

# DESIGN OF A HEAVY-DUTY DEEPSEA QUAY WALL FOR OFFSHORE WIND ENERGY

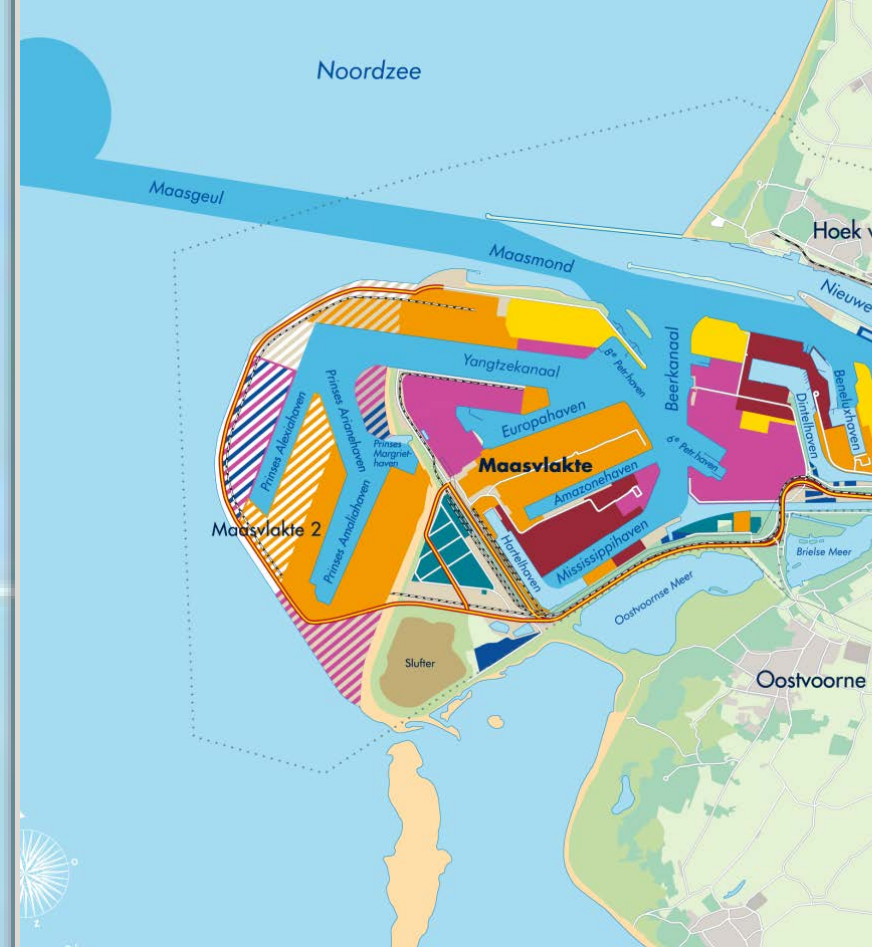


**Erik Broos**

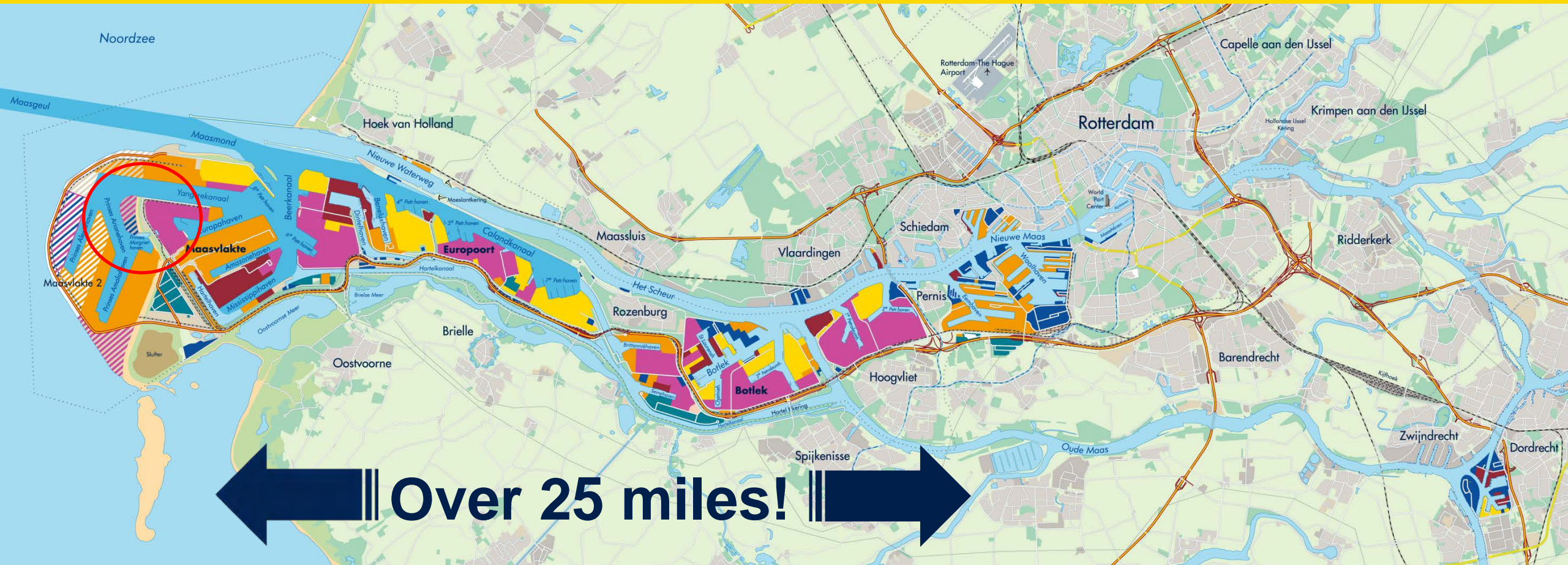
Jan Putteman, Caroline Bosschieter, Joris Meersschaert & Leon Tuunter



# Where is the Offshore Terminal Rotterdam?



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# Port of Rotterdam in figures

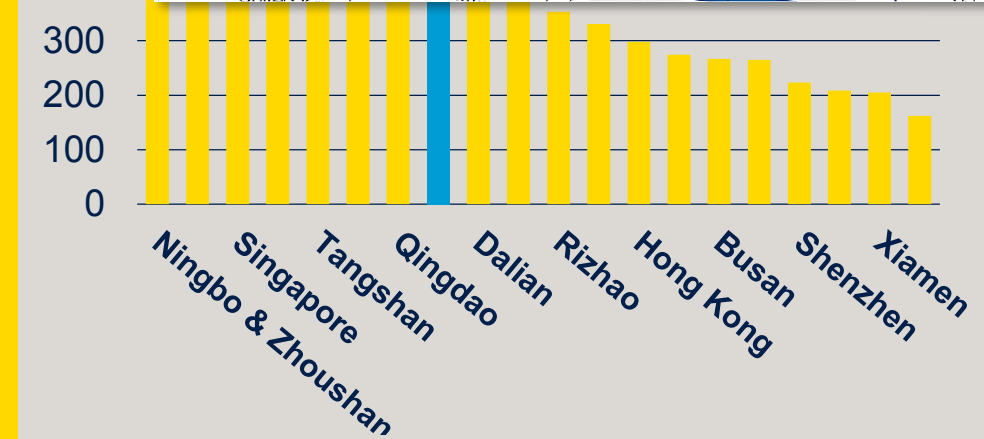
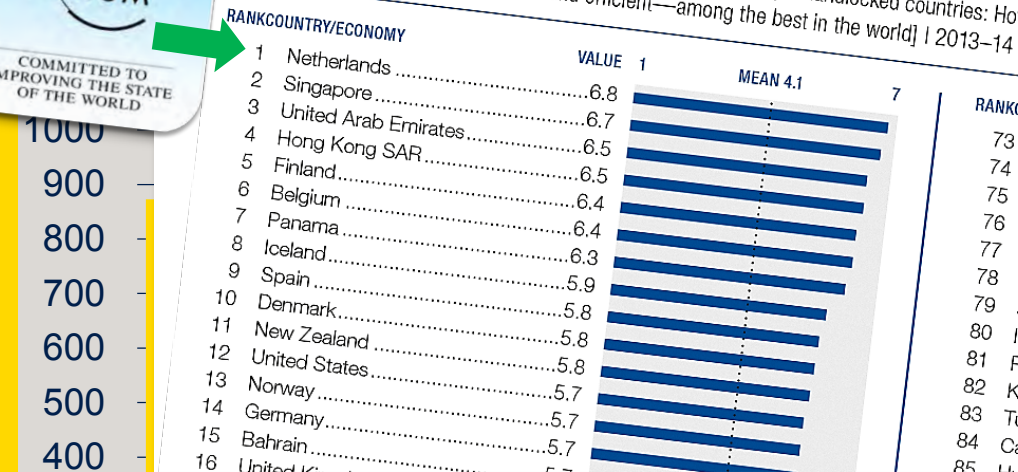
## Port of Rotterdam engine of the economy

