



Pile Load Testing Seminar, 21 Oct 2021, the Hague



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Researches • Develops • Informs

Static Pile Load Tests : Instrumentation of piles

Monika De Vos & Gust Van Lysebetten

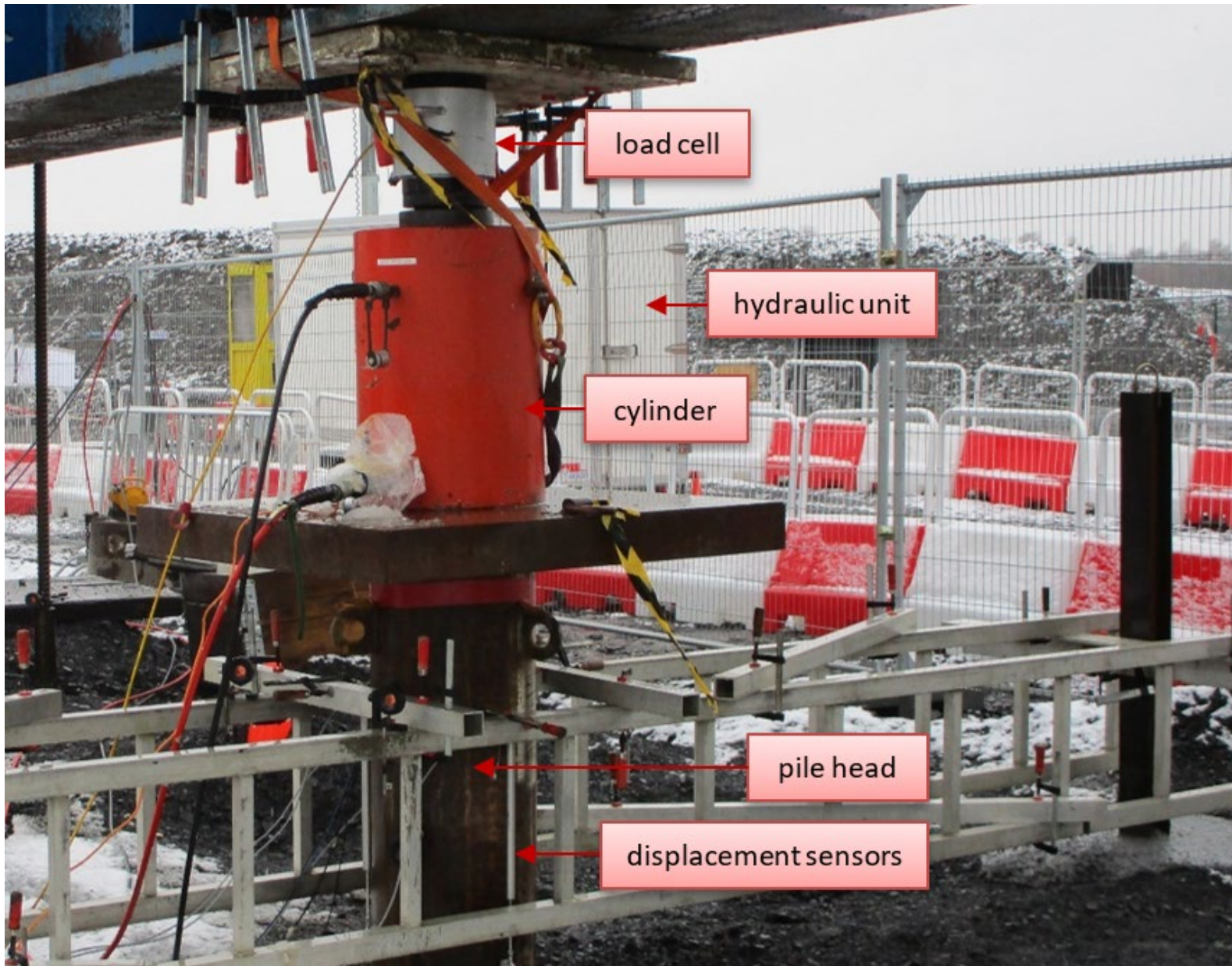
Belgian Building Research Institute, Laboratory of Geotechnics & Monitoring



Instrumentation of piles (Monika De Vos & Gust Van Lysebetten, BBRI)

Compression
Tension
Lateral loading

Traditional jack
O-cell





Test procedure

INTERNATIONAL STANDARD **ISO 22477-1**

First edition 2018-11
Corrected version 2019-03

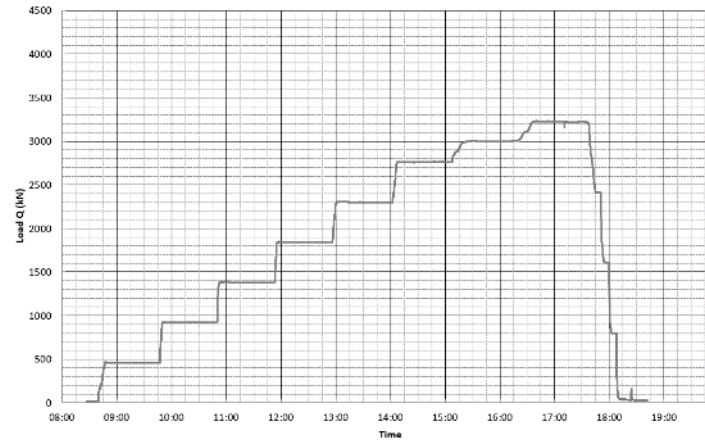
Geotechnical investigation and testing — Testing of geotechnical structures —

**Part 1:
Testing of piles: static compression load testing**

*Reconnaissance et essais géotechniques — Essais des structures géotechniques —
Partie 1: Essais de pieux: essai de chargement statique en compression*

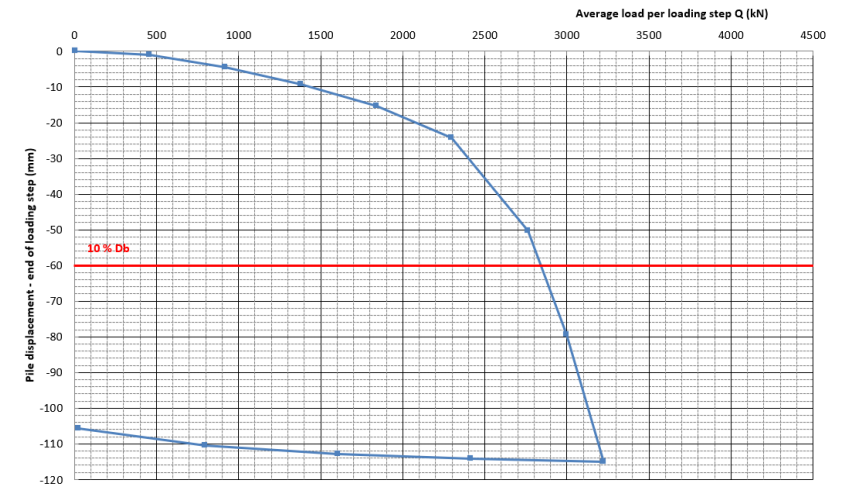
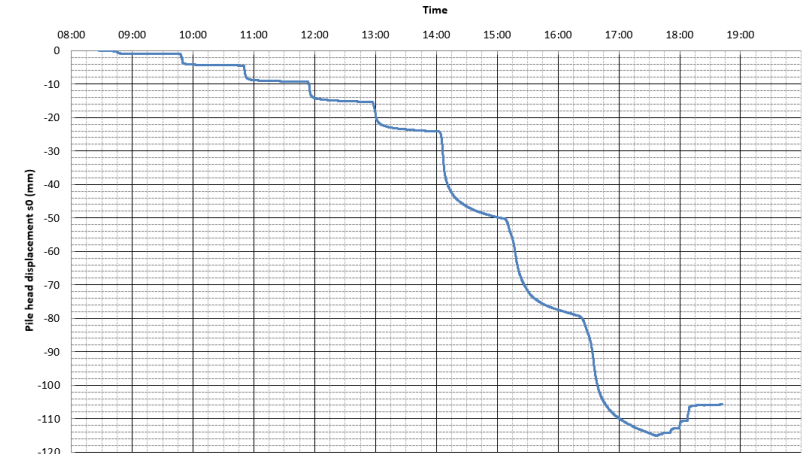
Reference number
ISO 22477-1:2018(E)

© ISO 2018



Min. 8 loading steps

Min. 60 min/step
(except first steps)



Test procedure

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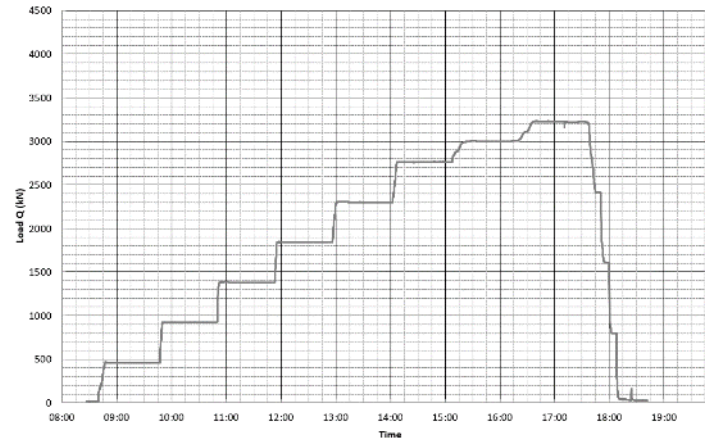
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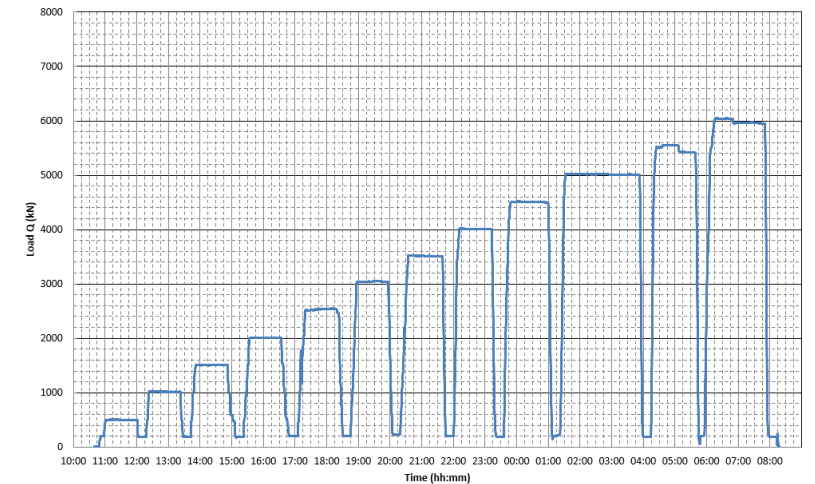
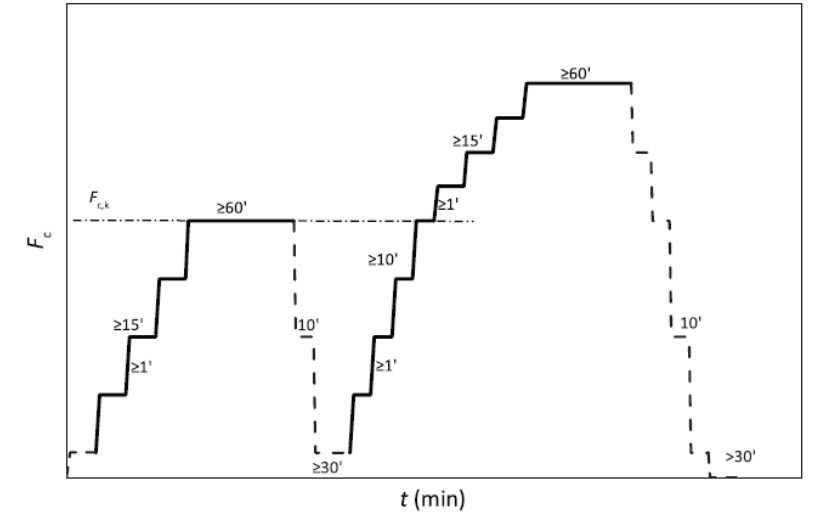


