

LA CONGÉLATION _

ARTIFICIAL FREEZING OF SOILS, *IN CIVIL ENGINEERING*

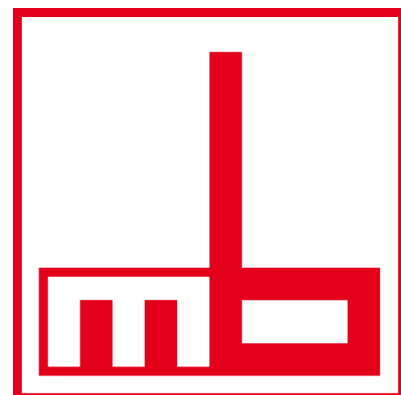
REx à l'international: Feedback out of France

CFMS SCIENTIFIC AND TECHNICAL DAY _ NOVEMBER 17TH 2023



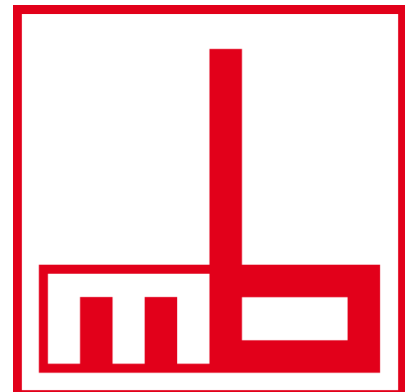
REx à l'international: Feedback out of France

