Irrigation and Drainage Engineering

(Soil Water Regime Management)

(ENV-549, A.Y. 2025-26)

4ETCS, Master option

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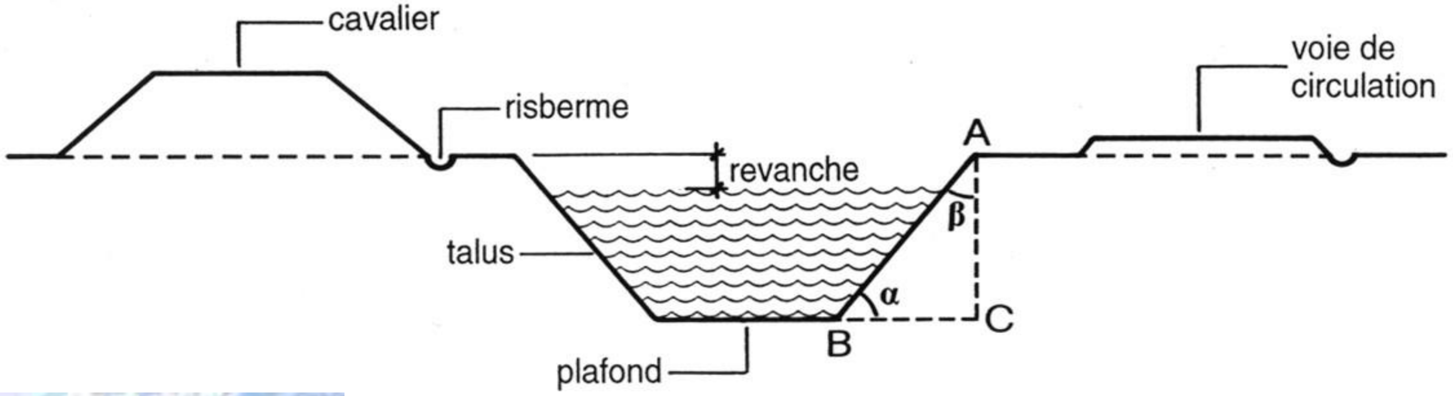
Platform of Hydraulic Constructions

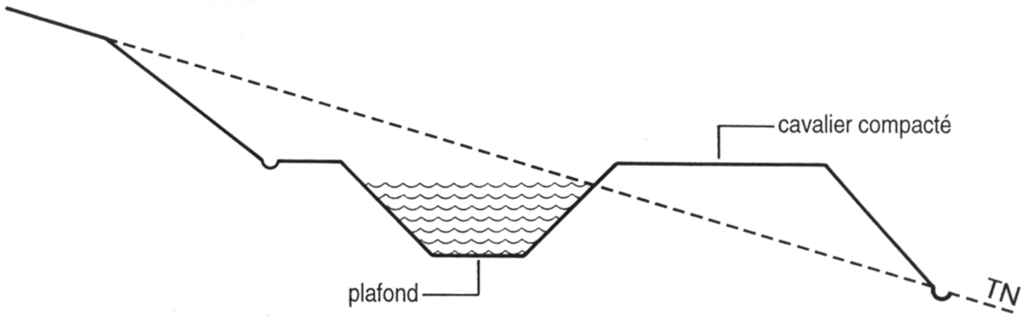
Lecture 4.1. Surface irrigation: embankment and lining techniques

Trapezoidal profile



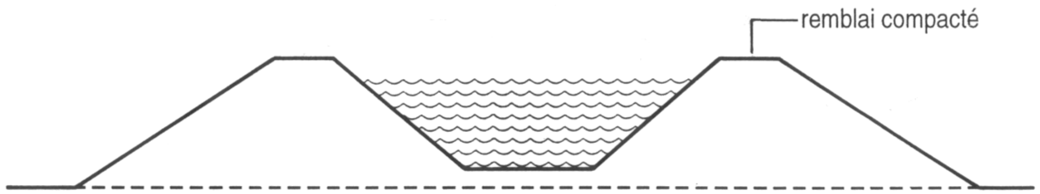
Excavated profile

(typical in flat surfaces)