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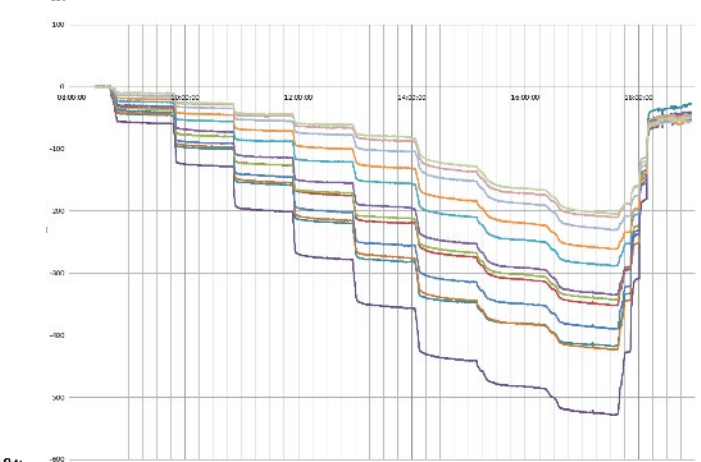
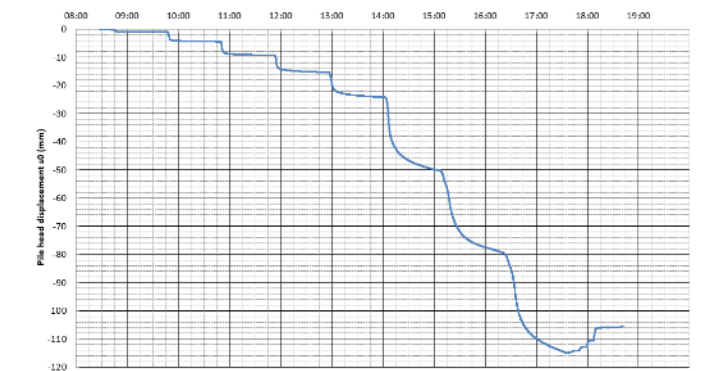
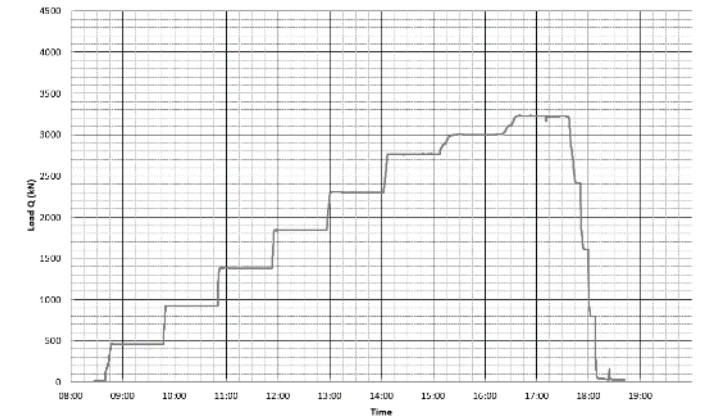
1, 2 or multiple loading cycles
Creep criteria

→ Total bearing capacity



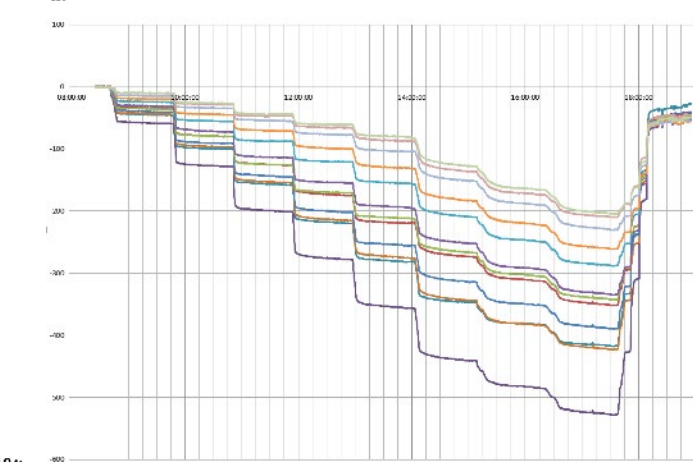
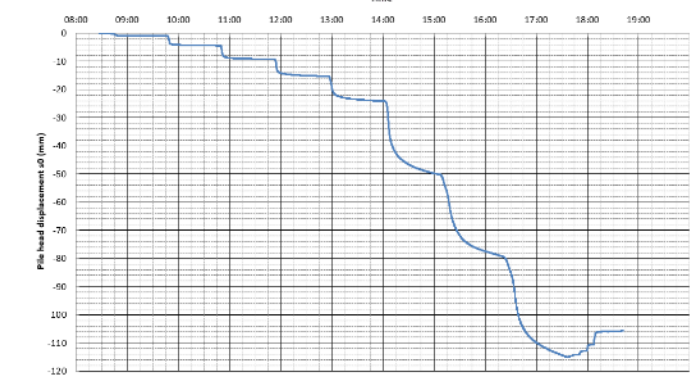
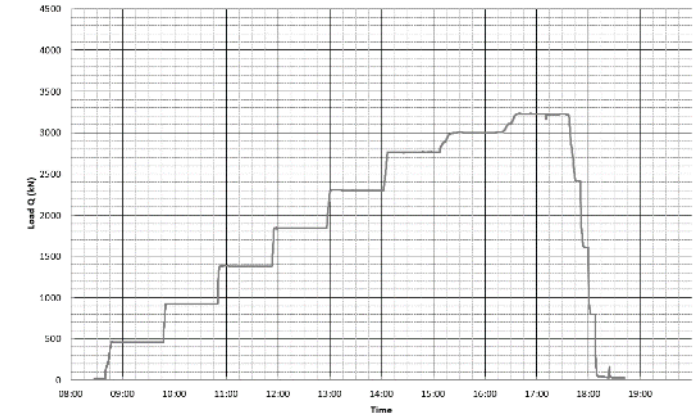
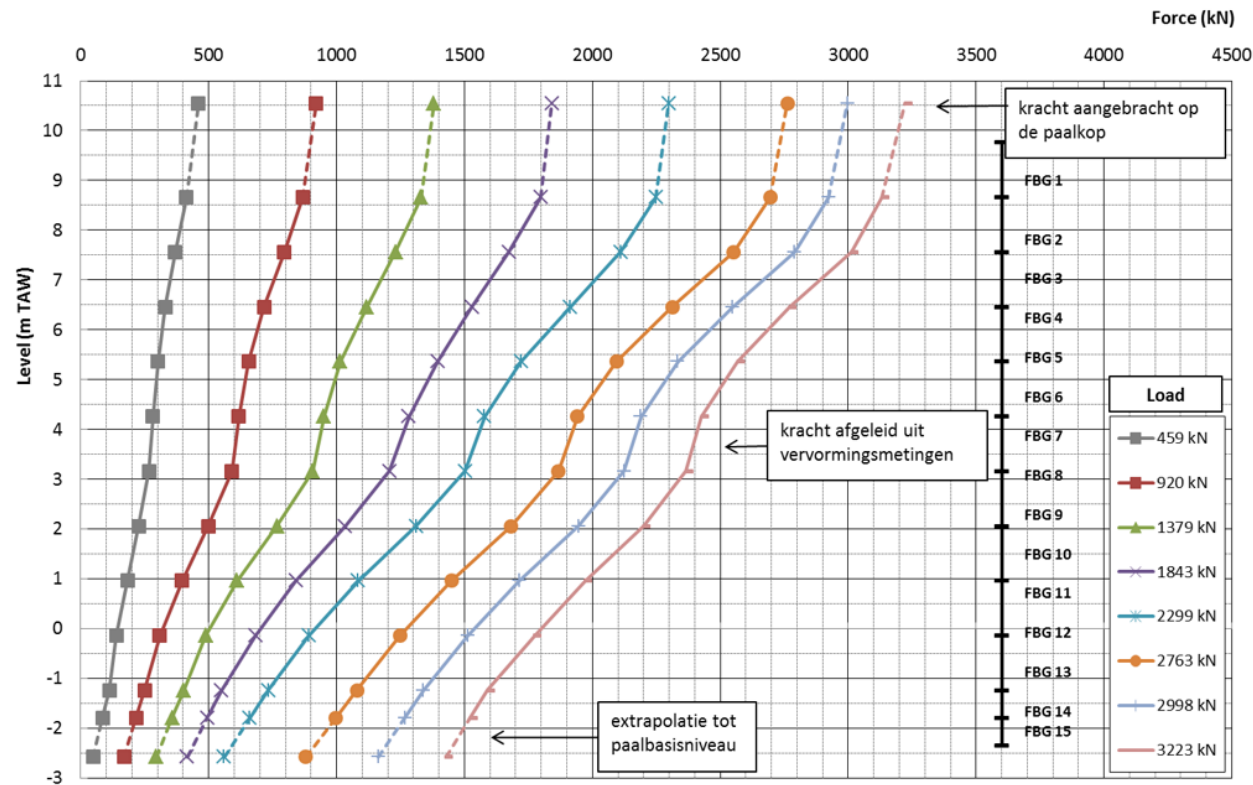
Instrumented pile load tests

- Measurement of deformations in the pile



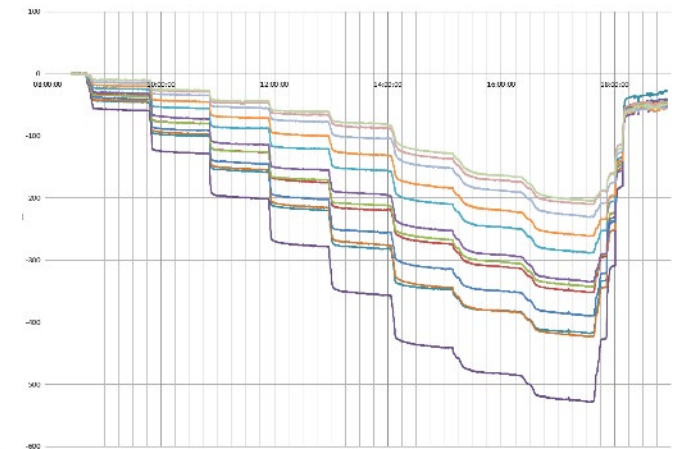
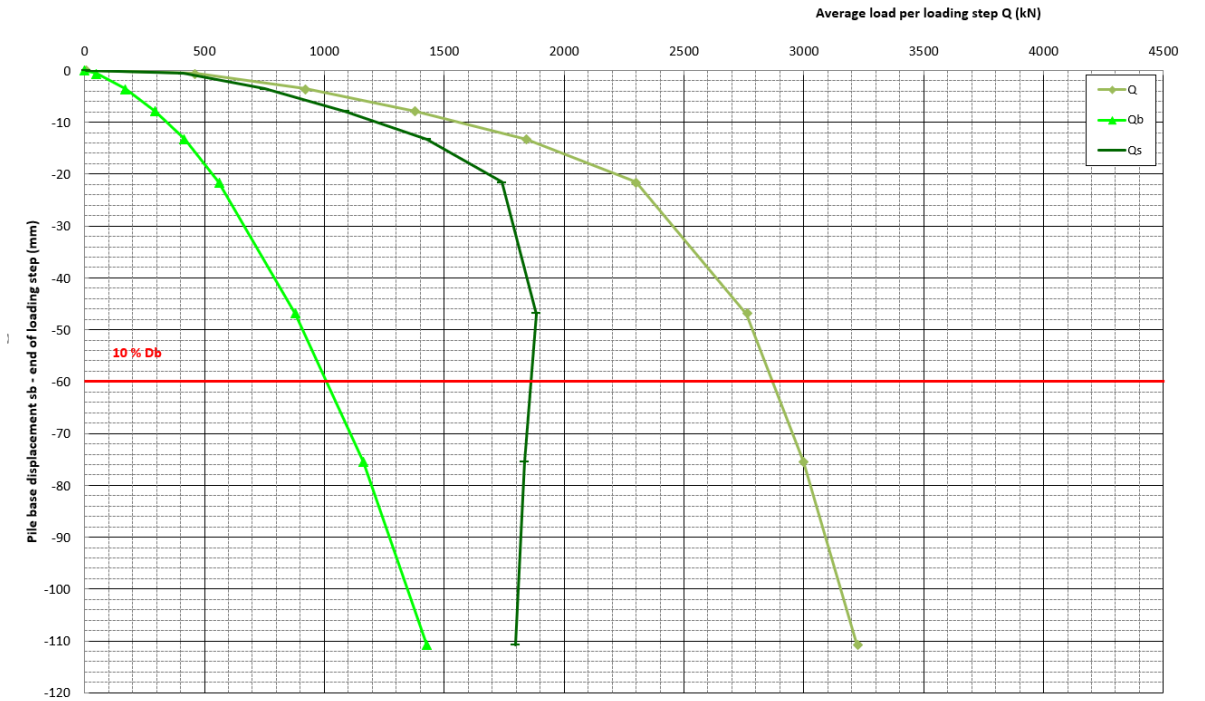
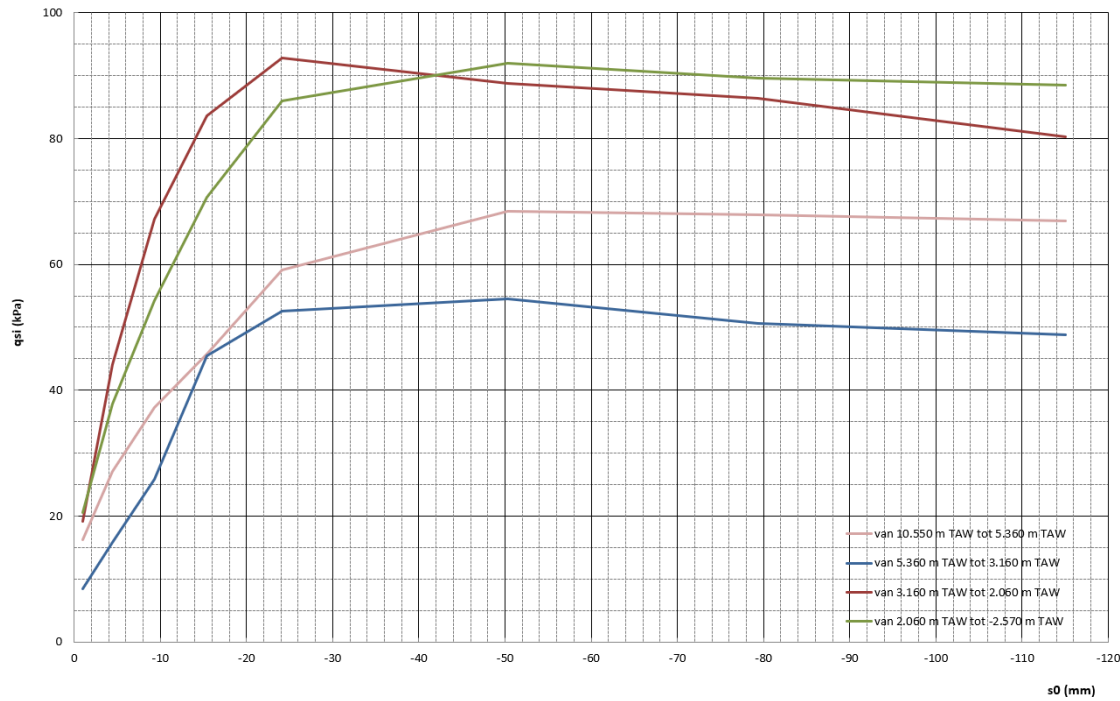
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- Measurement of deformations in the pile
- $\varepsilon_i \times EA = F_i$

