



Branschsamverkan i Grunden

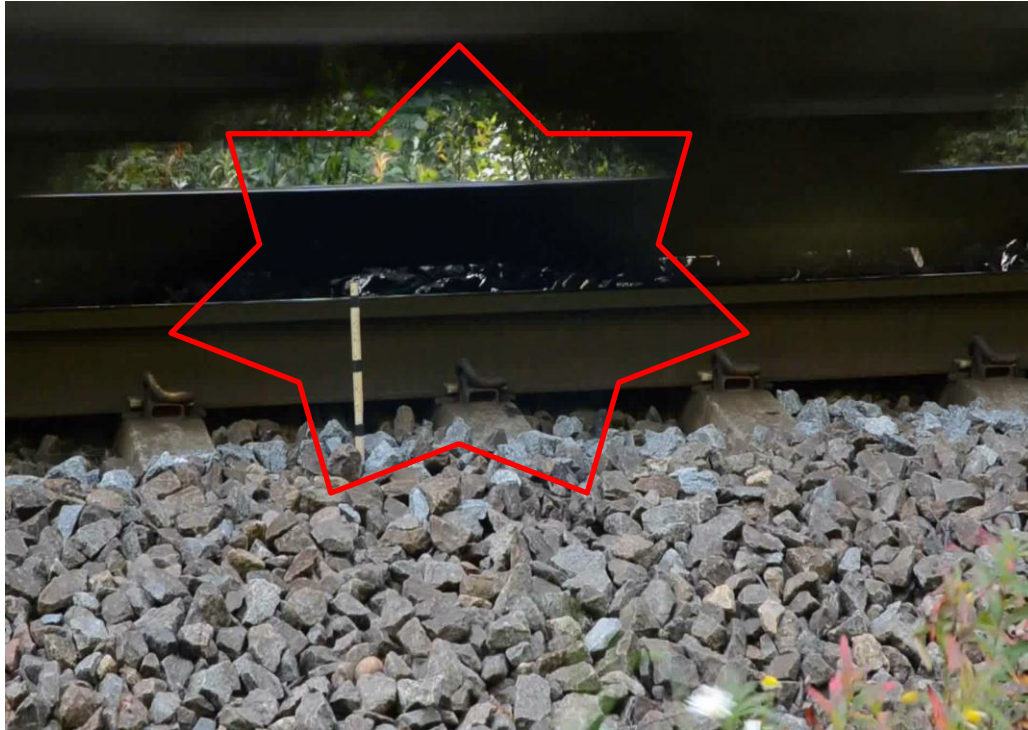
BIG - Branschsamverkan i Grunden VIP-möte 2023

Pore water pressure generation in subgrade soils under cyclic loading

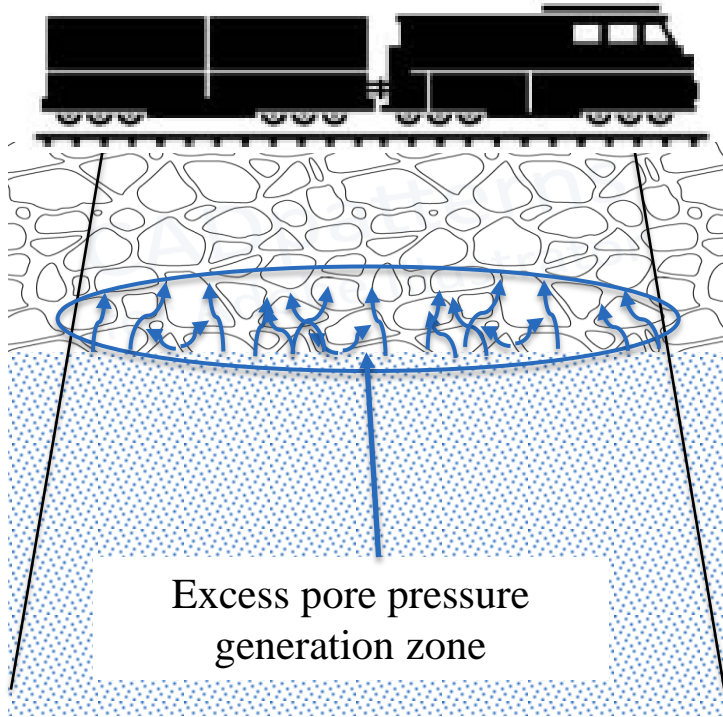
Tan Manh Do, Jan Laue, Hans Mattsson, Qi Jia

Research background

(Trafikverket)

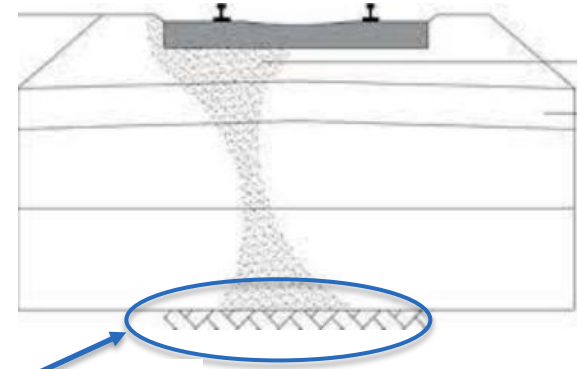


Research background

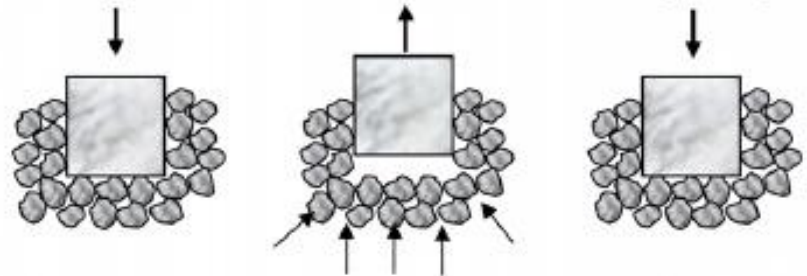


Excess pore pressure
generation zone

Railway



Excess pore pressure
generation zone



Tadatoshi 1977 

Research background



Mud pumping

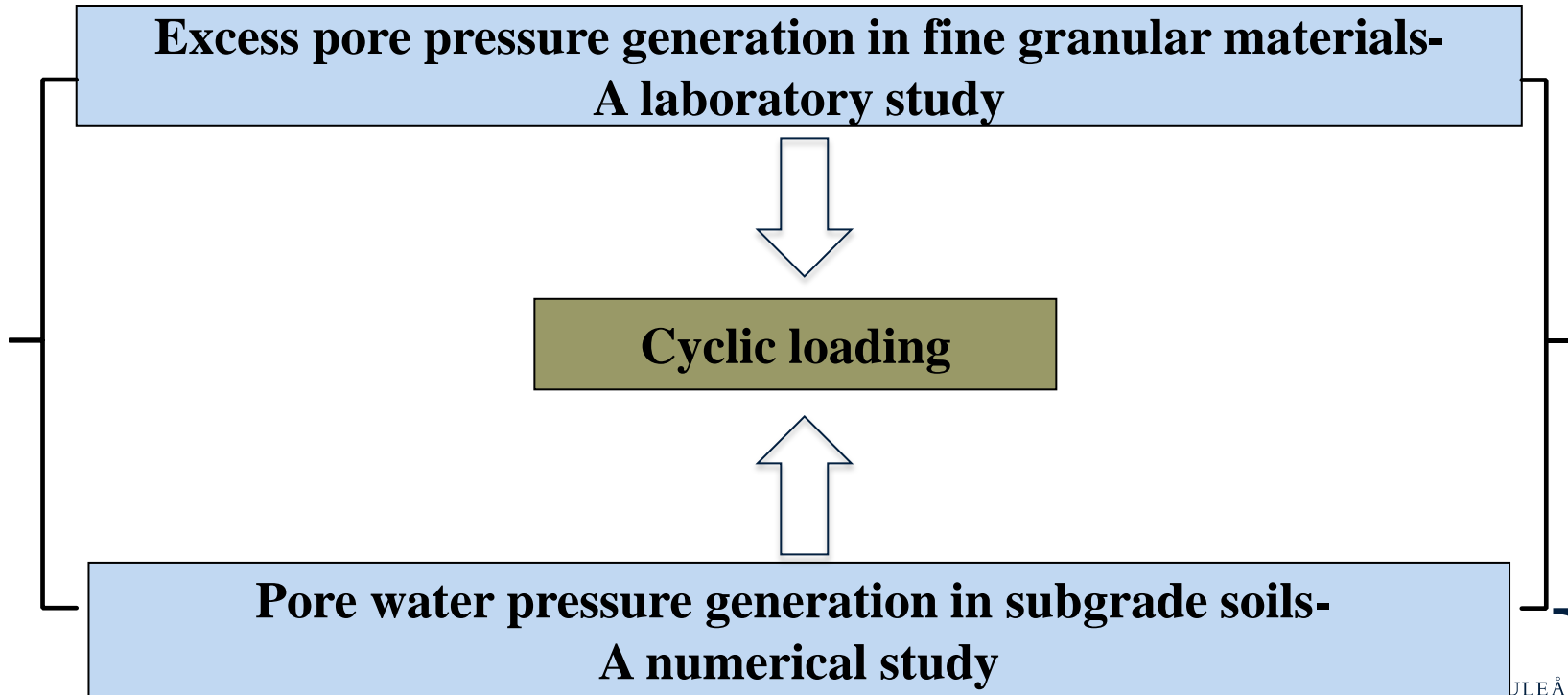


- Clogging of pores
- Reducing the drainage capacity
- Reducing shear strength



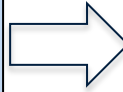
→ Increase maintenance costs

Research objectives



Research objective 1

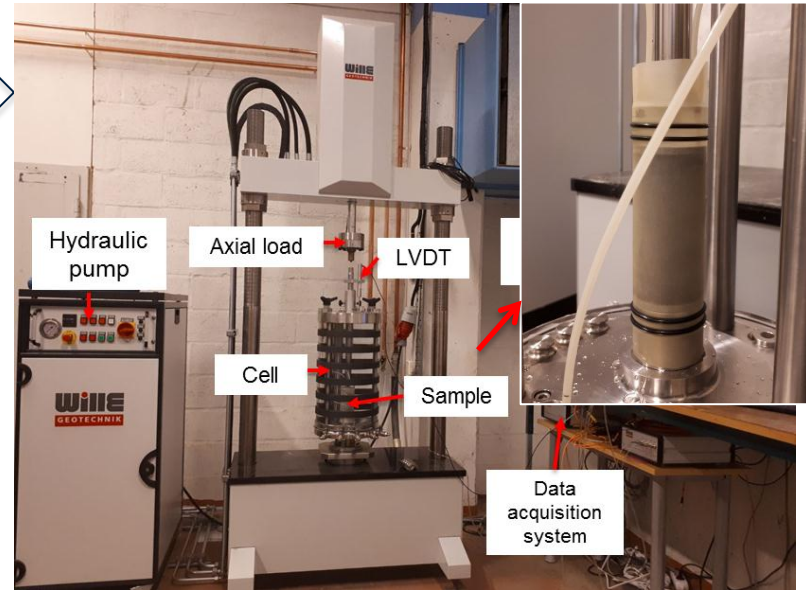
Excess pore pressure generation in fine granular materials-A laboratory study



