Concrete & DEEP FOUNDATIONS

Ir Maurice Bottiau

www.normen.be
Deep Foundations

**Piling**
- Driven
  - Precast
  - Cast-in-situ
- Bored
  - CFA
  - Kelly
- Displacement auger

**Retaining walls**
- Diaphragm walls
- Pile walls
- Soilmix

**Soil Improvement**
- Injections
- Stone columns
- Jetgrouting
- Rigid inclusions
- Soilmix
Driven piles
Bored piles
Secant pile walls
Foundation performance

It’s all about reliability
Soil characteristics

Importance of soil characterization
Intermediate or particular soil types
Layered conditions
Deep Foundation construction

Systems and installation parameters
Equipment
Materials
3

Monitoring & Testing

Document pile installation
Check design and/or execution
Detect defaults
Codes : European execution codes

Å Deep Foundations construction:
   ♂ CEN TC 288 : Execution of special geotechnical works (1992)

Å Concrete:
   ♂ TC 104 : NBN EN 206-1:2013 and its annex D.

Å Testing:
   ♂ TC 341 :

<table>
<thead>
<tr>
<th>Standard</th>
<th>EN 1536</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EN 1537</td>
</tr>
<tr>
<td></td>
<td>EN 1538</td>
</tr>
<tr>
<td></td>
<td>EN 12063</td>
</tr>
<tr>
<td></td>
<td>EN 12699</td>
</tr>
<tr>
<td></td>
<td>EN 12715</td>
</tr>
<tr>
<td></td>
<td>EN 12716</td>
</tr>
<tr>
<td></td>
<td>EN 14199</td>
</tr>
<tr>
<td></td>
<td>EN 14475</td>
</tr>
<tr>
<td></td>
<td>EN 14490</td>
</tr>
<tr>
<td></td>
<td>EN 14679</td>
</tr>
<tr>
<td></td>
<td>EN 14731</td>
</tr>
<tr>
<td></td>
<td>EN 25237</td>
</tr>
<tr>
<td>Technology</td>
<td>Bored Piles</td>
</tr>
<tr>
<td></td>
<td>Injection Anchor</td>
</tr>
<tr>
<td></td>
<td>Diaphragm Wall</td>
</tr>
<tr>
<td></td>
<td>Sheet Pile</td>
</tr>
<tr>
<td></td>
<td>Displacement Pile</td>
</tr>
<tr>
<td></td>
<td>Injections</td>
</tr>
<tr>
<td></td>
<td>Jet Grouting</td>
</tr>
<tr>
<td></td>
<td>Micro Piles</td>
</tr>
<tr>
<td></td>
<td>Reinforced Earth</td>
</tr>
<tr>
<td></td>
<td>Soil Nailing</td>
</tr>
<tr>
<td></td>
<td>Deep Soil Mixing</td>
</tr>
<tr>
<td></td>
<td>Deep Vibro Densification</td>
</tr>
<tr>
<td></td>
<td>Vertical Drain</td>
</tr>
</tbody>
</table>
Deep Foundations and concrete

structural engineering

< 5 m

> 5 m

Ø 3 m
l = 50 m

specialist geotechnical engineering

Ø 3 m
l = 125 m
Potential issues

• Deviation w.r.t nominal dimensions
• Bleeding/Channelling
• Segregation/surface defaults
• Thermal effects
• Tolerances
• Damage by external factors
Deep Foundations classification w.r.t concrete

- Direct casting under gravity
  - Driven Cast-in-situ
  - Some displacement auger

- Pumping through hollow stem
  - Augercast (CFA)
  - Cased auger (pile walls)
  - Some displacement auger

- Tremie pipe casting
  - Bored piles
  - Diaphragm walls
Direct casting under gravity
Direct casting under gravity

- Usually limited to diameters $< 650 \text{ mm}$.  
- Casting “in dry conditions” but concrete directly in contact with water and soil.  
- Plastic concrete with high resistance against segregation.  
- Attention to **bleeding** due to installation process (=displacement).
Pumping through hollow stem
Cased Augercast (FOW) piles
Pumping through hollow stem

Augercast systems
Difference between closed and open circuits.
High slump concrete > 180 mm
Usually placed in submerged conditions
Usually small quantities of concrete per pile: 1-4 m³/pile.
Mixers stay on site for 2-4 hours...
Placement of reinforcement cage in fresh concrete
Deviation from nominal dimensions

afgravingsspeil

afgravingsspeil

zeer slappe laag

Piles concreted lower than the working platform
Deviation from nominal dimensions