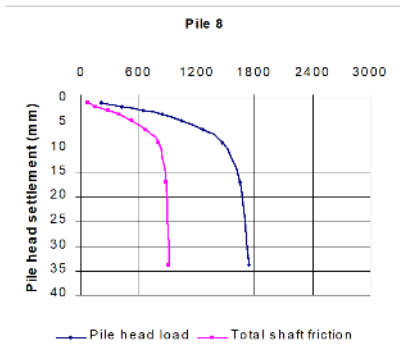


Instrumented pile load tests

- Measurement of deformations in the pile
- $\varepsilon_i \times EA = F_i$
- $F_1 - F_2 = R_{si}$
- $Q - \sum R_{si} = R_b$



Deformation measurements : evolution



1995
strain gauges
(2 or 3 levels)

1999-2003
retrievable
extensometers
(max. 7 levels)

2004-2008
small \varnothing retrievable
extensometers

2007
1st opt. fibres in
hollow bar jet grout
nails \varnothing 18 mm

2012
opt. fibres in bored
piles L = 36 m

Deformation measurements : evolution



2016
home made retrievable
extensometer with opt. fibre

local measurements
with grouted opt.
fibre (1/meter)

2021
Average over 30 to 50 cm

2025
???

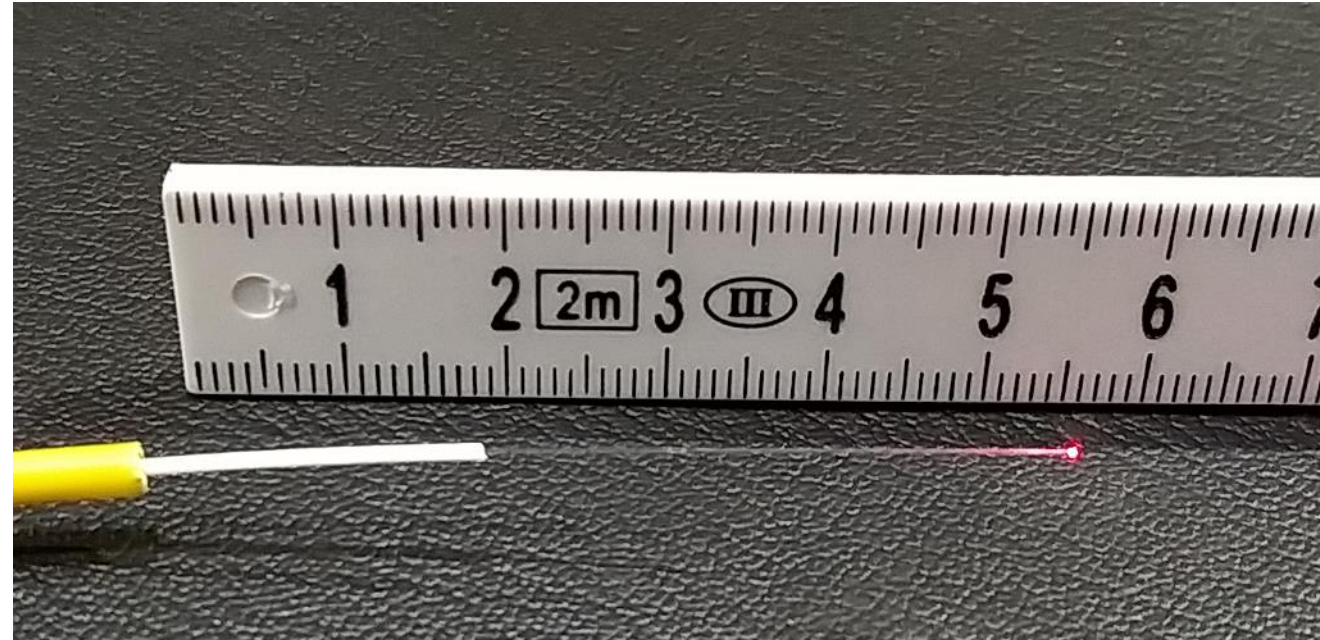
Optical fibre sensing techniques

Glass core : \varnothing 10-60 μm

Cladding : \varnothing 125 μm

Coating

(Jackets : < 1 mm to ...)



Technology improved over the last decades

Wide range of optical fibre techniques

Measures change of strain and/or temperature

Fibre = sensor + data carrier

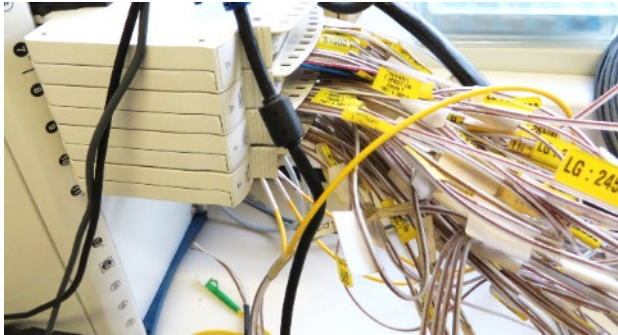
1 fibre = multitude of sensors

Optical fibre sensing techniques



Easy to integrate

Minimum of cables

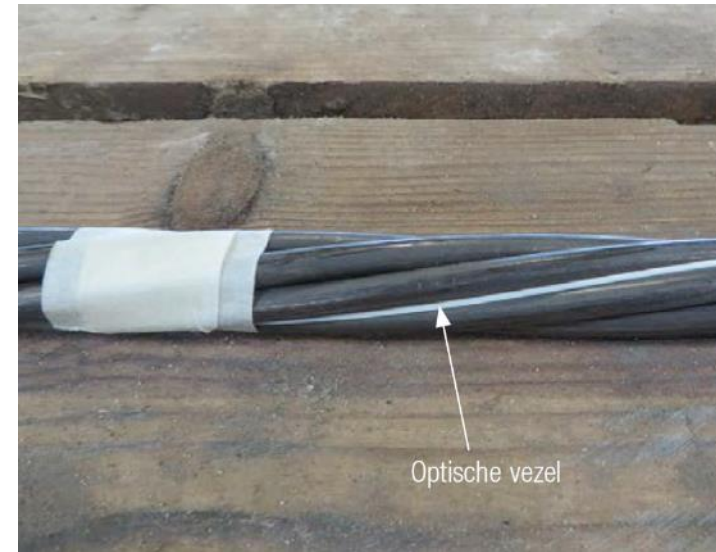


Very small diameter

Multiple sensors + data transmission on 1 fibre

Glass fibre

Reflected light waves



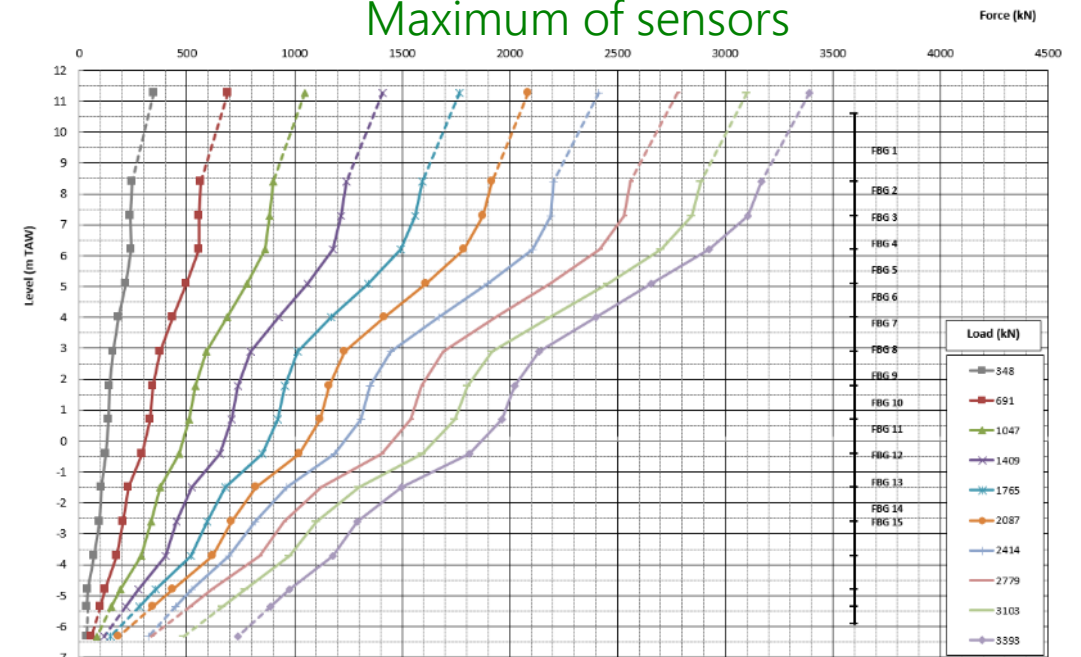
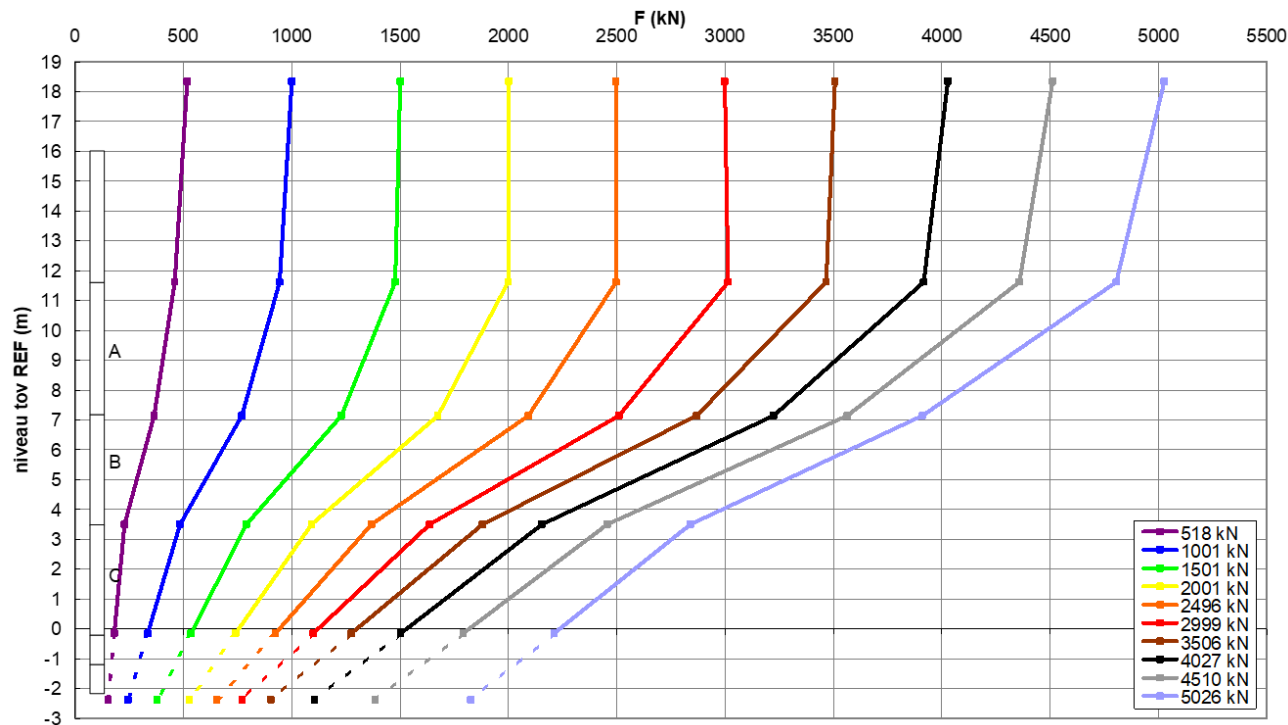
Optical fibre sensing techniques



