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Measurement of Porosity Distributions during Erosion Experiments using Spatial Time Domain Reflectometry (Spatial TDR)

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presented by
K. J. Witt

Motivation

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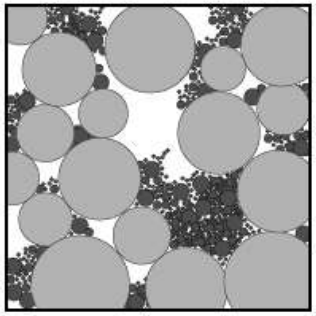
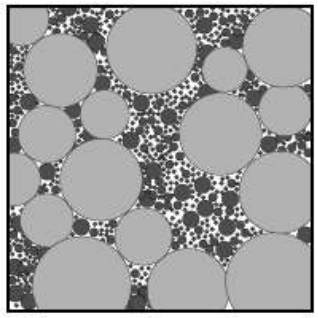
Microscale porosity changes due to erosion

Stage I



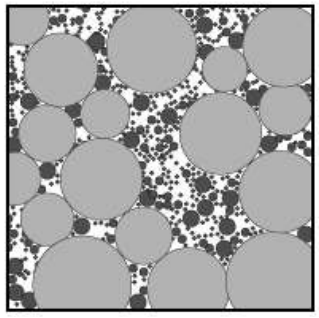
- basic condition
- primary fabric (skeleton, grey particles) with unstable erodible fine fraction
- laminar flow (small gradients)

Stage II



- critical hydraulic gradient
- loosening, mobilisation and redestribution of erodible fines (increase of porosity)
- turbulent flow (non-linear relationship v=f(i))

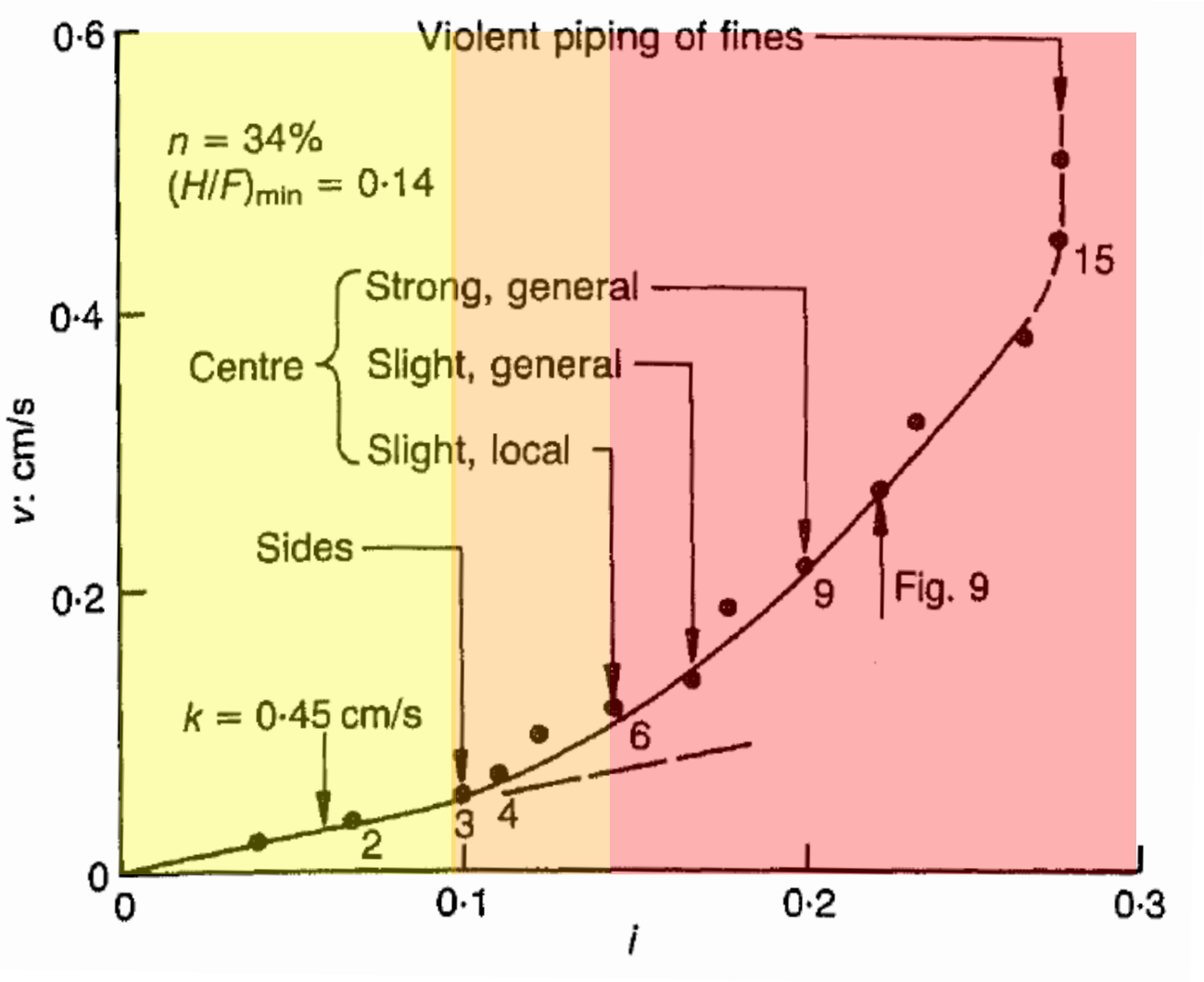
Stage III



- development of a fully fluidised bed (massive transport of erodible fines)
- piping like flow (convection cells)
- porosity waves with further increased i

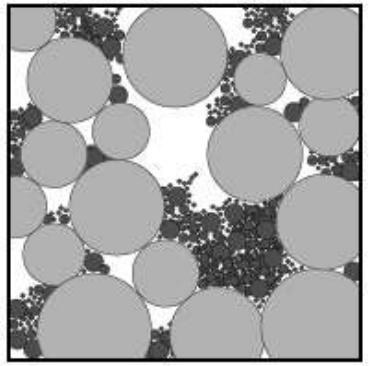
Motivation

Microscale porosity changes due to erosion

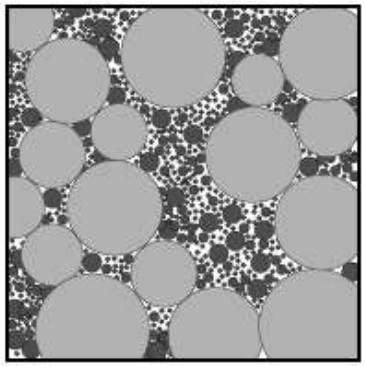


Quelle: Skempton A.W. & Brogan, J.W. (1994), Experiments on piping in sandy gravel, Géotechnique, 44, 449-460.

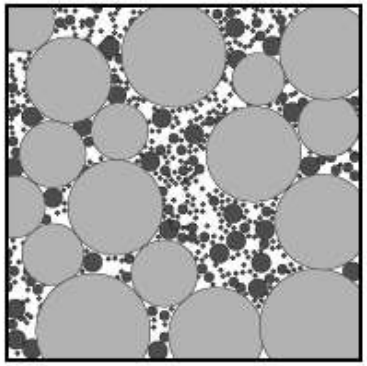
Stage I



Stage II



Stage III



Motivation

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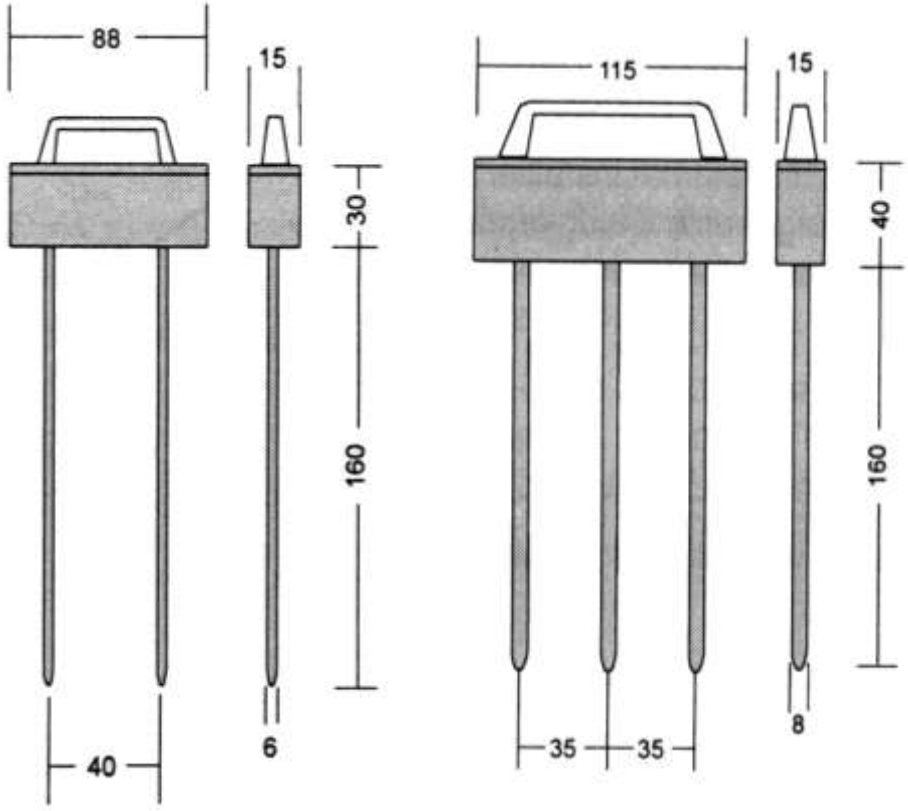
- Erosion processes are always accompanied by changes in porosity.
- Changes in porosity provide valuable information improving the understanding of erosion processes and providing data for the development of mathematical models.
- So far, no measurement method is available measuring porosity changes during erosion processes in a reasonable high resolution in space and time.
- Time Domain Reflectometry provides the possibility to measure transient changes in spatial porosity.

