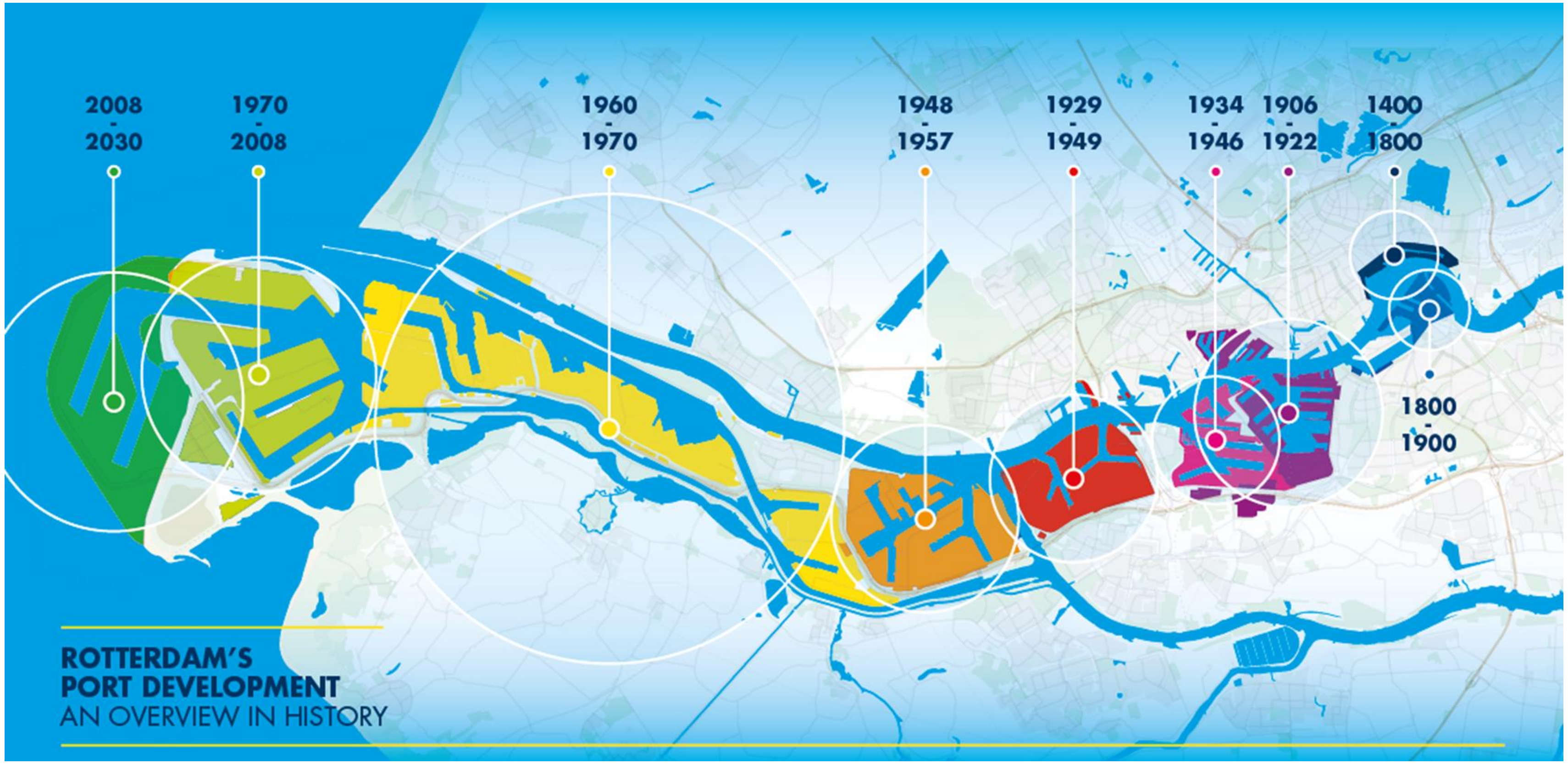
Port of Rotterdam and TU Delft Geotechnical Engineering collaborative research

Ken Gavin, Professor of Subsurface Engineering, TU Delft



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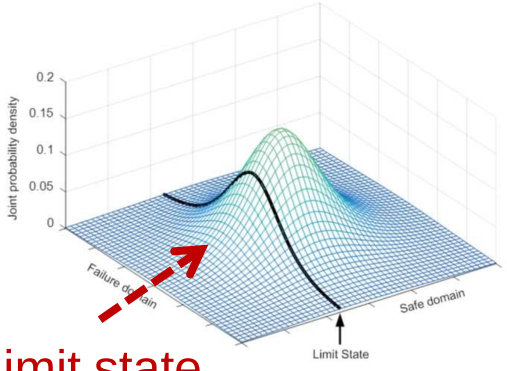
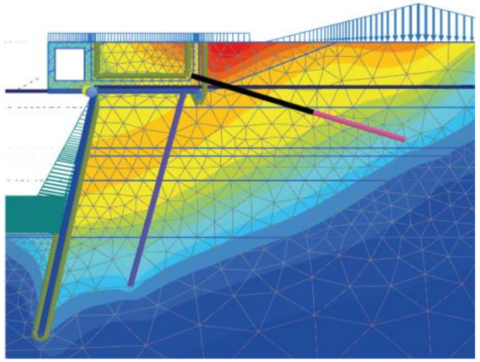
TRENDS IN QUAY-WALL ENGINEERING

