REMEDY
Et BegrensSkade prosjekt

Installation effects from pile drilling – experiences from case studies

Påldag 2019, 16. mai Göteborg

Einar John Lande, NGI

Agenda

- Remedy
- Case studies
- Model test – drilling in sand

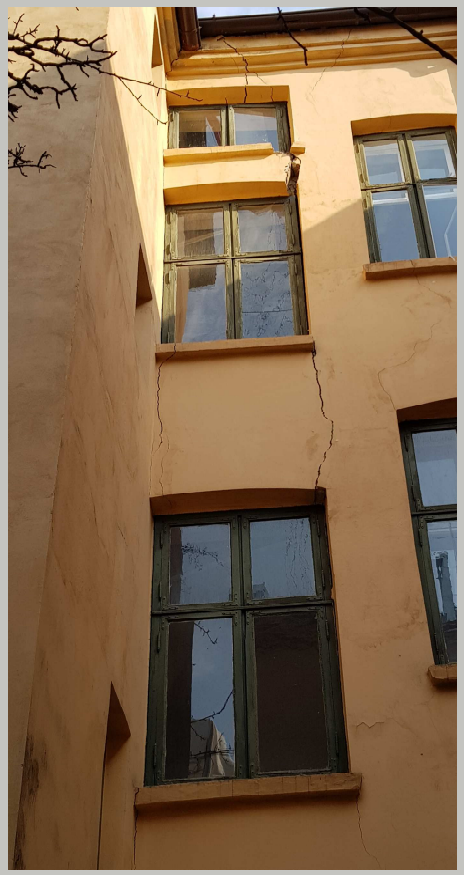
Remedy

what is it?

Remedy

- R&D project funded by the Norwegian Research council and the 18 partners.
- Sequal of BegrensSkade I (2012-2015)
- Project period 1. September 2017 – 21. August 2022
- Budget: 21 mill. NOK
- Five work packages:
  - WP 1 Drilling for installation of piles and tie-back anchors
  - WP 2 Deep excavations and foundations
  - WP 3 Hydrogeological methods, drainage and grouting
  - WP 4 Vibrations due to construction activities
  - WP 5 Risk assessment and management

Background



Problem:

Damage + costs

Aim:

Reduce risk

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PERIOD | 2017 - 2022
COUNTRY | NORWAY

Project | WP 1: Drilling for installation piles and anchor tie-backs

Develop model for estimating settlements caused by pile and tie-back anchor drilling

What are the main aims in WP1?

1. Guidelines for selecting drilling methods and procedures for different ground conditions

2. Method to estimate ground settlements caused by drilling

Case studies

E18 Knapstad – Retvet
Hobøl bridge

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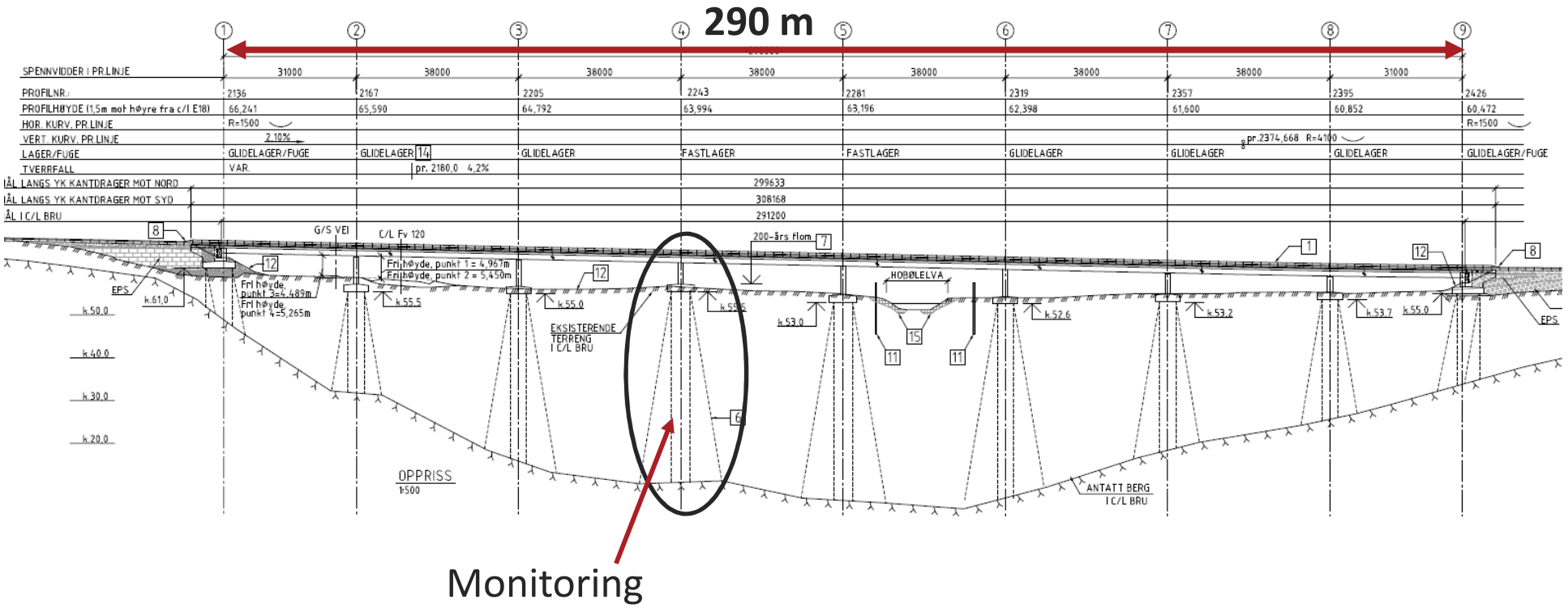
E18 Knapstad – Retvet, Hobøl bridge



Monitoring

Drilling method and procedure

Steel tube piles Ø711x12.5 mm

DTH air hammer (senkhammer)

Combined air + water flushing:

5-10 bar in clay and 10-20 bar in moraine and rock

Penetration rate 70-100 cm/min in clay

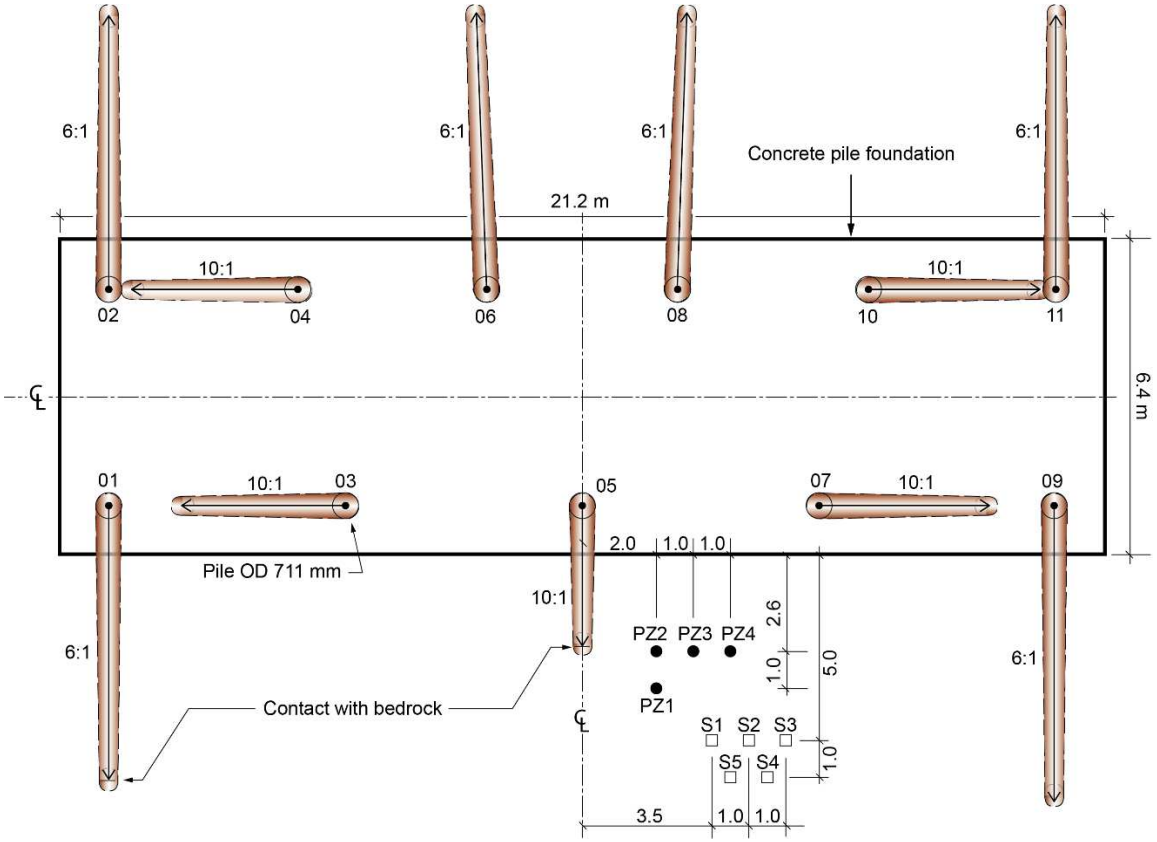
Water flushing:

250 l/min in clay and 350 l/min in silt and silty sand, use of air minimized.