Cyclic loading



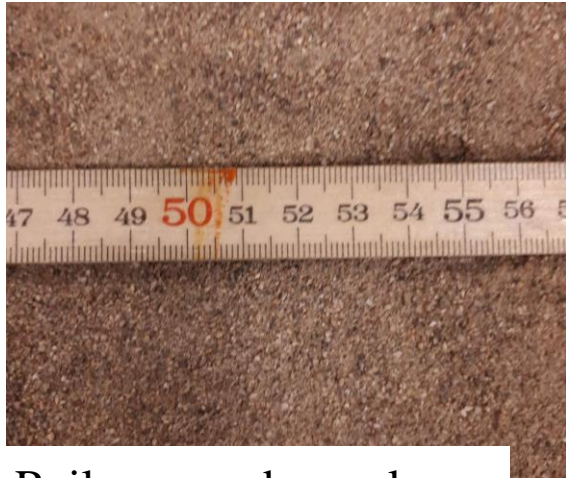
Pore water pressure generation in subgrade soils- A numerical study



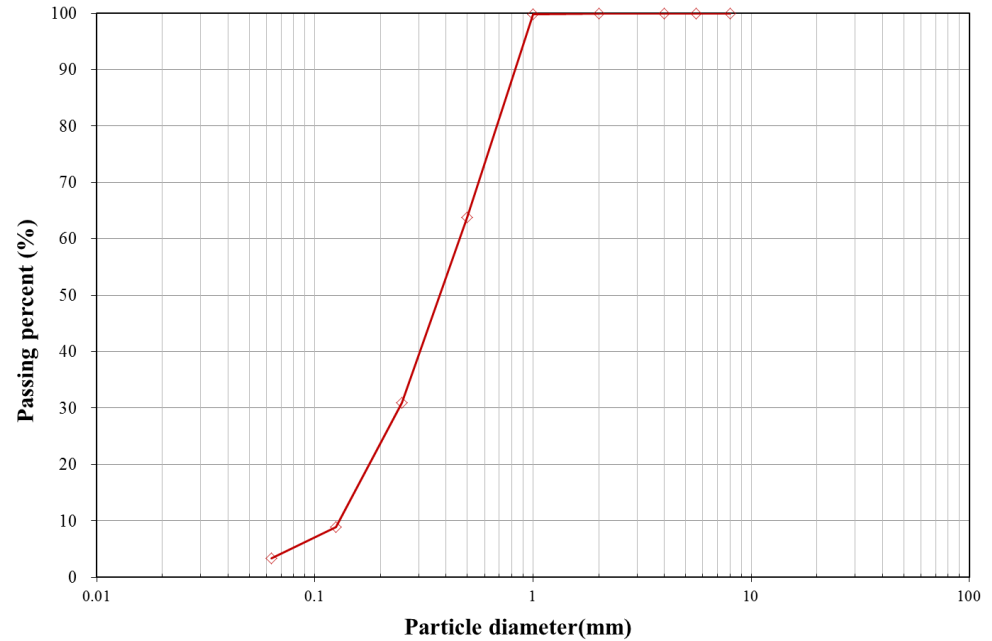
Triaxial system

Materials

Mesh 1 mm



Railway sand sample



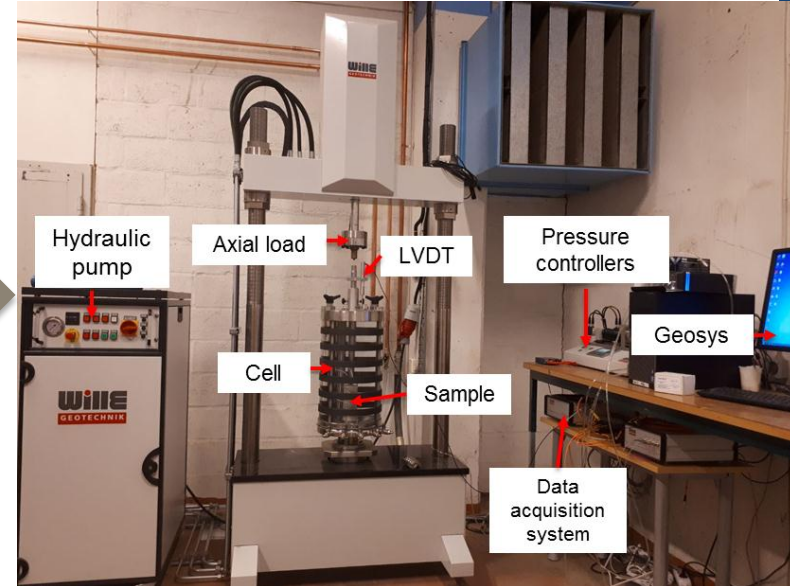
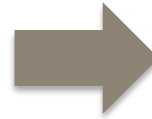
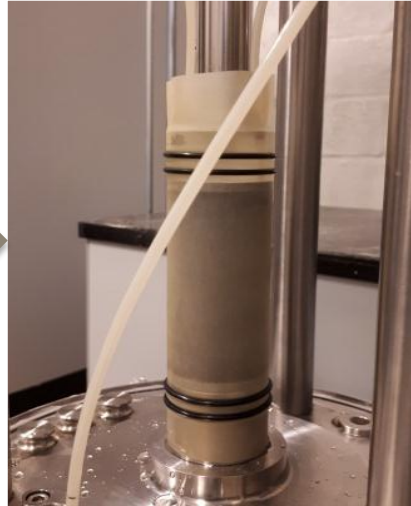
Particle size distribution curves of materials

Sample preparation

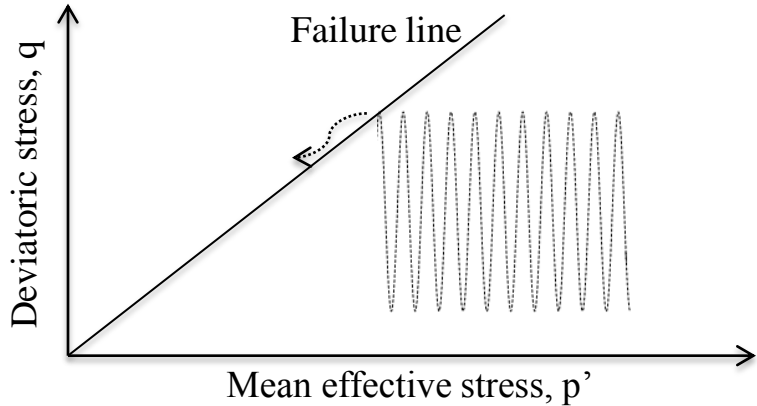
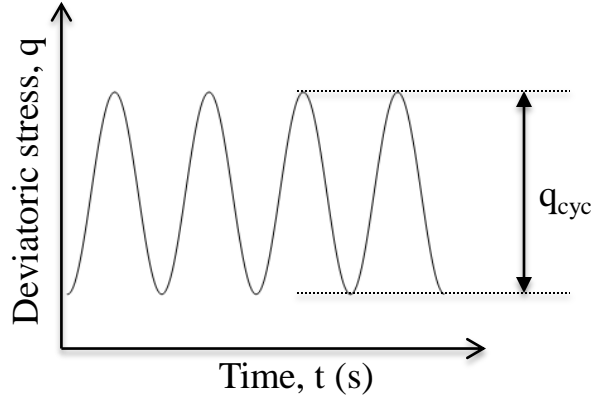
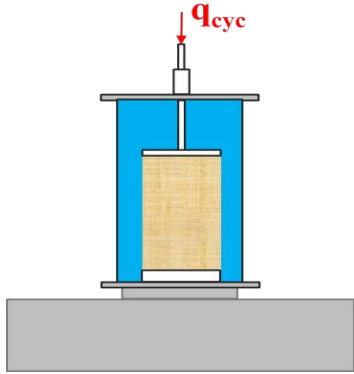
Railway sand



Moist Tamping



Experimental program



$$CSR = \frac{q_{cyc}}{2 \times \sigma'_c}$$

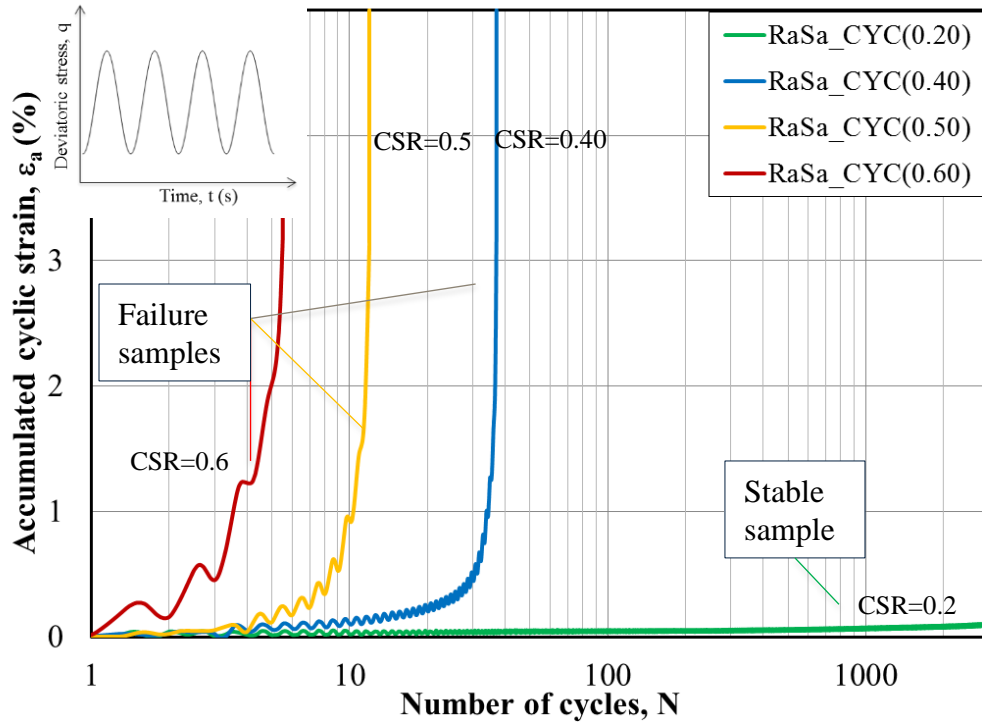
Cyclic stress ratio (CSR):