Mixed profile

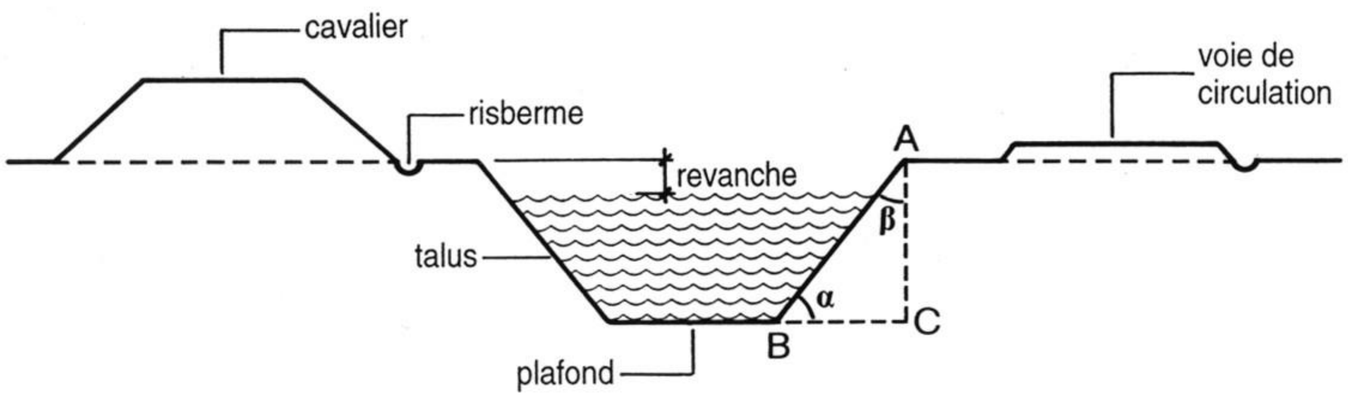
(dike compaction!!)



Embanked profile

(bank stability!!)

Embankment slope of trapezoidal canals



Slope = tg α = AC/BC

Fruit m = 1/tg α = BC/AC

Earthen channels : 1/3 < tg α < 1

Soils with low cohesion — Soils with good/high cohesion

Lined channels (with concrete revetment):

- ✓small channels: frequently 2/3 or 1
- ✓large channels: 2/3, 2, etc.

Freeboard r

- ✓Earthen channels: 0.3 < r < 1 m
- ✓Lined channels : 0.15 < r < 1 m

The freeboard is a delicate quantity to calculate as it depends on other network infrastructures downstream (e.g., gates), whose operation may induce propagating surface waves

Earthen channels

Advantages

- low cost
- achievable with local labour
- materials readily available

Disadvantages

- High leakage losses[1]
- high wall roughness
- high maintenance costs[2]

Empirical formulations

Formule de Ingham (établie en Inde)