Photo: Statens vegvesen

Robit drill bit

Monitoring foundation No. 4



4 Piezometers:

PZ1 d = 43 m

PZ2 d = 36 m

PZ3 d = 36 m

PZ 4 d = 42 m

5 settlement anchors:

S1 d = 16 m

S2 d = 26 m

S3 d = 31 m

S4 d = 36 m

S5 d = 41 m

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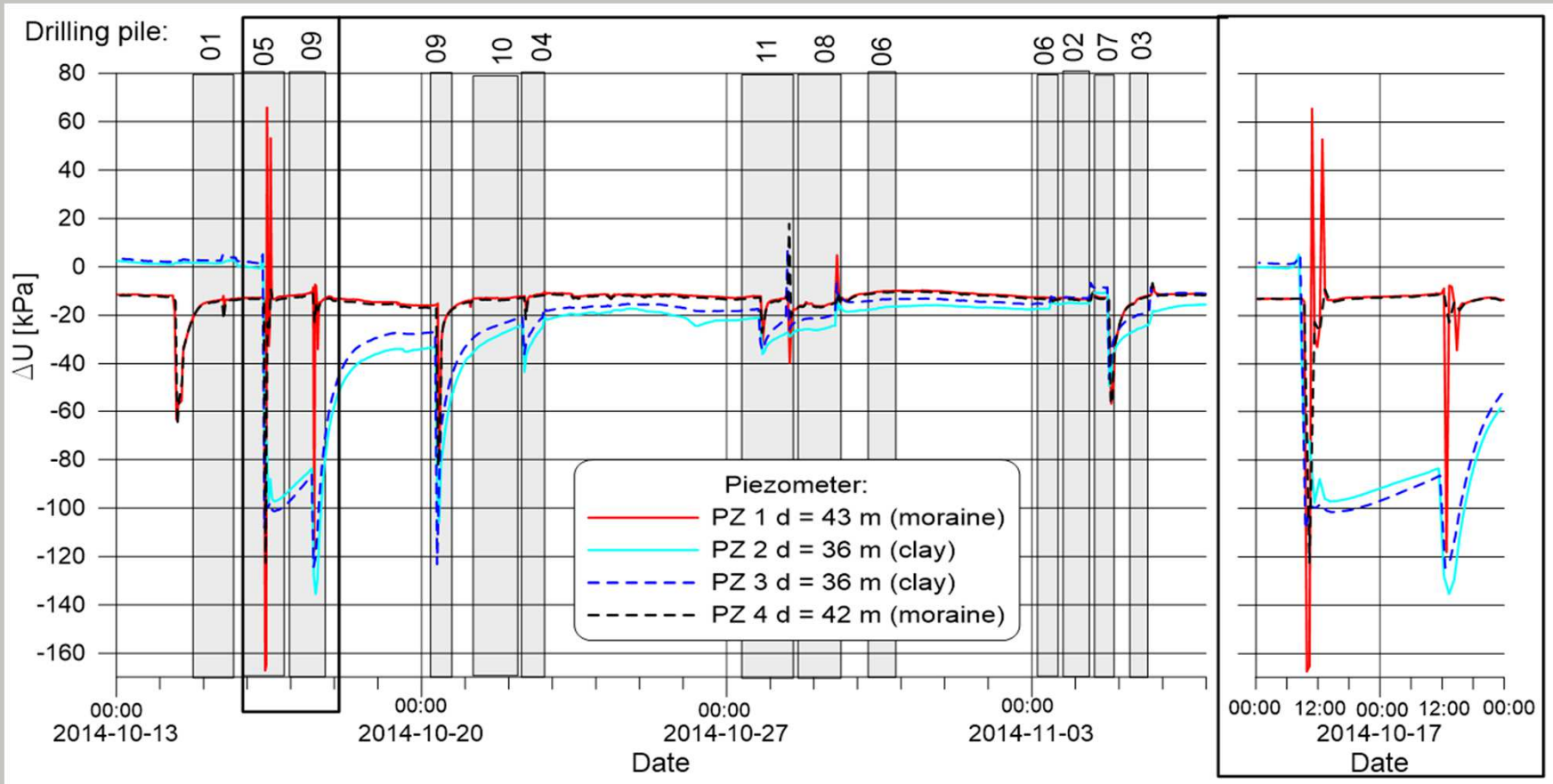
Pore pressure measurements



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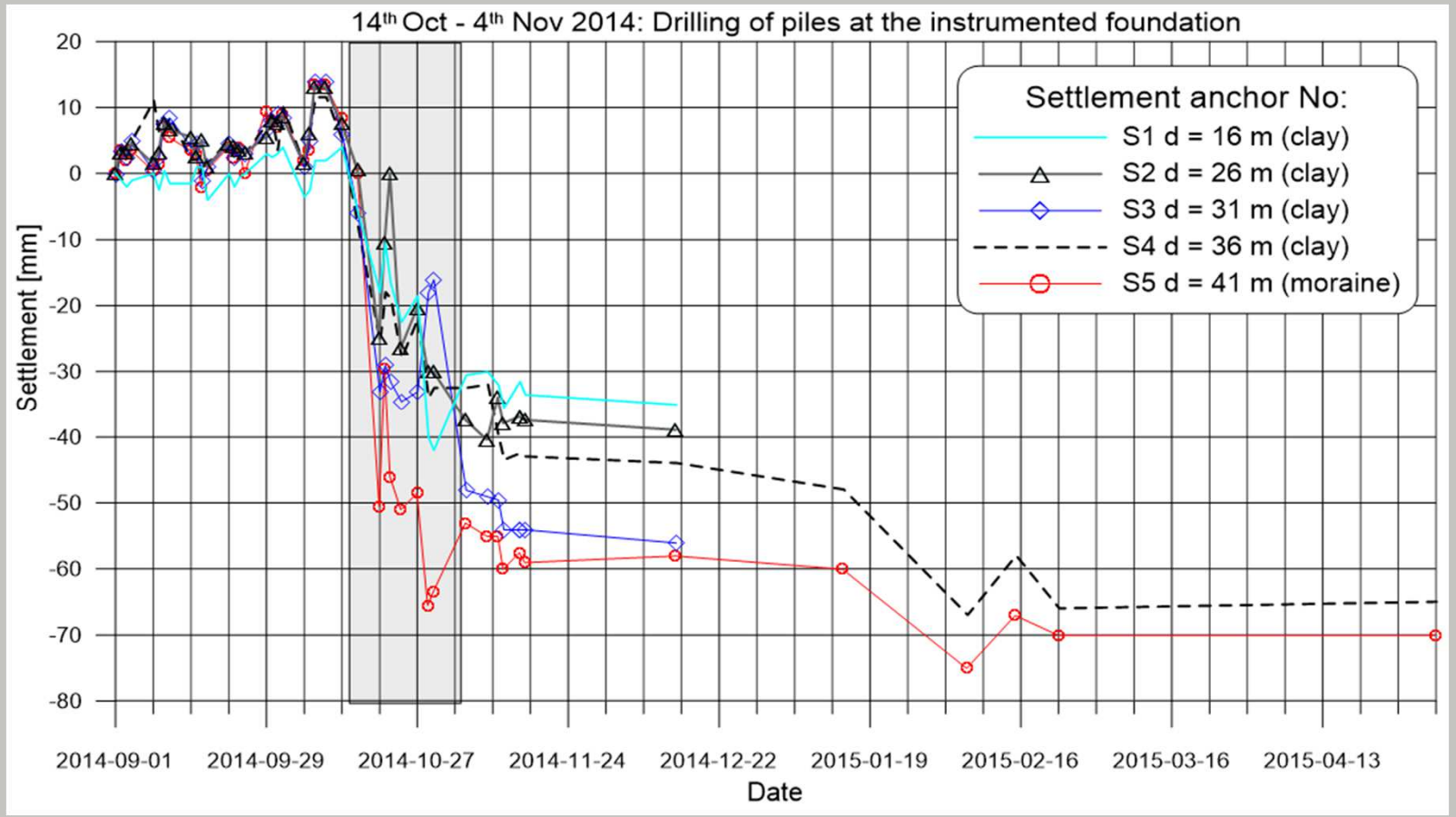
Ground settlements



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Ullevål pedestrian bridge

Ullevål pedestrian bridge

Steel bridge recently finished

Founded on reinforced steel tube piles drilled into bedrock

Dry crust over soft to medium stiff marine silty clay with some layers of sand.

