UPL and HYD in EC7

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UPL and HYD

• UPL
  • Uplift
  • Buoyancy problems
  • Generally static water

• HYD
  • Hydraulic heave
  • Disturbance of the soil caused by upward seepage of water
  • Internal erosion
Fundamental limit state requirement

\[ E_d \leq R_d \]

\[ E\{ F_d ; X_d ; a_d \} = E_d \leq R_d = R\{ F_d ; X_d ; a_d \} \]

\[ E\{ \gamma_F \, F_{\text{rep}} ; X_k / \gamma_M ; a_d \} = E_d \leq R_d = R\{ \gamma_F \, F_{\text{rep}} ; X_k / \gamma_M ; a_d \} \]

or \[ E\{ \gamma_F \, F_{\text{rep}} ; X_k / \gamma_M ; a_d \} = E_d \leq R_d = R_k / \gamma_R = R_n \phi_R \text{ (LRFD)} \]

or \[ \gamma_E \, E_k = E_d \leq R_d = R_k / \gamma_R \]

so in total

\[ \gamma_E \, E\{ \gamma_F \, F_{\text{rep}} ; X_k / \gamma_M ; a_d \} = E_d \leq R_d = R\{ \gamma_F \, F_{\text{rep}} ; X_k / \gamma_M ; a_d \} / \gamma_R \]

E = action effects

F = actions (loads)

R = resistance (=capacity)

X = material properties

a = dimensions/geometry

d = design (= factored)

k = characteristic (= unfactored)

rep = representative

ARUP
Existing EC7 – Uplift (UPL)

\[ \gamma_{dst} U_k \leq \gamma_{stb} G_k \]
Problems with factoring water pressure

- Leads to impossible situations
- Not good with frictional materials

HYD – Equation 2.9

\[ u_{dst;d} \leq \sigma_{stb;d} \quad (2.9a) \]  – total stress (at the bottom of the column)

\[ S_{dst;d} \leq G'_{stb;d} \quad (2.9b)'' \]  – effective weight (within the column)

Apply \( \gamma_{G;dst} = 1.35 \) to:

<table>
<thead>
<tr>
<th>Pore water pressure ( u_{dst;k} )</th>
<th>| Total stress ( \sigma_{stb;k} )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>H</strong> 2.78</td>
<td></td>
</tr>
</tbody>
</table>

Apply \( \gamma_{G;stb} = 0.9 \) to:

<table>
<thead>
<tr>
<th>Seepage force ( S_{dst;k} )</th>
<th>Buoyant weight ( G'_{stb;k} )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>H</strong> 6.84</td>
<td></td>
</tr>
</tbody>
</table>
Existing EC7 - Internal erosion

(6)P The critical hydraulic gradient for internal erosion shall be established taking into consideration at least the following aspects:

—— direction of flow;

—— grain size distribution and shape of grains;

—— stratification of the soil.

• No further advice or instruction.
• Nothing about safety margins needed.
Factors of safety for HYD


Das (1983) Fig 2.47
Essential to assess correct water pressures (permeabilities)

...then $F_T$ seems to be irrelevant

All other cases unstable!
The HYD problem – water seeping

- What are the real limit states – what are we afraid of?
- Wall stability may be a dominating issue and, but this is dealt with separately.
- We don’t want effective stress to fall to zero. $\sigma' \geq 0$
- In fact, we don’t want the design value of effective stress, calculated for a continuum, to get close to zero:
  - The real material is likely to be less continuous (possibly gap graded)
  - There are usually performance requirements: people need to walk or drive vehicles on the surface.
  - $\sigma' \geq ??$

$$\sigma'_d \geq \alpha \gamma'_d z \quad \text{or} \quad u_{e; d} = u_d - \gamma_w z \leq \gamma'_d z(1 - \alpha) + q_d$$

- $\alpha$ should be a material-dependent parameter (eg gap graded soils)
A possibility to combine UPL and HYD?

- Sometimes difficult to distinguish.
- Material-dependent parameter $\alpha$

$$\sigma_d' \geq \alpha \cdot \gamma_d'z$$

<table>
<thead>
<tr>
<th>Material Type</th>
<th>$\gamma$ kN/m$^3$</th>
<th>$\beta$</th>
<th>$\alpha$</th>
<th>$\gamma_{UPL}$</th>
<th>$F_T$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense sand (Germany)</td>
<td>20</td>
<td>2</td>
<td>0.18</td>
<td>1.10</td>
<td>1.4</td>
</tr>
<tr>
<td>Loose sand (Germany)</td>
<td>18</td>
<td>1.8</td>
<td>0.36</td>
<td>1.25</td>
<td>1.8</td>
</tr>
<tr>
<td>Silty, layered sand</td>
<td>18</td>
<td>1.8</td>
<td>0.54</td>
<td>1.43</td>
<td>2.5</td>
</tr>
<tr>
<td>Stiff clay (Germany)</td>
<td>20</td>
<td>2</td>
<td>0.175</td>
<td><strong>1.1</strong></td>
<td>1.39 *</td>
</tr>
<tr>
<td>NC clay (Germany)</td>
<td>16</td>
<td>1.6</td>
<td>0.15</td>
<td><strong>1.1</strong></td>
<td>1.35 *</td>
</tr>
<tr>
<td>Stiff clay (UK)</td>
<td>20</td>
<td>2</td>
<td>0.275</td>
<td><strong>1.2</strong></td>
<td>1.59</td>
</tr>
<tr>
<td>NC clay (UK)</td>
<td>16</td>
<td>1.6</td>
<td>0.225</td>
<td><strong>1.2</strong></td>
<td>1.48</td>
</tr>
</tbody>
</table>

Is this a good idea? Comments welcome.
Internal erosion – critical gradient or velocity

PT1: An equation should be proposed in order to check this criterion in terms of hydraulic gradient or seepage velocity:

\[ i_d < i_{c;d} \text{ or } v_d < v_{c;d}. \]

\[ i_{c;d} \text{ and } v_{c;d} \] are material-dependent parameters

• Which is the better form? PT2 chose hydraulic gradient.
• Might be worth considering which is the better constant as material grading varies unpredictably.
• Is critical gradient dependent on direction?
• How to derive its value?
  • International Levee Handbook?
  • Cross-over between geotechnics and dam design.
• How to give safety margins in practical cases?
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Thanks for your attention.