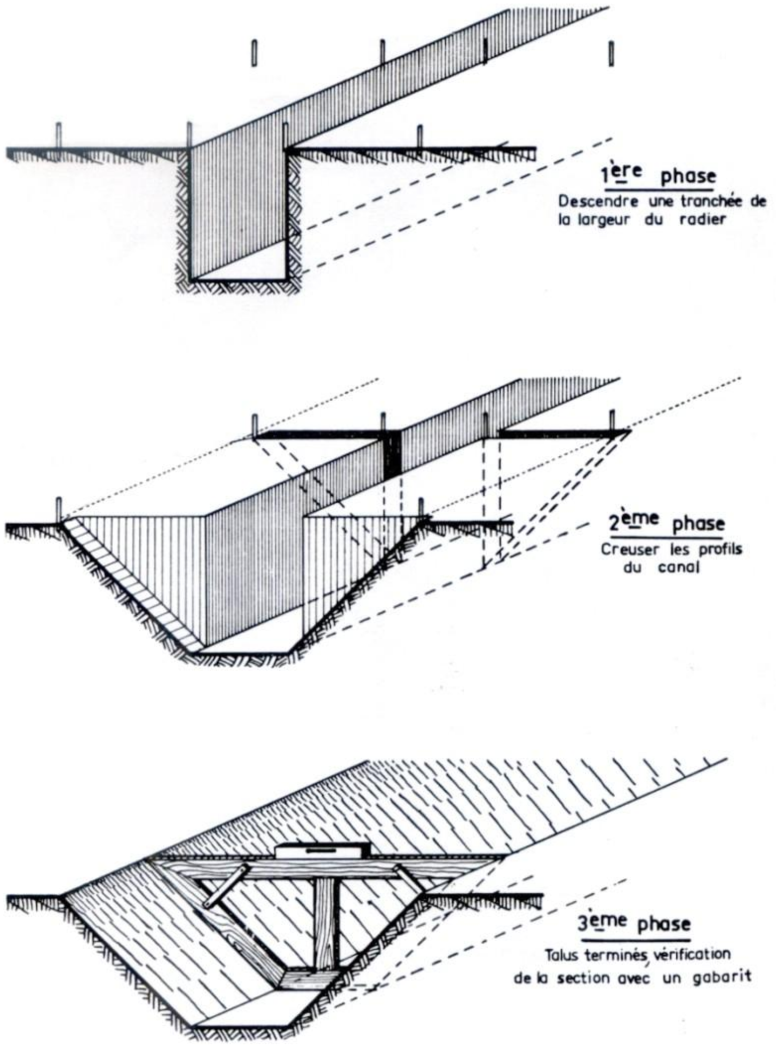
$$Q_{\text{loss}} = 2\ P\ L\ \sqrt{Y}\ 10^{-6}\ \text{m}^3/\text{s}$$

Formule de Davis et Wilson (USA)

$$Q_{\text{loss}} = 0.45\ C_{\text{DW}}\ \frac{P\ L\ \sqrt[3]{Y}}{4 \cdot 10^6 + 3650\ \sqrt{U}}\ \text{m}^3/\text{s}$$

[1] f(water-soil contact surface, height of water, nature of soil)
[2] annually, approx. 5% of construction costs

Practical realization of an earthen channel



Ameliorations (of earthen channels)

Objectives

- reduce losses
- increase flow rate
- lower maintenance costs

Types of interventions

- Actions on the mechanical properties of soils
- Crack sealing by sedimentation of fine material (silt, bentonite, bentonite-cement, bitumen emulsion, etc.)
  - short-term effectiveness → frequent renewal necessary
  - mainly used as an emergency measure
- Deposition of low-permeability layers
  - deposit of borrowed earth (30 to 60 cm)
  - deposit of earth concrete (approx. 10% cement; 10 to 15 cm thick) (shrinkage cracks!!)

Lining of canals

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

Quality of lining

- efficiency
- sustainability
- costs

Types of lining

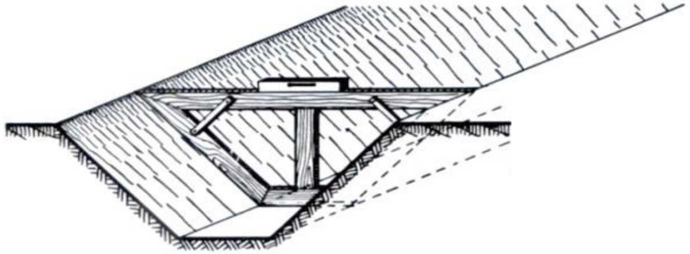
- Hard surfaces
  - ✓ masonry
  - ✓ bitumen, asphalt
  - ✓ concrete
- New materials
- Impermeable membranes