Easy to integrate

Minimum of cables

Maximum of sensors



Optical fibre sensing techniques



Easy to integrate

Minimum of cables

Maximum of sensors

Non-electrical (explosive environment)

No EM interference

Watertightness is not critical

LT stability



Optical fibre sensing techniques

Very small diameter

Multiple sensors +
data transmission on
1 fibre

Glass fibre

Reflected light waves



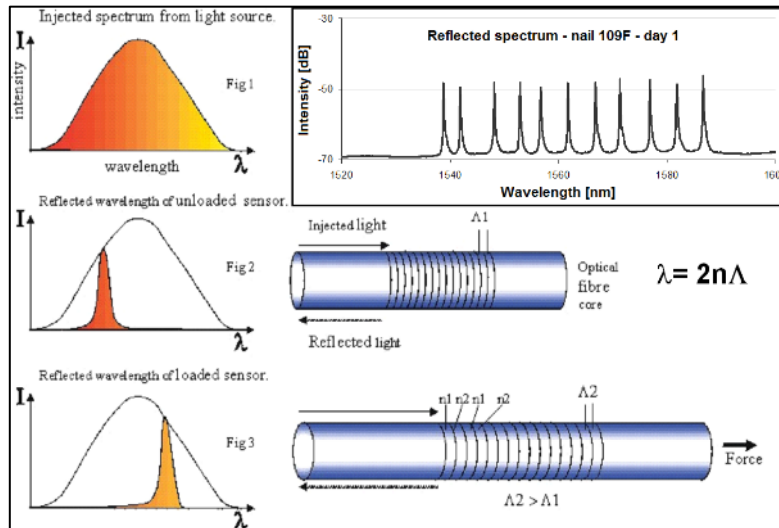
Fragile

Verification with proven methods

Multi-point vs. Distributed techniques

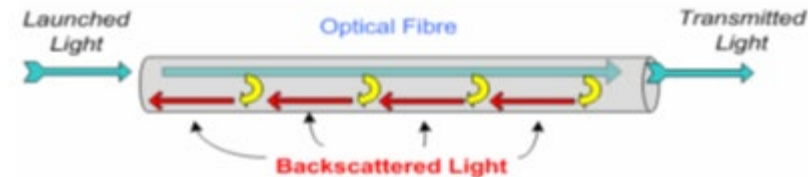
- Large range of techniques on the market
- Cost (DAQ and sensor cables), accuracy, spatial resolution, sensor density, max frequency,...
- Sensitive to strain and temperature variations

Multi-point technique : Fiber Bragg Grating (FBG)



20-30 sensors/cable

Distributed techniques : Brillouin/Raman/Rayleigh scattering



entire fibre = sensor

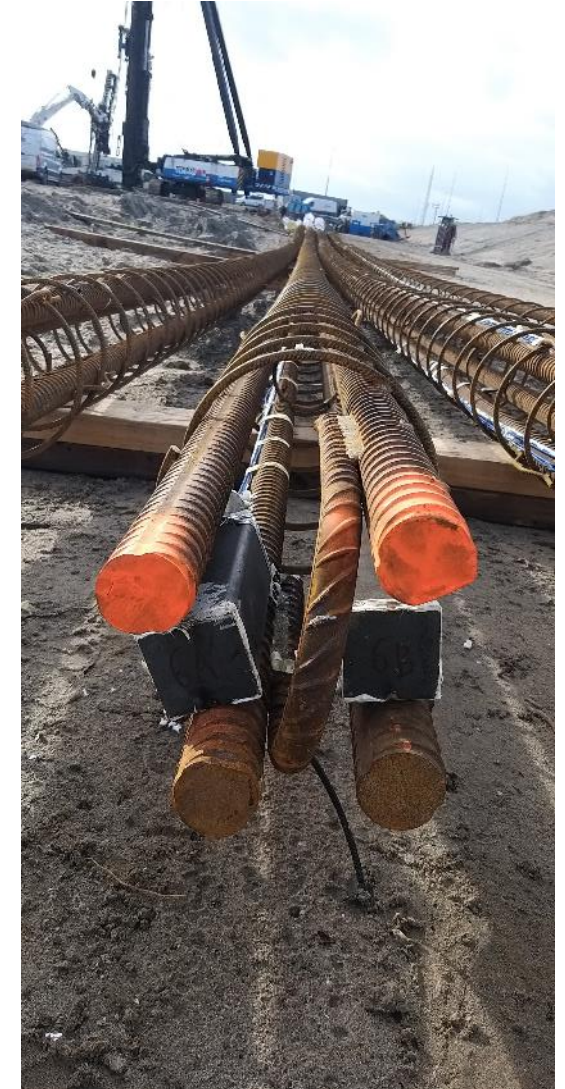
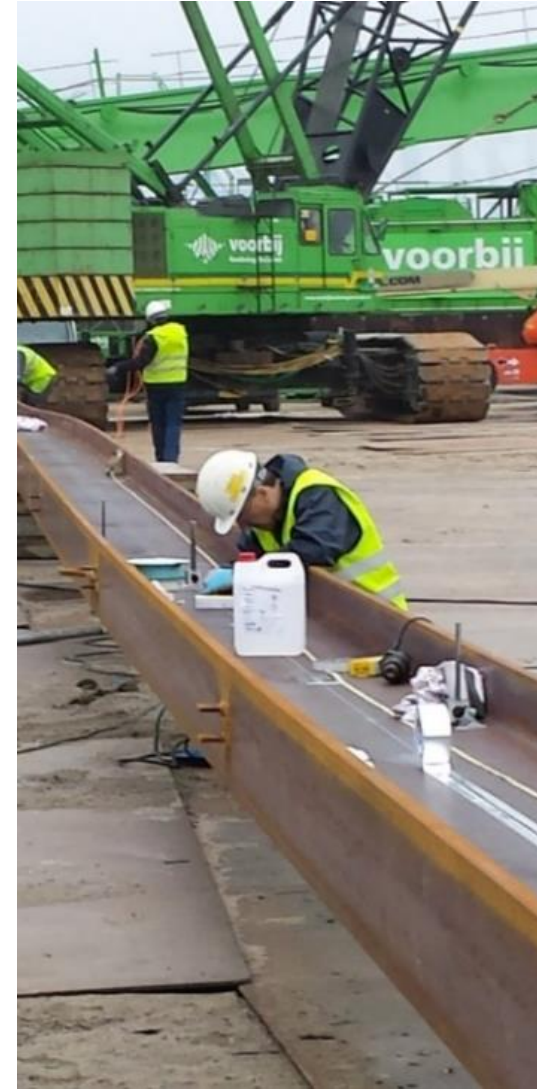
Brillouin (BOFDA)

Large distances

Low sensor cost-expensive DAQ

Limited sampling rate

Recent experiences with optical fibre in pile load tests



Installation in a reservation tube

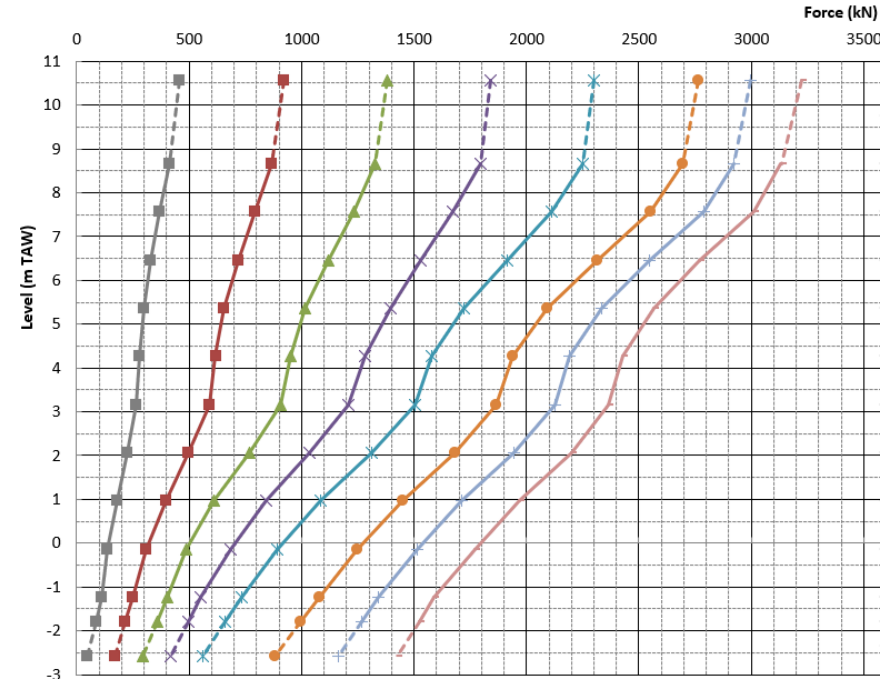
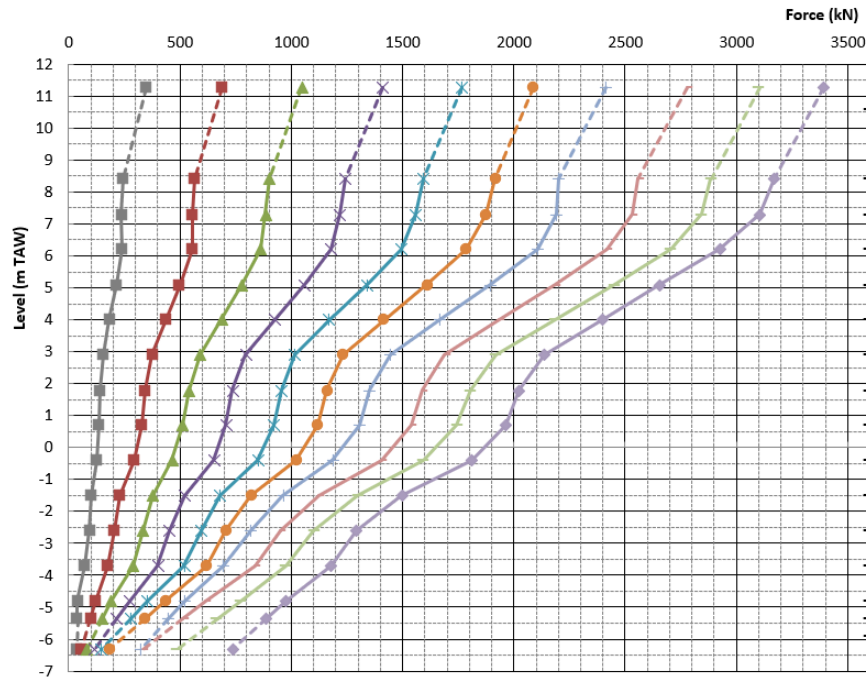


Risk of damage is limited

Intervention on site is more flexible in time

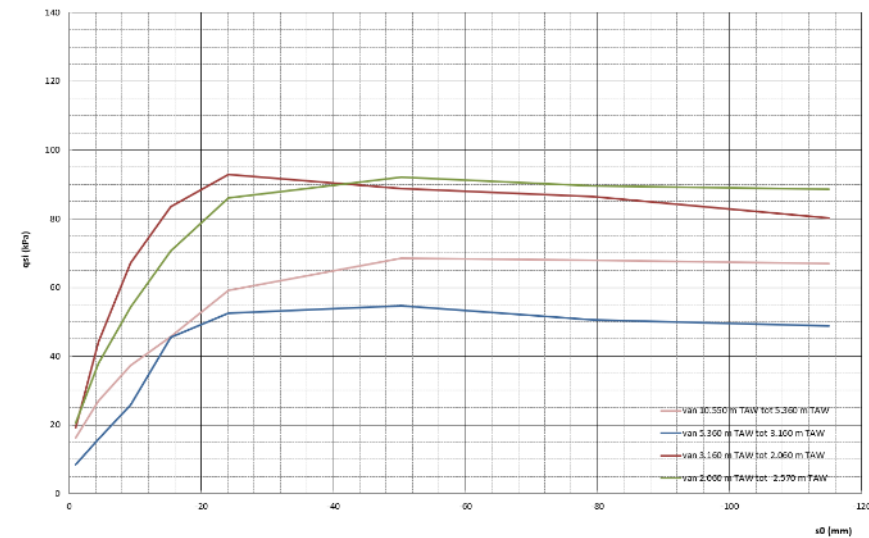
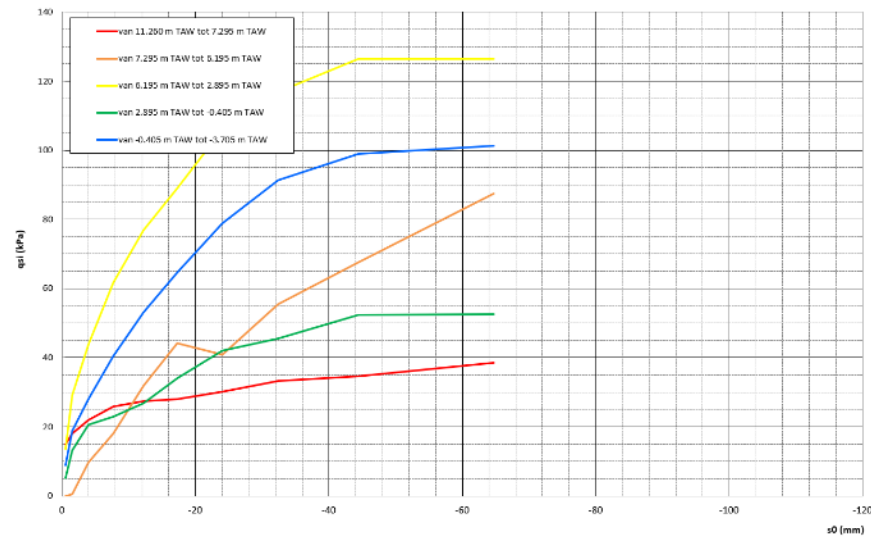
Installation in a reservation tube : example 1 (CFA)

