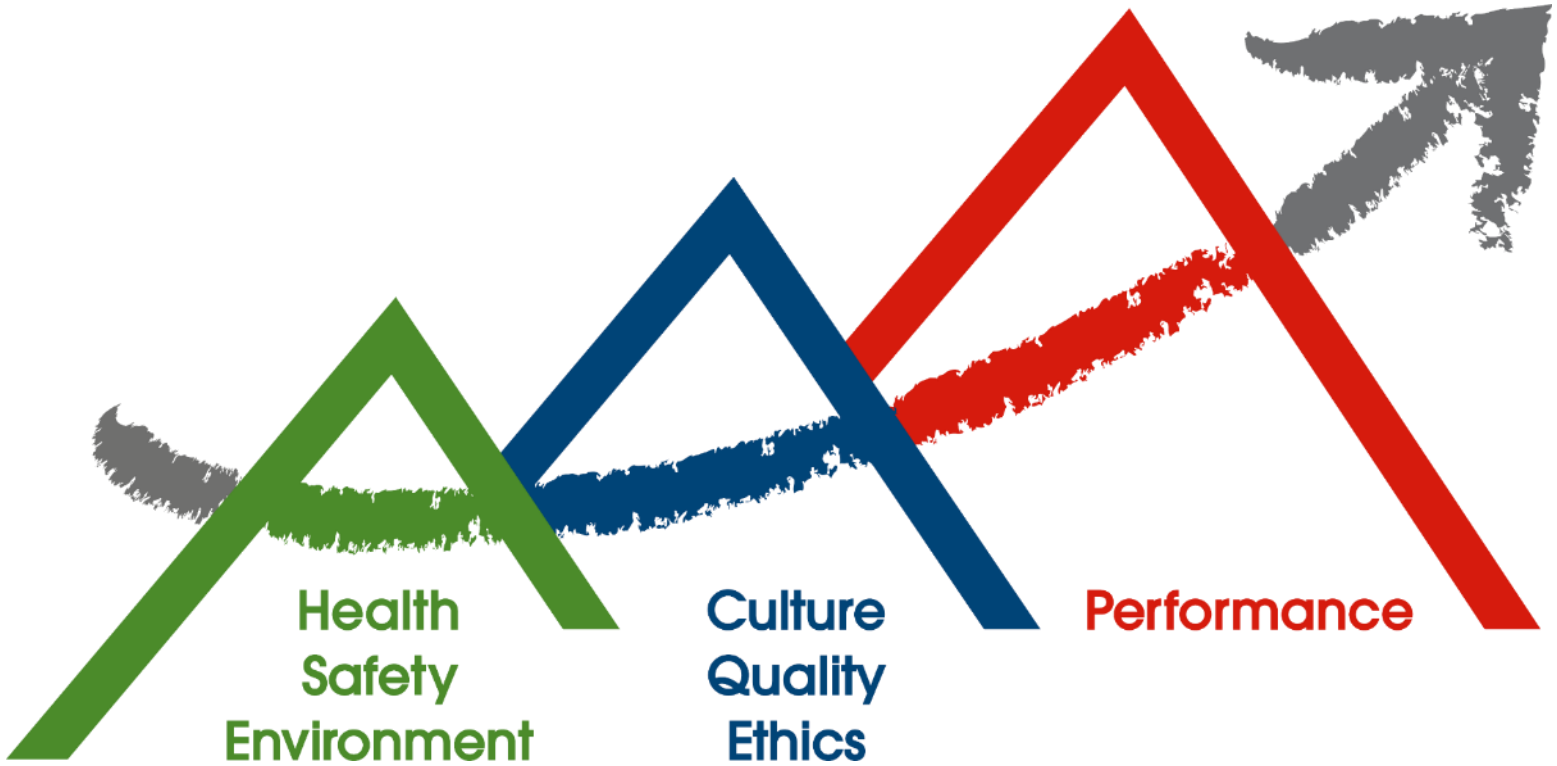
SEMINÁRIO Geotecnia em Obras Marítimas – Aprender com a Experiência
Auditório Infante D. Henrique (APDL - Porto de Leixões)
02-03 DEZEMBRO 2024

Execution of D-Walls as permanent quay walls – challenge accepted –

Karsten Beckhaus
BAUER Geotechnical Solutions

Organização
CPGT Comissão Portuguesa de Geotecnia nos Transportes
CPMT Comissão Portuguesa de Melhoramento de Terrenos
Sociedade Portuguesa de Geotecnia
APDL Administração dos Portos Douro • Leixões • Viana

BAUER's Triple A
Highest Standards for the BAUER Group‘s Key areas of focus



Health, Safety, Environment (HSE)

- Health and safety of the employees
- Work safety at sites and in all production facilities
- Sustainable behaviour and environmental protection

Culture, Quality, Ethics

- People are the focus of our attention
- Highest quality of products and services
- Behaviour based on the principles of national and international ethical values

Performance

- Steady growth with reasonable profit
- Long-term orientation incl. profit expectation and risk-taking
- Continuous productivity increase and optimization of processes

Equipment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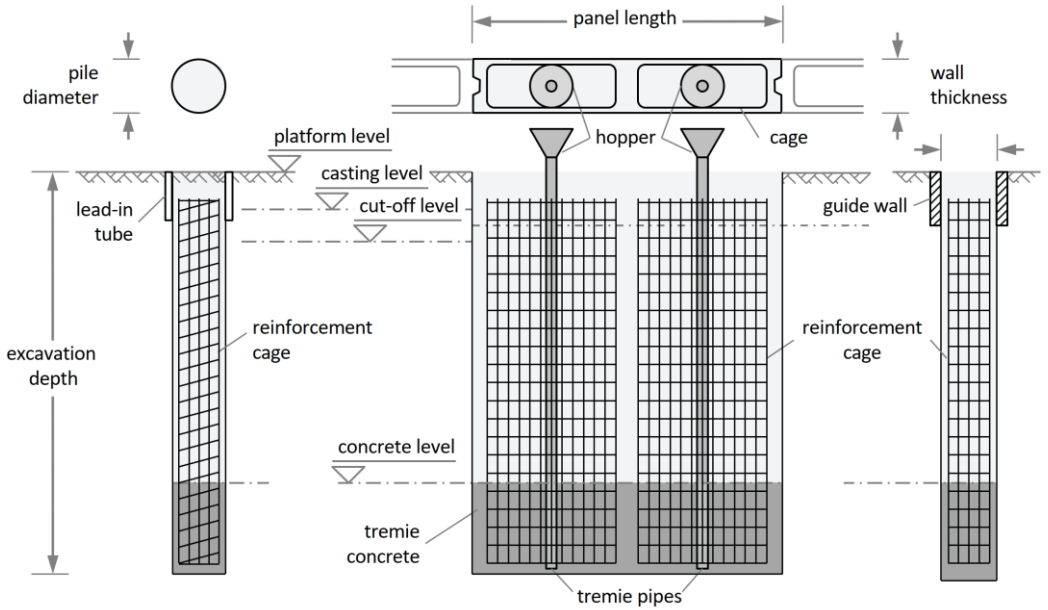
Execution of D-Walls as permanent quay walls

