



# Technical Committee P on CMD WORKSHOP

## *Cemented Soil Dams* ***CSD Bulletin presentation – Design*** Chapter 6 : Design

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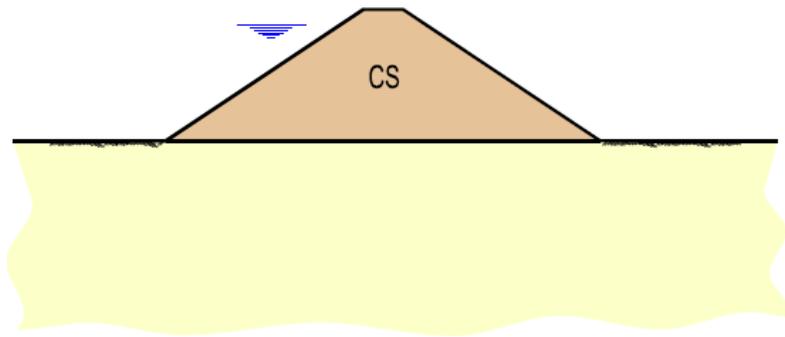


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## *CSD – Design for Small dam and levees*



### Design principles

- Homogeneous symmetrical profile
- No watertight upstream facing
- No drainage
- No protection of upstream and downstream slopes
- No foundation improvement
- No foundation cut-off

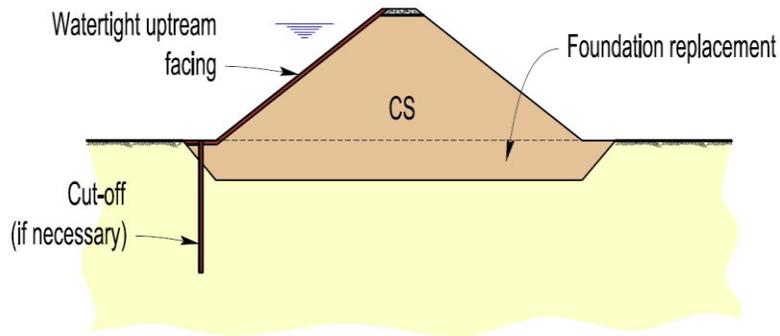
### Performance

The soil treated embankment provides:

- **Stability : slope 1,25H/1V à 1,5H/1V**
- Watertightness
- **Internal erosion resistance**
- **Slopes protection against :**
  - ✓ **Wave action on upstream slope**
  - ✓ Scour in case of overtopping
  - ✓ Burrowers damages
- ☐ Very simple structure
- ☐ Easy and fast building
- ☐ Limited overtopping acceptable



## *CSD design for medium range dams ( $h < 30-50$ m)*



### Design principles

- Homogeneous symmetrical profile (slope 1.25 to 1,5H/1V)
- Watertight upstream facing (geomembranes)
- Drainage under the facing
- Foundation improvement by substitution if required

Foundation cut-off if required

### Performance

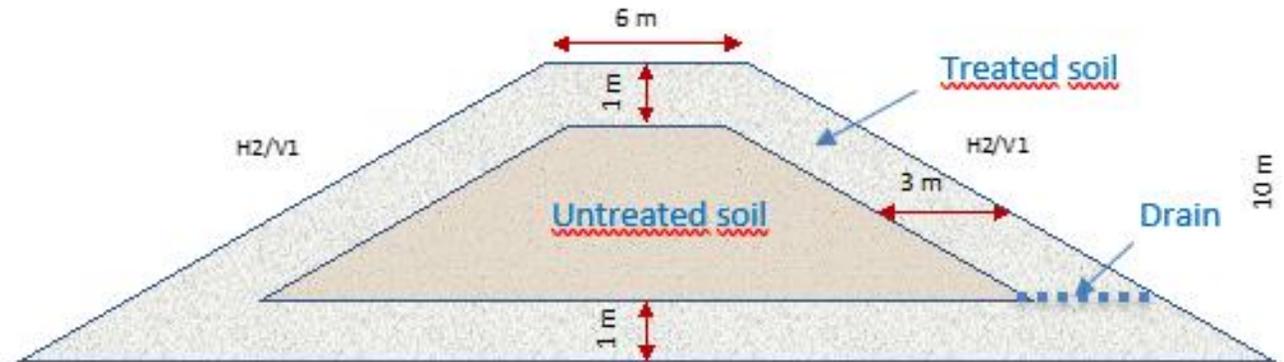
- The CS body is out of water
- ⇒ ***No need for CS watertightness***
- ⇒ ***No risk of internal erosion : CS is erosion resistant***
- Placing CS dryer than wet Proctor requirements acceptable
- ***No or little excess pore pressure during construction***
- Limited overtopping acceptable