- Total port area 12,500 ha (net 6,000 ha)
- Total employment 180,000 people
- Total added value € 21 billion (3.2% GNP)
- 3,000 companies
- Largest port in Europe, 8<sup>th</sup> port worldwide
- Throughput approx. 465 million tons;  
12 million TEU (containers)
- Depth up to 75 ft (= 24 m)



### 2.04 Quality of port infrastructure

In your country, how would you assess the quality of seaports? (For landlocked countries: How the worst in the world; 7 = extensive and efficient—among the best in the world) | 2013–14



Top 20 ports, x 1 million tons (2014)

# Offshore Industry new focal point in Rotterdam

## Growing offshore industry in Rotterdam

- Increasing demand offshore wind
- Decommissioning drilling platforms

## Advantages

- Strengthens existing offshore industry position
- Spin-off 700 M€



# Introducing SIF



Sif to produce mono pile foundations for wind turbines at Maasvlakte 2



# OTR: planned operations by SIF

Cans per barge from Roermond to R'dam

Assembly hall of 400/500 x 50 m

Barges sail into assembly hall

Production of piles up to 2000 ton (4/w)

Coating hall 120 x 120 m

Use of SPMT for transport

Use of crawler cranes

Surface load 10 ton/m<sup>2</sup>

Biggest Jack-ups 8 m from quay wall



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The challenge in the project:

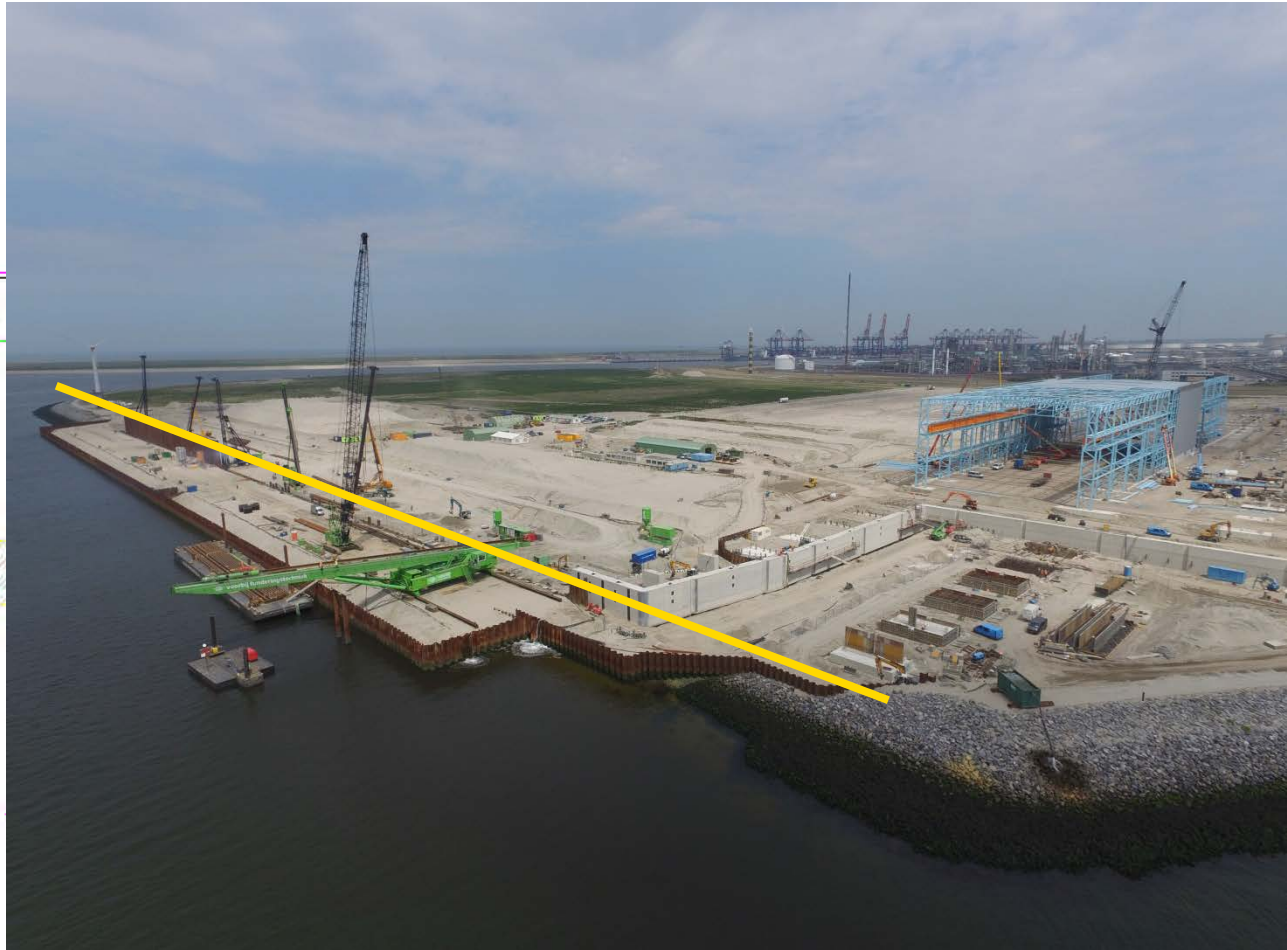
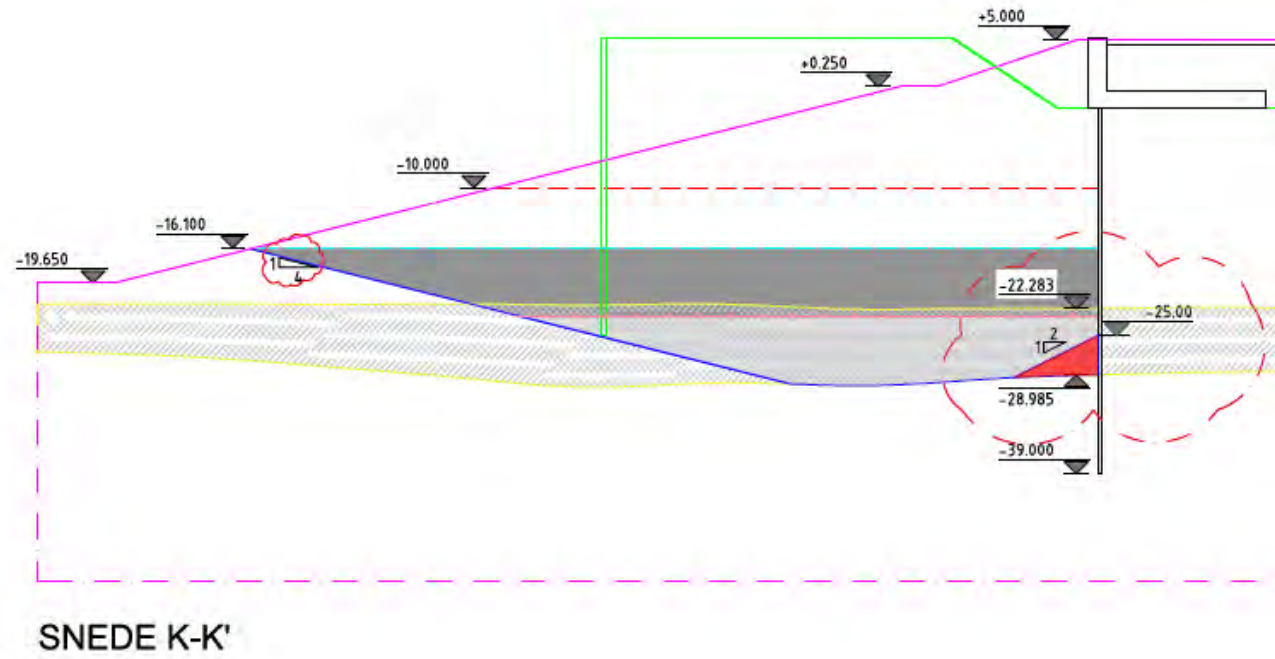


# aggressive development and construction schedule

27-3-2015	first contact with SIF
1-6-2015	first contract with SIF
3-6-2015	start engineering (MariTeam)
31-8-2015	first pile inland quay wall
10-11-2015	start procurement deep sea
6-1-2016	start deep sea contract
1-7-2016	inland quay wall finished
31-12-2016	first 150 m deep sea finished
1-7-2017	deep sea quay wall finished



