Bulletin Cemented Soil Dams
From Transport Infrastructure To Hydraulic Works

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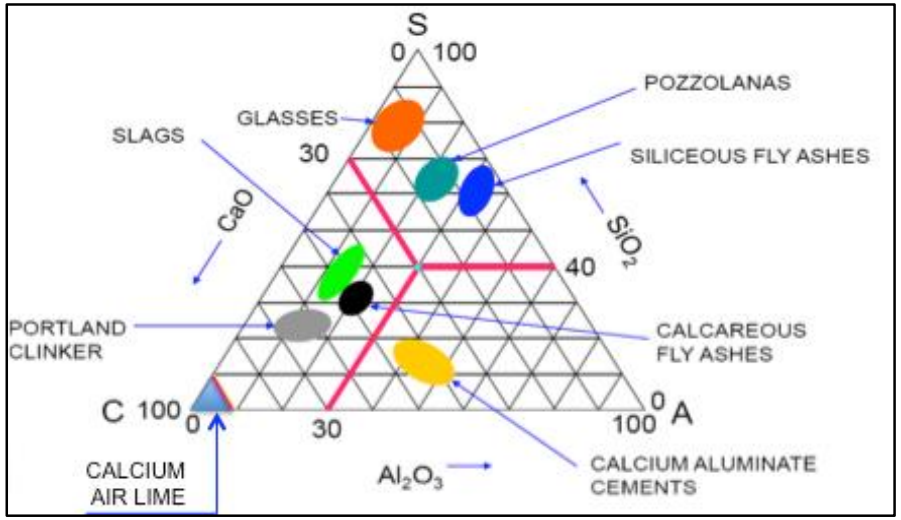
1. Soil treatment: a proven technic

- Last 60 years: dramatic increase in transport infrastructure
  - Motorways, airport, high speed lines, platforms, etc.
- Why?
  - Better use of the materials available on site,
  - Reduction of external borrowing and landfills,
  - Reduction of heavy trucks traffic,
  - Reduction of cost and duration of earthworks.

- How big?
  - European survey: 100 Mm^3 in 2012, equivalent to a 1000 km motorway (Paris – Berlin)
- Slow development in hydraulic works
  - Icold Bulletin 54: “Soil cement for embankment dams” (1986)
  - Some applications: cement as well as lime (often for correction of expansive or dispersive soils)

2. What cementitious materials?

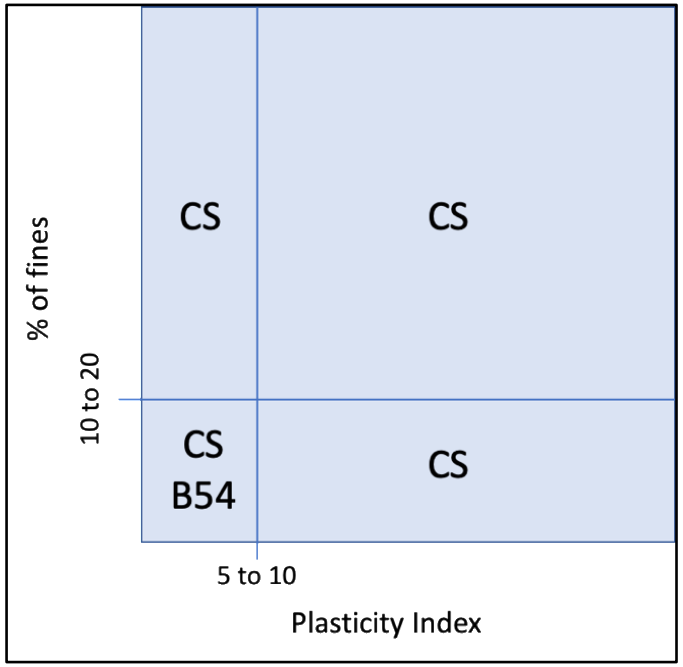
- Standardized binders:
  - Cement
  - Calcium air lime Lime (from calcium carbonate):
    - **Quicklime:** from limestone burning
      $CaCO_3$ + Heat ➔ **CaO** + CO_2
    - **Hydrated lime:** from quicklime hydration
      CaO + H_20 ➔ **$Ca(OH)_2$** + Heat



- Or a combination of two or several of the followings:
  - Cement, lime,
  - Fly ash and/or supplementary cementitious materials (e.g. slag)

3. What soils?

- Limits: depend on capacity of available technology and compatibility soil/binder(s)
  - Bulletin 54 (1986):
    - D_{max} less than 40 mm
    - % fines preferably below 10 to 20%
    - PI preferably below 5 to 10
    - Limited content of organic matters, SO_3
  - CSD Bulletin (2022):
    - D_{max} up to 100/150 mm
    - % fines: no limitation
    - PI over 45 (up to 60 to 80 in the USA)
    - Limited content of organic matters, SO_3, chlorides, nitrates, micas
      (these elements, when in sufficient proportion, combine with the clay and the binder and can cause damages or prevent the binder from setting)