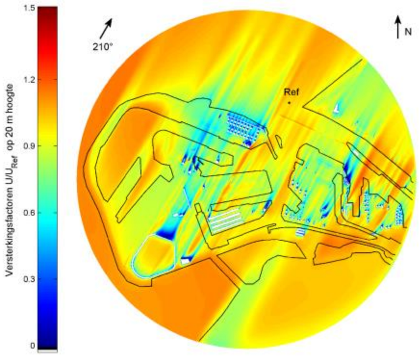
1) Reliability-based assessment

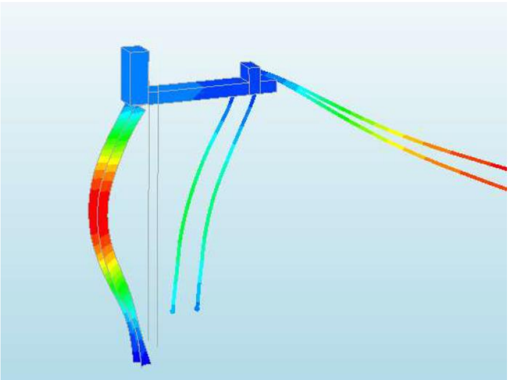


Limit state

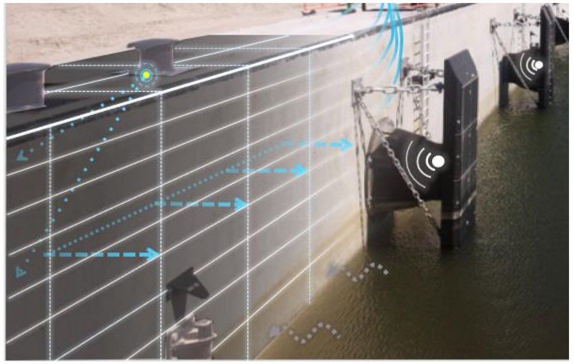


2) Advanced calculation models

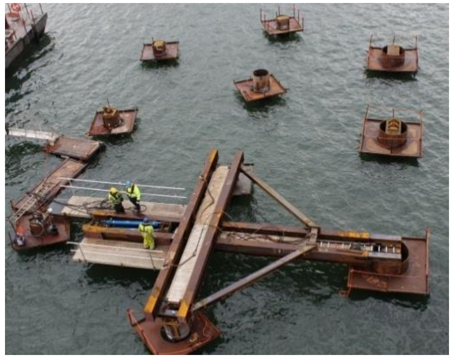




4) Sensors & digitisation



3) Stress testing (full scale field tests)