# Quay wall with dry construction method



# First quay wall in Rotterdam with Jack-up ops.

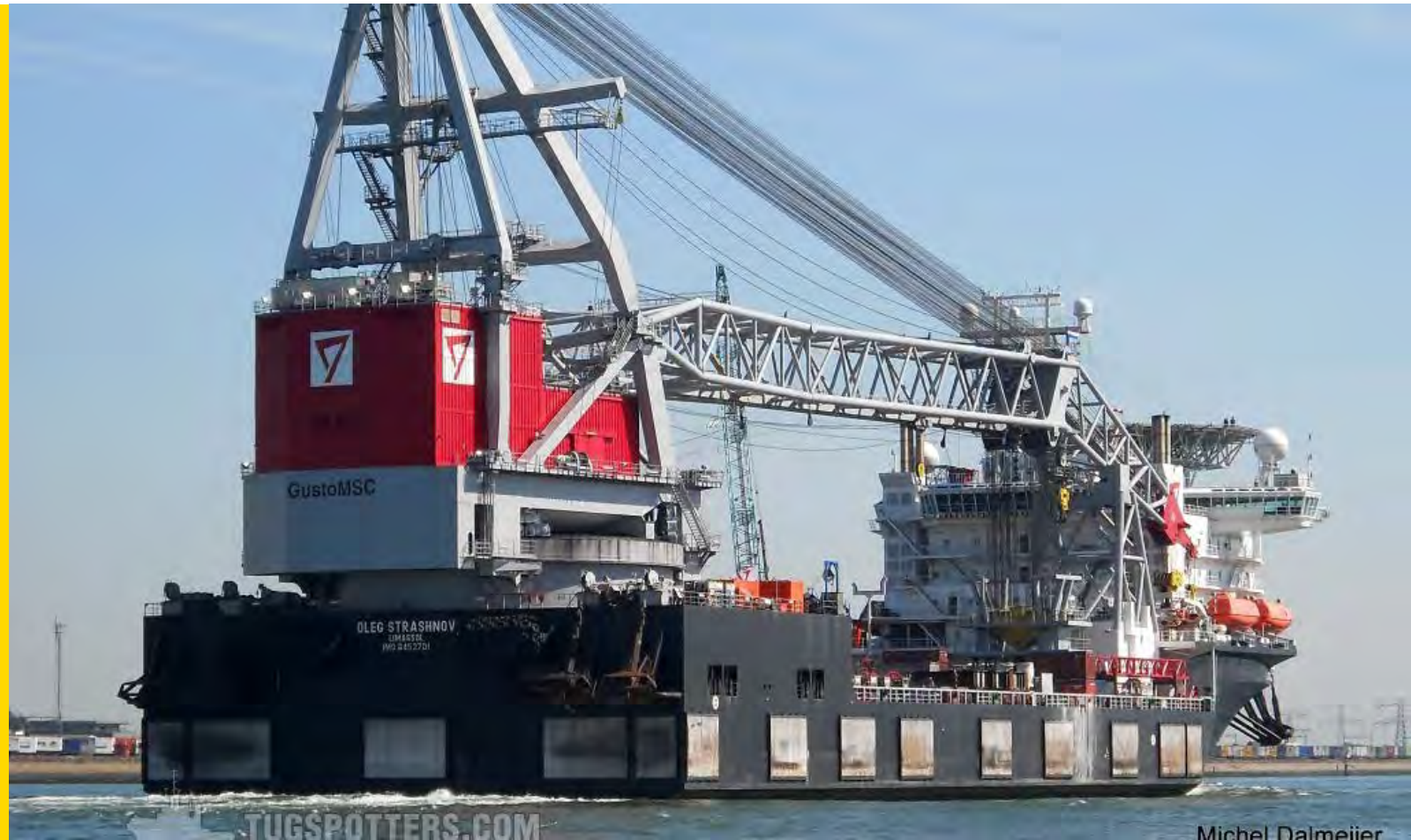
## Penetration of the spud can

- dredging level NAP-18,4m (Dmax = 15,5m)
- Preload, SNAME (2008)
- Geotechnical conditions
- Squeeze
- Punch through