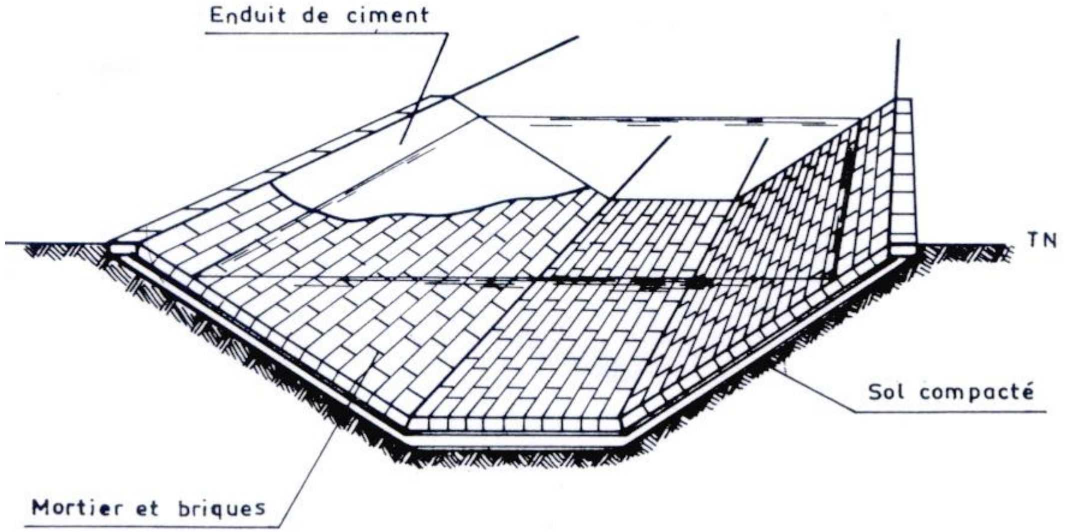
Choice of lining type

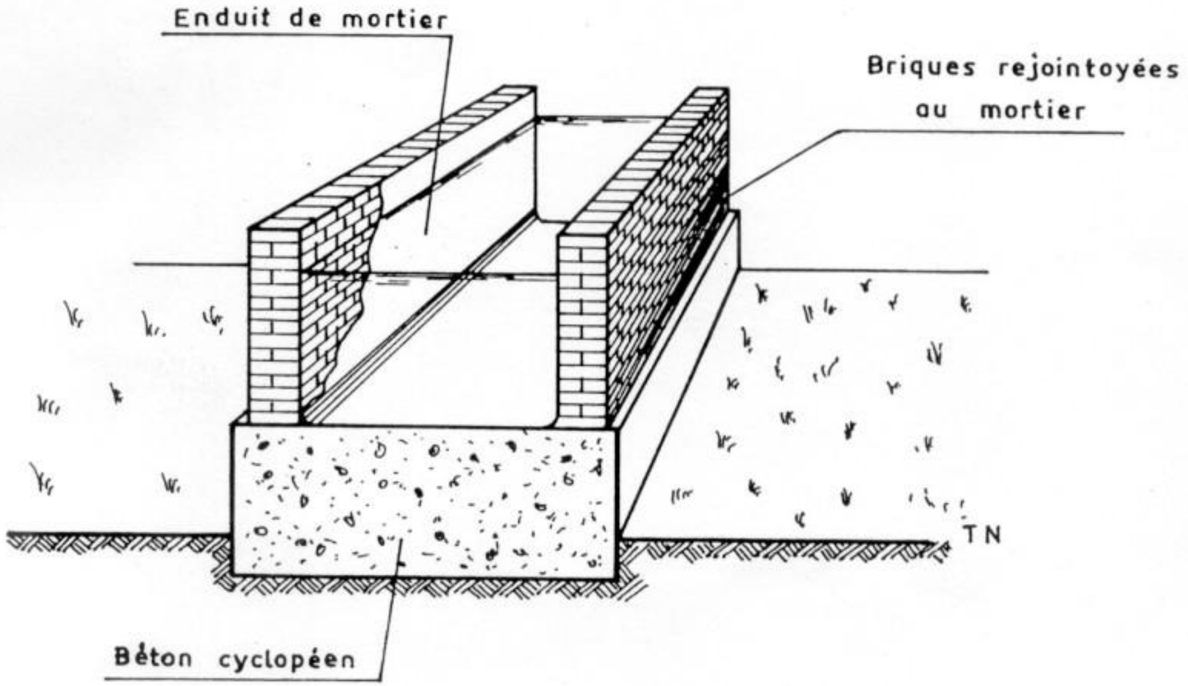
- availability of installation materials and equipment
- channel dimensions
- climatic parameters
- characteristics of the foundation soil