Small artesian pressure above bedrock

Illustration: Efla

Drilling method and procedure

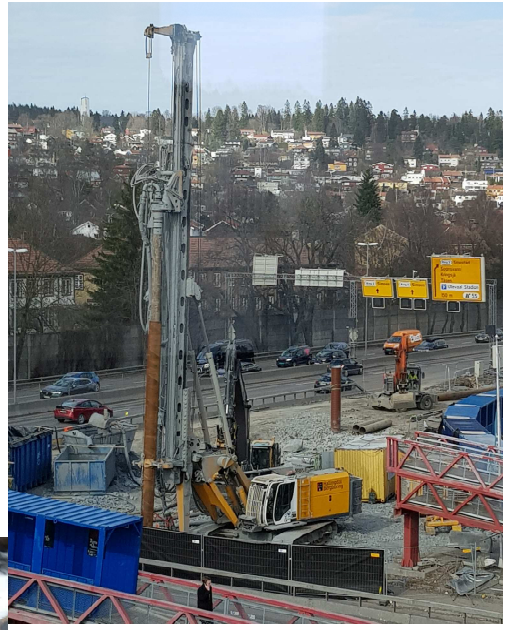
Steel tube piles Ø610x12.5 mm

DTH air hammer (senkhammer) with double-tubed RC system

Combined air + water flushing:

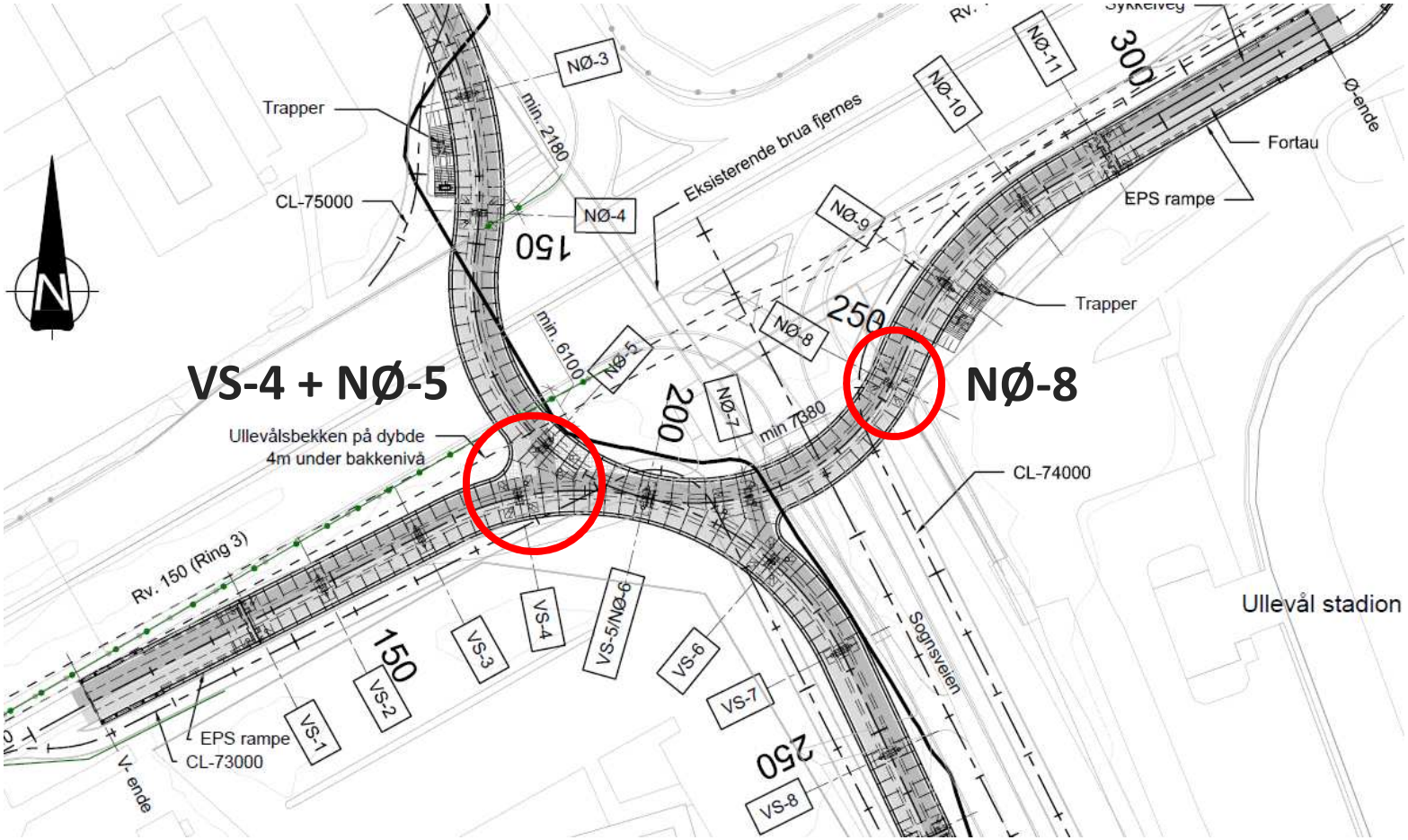
Typical 10-12 bar

Penetration rate 25-50 cm/min in clay



Robit drill bit - safety flow

Plan view



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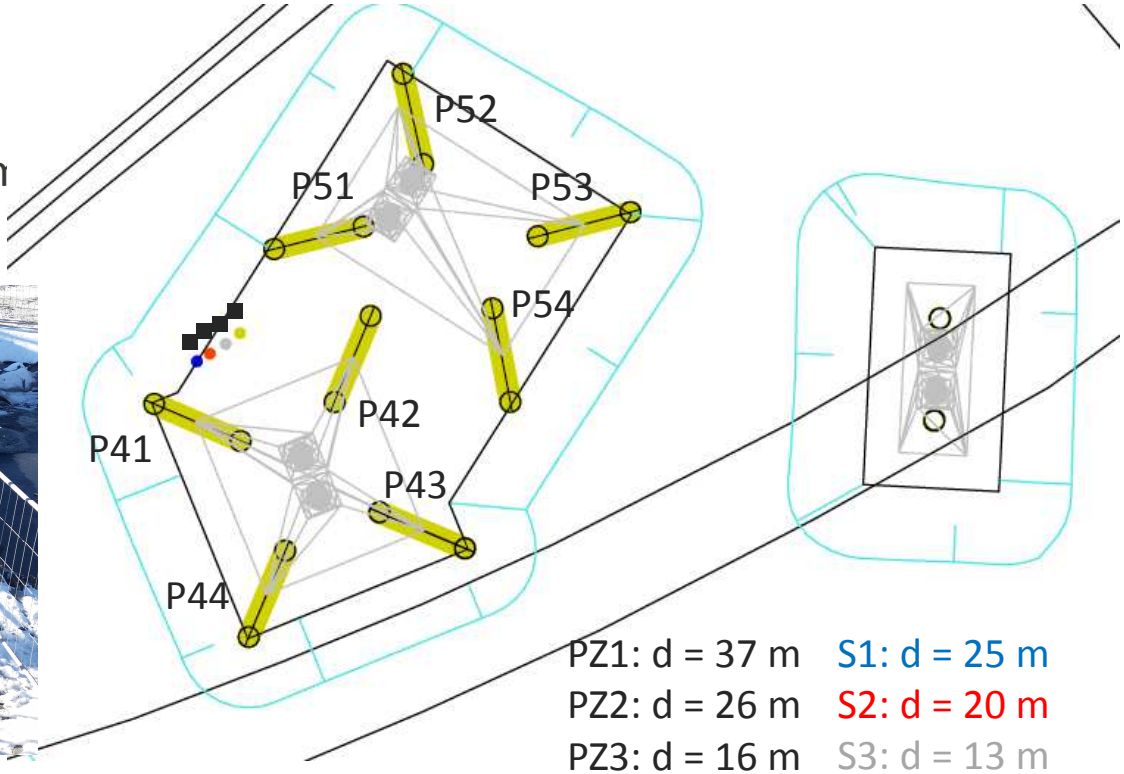
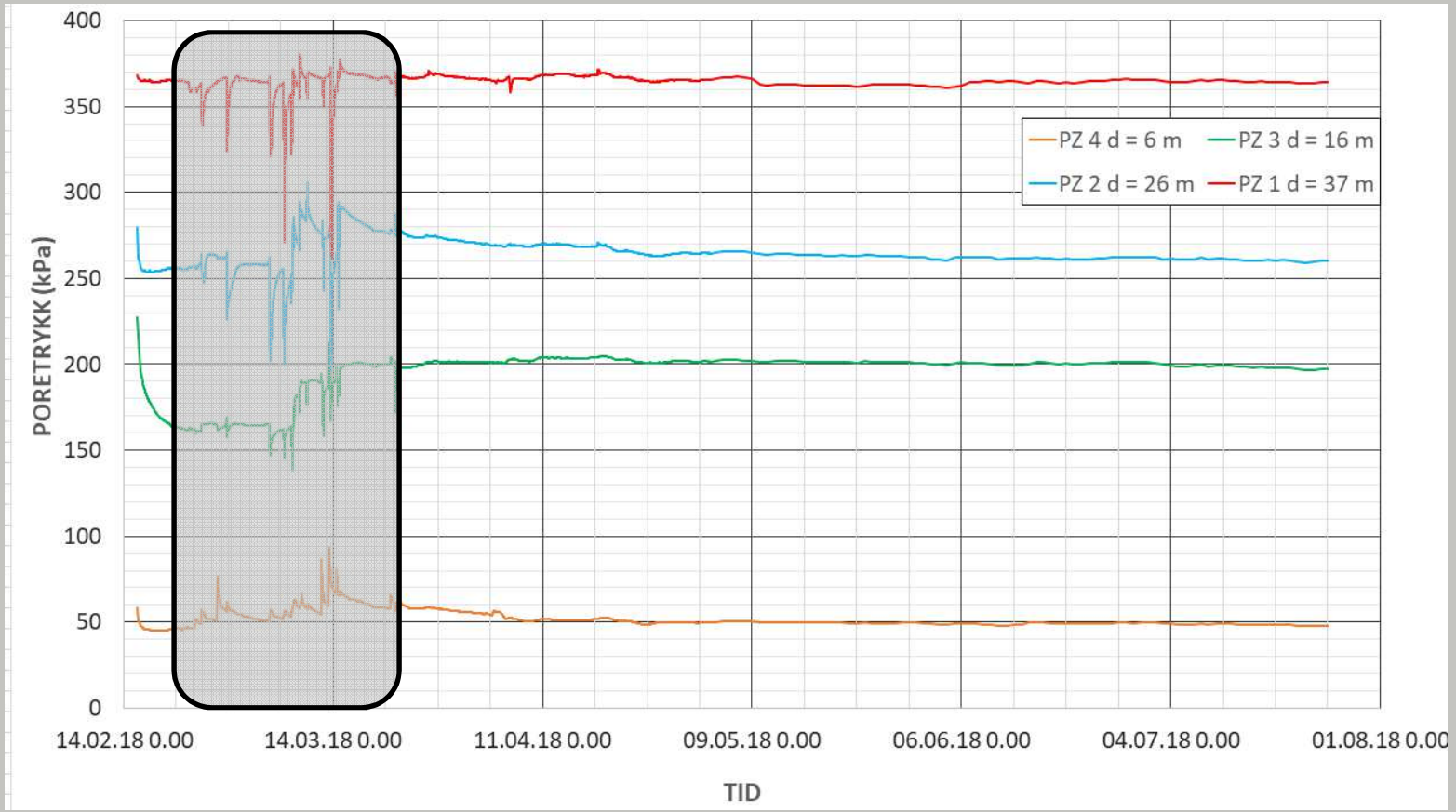
Instrumentation close to VS-4 and NØ-5