## Extraction of the spud can

## Distance spud can to quay wall

- Max penetration depth NAP -24 m
- Construction depth NAP -25 m



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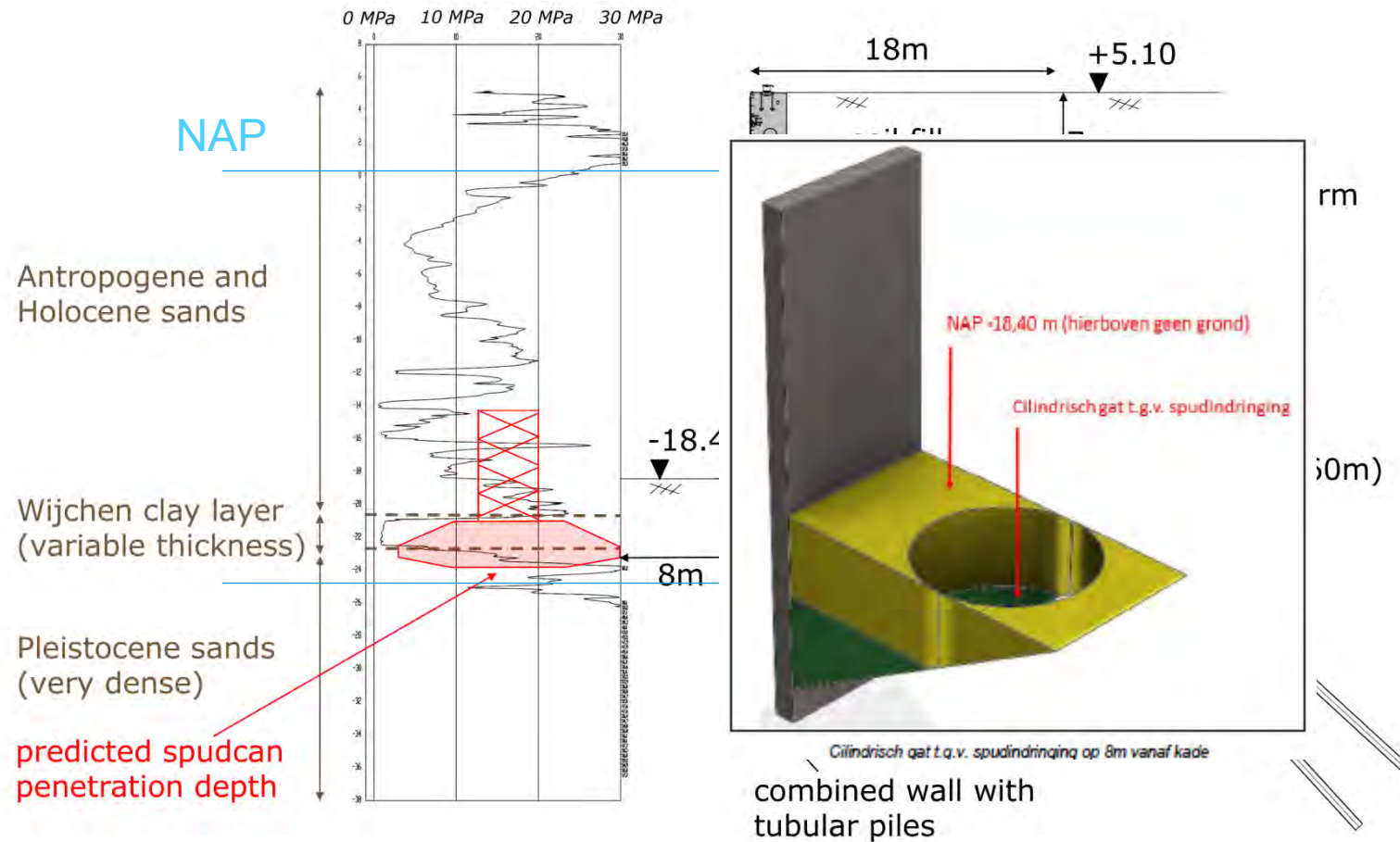
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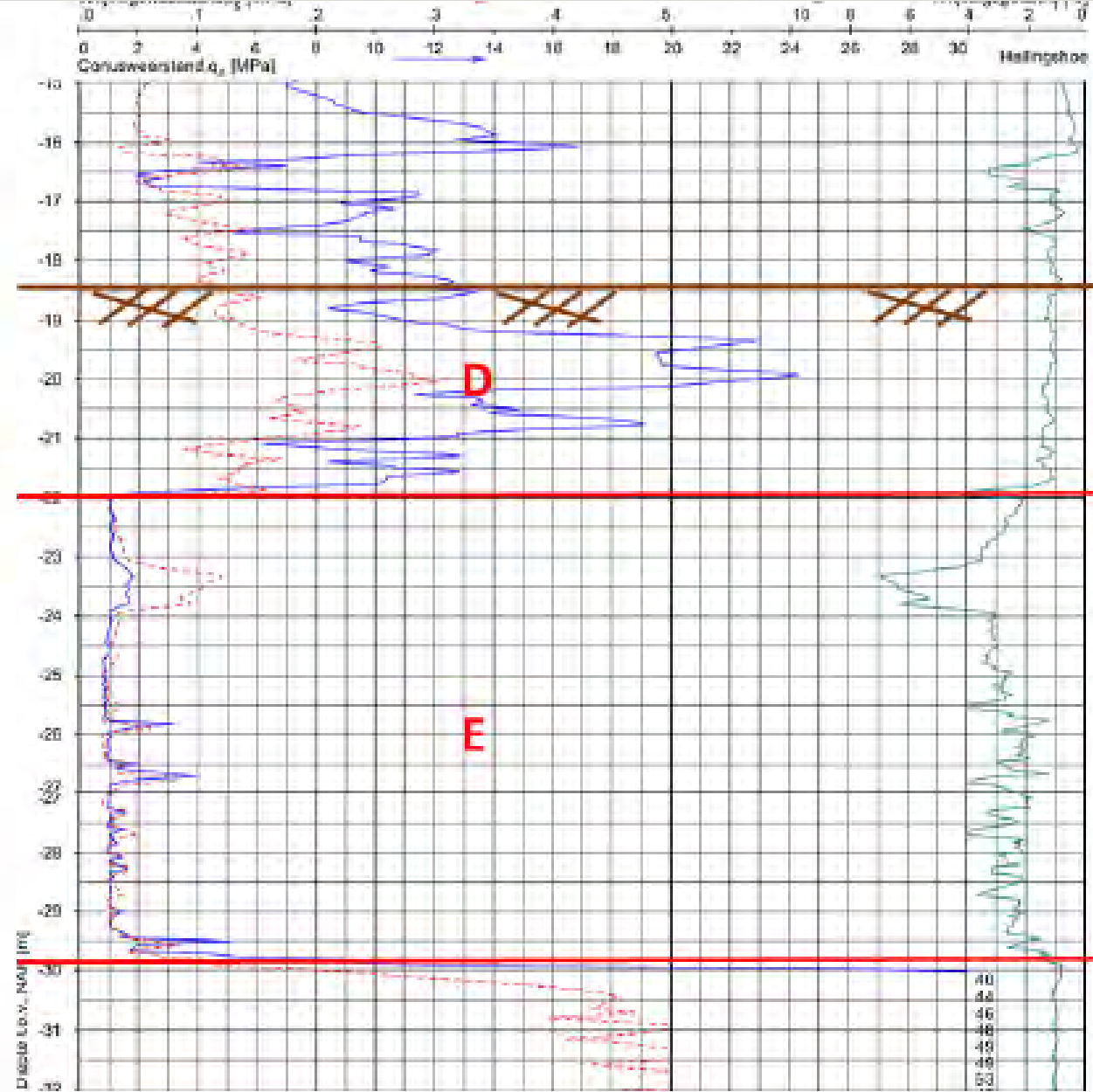
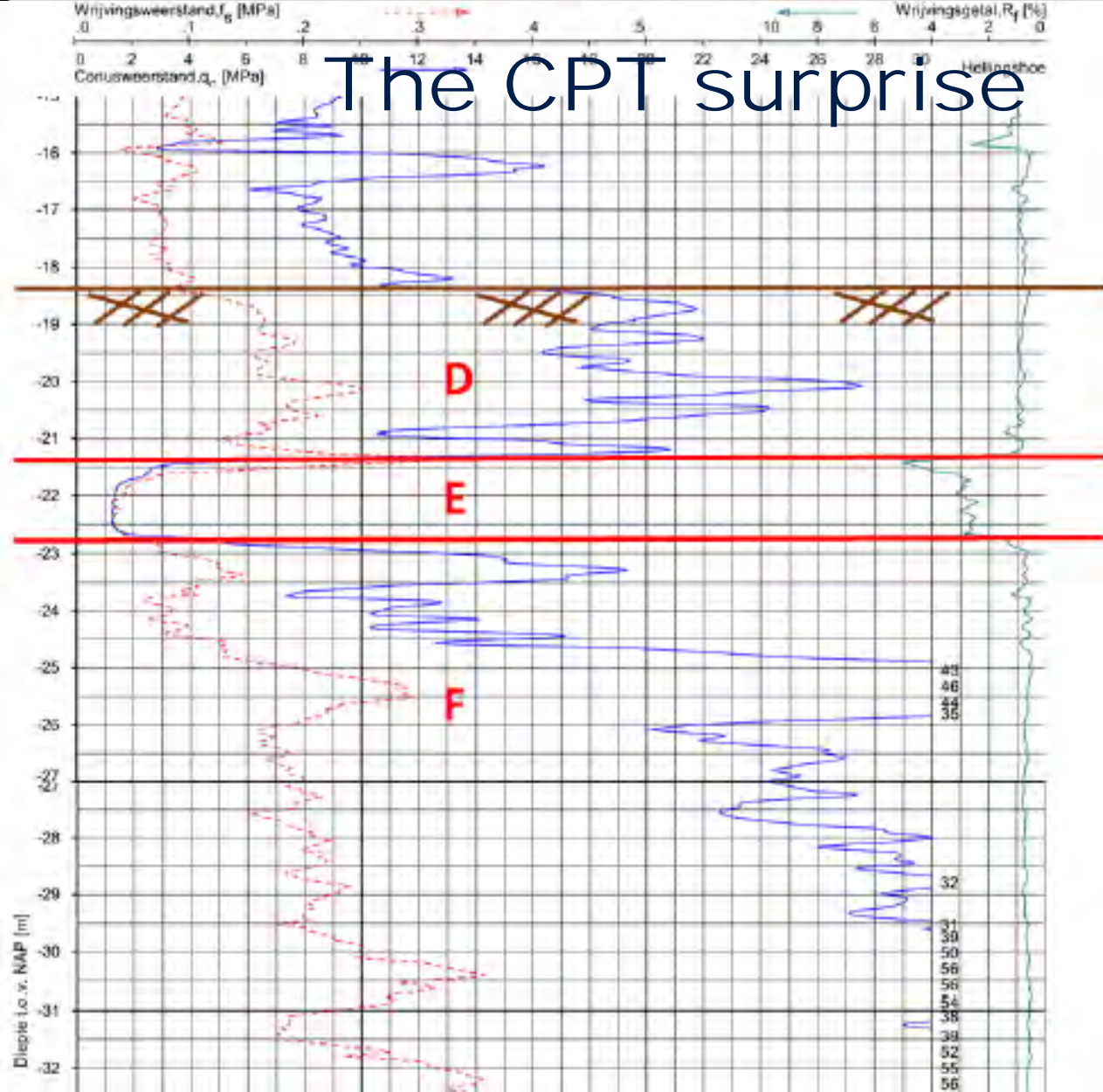
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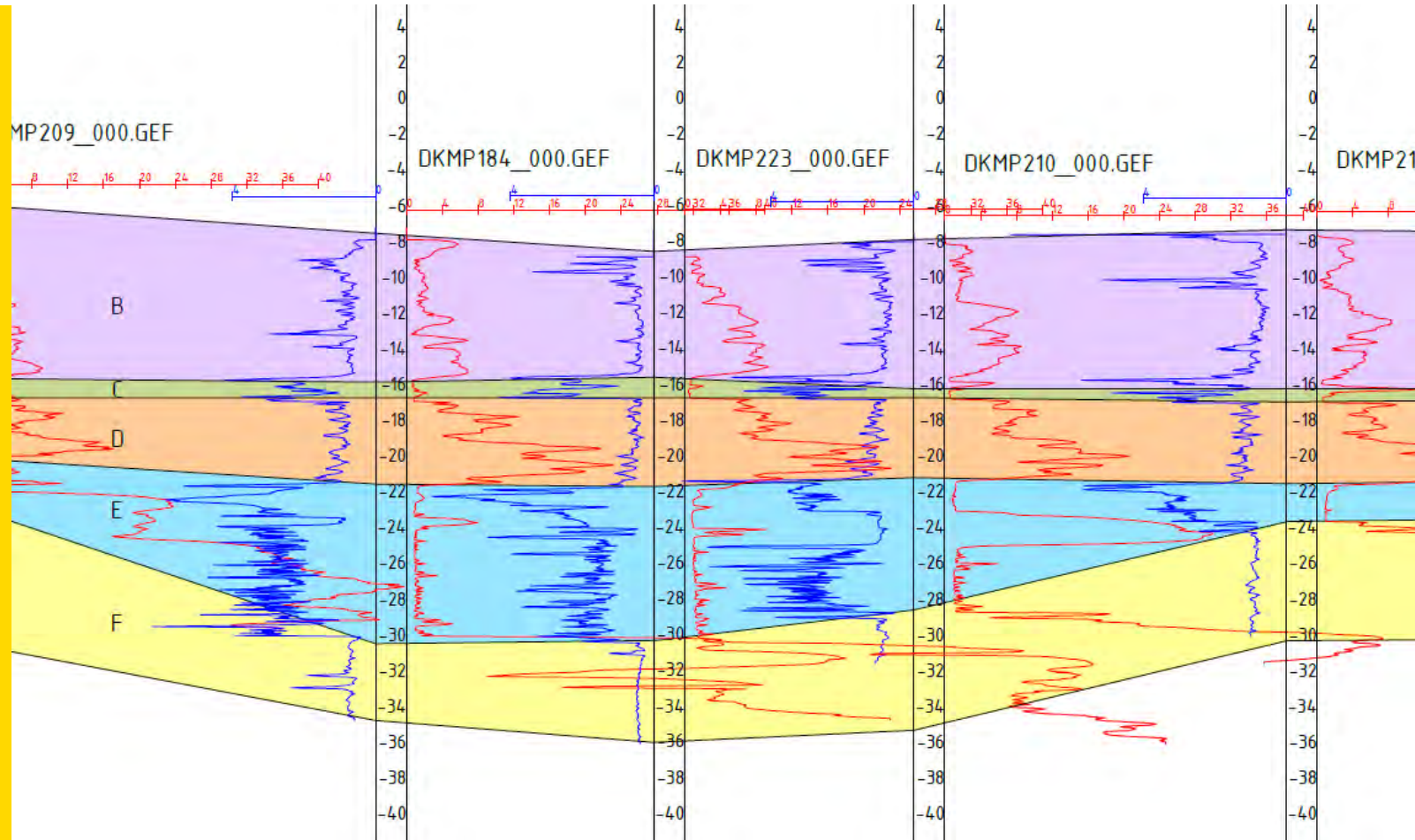