B54: soils according to Bulletin 54 (cement)
CS: soils according to CSD Bulletin (cement & lime)

4. Cement: OK! But what about lime?

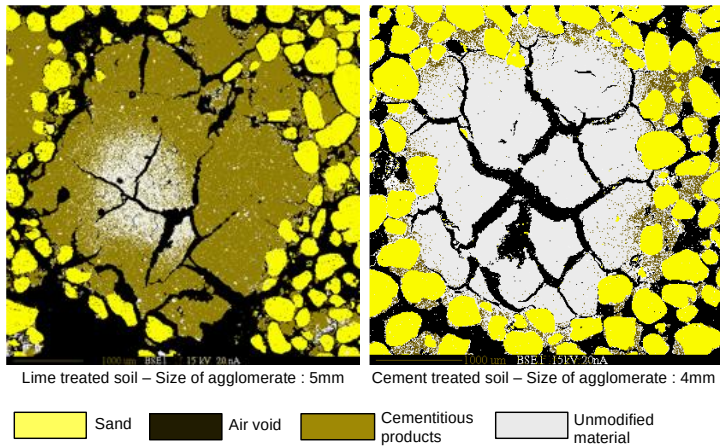
- Cement
  - Comparable to a glue
- Lime
  - A chemical reactant with a high pH: 12,4
  - Action on wet soils: Quicklime reduces water cont.

    ($CaO + H_2O$ ➔ $Ca(OH)_2$ + Heat)
  - Actions on clayey soils:
    - **Short term**

      Flocculation, modification of Atterberg Limits, increase of bearing capacity
    - **Long term**

      Progressive combination with clay particles to make a cementitious material, similar to a cement, leading to an increase in mechanical performance

- Cement treatment
  - Need for clean material (no clay or low clay content)
- Lime treatment
  - Suitable for clayey materials
    - Alone when clay content is enough
    - Before cement treatment (low to medium clay content)

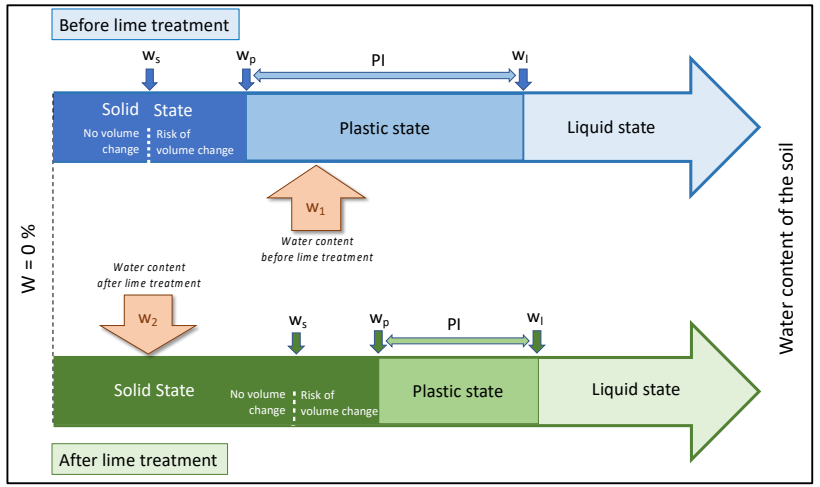


Based on Petrographic, EPMA, and X-ray diffraction analyses of thin-sections of soils (from Harris & Scullion)