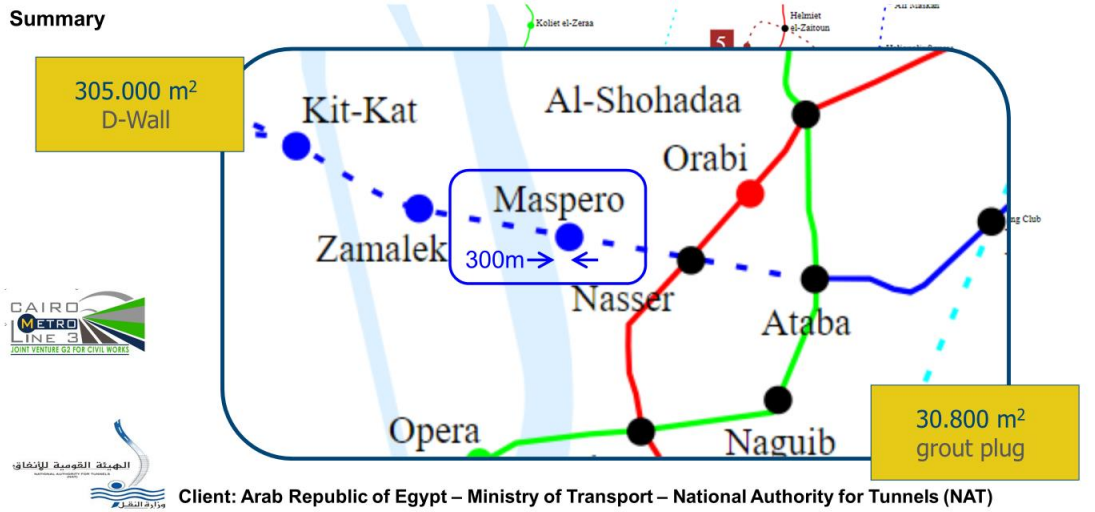
A challenge for:-

- constructability → execution in the field
- load transfer → rebar cage detailing
- permanent use → minimum concrete cover



Cairo Metro – Line 3, Phase 3

Summary



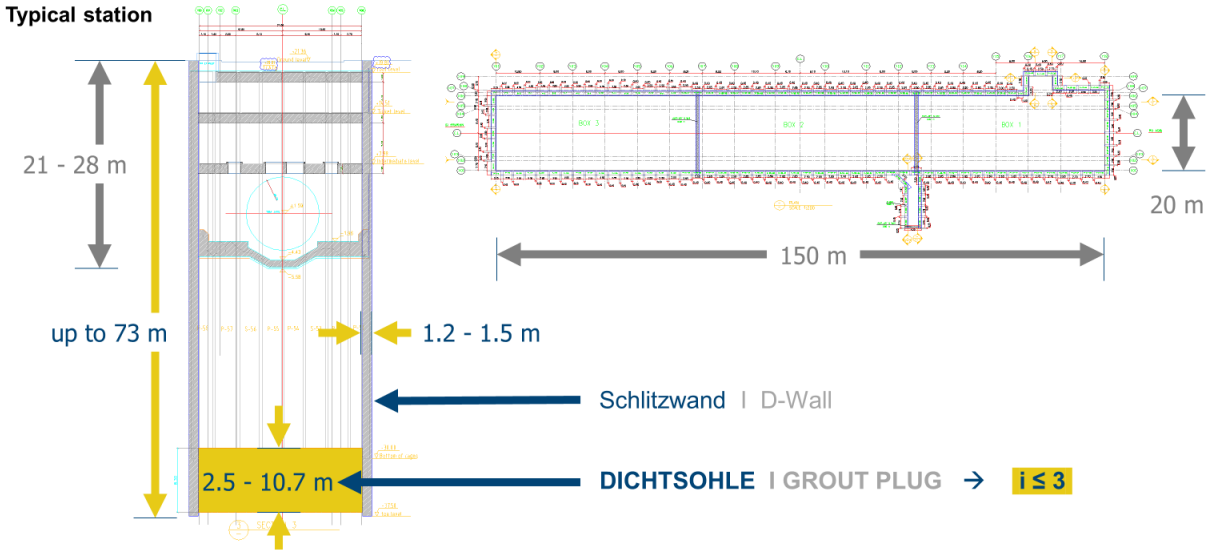
Client: Arab Republic of Egypt – Ministry of Transport – National Authority for Tunnels (NAT)

Consultant: SYSTRA I Main Contractor: Egyptian-French Joint Venture for Civil Works (L3-Ph3)

wikipedia.org

Cairo Metro – Line 3, typical Station Box Dimensions

Typical station



Liersch, L., Baltruschat, M.: Greater Metro Line 3, Cairo: Installation of underground construction pits using cut-off-wall and soft-gel-grouting. IS Rome '11


Sylvenstein Reservoir, Bavaria, Germany
Water management and Flood Protection

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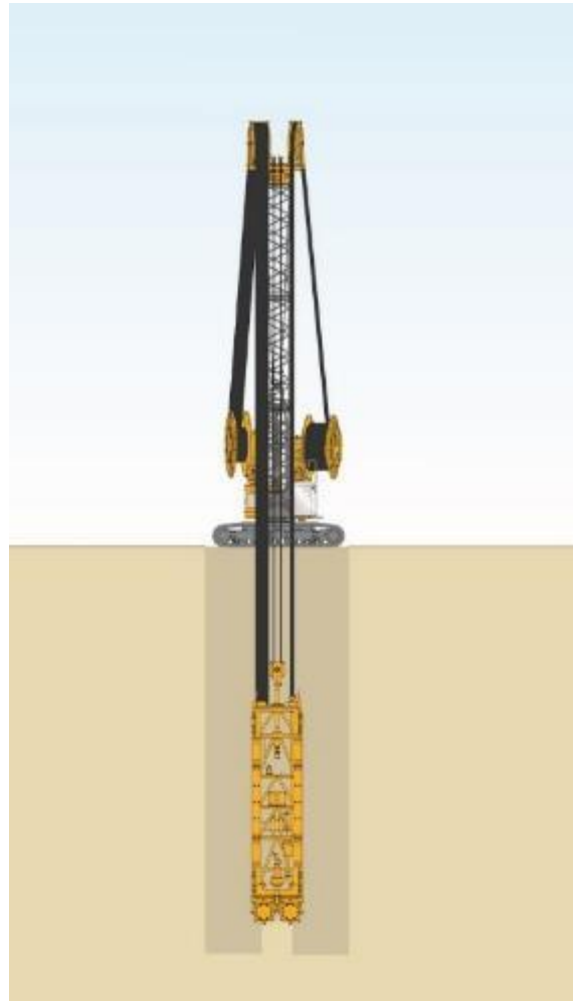
Products and Methods
Diaphragm or „Cut-Off“ Walls