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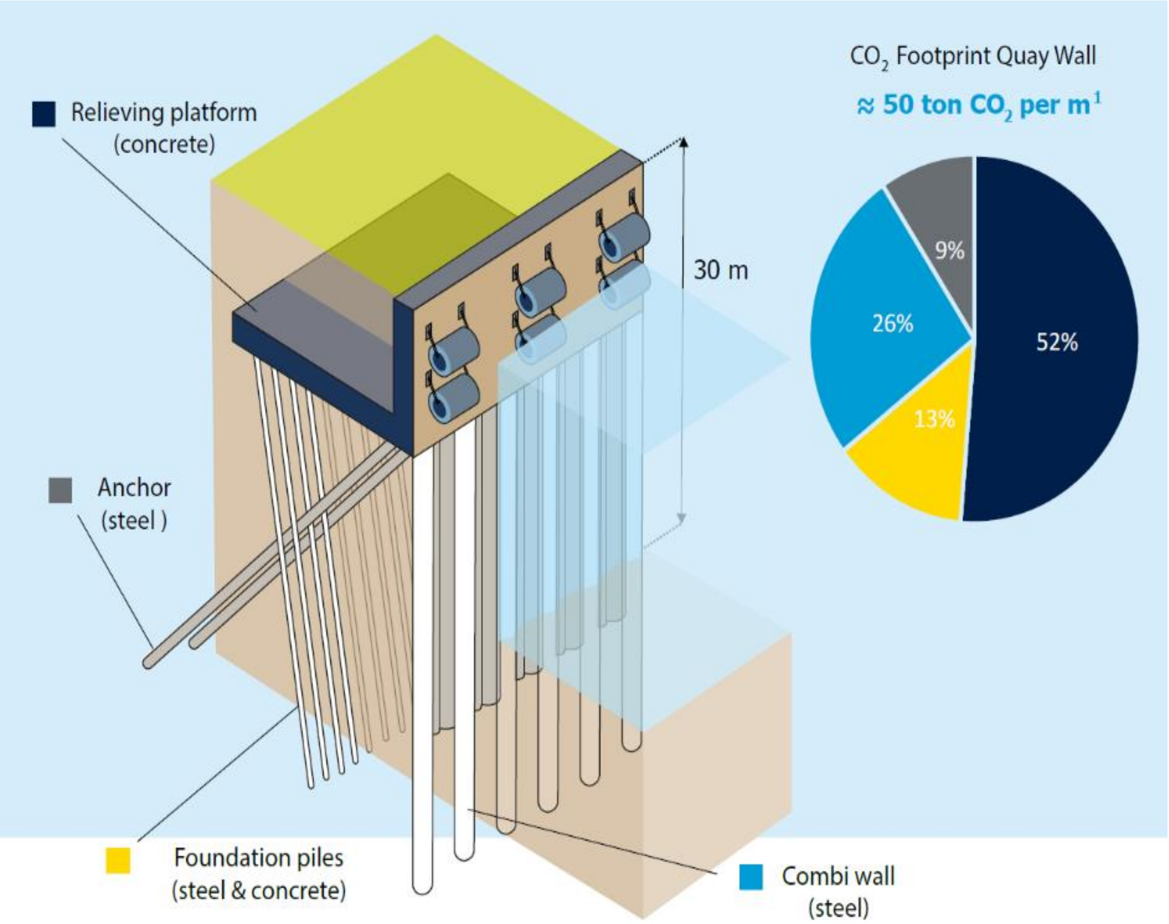
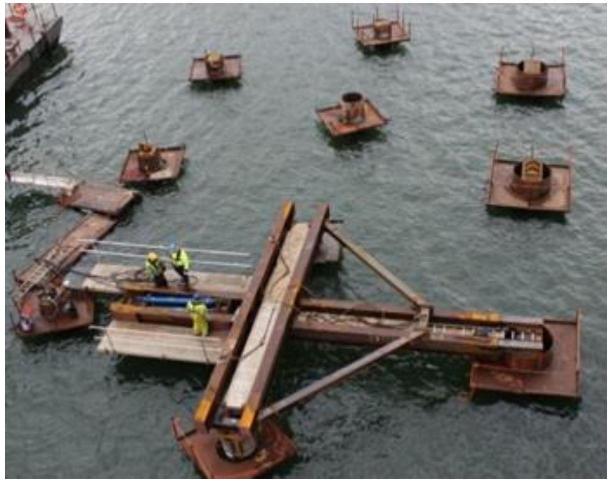
Deep Sea Smart Quay Walls

