GEOSYNTHETICS ENGINEERING: IN THEORY AND PRACTICE

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Module - 6
LECTURE - 32
Geosynthetics for reinforced soil retaining walls
Recap of previous lecture…..

- Example: Horizontal stress on retaining wall due to wheel load

- Excel program for Mechanically Stabilized Reinforced Soil Retaining Wall (Partially completed)
Geogrid reinforced earth wall, Durgapur (Photograph by J. N. Mandal)

Segmental precast concrete panels reinforced soil walls

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Geogrid reinforced earth wall near Ghansoli, Navi Mumbai
(Photograph courtesy of Mrs. B.S.Asha)

Segmental precast concrete panels reinforced soil walls

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Modular concrete block wall

Compliments Larsen & Toubro Ltd

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Modular block wall near Kanjurmarg, Mumbai
(Photograph courtesy of Mrs. B. S. Asha)

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Geogrid reinforced soil panel wall in Jaipur
(Photograph by J.N. Mandal)

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After Fumio Tatsuoka, Japan

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PART II

Geotextile or geogrid wrap-around-faced mechanically stabilized earth (MSE) walls

- General
- Design of geotextile wrap-around-faced wall
  - Internal stability
  - External Stability
- Wraparound face construction details

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The wrap-around facing wall is less expensive than any concrete facing blocks or panels.

Assumptions:

- The classical Rankine earth pressure distribution is used. The geosynthetic extends beyond an assumed Rankine failure surface/plane.

- As the design is conservative, Rankine’s active earth pressure coefficient \((K_a)\) is used.

- The classical Coulomb active earth pressure coefficient is less conservative.

- Boussinesq elastic theory is used for the live load.
Geosynthetic wrap around faced reinforced soil wall

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Physical properties of wall:
H = Height of the geotextile wall
L = length of geotextile

Properties of reinforced soil zone and backfill soil zone:
γ = unit weight of backfill or reinforced soil
ϕ = friction angle of backfill or reinforced soil, and
c = cohesion of backfill soil

Properties of foundation soil:
γ_f = unit weight of foundation soil,
ϕ_f = friction angle of foundation soil, and
c_f = cohesion of foundation soil.

Loading:
q = uniform surcharge load, and
P = Live load
Locus of maximum tensile force line and assumed failure plane

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Earth pressure distribution along a geosynthetic wrap around faced reinforced soil wall

- The internal and external stability of the wall should be checked properly

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### Internal stability:

- **Ultimate limit state:**
  - Tension failure
  - Pullout or anchor failure (Factor of safety ≥ 1.5)
- **Serviceability limit state:** Wall face deformation

### External stability:

- **Ultimate limit state:**
  - Sliding on the base (Factor of safety ≥ 1.5)
  - Overturning (Factor of safety ≥ 2.0)
  - Tilting/ bearing capacity of foundation (Factor of safety ≥ 2.5)
  - Global slip / deep seated stability failure (Factor of safety ≥ 1.3)
  - Seismic stability (Factor of safety ≥ 1.1)
- **Serviceability limit state:** Settlement
WRAP-AROUND FACE CONSTRUCTION DETAILS
(After Steward and Mohney, 1982)

- Remove all unsuitable materials from the site and compact in situ to achieve the desired foundation soil. No concrete foundation is needed for this structure.

- Place the geosynthetic and unroll it over the selected foundation soil using a temporary wooden face form.

  - ‘L’ shaped wooden form placed along the length of the wall.
  - Geotextile of around 1.0 m hangs beyond the form.

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Place the backfill material up to 200 mm to 400 mm and compact it with a light weight hand operated vibratory compactor.

The geosynthetic is folded back over the backfill material. The minimum return length should be about 1.0 m in order to satisfy the stability of adequate pullout resistance.

The wooden face form is removed from the front wall and placed over the completed layer. Same procedure continues until it reaches the desired height of the wall.

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In general if the height of the wall is more than 2.0 m, it is necessary to provide scaffolding in front of the wall.

The wraparound facing cannot be kept open in the sunlight due to UV radiation. Therefore, it should be covered by spraying bitumen emulsion, concrete mortar or shotcrete of thickness 150 mm-200 mm.

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In case of geogrids, a geotextile is needed to retain the backfill material in front of the wall.
Example:
Design a geotextile wrap around soil retaining wall of 5 m height.

Soil Properties of Reinforcing Zone:
Unit weight of reinforced soil, $\gamma_r = 17$ kN/cum
Cohesion of reinforced soil, $c_r = 0$ kN/sqm
Angle of Internal friction of Reinforced soil, $\phi_r = 35^\circ$
Angle of friction between soil and reinforcement, $\delta = 25^\circ$
Ultimate Tensile Strength of Geotextile, $T_{ult} = 60$ kN/m
Factor of Safety = 1.6
Properties of existing backfill:
Unit weight of existing backfill, $\gamma_b = 17$ kN/cum
Cohesion of existing backfill, $c_b = 0$
Angle of Internal friction, $\phi_b = \delta = 35^\circ$

Properties of foundation soil:
Unit weight of foundation soil, $\gamma_f = 18$ kN/cum
Cohesion of foundation soil, $c_f = 22$ kN/sqm
Adhesion between soil and reinforcement, $C_a = 0.8c_f = 17.6$ kPa
Angle of Internal friction, $\phi_f = 15^\circ$
Angle of friction between soil and reinforcement, $\delta_f = 0.95\phi_f = 14.25^\circ$
Wrapped Retaining wall