- Piles
  - Inclination 15:1
  - Depth to bedrock, ca. 42-44 m



PZ1: d = 37 m S1: d = 25 m
PZ2: d = 26 m S2: d = 20 m
PZ3: d = 16 m S3: d = 13 m
PZ4: d = 6 m S4: d = 3 m

Pore pressure measurements



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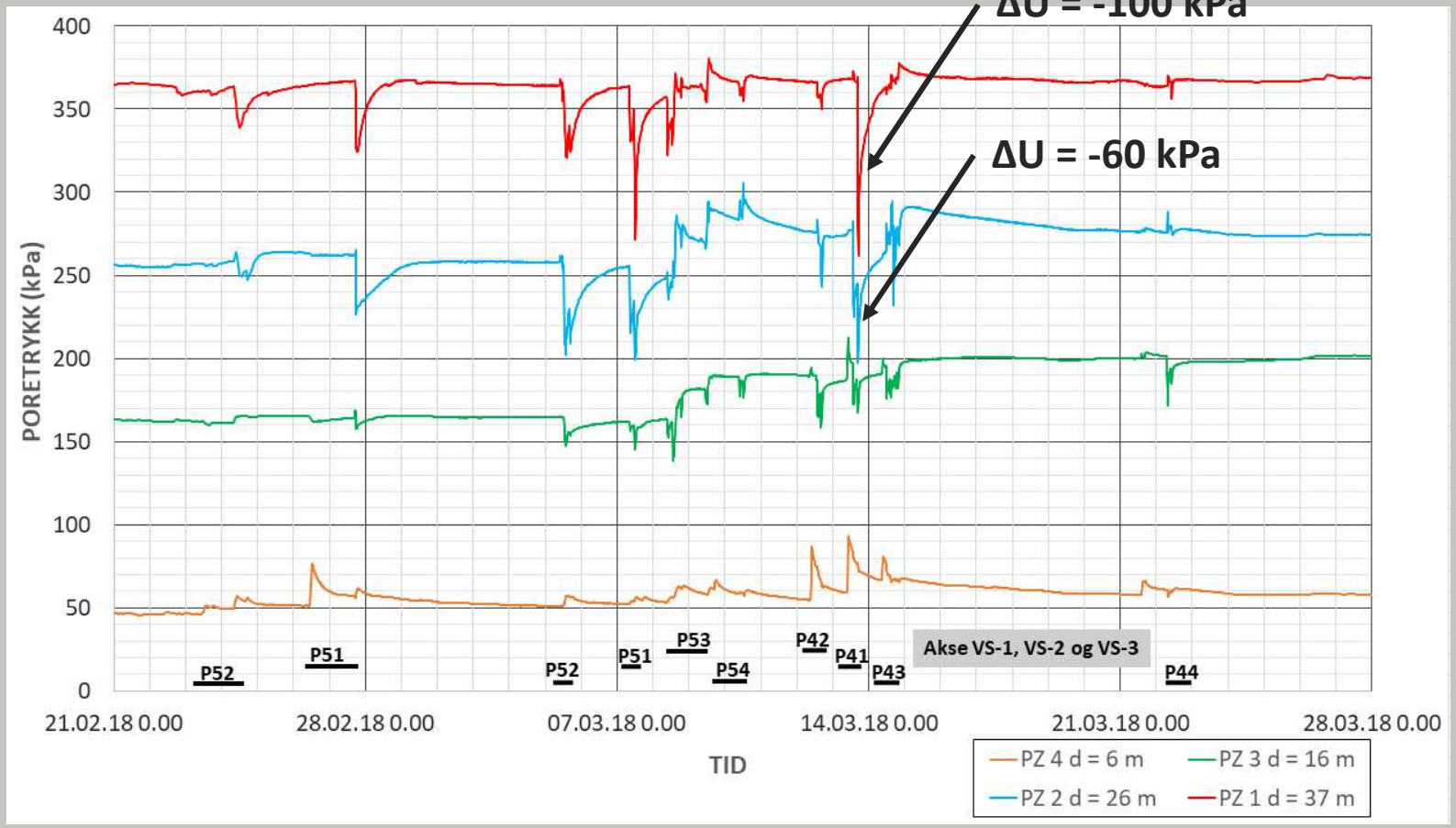
ΔU = -100 kPa
ΔU = -60 kPa
400
350
300
250
200
150
100
50
0
PORETRYKK (kPa)
P52
P51
P52
P51
P53
P54
P42
P41
P43
P44
Akse VS-1, VS-2 og VS-3
21.02.18 0.00
28.02.18 0.00
07.03.18 0.00
14.03.18 0.00
21.03.18 0.00
28.03.18 0.00
TID
PZ 4 d = 6 m
PZ 3 d = 16 m
PZ 2 d = 26 m
PZ 1 d = 37 m

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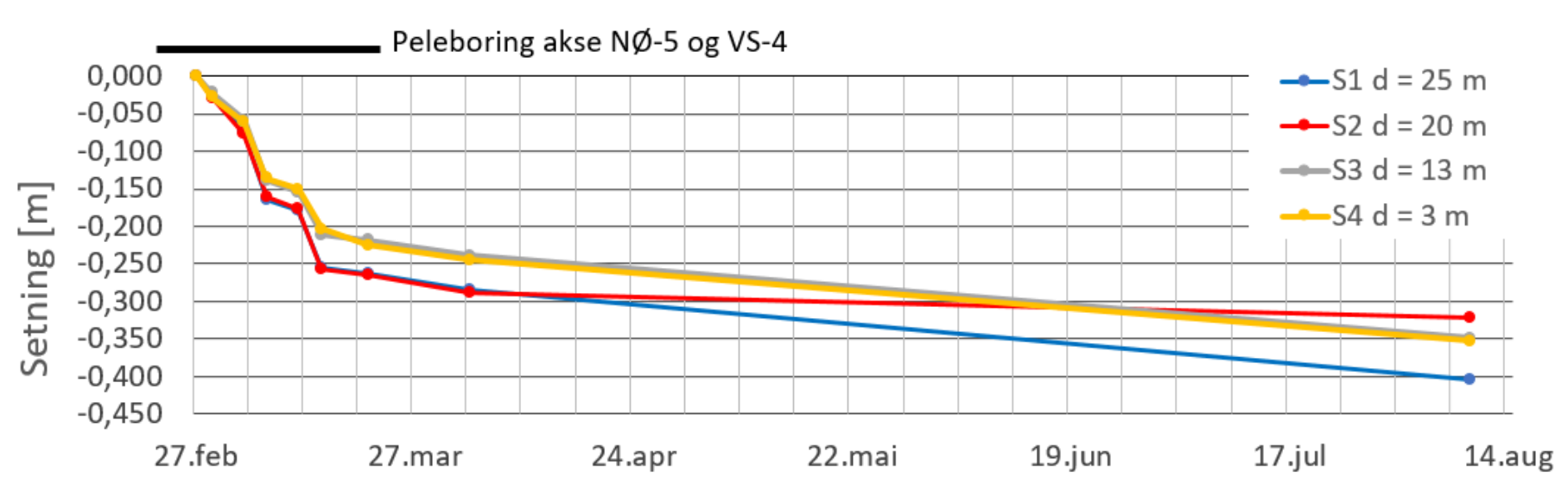
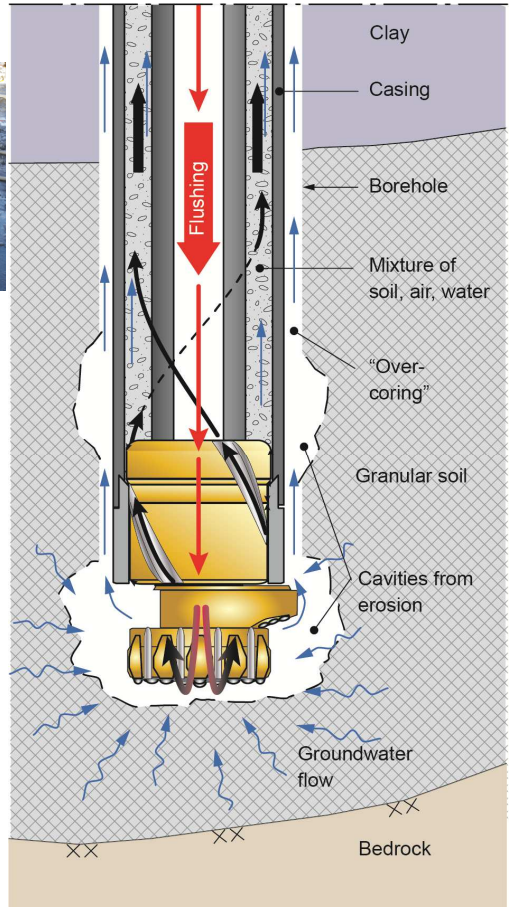
Ground settlements



So what happened?