Introduction

- Time Domain Reflectometry is an electromegnetic measurement method providing information about the electric permittivity of soils, which are used to retrieve water content informations.

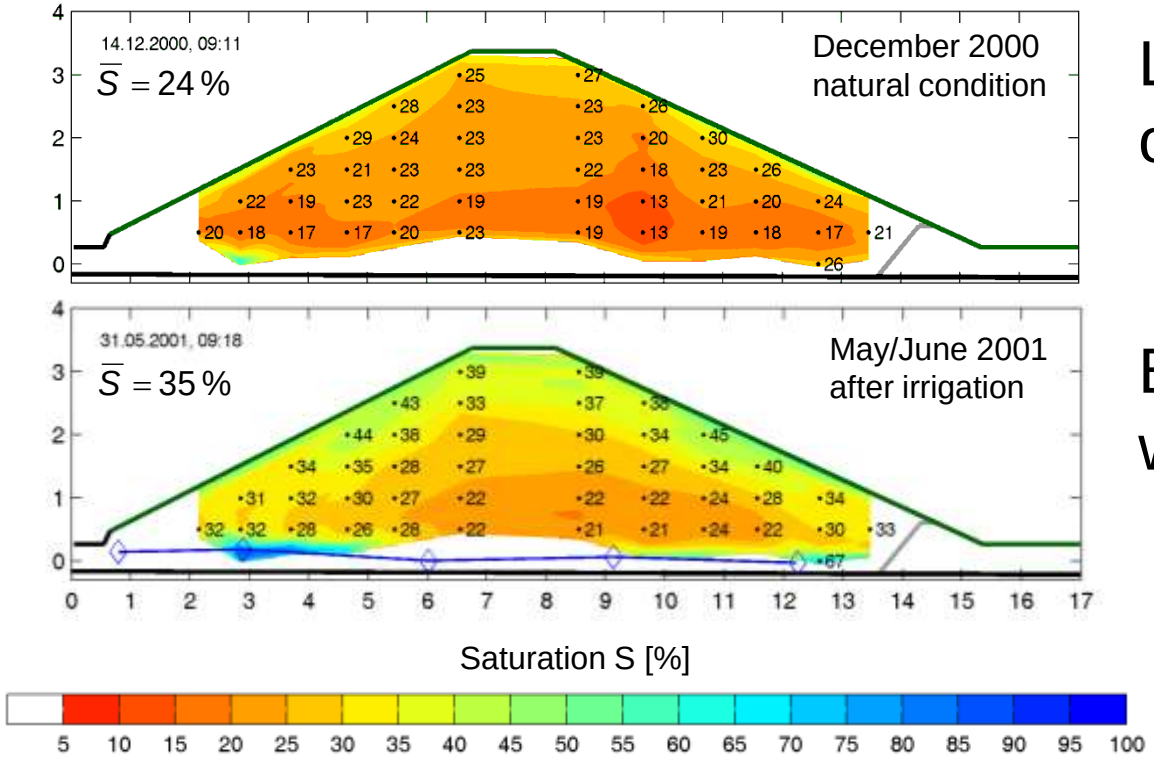


Conventional rod probes for measuring water contents of soils.

Source:
IMKO Micromodultechnik GmbH

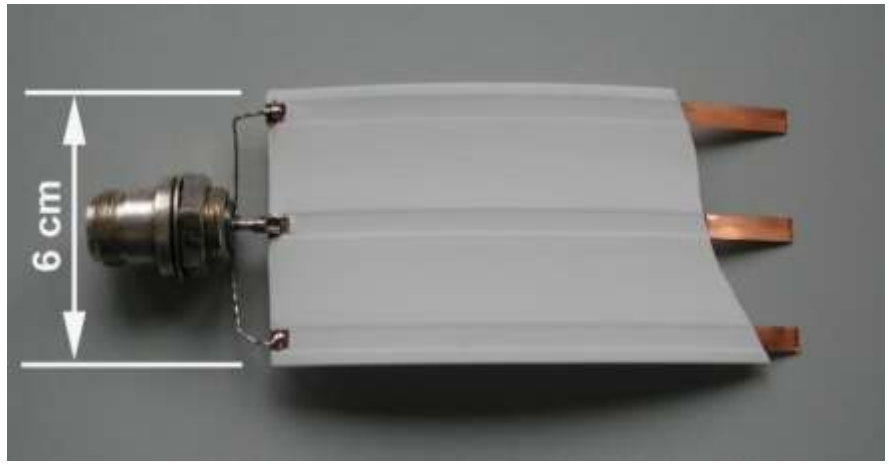
Introduction

- Spatial TDR offers the possibility to measure spatial permittivity distributions (providing e.g. water content distributions) along elongated transmission lines.



Left: Water content measuremtents on a natural scaled dike model

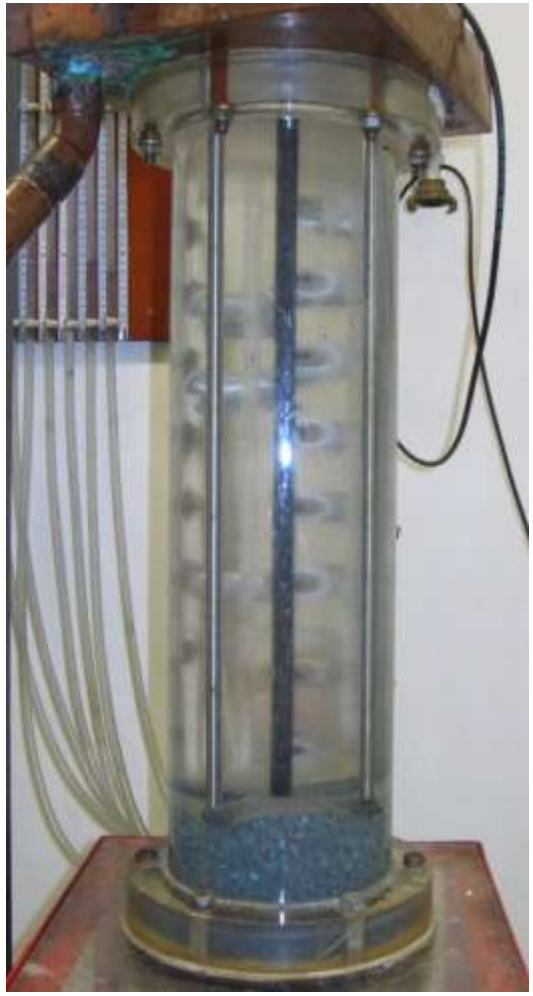
Below: Flat ribbon cable used for water content measurements



Scheuermann et al. 2009. Water Resources Research.

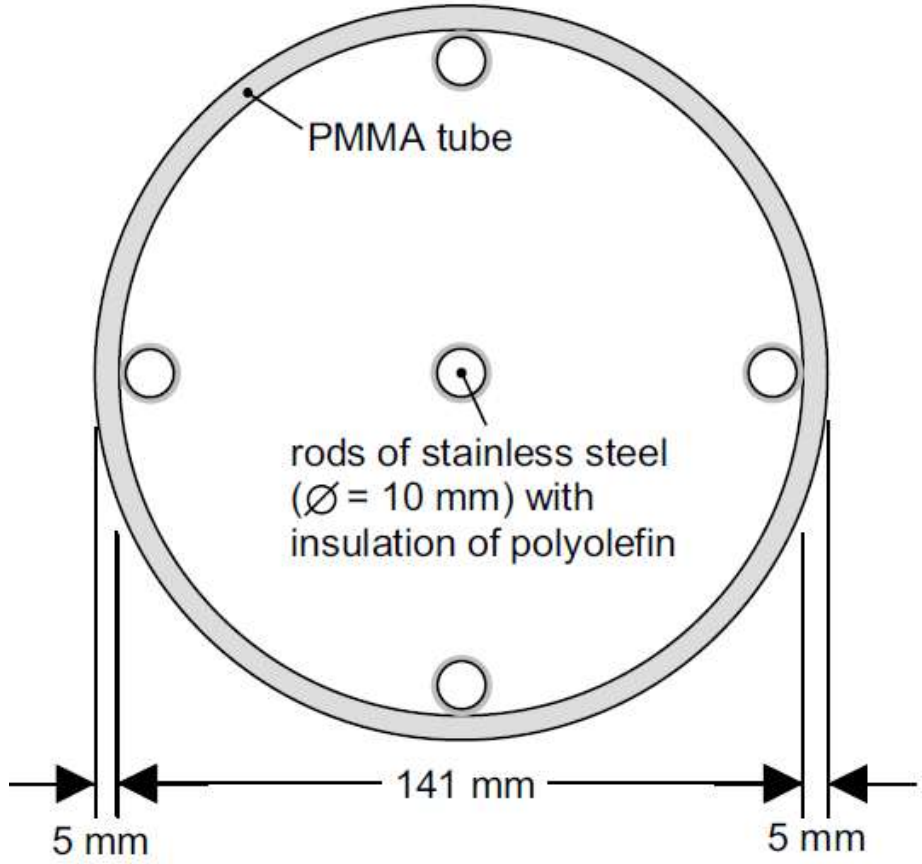
Feasibility Study

- Five rod probe in plexiglass cylinder is used to measure porosity changes along sample in cylinder.