Calibri gras corps 87pts



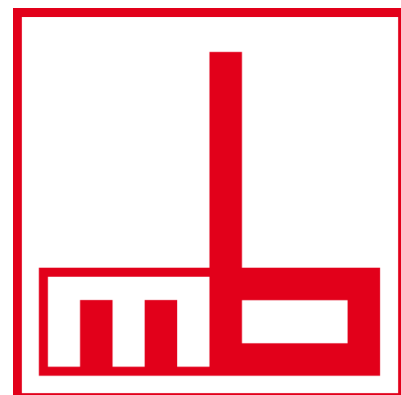
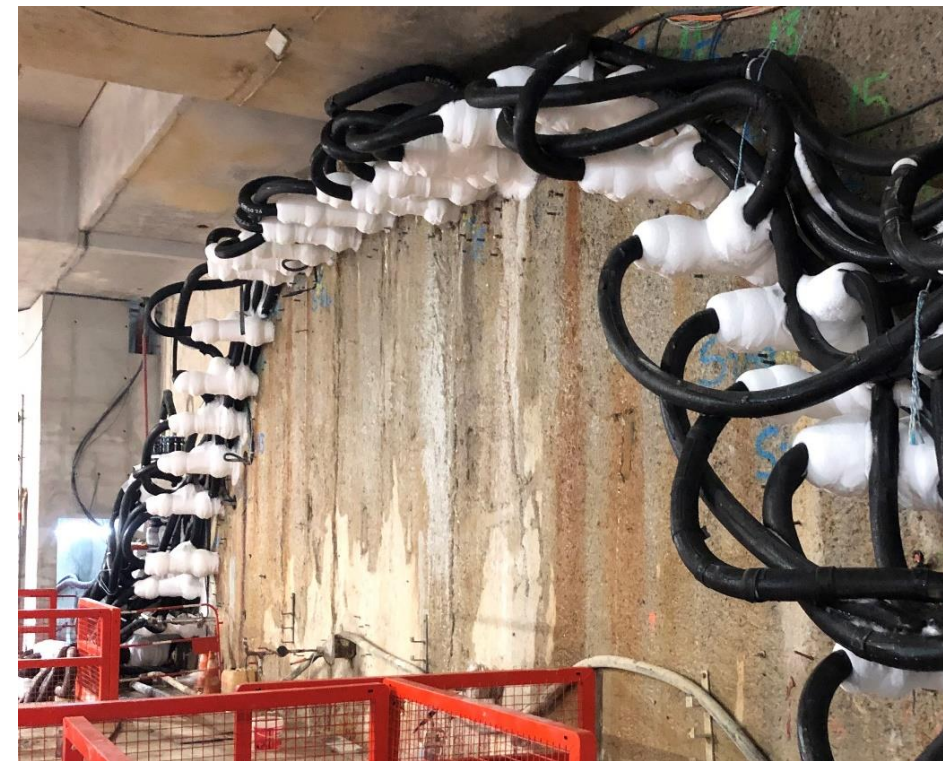
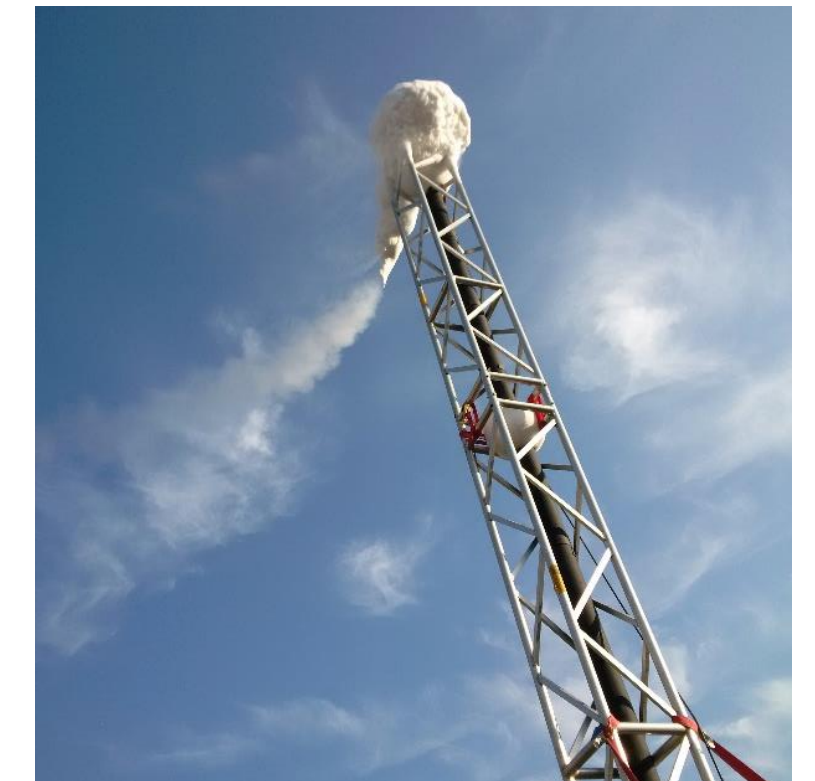
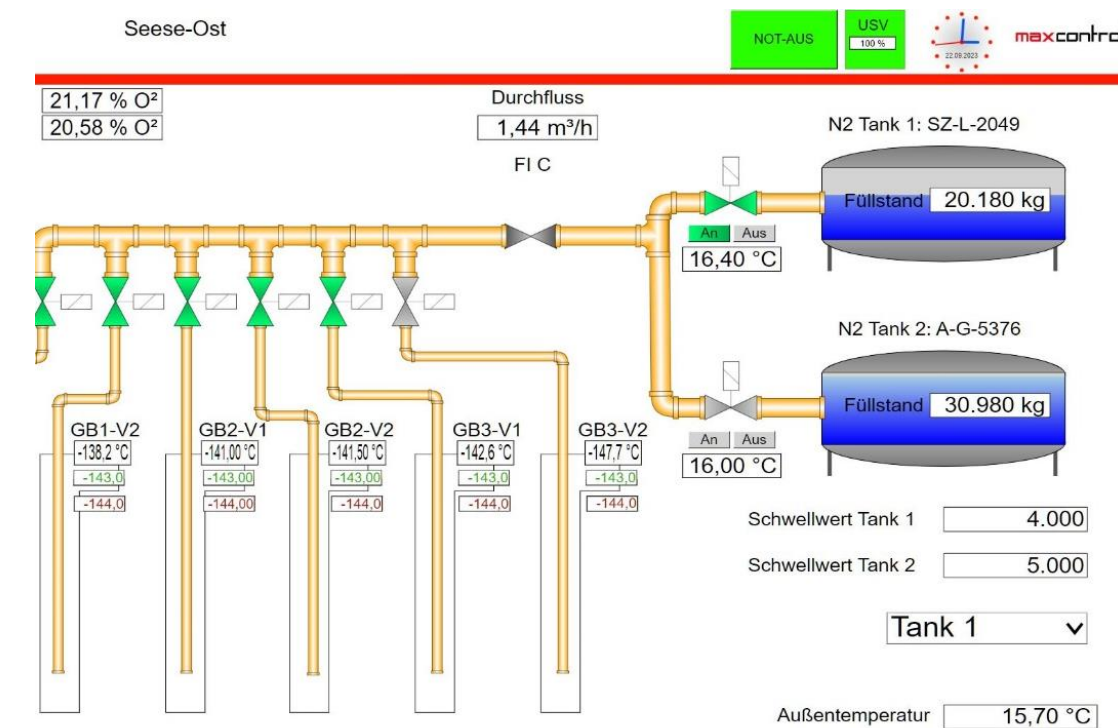
Content

- Max Bögl Groundfreezing
- Cuyperstrap – Amsterdam
- Metro - Brussels



Max Boegl Ground freezing

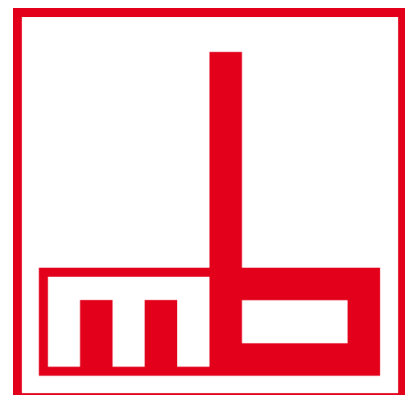
- Equipment for freezing with liquid nitrogen
- Equipment for freezing with brine
- In-house monitoring and surveillance platform
- Thermal calculations