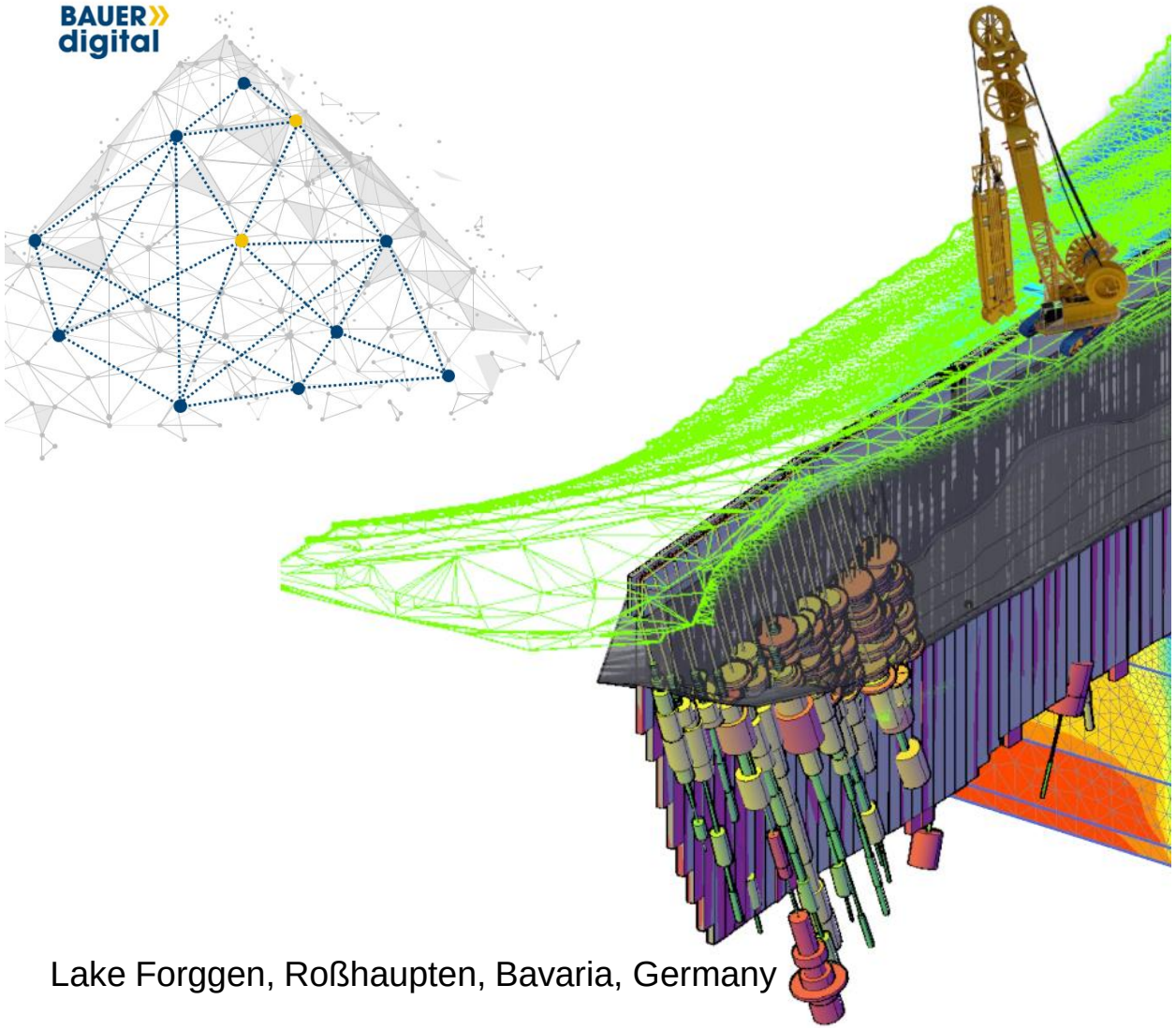
Lake Forggen, Roßhaupten, Bavaria, Germany

D-Wall method (with grab)



D-wall method (with cutter)

Products and Methods
Diaphragm or „Cut-Off“ Walls



Lake Forggen, Roßhaupten, Bavaria, Germany

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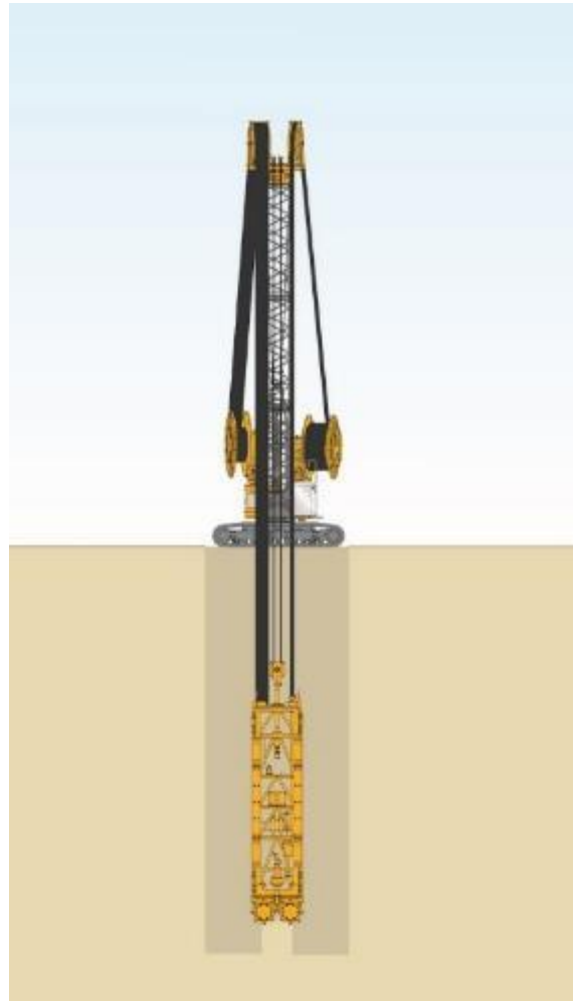
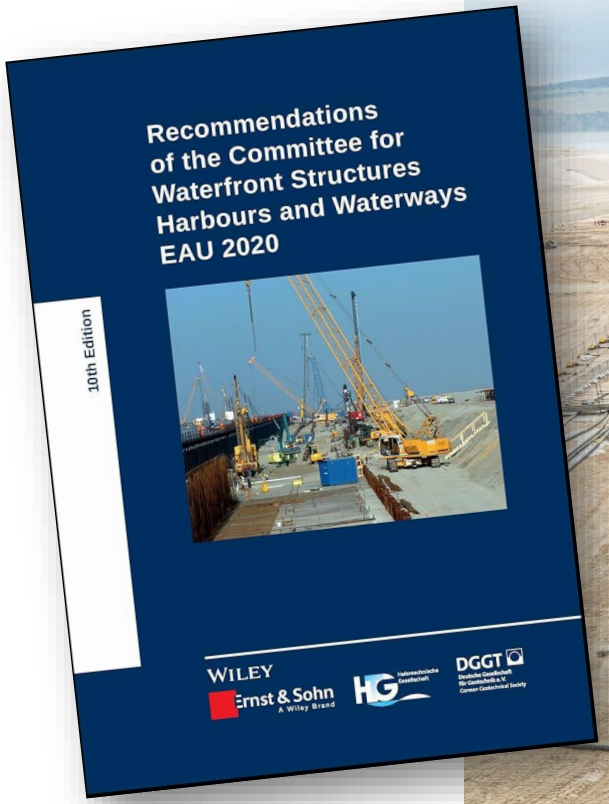


D-wall method (with cutter)



Ardersier Port, Scotland, UK

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Execution of D-Walls as permanent quay walls

The challenge is

- execution in the field, with regards to the
- rebar cage detailing and
- minimum concrete cover

- TO AVOID DEFECTS, ie relevant imperfections

Relevant Imperfections due to poor …

…
→ Support fluid behaviour?
→ Rebar configuration?
→ Concrete performance?
→ Working procedure?