Railway sand: CSR = 0.2-0.60

Confining pressure $\sigma'_c = 30$ kPa

Frequency $f = 1$ Hz

Cyclic strain response

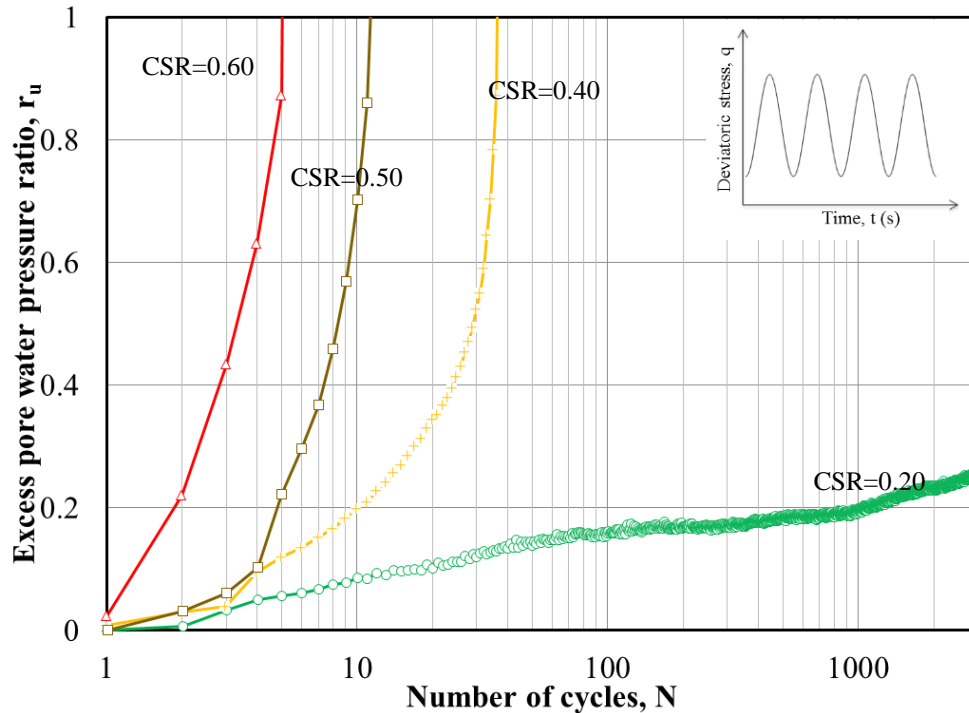


Samples after the undrained cyclic triaxial tests



Selected cyclic triaxial test results results (RD=84%)

Cyclic excess pore water pressure (PWP) response

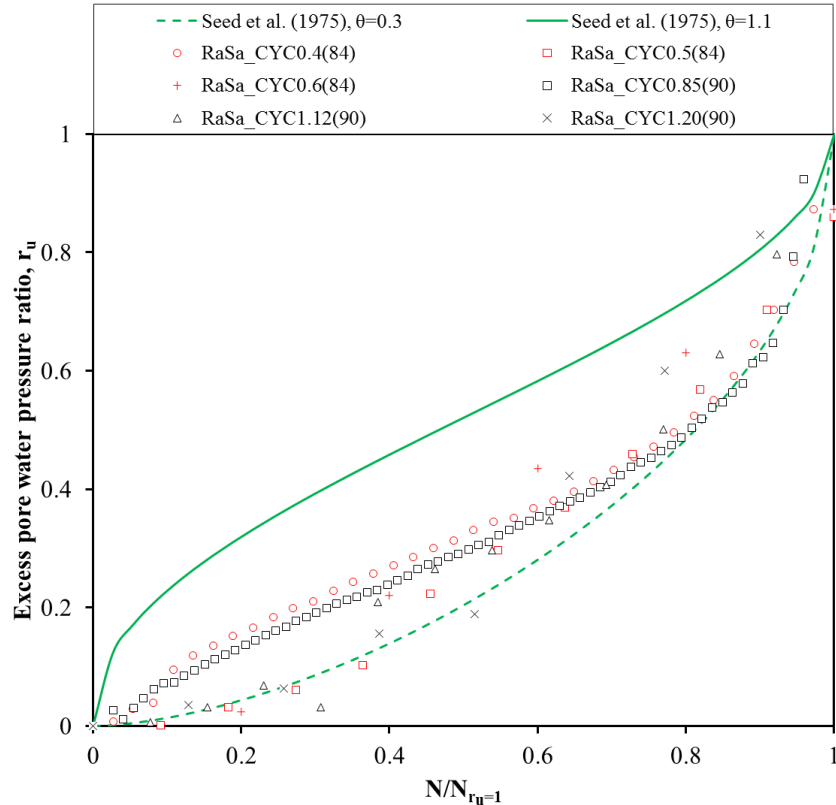


Selected cyclic excess PWP, $r_u = \frac{\Delta p_w}{\sigma'_{v0}}$
(Excess PWP ratio $r_u=1$ failure)

Samples after the undrained cyclic triaxial tests



Evaluation of excess PWP during cyclic loading



Excess pore water pressure response
(Seed et al. 1975)

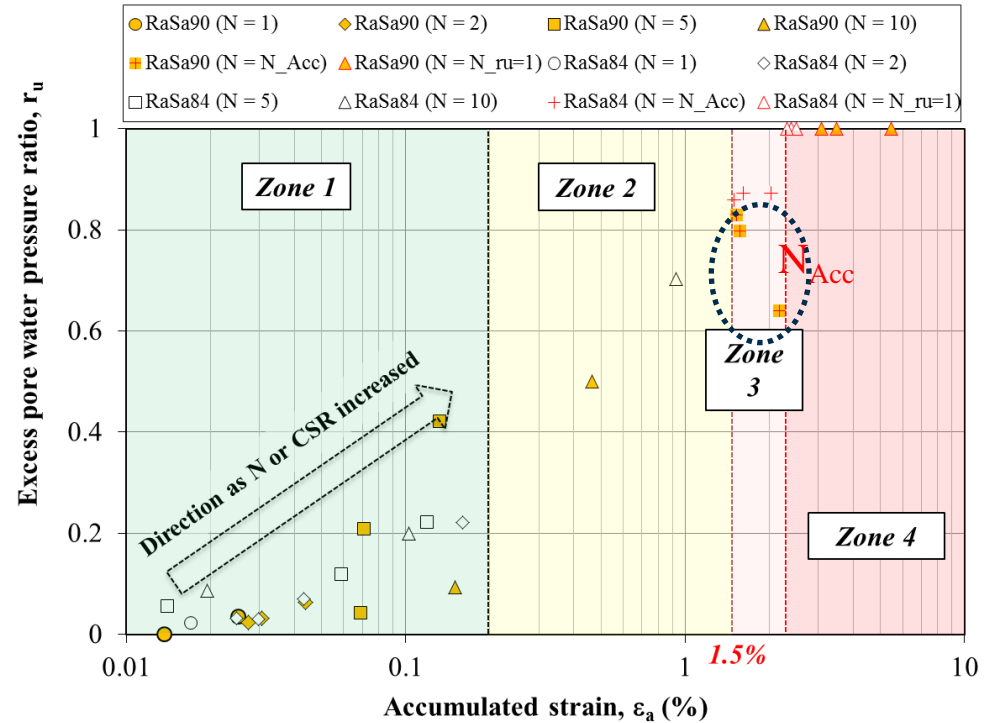
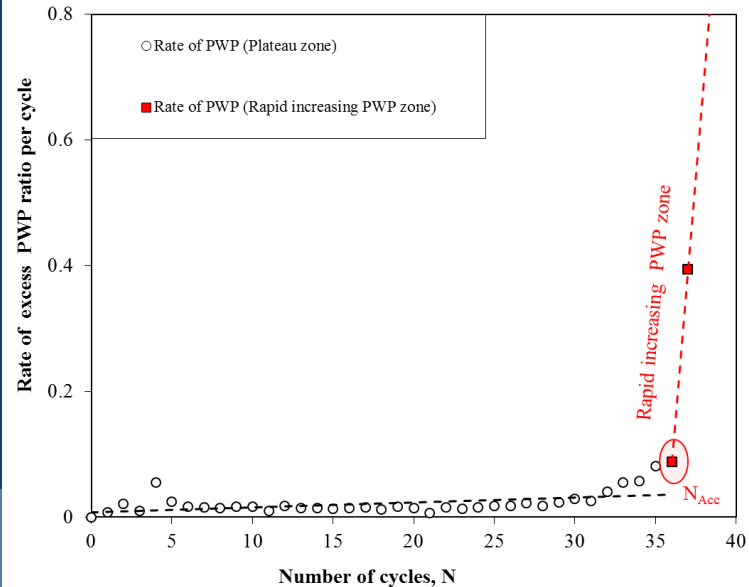
$$r_u = \frac{2}{\pi} \arcsin \left(\frac{N}{N_{r_u=1}} \right)^{1/2\theta}$$

Where θ is empirical constant determined from laboratory testing

$\left(\frac{N}{N_{r_u=1}} \right)$ is number of cycles (N) normalised by the number of cycles at $r_u=1$

Evaluation of the pore pressure response during cyclic loading

Excess PWP and accumulated strain



Typical rate of residual excess pore water pressure ratio

Proposed excess PWP build-up versus accumulated strain

Research objective 2

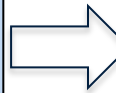
Excess pore pressure generation in fine granular materials-A laboratory study



