



**GHENT
UNIVERSITY**

Deltares

Enabling Delta Life



PILE-TUNNEL INTERACTION

CENTRIFUGE AND FIELD TESTS

Adam Bezuijen

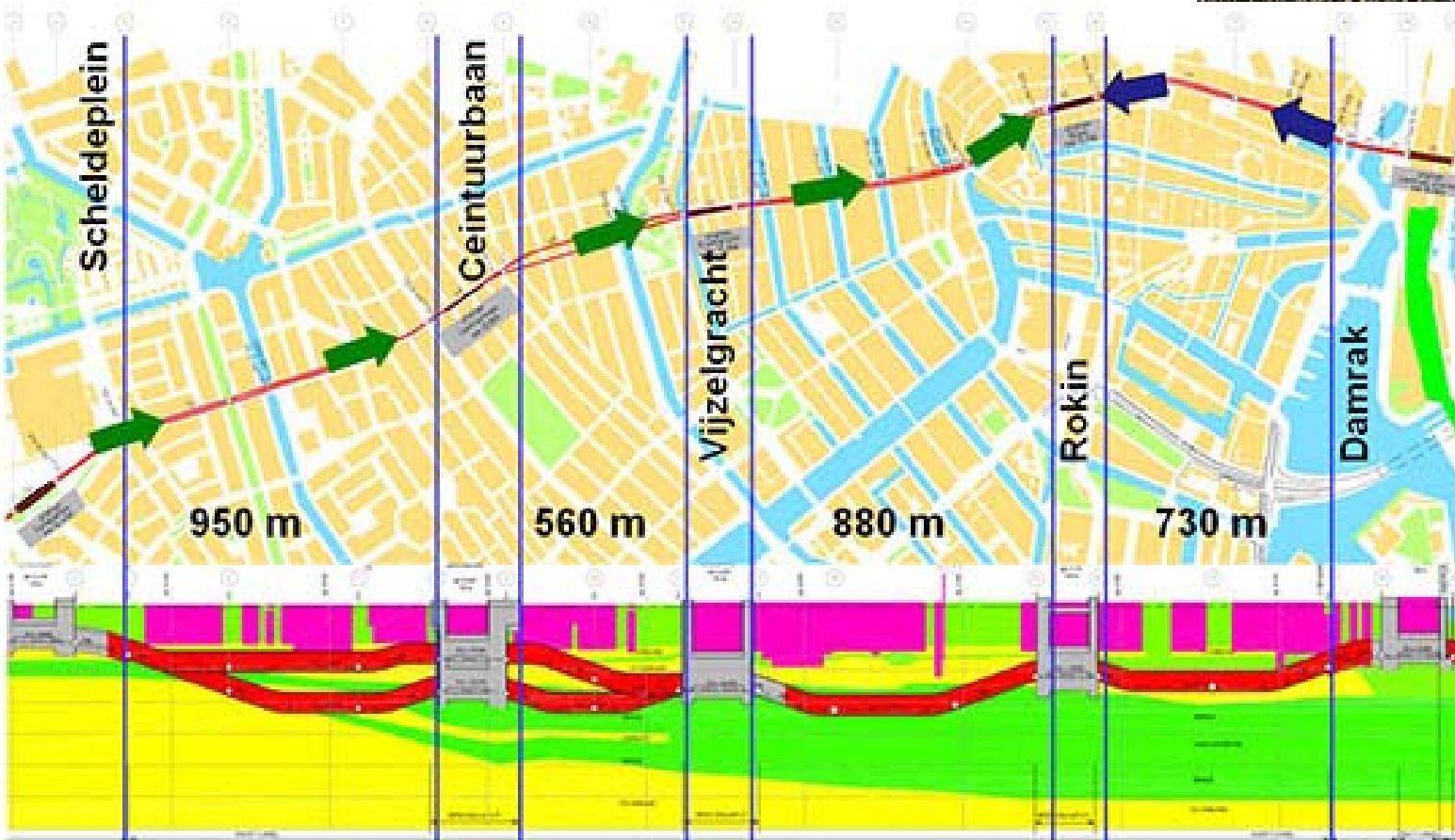
CONTENTS:

- Background
- First centrifuge tests
- Field tests
- Reality
- Further developments
- Conclusions

AMSTERDAM METRO



AMSTERDAM METRO N/S LINE

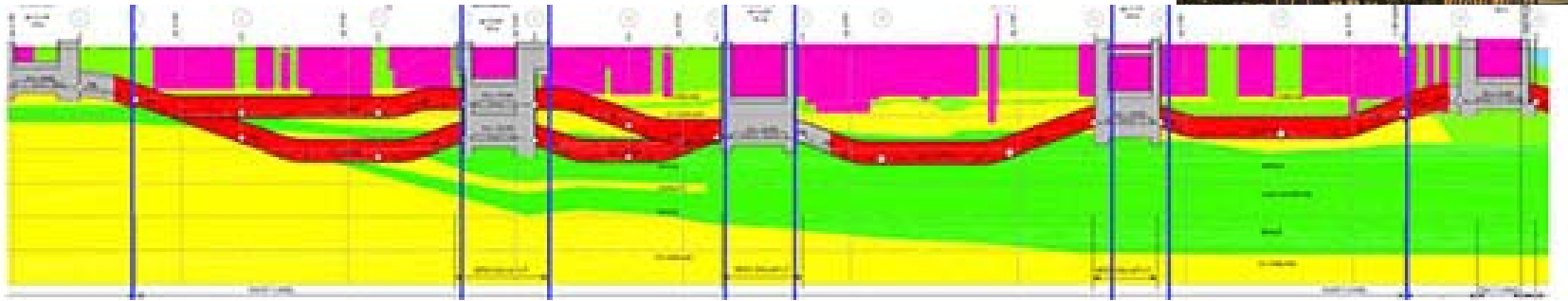


Amsterdam, that big city
It is built on piles
If that city falls apart
Who would pay for that?

NIEUWMARKT RIOTS

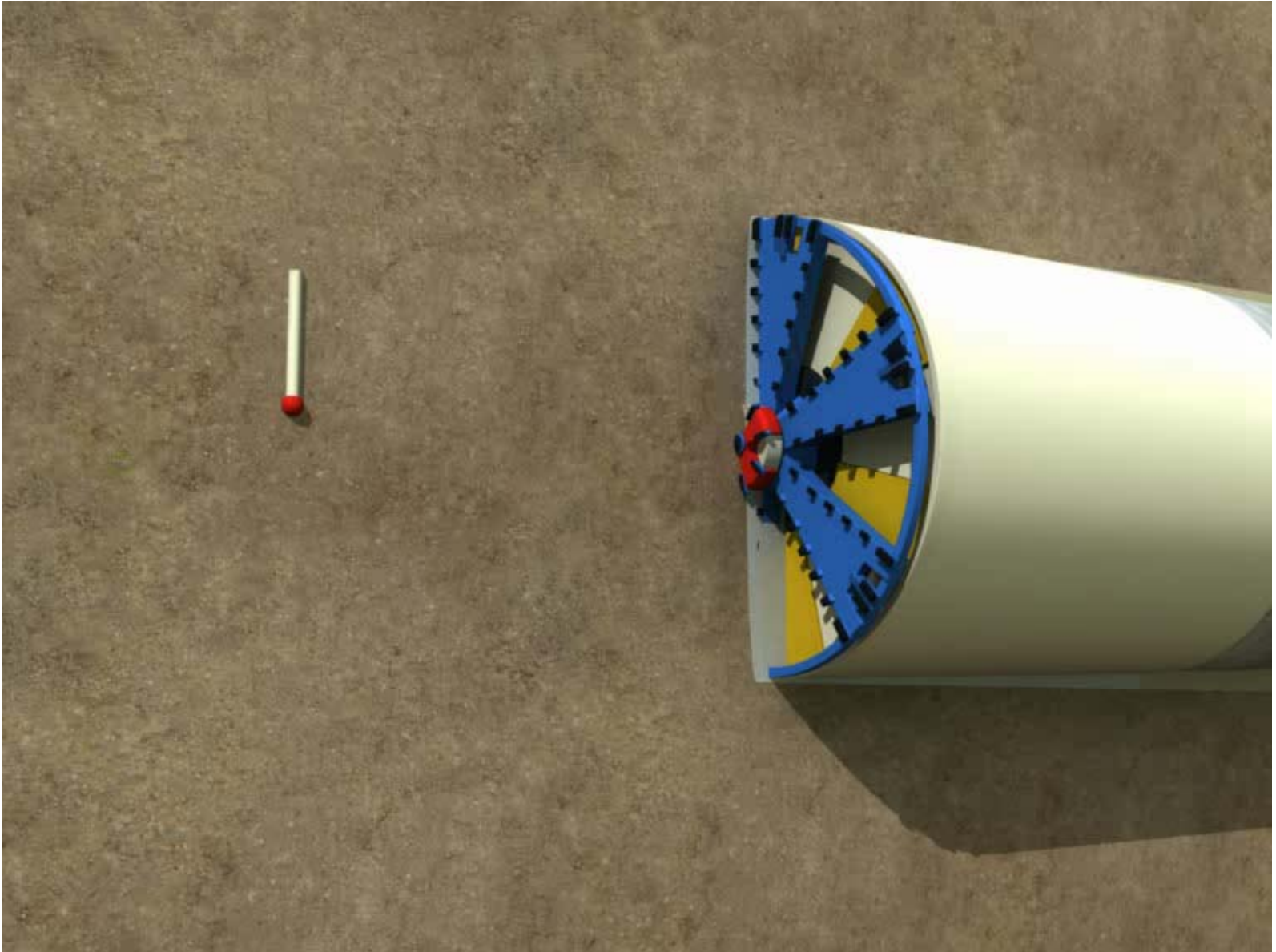


AMSTERDAM METRO N/S LINE: TBM TUNNEL



- No experience with TBM tunnelling in the Netherlands
- Can we safely (under)pass the existing pile foundations?

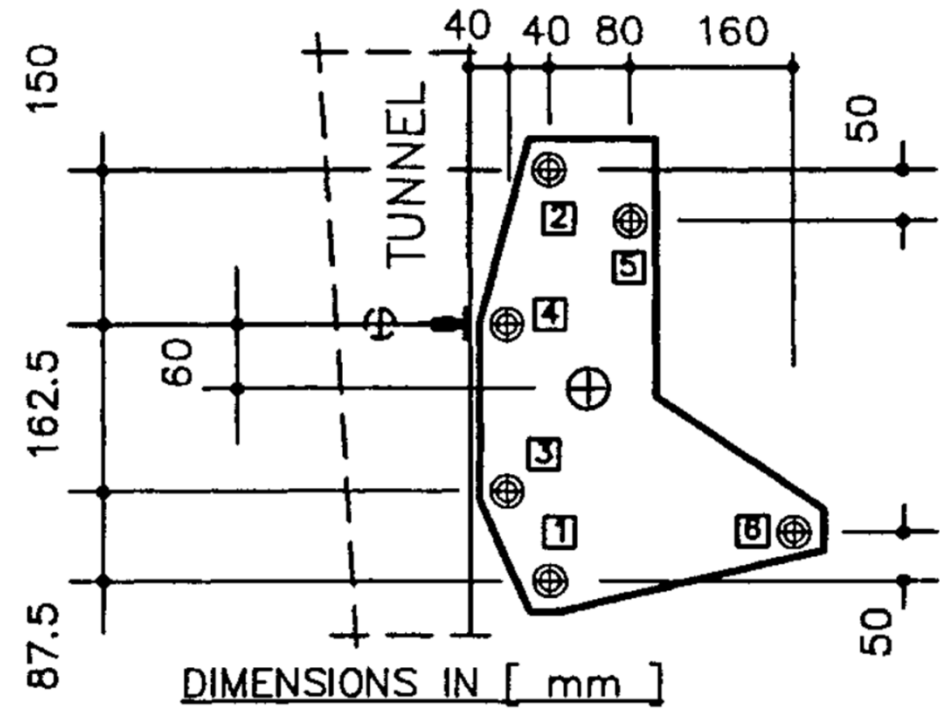
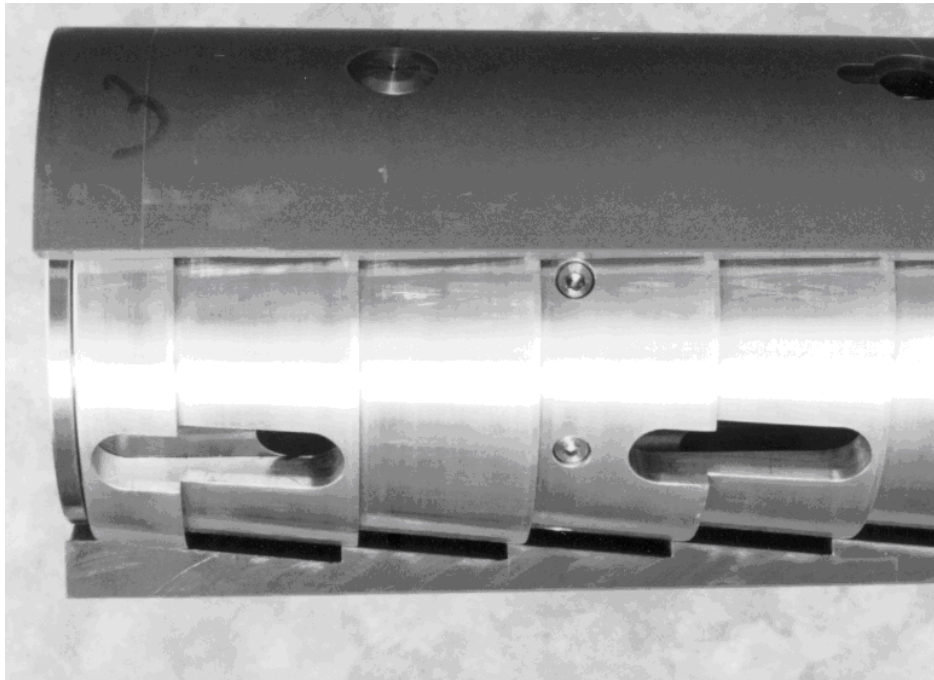