Preliminary actions

- Soil compaction
- Cross-section regularization







Examples of lined masonery channels

Bituminous coatings

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

Advantages

- good waterproofing (except permeable asphalt)
- flexibility (no joints)
- easy to repai

Disadvantages

- high cost
- risk of creep
- difficult to install
- strength and durability < concrete

Types of bituminous surfacing

- Asphalt mix
  - bitumen (5 - 10%) + aggregates (S and G)
  - permeable (predominantly coarse aggregates)
  - impermeable if porosity is < 4%.

  Used to produce homogeneous coatings of constant thickness

- Bituminous sealants
  - bitumen (12 - 20%) + fine aggregates (S and filler)
  - pasty liquid poured into place without compaction

  Used for coatings on uneven surfaces (! low stability)

- Prefabricated bituminous screeds

Concrete lining

Advantages

- long service life
- low maintenance
- very resistant

Disadvantages

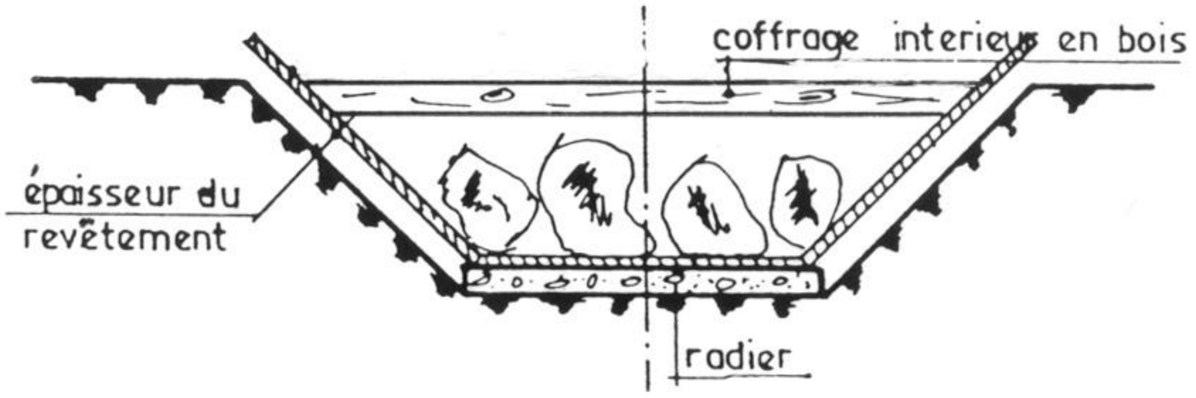
- high cost
- strong rigidity
- sensitive to changes in temperature[1]