## *CSD alternative cross section*

### Untreated soil encapsulated in cemented soil

- Foundation layer : protect against internal erosion at contact
- Upstream layer : protect against external erosion (waves, currents)
- Downstream layer : can accept limited overtopping or overspilling
- Drainage easy to implement
- Foundation cut-off if required



## *Overtopping and overspilling resilience*

Capacity to withstand overtopping or overspilling is an important feature of CSD

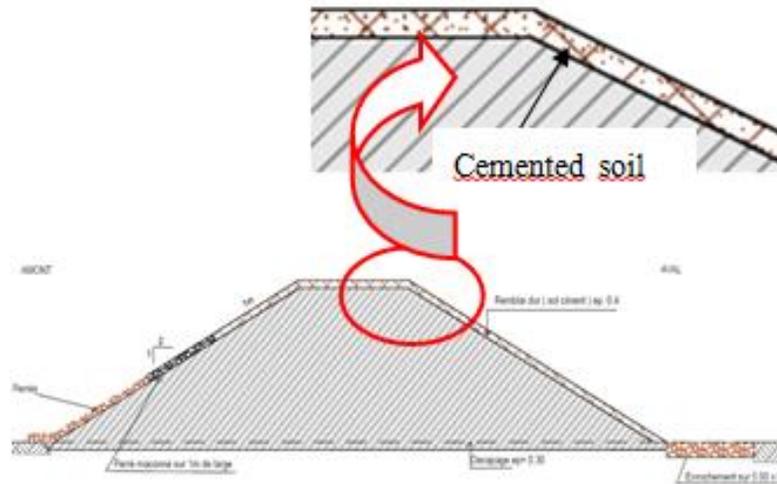
<b>France : Pannecière cofferdam</b>
Height : 17 m - Slope : 1.5H/1V
Granite arena (fines 14 %)
<b>Cement : 4 %</b>
8 hours overspilling Very little damage



## Overtopping and overspilling resilience

Burkina Faso

Loumbila dam emergency spillway :  
treated carapace (4.5 % cement)



Very rustic mixing method



@Adama Nombre



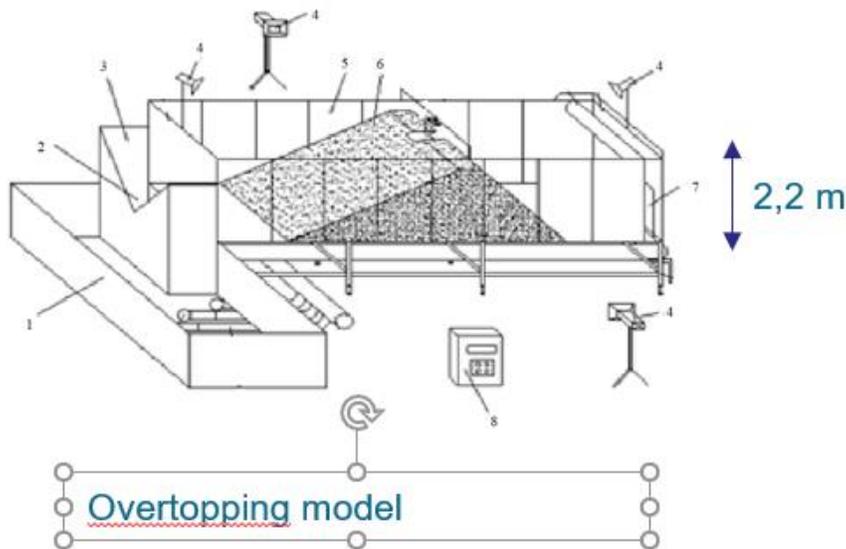
## Overtopping and overspilling resilience