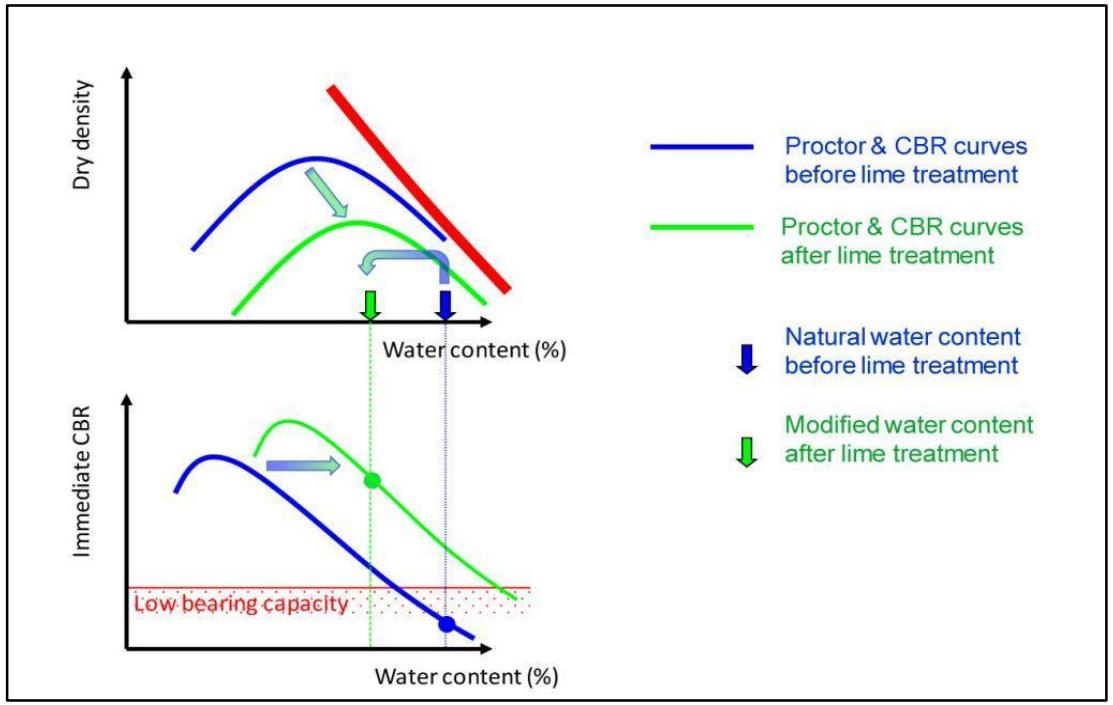
5. Lime: focus on short term actions on clayey soils

- Flocculation

- Atterberg limits

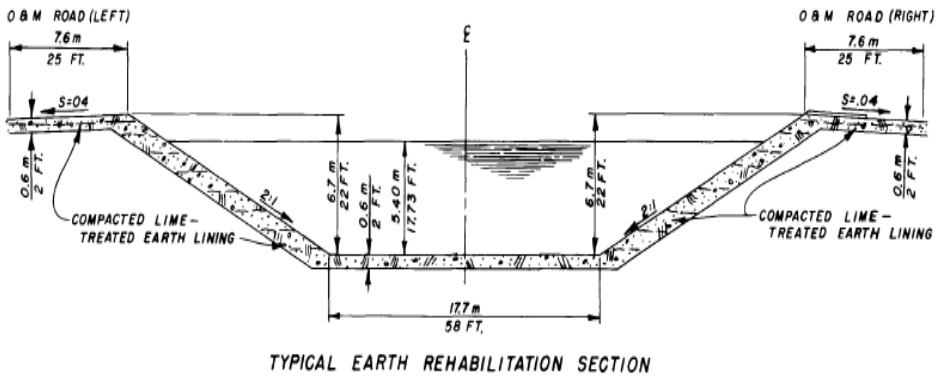


- Proctor curve and bearing capacity

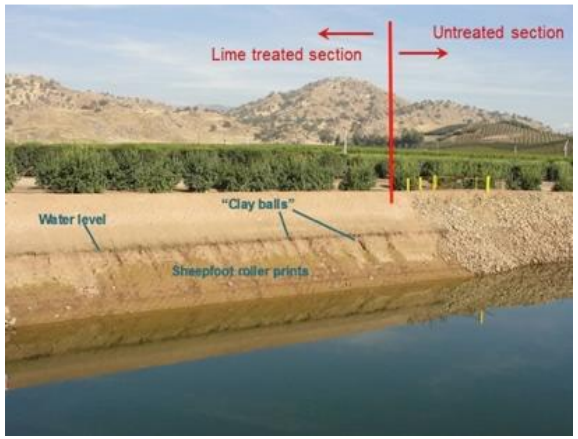


6. Example of application: lime treatment

- The Friant Kern canal (USA)
  - Irrigation canal
  - Built during the 40s
  - Bank slides due to expansive plastic clays (PI > 35)
  - Repaired during the 70s
    - Surface protection with lime treated sediments
    - 3 to 4% quicklime
    - No more damages since

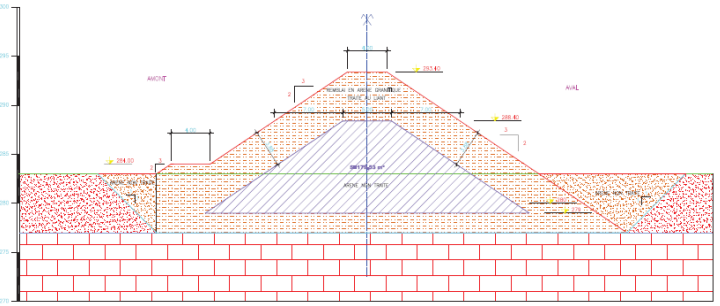


TYPICAL EARTH REHABILITATION SECTION



7. Example of application: cement treatment

- The Pannecière cofferdam (France)
  - 2011 - 2013
  - Untreated soil encapsulated into a treated carapace
  - Granite Arena
  - 4% Hydraulic Road Binder (cementitious material specially designed for soil treatment)



Thank you for your attention