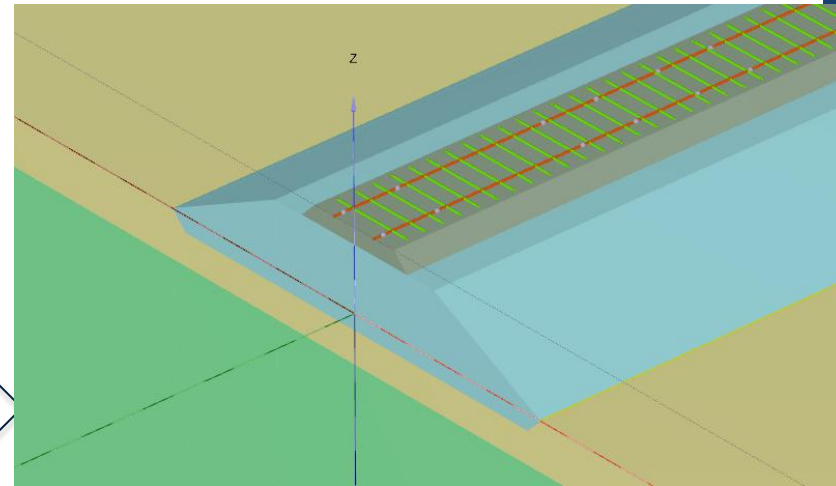
Cyclic loading



Pore water pressure generation in subgrade soils- A numerical study



FEM

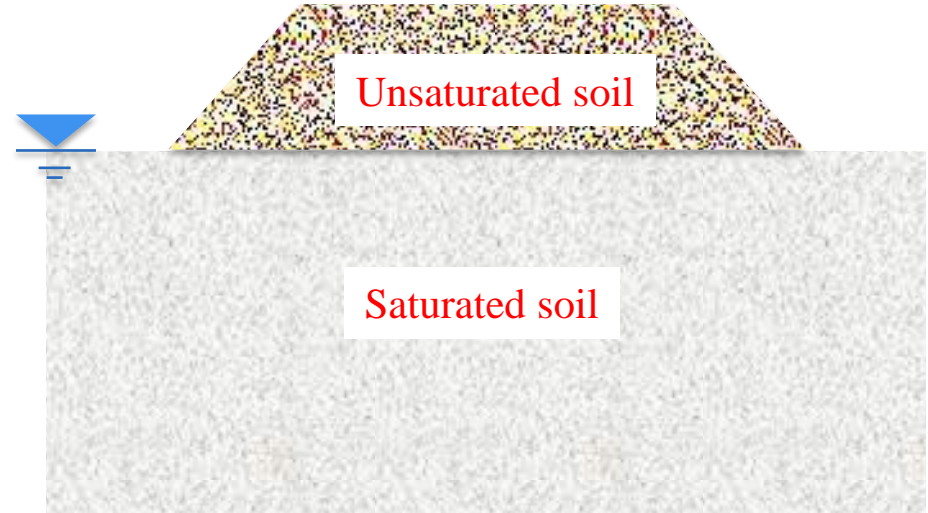


Methodology

**Pore water pressure generation in subgrade soils
under cyclic loading**



A case study



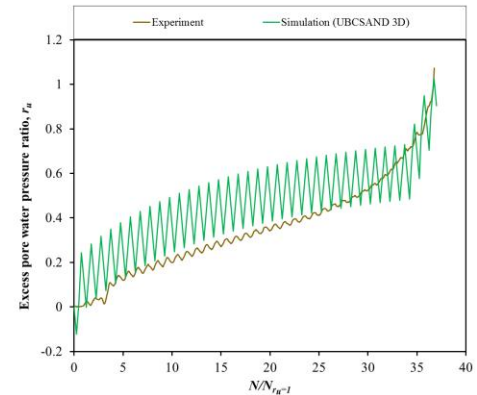
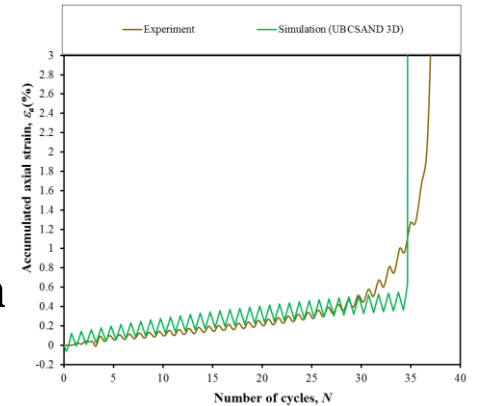
Methodology

Saturated soil
(UBCSand model)

LAB & Calibration

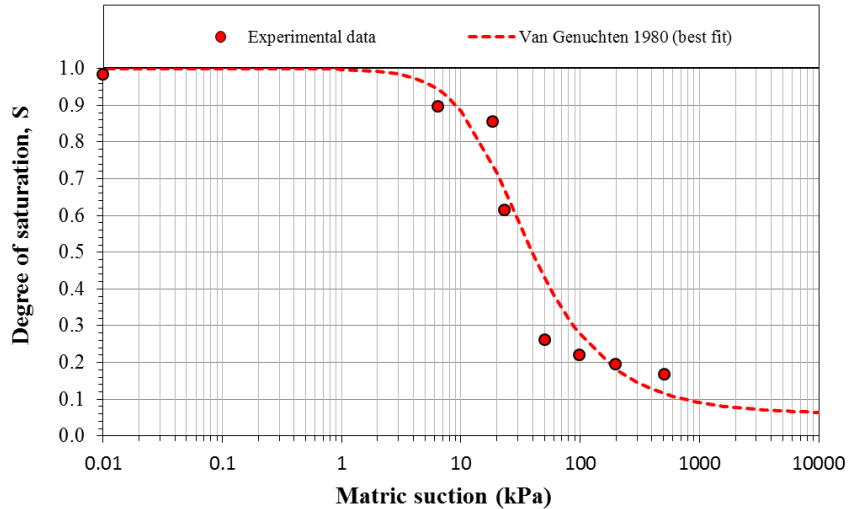


Curve fitting

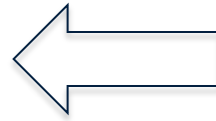


Methodology

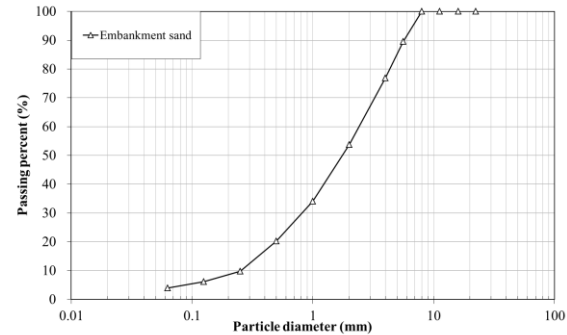
Unsaturated soil
(UBCsand coupled van Genuchten)



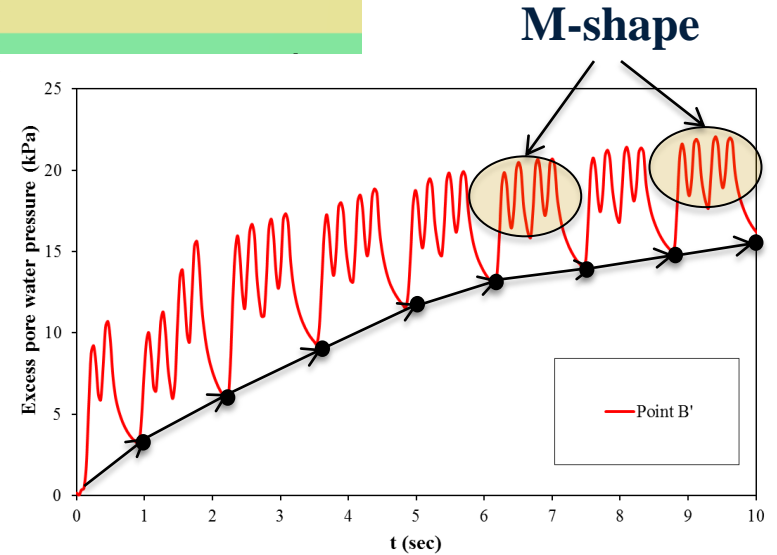
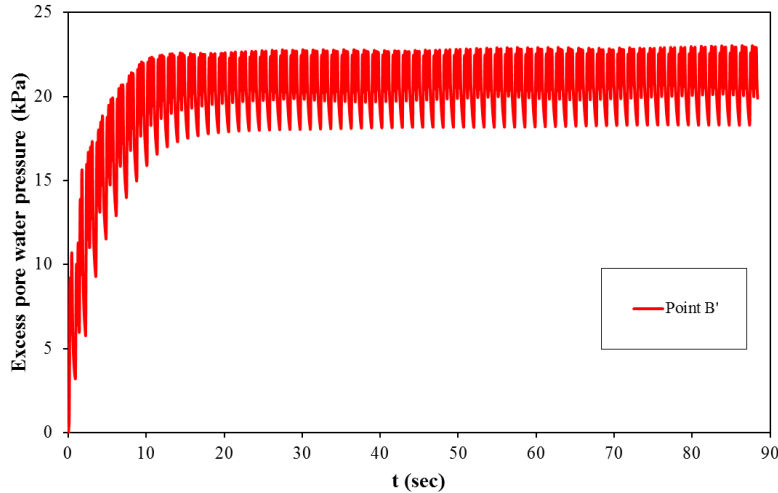
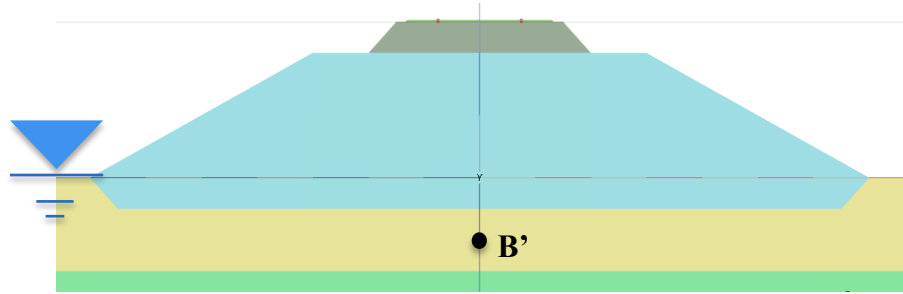
LAB & Calibration