Left: Five rod probe in plexiglass cylinder

Below: Cross-section through cylinder with probe



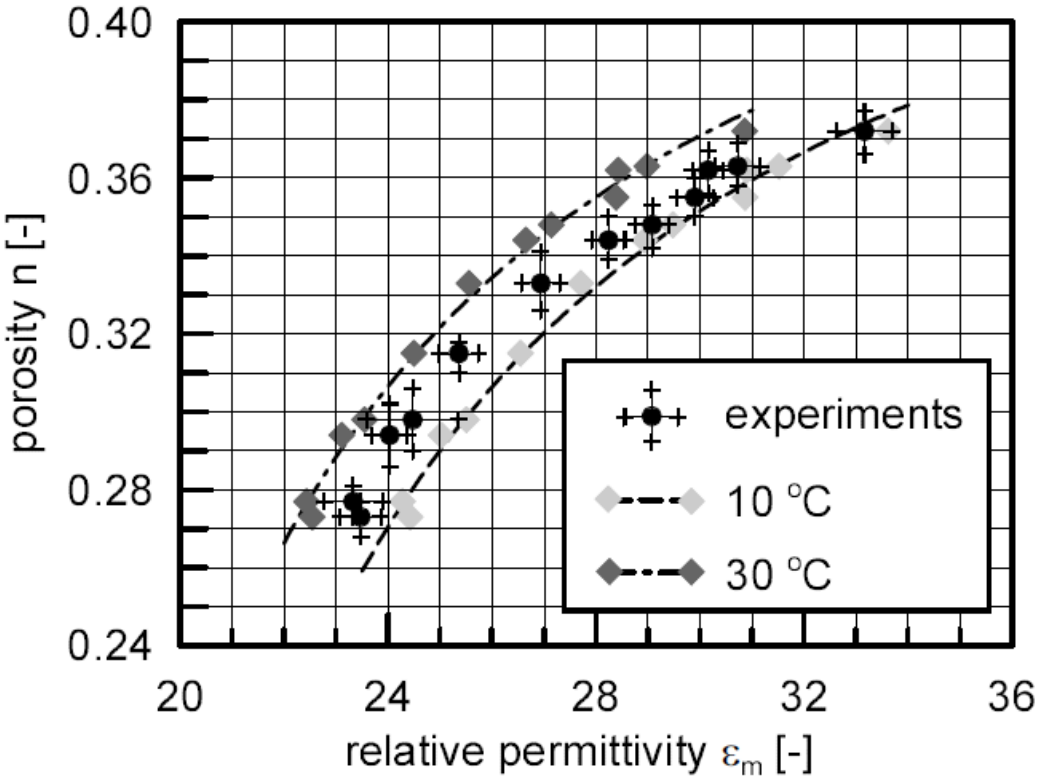
Scheuermann 2012. Geotechnical Testing Journal.

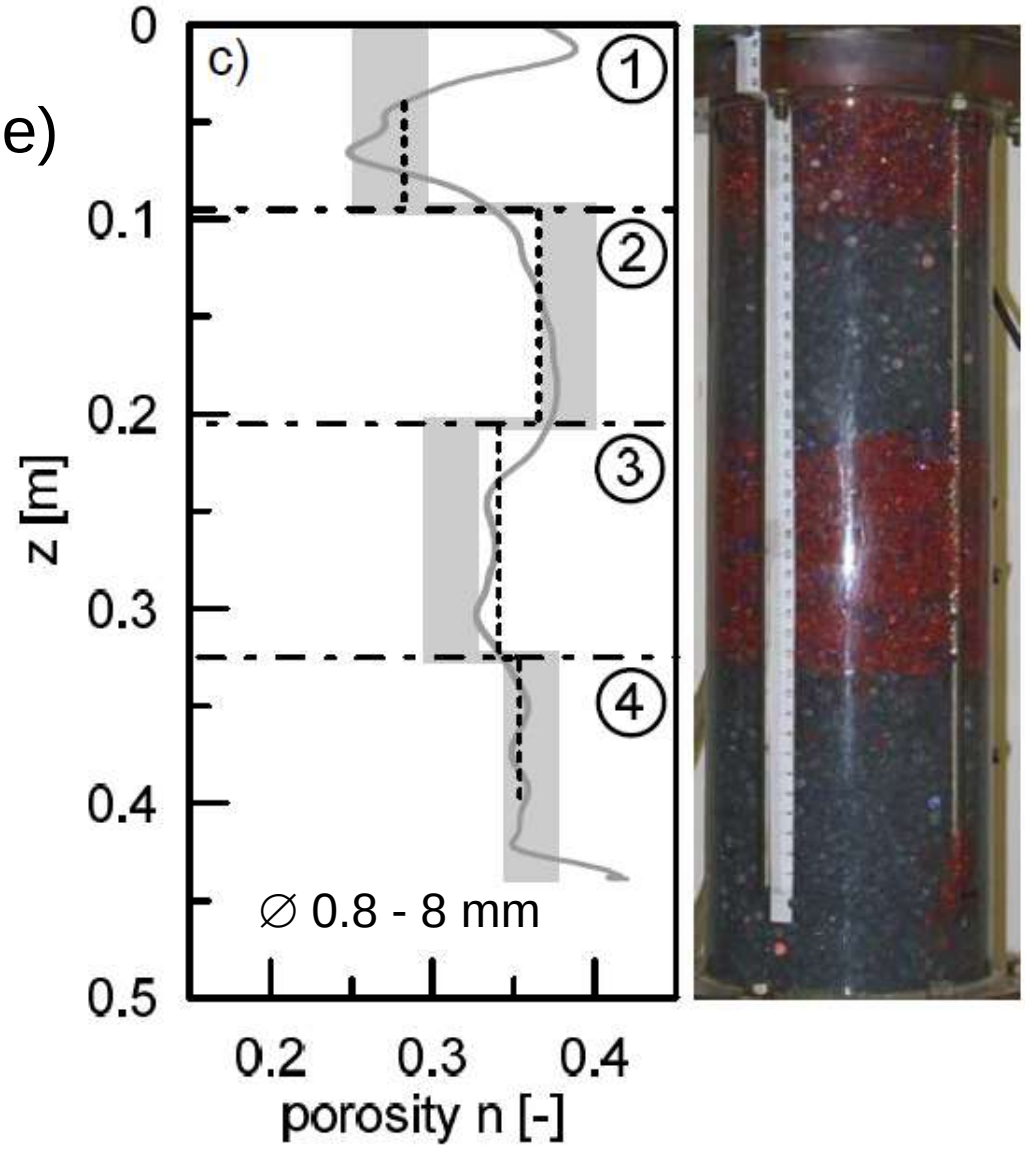
Feasibility Study

- Comparison between porosity measurements and calculated porosities.

Right: Measurement result (dashed line) in comparison with calculated porosity band (light grey columns).