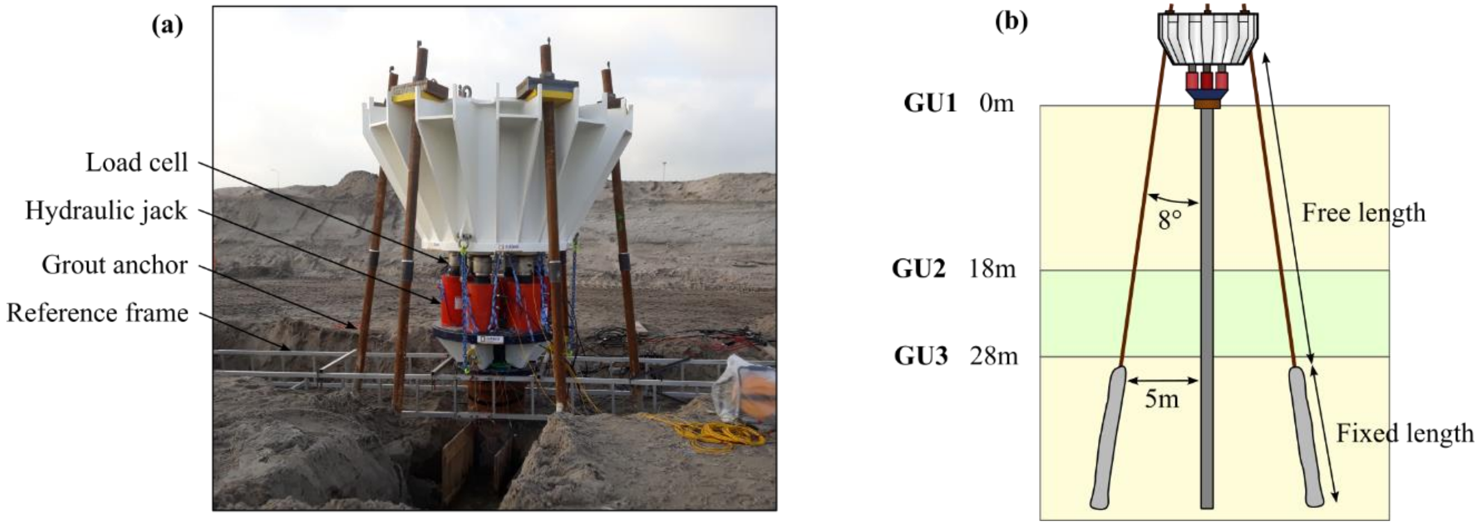


Full-Scale Load Tests



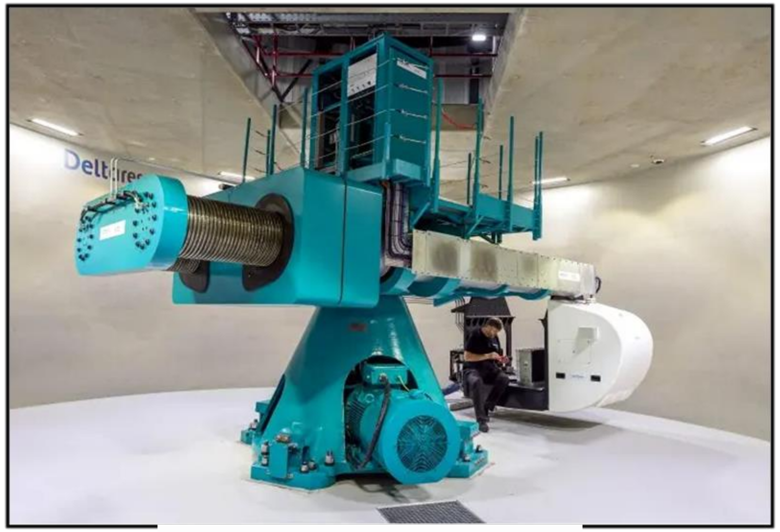
InPAD TKI Project- Hidden Safety Factors in Pile Design

What about limiting values of q_c?



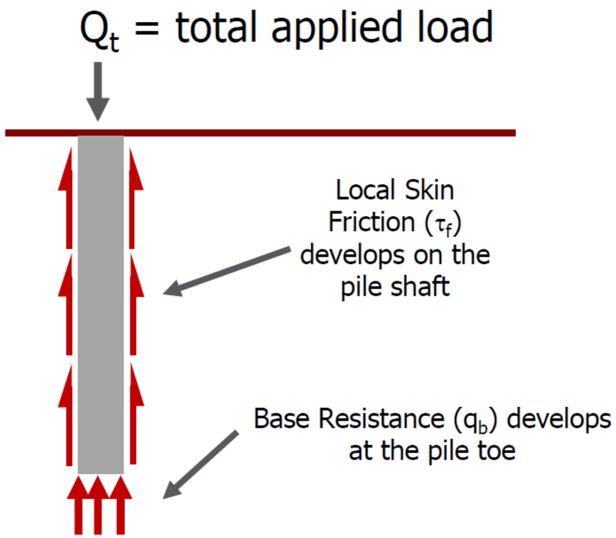
Amaliaahven load test costs ≈ €2,5 million

⇒Max test load **25,000 kN** !!!



TUDelft Port of Rotterdam Deltares Enabling Delta Life FUGRO Rijkswaterstaat Ministerie van Infrastructuur en Gemeente Rotterdam NVAF

The problem!



$$q_b = \alpha_p \, q_c$$

- Pile reduction factors are constant
- Max Base resistance is limited to 15,000 kPa, correspond to q_c of 21.5 MPa