# The CPT surprise



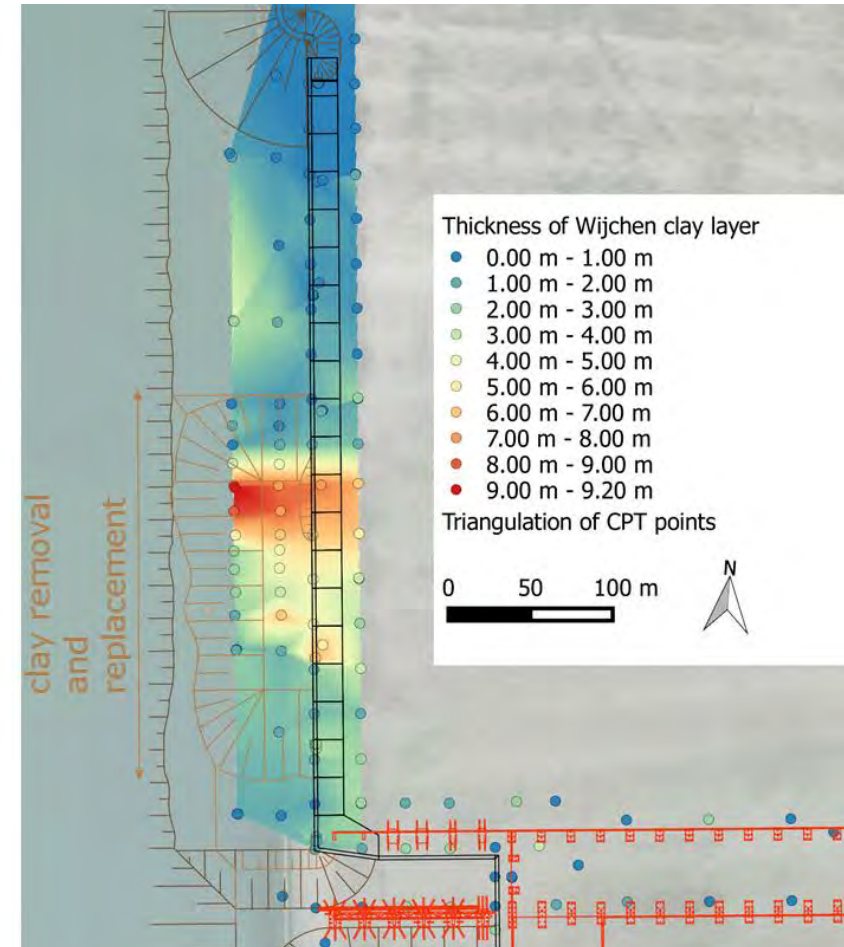
# Replacing clay by sand

- Up to 9 m Clay
- Unexpected prehistoric river gully
- Large spud can penetrations
- Always punch through



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# Replacing clay by sand

## Measurement

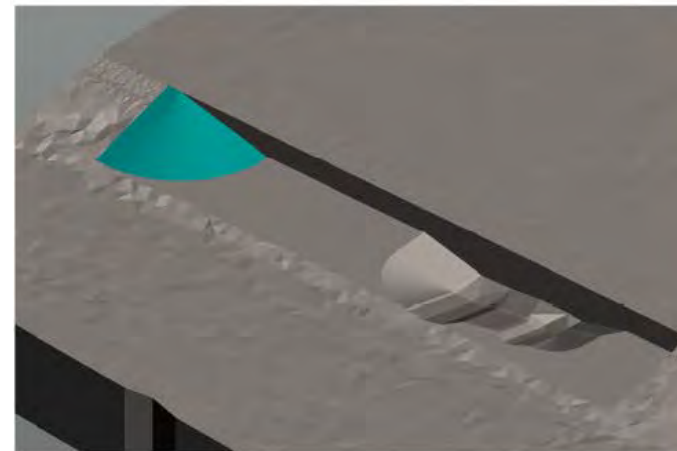
Dredging to NAP -16,1 (400,000 m<sup>3</sup>)

Ground water temporarily at NAP -6,0 m (construction level NAP -2,5)

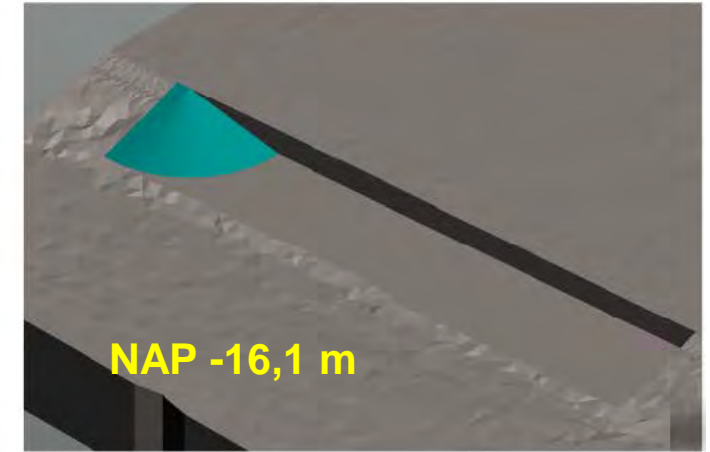
Pocket: ca 85,000 m<sup>3</sup>, of which 50,000 m<sup>3</sup> clay tot NAP -30.0 m!

Back fill gap with coarse sand, densify such that  $\phi \geq 35^\circ$ .