Below: Calibration curve

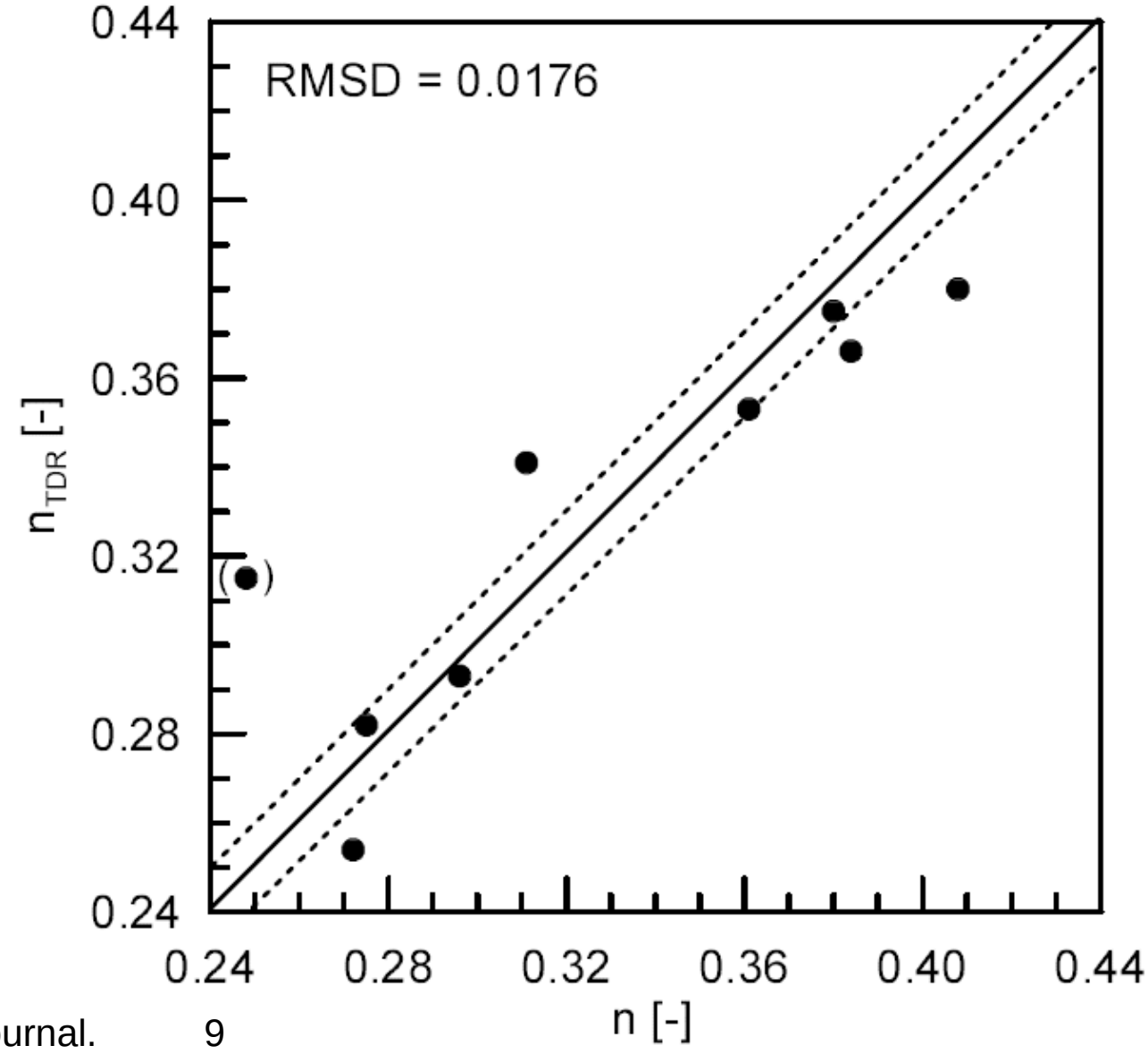




Scheuermann 2012. Geotechnical Testing Journal.

Feasibility Study

- Resulting accuracy within feasibility study



Scheuermann 2012. Geotechnical Testing Journal.

Application

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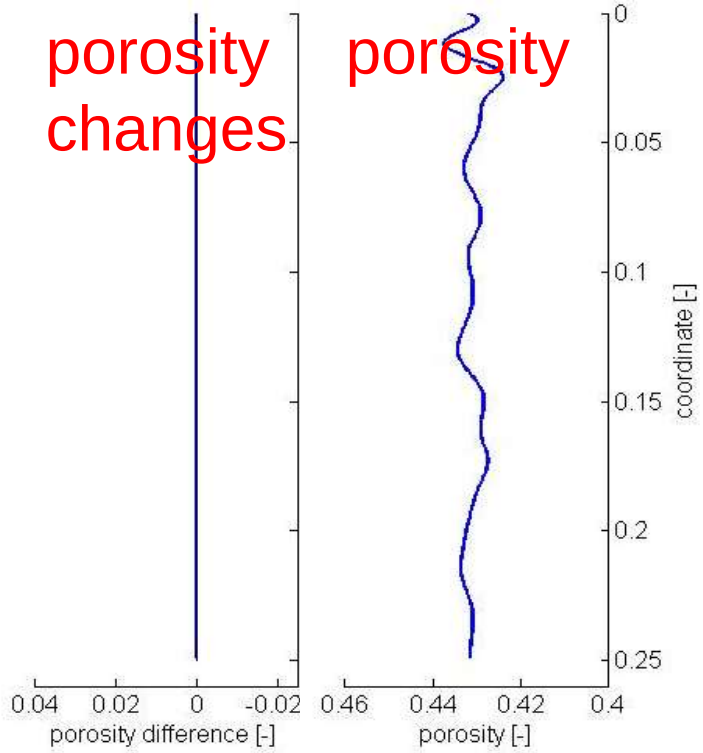
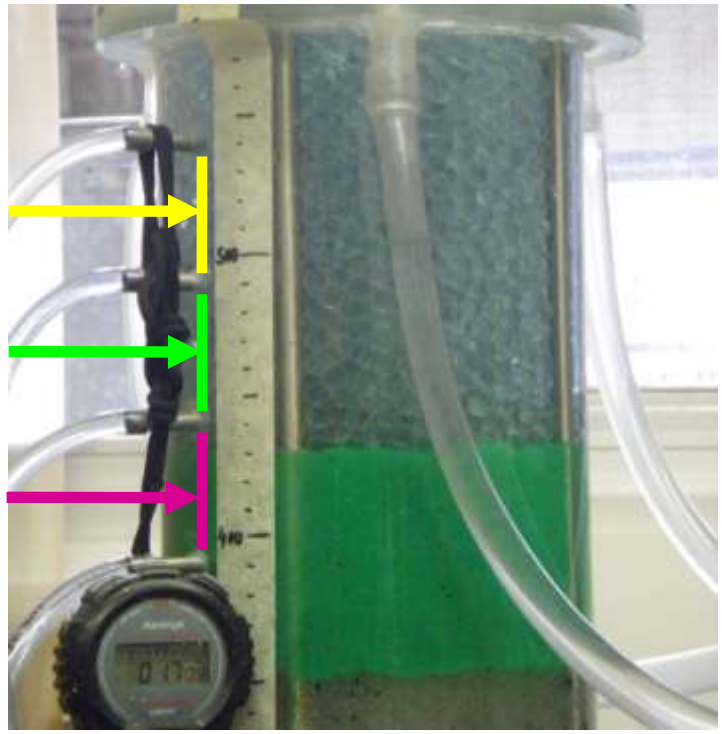
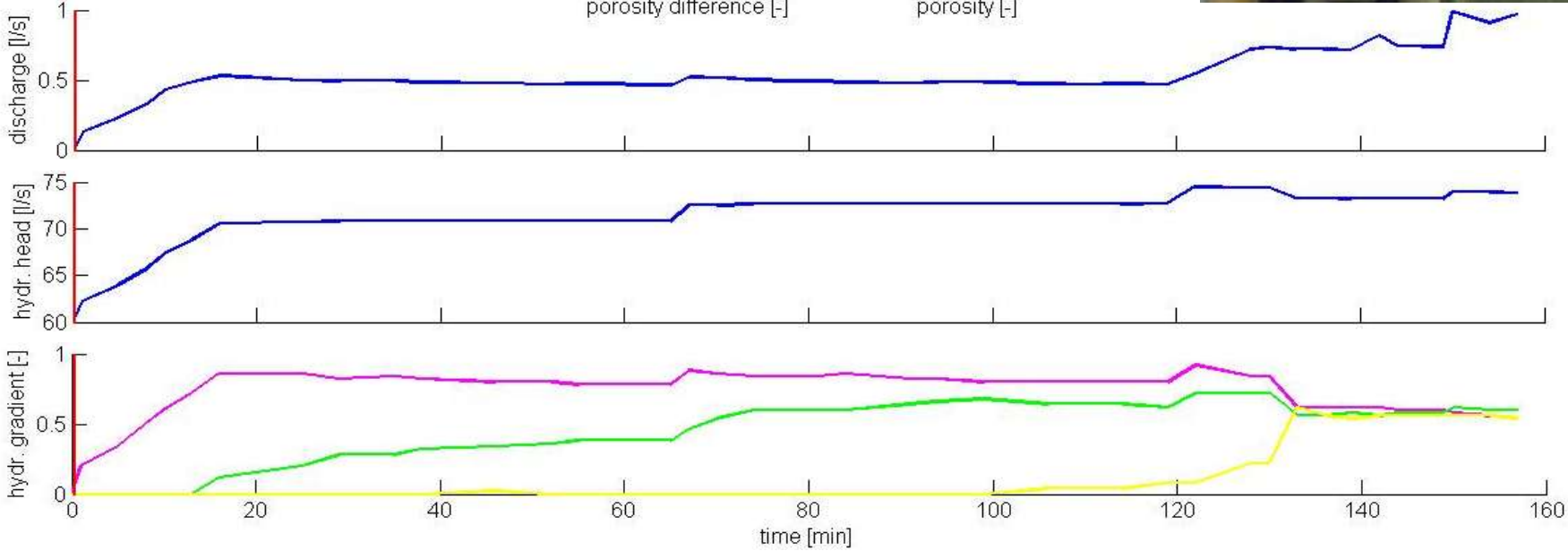
Preliminary investigations