Cuyperstrap – Amsterdam Central

Overview

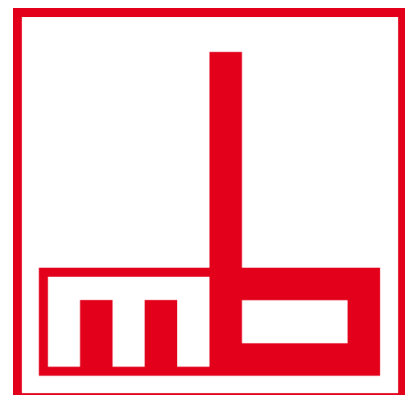
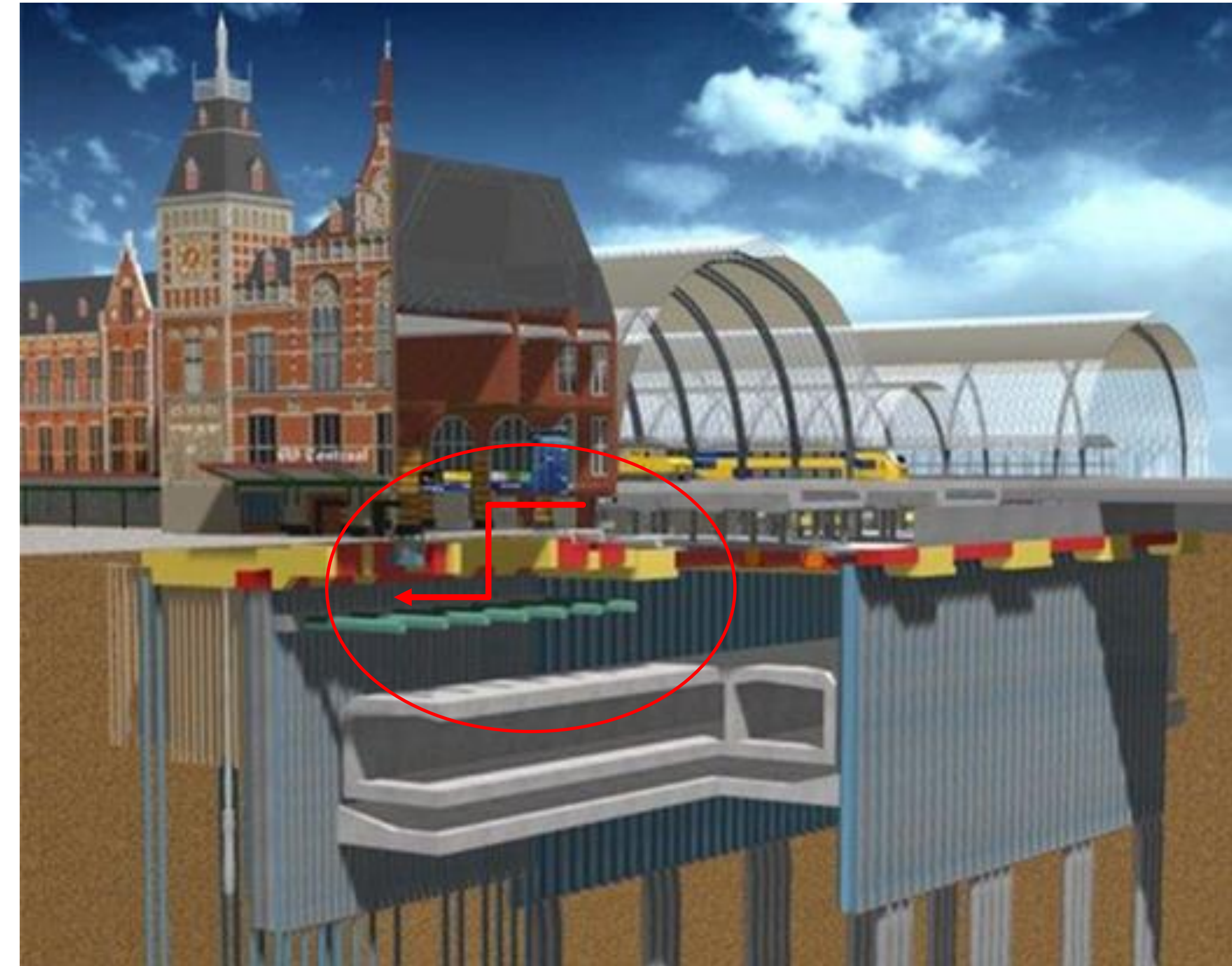
- Part of the overall project "de Entrée"
- Functional tender for staircase with single-sided escalator
- New staircase connecting the entrance hall and the metro distribution level
- Planning, execution and self-supervision
- Client: City of Amsterdam
- Construction time: 01/2019 – 06/2020
- Freezing: 04/2019 – 11/2020
- Freezing Methode: Brine freezing



Cuyperstrap – Amsterdam Central

Initial situation

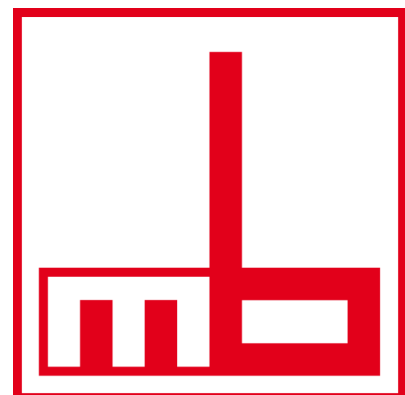
- Most important junction of the city of Amsterdam
- Historical building from the 19th century
- Metro distribution hall below the station square
- Immersion tunnel for the metro under the station
- Existing braced excavation with sandwich and bored pile walls
- Backfilling with flushed-in sand
- Groundwater level \approx upper edge of sand layer
- Excavation pit not watertight (anymore)