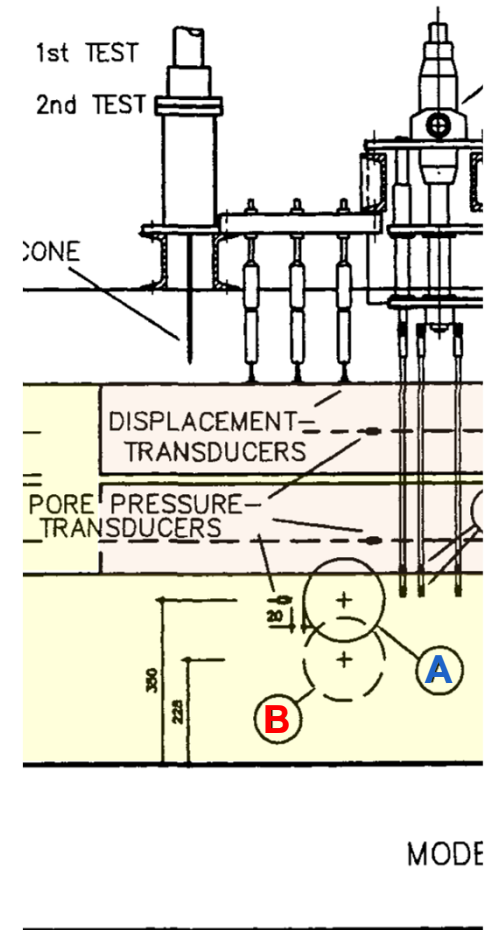
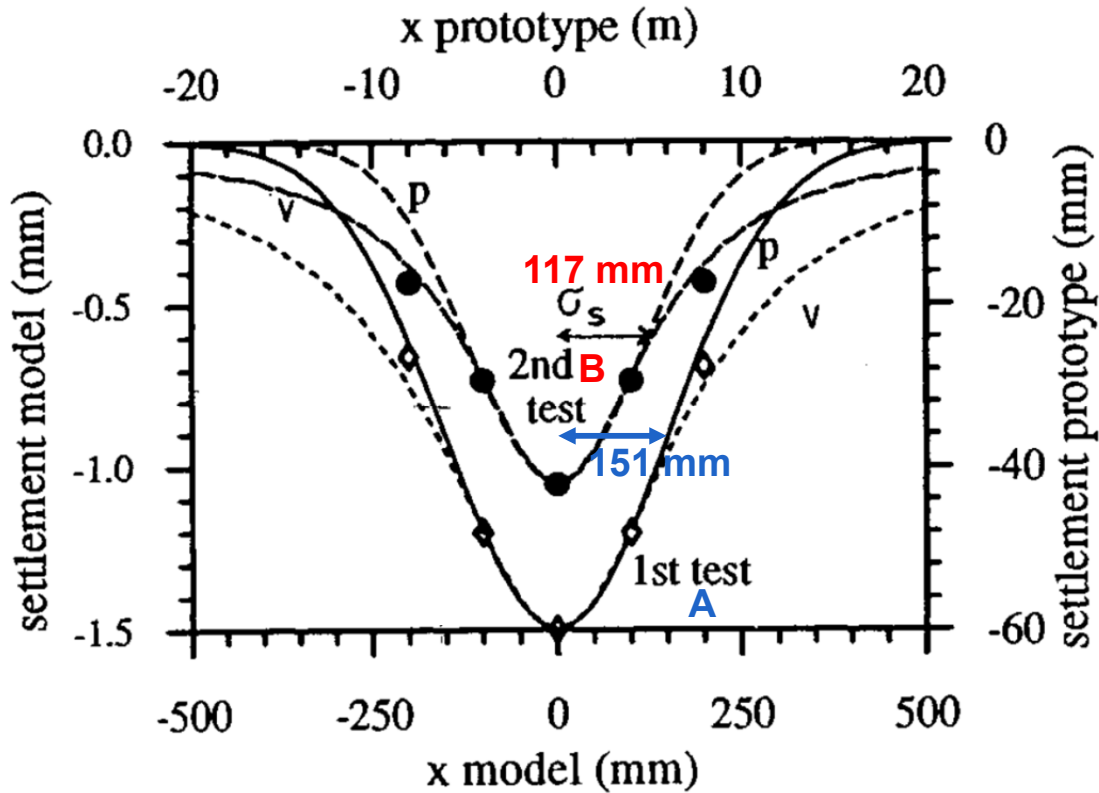
RESEARCH PROGRAMME

- *TBM tunnel underneath river*
- Centrifuge tests
- Field tests

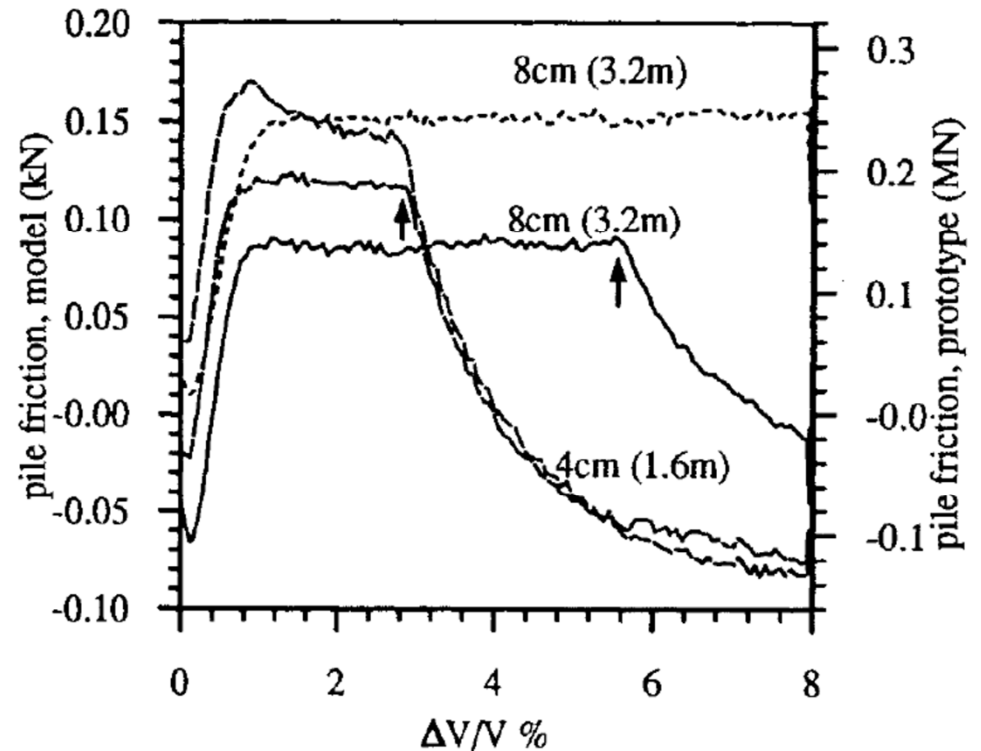
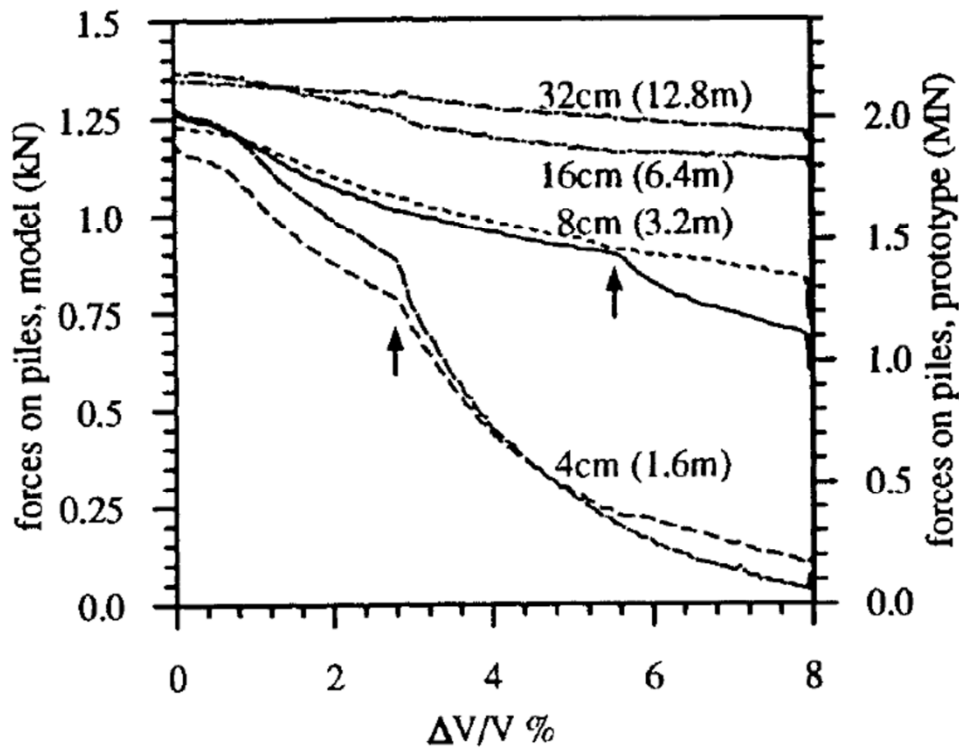
SET-UP DETAILS



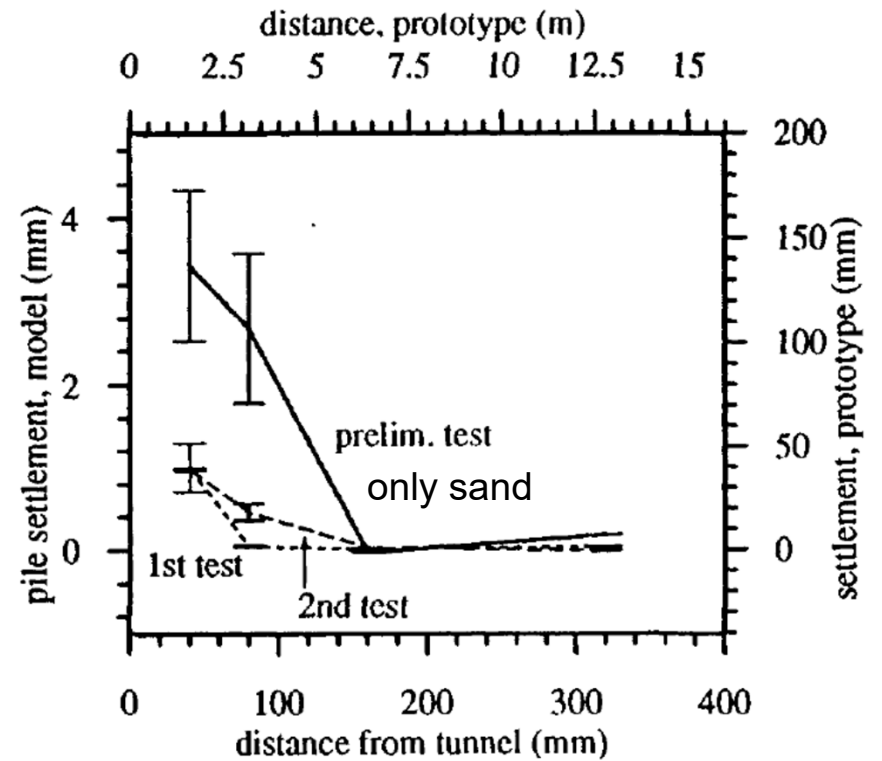
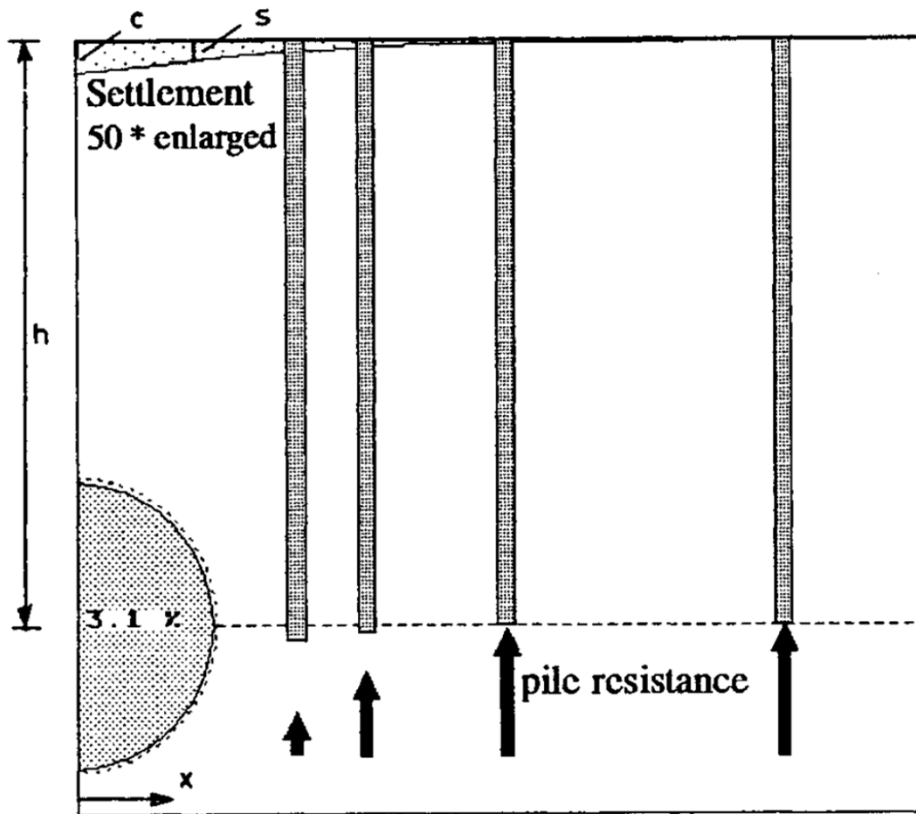
RESULTS, SETTLEMENT TROUGH