Curve fitting

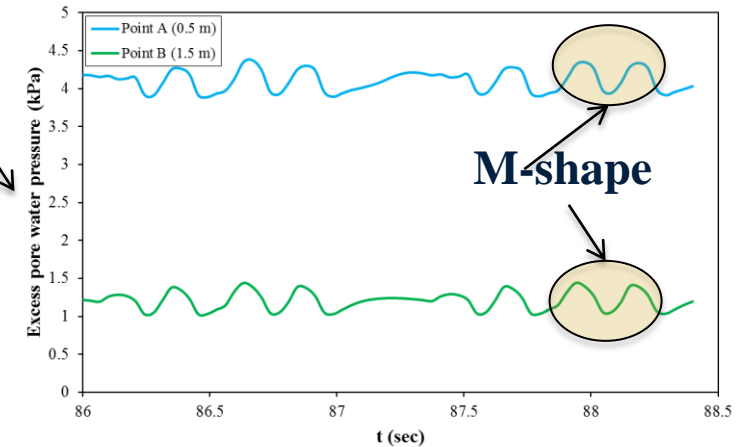
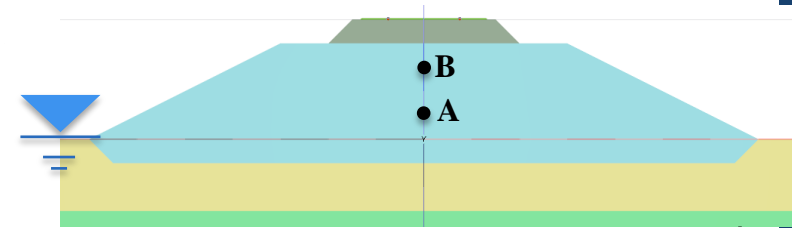
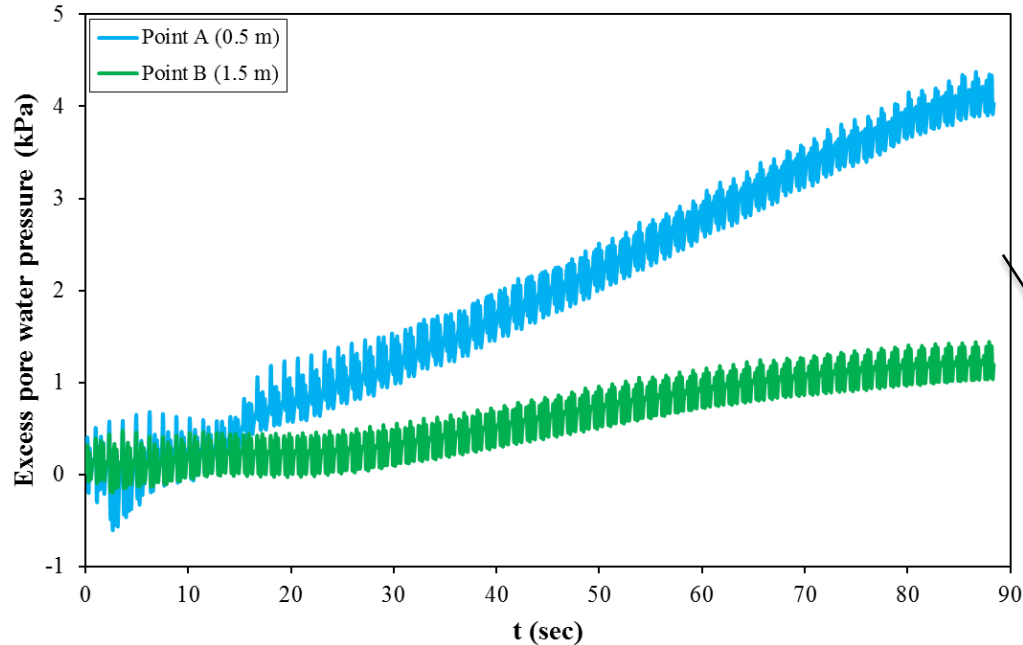


Pore water pressure generation in **saturated soil**



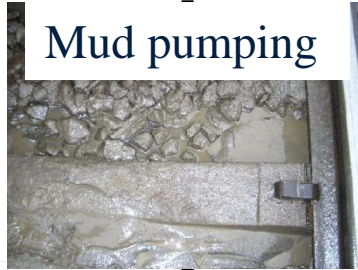
Concept of excess pore water pressure build-up during train passing