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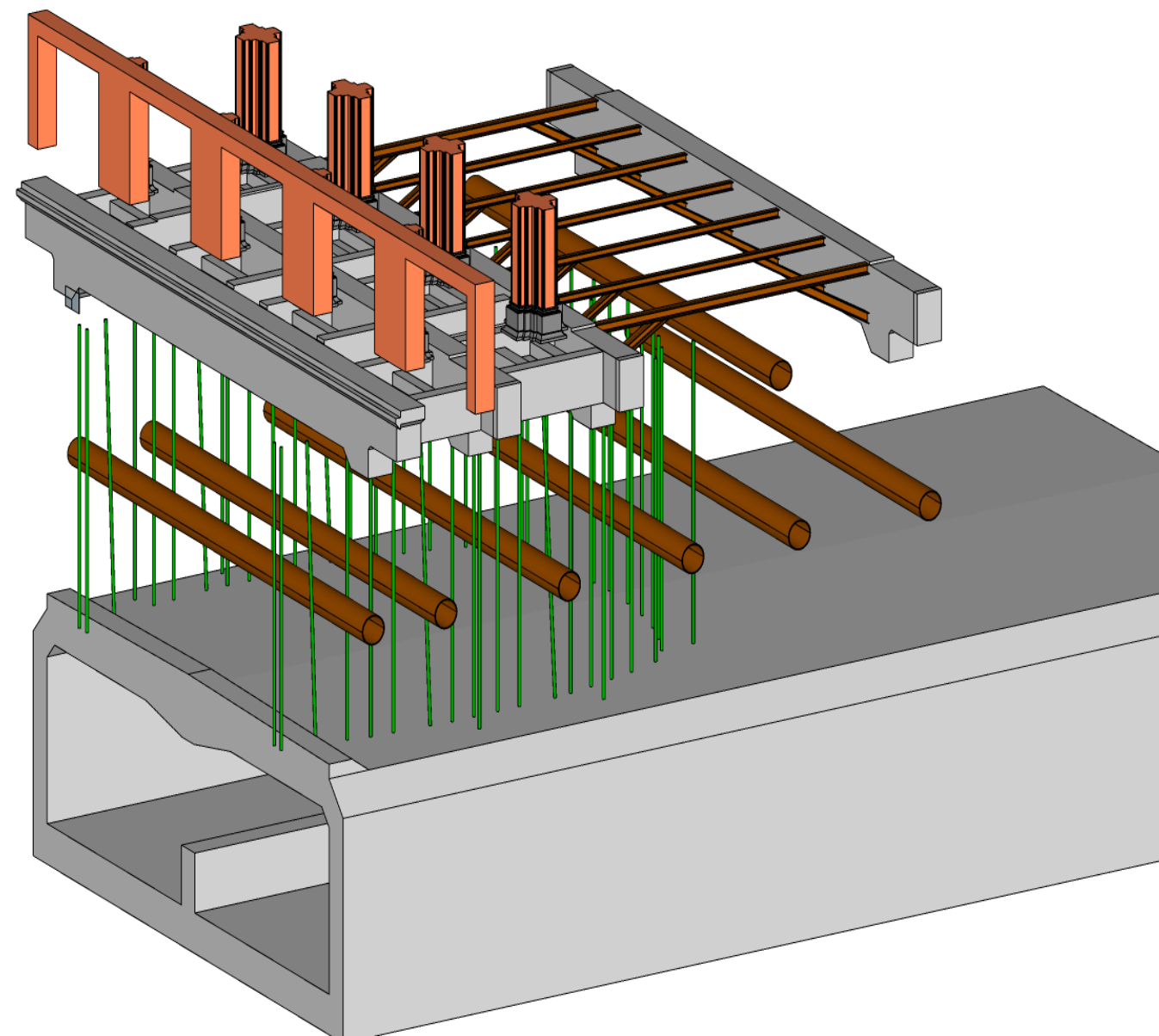
Constraints and site conditions

- Historical and new building structures
 - Low working height (<2.5 m) in the station concourse
 - Limited accessibility of the working area under the station hall
 - Constrained space conditions underneath the station hall
 - Limited space inside the station and in front of the station
 - Problem: Creating a watertight excavation pit
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- Excavation pit solely made of a frozen wall without bracings