- Likely combination of
  - Drilling penetration rate 2-4 min/m)
  - Flushing (10-12 bar)
  - Sensitive and quick clay, silt and sand above bedrock



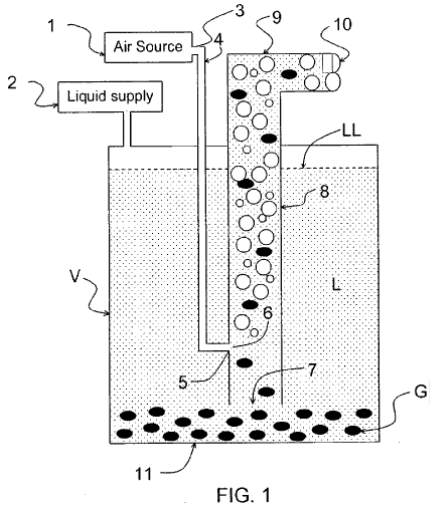


FIG. 1

«Airlift» pump?

Source: https://en.wikipedia.org/wiki/Airlift_pump

Follo line project, Oslo

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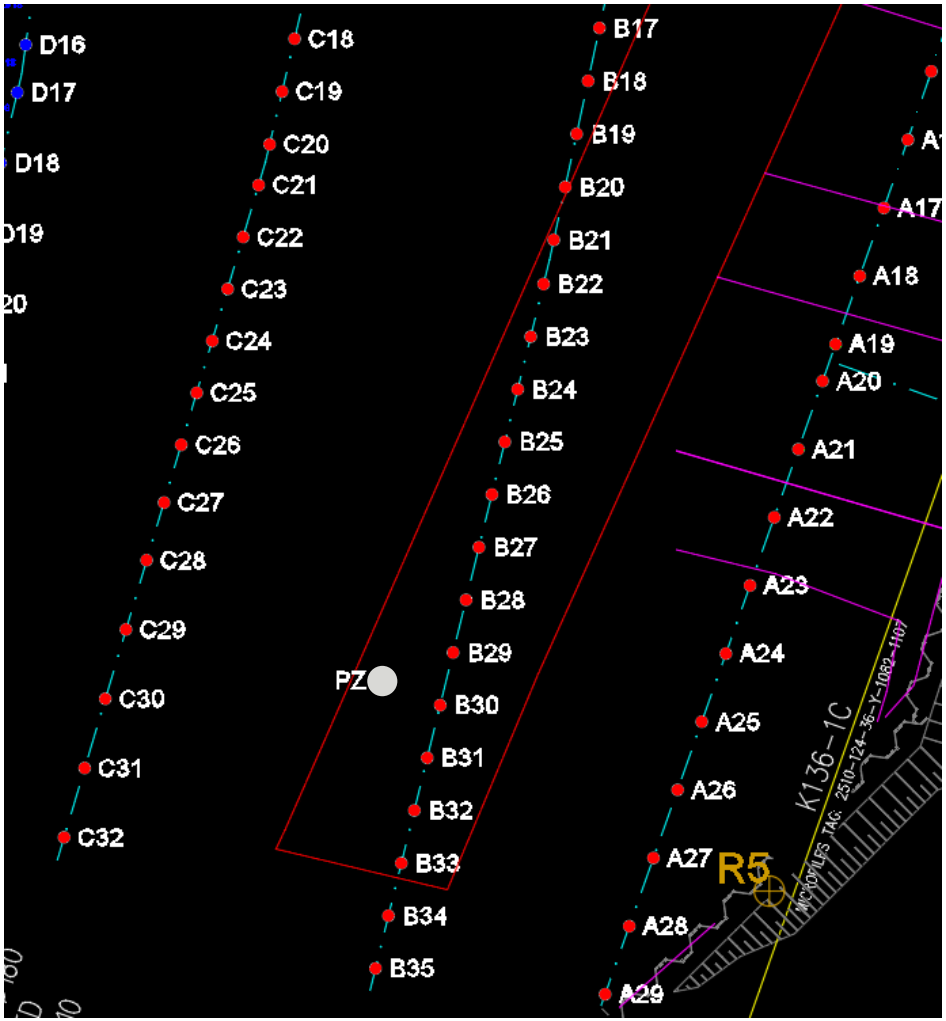
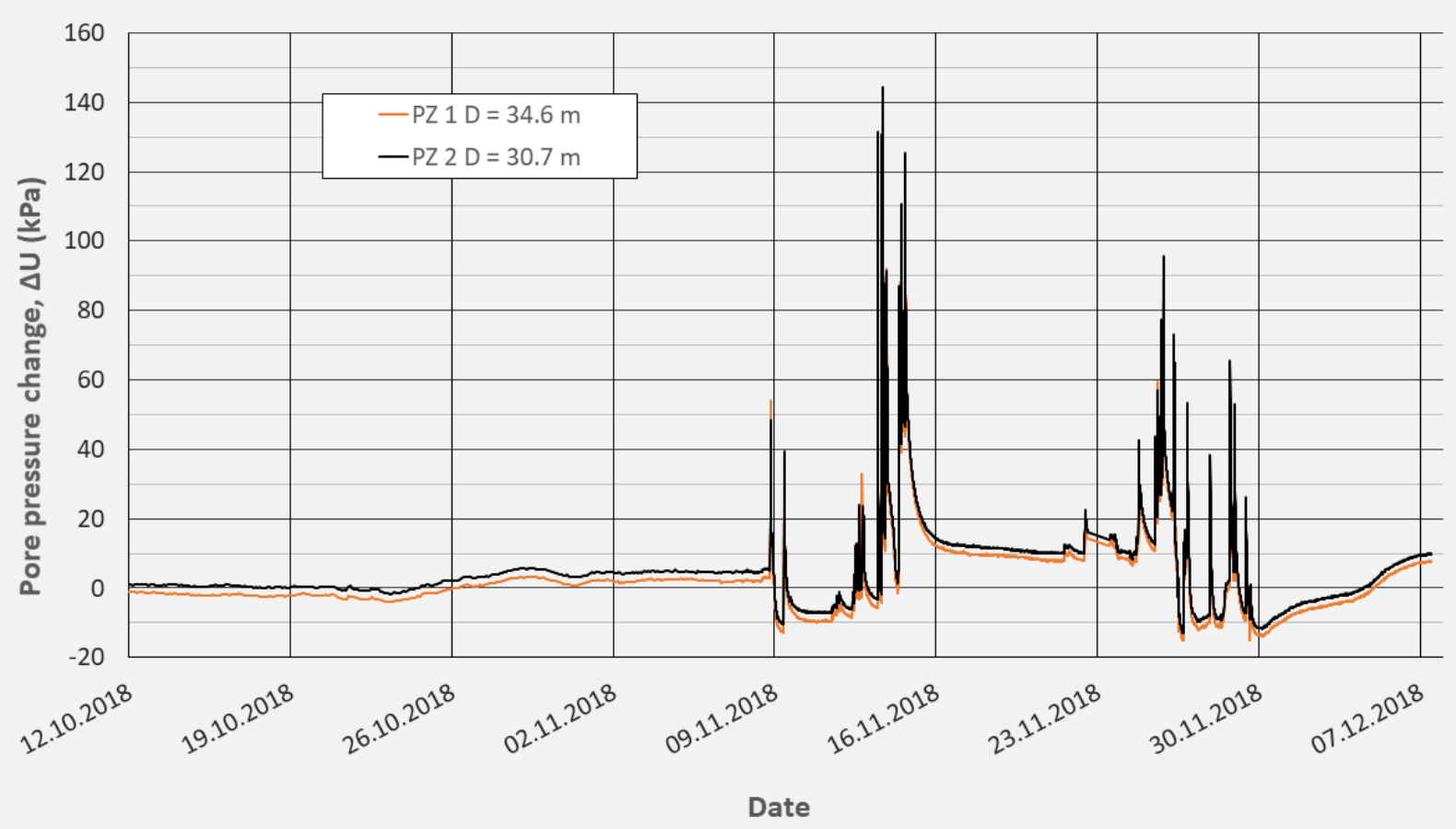
Pile drilling with DTH water hammer