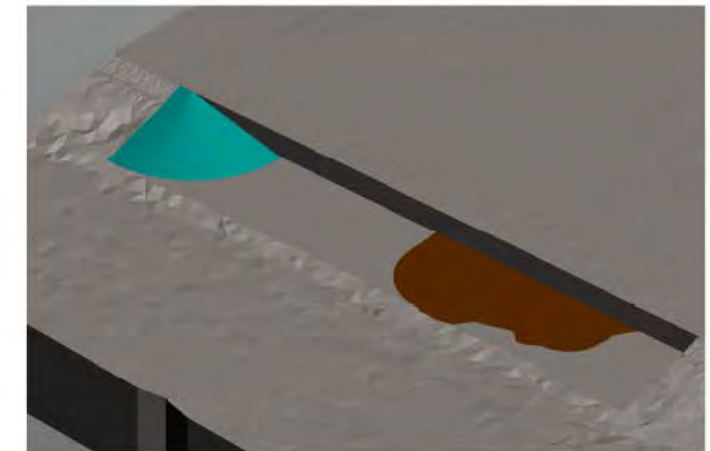
TSHD



FASE 2: VERWIJDEREN KLEILAAG

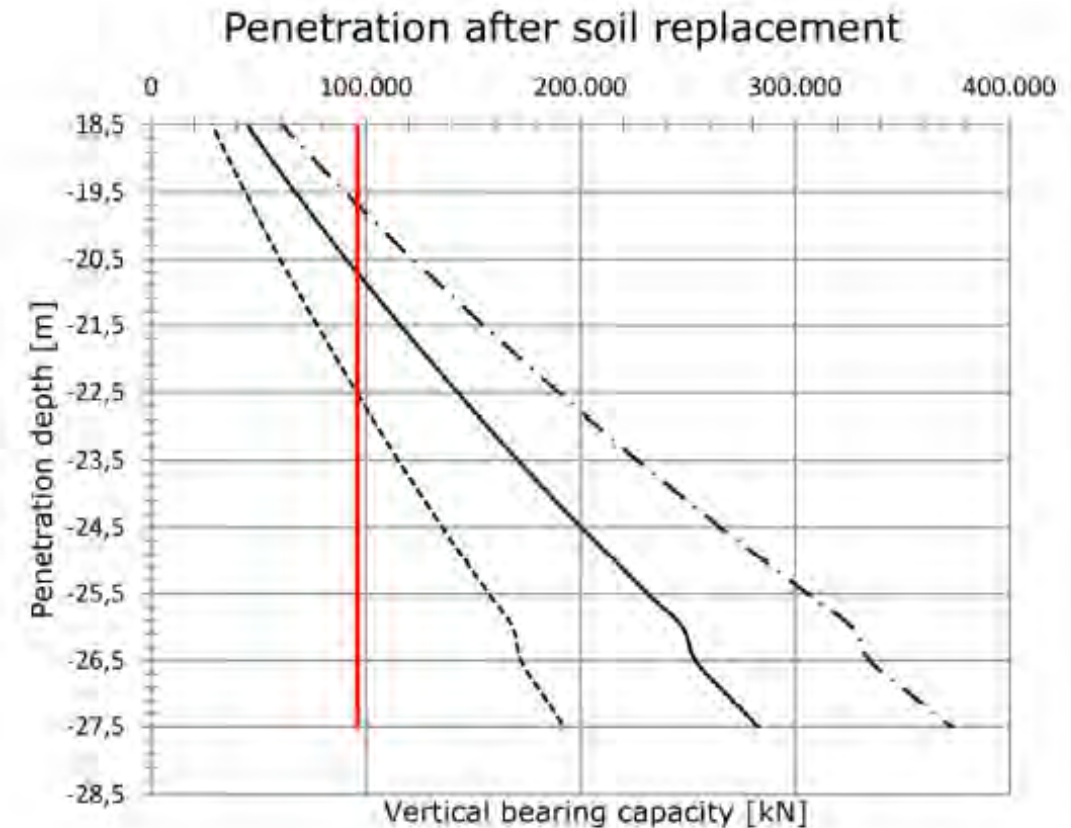
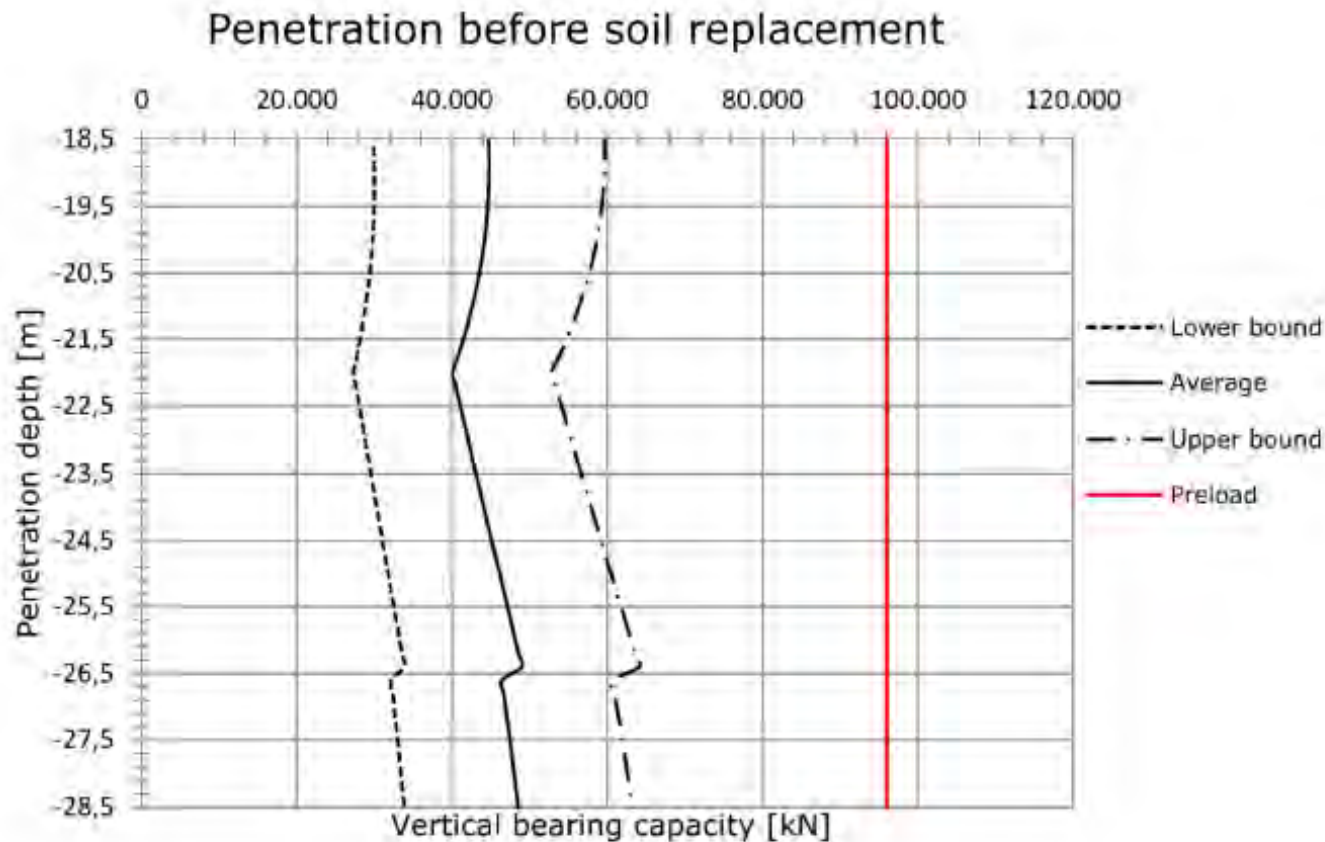


NAP -16,1 m



FASE 3: AANVULLEN TOT PEIL -16.10 N.A.P.