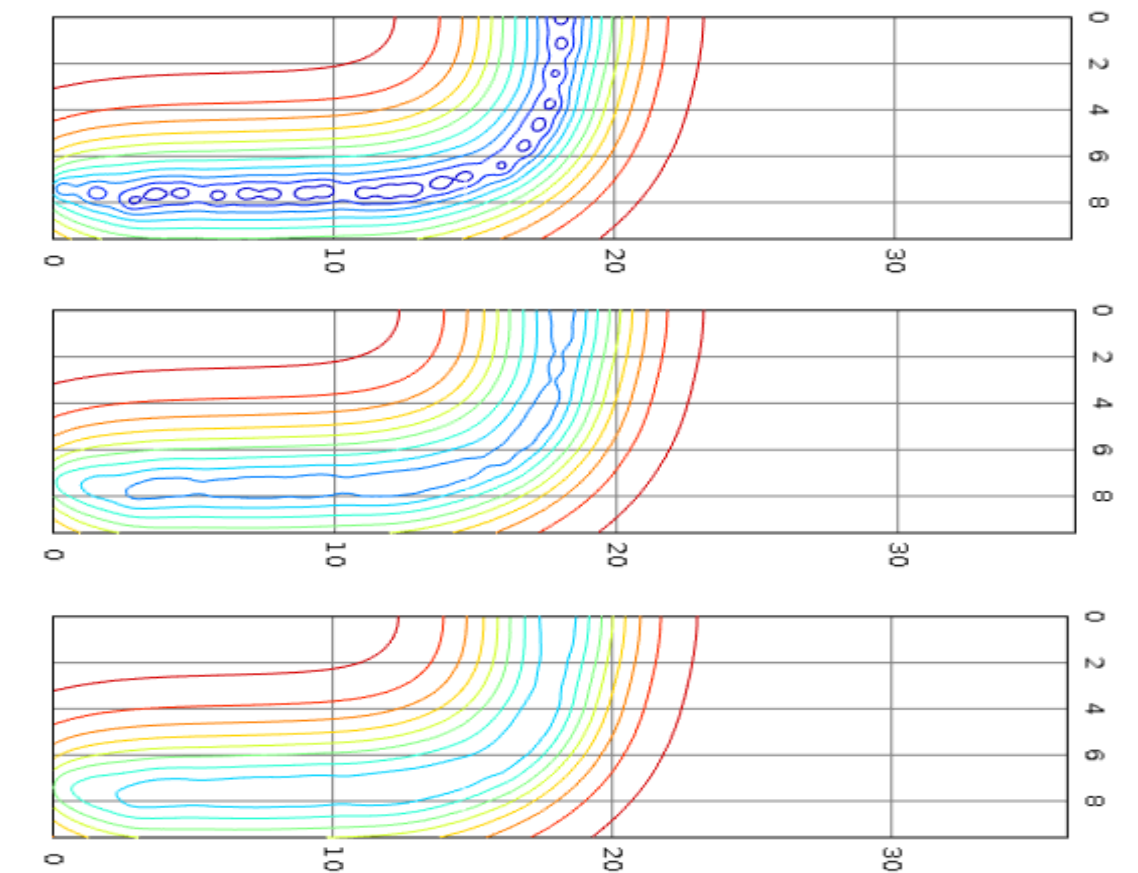
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Design of the frozen body