Pore water pressure generation in **partially saturated embankment**

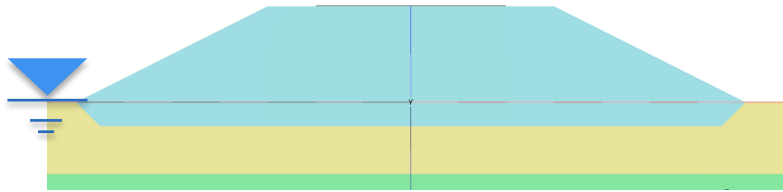


Practical implications

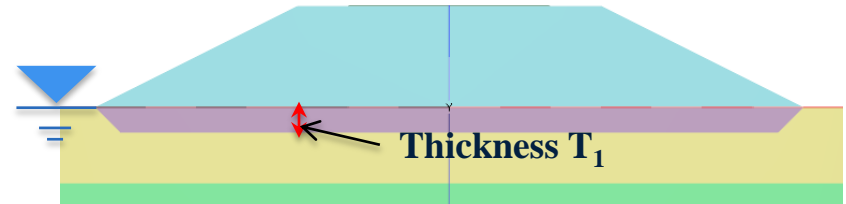
Mud pumping



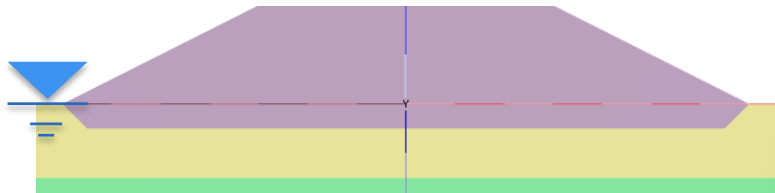
Original embankment



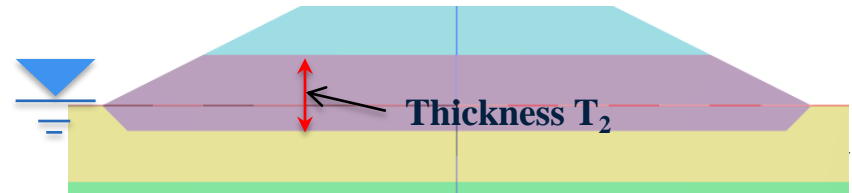
Partially fouled embankment



Fully fouled embankment

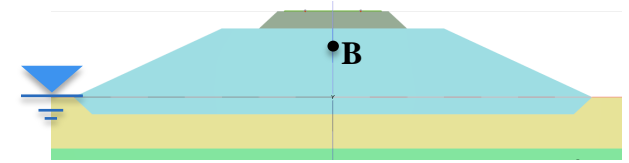


Partially fouled embankment

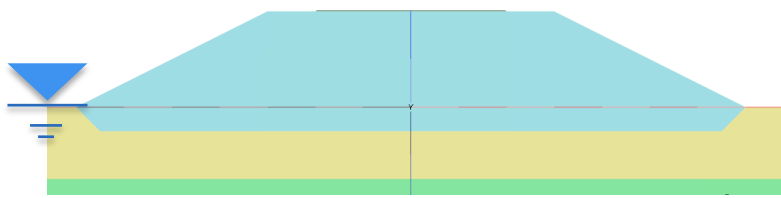


OF TECHNOLOGY

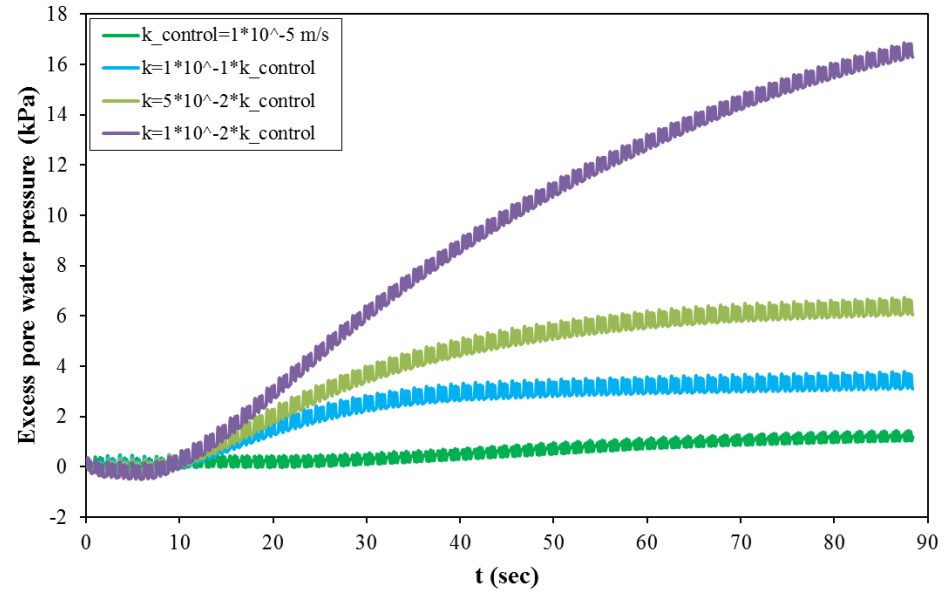
Practical implications



Original embankment

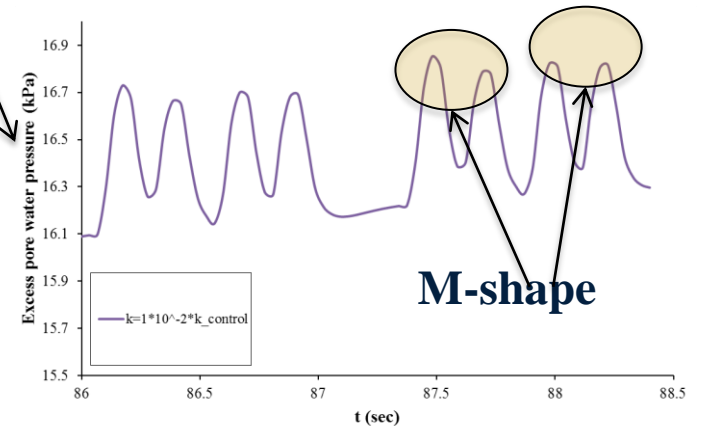
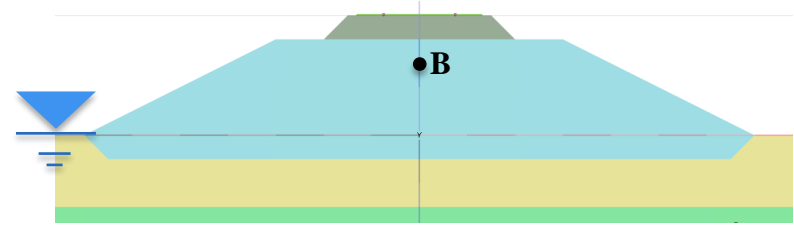
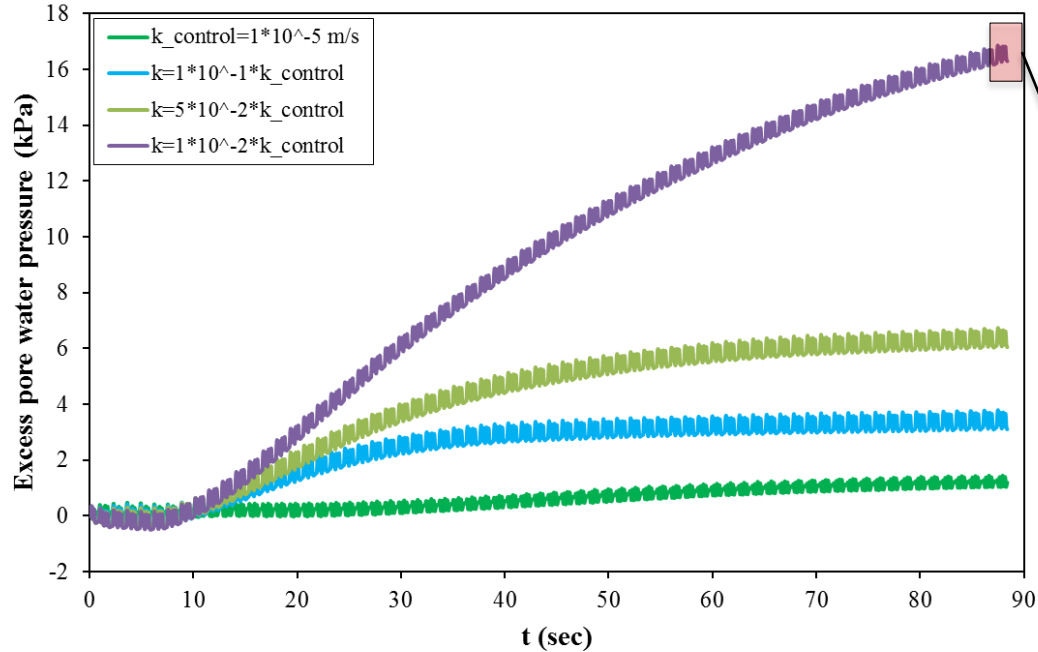


Fully fouled embankment



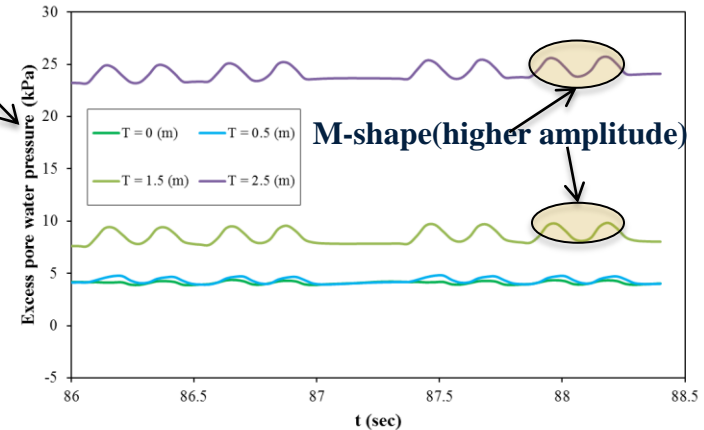
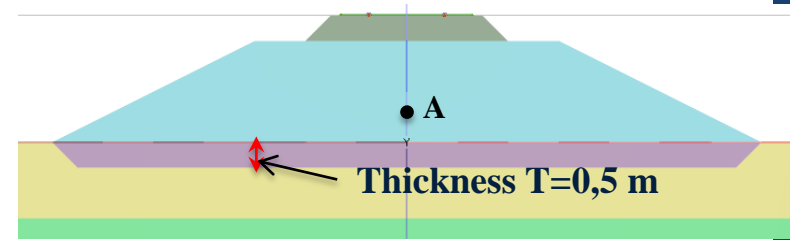
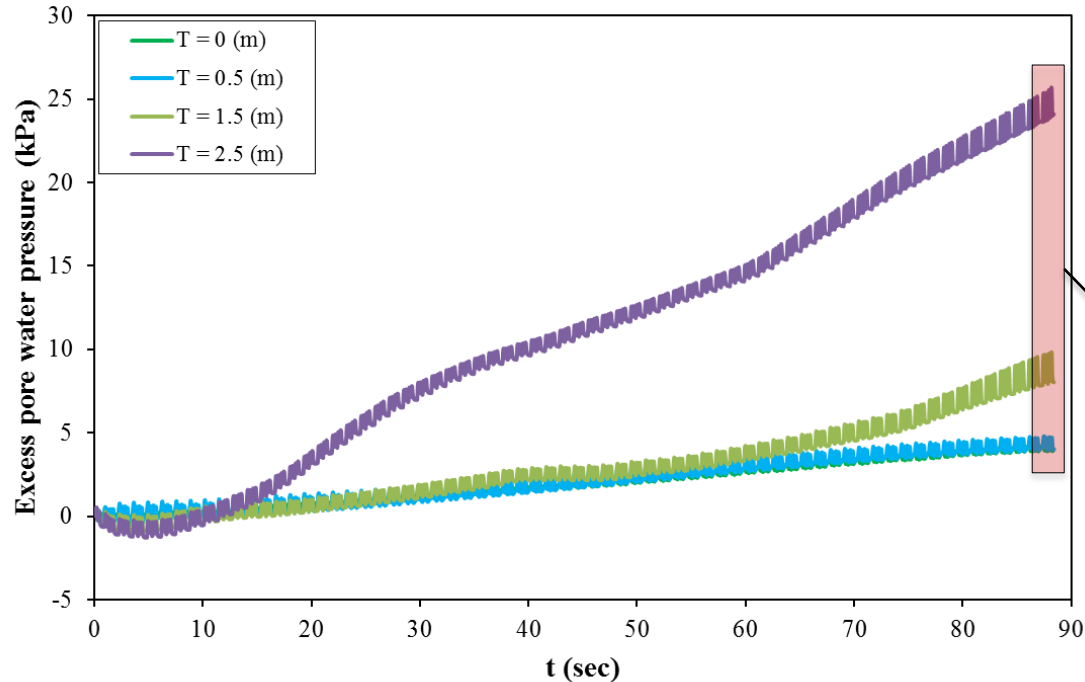
Practical implications