Imperfections due to poor <u>teamwork</u>
… shall be avoided!

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Norms

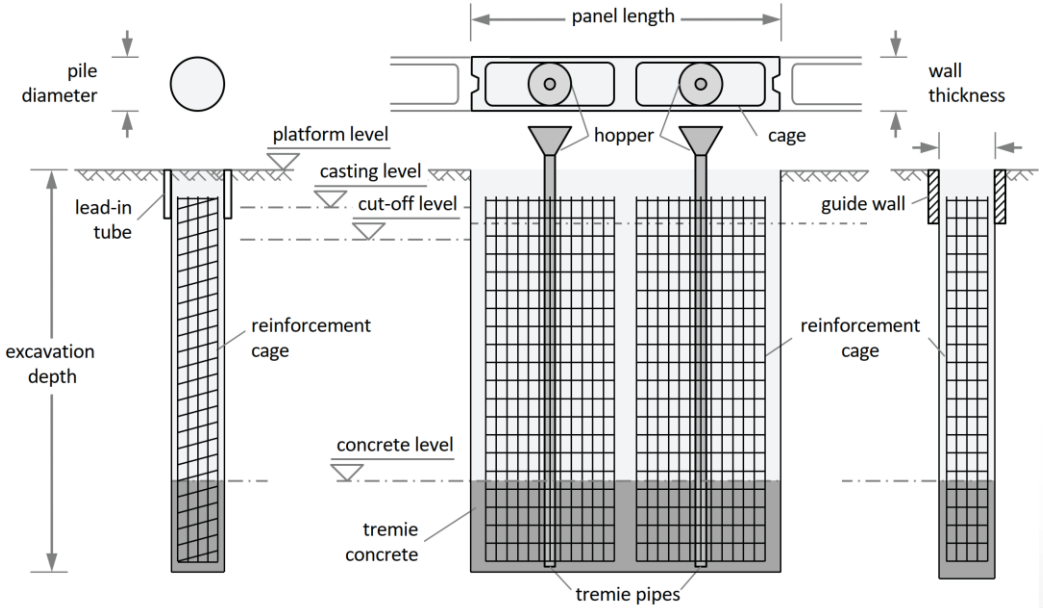
- ❑ EN 1997 → • Geotechnical Design
- ❑ EN 1536 → • Bored Piles
- ❑ EN 1538 → • Diaphragm Walls
- ❑ EN 206 → • Concrete — Specification, performance, production and conformity
- ❑ EN 1992 → • Design of Concrete Structures

Special Geotechnical Works

Code of Practice for “no defects”

- **Norms define the standard, plus**
- **The Tremie Guide for good practice**

→ **Performance**



→ **Sustainability**

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Typical evolution of concrete mixes

EC 2
EC 7

CLIENT: relevant codes and standards, service life, other service/operational related requirements including sustainability…

EC 2

STRUCTURAL DESIGNER: dimensions, concrete characteristic strength, cover, reinforcement details, restrictions on binder/other constituents, water/cement ratio, exposure class…

EN 206

CONSTRUCTOR: Fresh concrete properties relevant to execution, e.g. workability, workability retention, stability, early strength gain, supply rate…

SPECIFIER: concrete specification (combines Client's, Structural Designer's, and Constructor's requirements)

EN 206

SUPPLIER: concrete mix design considering available constituents and all the specified requirements

EN 206

EXECUTION: initial batch testing and concrete mix validation

EN 1536
EN 1538

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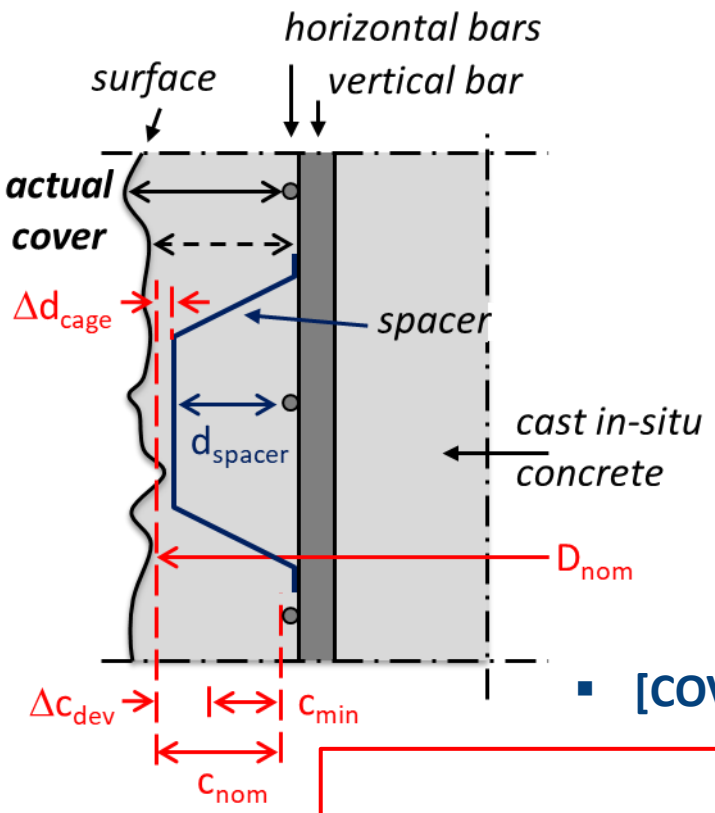
Appendices A, B, C, D, E, F, G