- Different ground conditions :
 - loose to medium silt/sand
 - dense sand
- Different pile base level



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$$(Q_{\text{measured}} / Q_{\text{calculated}})_{\text{shaft}} >$$

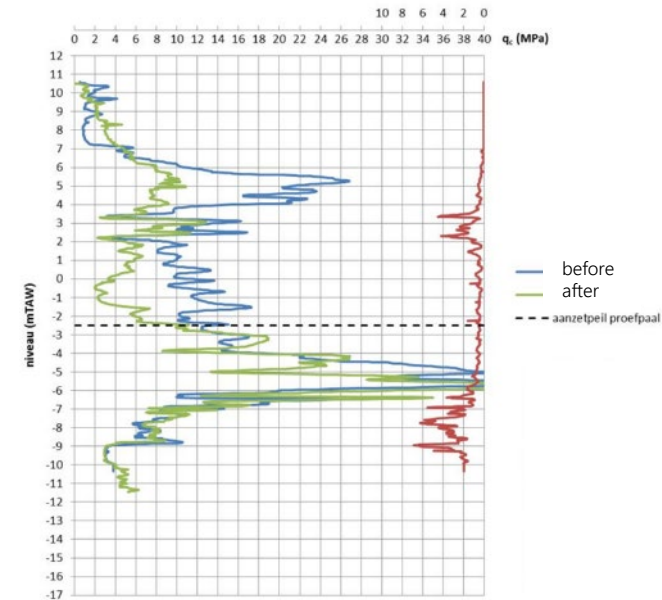
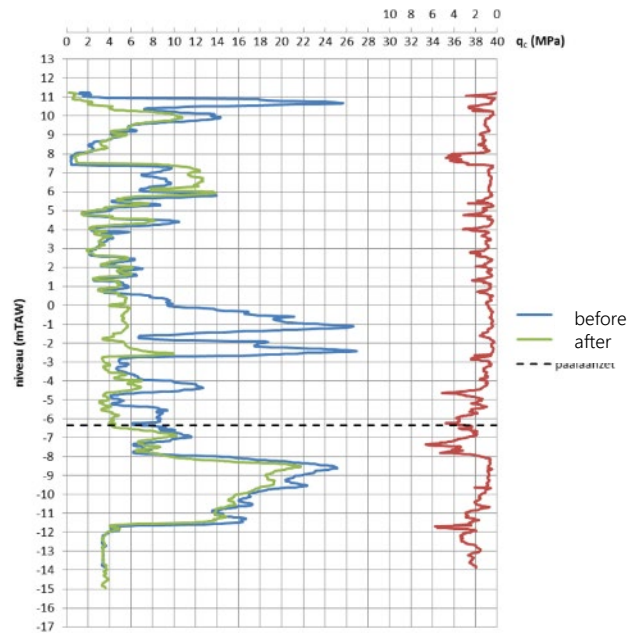
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Installation in a reservation tube : example 1 (CFA)

- Different ground conditions :
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- Different pile base level

dense sand

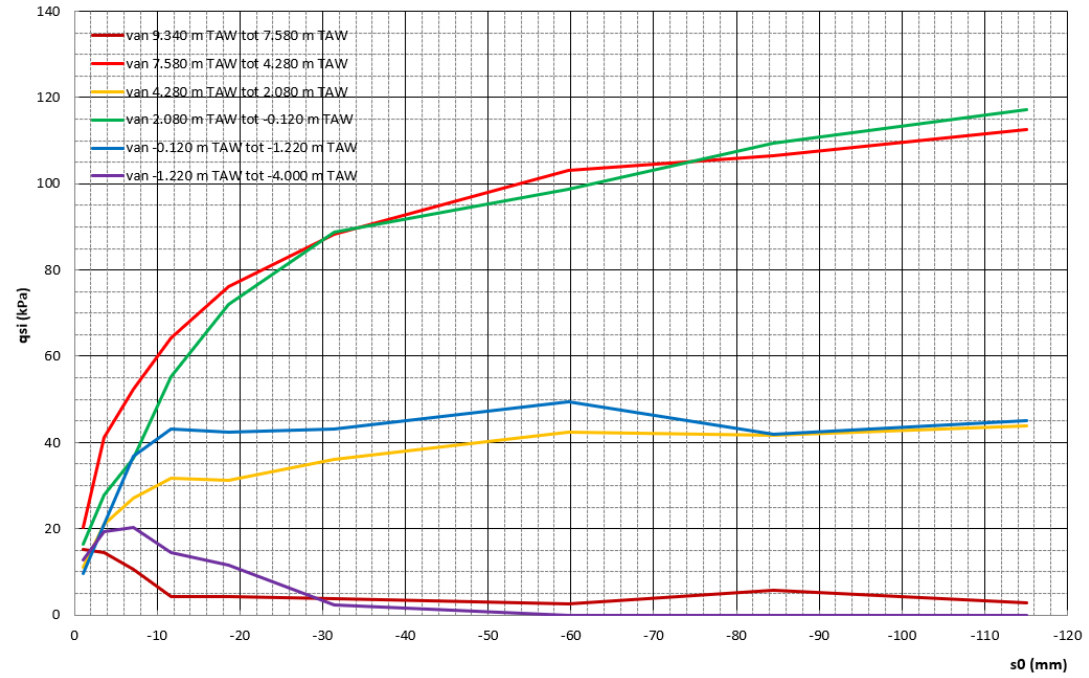
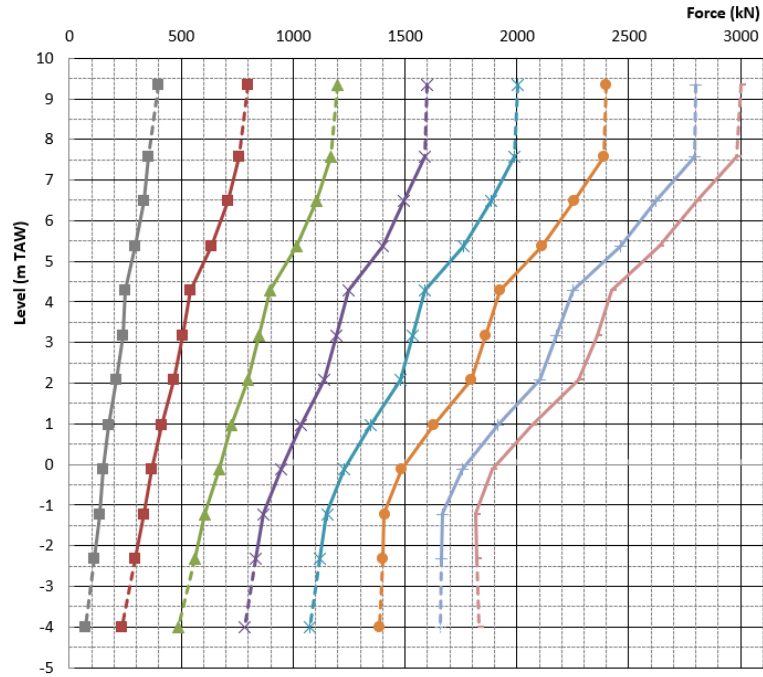


$$(Q_{\text{measured}} / Q_{\text{calculated}})_{\text{shaft}} >$$

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Installation in a reservation tube : example 2 (Vibro)

- Casing diam. 508 – base diam. 600

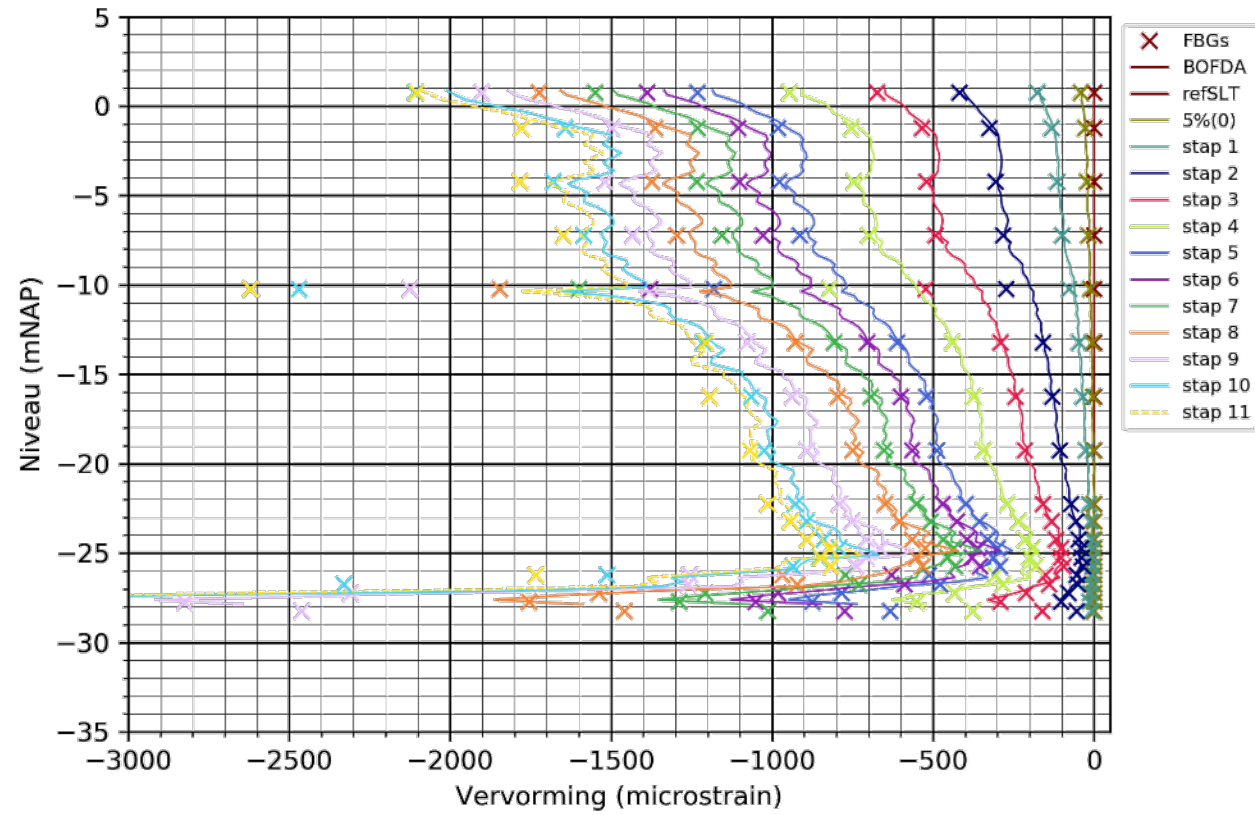
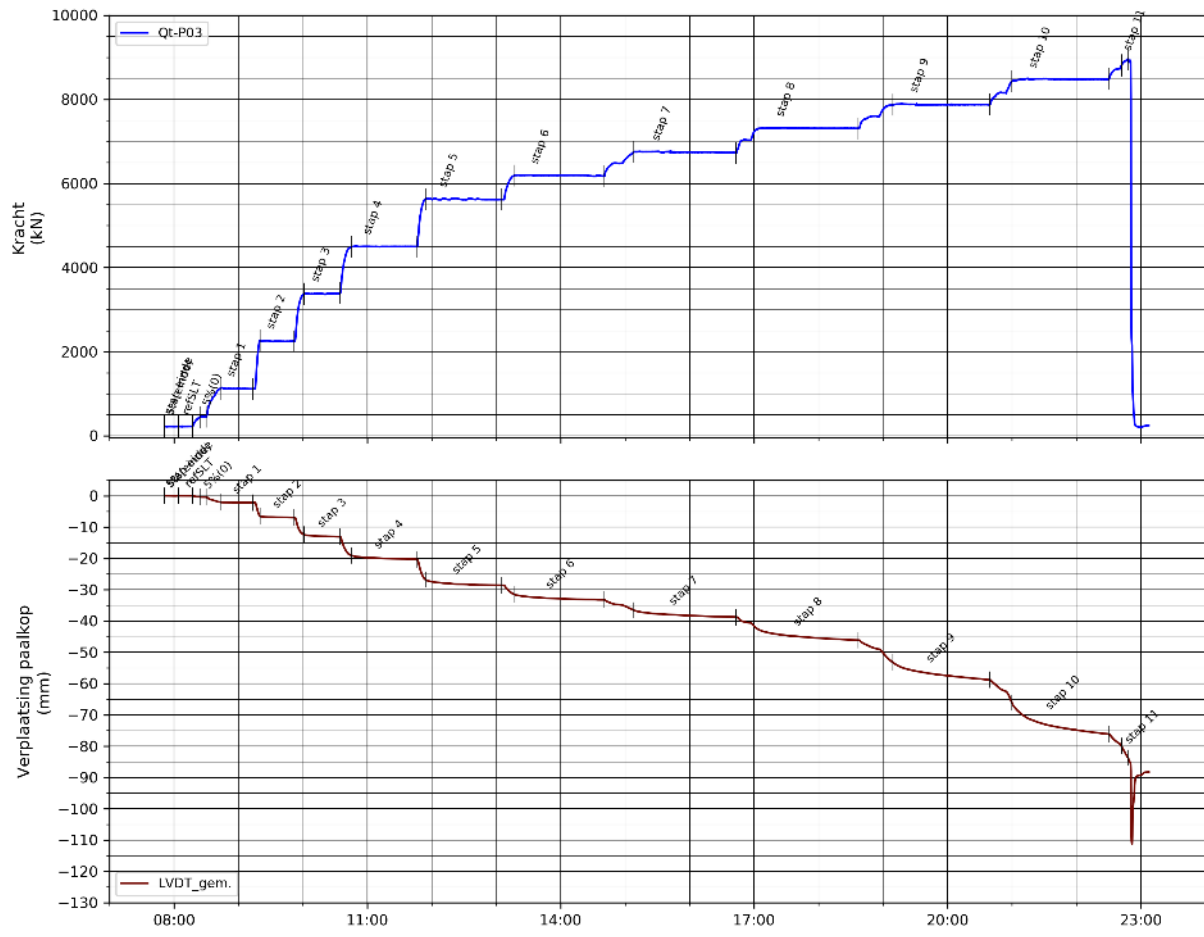