Point B



Practical implications

Point A



Research objective 3

Excess pore pressure generation in fine granular materials-A laboratory study



Under cyclic loading

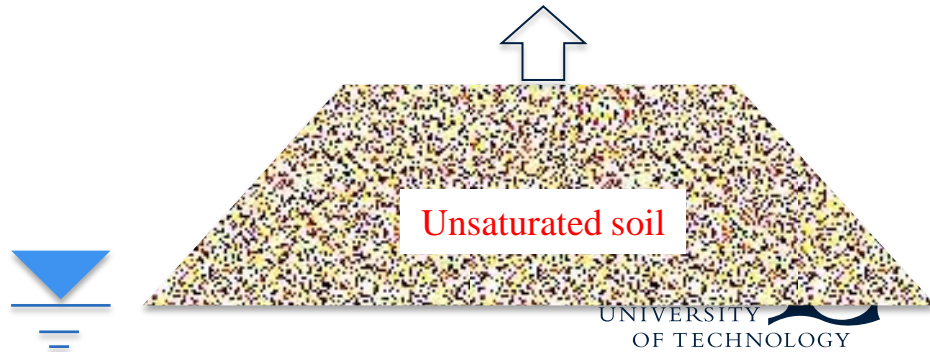


Pore water pressure generation in subgrade soils- A numerical study



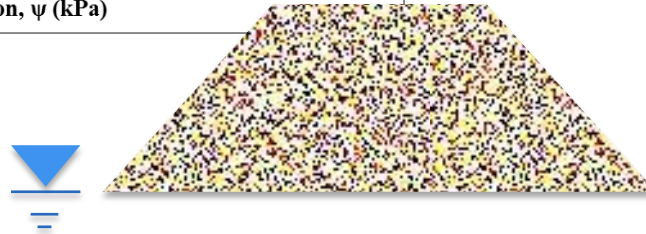
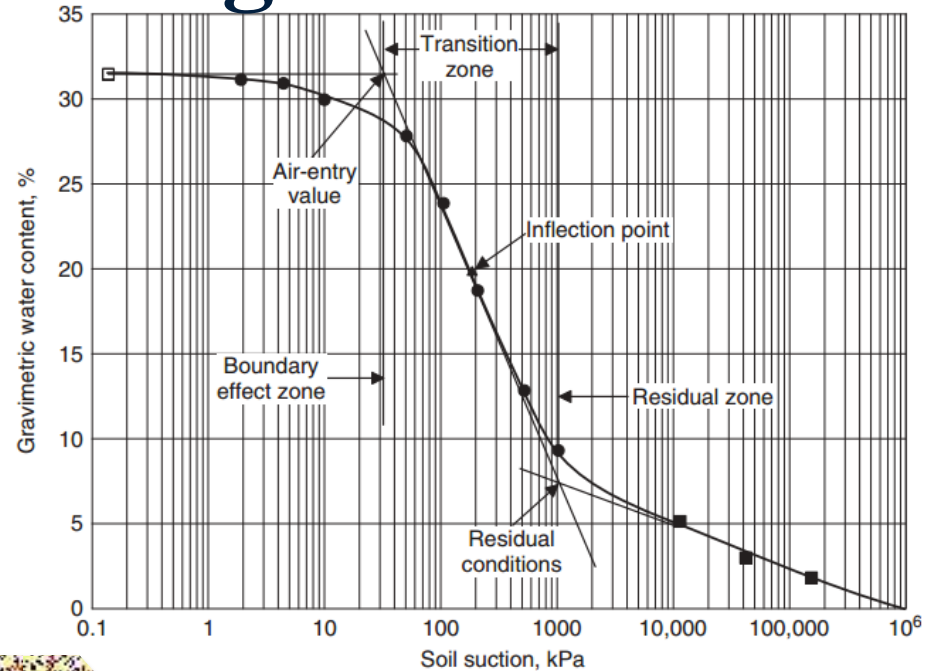
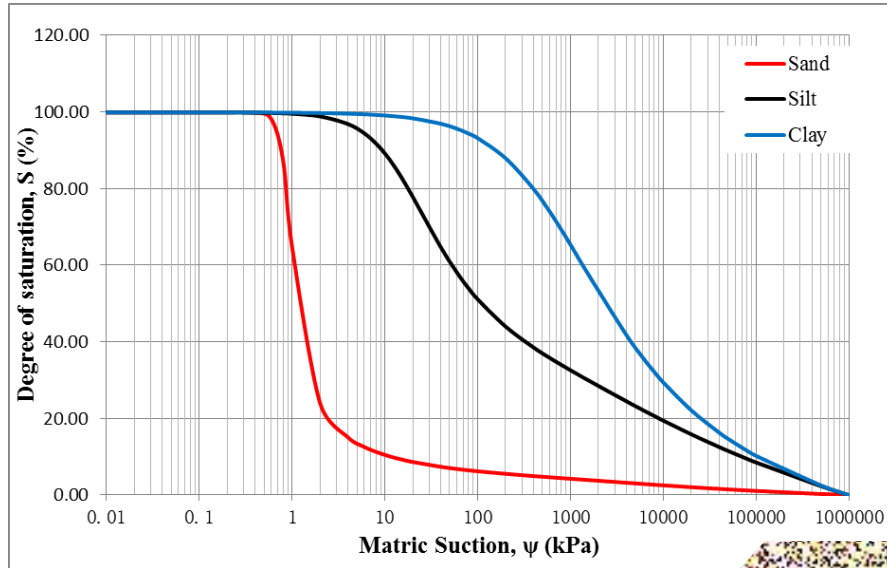
How unsaturated soil characteristics affect to pore water pressure generation:

- Air entrance values
- Rate of water extraction
- Residual saturation



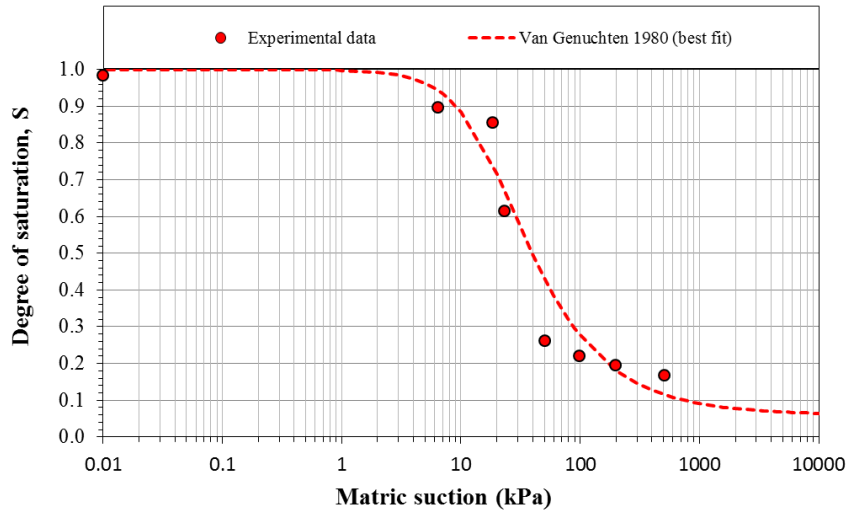
Research background

Fredlund, H. et al., 2012

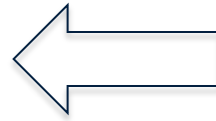


Methodology

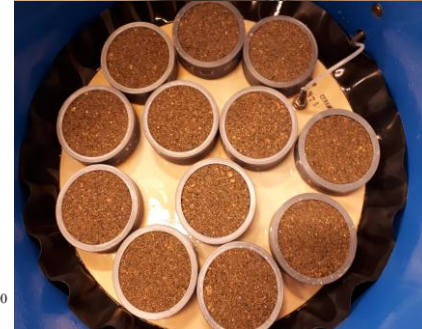
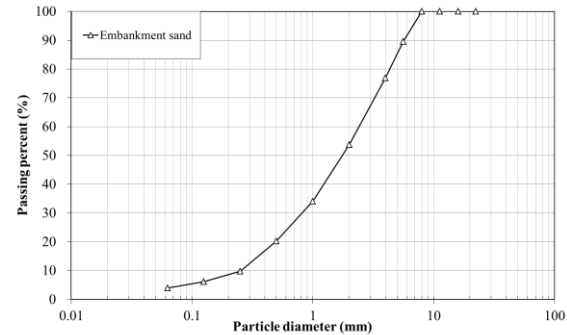
Control case



