A 25 m Deep Secant Pile Retaining Shaft in Sensitive Clay

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NGM 2012, Copenhagen May 10th 2012
Midgardsormen - An Environmental Project
purifying the Oslo fjord and Akerselva River
Transportation by gravity from Kuba towards Bekkelaget; 5 km

Pipejacking
Trenching

Outlet tunnel at deep water

Shaft S9

Bekkelaget wastewater treatment plant
Introduction

- **Owner:** City of Oslo, Water and Sewerage Works (VAV)
- **Costs and Project Duration**
  - Total costs 1.3 billion NOK (approx. 160 million EUR)
  - Planning started in 2005
  - Completion in 2014

- **Norconsult's Role:**
  - A large, and inter-disciplinary challenging project.
  - Design, all disciplines is being done by Norconsult AS:
    - Rock mechanics
    - Civil engineering
    - Geotechnical engineering
    - Environmental engineering
    - Water and wastewater engineering
Main contractor
Veidekke Entreprenør AS

Subcontractor for the secant pile works
Züblin AS
Shaft S9
Location

S9
Vital Connectio
npoint.

…the most suitable location

Photo: Gule sider
Anleggsområdet

Rock tunnel towards Bekkelaget

Pipes are jacked/bored from Shaft S9

Sheet pile wall towards Mosseveien

Mosseveien road

Østfoldbanen railway

Rock tunnel towards Bekkelaget
Sjakt S9: Cross-sectional View. The Deepest Shaft in Oslo?

- Diameter 16 m
- ca. 15 m
- ca. 25 m
Three-dimensional FEM Analysis

- 3D analyses in ABAQUS
- Tension forces (gray area)
Ground Conditions

- Approx. 5 - 6 m of miscellaneous fill material on top of sensitive clay.
- Significant local variation in clay sensitivity.
- Undrained shear strength in the order of 25-40 kPa.
- Ground water assumed 2 - 4 m below ground surface.
- Secant piles
- Diameter 1080 mm, c/c 813 mm
- 33 primary piles
- 33 secondary piles
- Lime-cement columns as ground stabilization
Ground Improvement: Cylinder Formation of Lime Columns. Plan View
July 2010

The works are initiated
Sheet pile wall towards Mosseveien

Securing Mosseveien: 6 m long Sheet pile wall, anchored into the concrete slab.
140 ton pile driver

Soft clay replaced by light fill material in order to maintain acceptable stability in the area.
Drilling Template to Assure Accurate Installation of the Secant Piles.

"Barrel hoop" on the outside of the template, in order to ensure contact between the piles.

Cross sectional view of the "barrel hoop"
Soil Removal Done by Augering
Casting of Concrete and Casing Removal

Successive concreting and extraction of the casing.
Pile installation complete. Installation of 6 rock anchors remains.
Excavation Initiated by a (relatively) Small Excavator...
...Which later was replaced by a 70 tons backhoe with 20 m range
After approx. 10 m of excavation
18 m depth

A 9-tonner was placed at the current level, causing significant loss of efficiency.

Lime columns were so stiff at the bottom of the shaft that they had to be chizzled.
It clearly is a long way down...
...and make no mistake - a long way up!
Overview. Excavation is still ongoing
Concrete astray - "The remarkable sculpture"
From above - "the sculpture":

![Image of the sculpture from above]
The "sculpture" is being revealed.

ca. 7,0 m
The sculpture was secured
Pipe jacking - Ø 3 m. 520 m to shaft S7. Exciting but successful!
Thank you!