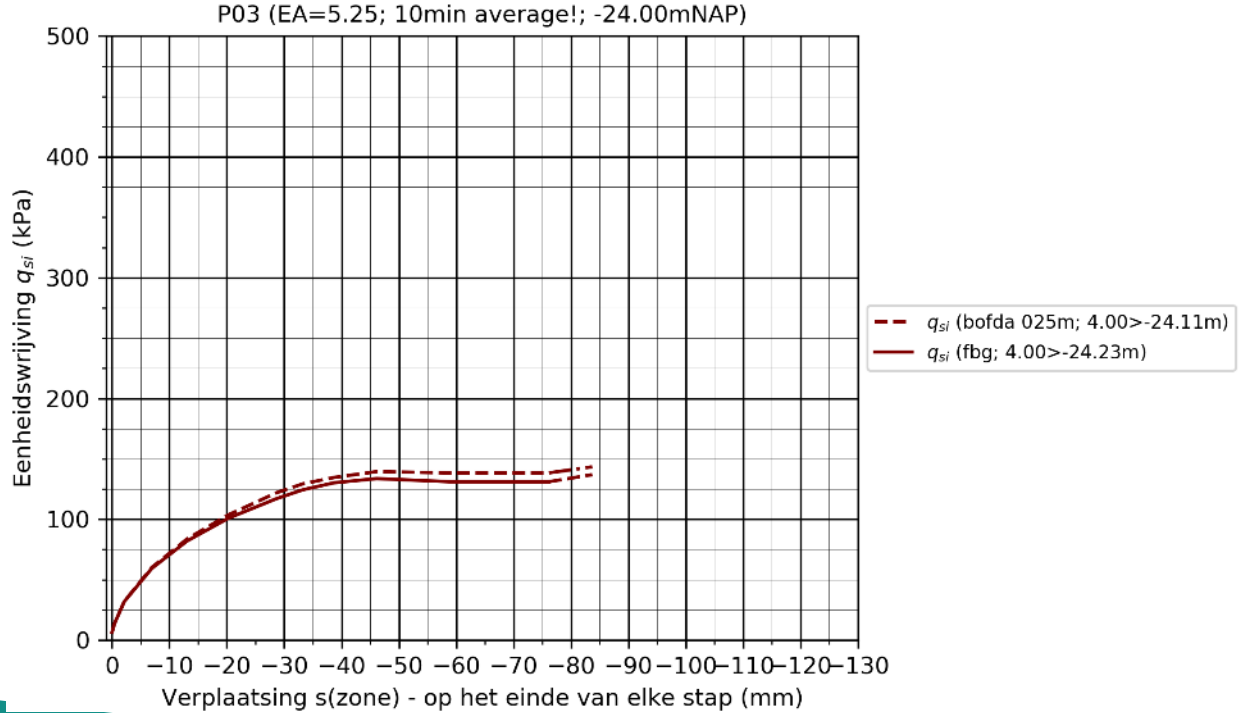
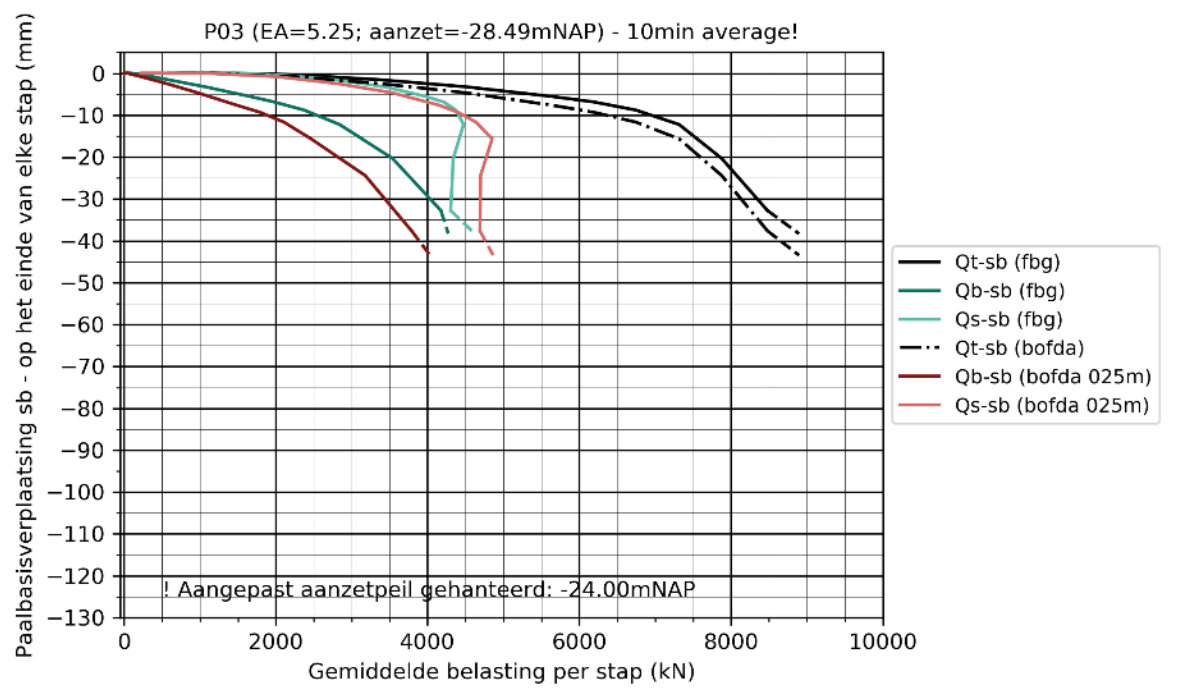
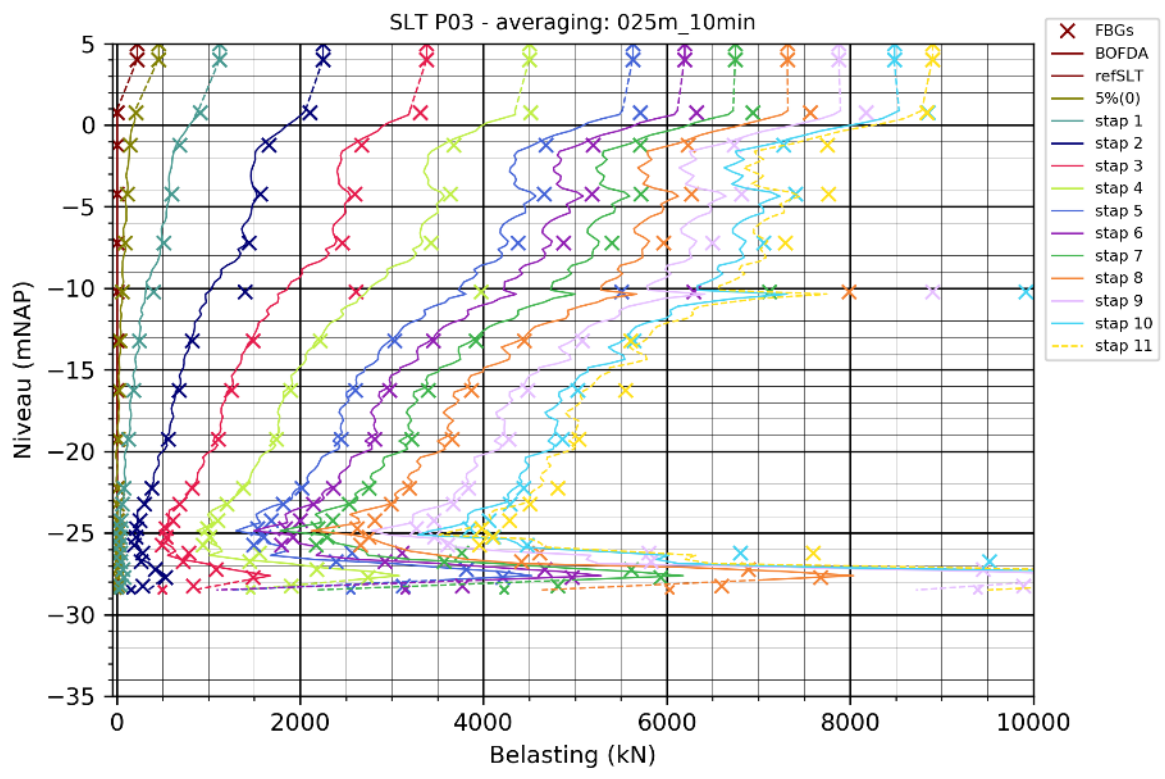
Attached to the reinforcement cage