Update
Dec 2024

→ Design Considerations



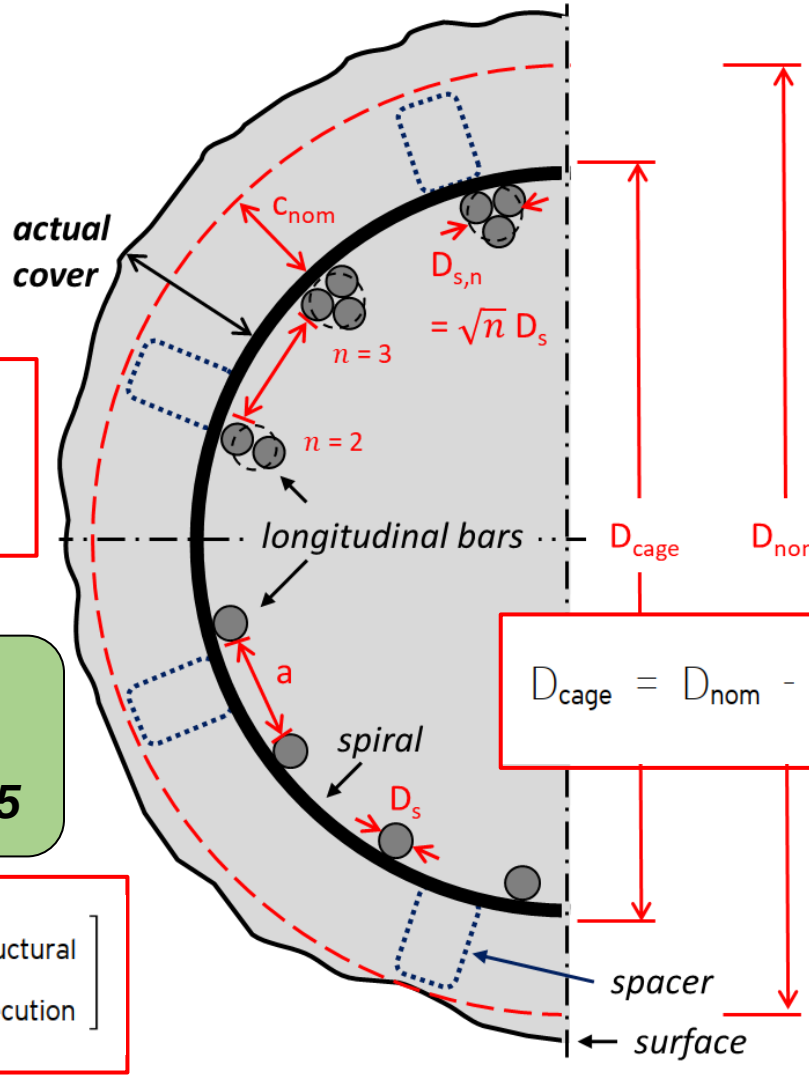
- **[COVER]**

$$c_{nom} = c_{min} + \Delta c_{dev} \text{ with } c_{min} \geq \max \begin{bmatrix} c_{min,\,structural} \\ c_{min,\,execution} \end{bmatrix}$$

$$a \geq \max \begin{bmatrix} \min a \\ 4 \times D_{max} \end{bmatrix}$$

- **[SPACING]**

partly conflicting with EN 1992 → CEN/TC 288/WG25



$$D_{cage} = D_{nom} - 2\,c_{nom} - 2\,\Delta d_{cage}$$

- **[CAGE]**

→ Design Considerations

FprEN1992-1-1:2022

6.5.3 Allowance in design for deviation in cover

(1) To calculate the nominal cover c_{nom}, an addition to the
(6.2) shall be made in design to allow for the deviation Δc_{dev} v
the accepted negative deviation specified in the execution s
drawings (see EN 13670). Values for Δc_{dev} are given in Table

NOTE Cases and values of Table 6.7 (NDP) apply unless the Na

c_{nom} = (25*+5**) mm + 75 mm = 105 mm

* *ERC 4 for XC 4 and 50 years service life*
** *+Δc_{min} for concrete cast against soil acc to 6.5.2.1 (2)*

$-\Delta c_{min,30}$. *Reduce for service life 30 years or less?*
Reduce for favorable curing conditions?
$-\Delta c_{min,exc}$ *Reduce to "prepared soil", when …*

Table 6.7 (NDP) — Allowance for deviation Δc_{dev}

	Case	Δc_{dev}
1	In general: for execution in tolerance class 1 according to EN 13670	10 mm
2	For execution in tolerance class 2 according to EN 13670	5 mm
3	Where fabrication is subjected to a quality assurance system, in which the systematic monitoring includes measurements of the cover	5 mm
4	Where it can be assured that an accurate measurement device is used for systematic monitoring and non conforming members are rejected (e.g. precast elements)	0 mm
5	For concrete members in exposure class XC1, where the risk of corrosion is insignificant	5 mm
6	For concrete cast against surfaces with exposed aggregate (e.g. interfaces)	5 mm
7	For concrete cast against unevenness due to formwork or excavation sheeting (e.g. ribbed finishes or architectural textures)	10 mm + dimension of unevenness
8	Concrete cast against prepared ground (including uneven blinding layer)[a]	40 mm[a]
9	Concrete cast directly against unprepared soil[a]	75 mm[a]
10	Post-installed reinforcing bars	5 mm or according to project specification

[a] These allowances for deviation Δc_{dev} also apply for bored piles and for diaphragm walls designed according to this Eurocode, unless the National Annex gives other special values.

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Update
Dec 2024

→ Execution

Ardersier Port, Scotland, UK

→ Execution

- Trench Stability → needs planning, possibly design:
  - for bentonite based fluid support: calculation acc. to DIN 4126
  - for polymer based fluid support: add time-dependent considerations
  - Quality control in accordance with „EFFC/DFI Guide on Support Fluids“