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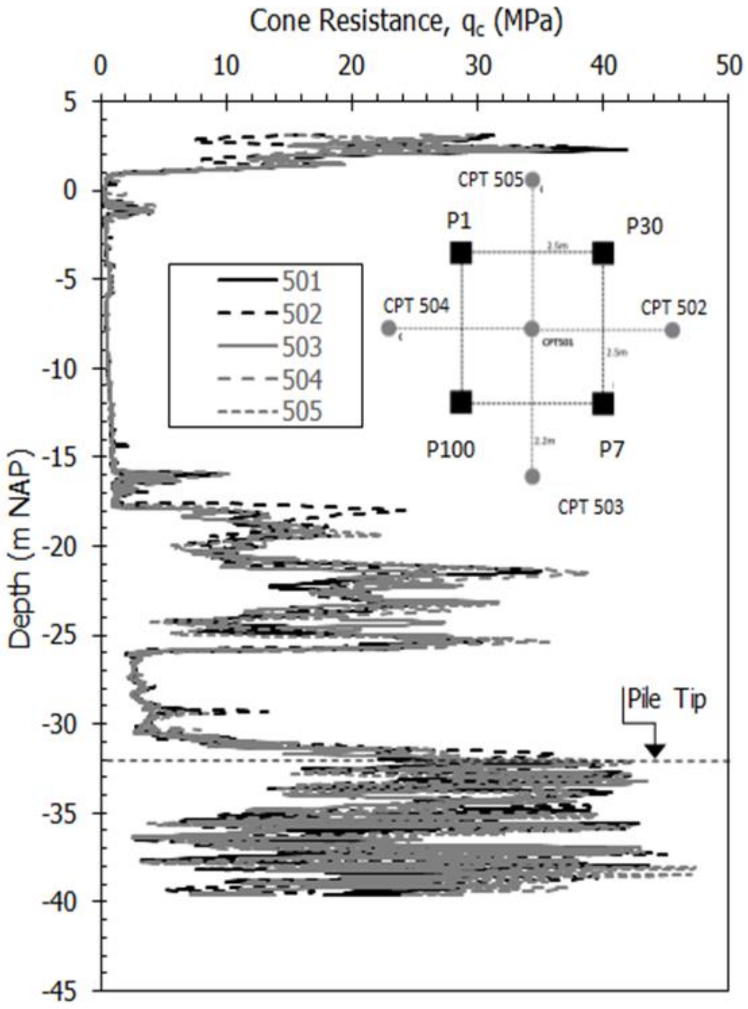
