Contribution of Suction in the Stability of Reinforced Retaining Walls

Presented by
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Objectives

To evaluate the contribution of cohesion (derived from soil’s mineralogy and suction) on the stress transferred to the reinforcing element using three different methods (A, B and C).

Scope of works

Analyses were carried out on a typical reinforced soil retaining wall (3.6 m high, sloping at 70° to horizontal, and reinforced by six geotextile layers). The reinforced backfill was cohesive soil with total cohesion of 15 kPa. A parametric study was performed for a range of suctions from 10 to 50 kPa with intervals of 10 kPa.
Case studied

Surcharge = 10 kPa

Geosynthetic Reinforcement
- $T_u = 20$ kN/m
- $E @ e_{10\%} = 118$ kN/m
- $A = 5 \times 10^{-4}$ m$^2$

Compacted soil
- $c' = 15$ kPa ; $\phi' = 30^\circ$ ; $\gamma_b = 20.5$ kN/m$^3$

Foundation soil
- $c' = 5$ kPa ; $\phi' = 28^\circ$ ; $\gamma_b = 17.5$ kN/m$^3$

$H = 3.6$ m

$B = 2.6$ m

Ref: Gofar, 1994
Components of Reinforced soil wall for case study

<table>
<thead>
<tr>
<th>Components</th>
<th>Material</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backfill soil</td>
<td>Compacted in-situ soil</td>
<td>(c' = 15 \text{kPa} ); (\phi' = 30^\circ); (\gamma = 20.5 \text{kN/m}^3)</td>
</tr>
<tr>
<td>Reinforcement</td>
<td>Geotextiles</td>
<td>(T_u = 20 \text{kN/m} ); (E \text{ at } \varepsilon=10% = 118 \text{kN/m} ); (A = 5 \times 10^{-4} \text{m}^2)</td>
</tr>
<tr>
<td>Facing Element</td>
<td>Geotextiles</td>
<td>Wrap around face</td>
</tr>
<tr>
<td>Foundation soil</td>
<td>Cohesive</td>
<td>(c' = 5 \text{kPa} ); (\phi' = 28^\circ); (\gamma = 17.5 \text{kN/m}^3)</td>
</tr>
</tbody>
</table>
## Methods considered in the study

<table>
<thead>
<tr>
<th>Method</th>
<th>Reference</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>AASHTO (2009), FHWA (2009)</td>
<td>Consider suction by adopting Rankine’s/Coulomb’s lateral pressure distribution on retaining walls</td>
</tr>
</tbody>
</table>

## Assumptions involved

- **Direction of reinforcement force**
- **Failure plane**
Results: Baseline case; $c = 0$

External stability

FoS sliding = 2.20;
FoS overturning = 9.72;
FoS bearing capacity = 7.16
Results: Baseline case; $c = 0$
Tensile/Pull-force in each reinforcing element calculated using Methods A, B, and C

![Graph showing pullout force vs. depth of layer for baseline study with $c = 0$. The graph includes data points for Methods A, B, and C, with line styles and markers indicating each method.]
Suction values and total cohesion

<table>
<thead>
<tr>
<th>Suction (ψ) (kPa)</th>
<th>Total cohesion $c = c' + \psi \tan \phi^b$ (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>10</td>
<td>18.6</td>
</tr>
<tr>
<td>20</td>
<td>22.3</td>
</tr>
<tr>
<td>30</td>
<td>25.8</td>
</tr>
<tr>
<td>40</td>
<td>29.6</td>
</tr>
<tr>
<td>50</td>
<td>33.2</td>
</tr>
</tbody>
</table>

Effect of suction

**Method B**

\[ \sigma'_v K_a - 2c \sqrt{K_a} \]

**Method C**

\[ \Phi_c = e^{\lambda c / \gamma H} \]

where $0 \geq \Phi_c \geq 1$
Effect of suction on the Normalized Tensile / Pull- force in each reinforcing element calculated using Methods A, B, and C
Effect of suction on the internal stability of reinforced soil retaining wall

![Graph showing the effect of suction on the internal stability of reinforced soil retaining wall. The graph plots Factor of Safety against Effective cohesion (kPa) and Suction (kPa). The trend line indicates an increase in Factor of Safety with increasing suction.]
Conclusions

1. The presence of suction decreases the maximum force resisted by the reinforcing element. However, methods A, B, and C showed different degrees of influence of suction on the stress transferred to the reinforcing element.
2. The contribution of cohesion on the current design guidelines by adopting Rankine’s horizontal pressure distribution in the retaining wall for active condition provides a more reasonable effect as compared to the simplified stiffness method. Therefore, the contribution of suction as part of cohesion existing in the cohesive backfill could be considered for the stability analysis of reinforced soil retaining walls using the available design guidelines.
3. There is an increase in the local stability of the reinforced soil retaining wall due to suction. However, in order to preserve the contribution of the suction in the stability of the wall, the compacted backfill soil should be maintained by protecting the wall from rainfall infiltration, rise of the ground water table and seepage from the back of the reinforced zone.
Thank you

Terimakasih