discharge

hydraulic head

hydraulic gradient

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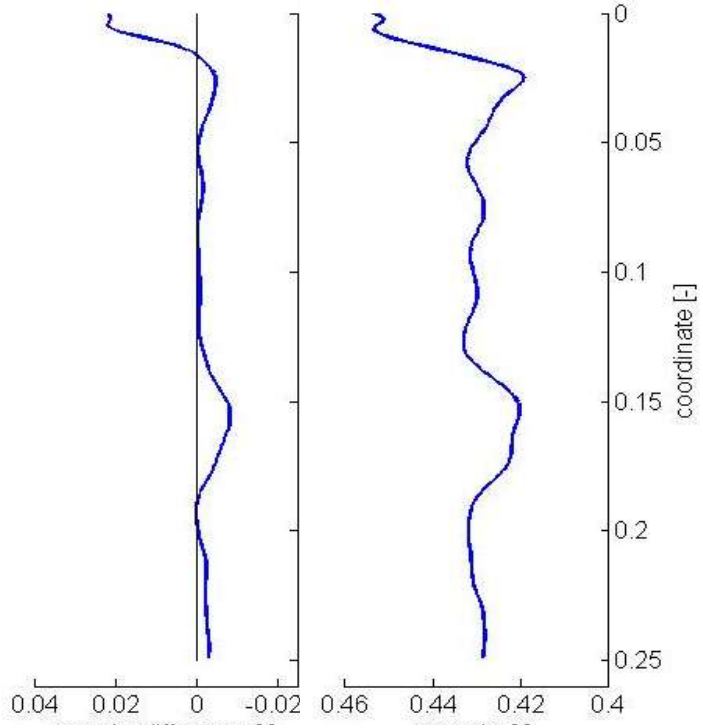
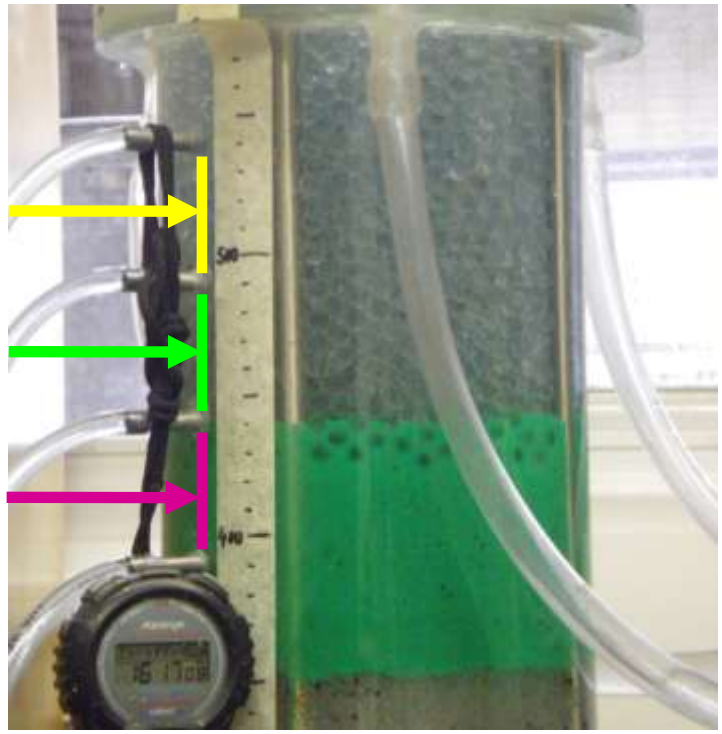
Fluidization of fine particles starts at a gradient
$i = 0.89 \pm 0.03$





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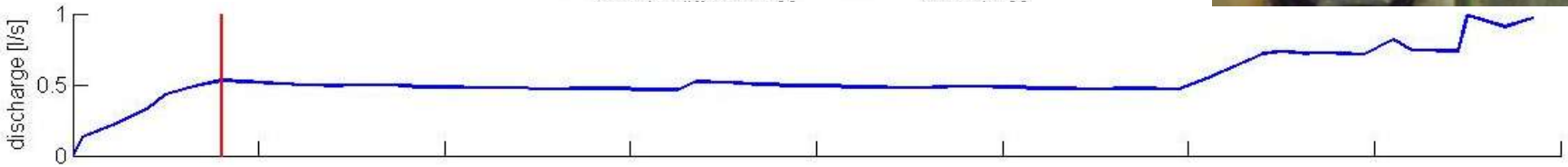
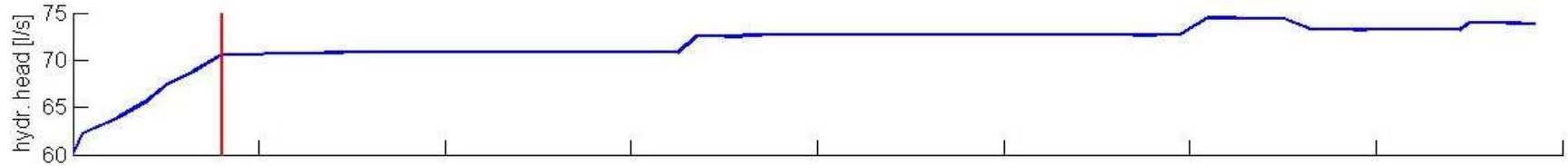


discharge

h



hydraulic head

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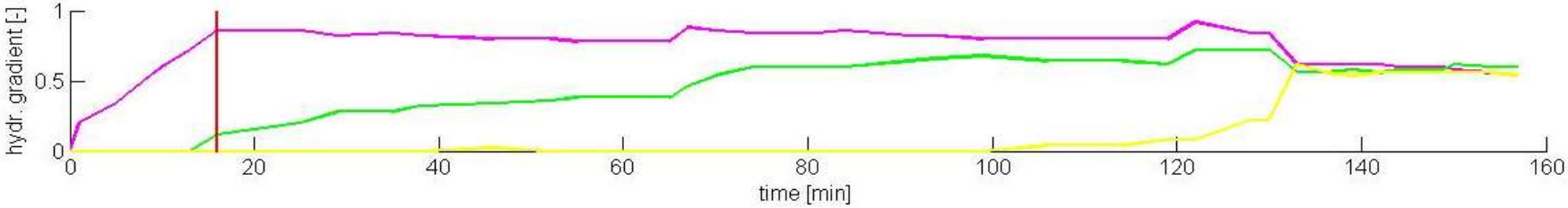

hydraulic gradient

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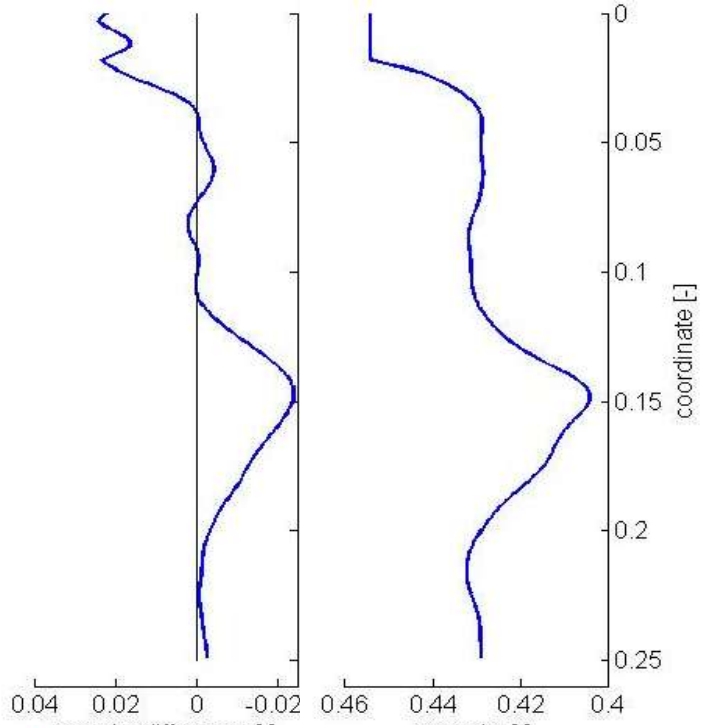