Plan pile drilling

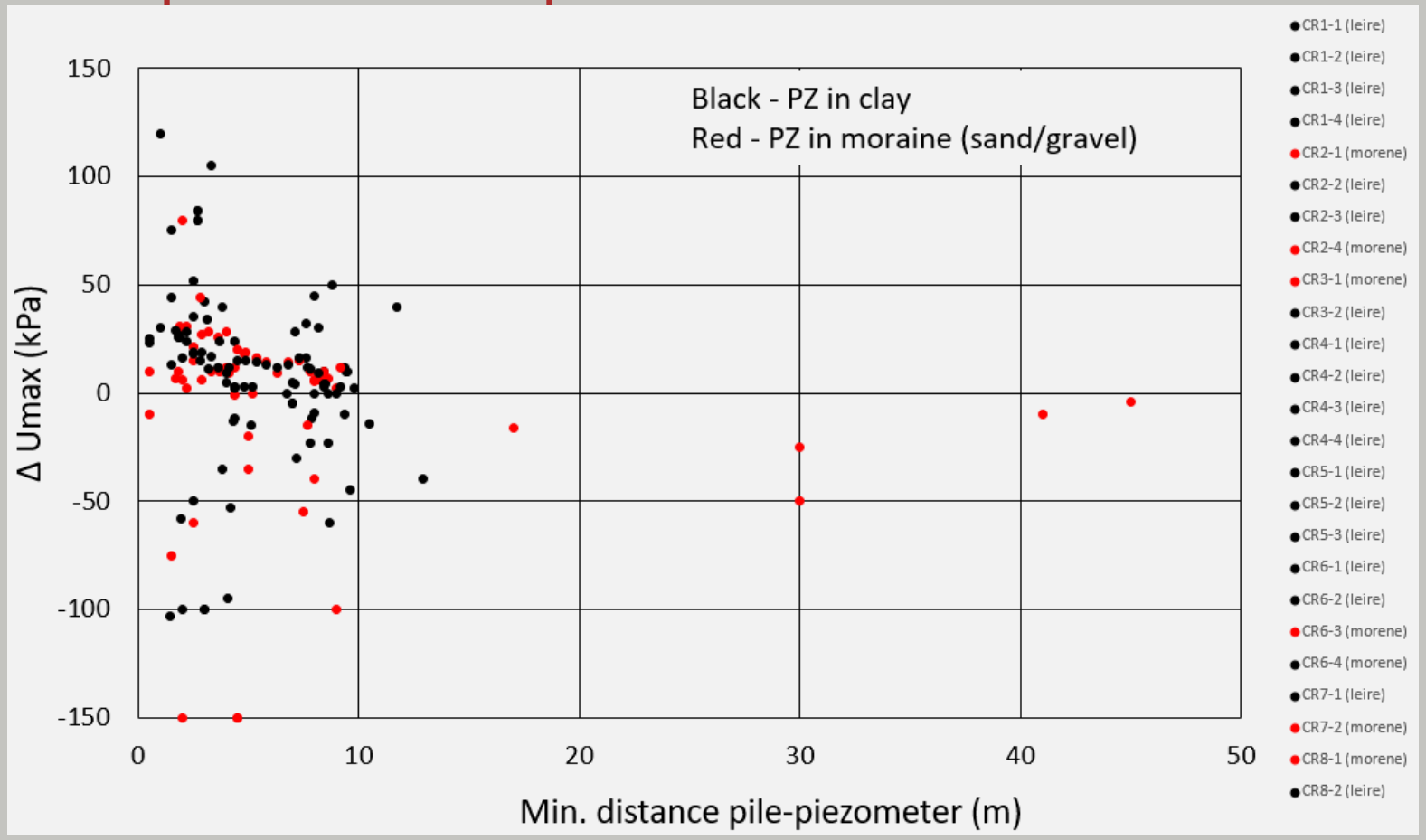
PZ installed close to line B



Pore pressure measurements



Pore pressure compiled - 9 case studies



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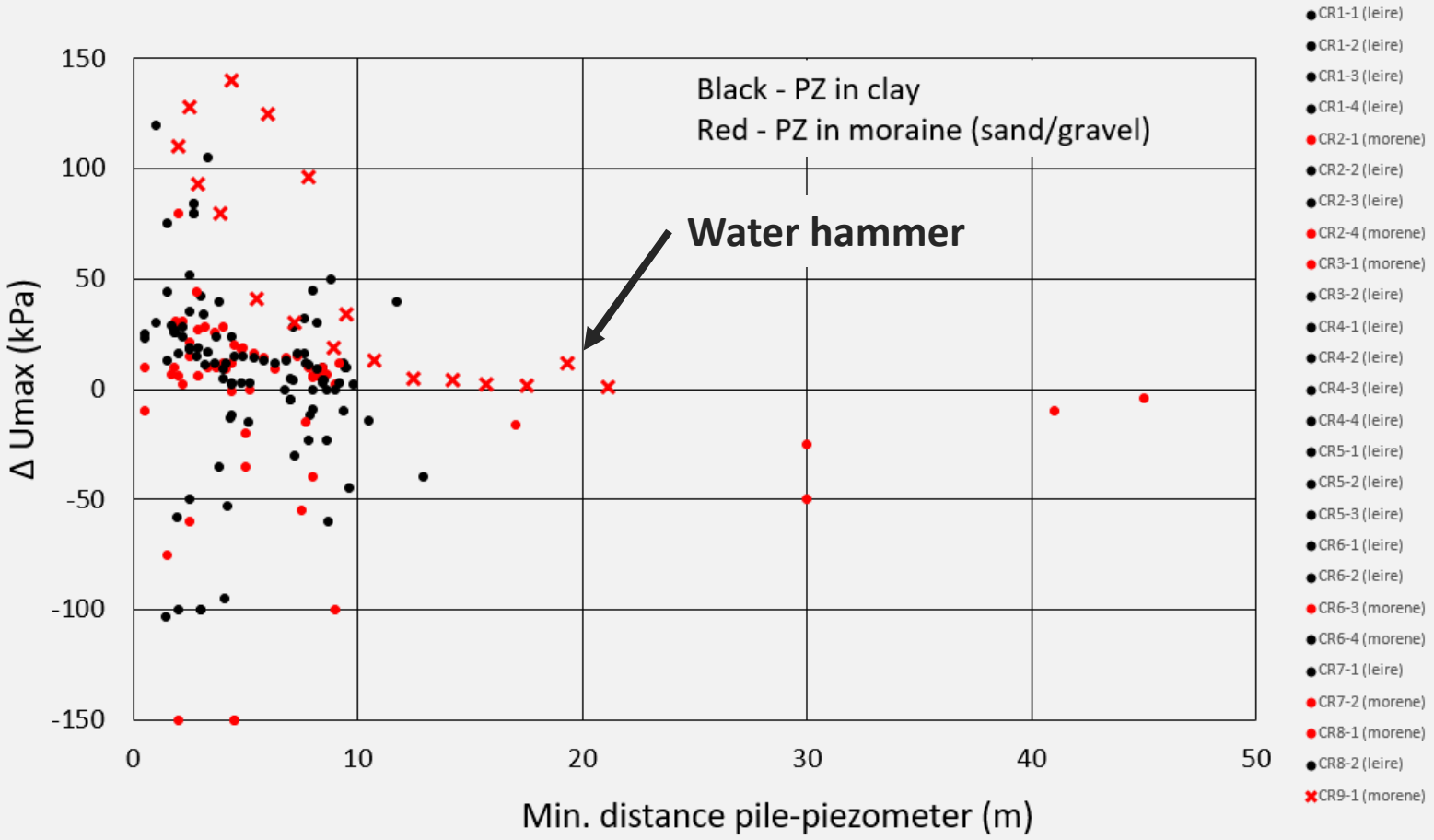
Pore pressure compiled - 9 case studies



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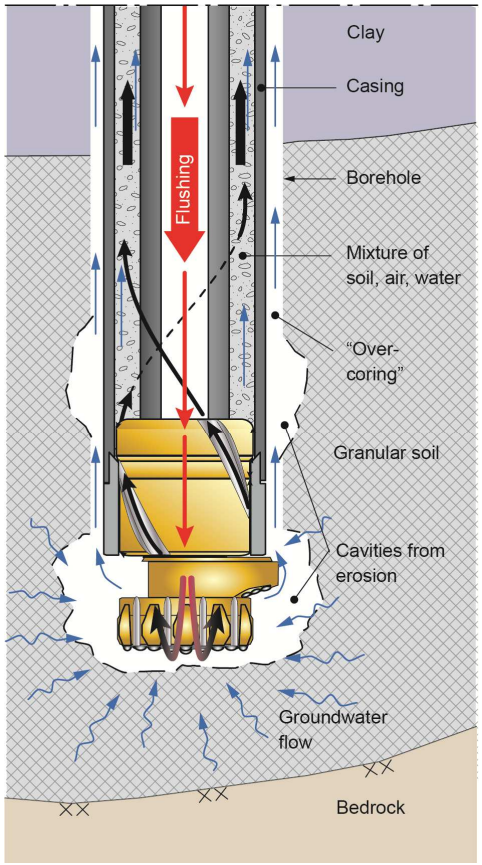
Conclusions so far

Main installation effects “confirmed”

- Pore pressure
- Loss of soil mass

Function of penetration rate, flushing media and pressures, ground conditions, drill system, workmanship