RESULTS, PILE RESPONSE

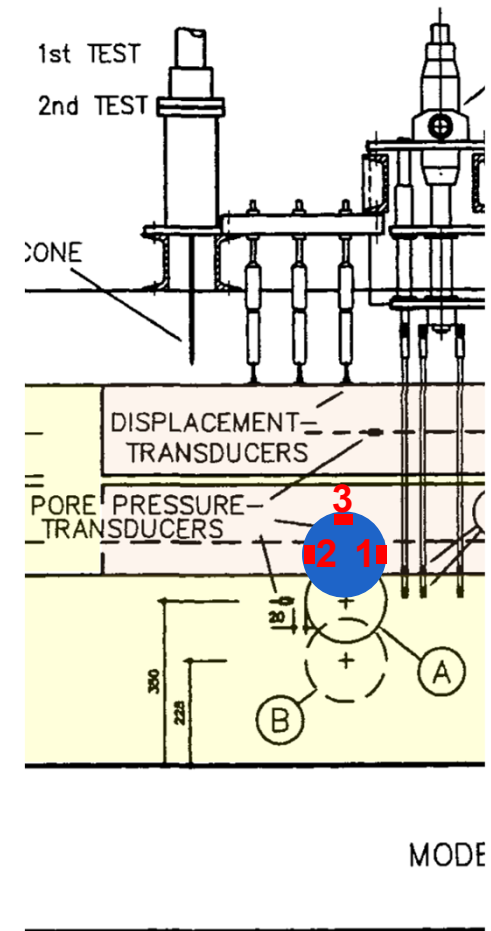
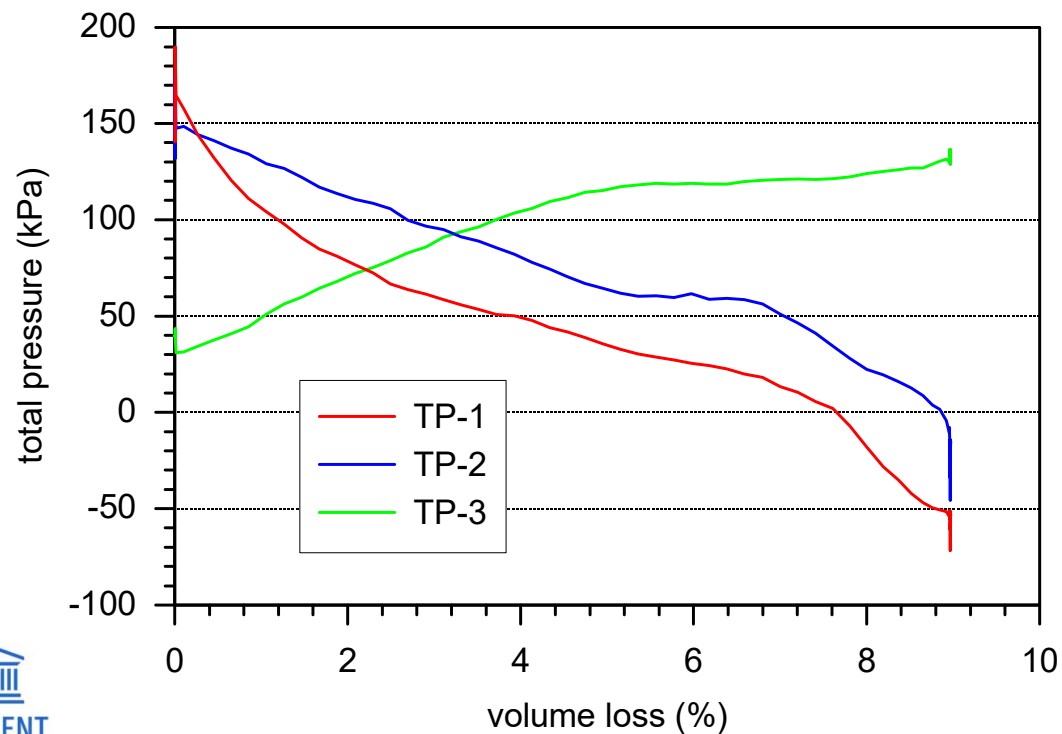


RESULTS, PILE RESPONSE

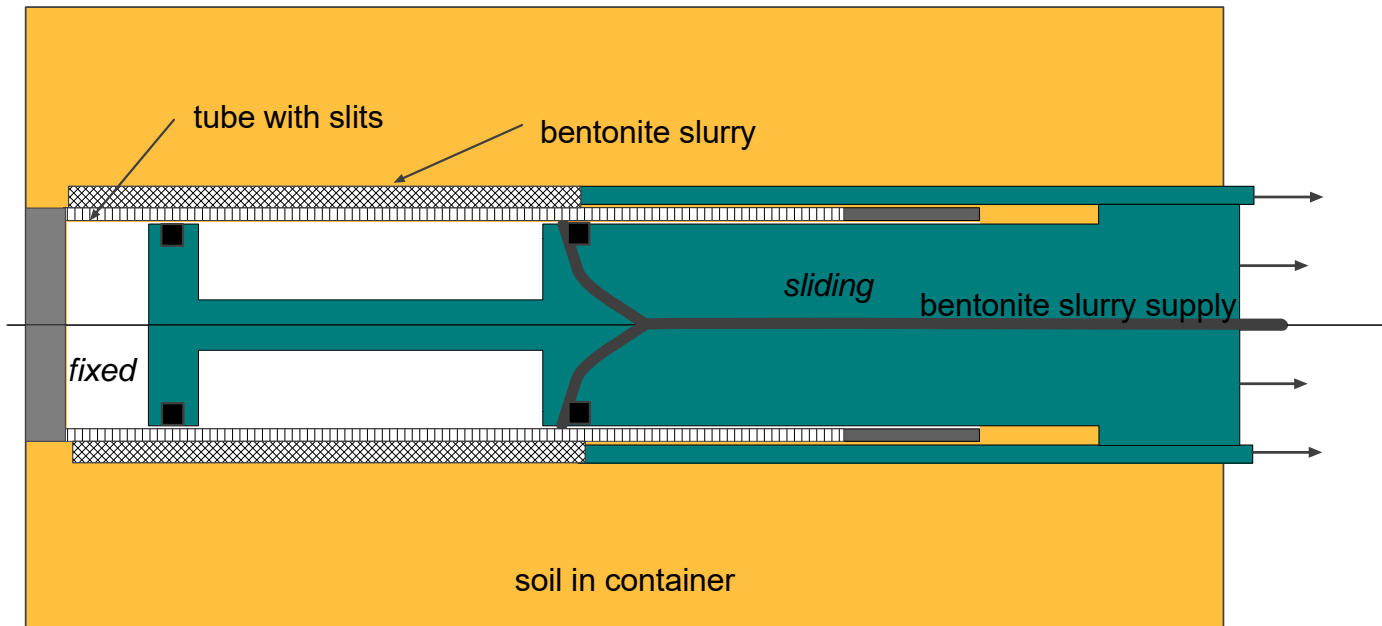


VOLUME LOSS IS ARTIFICIAL

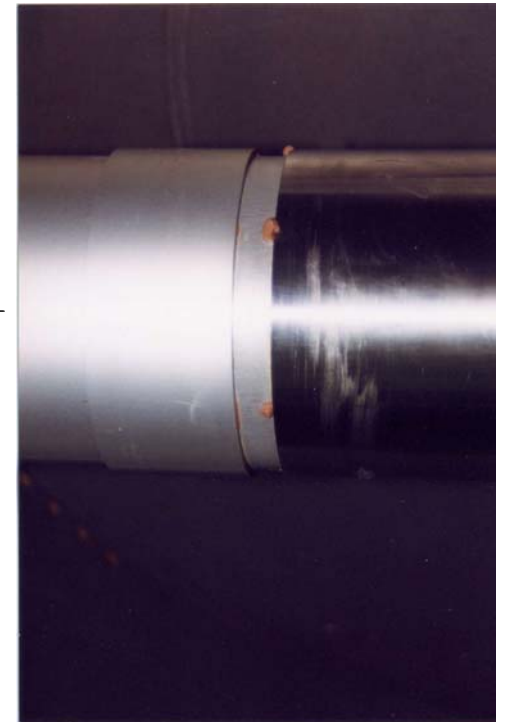
- Sometimes negative pressures around model tunnel



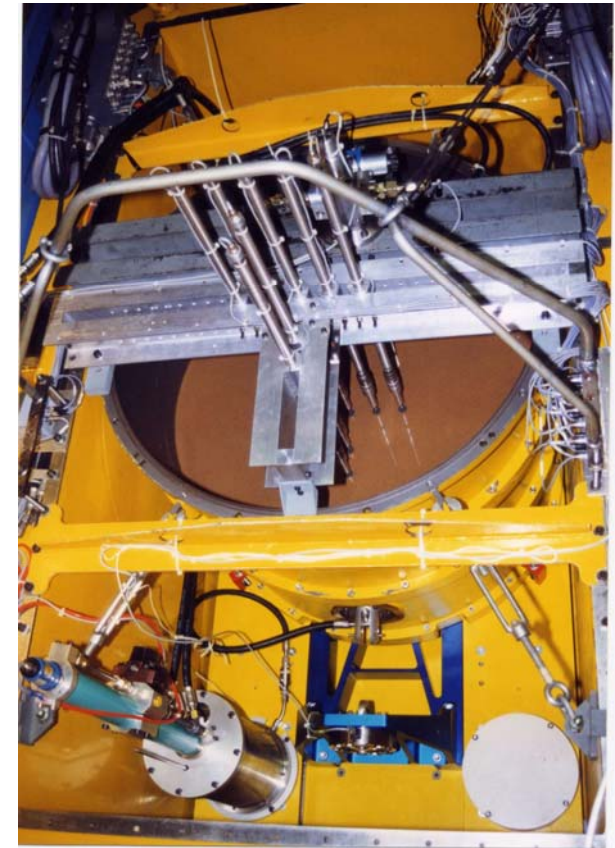
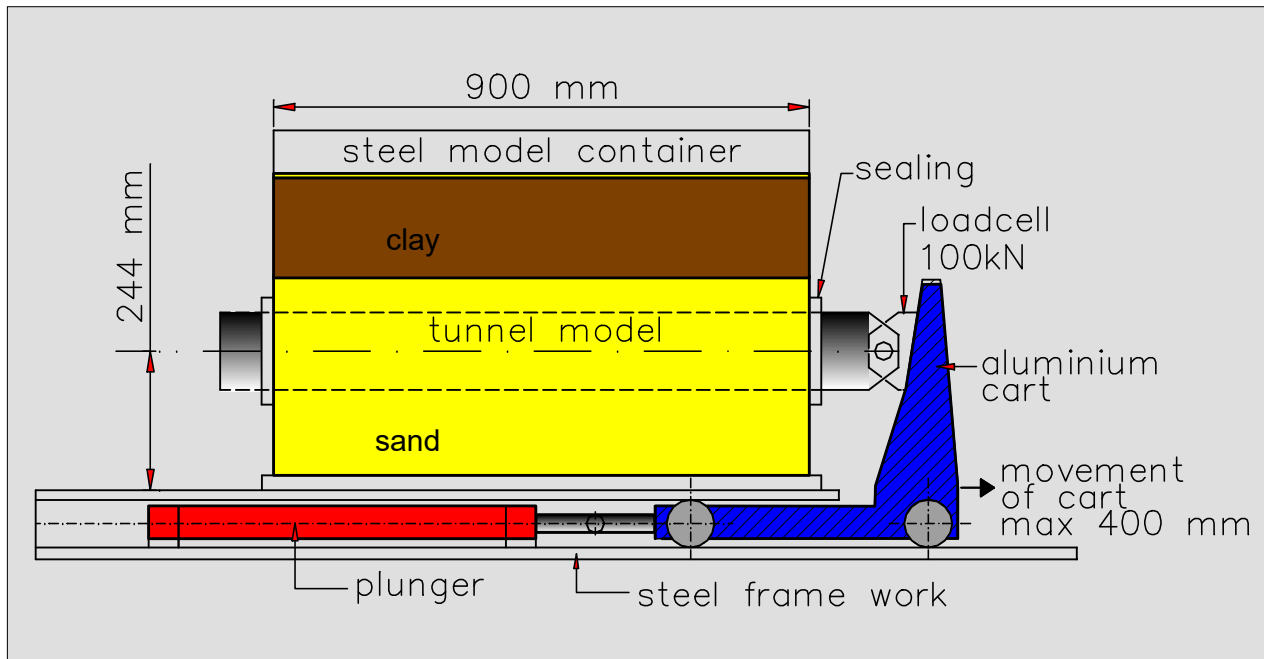
SIMULATION OF TAIL VOID GROUTING