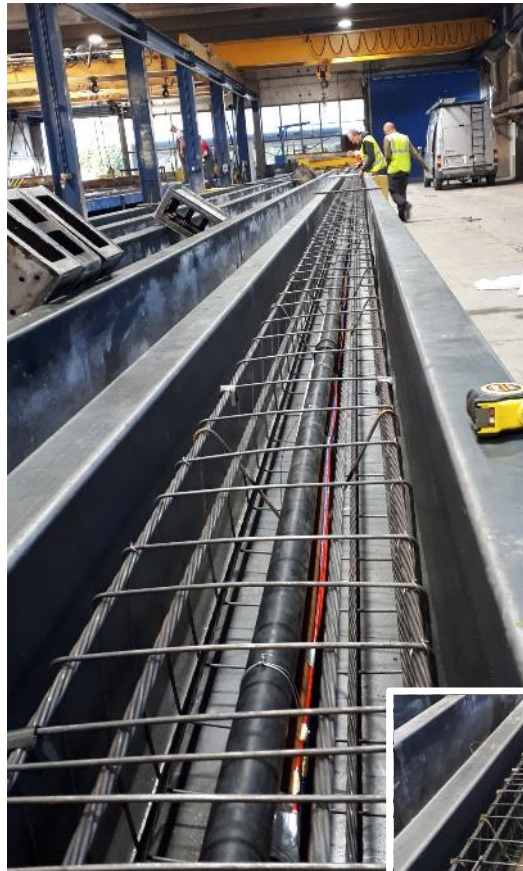
BOFDA + FBG
Risk of damage
Access

Presented before, during, after pile installation

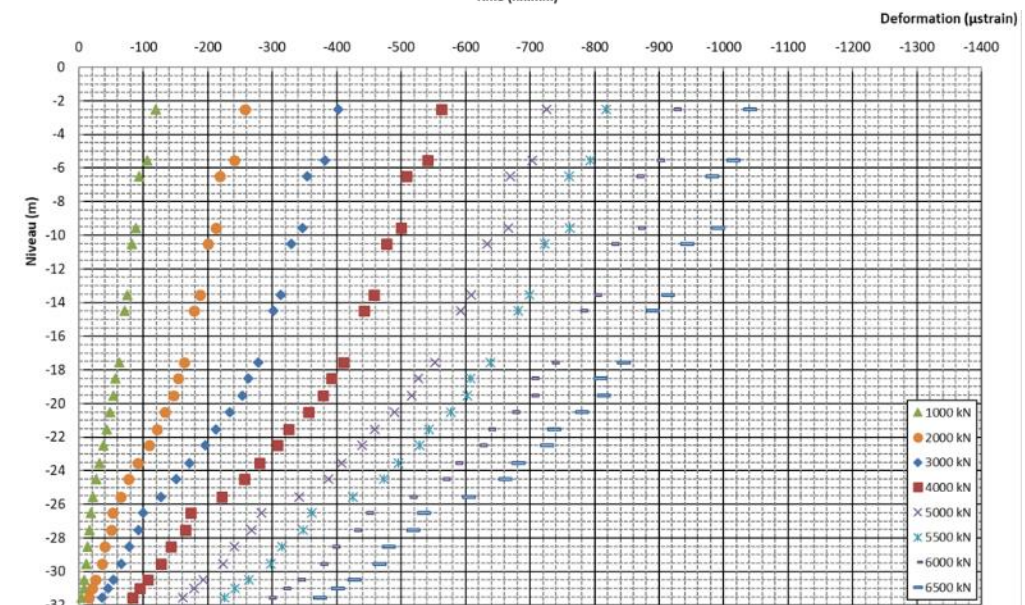
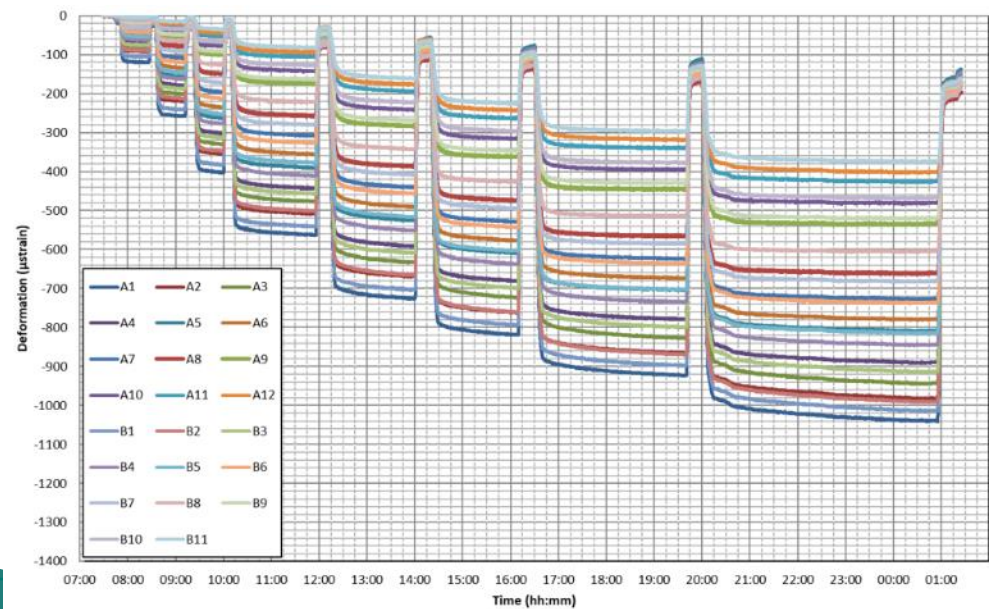
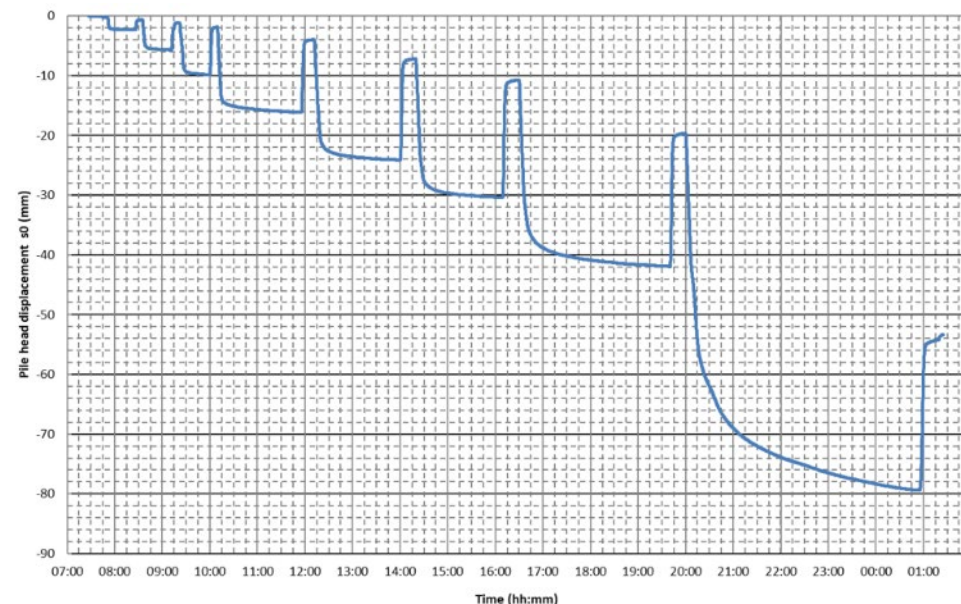
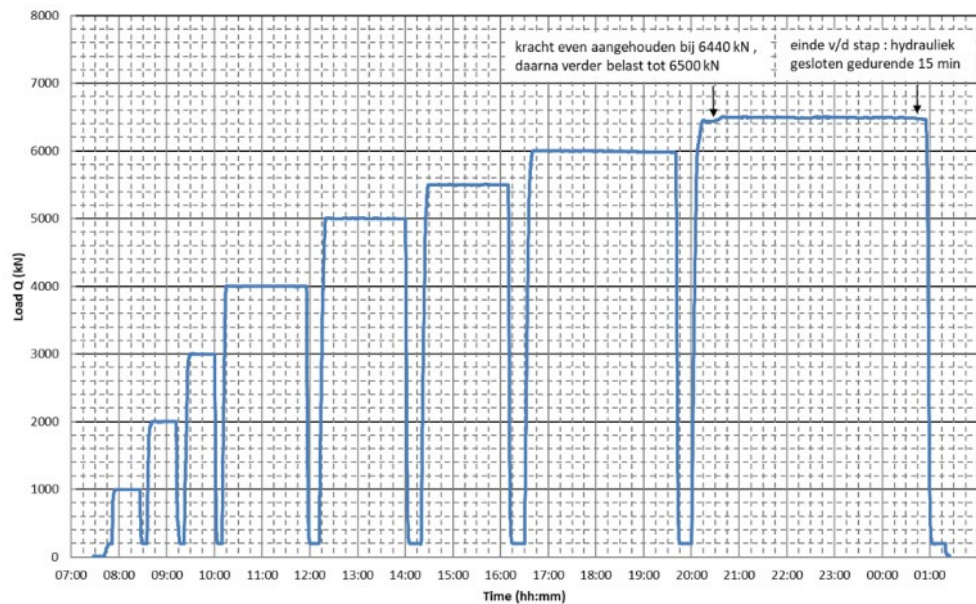


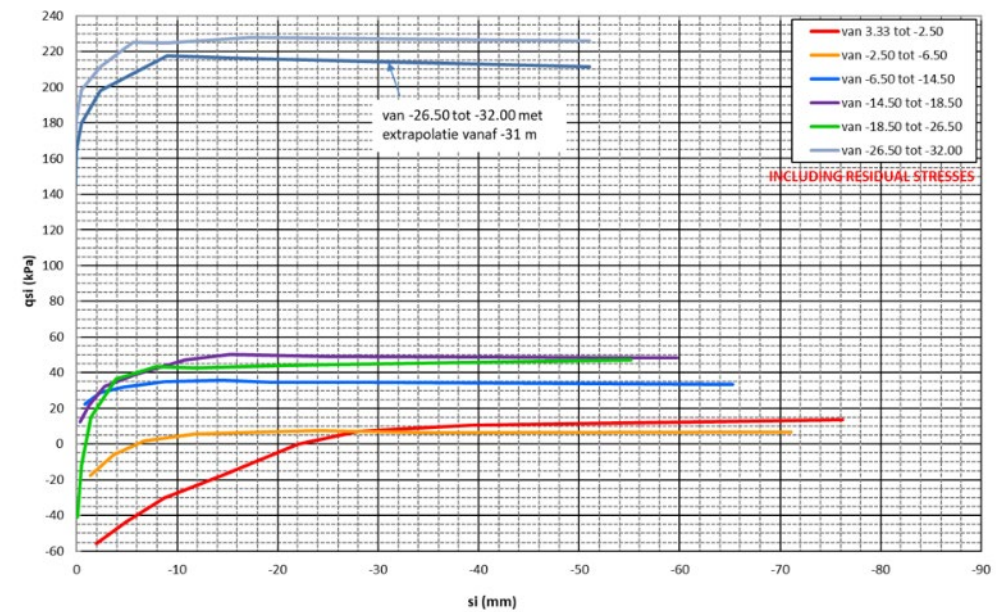
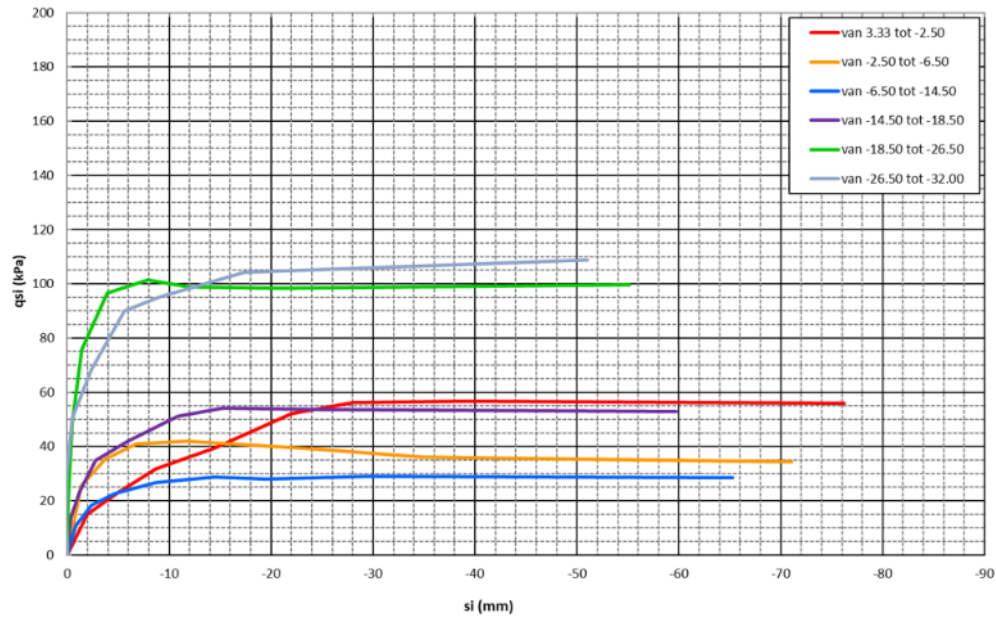
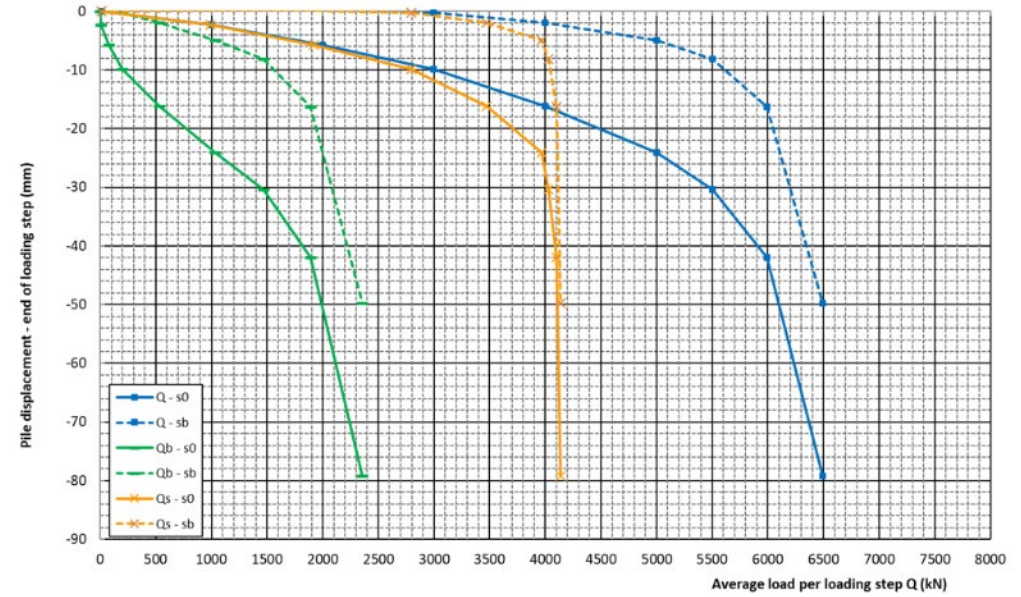
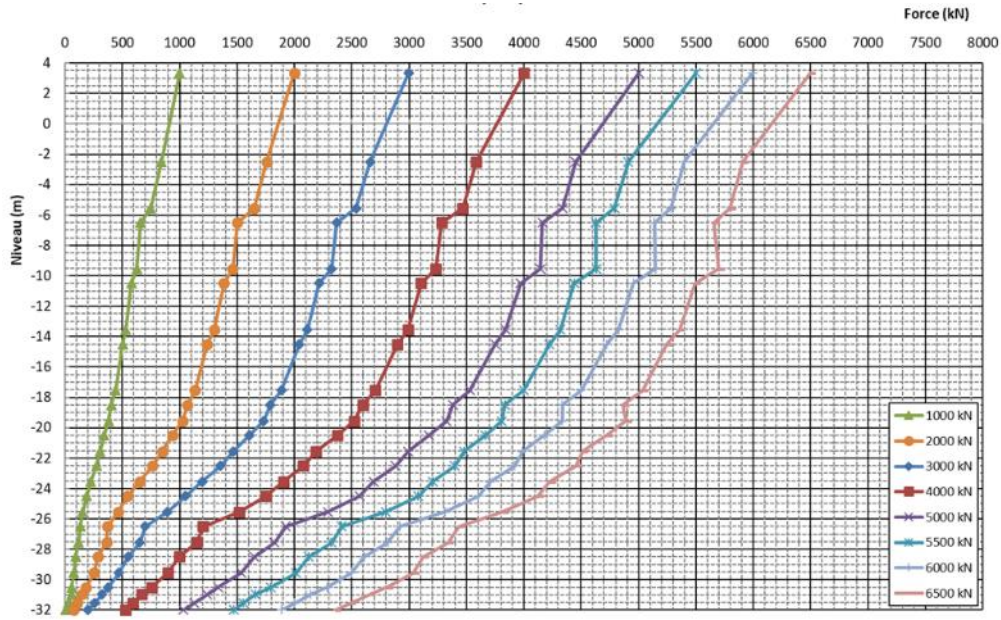