→ *Extra measures might be necessary to allow trenching*

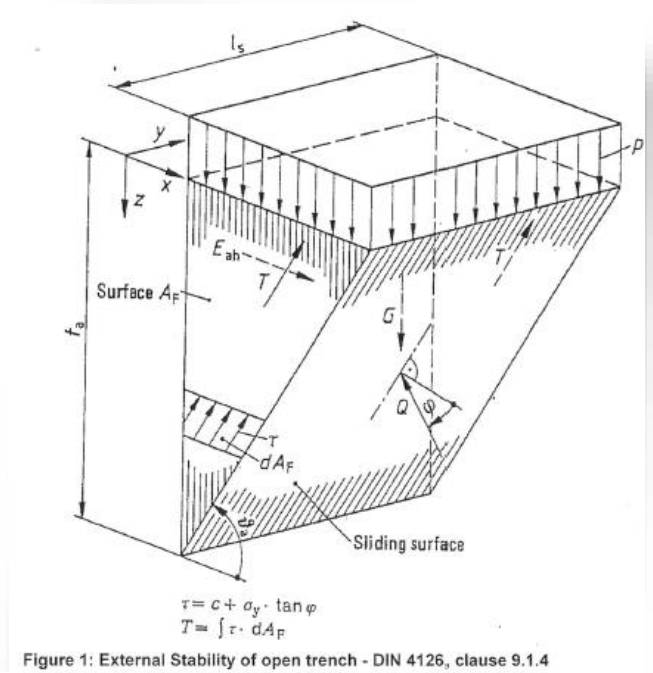


Figure 1: External Stability of open trench - DIN 4126, clause 9.1.4

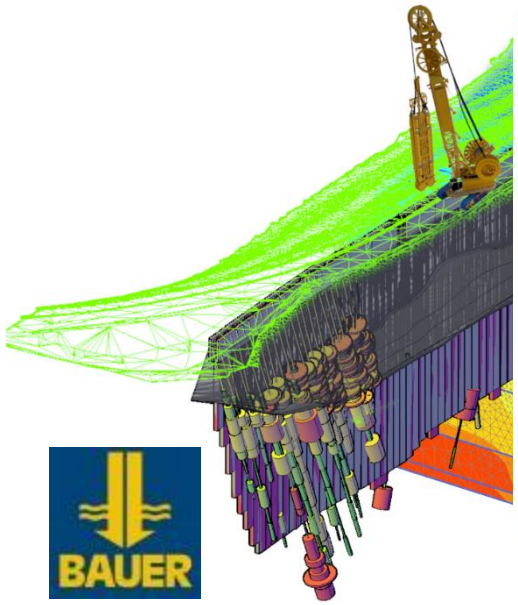


FIGURE 2 SURFACE AND DEEP FILTRATION

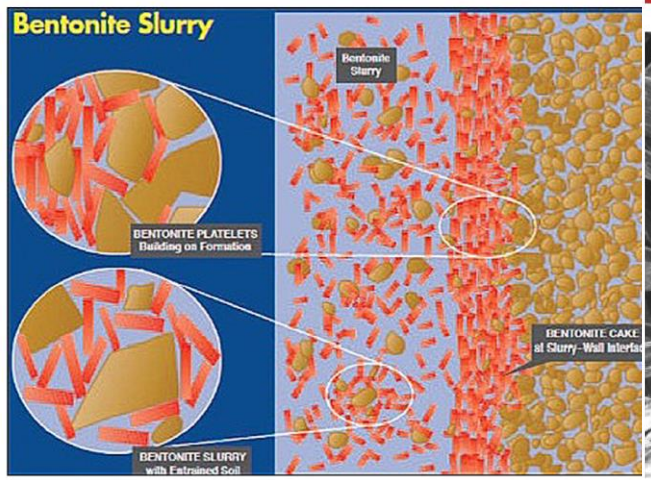


FIGURE 3.A SCANNING ELECTRON MICRO-PHOTOGRAPH OF POLYMER DRILLING FLUID (photo: Univ. of Missouri-Columbia)

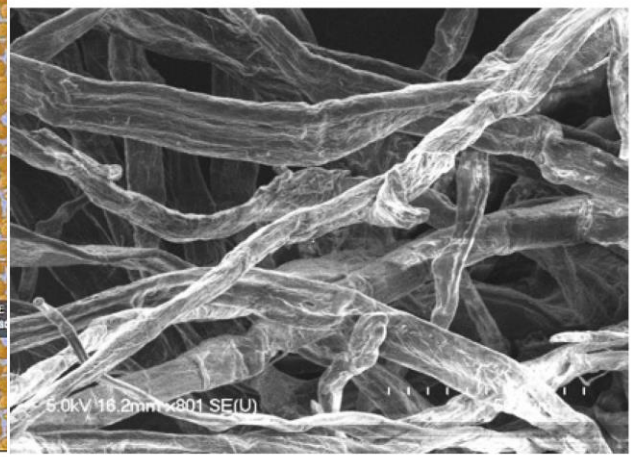
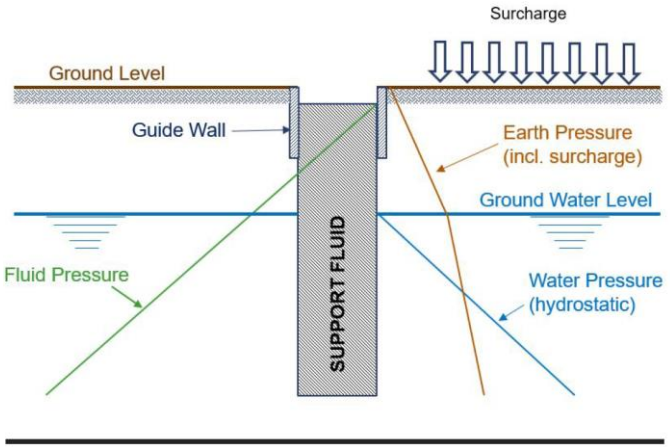
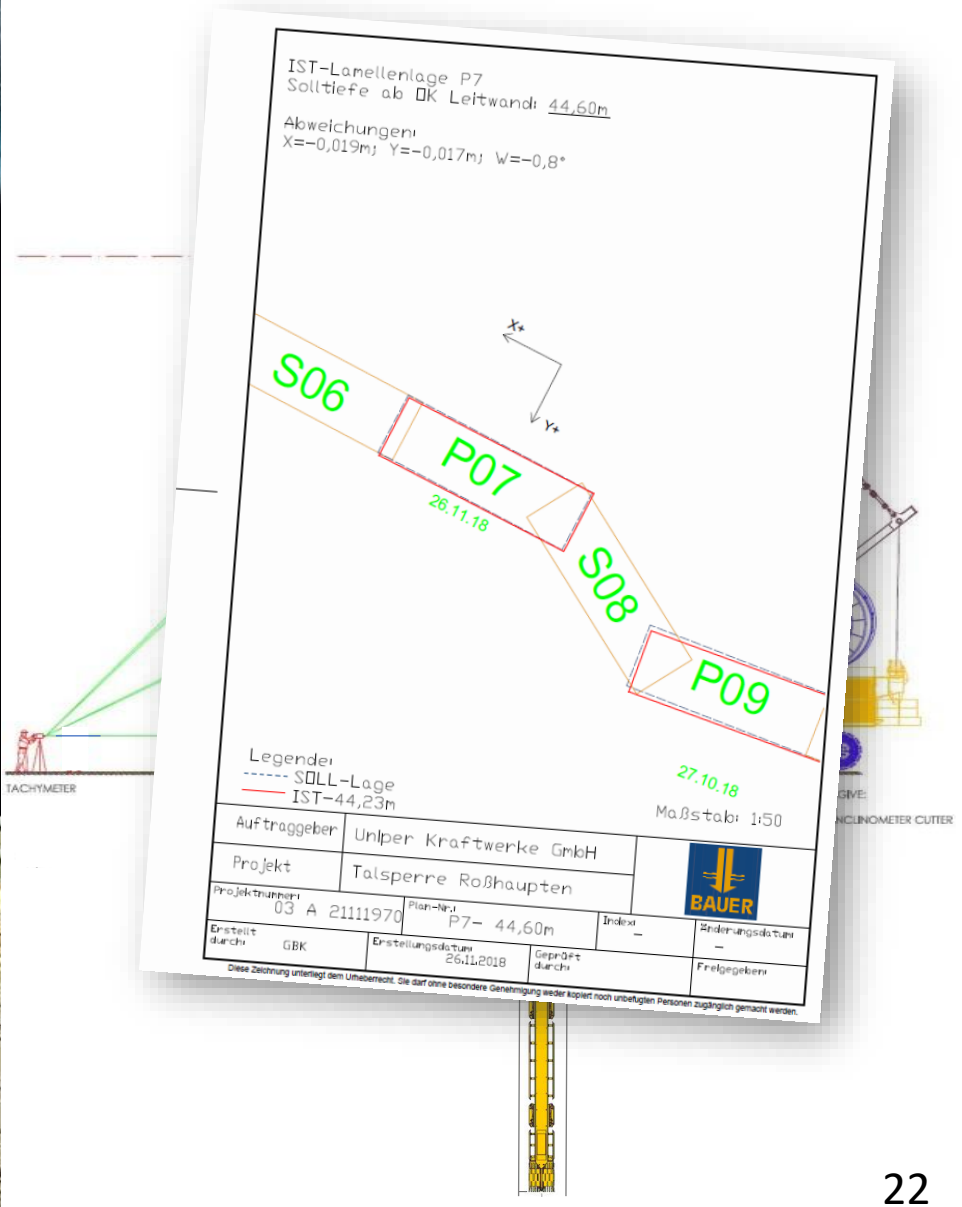


FIGURE 4 HYDRAULIC SUPPORT WITH FULL MEMBRANE EFFECT (SCHEMATIC ONLY – NOT TO SCALE)