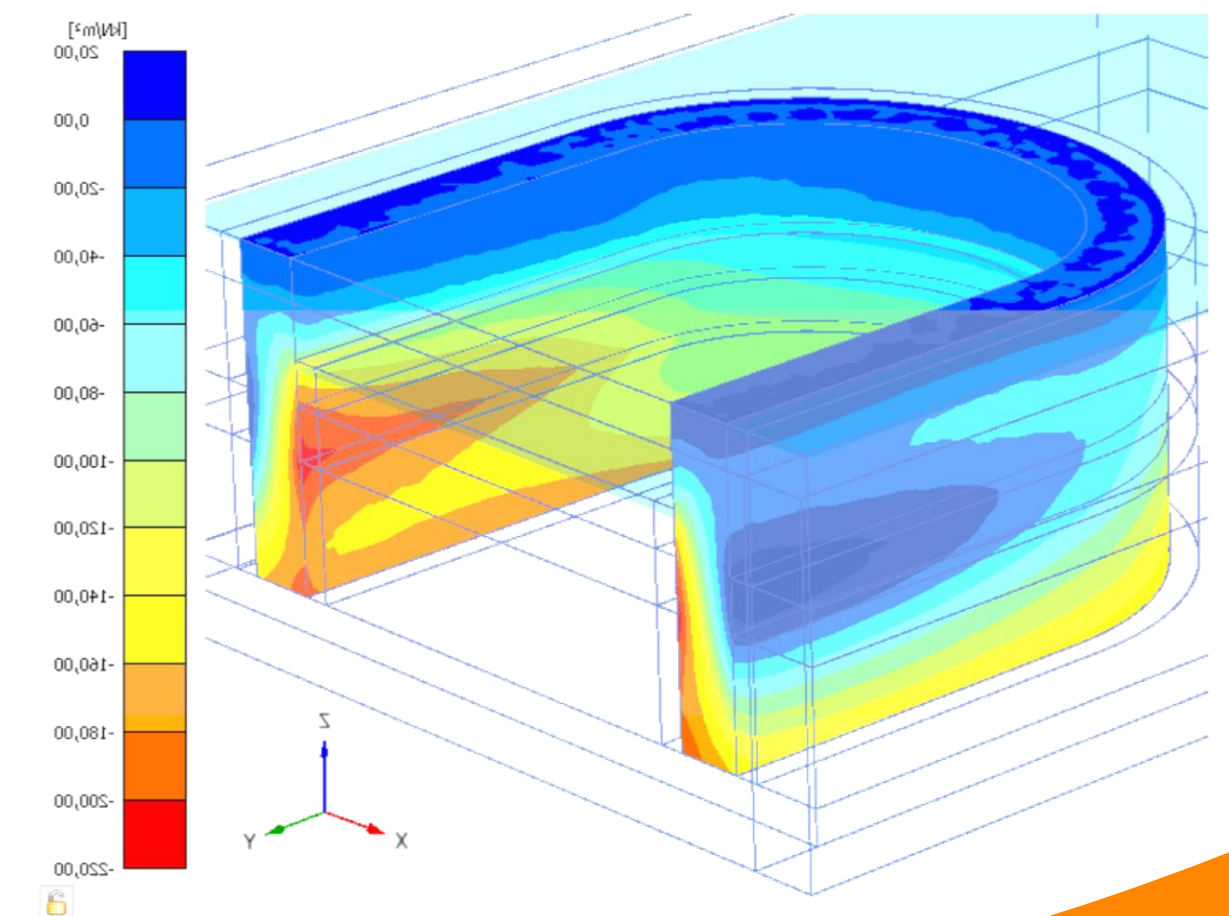


Constraints

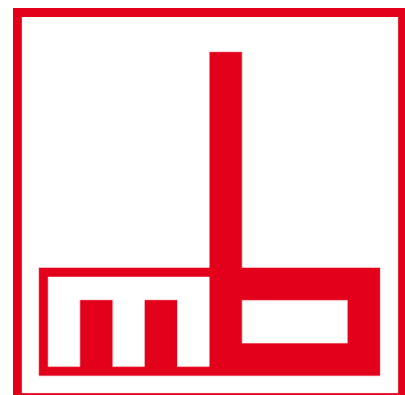
- Obstacles in the ground
- Connection to tunnel roof, diaphragm wall and bracing
- Limiting influence of frozen body to the existing structures



