An experimental full-scale hydraulic earthen structure in lime-treated soil

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Objectives

- Proving the feasibility of the specific lime treatment and placement procedure at an industrial scale
- Correlating the laboratory observations on lime-treated soil properties at a real scale
- Evaluating the benefits of lime treatment compared to natural soil (mechanical and hydraulic behavior)
Experimental dike with lime-treated soil

Specific characteristics of the treated soil with 2.5% quicklime:

\[ \gamma_d = 17.3 \text{ kN/m}^3 \text{ at } w_{OMC} = 17.8 \% \]
Dike with natural untreated soil

Specific characteristics of the natural soil:

\( \gamma_d = 18.2 \, \text{kN/m}^3 \) at \( \text{WOMC} = 14.5 \% \)
Experimental dikes construction
Sept. 2011 – CER (Rouen / France)

Material preparation

Compaction

Lime-treated dike

Dikes in lime-treated and natural soil
Construction steps - Movie
Compaction control

- High homogeneity level of the lime-treated material
  - Water content
    - average = 19.4 % (OMC + 1.6 %)
    - st dev = 0.7 % (118 measurements)
  - Dry density (Variable-depth point gammadensitometer)
    - 96.7 % $\rho_d$ OMC
    - objective was $\geq$ 95 % $\rho_d$ OMC
    - Top layer : 98.5 % $\rho_d$ OMC
    - st dev = 1.1 % (42 measurements)

![Compaction level recalculated from volumic weight measurements (gamma probe)](image)
Measurements - 28 days & 6 months after construction

- Permeability

<table>
<thead>
<tr>
<th></th>
<th>Untreated</th>
<th>Lime-treated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>28 days</td>
</tr>
<tr>
<td><strong>In situ:</strong></td>
<td></td>
<td></td>
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<tr>
<td>Lefranc or Nasberg</td>
<td>3. $10^{-9}$ m/s</td>
<td>8. $10^{-10}$ m/s</td>
</tr>
<tr>
<td>(drilled holes)</td>
<td></td>
<td>1. $10^{-9}$ m/s</td>
</tr>
<tr>
<td><strong>On cored specimens</strong></td>
<td></td>
<td>10^{-9} to $10^{-8}$ m/s</td>
</tr>
<tr>
<td>Triaxial tests (CD)</td>
<td>1. $10^{-9}$ m/s</td>
<td>In progress</td>
</tr>
</tbody>
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Diagram: Humid silt for watertightness, lid, big diameter pipe (200 mm), head of the pipe (50 mm), perforated pipe.
Measurements - 28 days & 6 months after construction

- **Shear strength (triaxial tests)**

<table>
<thead>
<tr>
<th></th>
<th>Untreated</th>
<th>Lime-treated</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c$ (kPa)</td>
<td>0 kPa (conventional)</td>
<td>61 kPa (CD, 75 days)</td>
</tr>
<tr>
<td>$\phi$ (°)</td>
<td>35°</td>
<td>32° to 39°</td>
</tr>
</tbody>
</table>

- **In situ pressuremeter and dilatometer tests**

<table>
<thead>
<tr>
<th></th>
<th>Untreated</th>
<th>Lime-treated</th>
<th>Lime-treated</th>
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<tbody>
<tr>
<td></td>
<td>28 days</td>
<td>180 days</td>
<td></td>
</tr>
<tr>
<td><strong>Pressuremeter :</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Limit pressure</td>
<td>0.25 MPa</td>
<td>3.77 MPa</td>
<td>4.23 MPa</td>
</tr>
<tr>
<td>Modulus</td>
<td>1.57 MPa</td>
<td>37.8 MPa</td>
<td>52.70 MPa</td>
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<tr>
<td><strong>Dilatometer :</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deformation modulus (G)</td>
<td>-</td>
<td>-</td>
<td>50 to 90 MPa</td>
</tr>
<tr>
<td>Young Cyclic Modulus (E)</td>
<td>-</td>
<td>-</td>
<td>400 to 480 MPa</td>
</tr>
</tbody>
</table>
Measurements - 28 days & 6 months after construction

- Erosion test – Mobile Jets (in situ)

\[ M_{600, \text{lime-treated}} = \frac{M_{600, \text{untreated}}}{25} \]

\[ M_{2000, \text{lime-treated}} = \frac{M_{600, \text{untreated}}}{12.5} \]
Conclusion

- The results of the measurements on the experimental lime-treated dike in comparison with the natural dike show:
  - feasibility of producing the lime-treated soil with a high level of homogeneity
  - increase of mechanical performance parameters
  - preservation of the low hydraulic permeability level
  - increase of erosion resistance
Thank you for your attention