Air flushing → increased risk of setttlements



Field data

inherent uncertainties

ground conditions, workmanship, simultaneous construction process,…

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image: embraceablemind.com

Model test

controlled environment

qualitative and/or quantitative information

… but soil behaviour is rather complex

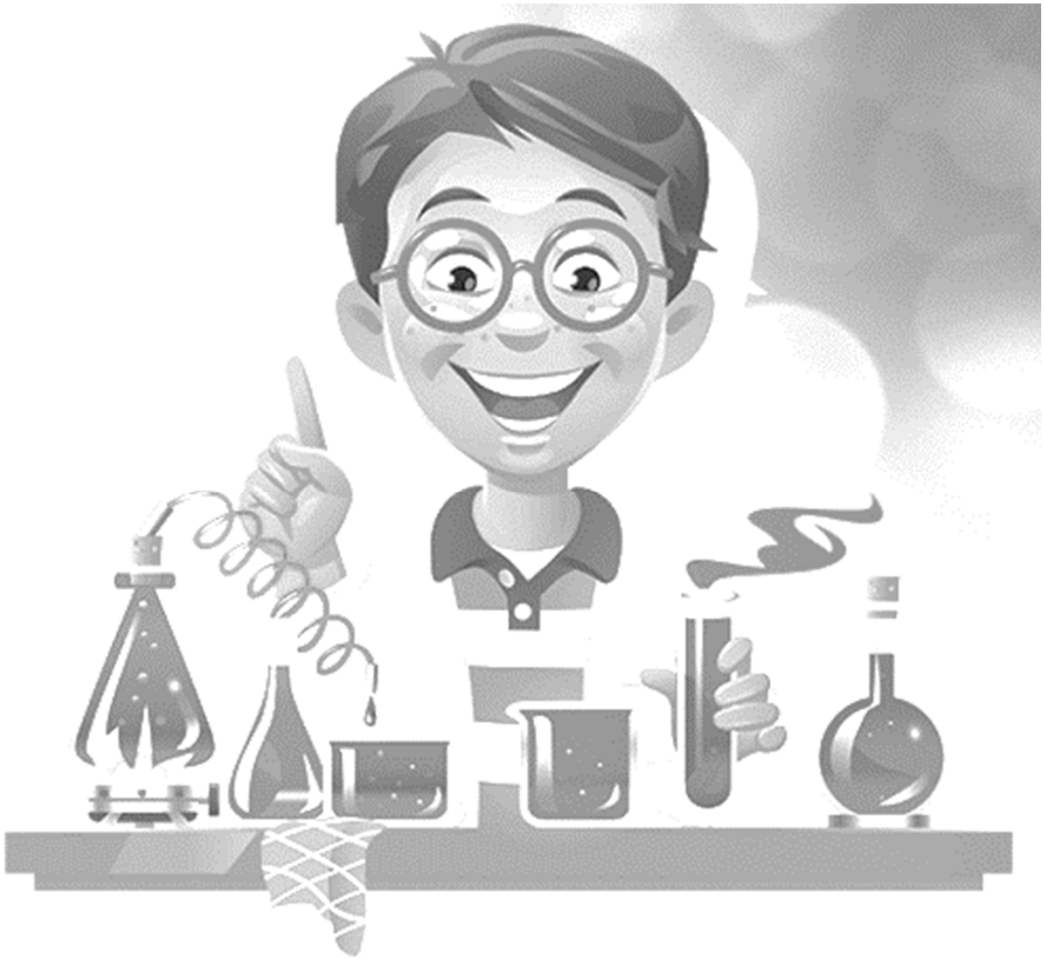


image: https://boyslife.org/hobbies-projects/funstuff/143815/conduct-7-sweet-science-experiments-with-candy/

Hypothesis

representative small-scale model

↓

deepen understanding

↓

guidelines on pile and anchor drilling to prevent damage

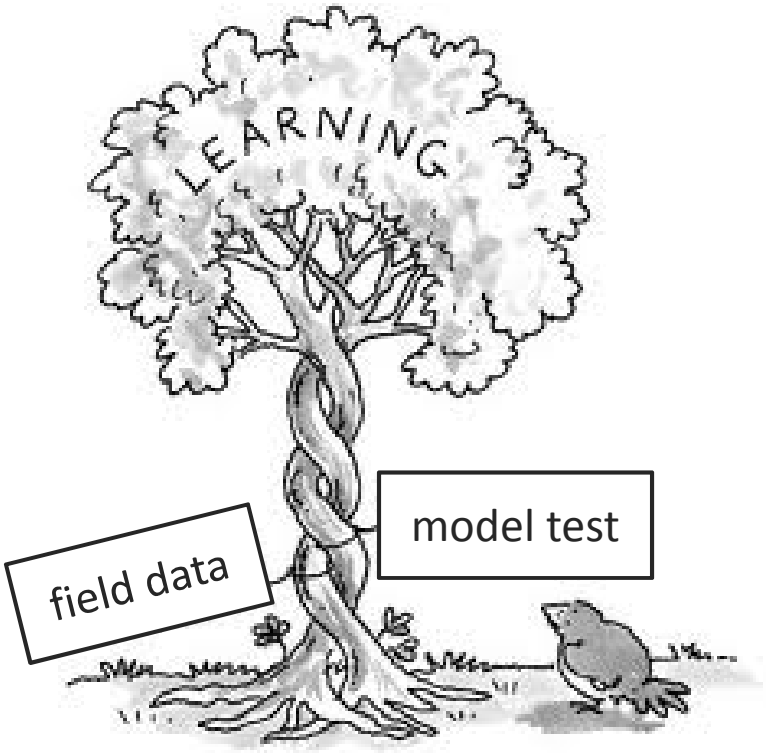


image: https://sylviamoessinger.wordpress.com/2011/10/28/the-difference-between-theory-and-practice/

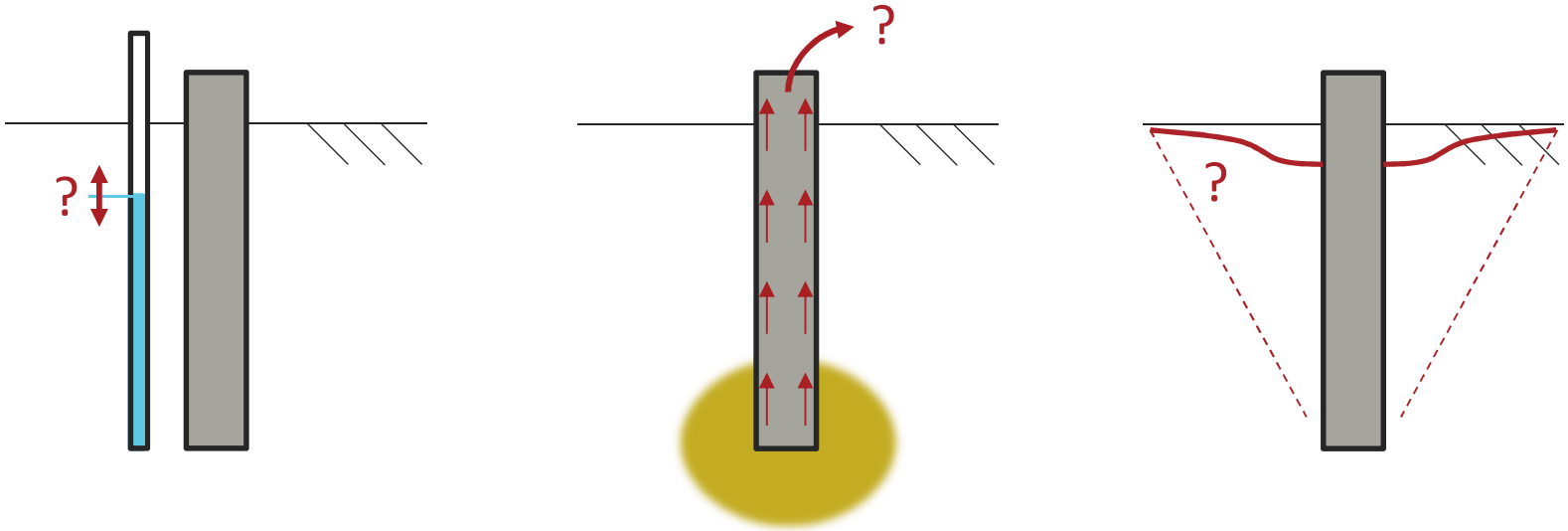
Objectives

flushing parameters & ground conditions

pore water pressure

drill cuttings

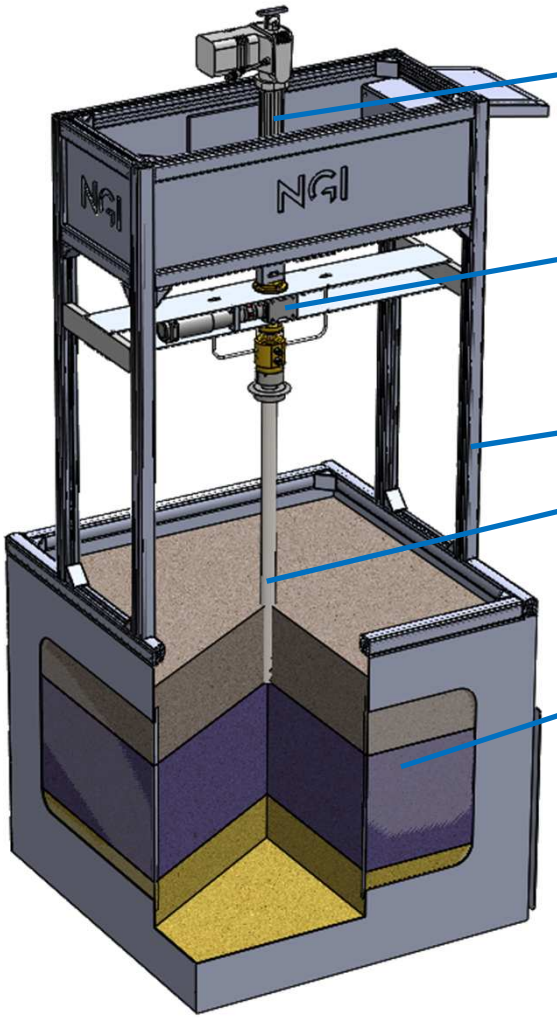
displacements



Physical model

setup – programme

Setup



linear actuator (300 mm stroke)

Rotation motor

frame

model pile (D = 35 mm)

soil model (sand – blue zone indicates drilling length)