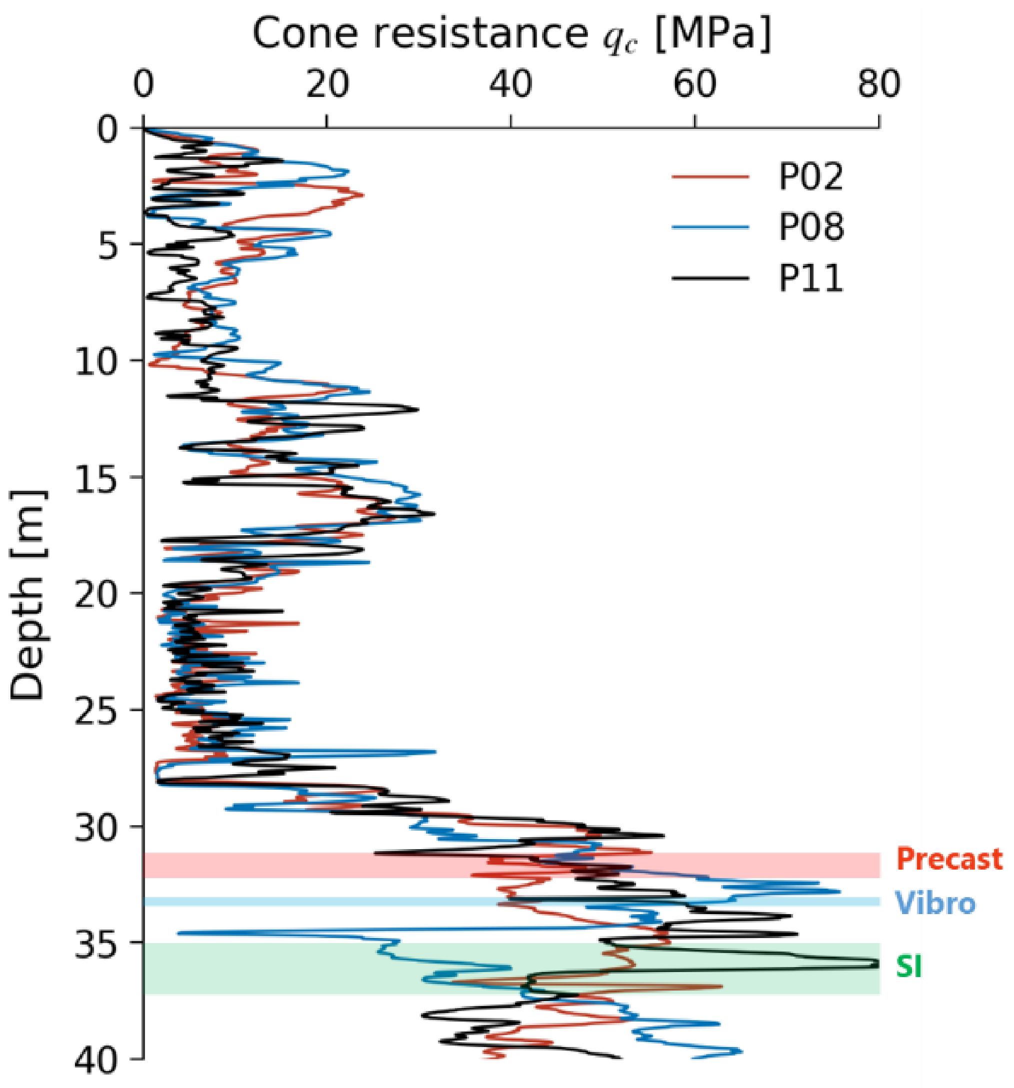
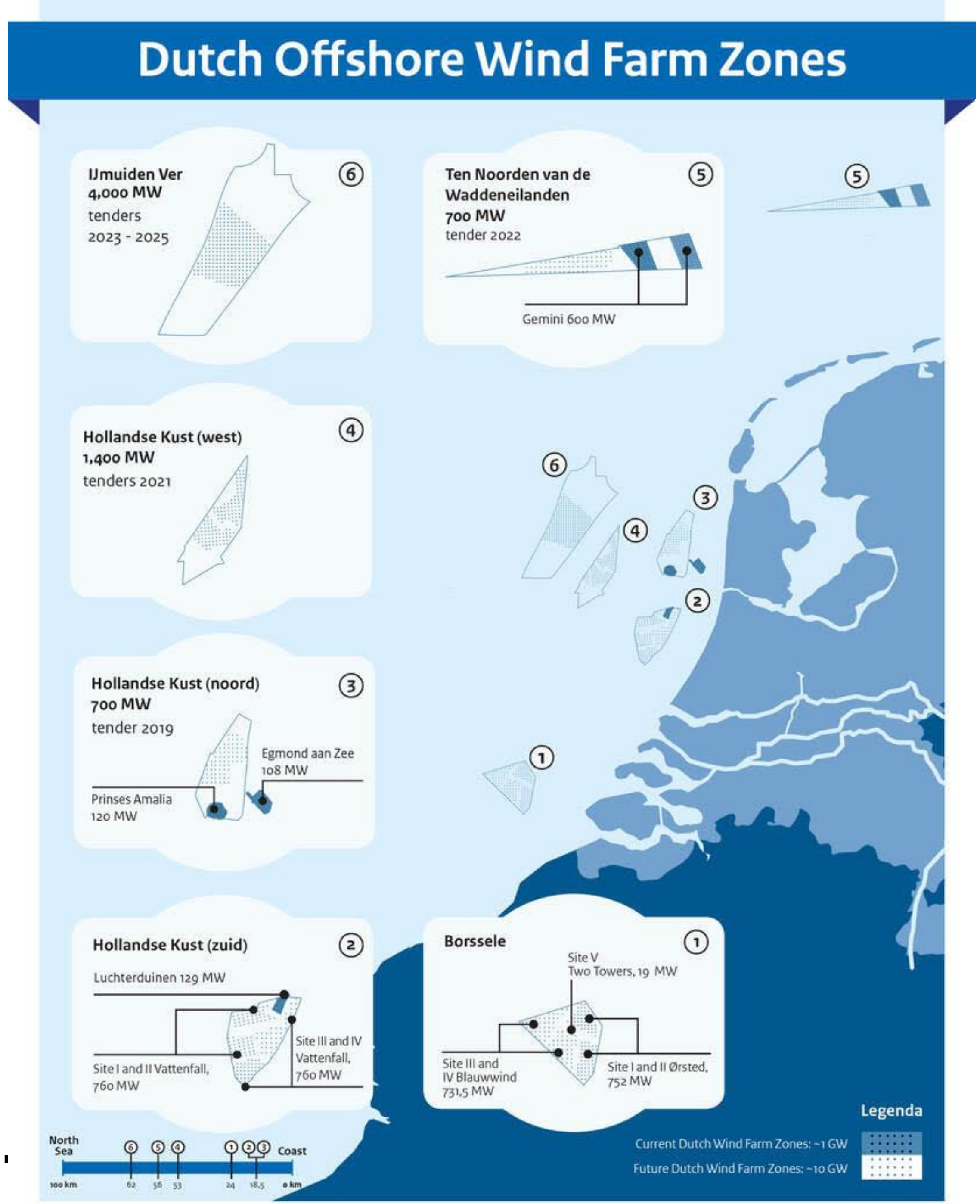
Location – Soil Conditions



