5 + 15 = 100 \text{ kN/m}^2 \]

FS_{\text{bearing capacity}} = \frac{q_{\text{ult}}}{q_{\text{act}}} = \frac{328.8}{100} = 3.288 > 2 \quad \text{(OK)}
Geotextile Wrap-around wall with growing vegetation
(Photograph by J.N.Mandal)

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Welded steel wire mesh facing with geogrid-geotextile wrapping and vegetated erosion control

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Part – III

Gabion walls and Geocell walls

- General
- Gravity gabion wall design
- Reinforced soil gabion wall design
- Feasibility Study on Fly Ash as a Backfill Material
- Geocell walls

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Gabions are made of galvanized mild steel or welded corrosion resistance hexagonal wire mesh in the form of cube or rectangle.

Gabion boxes or baskets are filled with round rocks or rubble or quarried stones. It is highly permeable.

The stones must be insoluble, hard, weather resistant, nonfriable and of higher specific gravity.

The mild steel should be coated with polyvinyl chloride (PVC) to prevent corrosion of the steel.

Gabion can be used for retaining walls and erosion control.
Geosynthetics Engineering: In Theory and Practice

Gabions

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Individual gabion baskets are tied together with the help of strong spiral binders or wires to form the retaining walls.

The buckets are placed in multiple layers until it achieved the desired height. The layers can be placed to form a battered face or vertical stepped wall.

Gabion wall can be designed as simple gravity retaining wall or as reinforced soil gabion wall.

In case of reinforced soil gabion wall, the flat welded wire mesh layers will act as soil reinforcement layers or tie backs for the gabion wall.

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The design of gabion wall is conservative. The following assumptions are made.

- The passive thrust acting at the toe of the wall is not taken into account for stability analysis.

- When the gabion wall is designed as gravity retaining wall, its own weight resists the lateral earth pressure.

- The Coulomb’s method is used to determine the active thrust coefficient.
Geosynthetics Engineering: In Theory and Practice

Vertical gravity wall

Inclined stepped back face

Inclined stepped front face

Gravity gabion retaining wall

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\( W = \) weight of the wedge
\( W_g = \) weight of the gabion

\( R = \) resultant of the normal force and shearing resistance force at the failure surface (AC) and acts at an angle ‘\( \phi \)’ to the normal force

\( \phi = \) angle of internal friction of soil
\( i = \) backfill surface (BC) inclination with the horizontal
\( \alpha = \) acute angle of back face slope of the wall with vertical
\( \delta = \) angle of wall friction,
\( P_a = \) active earth pressure force per unit length of the wall
Reinforced soil gabion wall

\[ H_g = \text{height of wall} \]
\[ \alpha = \text{wall inclination with vertical} \]
\[ L_e = \text{embedded length of the metallic strips} \]
\[ S_v = \text{vertical spacing of the metallic strips} \]
\[ t_g = \text{thickness of gabion facing} \]
\[ L = \text{width of the wall} \]
DESIGN OF GRAVITY GABION WALL

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Wall height = H, Surcharge = q
Backfill slope angle = i
Angle of friction between wall and soil = δ
Wall inclination with vertical = α
Soil friction angle = ϕ
Soil density = γ_s
Gabion fill density = γ_g
Soil bearing pressure = q_{allowable}
Scale correction factor = C_i
Maximum total base width (L) = 0.7 H
a, b, c, d, e = width of gabions in steps
**Design steps:**

**Step 1:** Calculation of total earth pressure and its point of application

The active earth pressure co-efficient = $K_a$

According to Coulombs’ derivation,

$$K_a = \frac{\cos^2 (\phi - \alpha)}{\cos^2 \alpha \cos(\delta + \alpha) \left[ 1 + \frac{\sin(\phi + \delta) \sin(\phi - i)}{\cos(\delta + \alpha) \cos(i - \alpha)} \right]^2}$$

- $i$ = Backfill slope angle
- $\delta$ = Angle of friction between wall and soil
- $\alpha$ = Wall inclination with vertical
- $\phi$ = Soil friction angle

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Total active thrust on the wall ($P_a$) = $K_a (\gamma_s H^2/2 + qH)$

$H$ = wall height along the inclination of the wall

- Considering the wall friction ($\delta$) = 0, the active earth pressure force acts normal to the slope of the back face at a vertical distance of $H_v/3$ above the backfill base.

- When surcharge is there and wall is inclined at an angle $\alpha$, the vertical distance of the point of application of the resultant normal force ($P_a$) from toe = $h_y$

\[
H_v = \text{Vertical depth of the backfill} = H \cos \alpha
\]

\[
h_y = \frac{H_v}{3} \times \left( \frac{H_v + \frac{3q}{\gamma_s}}{H_v + \frac{2q}{\gamma_s}} \right) - L \sin \alpha
\]

$\alpha$ = Wall inclination with vertical

$\gamma_s$ = Soil density

Maximum base width ($L$) = 0.7 $H$
Please let us hear from you

Any question?

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THANKS FOR LISTENING