Towards migration of fines within a soil matrix

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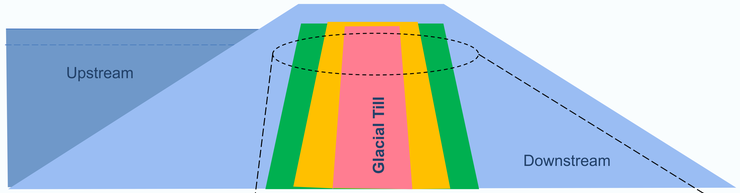
A. Background

Embankment dams are structures often used in mining and hydropower, consisting of:

Core — Fine filter
Coarse filter — Shoulders



Cross section of embankment dam.

Hydraulic conductivity values (ref.), k (m/s)

Source: Toromanovic J. (2021)

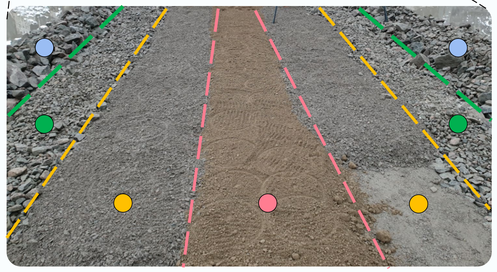
1	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}	10^{-11}
Gravel			Sand			Silt			Clay		

Internal erosion

Internal deterioration process when seepage forces exceed dam core resistance ability.

Depends on:

- Particle size distribution
- Stress conditions
- Hydraulic gradient ⇨ - Rate of increase
  - Time interval increment



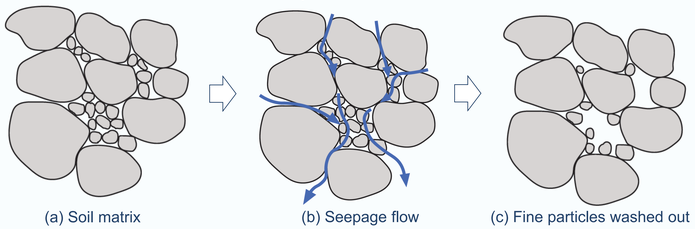
Top view of horizontal cross section of embankment dam under construction. Photo by: Toromanovic J.

Development of suffusion

Suffusion

It is a mechanism of internal erosion
Main characteristics:

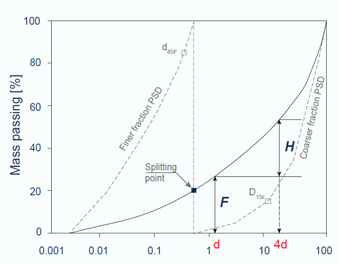
- No loss of matrix integrity
- No bulk volume change

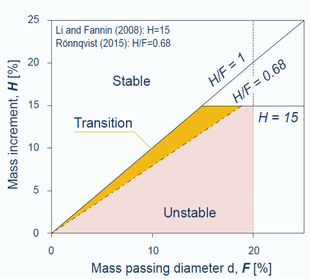


(a) Soil matrix (b) Seepage flow (c) Fine particles washed out

Empirical method for assessing suffusion susceptibility

Particle size distribution potentially internally unstable ⟶ If: H/F < 1 (Deficiency of fine fraction)
H < 15 (H/D_{15C} or H/d_{85F} = 15%)





Kenney and Lau method (1985, 1986) after Li and Fannin (2008) and Rönnqvist (2015) (right). Characteristic values from particle size distribution used in this method (left). Source: Silva I. (2022)

Note: This method was developed based on tests on sand – gravel up to 60mm

B. Motivation

⚠ Internal erosion processes remain **unclear** specially for **suffusion** mechanism, which may lead to **possible dam failures**

⇩

What triggers internal erosion by suffusion?

⇩

✓ Look into **migration of fine particles** within a soil matrix through materials that allow visibility, e.g., Transparent soils

C. Materials: Transparent soils

Transparent soils, emerging as a viable alternative with likely properties to sand and clays, consist of a two-phase media made by refractive index matching of solids to represent the soil skeleton and a fluid solution to mimic pore fluids.

Tool for modelling:

- The physical modeling of soil-structure interaction mechanisms
- Saturated-unsaturated hydraulic behavior
- Thermal processes

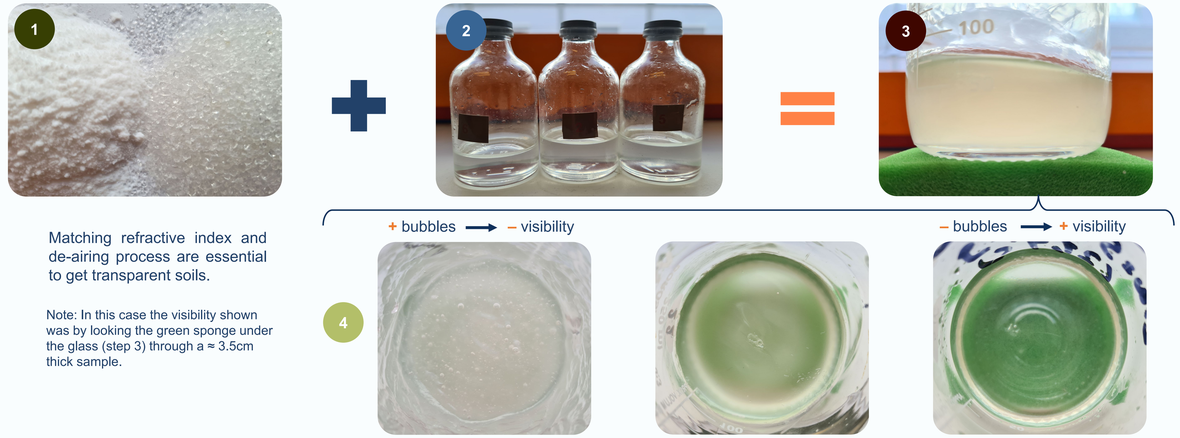
Family	Amorphous silica powder	Silica gel	Aquabeds	Fused quartz	Laponite
Best suited for modeling	Clay	Sand	- Flow of water in soil - Very weak marine deposit	Saturated and unsaturated sand	Soft marine clays
Pore fluid	Mineral oil and paraffinic solvent blend or calcium bromide brine		Water	Mineral oil blend or sucrose solution	Water

Source: Materials to manufacture transparent soils - Based on Iskander et al. (2015)

Preparation procedure

1 Determine the range of solid particle size ⇨ 2 Pore fluid with matching refractive index ⇨ 3 Mix solids and pore fluid ⇨ 4 De-airing and resting sample

Silica powder — Silica gels | Calcium bromide brine | Transparent soil



Matching refractive index and de-airing process are essential to get transparent soils.

Note: In this case the visibility shown was by looking the green sponge under the glass (step 3) through a ≈ 3.5cm thick sample.

D. Outlook

Transparent soils may offer the potential to replicate the behavior of glacial till core material employed in embankment dams ⇨ Likely mechanical properties as sand and clay particles. However, further research must be carried out.

Main references

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