Excavation Pits for Contract E 101
City Tunnel Malmö, Central Station,
May 2005 to Dec 2007

Brückner Grundbau GmbH
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Excavation Pits for Contract E 101

General
Geological conditions
Execution of Diaphragm-Walls
Execution of temporary anchors
Execution of uplift anchors
Excavation pits for Contract E 101

General: Selected construction methods for retaining walls

Areas without sensitive adjacent properties:
- Overburden ground to head of limestone: anchored sheet pile walls
- In limestone: shotcrete walls, tied back with rock bolts
- Penetration grouting of fractures and joints in limestone

Areas with sensitive properties:
- In overburden ground and rock: stiff D-Walls (width = 0.8m, anchored)
- D-Walls for temporary use only
- Water tightness of D-Wall and joints required
Excavation pits for Contract E 101: City Tunnel Malmö, Central Station

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General: lay out of pits

<table>
<thead>
<tr>
<th>Etapp</th>
<th>Walls</th>
<th>Temporary Anchors</th>
<th>Uplift Anchors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Etapp 1</td>
<td>sheet piles / shotcrete</td>
<td>2 rows, strand-anchors</td>
<td>GEWI</td>
</tr>
<tr>
<td>Etapp 2</td>
<td>D-Wall</td>
<td>3 rows, strand-anchors</td>
<td>GEWI</td>
</tr>
<tr>
<td>Etapp 3</td>
<td>D-Wall / sheet piles</td>
<td>2 rows, strand-anchors</td>
<td>GEWI</td>
</tr>
<tr>
<td>Etapp 4</td>
<td>D-Wall</td>
<td>2 rows, strand-anchors</td>
<td>GEWI</td>
</tr>
<tr>
<td>Etapp 5</td>
<td>sheet piles</td>
<td>2 rows, strand-anchors</td>
<td>GEWI</td>
</tr>
</tbody>
</table>
# Excavation pits for Contract E 101

## Geological conditions – general elevation

<table>
<thead>
<tr>
<th>Etapp 5</th>
<th>Etapp 3</th>
<th>Etapp 4</th>
<th>Etapp 1</th>
<th>Etapp 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>-30</td>
<td>-10</td>
<td>-20</td>
<td>-10</td>
<td>-30</td>
</tr>
<tr>
<td>-20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overburden ground</td>
<td>Copenhagen ridge</td>
<td>Limhamn ridge</td>
<td>Diaphragm-Wall</td>
<td></td>
</tr>
</tbody>
</table>

### Layer Average thickness

<table>
<thead>
<tr>
<th>Layer</th>
<th>Average thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overburden ground</td>
<td>8 m</td>
</tr>
<tr>
<td>Copenhagen ridge</td>
<td>3 m</td>
</tr>
<tr>
<td>Limhamn ridge</td>
<td>70 m</td>
</tr>
</tbody>
</table>
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Geological conditions – hardness of rock

<table>
<thead>
<tr>
<th>Geological formation</th>
<th>H1 [%]</th>
<th>H2 [%]</th>
<th>H3 [%]</th>
<th>H4 [%]</th>
<th>H5 [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
<td>a</td>
<td>b</td>
<td>a</td>
</tr>
<tr>
<td>Copenhagen layer</td>
<td>20 0-30</td>
<td>20 10-30</td>
<td>5 0-10</td>
<td>25 20-30</td>
<td>30 25-35</td>
</tr>
<tr>
<td>Limhamns layer A, B, D, E</td>
<td>5 0-10</td>
<td>17 15-25</td>
<td>18 15-25</td>
<td>55 50-60</td>
<td>5 0-10</td>
</tr>
<tr>
<td>Limhamns layer C</td>
<td>3 0-5</td>
<td>35 30-40</td>
<td>45 40-50</td>
<td>15 10-20</td>
<td>2 0-5</td>
</tr>
</tbody>
</table>

source: contract documents
## Excavation pits for Contract E 101

### geological conditions – strength of rock

<table>
<thead>
<tr>
<th>Hardness class</th>
<th>Unconfined compressive strength [MPa]</th>
<th>Tensile strength (Brazilian Test) [MPa]</th>
<th>MOE [GPa]</th>
<th>Shear strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>H1</td>
<td>0.3</td>
<td>0.05-0.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>H2</td>
<td>6</td>
<td>3-10</td>
<td>0.6</td>
<td>0.3-2</td>
</tr>
<tr>
<td>H3</td>
<td>12</td>
<td>5-25</td>
<td>2</td>
<td>0.4-4</td>
</tr>
<tr>
<td>H4</td>
<td>35</td>
<td>10-75</td>
<td>5</td>
<td>0.6-9</td>
</tr>
<tr>
<td>H5</td>
<td>250</td>
<td>100-400</td>
<td>25</td>
<td>10-40</td>
</tr>
</tbody>
</table>

Source: contract documents
Excavation pits for Contract E 101

Excecution of D-Walls

The Diaphragm-Walls were constructed to depths between 14 and 24 m, up to 14 m of which in limestone formations.

- The overburden ground was excavated by grab.
- Due to high rock strength, a hydro mill was necessary for excavation in limestone.