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Solution:

- **Internal Stability**

**Step 1:** Calculate the total horizontal stress behind the given retaining wall

\[
\sigma_{hs} = \text{horizontal earth pressure due to backfill} = K_a \gamma_b \cdot z,
\]

\[
\sigma_q = \text{Horizontal earth pressure due to surcharge} = K_a \cdot q,
\]

\[
\sigma_h = \text{Total horizontal stress behind the retaining wall} = \sigma_{hs} + \sigma_q
\]
At a depth ‘z’ below the wall top,

\[ \sigma_h = \sigma_{hs} + \sigma_q = K_a \gamma_b z + K_a q \]

\( K_a = \) Coefficient of active earth pressure of backfill,
\( \gamma_b = \) Unit weight of existing backfill, \( = 17 \text{ kN/ m}^3 \)
\( q = \) surcharge over the wall top \( = 15 \text{ kPa} \)

\[ K_a = \frac{1 - \sin \phi_b}{1 + \sin \phi_b} \]

\( \phi_b = \) Angle of internal friction of backfill soil \( = 35^\circ \)

Calculating,

\[ \sigma_h = 4.61Z + 4.065 \]
Step 2: Calculate the allowable tensile strength ($T_{allow}$)

$$T_{allow} = \frac{T_{ult}}{RF}$$

RF = Cumulative Reduction factor = 4.68 (considering creep, installation damage, chemical and biological clogging)

$$T_{ult} = 60 \text{ KN/m (given)}$$

$$T_{allow} = \frac{60}{4.68} = 12.821 \text{ kN/m}$$
Step 3: Spacing of reinforcement ($S_v$) and No. of layers

$$S_v = \frac{T_{\text{allow}}}{(\sigma_h \times \text{Factor of safety})}$$

$S_v$ = Spacing between the reinforcement layers

Factor of safety = 1.6

$T_{\text{allow}} = 12.821 \text{ kN/m} \text{ (previously calculated)}$

$\sigma_h = 4.61Z + 4.065 \text{ (previously calculated)}$

Therefore, $S_v = \frac{12.821}{(4.61Z+4.065) \times 1.6}$
\[ S_v = \frac{12.821}{(4.61z+4.065) \times 1.6} \]

<table>
<thead>
<tr>
<th>Z from top (m)</th>
<th>( S_v ) (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 m</td>
<td>0.3 m</td>
</tr>
<tr>
<td>3 m</td>
<td>0.45 m</td>
</tr>
<tr>
<td>1.5 m</td>
<td>0.70 m</td>
</tr>
</tbody>
</table>

Top two layers taken as \((2 \times 0.7) = 1.4\) m

Provided spacing from bottom and Number of layers

<table>
<thead>
<tr>
<th>Layers (form bottom)</th>
<th>Spacing (m)</th>
<th>Remaining height (m)</th>
<th>Total layers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Six</td>
<td>0.3</td>
<td>( 5 - (6 \times 0.3) = 3.2 ) m</td>
<td>12</td>
</tr>
<tr>
<td>Four</td>
<td>0.45</td>
<td>( 3.2 - (4 \times 0.45) = 1.4 ) m</td>
<td></td>
</tr>
<tr>
<td>Two</td>
<td>0.7</td>
<td>( 1.4 - (2 \times 0.7 ) = 0 )</td>
<td></td>
</tr>
</tbody>
</table>
Step 4: Length of Reinforcement

\[ L_e = \text{Embedment length} \]

\[ L = L_e + L_R \]

\[ L_e = \frac{(S_v \sigma_h \text{FS})}{{2(\gamma_r z \tan \delta_r + c_a)}} \]

\[ S_v = \frac{T_{allow}}{(\sigma_h \times \text{Factor of safety})} \]

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Hence, \( L_e = \frac{T_{\text{allow}}}{\{2(\gamma_r z \tan \delta_r)\}} \) \hspace{1cm} (c_a = 0)

\( T_{\text{allow}} = 12.821 \text{ kN/m (previously calculated)} \)

\( \gamma_r = \text{unit weight of reinforced soil} = 17 \text{ kN/cum} \)
\( \delta_r = 25^\circ, \)
\( \tan \delta_r = \tan 25^\circ = 0.4663 \)

Therefore, \( L_e = \frac{12.821}{(2(17\times z\times 0.4663))} = 0.81/ z \)
\( L_R = \) length of geotextile in front of the failure line up to the facing

\[ L_R = (H-z) \tan (45 - \phi/2) \]

\( H = \) Height of the retaining wall = 5 meter (given),
\( z = \) Depth from top,
\( \phi = \) Angle of Internal friction of soil = 35° (given),

\[ L_R = (5-z) \tan (45^\circ - 35^\circ/2) = (2.60 - 0.52 z) \]

\( L = L_e + L_R \)

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Now assume $L_o$ as overlap length generally provided one half of the embedded length

Therefore,

$$L_o = \frac{1}{2} L_e = S_v \cdot \sigma_h \cdot \frac{FS}{(4 \gamma_z \tan \delta)}$$

$$L_e = 0.81/z \text{ (previously calculated)}$$

Hence, $L_o = (0.81/z)/2 = 0.405/Z$

Total Length ($L_{total}$) = $L + S_v + L_o$

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Please let us hear from you

Any question?
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THANKS FOR LISTENING