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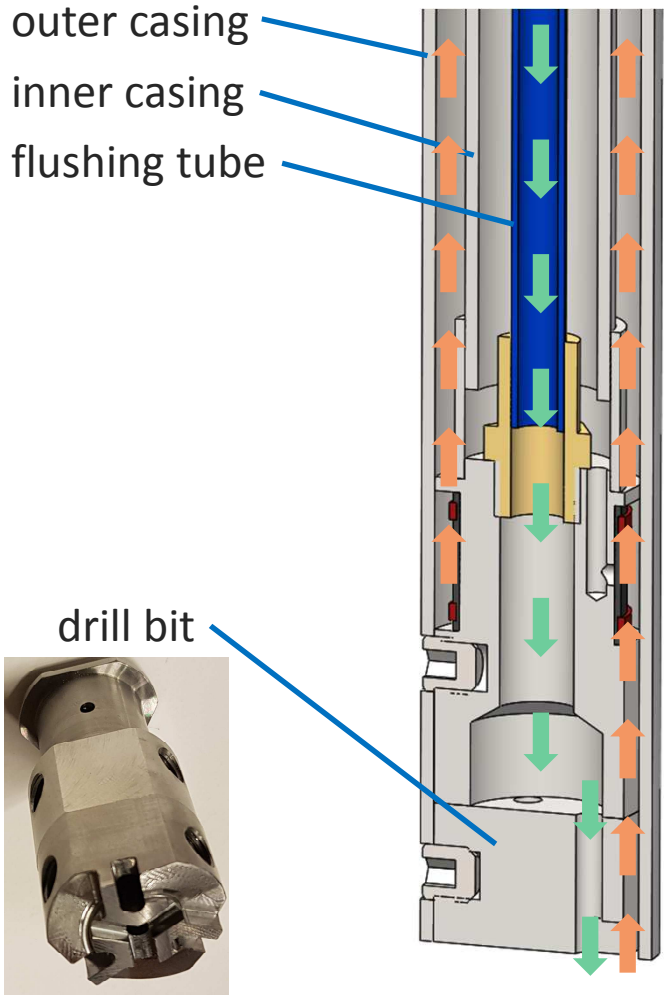
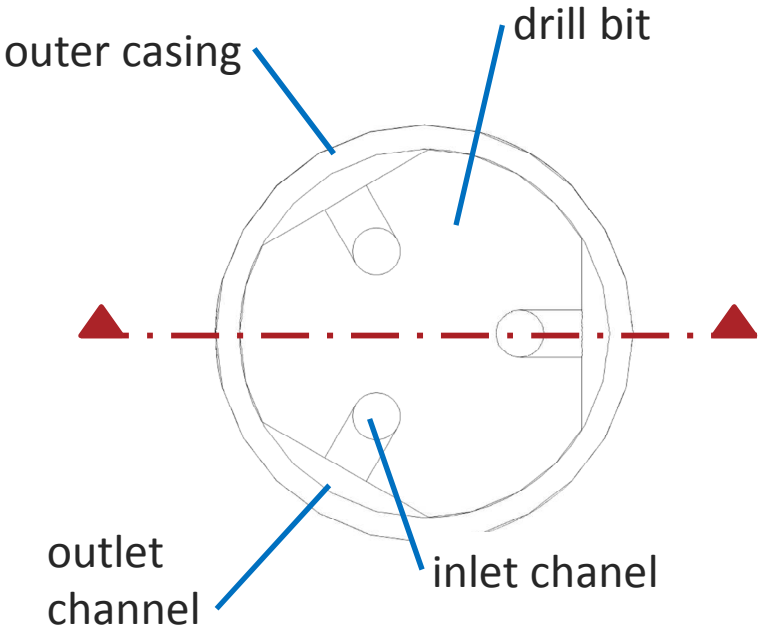
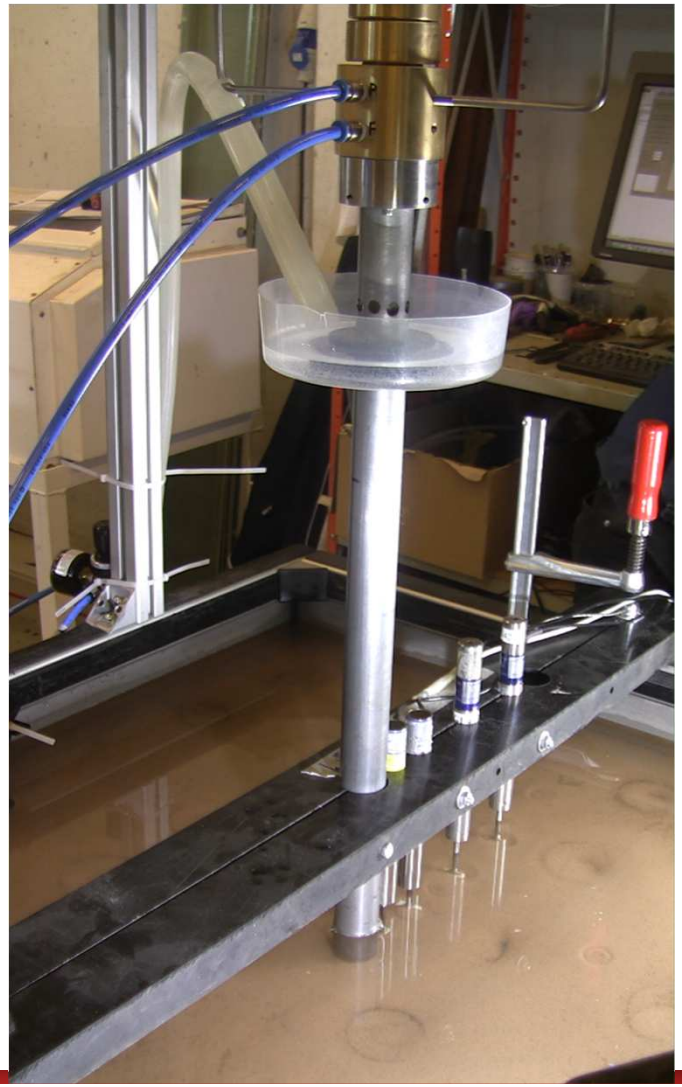


inlet (air or water)

outlet (soil, air, water)



Water flushing
Flow 1.5 l/min
2.5 mm/sec



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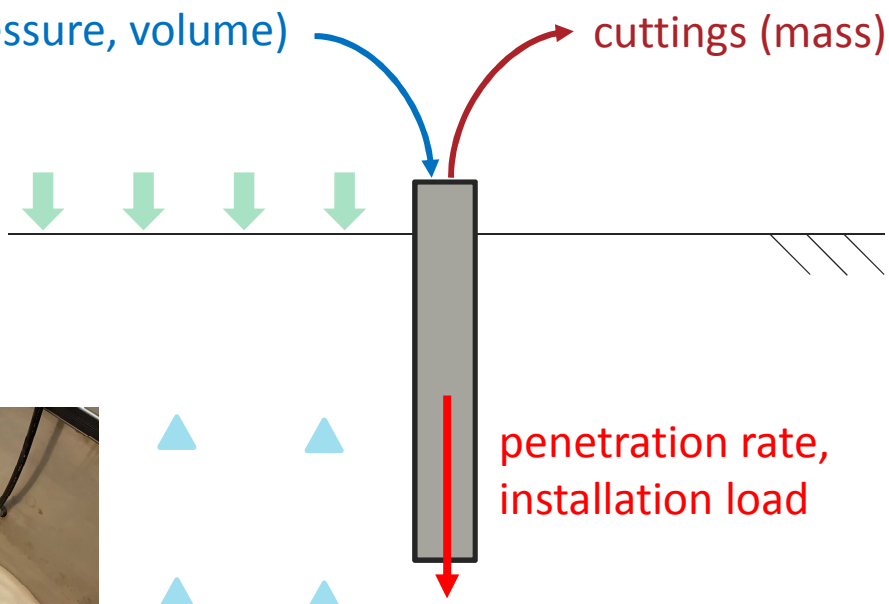
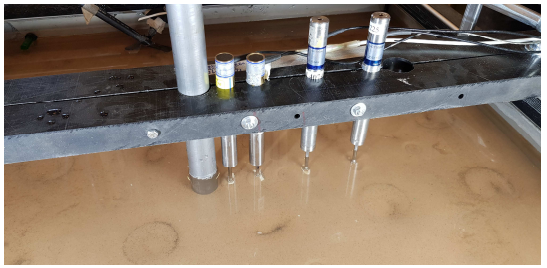
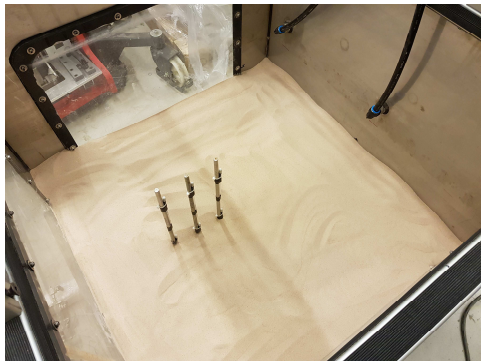
Instrumentation







pore pressure transducer (PPT)

linear variable differential transformer (LVDT)

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Test programme (stage 1)

6 tests	+	3 tests	+	3 tests	=	**12 tests**
flushing parameters		penetration rates		soil properties		
air & water different pressures				soil relative density		

Field & experimental data

- deepen understanding
- industry guidance
- prevent damage

image: https://www.clebaby.com/clebaby-cleveland-doula-service-blog/product-review/kiinde-twist-bottle-feeding-system

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Et BegrensSkade prosjekt

https://www.ngi.no/remedy

Takk for oppmerksomheten!