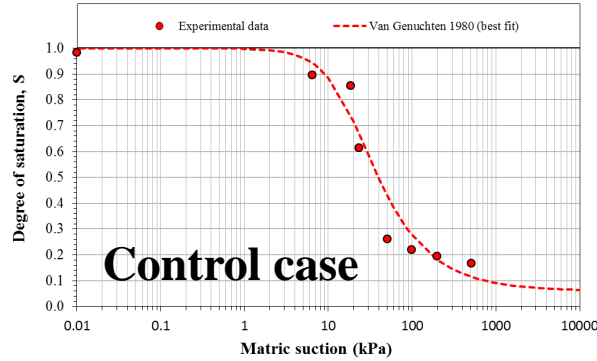
LAB & Calibration



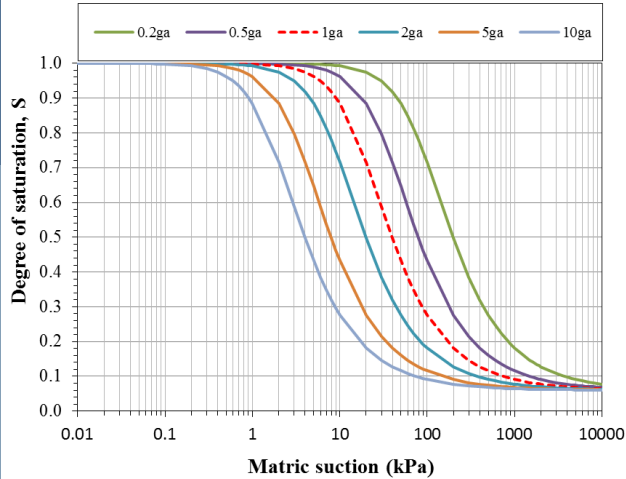
Curve fitting



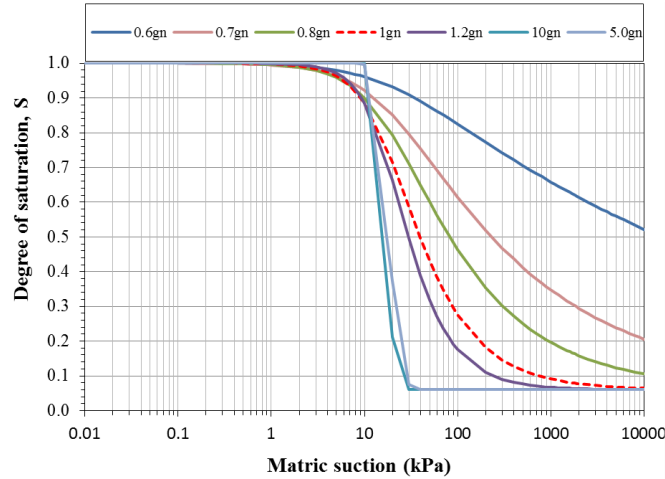
Methodology



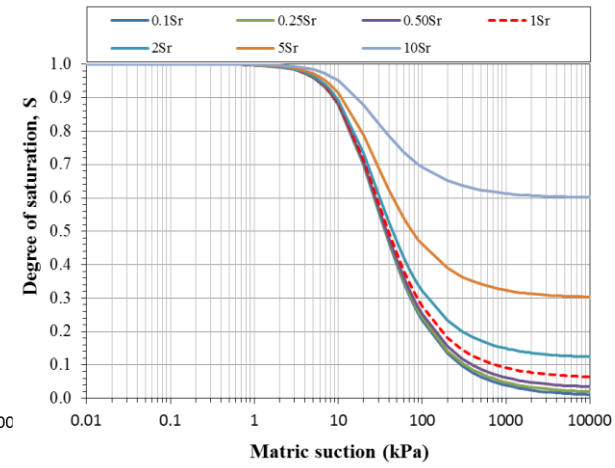
Effects of air entrance values



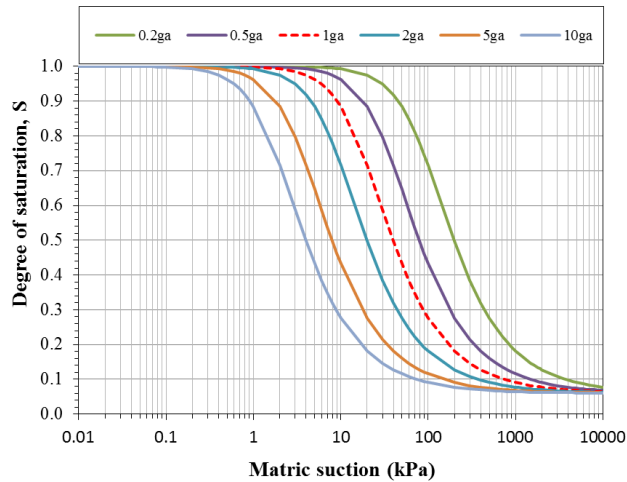
Effects of Rate of water extraction



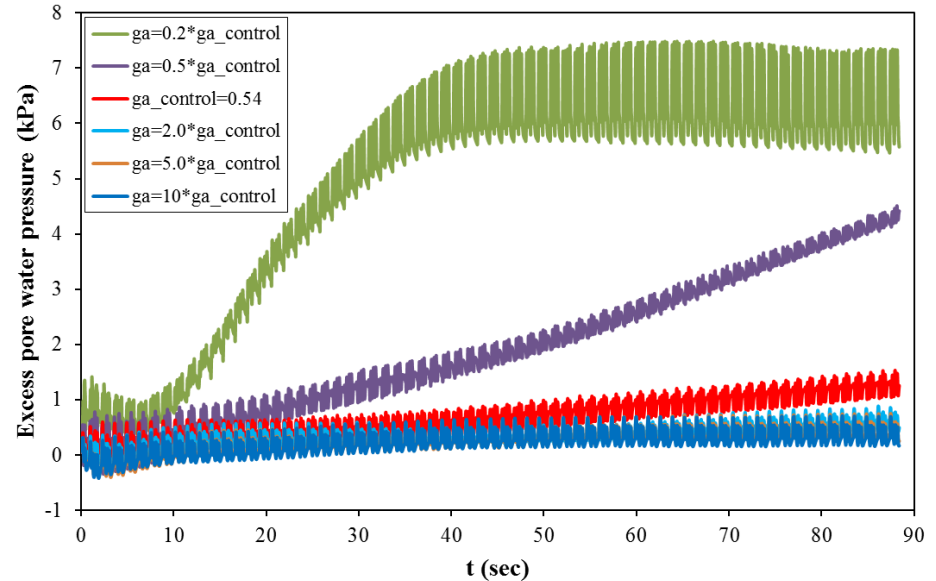
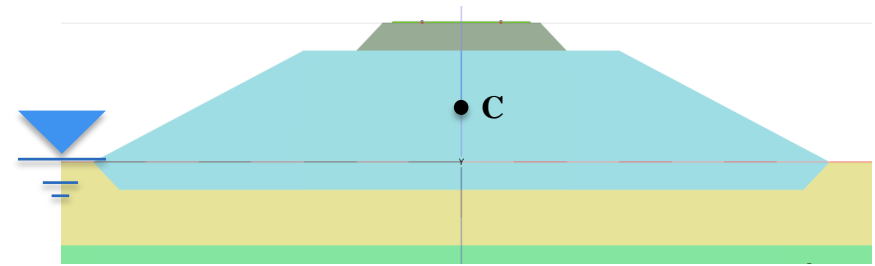
Effects of Rate of Residual saturation



Effects of air entrance values



Point C



Summary

- From cyclic triaxial tests (LAB)
 - Excess PWP and axial strain **accumulates over time** due to **cyclic loading**
 - The **accumulations are significantly dependent** on CSR
 - Relationship between excess PWP and accumulated strain is proposed

Summary

- From numerical studies

- Excess pore water pressure build-up during train passing: **both saturated and unsaturated zones**

- + Saturated zone: fast and significant build-up excess pore water pressures

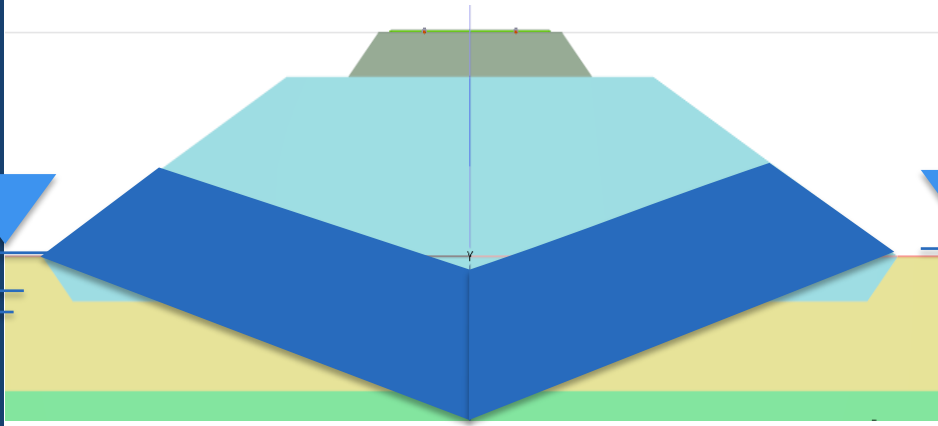
- + Unsaturated zone: less than in the saturated zone

- but excess pore water pressures **can still built-up depending on the embankment conditions**

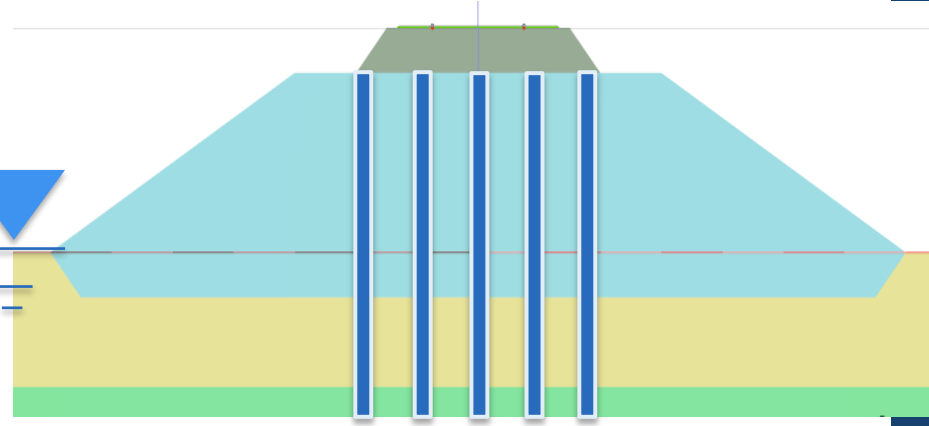
- Unsaturated soil characteristics (**Air entrance values, Rate of water extraction, Residual saturation**) also affect to pore water pressure

generation.

Further studies

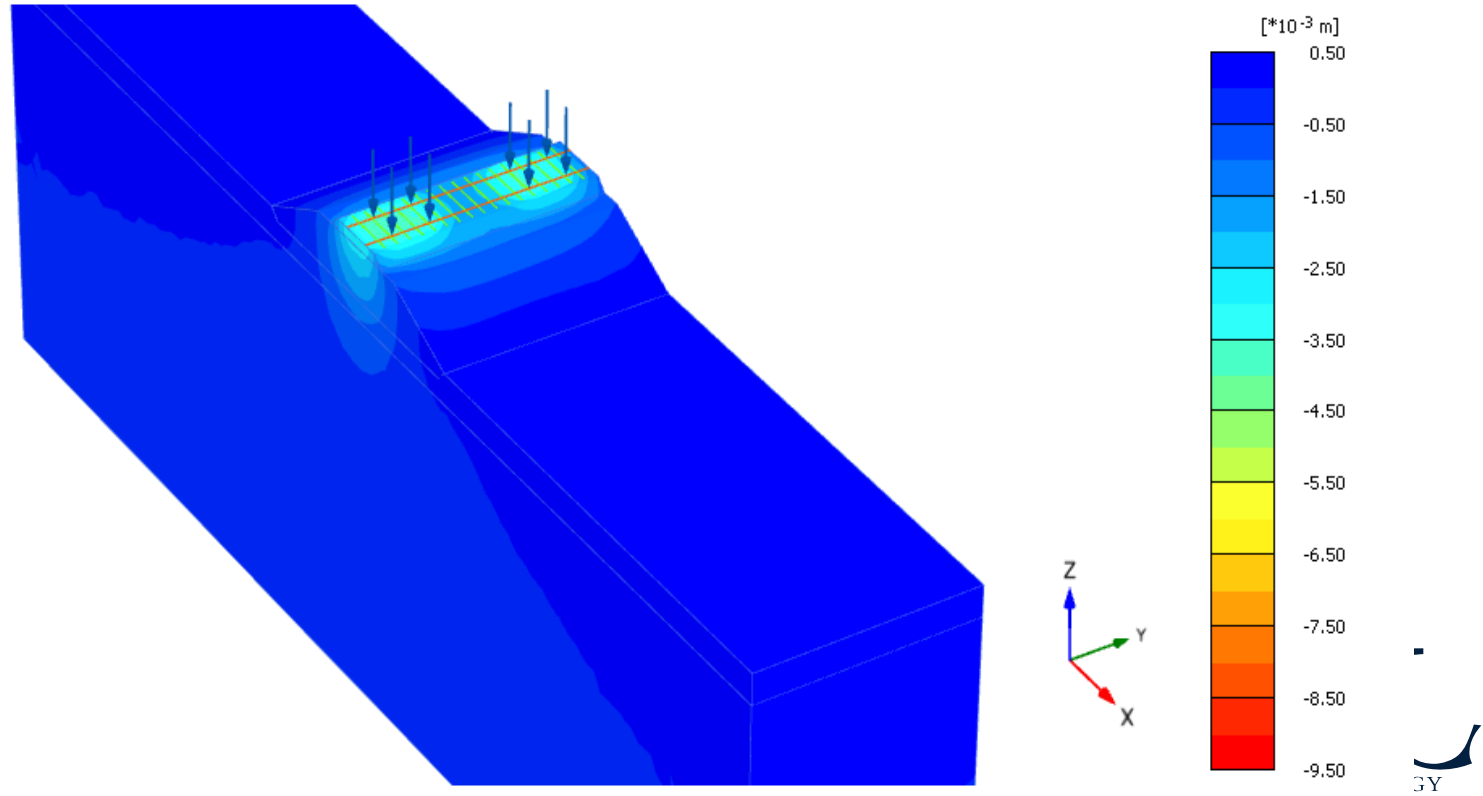


Chemical stabilization



Prefabricated Vertical Drains (PVD)

Further studies



Tack!



Project requirements	Project outcomes	Comments
<input type="checkbox"/> Conference, workshop presentation: 1	<input type="checkbox"/> Conference proceeding: 1 <input type="checkbox"/> Workshop presentation: 2	OK
<input type="checkbox"/> Publications: 3	<input type="checkbox"/> Publications: 4 <input type="checkbox"/> Submitted manuscript: 1 <input type="checkbox"/> Prepared manuscript: 2	OK

Publications can be found

https://scholar.google.co.kr/citations?hl=en&user=N6XB5H4AAAAJ&view_op=list_works