→ Execution

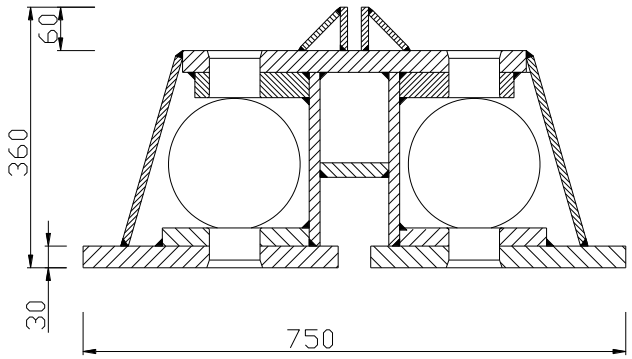
- Verticality →

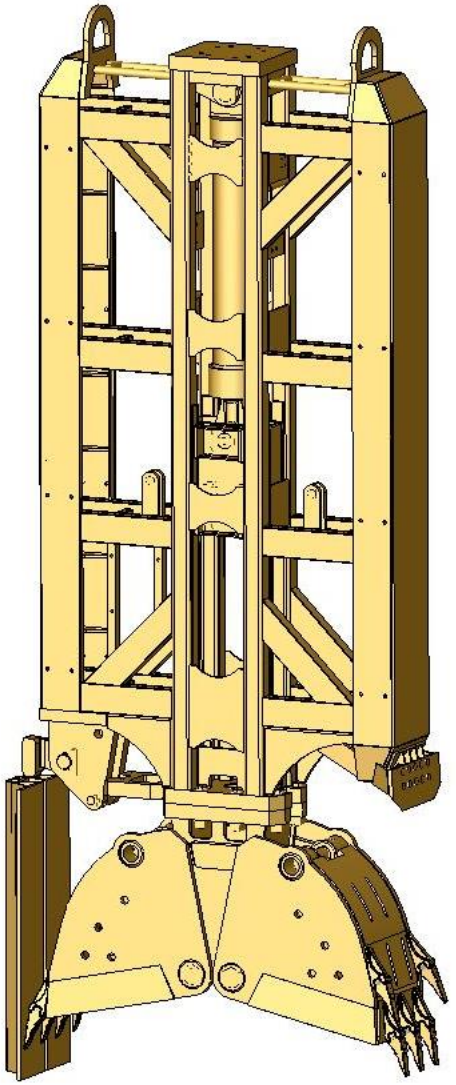


→ Execution

- Watertight Joints

- stop-ends; segments of various lengths
- rubber water stop
- concrete flowing around the stop end is accepted
- stop end to be freed by defiend process





→ Execution

- rebar cage detailing ↓ & ↓ minimum concrete cover

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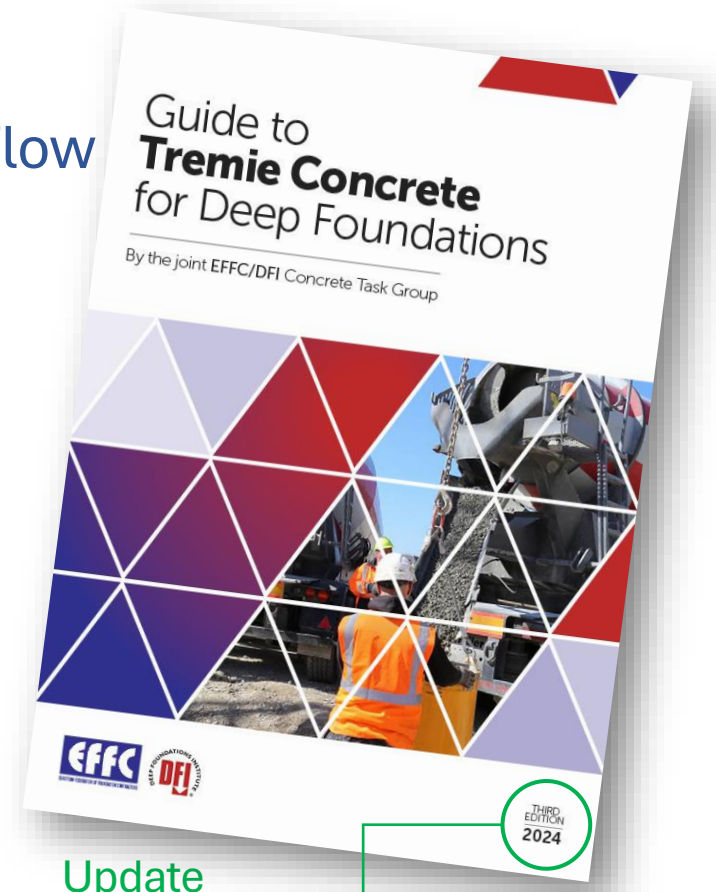