China

Heilongjiang Pangtoupao Levee

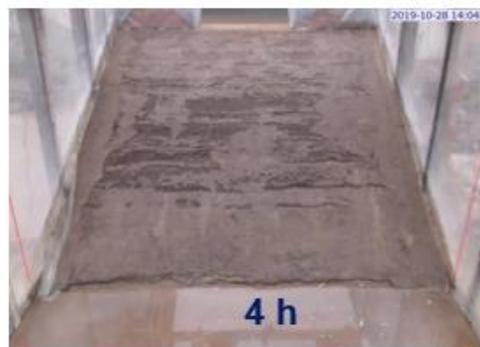
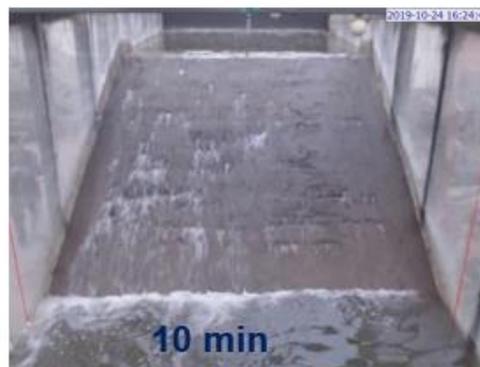
5% cement, 2.5% lime and 2.5% fly ash

30 cm thick carapace



✓ Overtopping height : 5 to 55 cm

✓ Water velocity : up to 4 m/s



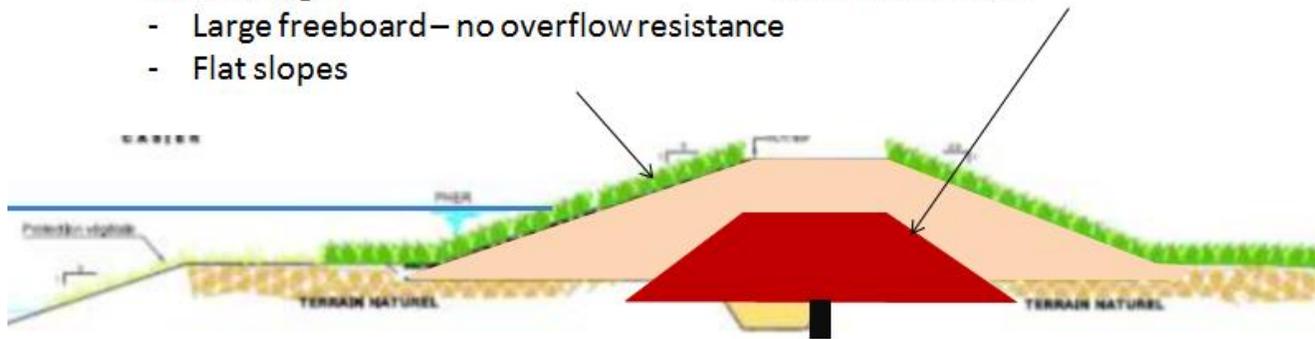
## Application to overtopping levee

Usual design:

- Large freeboard – no overflow resistance
- Flat slopes

Lime treated soil design:

- No freeboard, overflow resistant dike
- Steepened slopes



Comparison between a classical design and CSD design



CS carapace on a existing protection levee (Belgium)



## *CSD stability analysis*

- Usual **limit equilibrium methods** can be used for the justification of the stability of dams <30m, provided that the development of pore pressure is well controlled on site through appropriate specifications and proper quality control
- Stability during construction & end of construction dimensioning
- **Strain-hardening time-dependent constitutive models** are useful to check stability and settlements.
- And these justifications shall be imperatively required for dams higher than 30m.
- However, care should be taken with standard commercial Finite Element Models, as they do not properly account for the **development of pore pressure** within the unsaturated material.