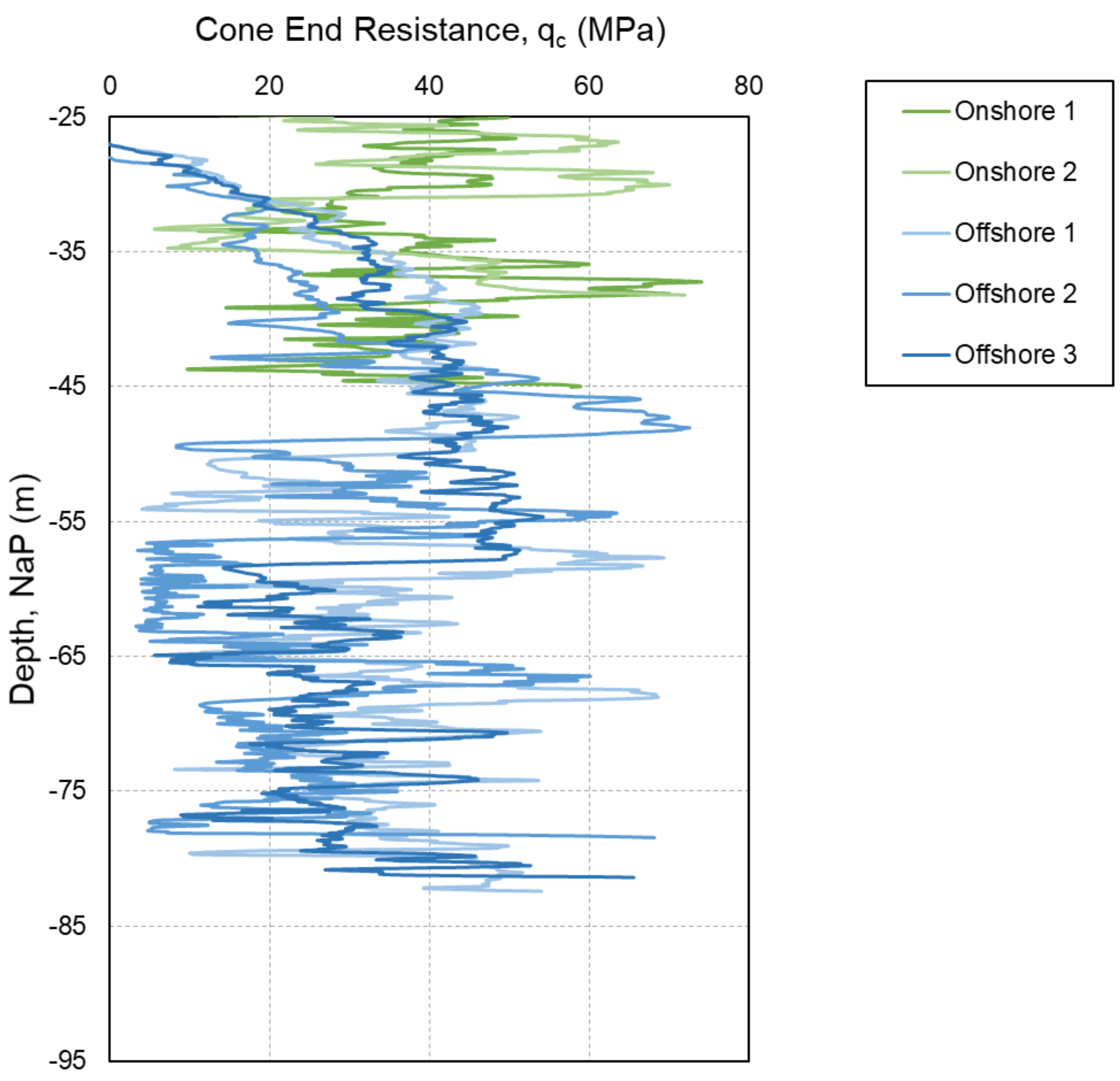
Location - Port of Rotterdam

Foundation pile tests Amaliahaven (2020)