Update
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→ Full Scale Trials

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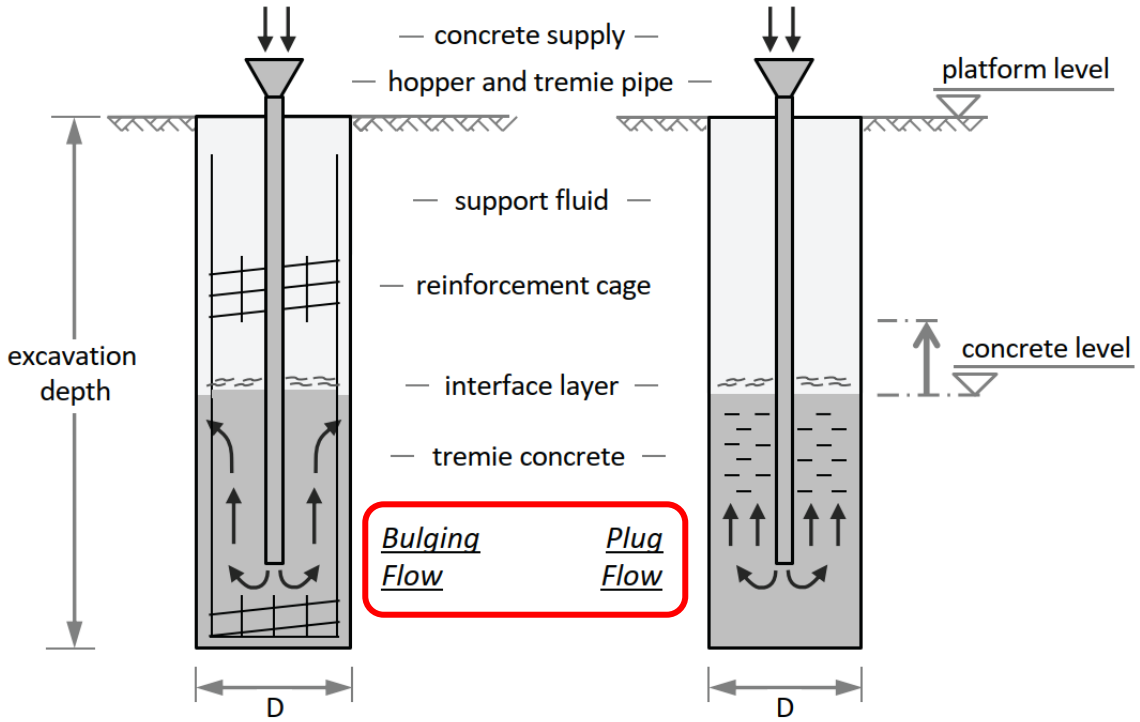
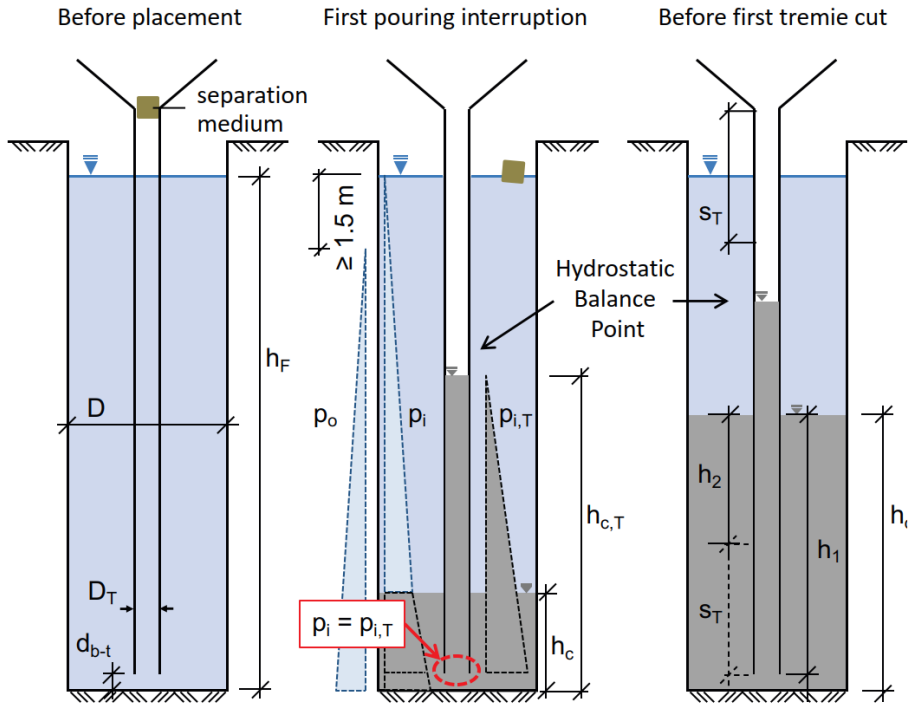
Update
Dec 2024

→ Numerical Modelling of Concrete Flow

- … understanding flow mechanism → controlling the casting process incl. the initial batch



- **Concrete Flow Mechanisms are NOT BINARY**

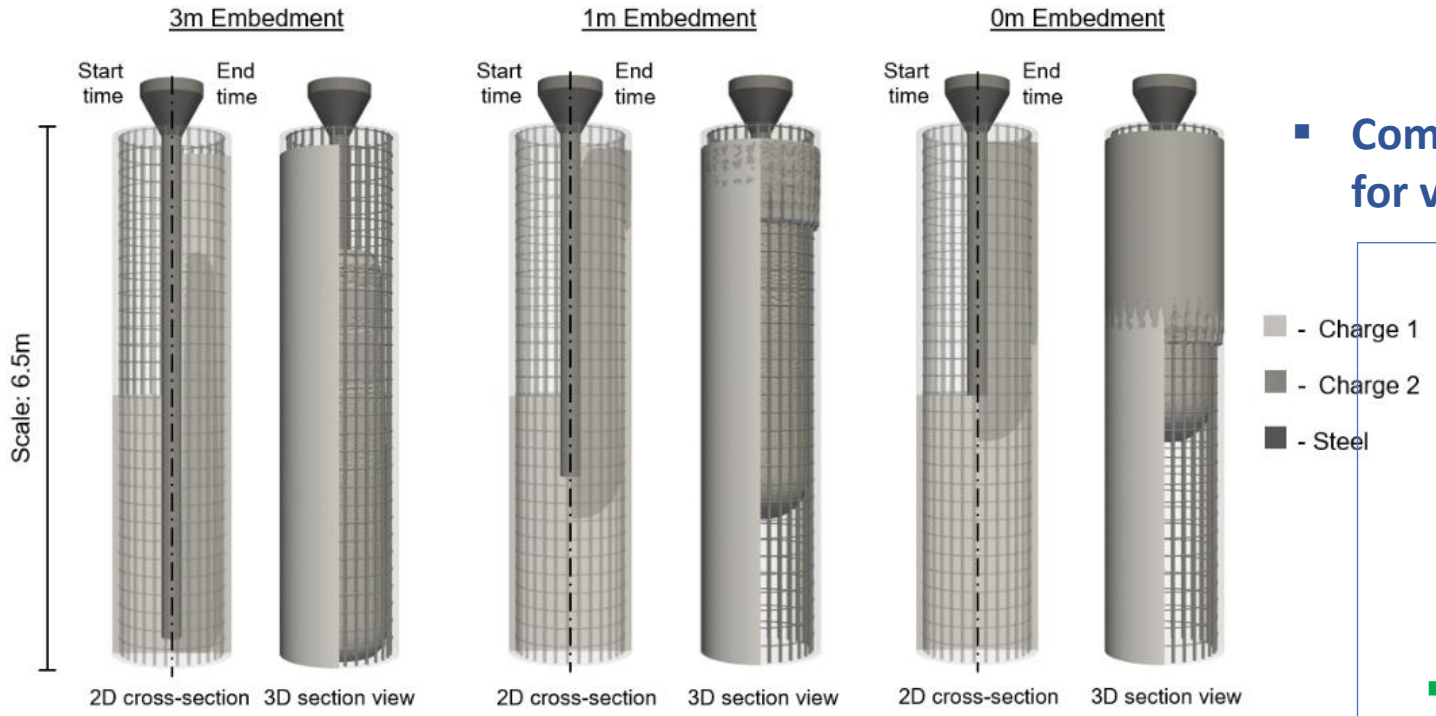


Where:

h_F	Fluid level in excavation	$h_{c,T}$	Concrete level in tremie pipe (= hydrostatic balance point)
D_T	Diameter of tremie pipe	h_1/h_2	Embedment of tremie pipe before (1) / after (2) tremie pipe cut
D	Dimension (diameter or thickness) of excavation	s_T	Section length of tremie pipe section to cut, with: $h_2 \geq 3$ m [10ft]
d_{b-t}	Distance from bottom of excavation to tremie pip	p_o/p_i	Hydrostatic pressure outside (o) / inside (i) of excavation
h_c	Concrete level in excavation	$p_{i,T}$	Hydrostatic pressure inside the tremie pipe

→ Numerical Modelling of Concrete Flow

Concrete Flow Mechanisms → Numerical Modelling ++



- Comparison of concrete flow patterns for varying tremie embedment

- COMPREHENSIVE LEARNINGS from a NUMERIC MODELLING parametric study
- Results will merge into the 4th edition of the TREMIE GUIDE

→ CONCLUSION

Execution of D-Walls as permanent quay walls

– challenge accepted –


→ Thank you
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PASSION for PROGRESS