■ pressure gauge



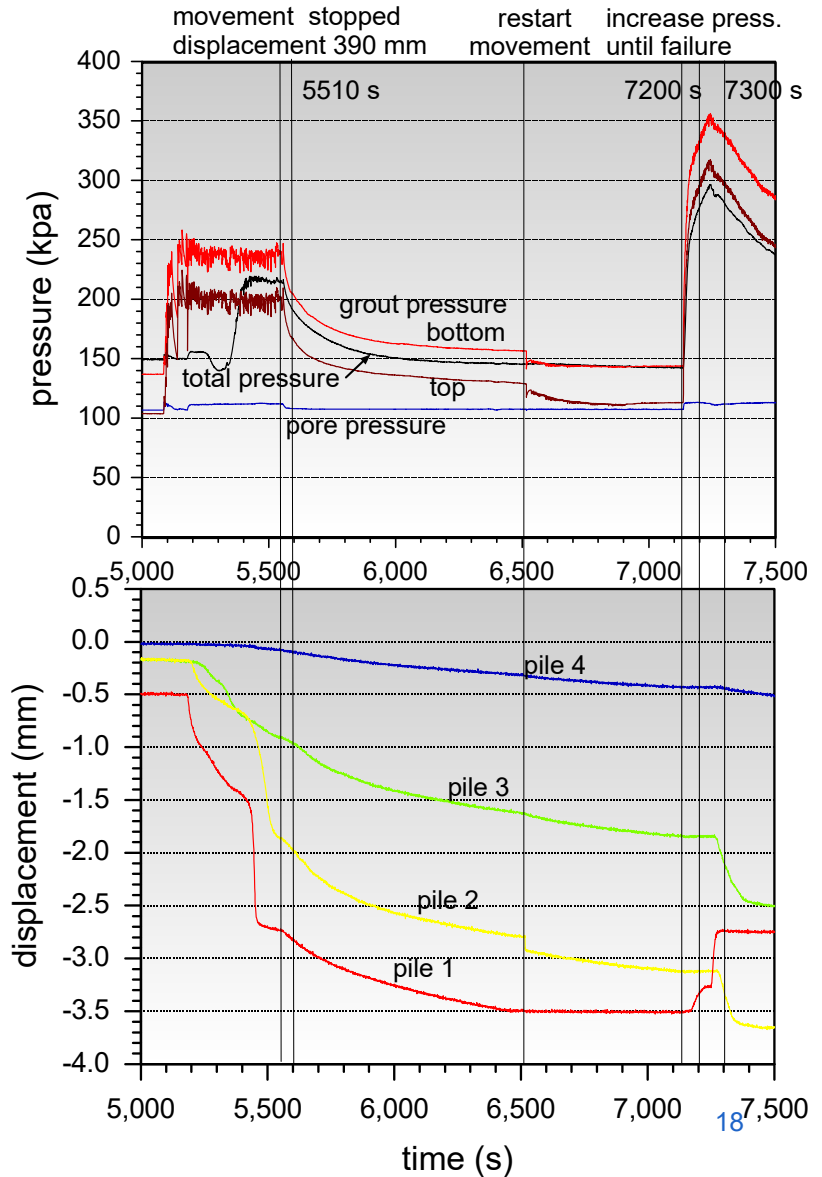
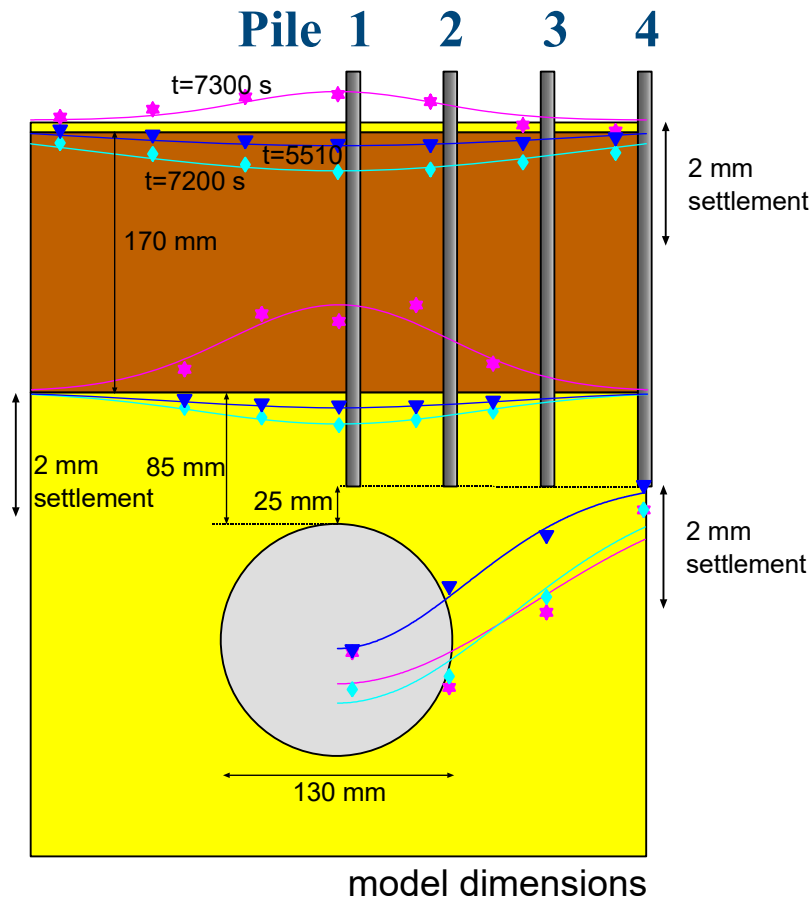
SIMULATION OF TAIL VOID GROUTING



SIMULATION OF TAIL VOID GROUTING

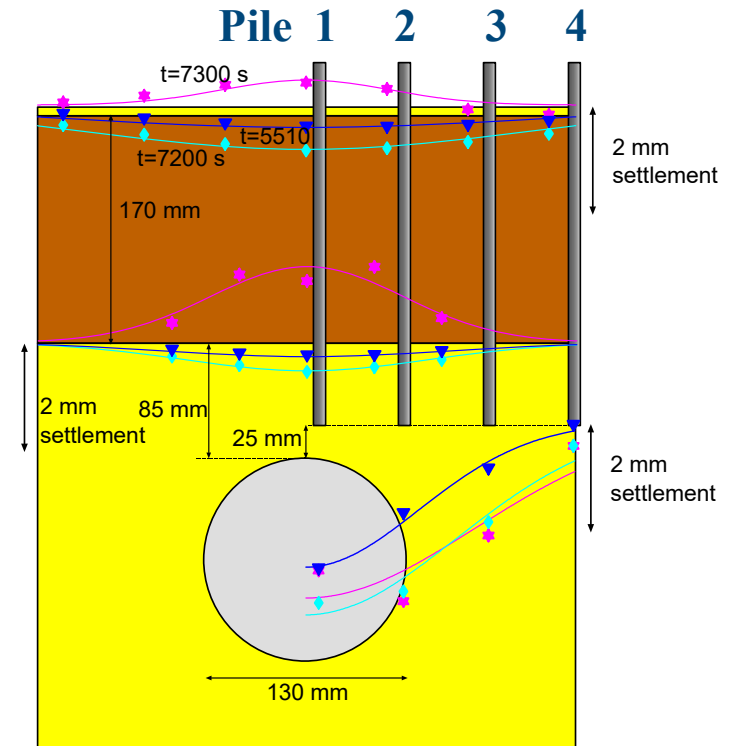
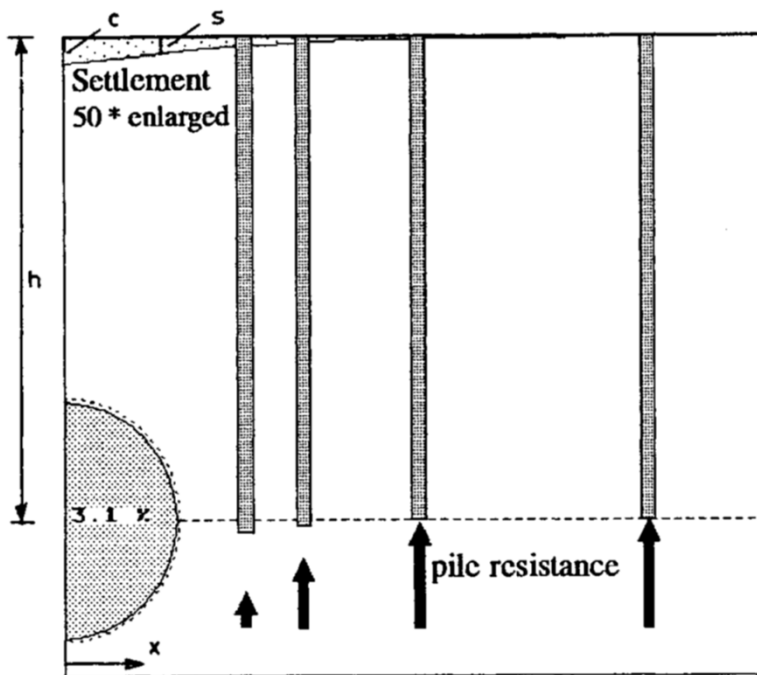
Results 40g test

Pile settlement cannot be compensated



PROBLEM FOR METRO CONSULTANT

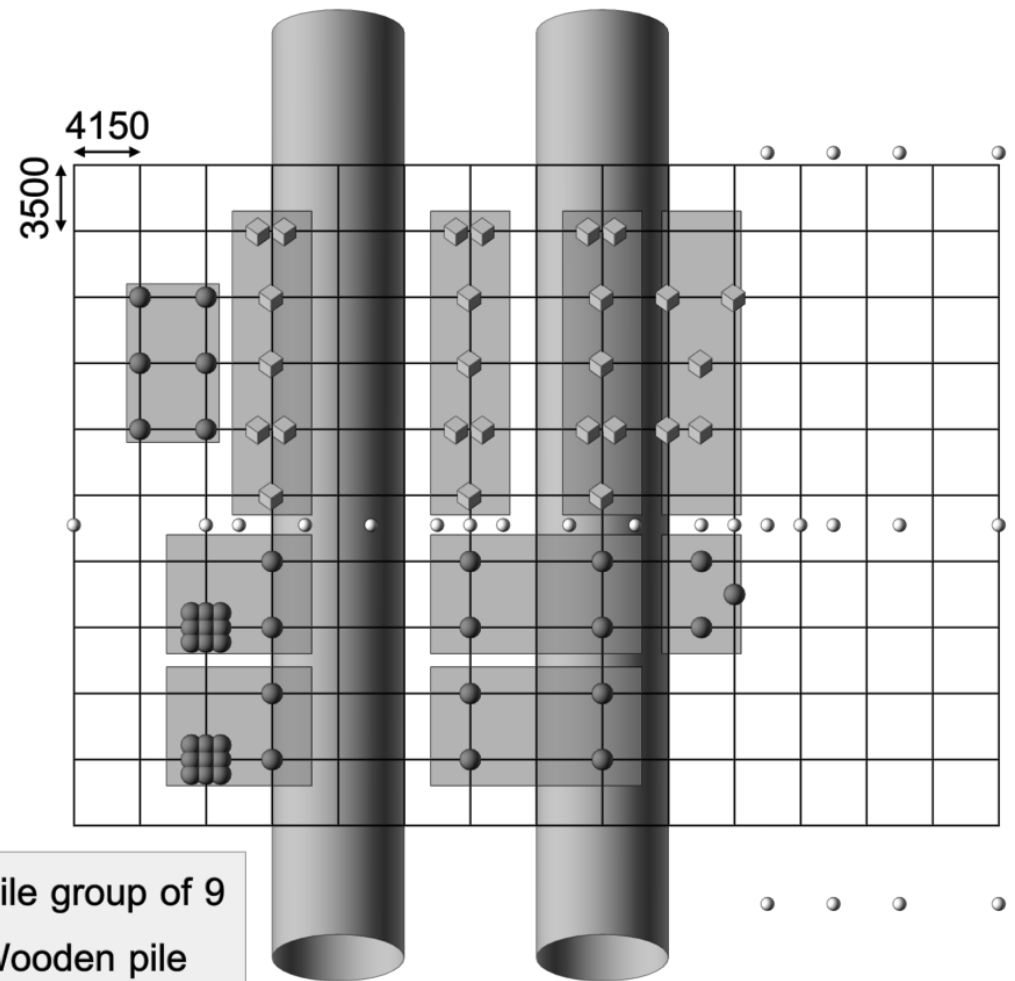
- Piles settle more than the soil in both cases







undesired result!

HOW IN THE FIELD? TEST DURING DRILLING 2ND HEINENOORD TUNNEL

Kaalberg et al. 2005



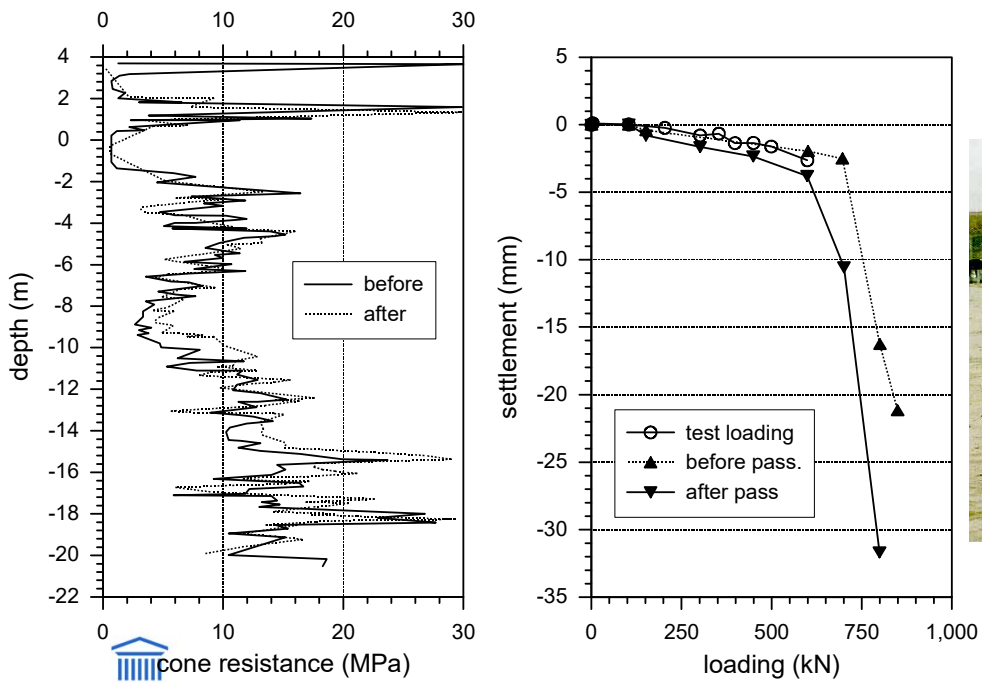
-  Pile group of 9
-  Wooden pile
-  Concrete pile
-  Displacement T

