Lime Treatment of Soils
Hydraulic Earthworks Application

G. Herrier  Lhoist Group
C. Chevalier  Ifsttar
M. Froumentin  CER/CETE Normandy
O. Cuisinier  Laego – Nancy University
S. Bonelli  Irstea
J.-J. Fry  EdF
Friant-Kern Irrigation canal
- Built in 1946, 240 km long
- Canal discharge rate: 100 m$^3$/s
- Speed of 1.3 m/s
- 6.4 km of blankets treated with 4% lime between 1972 and 77
- Highly plastic clays: PI ~ 40

Mississippi dikes: « Alton to Gale » (350 km)
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**Immediate improvement of workability:**
Wet silty or clayey soils can be treated and used in embankments.

<table>
<thead>
<tr>
<th>Solid state</th>
<th>Plastic state</th>
<th>Liquid state</th>
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<tbody>
<tr>
<td>LP</td>
<td>PI</td>
<td>LL</td>
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**Water content**

**Natural soil**

**Lime treated soil**

**Action of lime: soil improvement by clay flocculation**

Untreated

Na\(^{+1}\) Saturated

Lime Treated

Ca\(^{+2}\) Saturated

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Well-known benefits of lime treatment

- Placement of materials: workability, bearing index
- Increase of cohesion and mechanical properties
- Reduction of swelling-shrinkage of clayey soils
- Displacement of shrinkage limit above OMC

State of the art in 2005

- Is lime treatment of soils relevant for earthfill hydraulic structures?
- **Negative approach**: “Density will decrease, therefore porosity and permeability will rise up??”
- Only a few data published
- Lhoist have launched a research program on treated soils permeability
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Kneading Compaction Procedure

Figure 14. Outil de pétrissage à 3 pieds.
Measurements of permeability coefficients (k)

Standard Proctor Compaction

Kneading Compaction

Water content (%)

k (m/s)

Untreated – no lime
2 % quicklime
3% quicklime

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Measurements of permeability coefficients (k)

Lime-treated soil show the minimal permeability level if:
- Compacted by kneading
- High moisture content

- Untreated – no lime
- 2% quicklime
- 3% quicklime
Why density and permeability are not correlated?

- **Voids size distribution in the soils**
  - Mercury Porosimetry at Laboratoire Central des Ponts et Chaussées (Nantes, France) (now IFSTTAR)
  - Untreated soil:
    - pores \(\sim 1\mu m\) and \(\sim 10\mu m\) (Proctor + OMC)
    - pores \(\sim 1\mu m\) (Proctor+ Humid or kneading + Humid)
  - With lime:
    - pores \(\sim 0.1\mu m\) / \(\sim 1\mu m\) / \(\sim 10\mu m\) (Kneading+OMC)
    - pores \(\sim 0.1\mu m\) / \(\sim 1\mu m\) (Kneading + Humid)
Additional Results: mechanical Stability

- **Triaxial tests on silts (IP = 11)**
  - Results from Univ. Libre Bruxelles / Cogestac project
  - Friction angle unchanged
  - Cohesion highly improved
Erosion resistance

 Trials at IRSTEA (ex-Cemagref) and IFSTTAR

\[ \varepsilon = K_d \cdot (\tau - \tau_c) \]

Amount of eroded soil = erosion rate x (water pressure – critical stress)
Internal erosion resistance

Internal erosion: results
Tests from IRSTEA (2011) – Clayey silt from the Rhône River, IP = 11

Erosion rate (cm/mn)

\[ \dot{\epsilon} = \frac{C_e}{\rho_{dry}} (\tau_b - \tau) \]

- Internal erosion: results
- Tests from IRSTEA (2011) – Clayey silt from the Rhône River, IP = 11

CaO 2% after 3 days

untreated

after 7 days

after 14 days
Dispersivity

Enhanced Crumb-test trials from IFSTTAR (2011)

- silt PI= 11 untreated (90d)

- silt treated with 2% lime (90d)
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Lime treatment of soils confers

- An enhanced workability (known from geotechnique)
- A permeability level close to initial permeability
  - If kneading compaction (sheepfoot rollers) and humid state of materials applied
- An improved mechanical stability
- An improved resistance against internal and external erosion
- A displacement of the shrinkage limit
- A good chemical stability
- A possible revegetalization

Jobs examples show the durability of this technique in hydraulic environment

- Friant-Kern Canal
- Other works: examination in progress
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Experimental dike in lime-treated soil
- Isabelle Charles, CER / CETE Normandy
- Friday August 31, 10h54, room C3

The 35-years old experience from Friant-Kern canal
- Gontran Herrier, Lhoist Group
- Friday August 31, 14h10, room Esquillan
Lime Treatment:
A new solution with new perspectives for silty to plastic soils in hydraulic earthworks

gontran.herrier@lhoist.com
daniel.puiatti@lhoist.com
didier.lesueur@lhoist.com

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