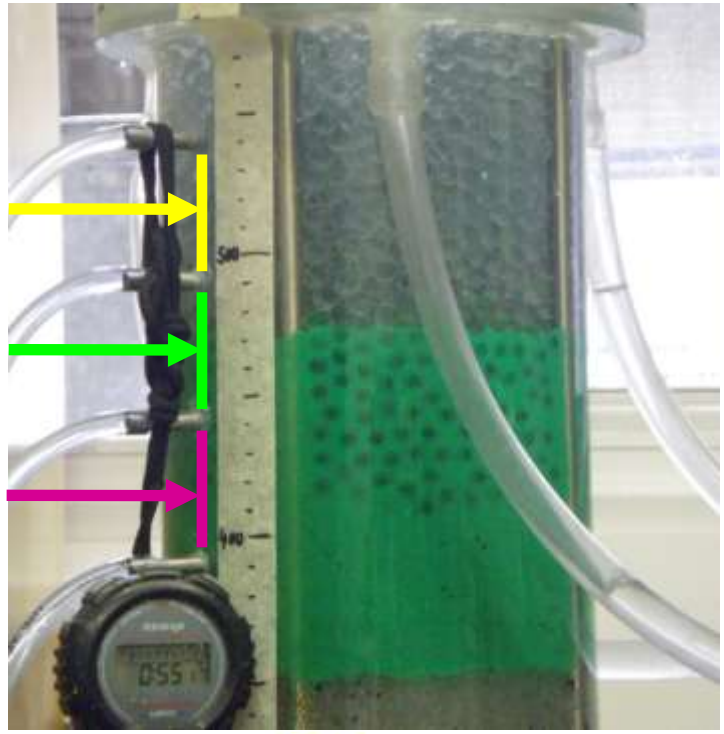

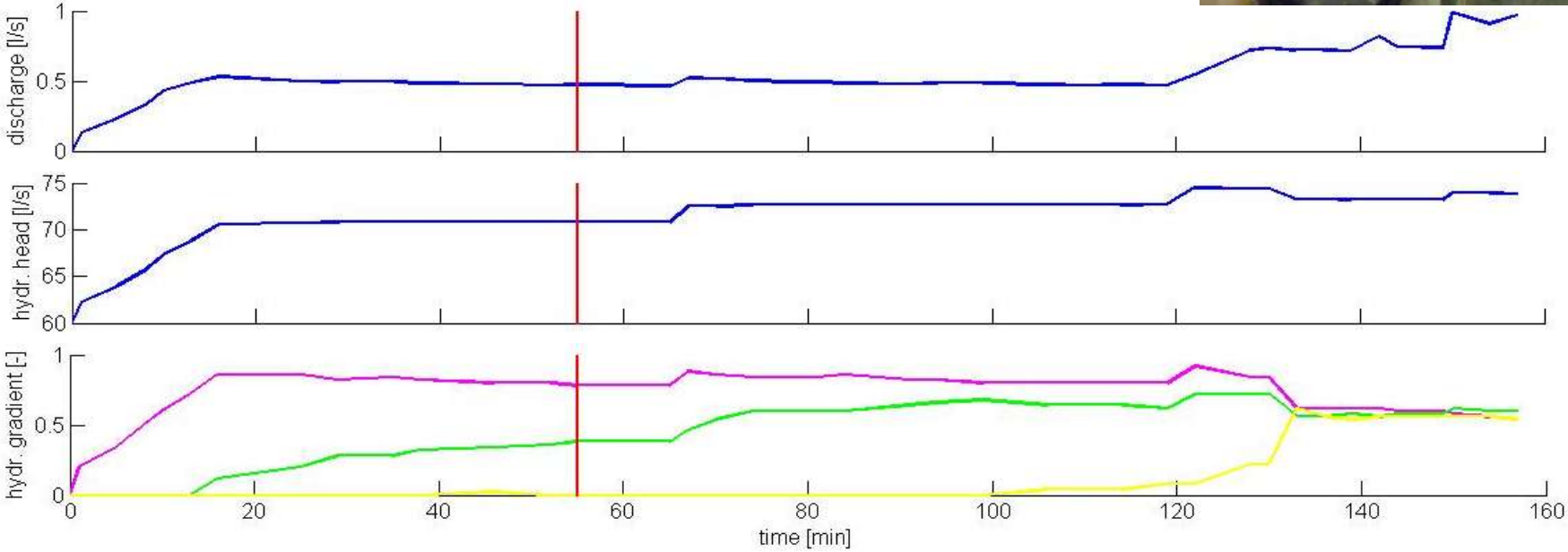

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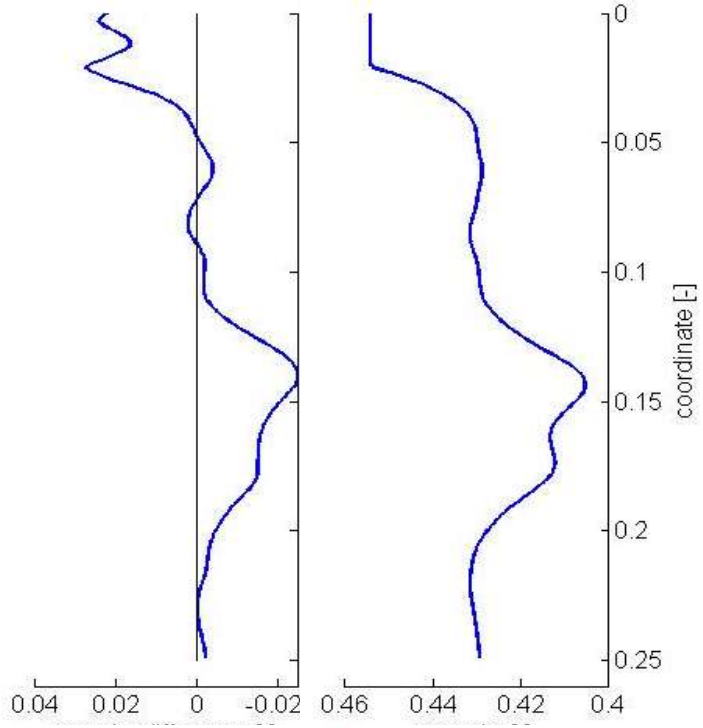

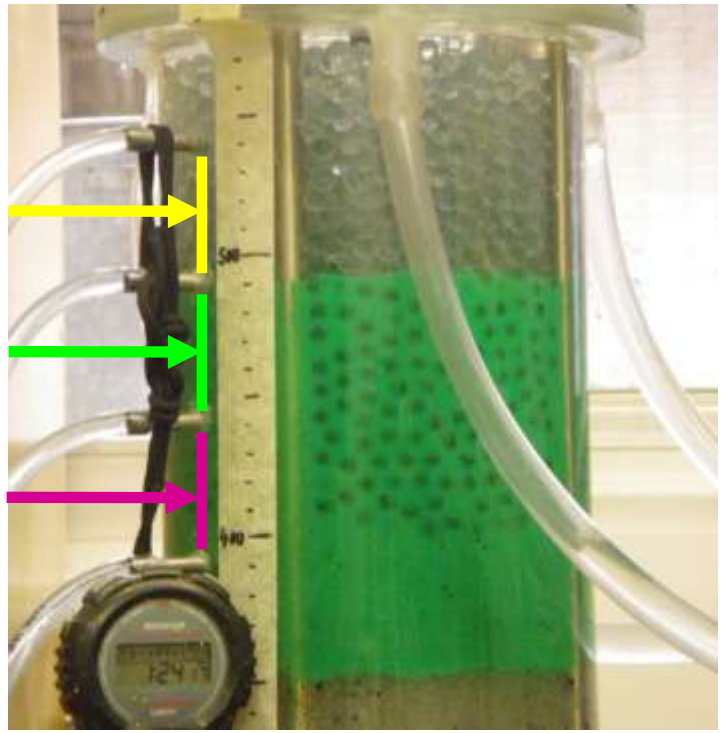

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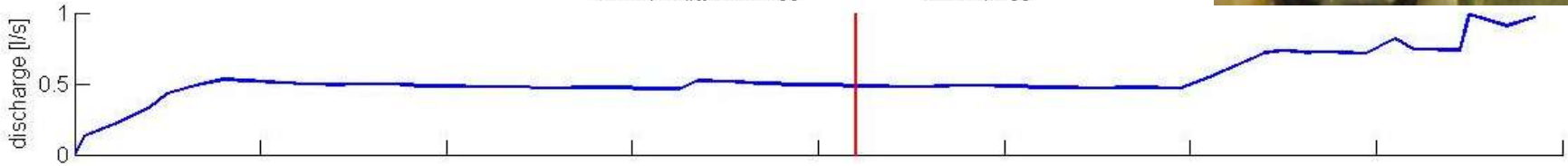

discharge

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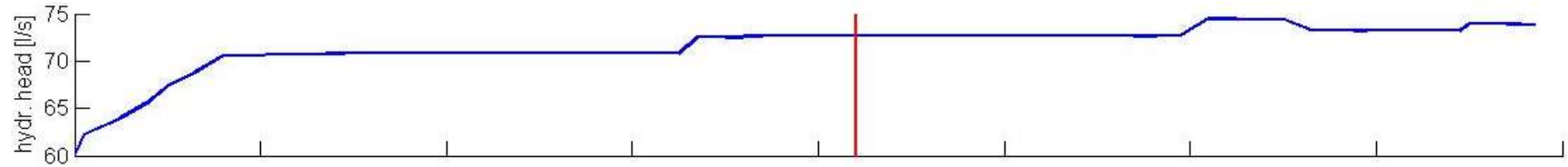

hydraulic head

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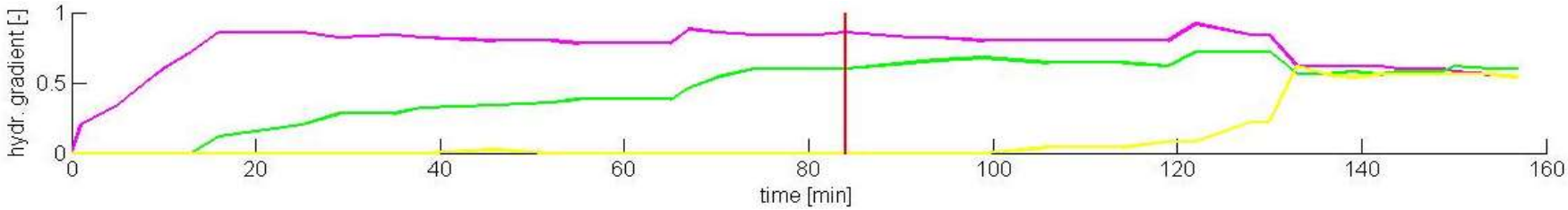

hydraulic gradient

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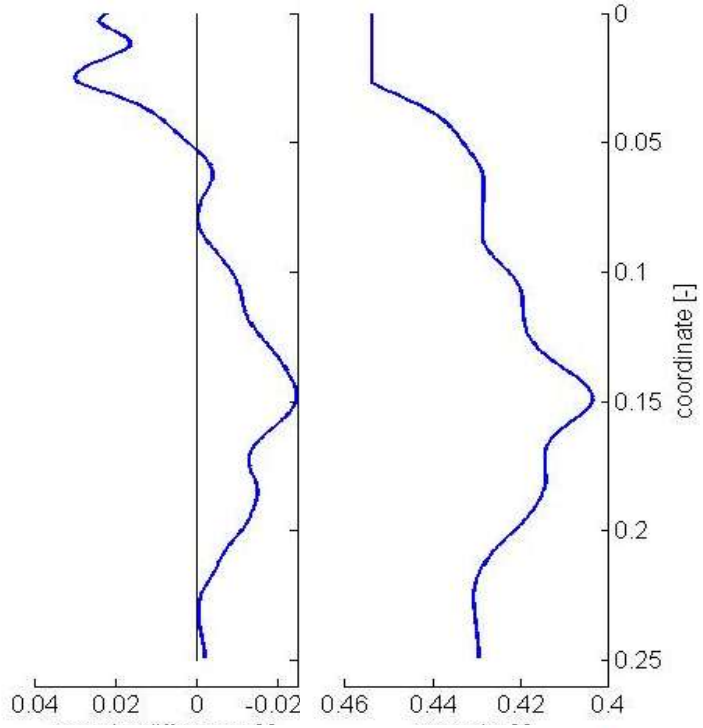