Execution

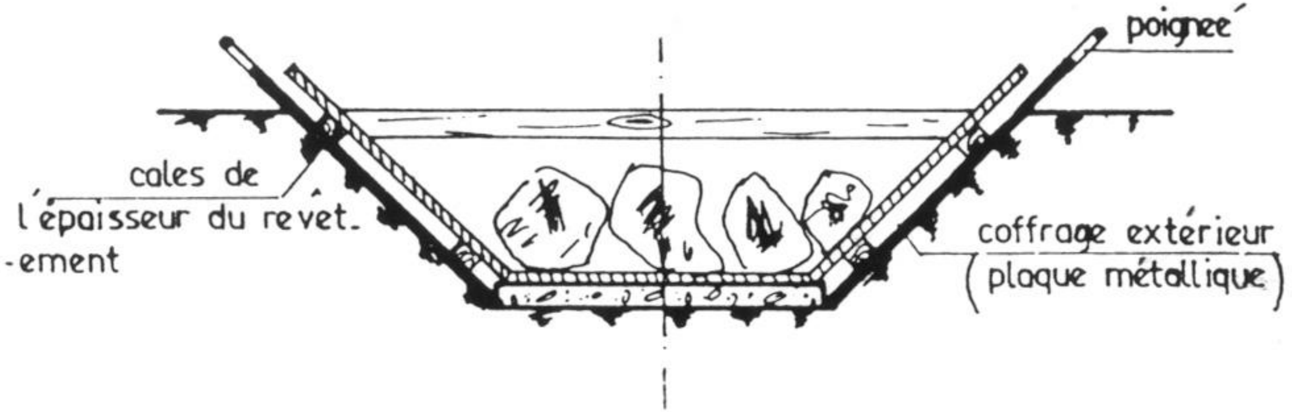
- Cast-in-place concrete
  - With or without reinforcement
  - Implementation
    - ✓ manual
    - ✓ automatic
  - Thickness is function of
    - ✓ importance of the canal
    - ✓ desired tightness
    - ✓ soil stability

- Prefabricated concrete slabs or tiles

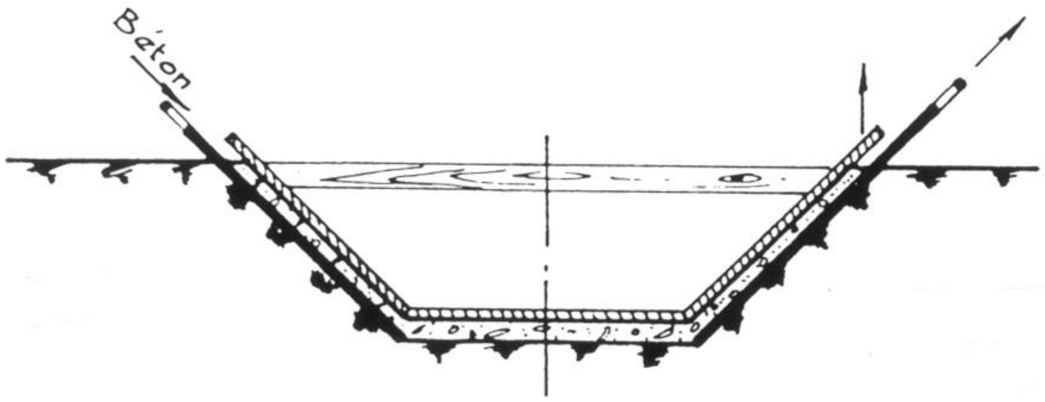
[1] Seals required
- shrinkage (partial sectioning): approx. every 5 m
- expansion (total sectioning): approx. every 15 m



- Thickness depends on channel size (5-10 to 8-20 cm)
- Wooden formworks or templates
- Concrete can be reinforced or not