# Predicted (SNAME) spudcan penetration before and after ground improvement (relatively small canned vessel)



# Heavy design quaywall

## Combi-wall:

- King pile, 32-37m, 1420-21/23mm

- 3x PU28 sheet pile, 26-29 m

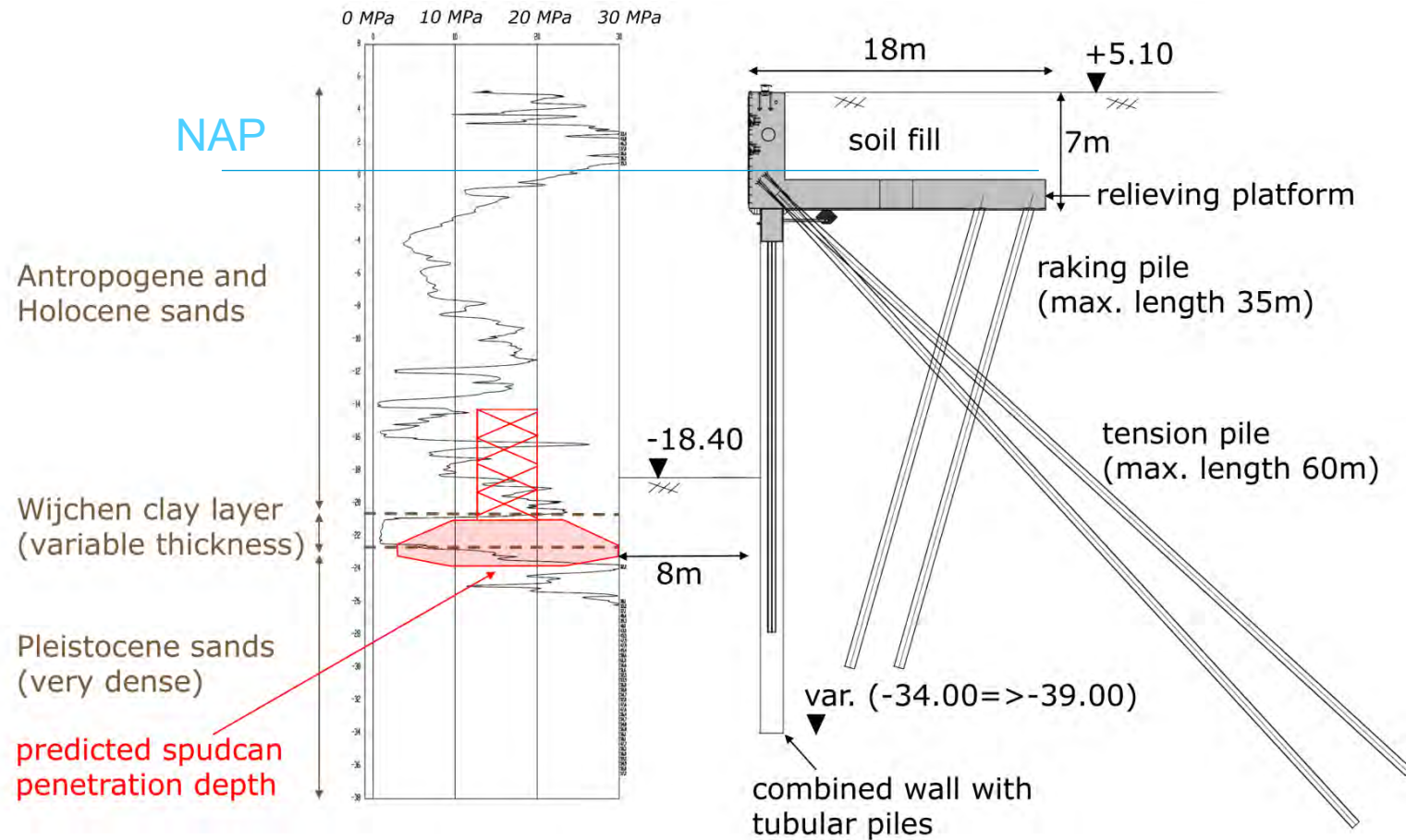
MV-piles 52,5 - 58,5 m, ctc 2,88 m

Raking pile 32 – 35 m, screw grout injection, permanent casing

## Super structure:

L shaped concrete relieve platform

23 x 18 x 7 m, 1000 m<sup>3</sup>

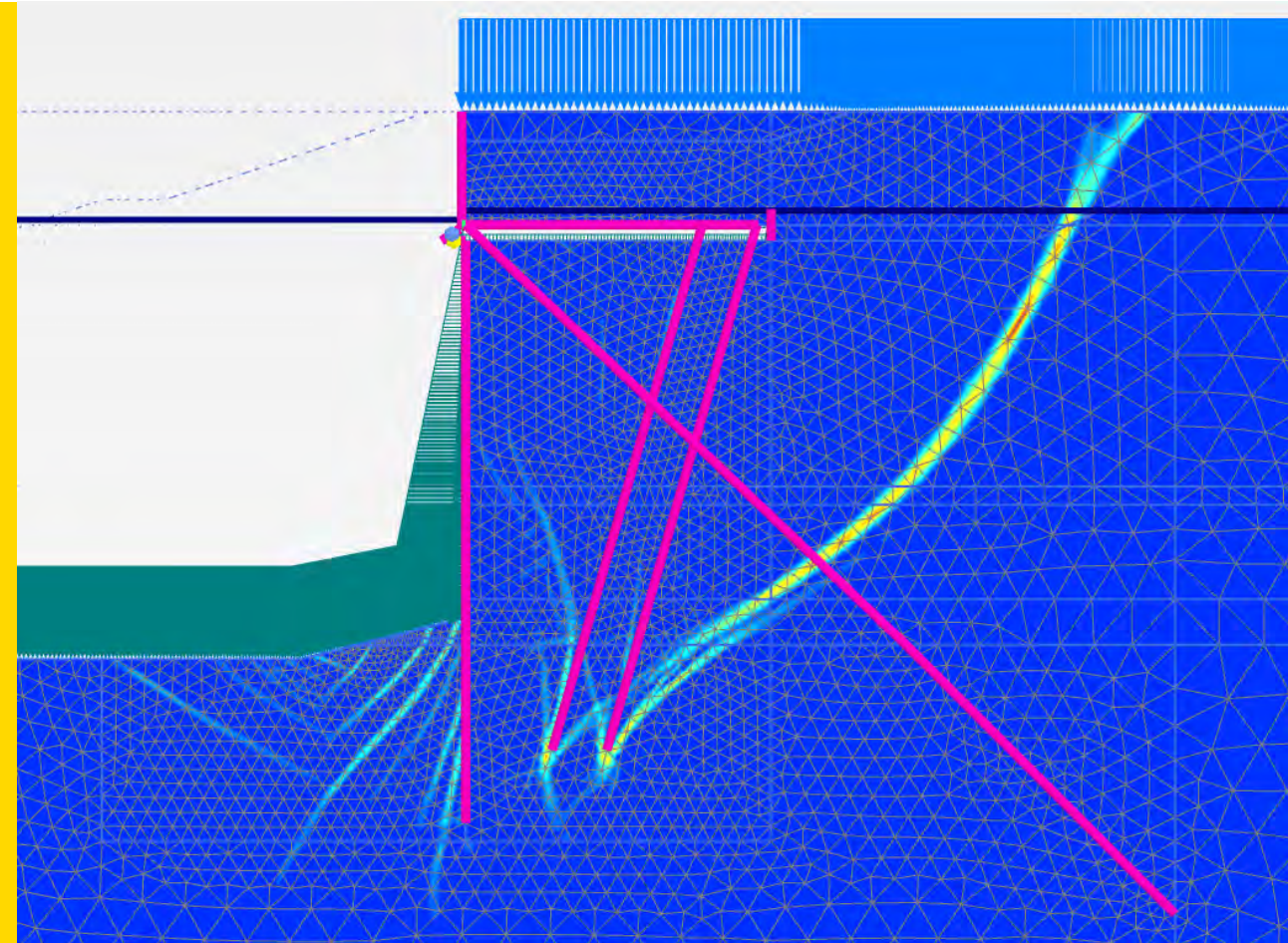


# What will we do?

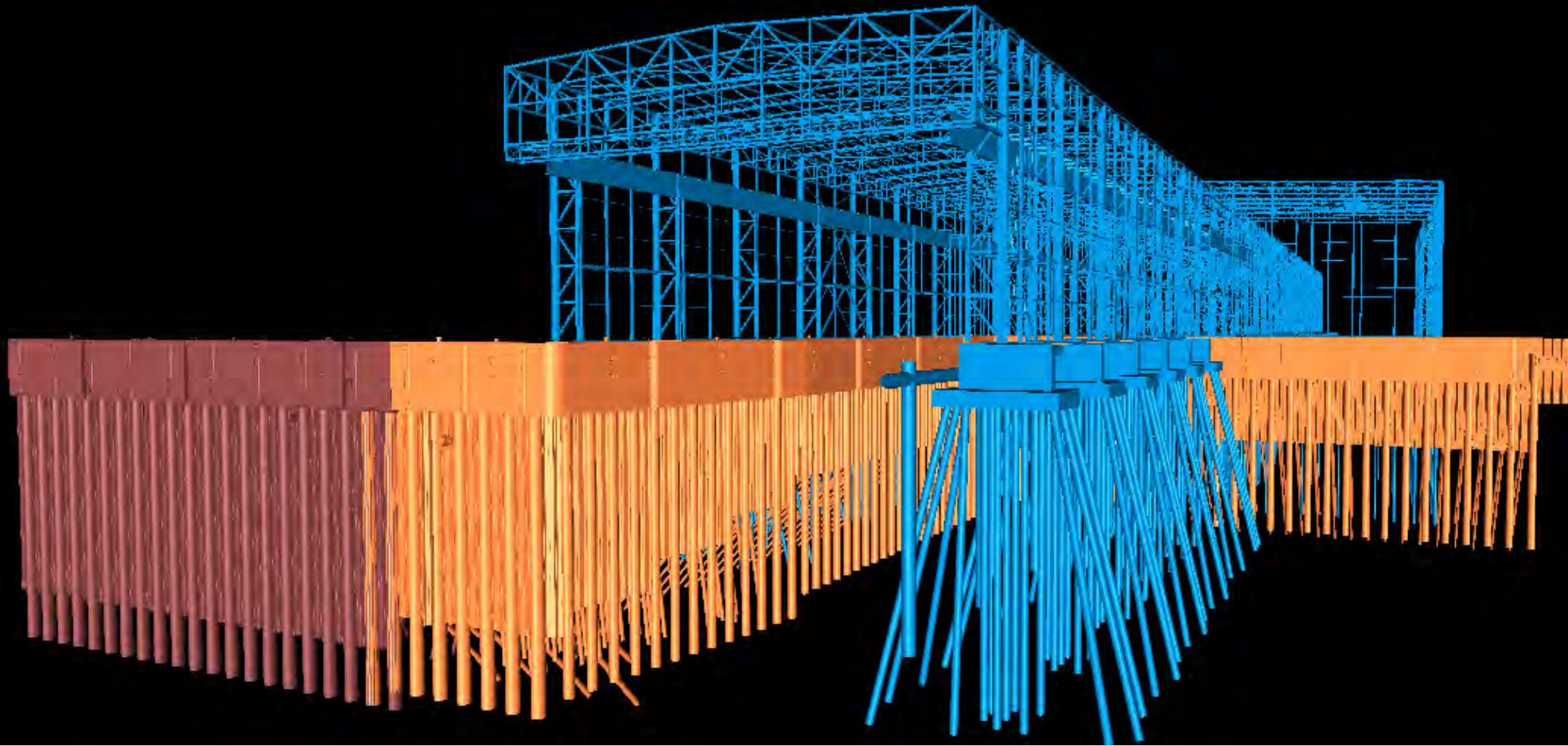
First jack-up vessels will be monitored closely, to verify penetration depths and ground deformations.

Permanent monitoring:

- Glass fiber under relief floor
- Classical deformation measurements
- 4 continuous inclinometers (SAAF)
- 16 old fashioned incline gauges.
- Continuous water pressure monitoring