Embedded during manufacturing of the pile (precast)

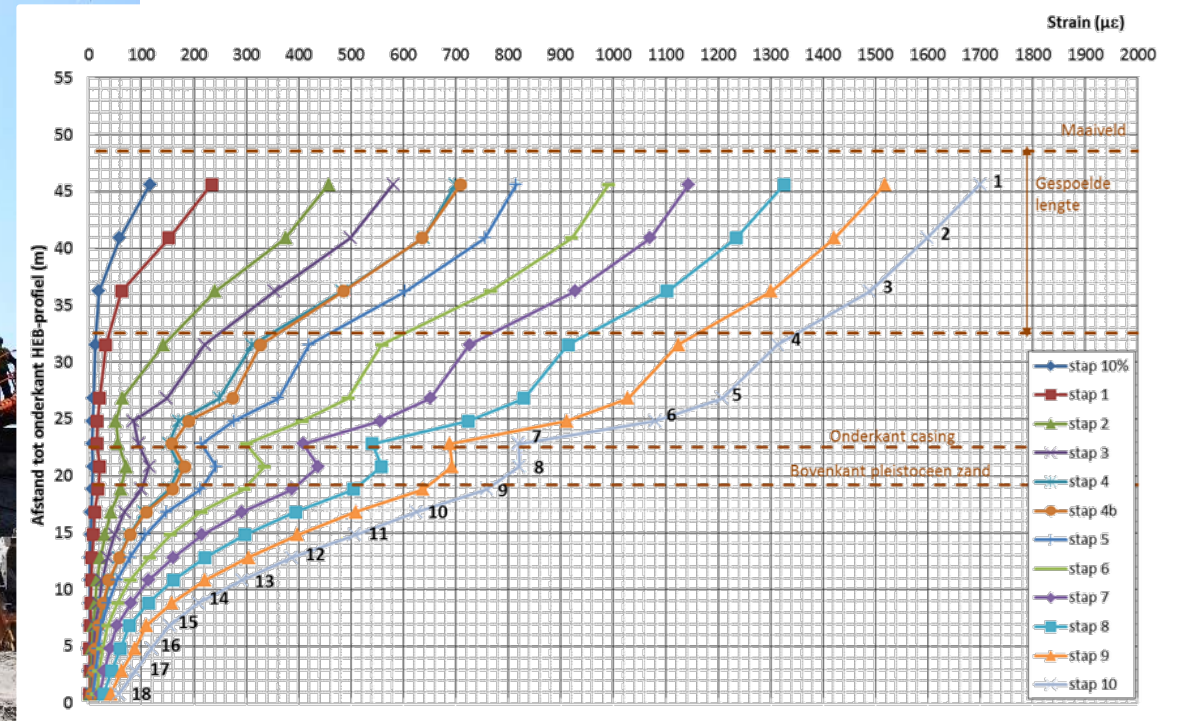
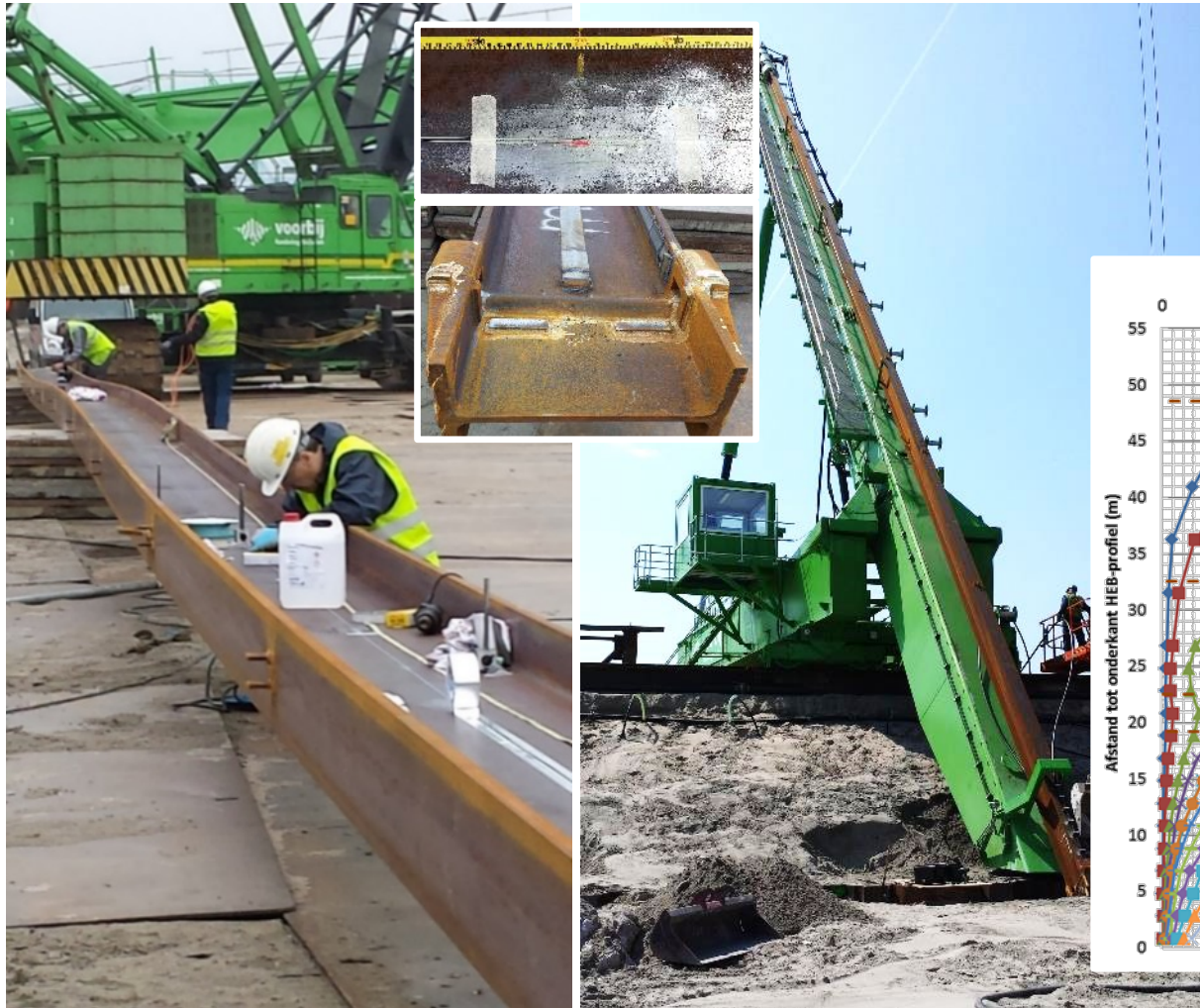


Measuring residual strains
Risk of damage
BOFDA + FBG + Raman

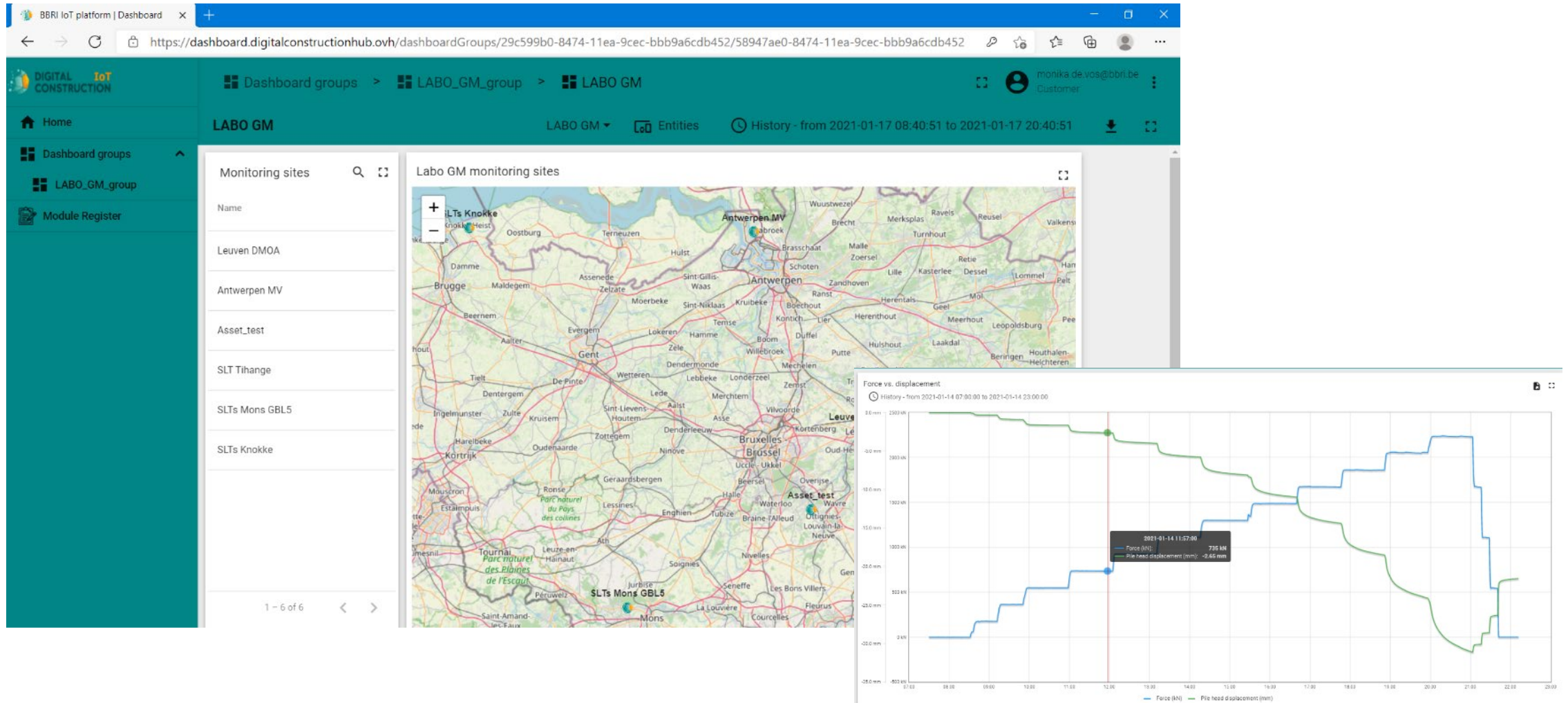




On steel profiles (MV piles, profiles in soil mix piles)



Digitalisation



Conclusions

- Testing piles = very valuable information
- Optical fibre techniques = advantages
- Redundancy = essential
- New type of sensor/technology/... : always check with proven method
- Static, Rapid & Dynamic Load Tests



Pile Load Testing is...

- ... increased understanding of the pile behaviour
- ... growing insight
- ... QC and augmented reliability
- ... costs money or saves money ?