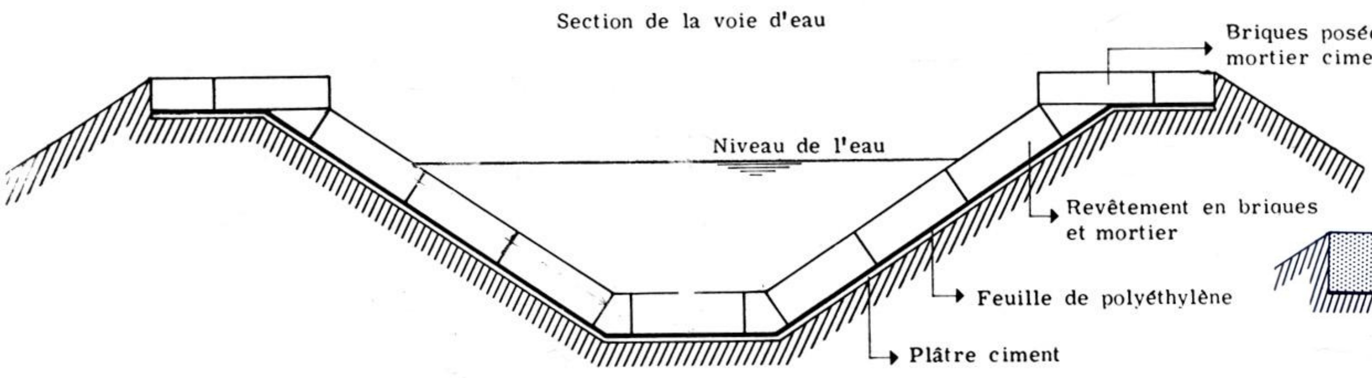
Manual realization of a concrete paving

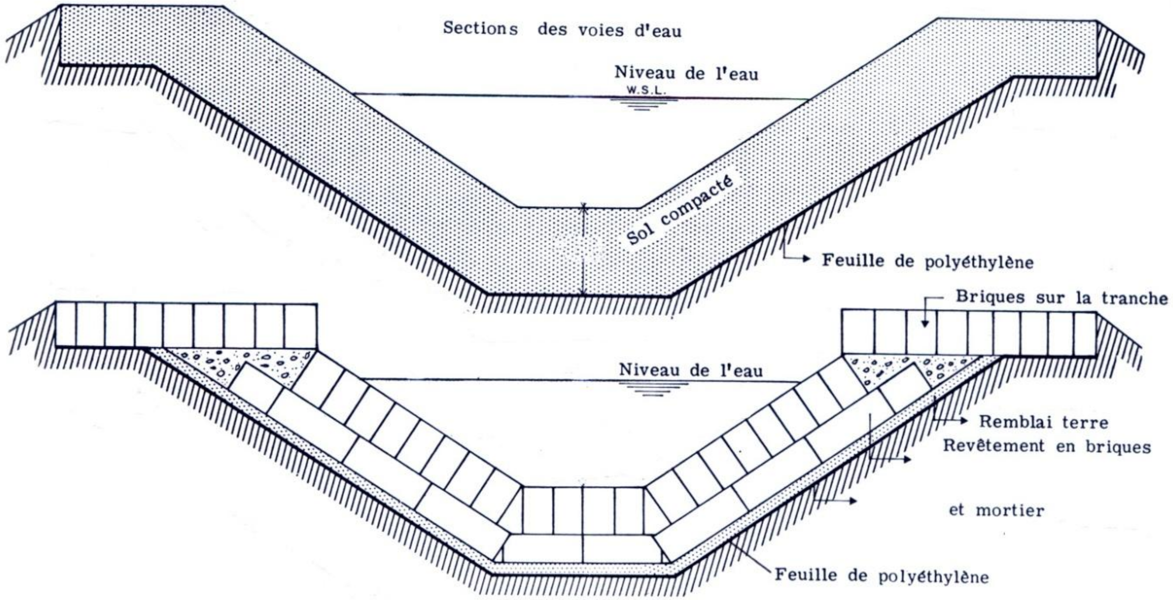


Examples of

canals lined

with concrete





Use of impermeable membranes

- Asphalt sprayed on site (5-8 mm layer)
- Prefabricated asphalt sheets (3-6 mm thick , small sections)
- Plastic membranes (PVC or PE, large rolls): reduces the number of joints.
- Simple application on the bank surface after soil compaction: deterioration (sunlight, erosion, animals…)
- Membranes buried and covered by 20 cm soil: excavation of larger sections, longer duration (15 years)