drawing Arne Bezuijen

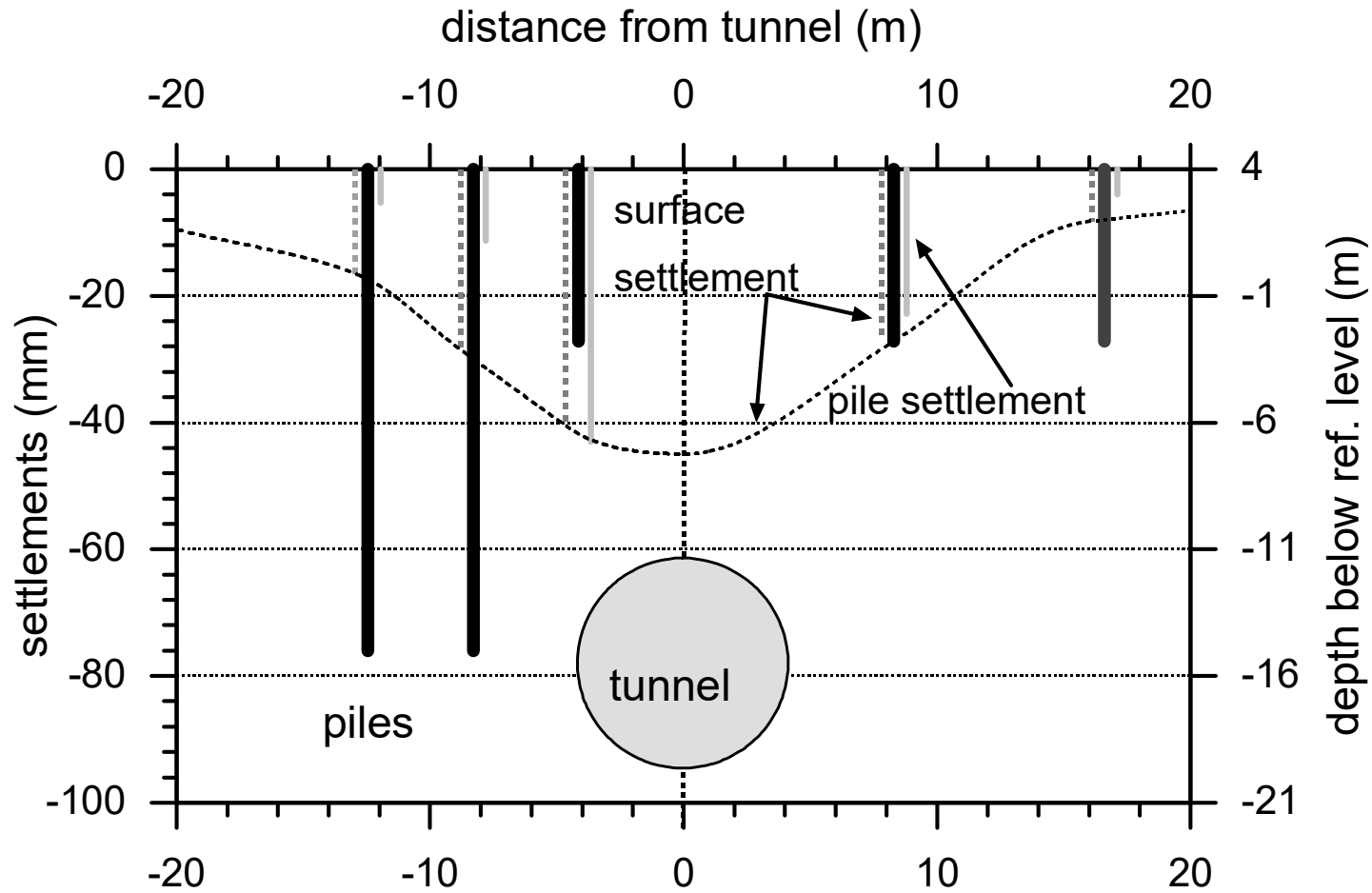
HOW IN THE FIELD?

TEST DURING DRILLING

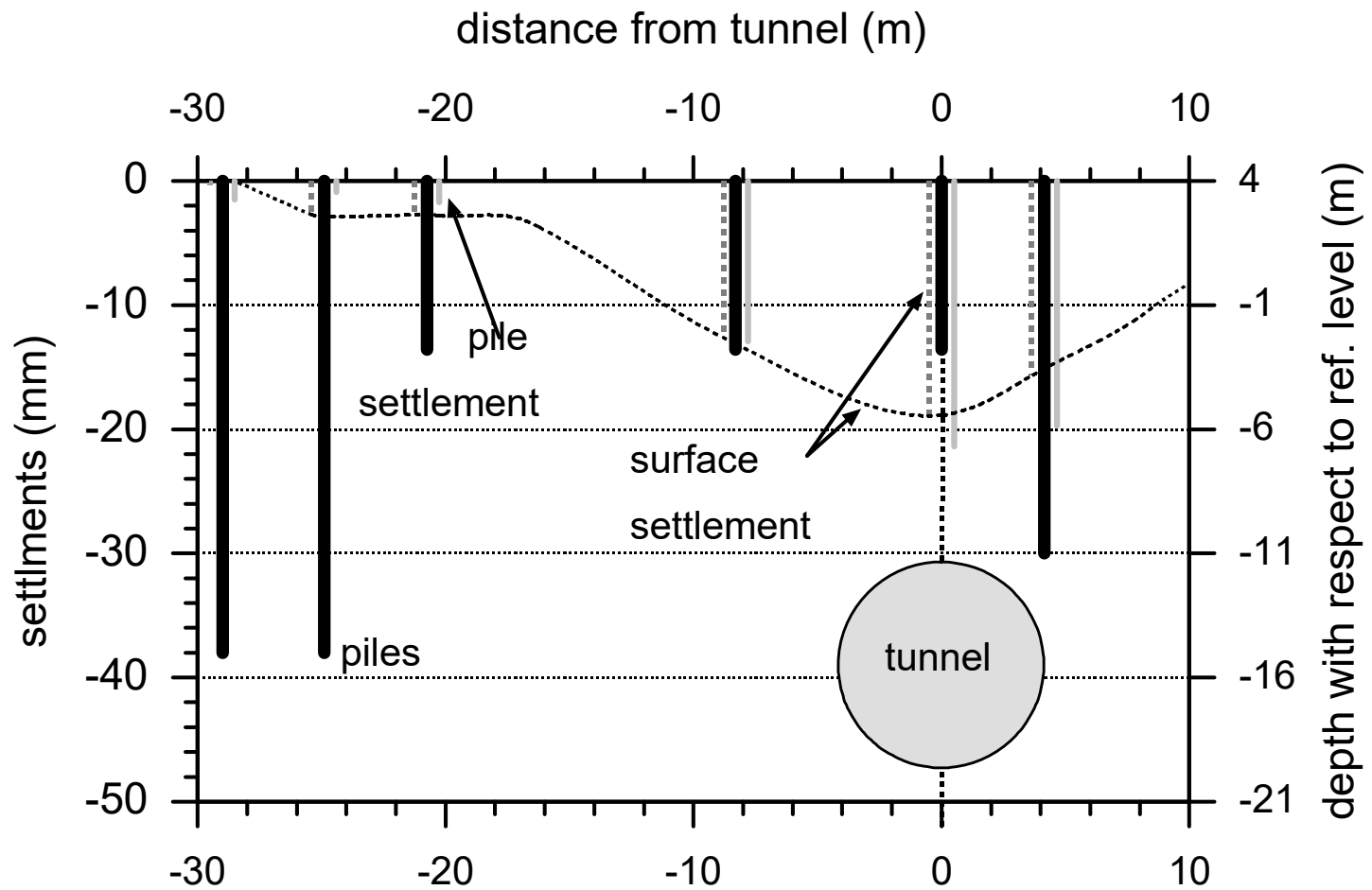
2ND HEINENOORD TUNNEL



HOW IN THE FIELD?



HOW IN THE FIELD?



HOW IN THE FIELD?

Conclusion of field tests was:

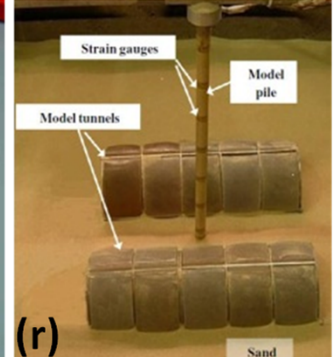
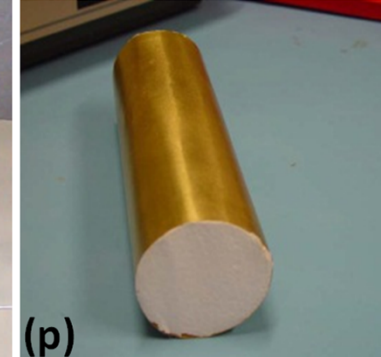
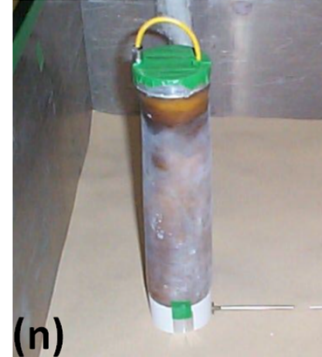
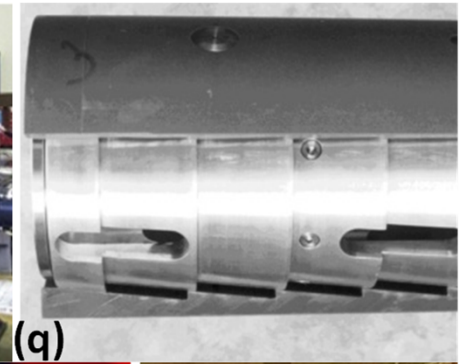
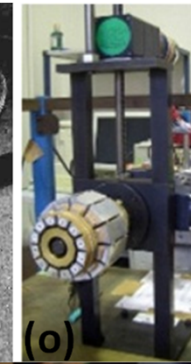
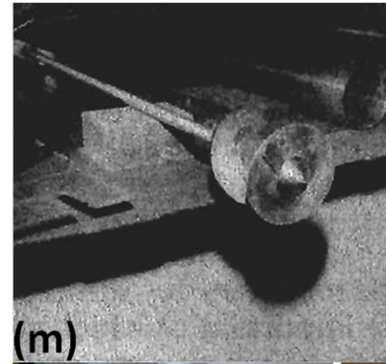
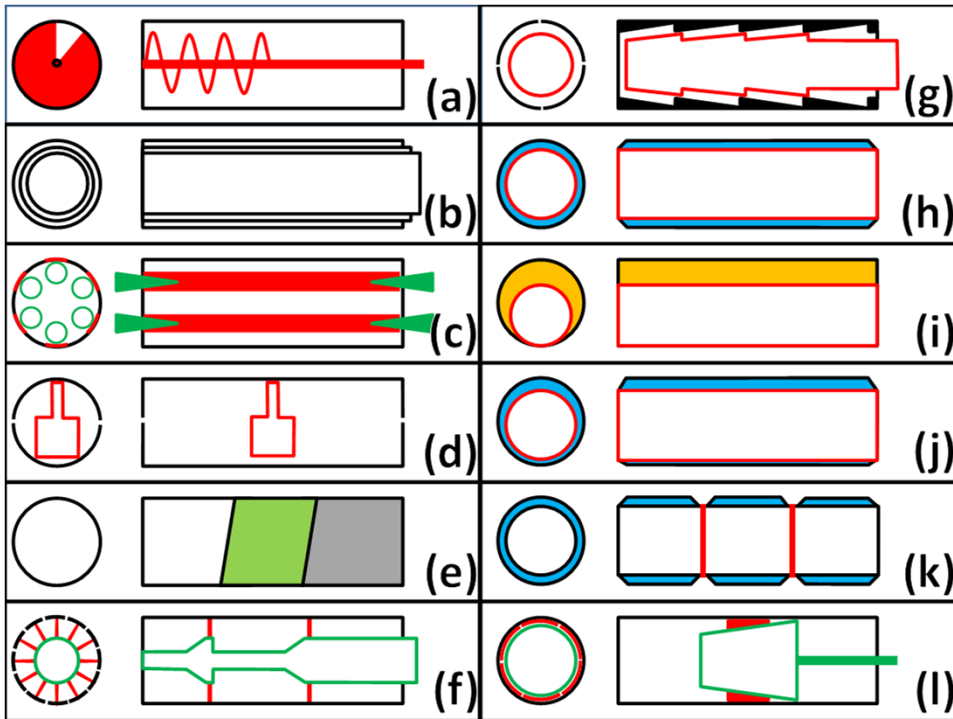
- Centrifuge test what pessimistic
- Large pile settlements, compared to surface settlements, do not occur
- Depends on volume loss and pile position

ONGOING RESEARCH

NOW MORE CENTRIFUGE (AND FIELD) TESTS

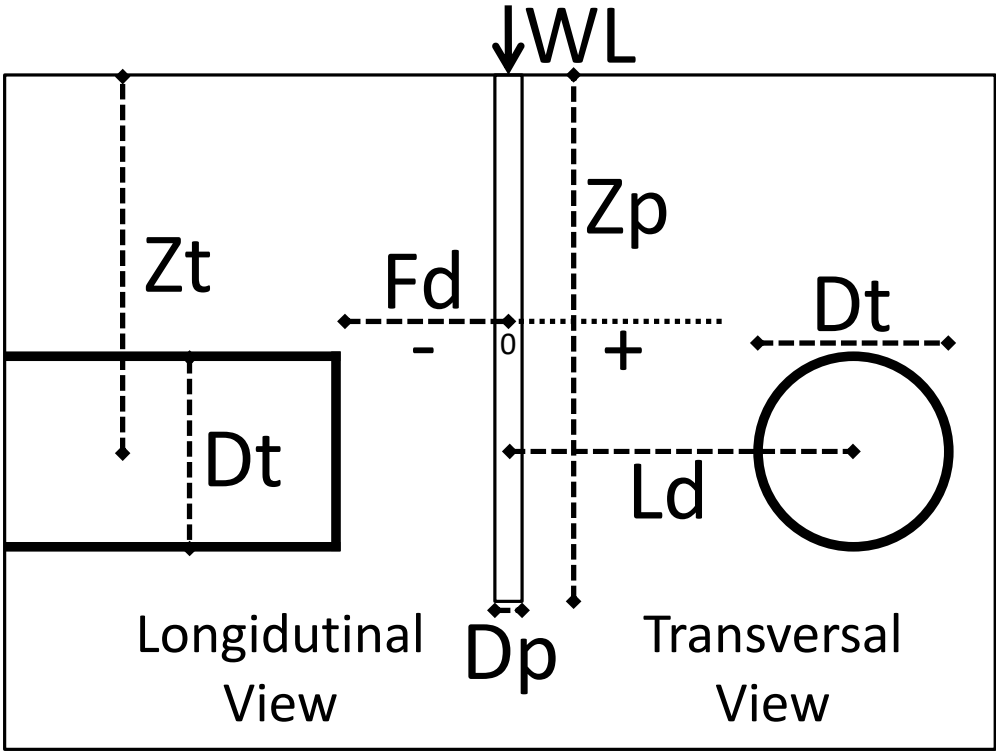
- Several Phd projects
- Different aspects of tunnelling
- Influence of 2 tunnels
- Interaction with buildings