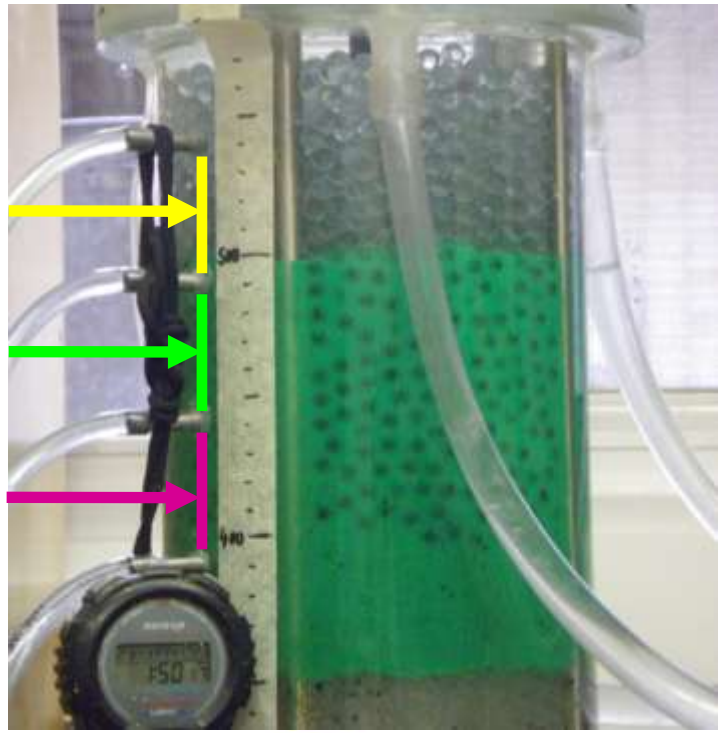

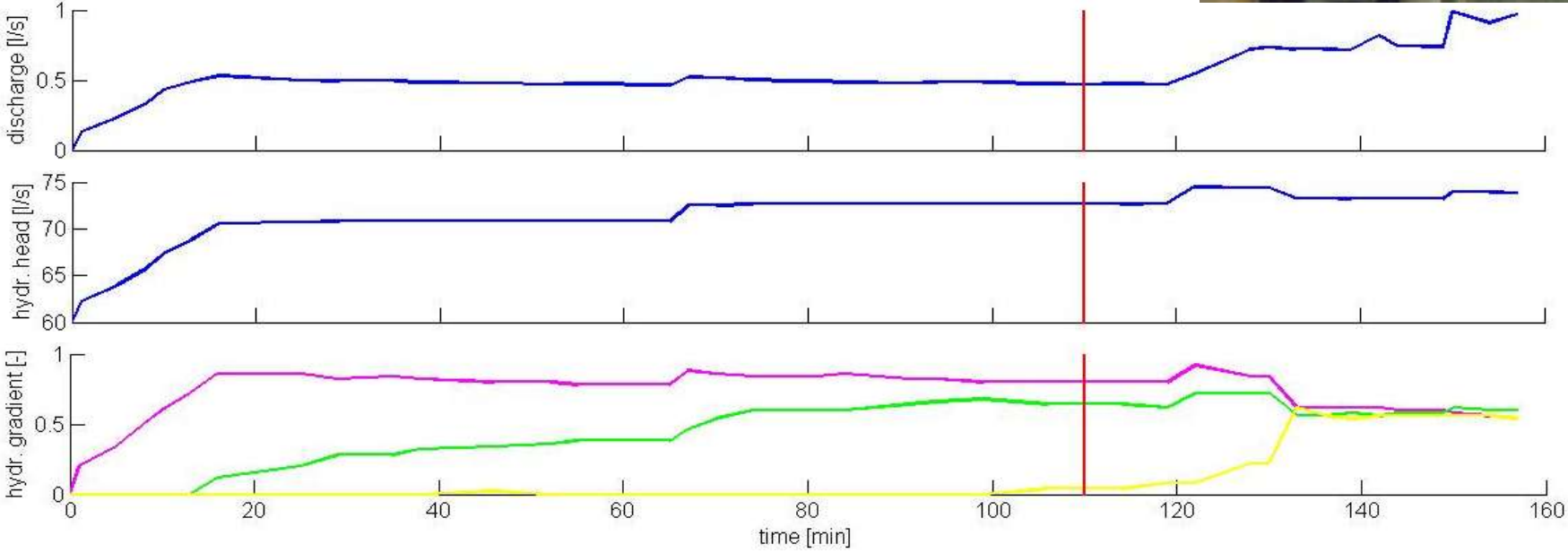

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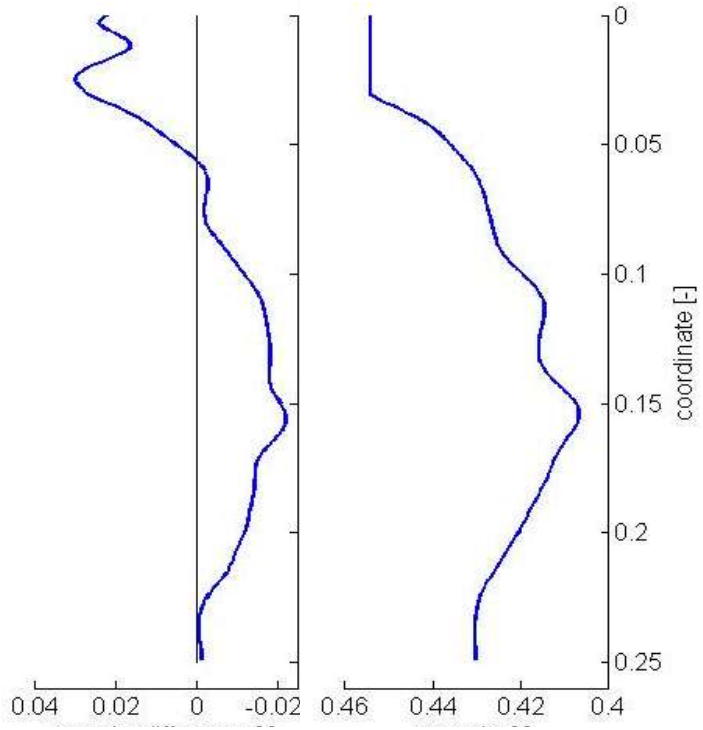

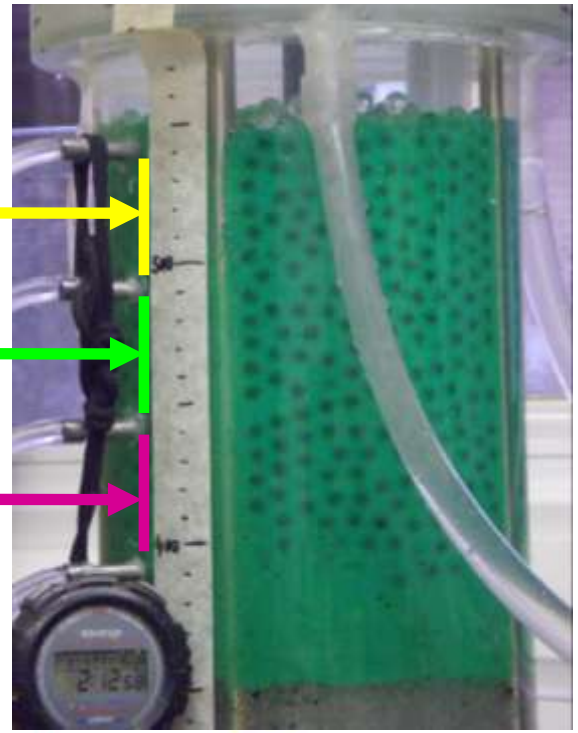

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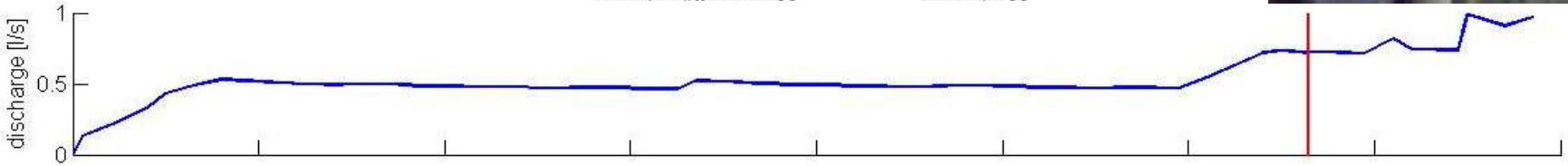

discharge

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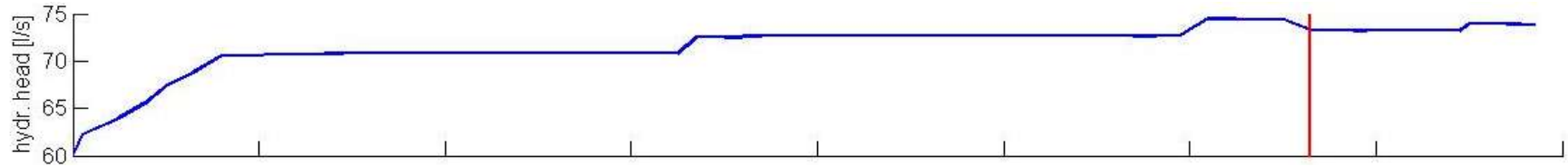