D-Wall surface
over all surface: 11.700 m²
overburden ground: 6.700 m²
limestone: 5.000 m² limestone cubature: 4.000 m³

Contractual construction time: 148 days
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Excecution of D-Walls

**Production sequence:**

- Construction of guide walls,
- Excavation by grab until rockhead of limestone (1\textsuperscript{st} rig),
- Further excavation by hydro mill (2\textsuperscript{nd} rig),
- Change of process bentonite suspension to clean suspension,
- Installation of stop ends (3\textsuperscript{rd} rig),
- Installation of reinforcement cages (3\textsuperscript{rd} rig),
- Concreting (3\textsuperscript{rd} rig).
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Execution of D-Walls

1st rig

2nd rig

3rd rig
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Execution of D-Walls – construction of guide walls

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- City Tunnel Malmö, Central Station

- Brückner Grundbau GmbH

- 700 mm
- 820 mm
- 200 mm
- 1200 mm

- 200 mm
- 820 mm
- 700 mm
- 1200 mm
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Execution of D-Walls – excavation by grab
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Excecution of D-Walls
– excavation by hydro mill

Hydro mill BC 30:
- Long frame (approx. 30 t)
- Powerpack (total. 650 KW)
- Total weight: approx. 115 t
- Cutting wheels with round shank chisels
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Excecution of D-Walls – excavation by hydro mill

- max. 450 m
- desander, 500 cbm/h
- bentonite mixing stn., 40 cbm/h
- storage basin, 500 cbm (process susp.)
- clean susp
- 6” pipes
- 2 x 10” pipes
- 4” pipe
- hydro mill BC 30
- mud pump
- remote control for mud pumps
- centrifugal mud pump
- fine screen and cyclons
- coarse screen
- fine screen and cyclons
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Execution of D-Walls – flint and limestone

crushed flint and limestone – separated in the coarse screen
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Execution of D-Walls – flint and silicified limestone boulders
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Execution of D-Walls – construction of joints

- Prefabricated concrete element
- Waterstops
- Gravel fill to avoid concrete flow
- Primary panel

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Execution of D-Walls – construction of joints

Core through stop-end element and cast in situ concrete panel
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Execution of D-Walls – installation of a reinforcement cage with box outs for temporary anchors
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Excecuton of D-Walls – installation of combined steel and glasfibre reinforced plastic (GRP) cage in TBM-penetration walls
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Execution of D-Walls – lifting of combined steel and GRP-cage
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Execlution of D-Walls – concreting

- to desander
  - 30 cbm/h
- concreting with 2 tremie pipes
- pump
- stop end
- gravel material

guide wall
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Execution of D-Walls – quality control of the bentonite suspension
Agenda

Excavation Pits for Contract E 101

General
Geological conditions
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**Execution of temporary anchors**
Execution of uplift anchors
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Total:
545 anchors in 1\textsuperscript{st} row, max. 870 kN, max. 30 m
760 anchors in 2\textsuperscript{nd} row, max. 1080 kN, max. 17 m
80 anchors in 3\textsuperscript{rd} row, max. 1080 kN, max. 12 m

Overburden ground

Limhamn

ridge

Copenhagen

ridge

D = 133 mm
D = 114 mm
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Execution of temporary anchors

- 1\textsuperscript{st} row, just above groundwater level,
- 2\textsuperscript{nd} and 3\textsuperscript{rd} anchor rows required drilling and installation against water head,
- Duplex method, outer casing and inner rod are simultaneously driven by a strong hydraulic drifter (Klemm-Serial KD 2728).
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Execution of temporary anchors – drilling tools

Standard drill bits:

new

after drilling 15 m in limestone
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Execution of temporary anchors – drilling tools

Standard drill bits:

Specialy improved drill bits:

new drilling of 180-200 m in limestone made possible
Agenda

Excavation Pits for Contract E 101

- General
- Geological conditions
- Execution of Diaphragm-Walls
- Execution of temporary anchors
- Execution of uplift anchors
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Execution of uplift anchors – general elevation

**total:** approx. 2500 uplift anchors GEWI Ø 63,5 mm with double corrosion protection, 1050 kN, max. L = 19 m
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Execution of uplift anchors – drilling operation
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Execution of uplift anchors

1. Erection of GEWI
2. Filling of cement grout
3. Tendon installation
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Special features

- 2\textsuperscript{nd} Diaphragm-Wall project in Scandinavia, therefore required:
  - thorough planning, detailing and coordination work with Main Contractor and Client,
  - high requirements on quality management and documentation,

- environmental politics:
  - all materials used on site must have an environmental approval (declaration of all ingredients, environmental risk assessments etc.), any material used was documented in weekly „running reports“,
  - only bio-degradable oils were permitted for any hydraulic drives, hydraulic fluids and grease had to be based on vegetable originated products,
  - Diesel-engined machinery with installed power > 75 kW was to fulfill emission values for NO\textsubscript{x} of max 4,0 g/kWh. Machinery not meeting this limit were to be equipped with NOx-filters to keep emission limits,
  - Units were to be equipped with hose protective valves providing the immediate shut up in case of sudden loss of pressure.
Grundriss 1:100
to many thanks for your attention!

H. W. Neuenhaus, Brückner Grundbau, Germany