DIFFERENT CENTRIFUGE (AND FIELD) TESTS model tunnels

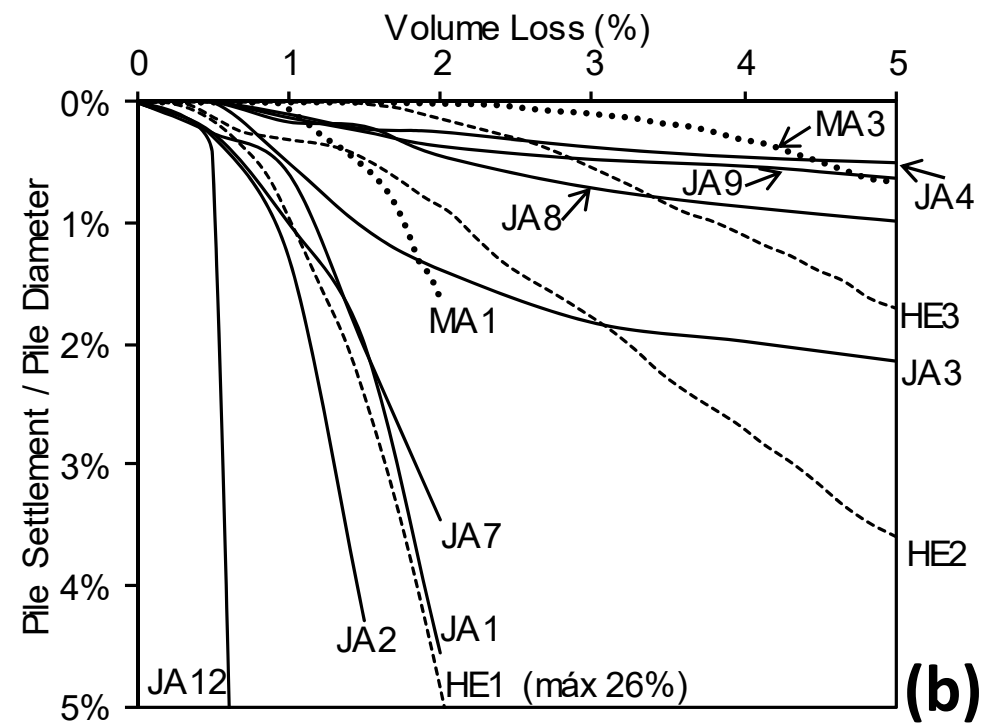
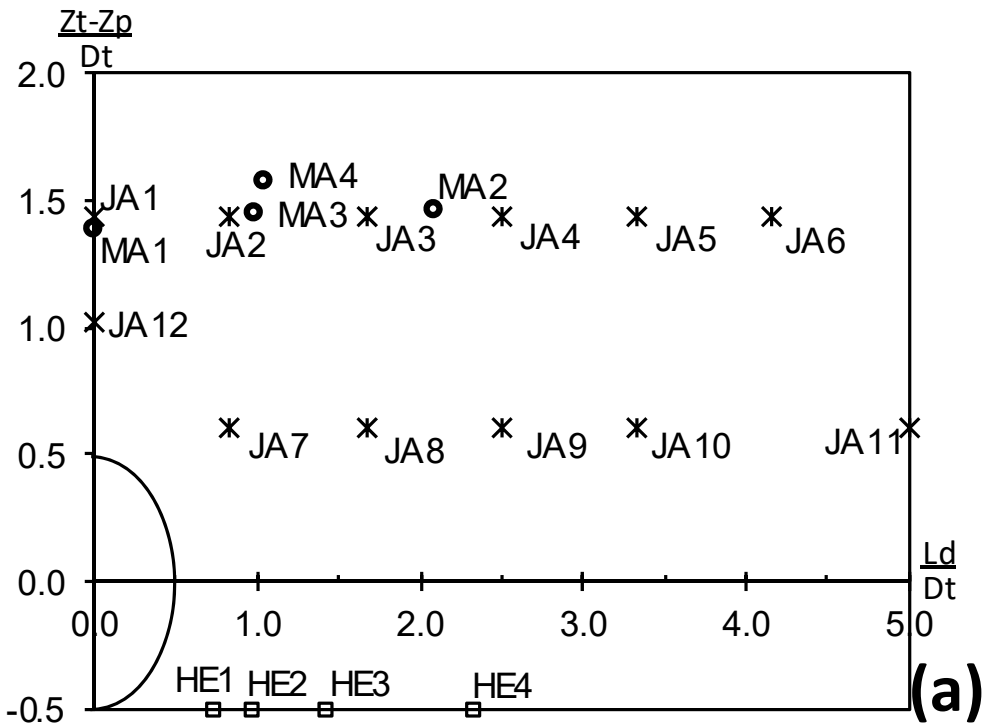


Dias & Bezuijen, 2015

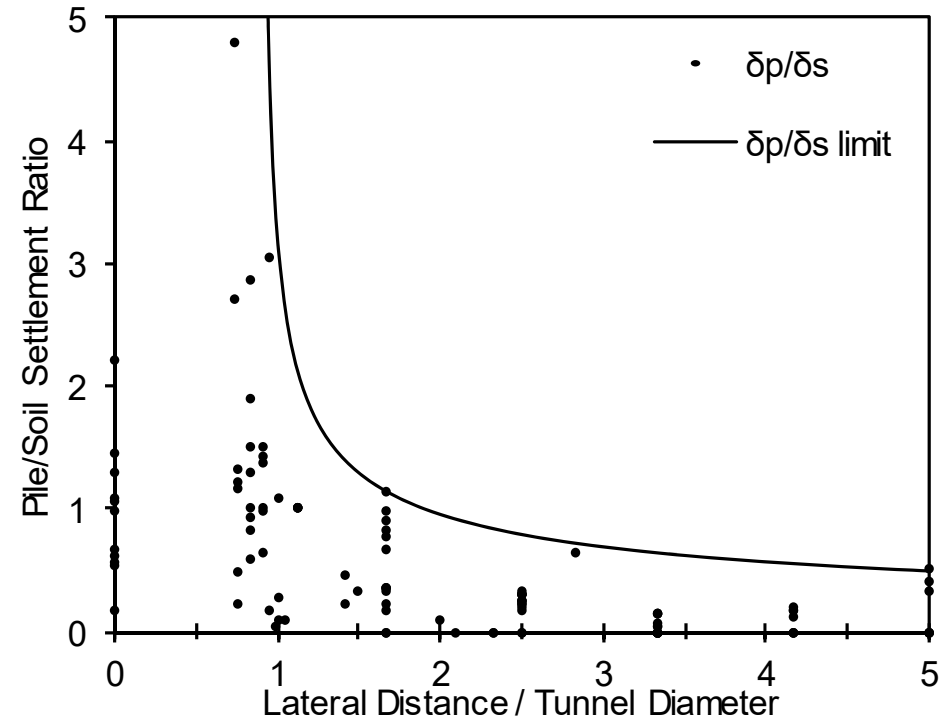
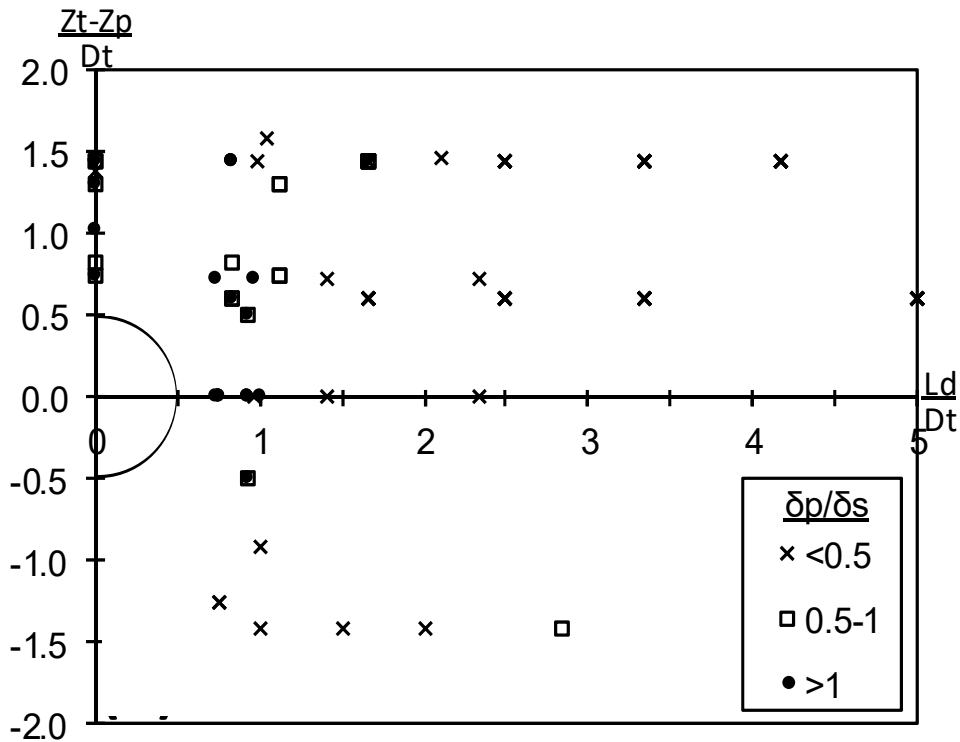
DIFFERENT CENTRIFUGE (AND FIELD) TESTS



DIFFERENT CENTRIFUGE TESTS

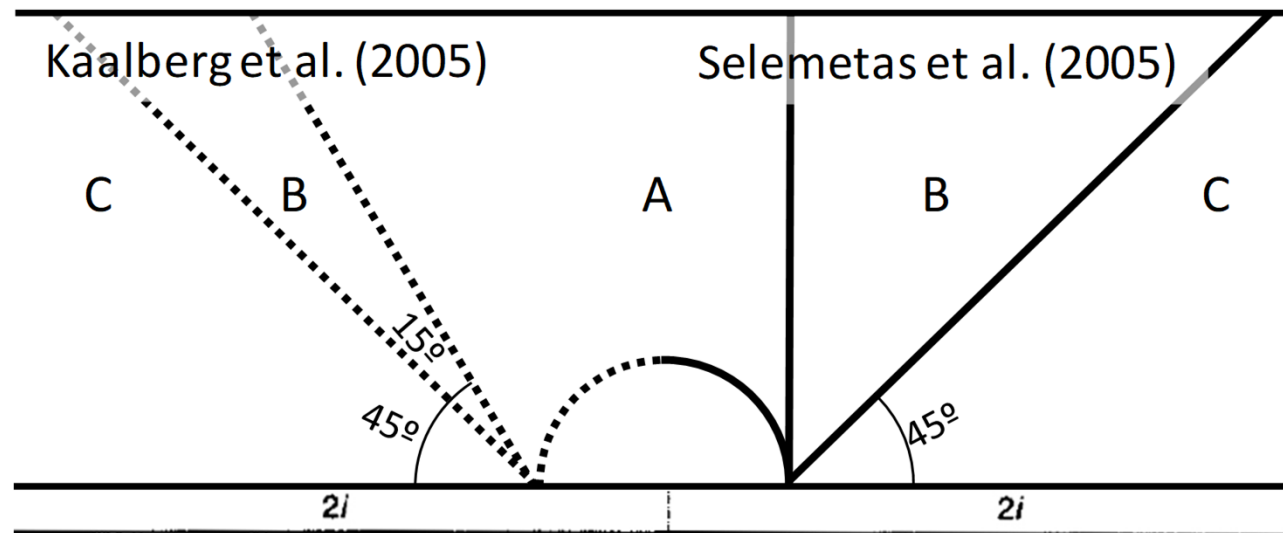


DIFFERENT CENTRIFUGE TESTS

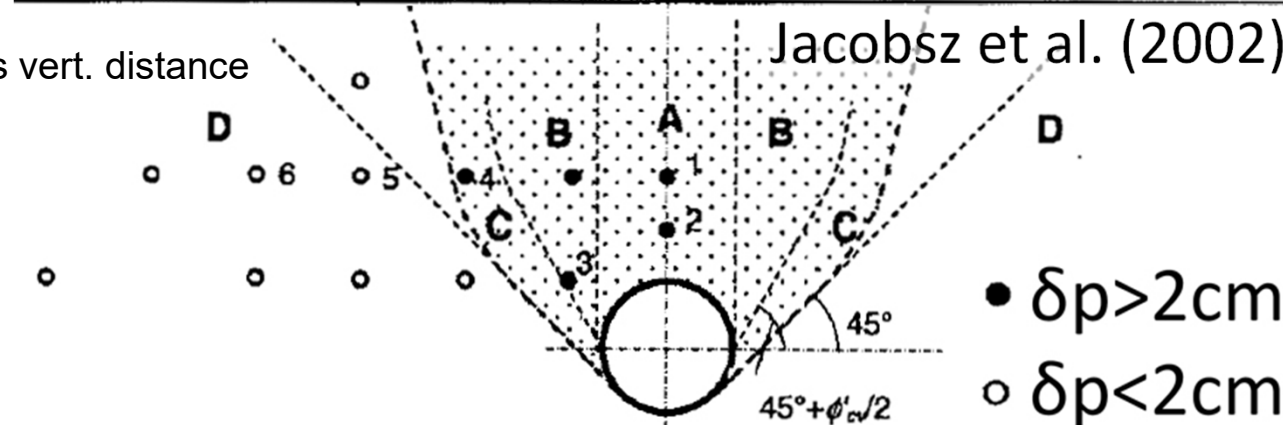


AREAS OF SMALL AND LARGE SETTLEMENT

A pile settlement > soil
 B pile settlement = soil
 C pile settlement < soil



A pile settlement > soil depends vert. distance
 B pile settlement > soil
 C pile settlement = soil
 D pile settlement < soil
 A and B reduction of base load