Thermal calculations

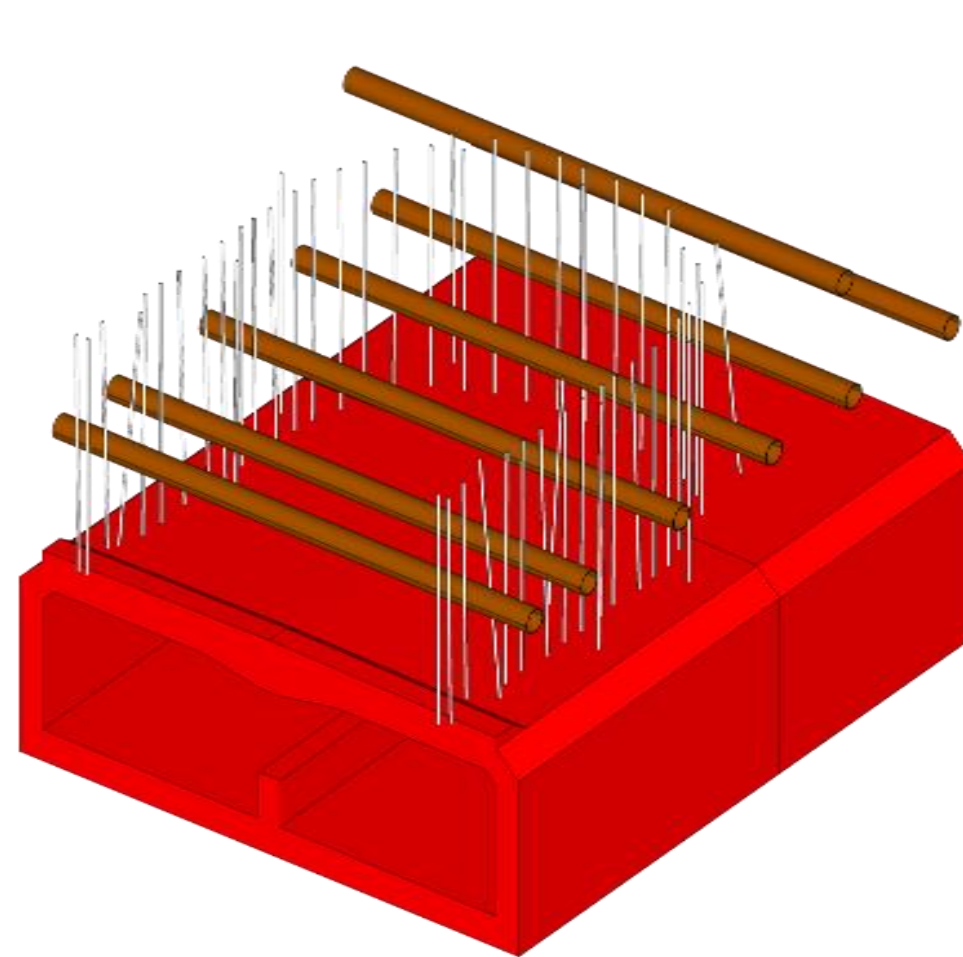


Structural calculations



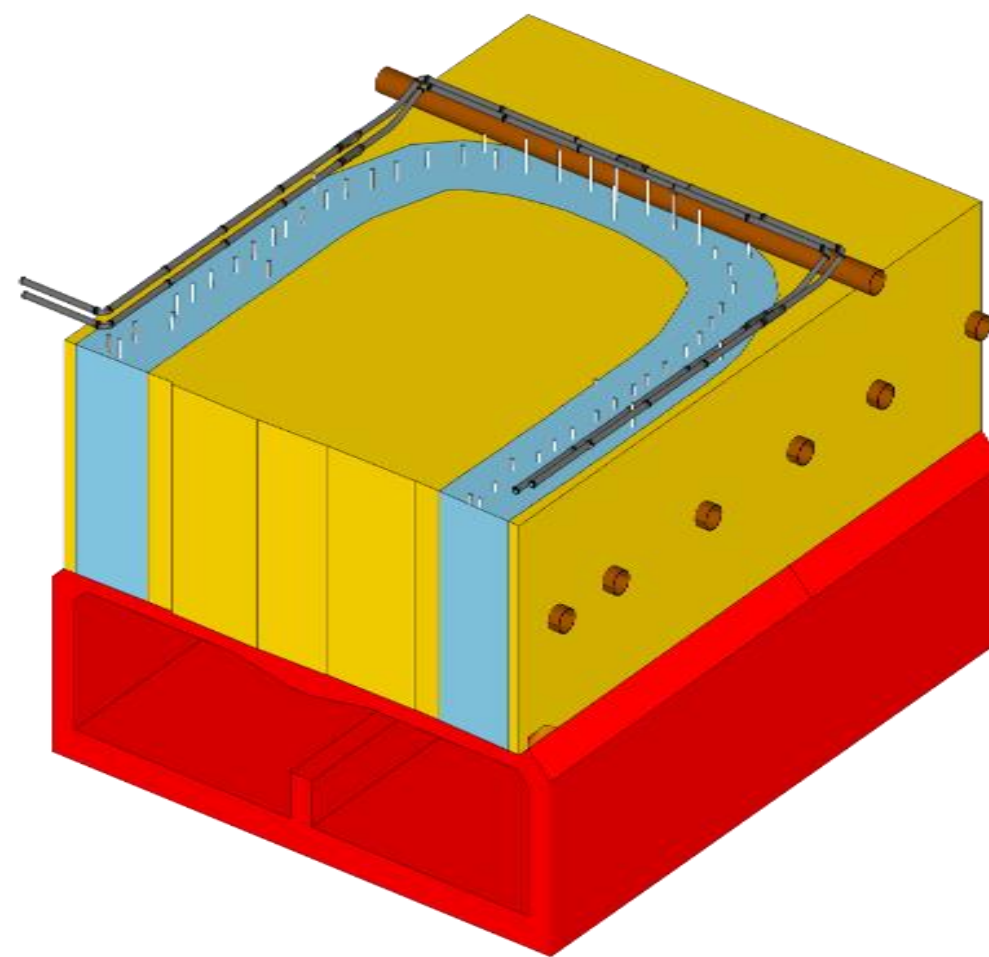
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Execution – phasing of works