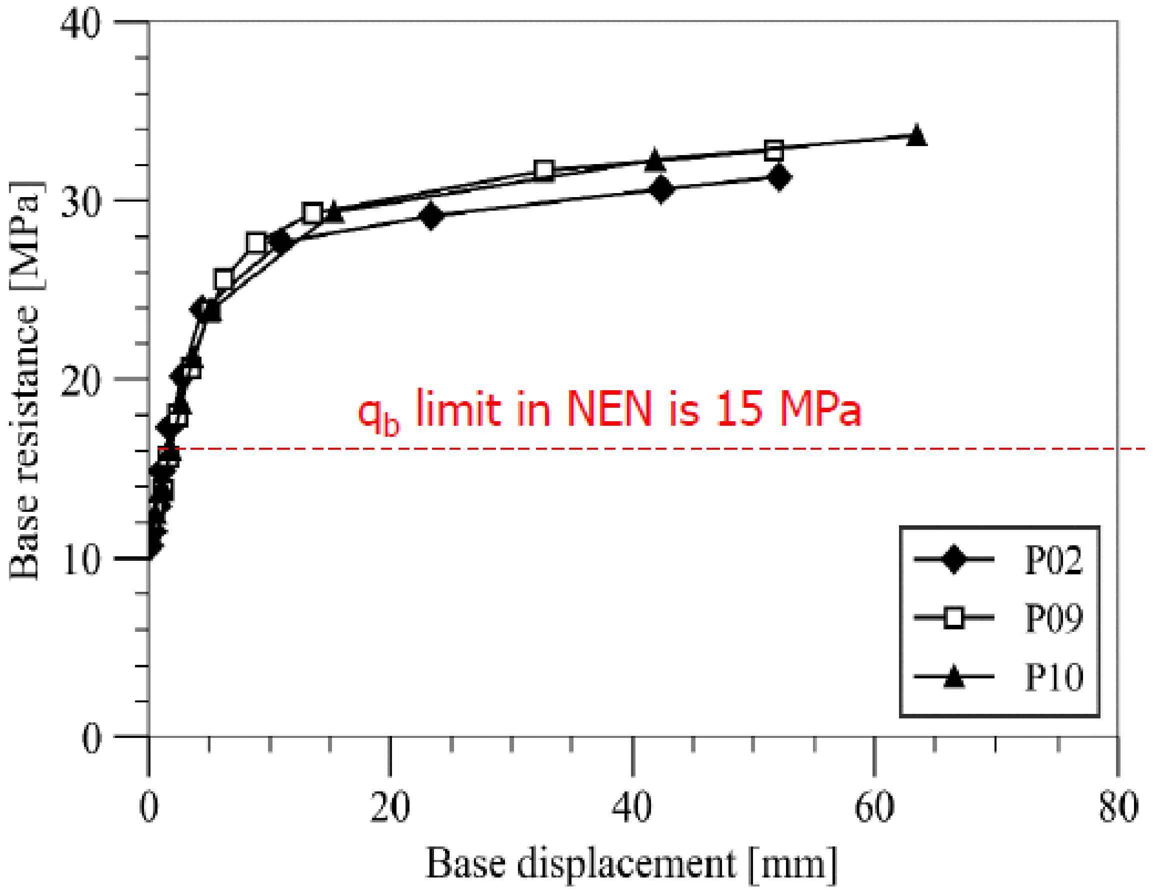


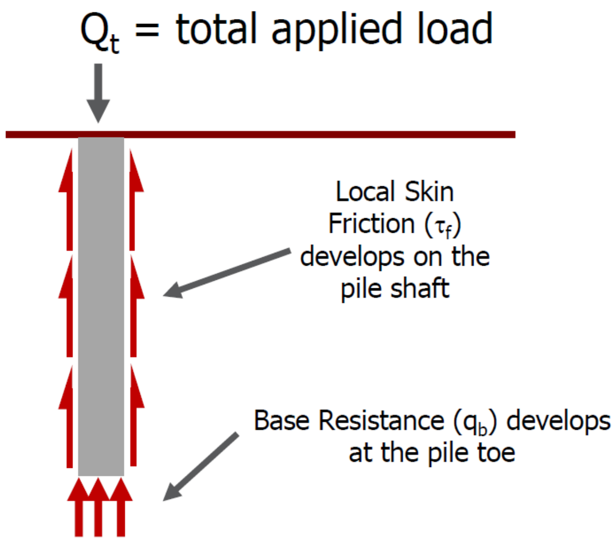
Dutch Offshore Wind Farm Zones
IJmuiden Ver
4,000 MW
tenders
2023 - 2025
6
Ten Noorden van de Waddeneilanden
700 MW
tender 2022
Gemini 600 MW
5
Hollandse Kust (west)
1,400 MW
tenders 2021
4
Hollandse Kust (noord)
700 MW
tender 2019
Egmond aan Zee 108 MW
Prinses Amalia 120 MW
3
Hollandse Kust (zuid)
Luchterduinen 129 MW
Site I and II Vattenfall, 760 MW
Site III and IV Vattenfall, 760 MW
2
Borssele
Site V Two Towers, 19 MW
Site III and IV Blauwwind 731,5 MW
Site I and II Ørsted, 752 MW
1
North Sea
Coast
100 km
62
56
53
24
18,5
0 km
Legenda
Current Dutch Wind Farm Zones: ~1 GW
Future Dutch Wind Farm Zones: ~10 GW



Cone End Resistance, q_c (MPa)
0
20
40
60
80
Depth, NaP (m)
-25
-35
-45
-55
-65
-75
-85
-95
Onshore 1
Onshore 2
Offshore 1
Offshore 2
Offshore 3

Compare Base Resistance





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Impact of Axial Load Tests?

Impact of the 1st test programme

- Cost saving on pile types used in Quay Wall at Amaliahven = €10 million. In addition a reduction of 8 kton of CO2 was achieved.
- Cost Savings on Quay Wall Upgrade at Amazonehaven €4.5 miljoen; ≈ 3 kton less CO_2.
- Projected additional cost savings in 2nd Maasvlakte of €15-20 million; ≈ 30 kton reduction in CO_2.

Port is very happy with €2.5 million investment

Wall corrosion

Safety factor calculation for quay walls management

Assumptions:

- Failure only on the wall side
- $M_d = \frac{M_{y0}}{1.5}$ constant with time
- $M_y(t)$ calculated from corrosion curves

$$F_s = \frac{M_y(t)}{M_d} = 1.5\frac{M_y(t)}{M_{y0}}$$