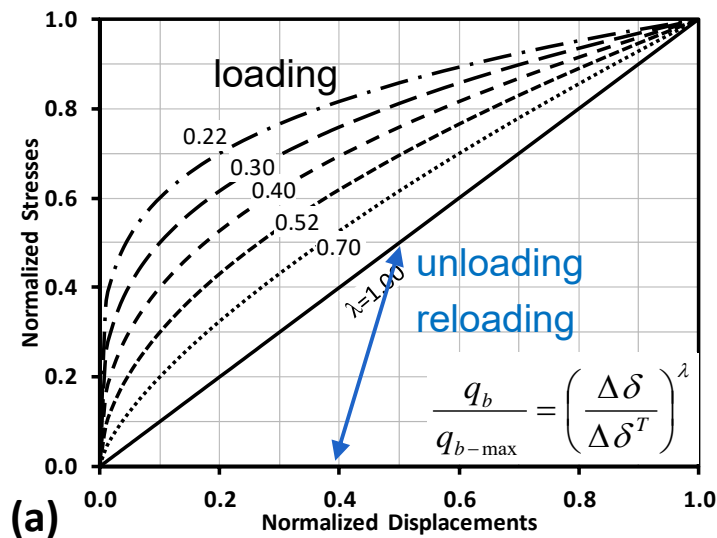


● $\delta_p > 2\text{cm}$
 ○ $\delta_p < 2\text{cm}$

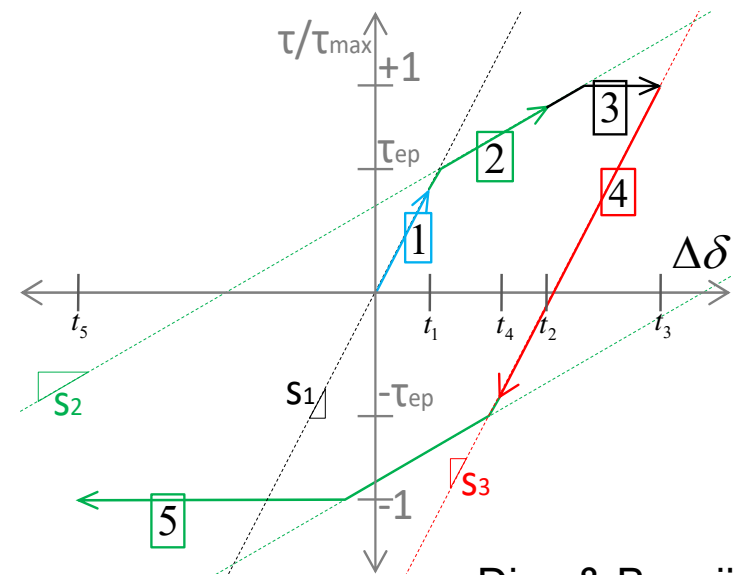
Dias & Bezuijen, 2015

LOAD TRANSFER METHOD

- Assume limited tunnel deformation
- No base degradation
- Calculate or measure soil deformation pattern



base



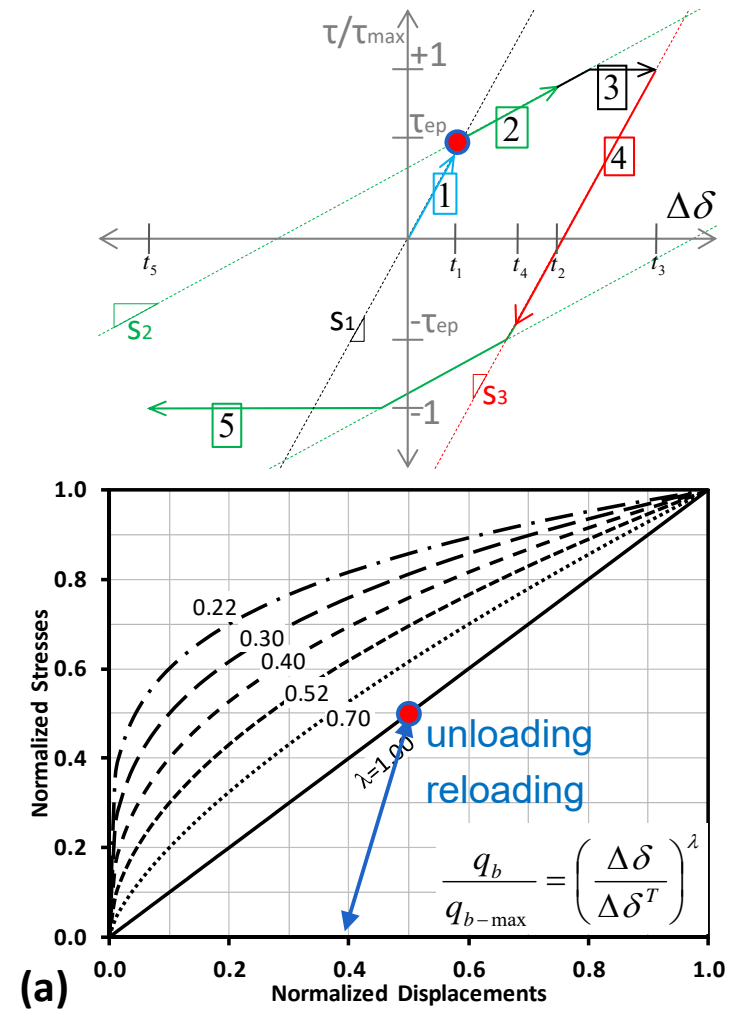
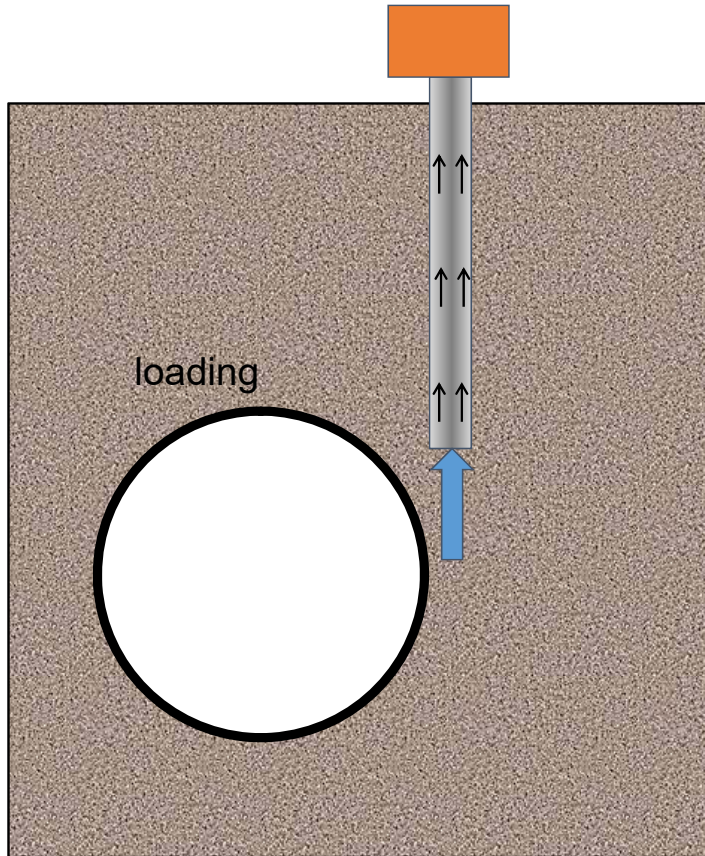
shaft

Dias & Bezuijen, 2018

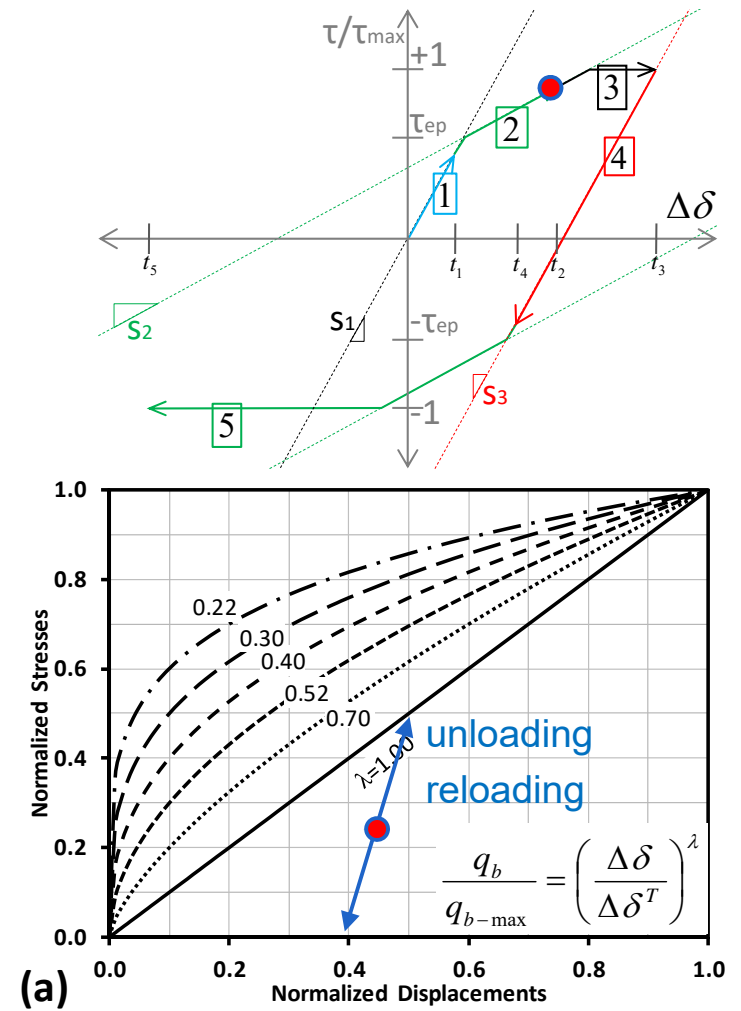
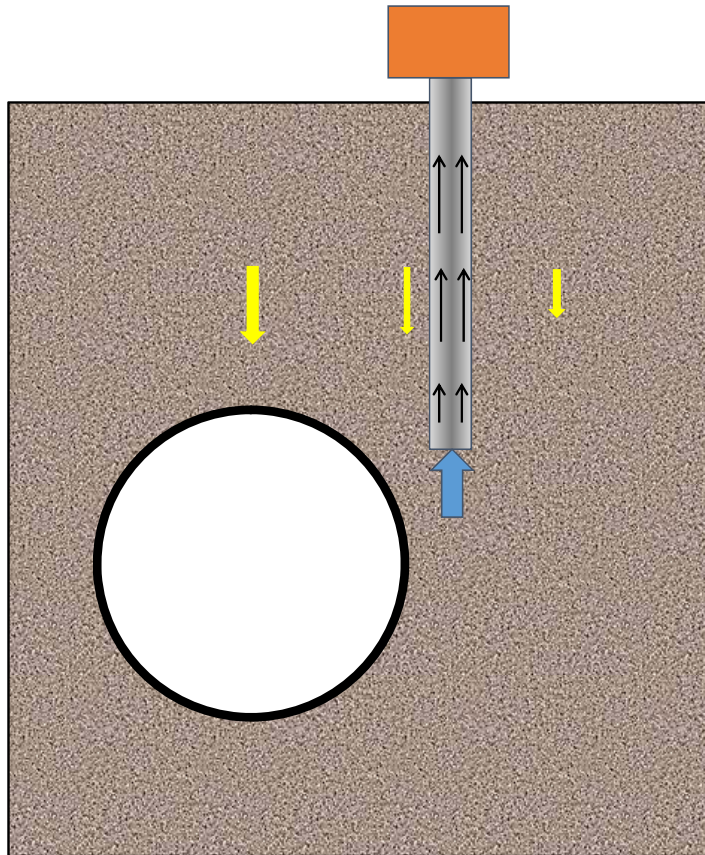
Dias, 2017