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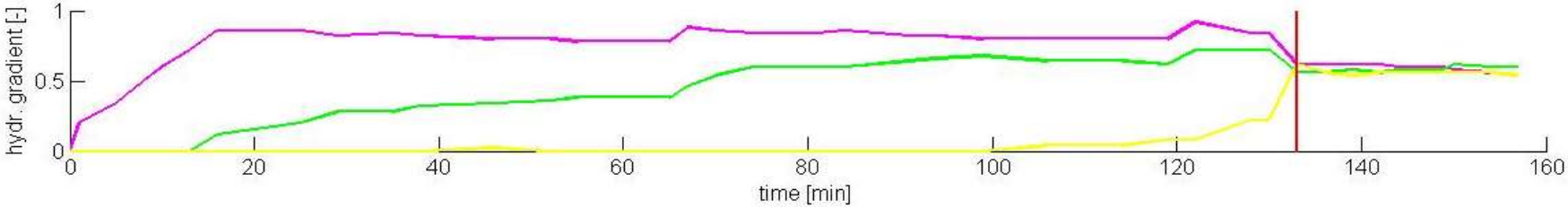

hydraulic gradient

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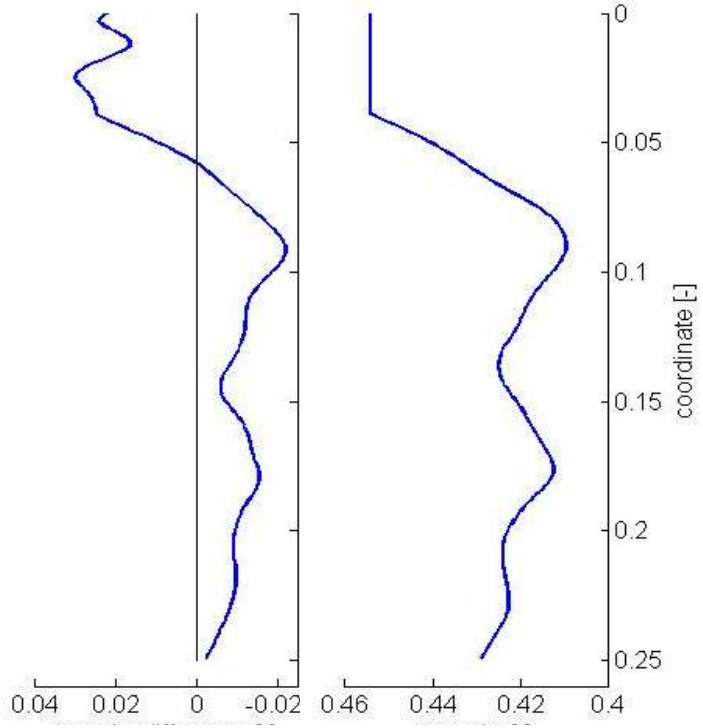

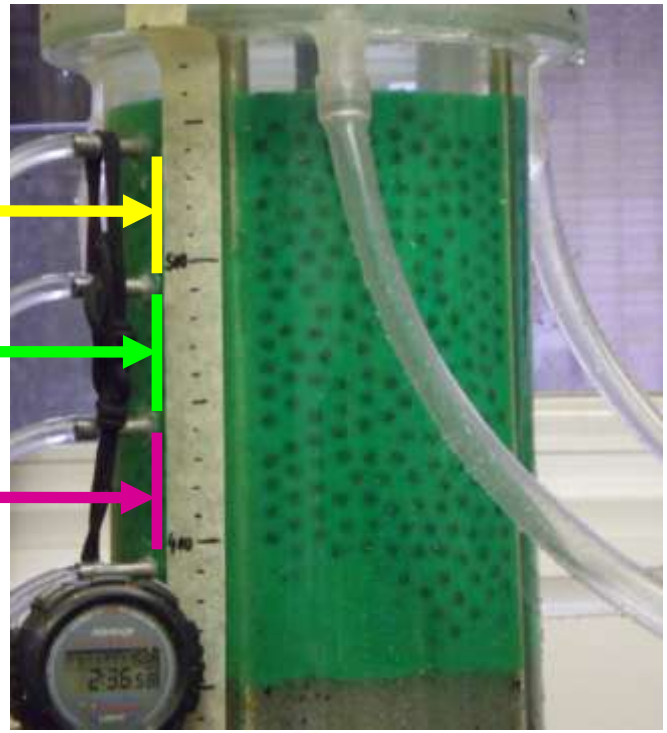

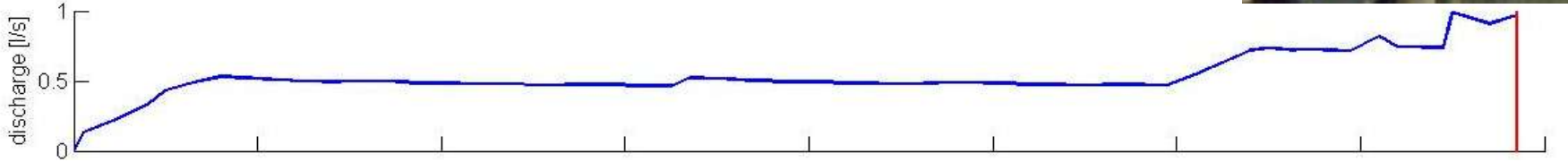

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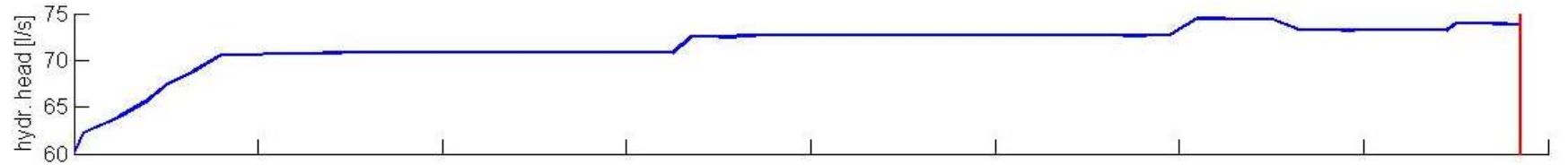

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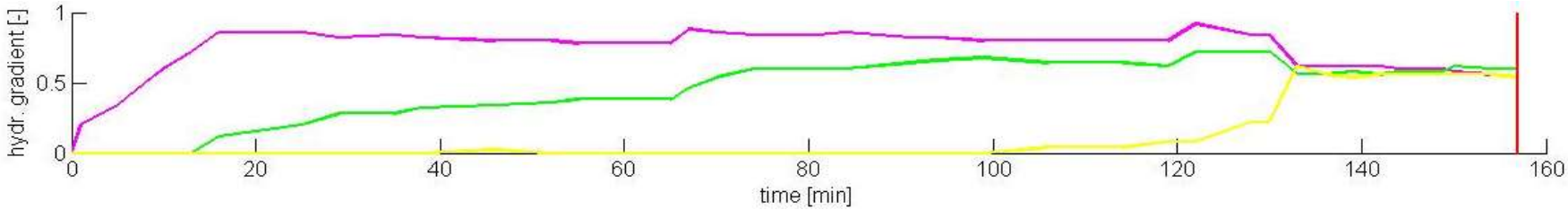

hydraulic gradient

Summary

- Measurements of porosity distributions are possible within cylindrical samples using spatial TDR with reasonable resolution (in space and time) and accuracy.
- A five rod probe was used in preliminary investigations for the measurement of porosity distributions during erosion test.
- Future investigations include the development of a new sensor in combination with an hydraulic set-up for the implementation of erosion experiments.
- Measured porosity distributions are used for improving the understanding of erosion processes and the development of mathematical models.

Achknowledgement

- ARC Discovery Project (DP120102188)
  Hydraulic Erosion of Granular Structures: Experiments and Computational Simulations
- Go8 / DAAD Personnel Exchange Project
  Experimental and Numerical Investigation of Erosion of Granular Media