Local necking.
Tremie pipe casting
Bored piles
BORED PILES

Principle of execution
Concrete for bored piles

Excavation supported by **SLURRY**

Excavation supported by **CASING**
Deviation from nominal dimensions

Insufficient concrete flow through reinforcement cage
BLEEDING/CHANNELING
Vb. In de grond gevormde schroefpalen – lengte 13.5 m
Diaphragm walls
Diaphragm walls
Tremie Concreting Process

- Pour through tremie pipe to avoid segregation
- Pipe at pile/excavation bottom, concrete pushes aside residues and not cleaned deposits on bottom
- Continuous concrete pouring operation while tremie pipe remains 1,5 to 2 m in fresh concrete; pipe is retracted during pouring
Tremie pipe casting

- For large diameter bored piles and diaphragm walls.
- High slump concrete.
- Usually placed under submerged conditions
- **Large quantities** (sometimes > 200 m³)
- Concreting cadence: 50 to 80 m³/h
- Concrete should remain *workable* through the whole process. Attention to *timeframe*!
- Concrete should be able to completely fill the excavation and embed any reinforcement or box-out
D wall concreting process

trench excavation in hard rock
D wall **concreting** process

Concrete surface should be kept as **horizontal** as possible.

Three measurement points.
D Wall concreting process

**Diagram:**
- **Concrete** flows from a hopper and tremie pipe into the excavation.
- **Excavation depth** is marked.
- **Nominal panel length** is indicated.
- **Regular flow** and **irregular "piping"** are shown.
- **Measure for actual concrete level** is ≤ 0.3 m.
- **Cut-off level** and **platform level** are marked.
- **Excavations supported by slurry** are indicated.
- **Concrete level 1** and **Concrete level 2** are shown.
- **Tremie outlet level** and **Flow of concrete** are depicted.
- **Laitance entrapped** is noted.
Vb. Diepwand met dense en assymetrische wapening;  
- preferentiele stroming van beton = laterale druk op de wapening  
- onvoldoende dekking

Vb. onderbreking van betonstort (>1h) laatste levering beton  
- Eerst ingebrachte betonspecie (vervuild met bentoniet/zand) wordt niet verder naar boven gedrukt
Vb. Diepwanden: bentonietinsluitingen t.h.v. de voeg, mogelijke oorzaken:

- Onderbrekingen in het betonneerproces
- Te geringe afstand wapeningskorf – voeg (bemoeilijkt doorstroming)
- Te geringe vloeibaarheid beton
- Onvoldoende ontzanding van de steunvloeistof
Deep Foundations and concrete

- Placement is usually in **wet** conditions.
- Sometimes casted at **large depths** (> 50 m), or pumped on long distances.
- Through small diameters tremie pipes or hollow stem of augers.
- Against soil and/or supporting fluid.
- Sufficiently **workable** to fill the voids created by the tubes/tools or present in the surrounding soil.
- Technological aspects linked with **reinforcement**/cover/tolerances...
- Attention to supply cadences and **continuity**.
Concrete for Deep Foundations-General requirements (1)

Special properties in concrete’s fresh stage (during the casting process):
- completely fill the excavation and embed any reinforcement or box-out,
- allow self-levelling and **self-consolidation**,
- not undergo excessive **segregation**, **bleeding**, or filtration
**Rheology**

**Å Rheology** determines the success of placement and the quality of the final product.

**Å The key rheological characteristics are:**

- Workability (ability to completely fill the excavation and compact by gravity);
- Flow retention (how long specified fresh properties will be retained); and
- Stability (resistance to segregation, bleeding and filtration).
Concrete for Deep Foundations-General requirements (2)

Design of concrete mix:
Å duration in addition to strength
Å tendency to specify
   ï higher strength classes (C35/45)
   ï lower water/cement ratios.
Å Higher dependence on chemical admixtures
Concrete for deep foundations

Revision of EN 206-1

A Revised version of NBN EN 206-1:2013: specification, performances, production and conformity of concrete

A Annex D: additional requirements for concrete for special geotechnical works (formerly in EN 1536:2010 and EN 1538:2010)
Lookout

Concrete is key in structural capacity and essential to Deep Foundation Performance.
Lookout

Concrete for **Deep Foundations**:
- Specific requirements
- Specific delivery aspects
- Specific testing methods
Concrete and Deep Foundations

Thank you for your kind attention