32

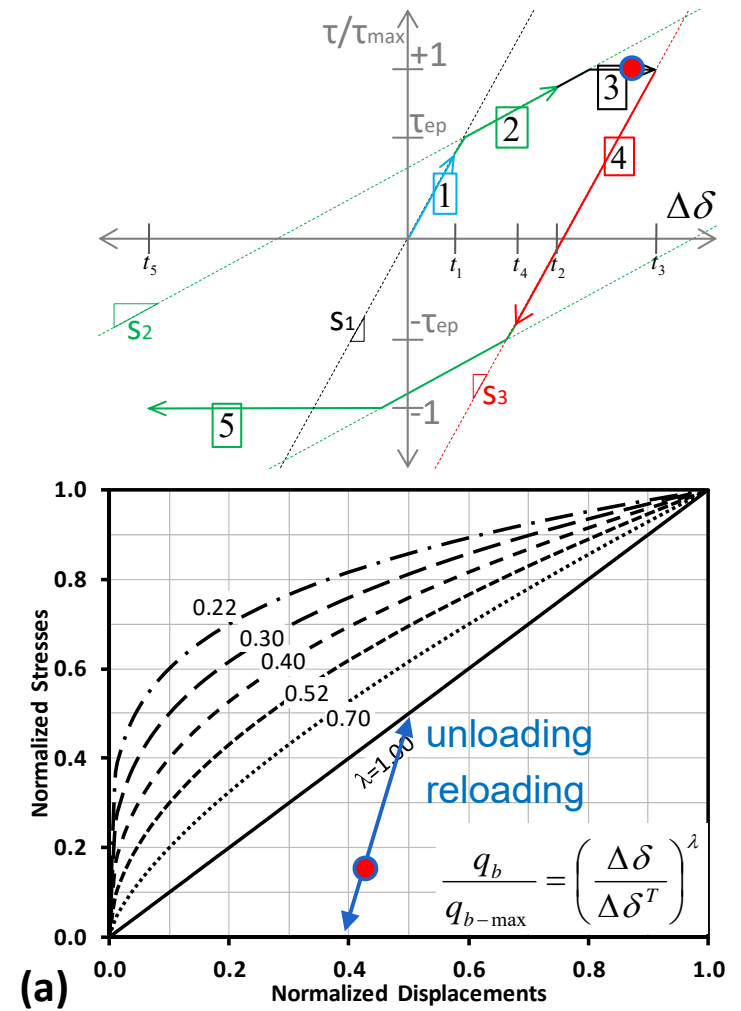
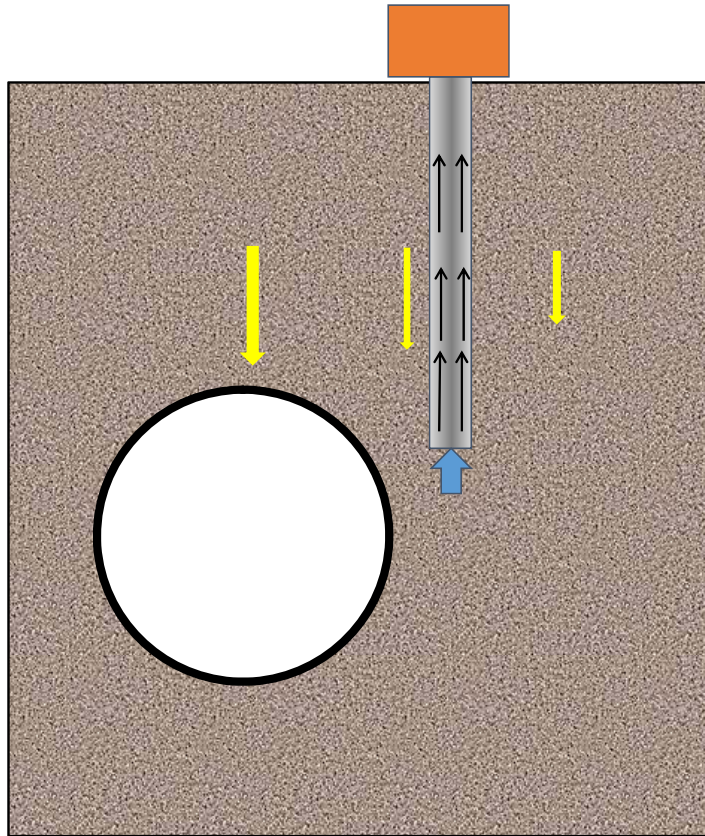
PRINCIPLE



PRINCIPLE



PRINCIPLE



BACK TO AMSTERDAM

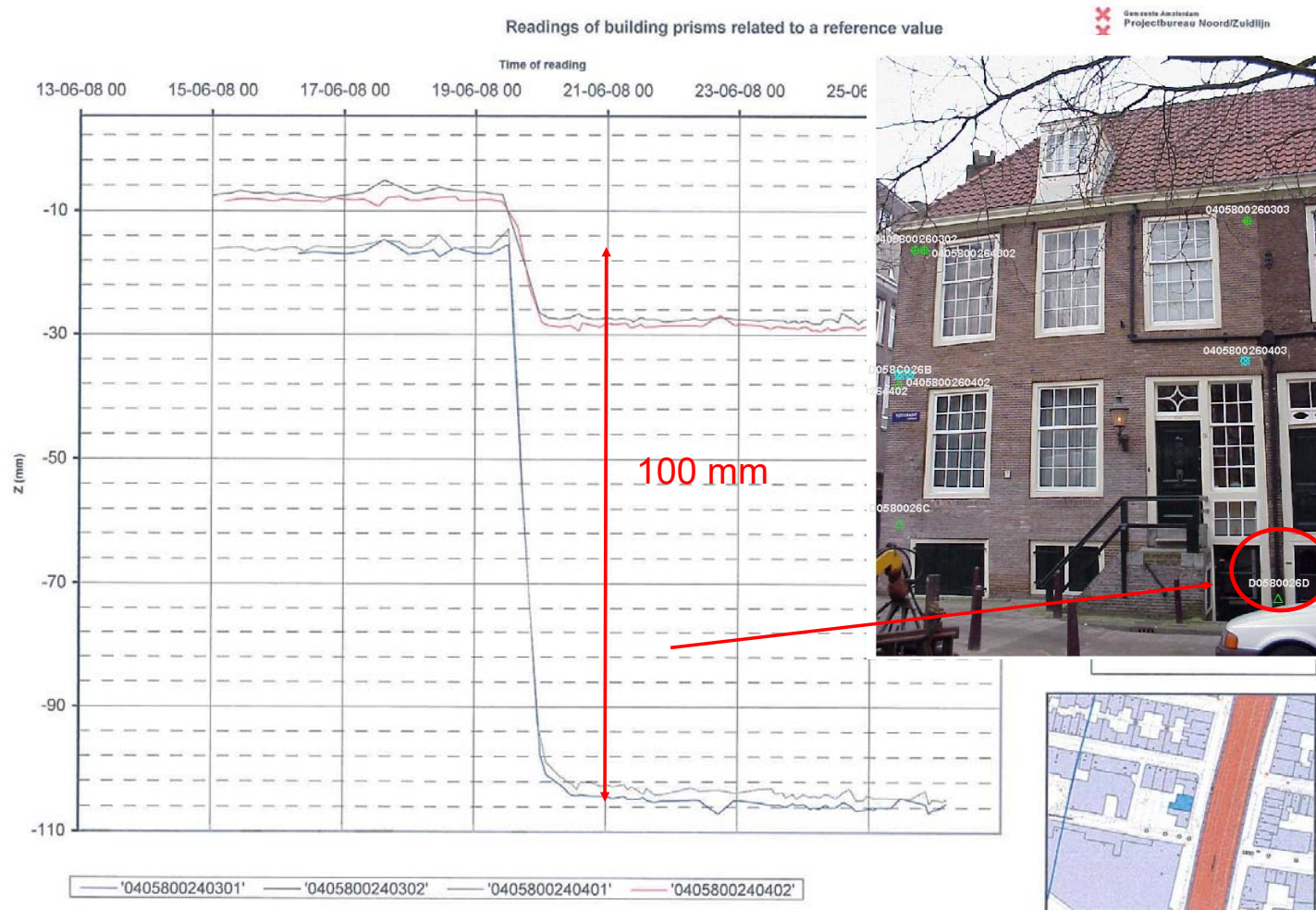
- TBM tunneling went very well
- Limited settlements
- No problems with pile foundations along the TBM track
- However

STATION VIJZELGRACHT



Deltares


SETTLEMENT 100 mm AND LATER 230 mm



HISTORIC HOUSES BADLY DAMAGED

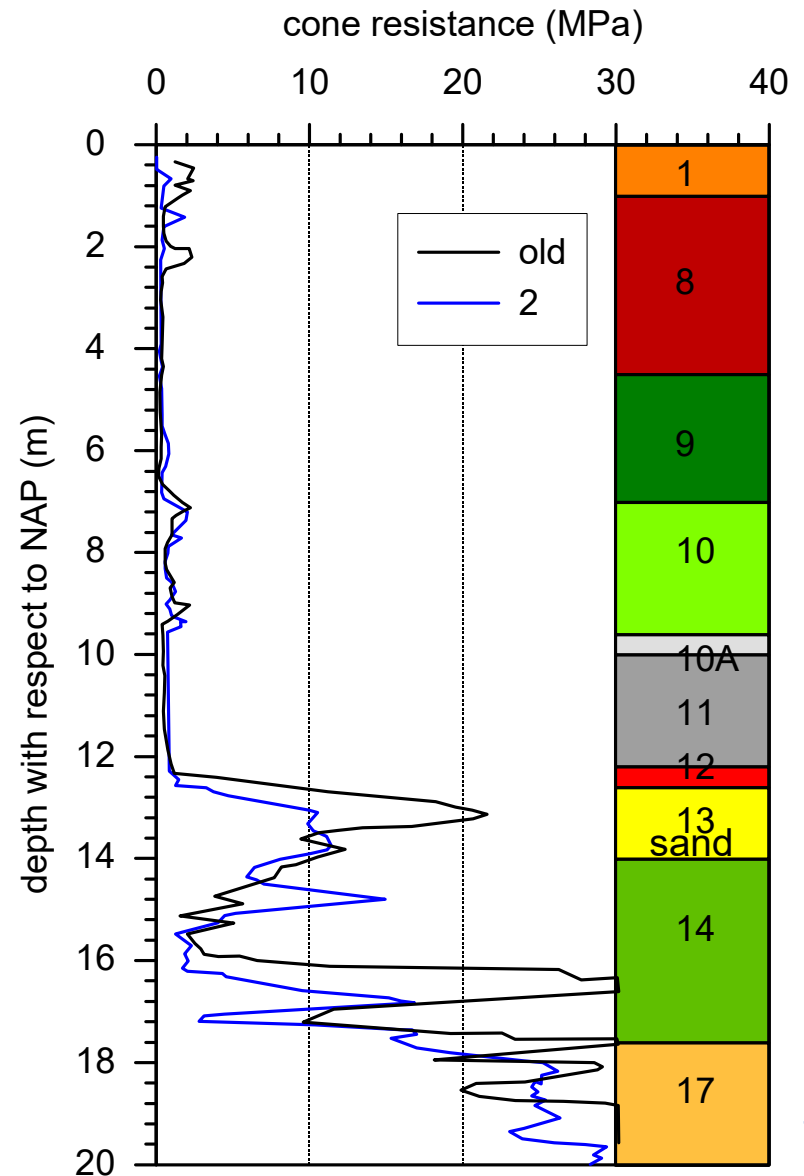


Houses before and after settlements

CPT VIJZELGRACHT

Real disturbance will lead to base degradation as in the first tests

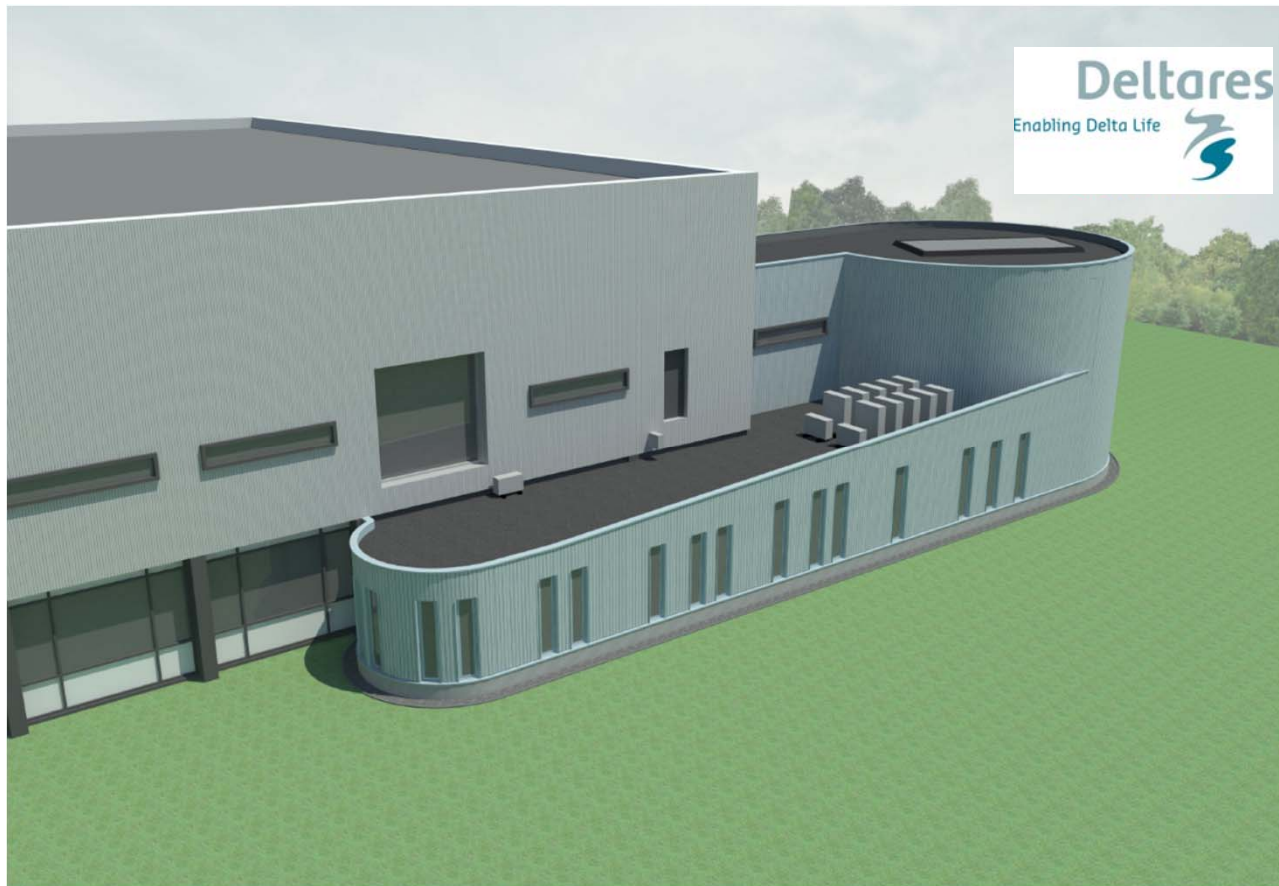
This will not happen with a volume loss of 0.5%



CONCLUSIONS

- The centrifuge is a valuable tool to investigate pile-tunnel interaction
- The results are confirmed in the field
- Base degradation due to tunnelling will only occur at high volume losses during tunnelling
- Soil deformation along the whole pile is important

NEW DELTARES CENTRIFUGE



planned opening 2020

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