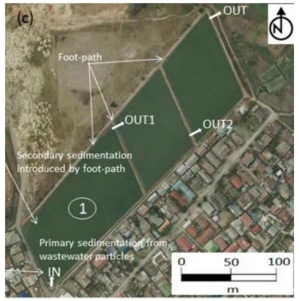
New material: Hyperelastic membranes

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

New material: Biocement

Main idea: similar to the use of brick and cement blocks, but using an innovative, carbon capturing material

Sludge (evt add bacteries)

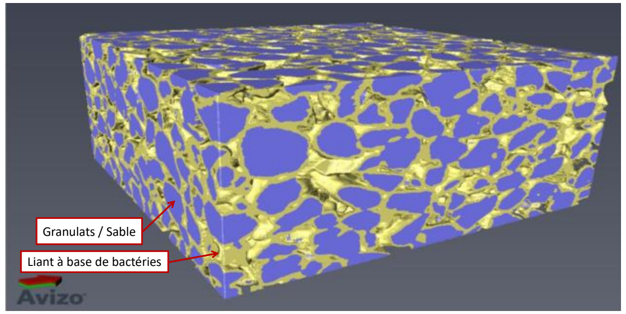


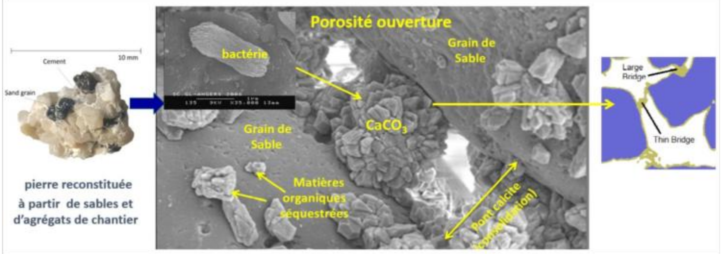
Sand

Calcium ($CaOH_2$)

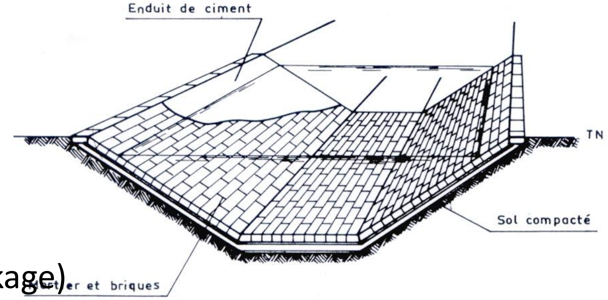
Water

BIO-CEMENT
(Net CO_2 absorbant process)

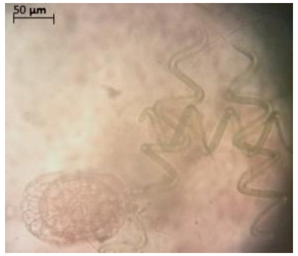




MICP: Microbial-Induced Calcite Precipitation



Efficient use (e.g., reduced leakage)



Improve health (e.g. H-E removal)

Valorisation (e.g. sludge re-use)

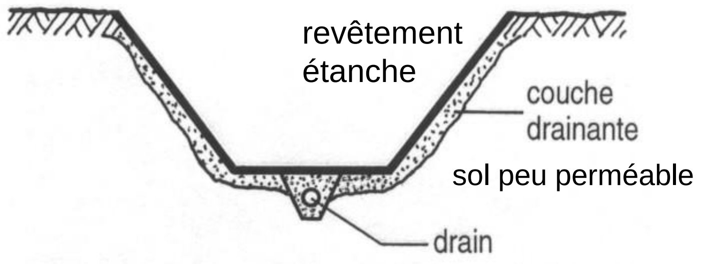
Drainage of irrigation canals

Shallow groundwater can exert hydrostatic pressure on the lined channels

- Channel lifting
- Lining degradation

✓ **poorly permeable foundation soil :**

- **permeable lining if the intrusion of groundwater into the channel is tolerated**
- **waterproof lining + drainage (drainage layer and drains) otherwise**



✓ **Permeable foundation soil:**

- **waterproof coating and drainage**