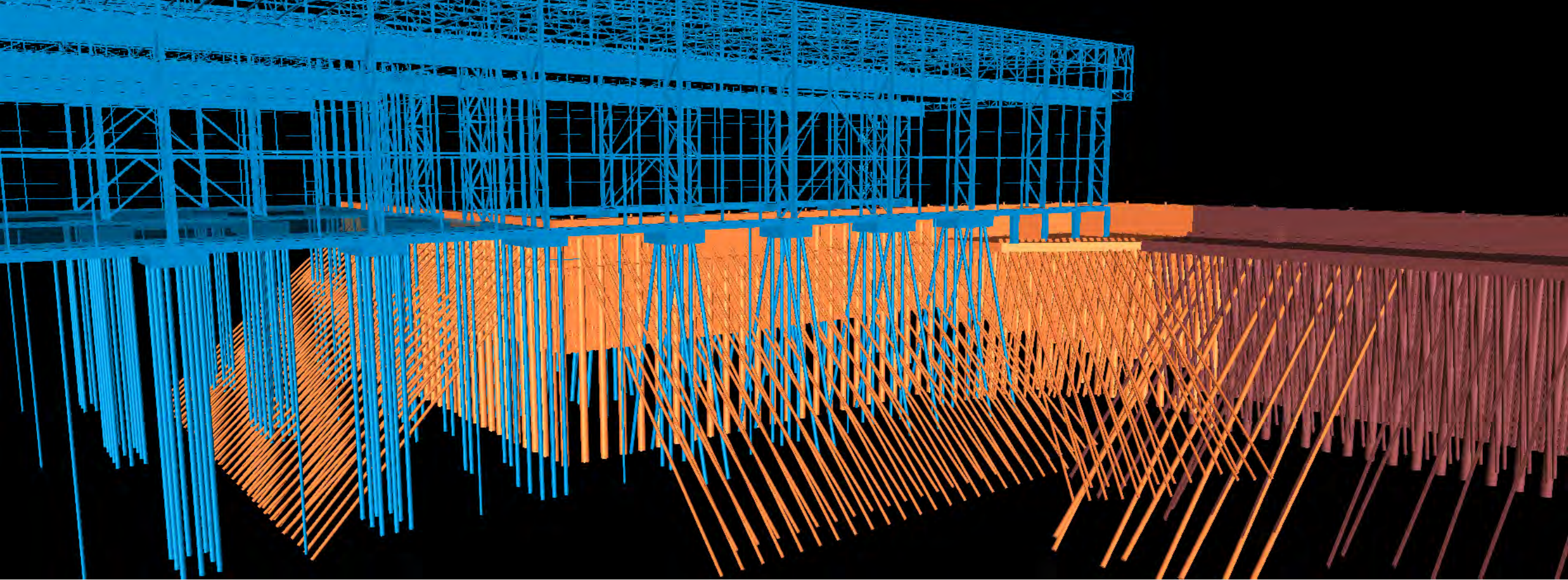


# Drivability





# Drivability (from vibro to SI piles)

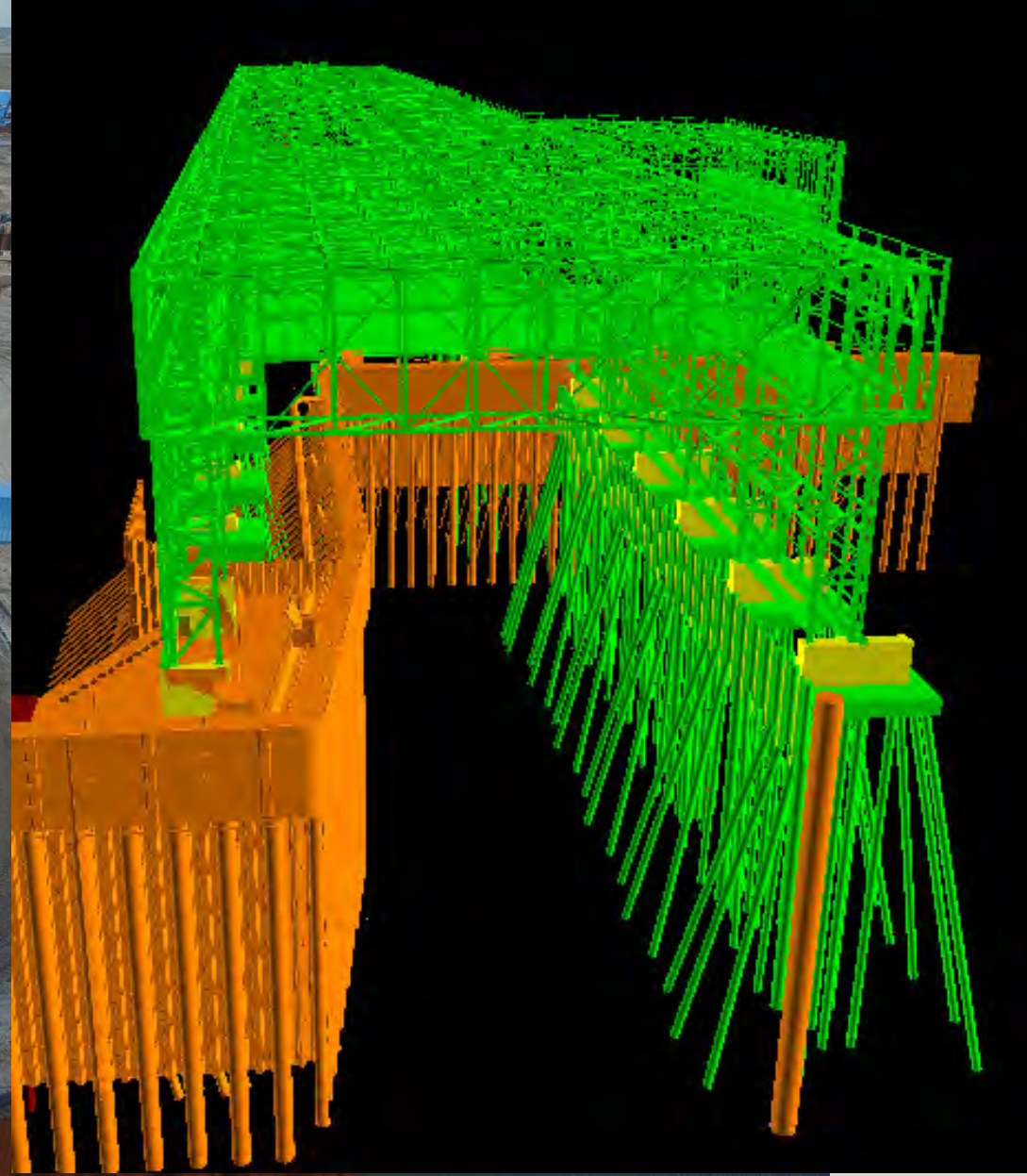








# Questions?

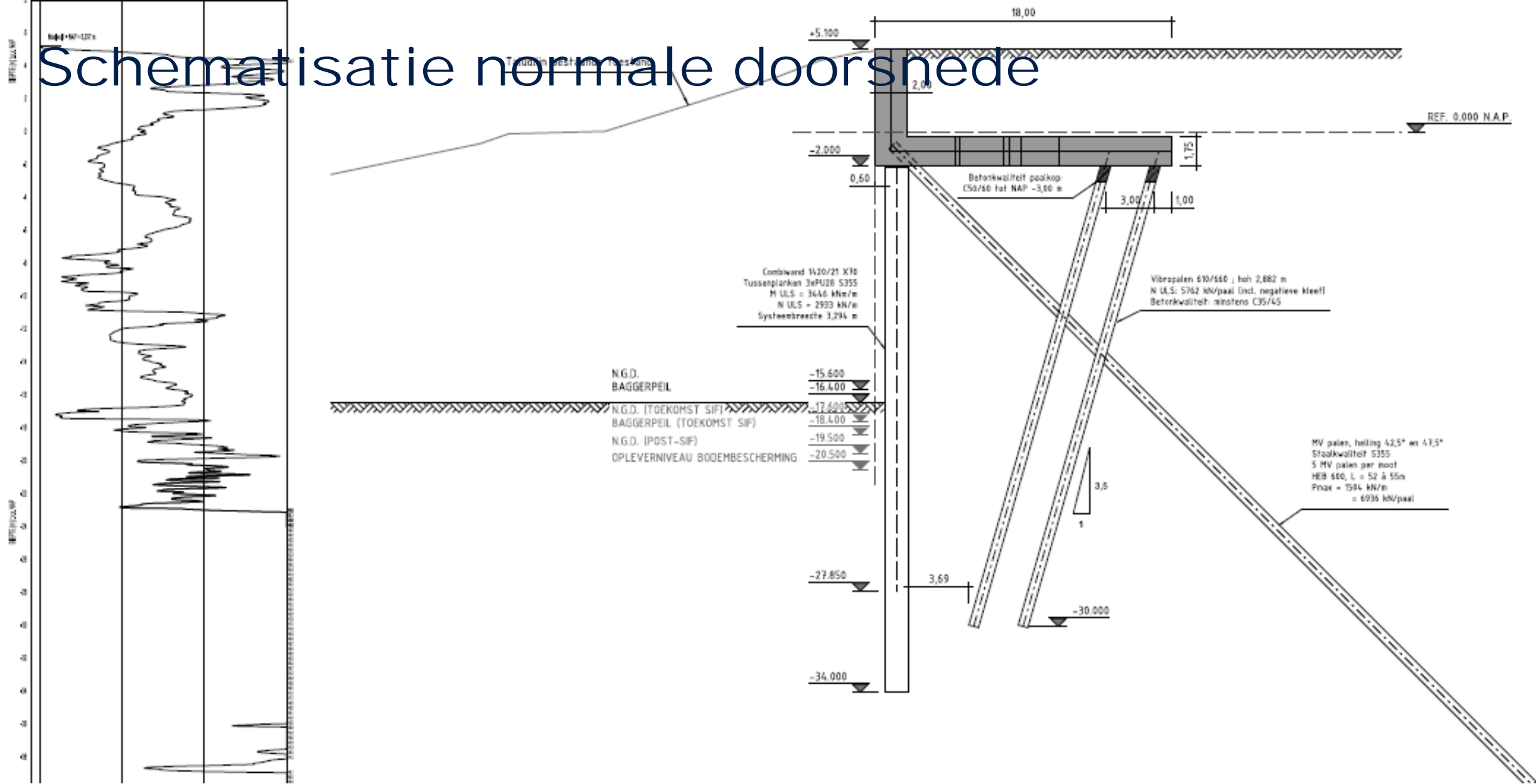






Offshore Terminal Rotterdam

# Schematisatie normale doorsnede





# Schematisatie doorsnede dikke klei laag