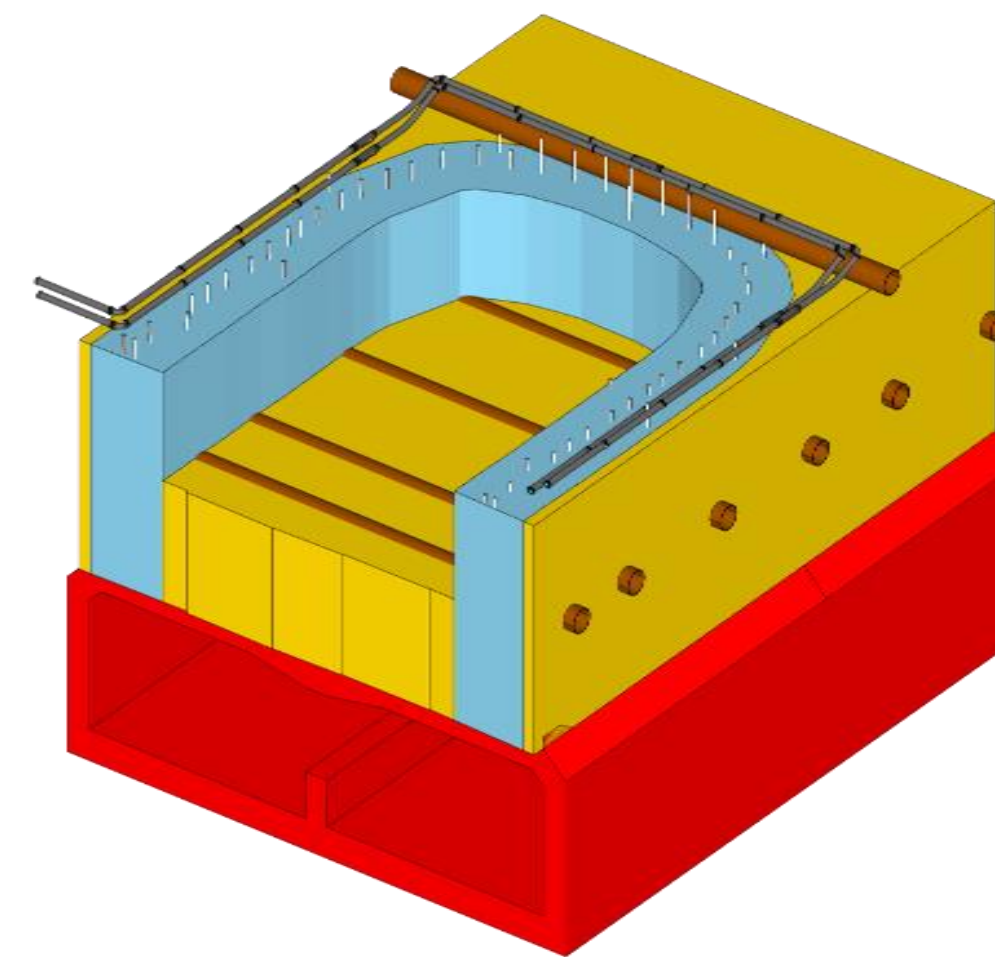
Phase 1: Drillings

- 43 Freeze pipes
- 10 Temperature pipes
- Length up to 9,0 m
- Threded pipes



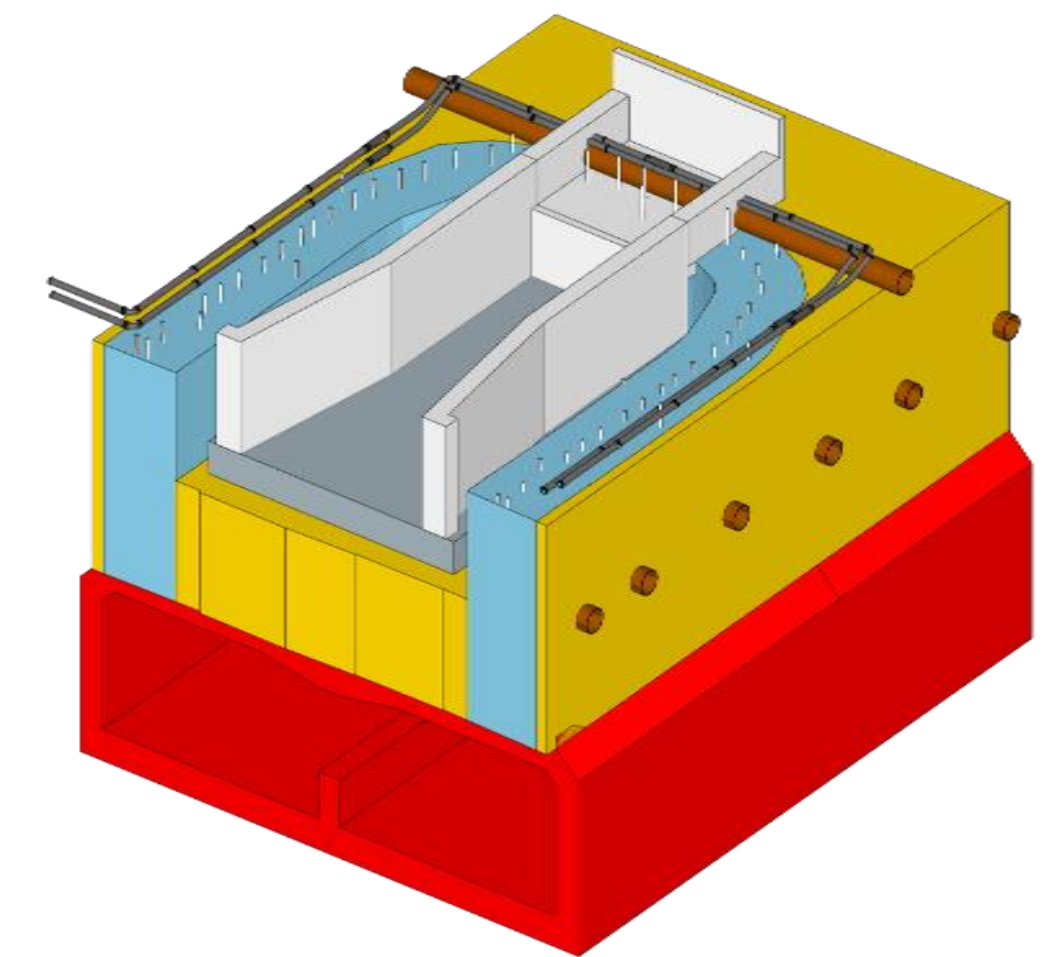
Phase 2: Primary freezing

- 200 m of brine circuit
- 180 Temperature sensors
- 120 kW freezing capacity
- 6 weeks



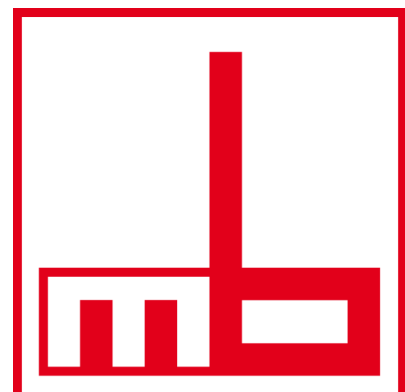
Phase 3: Excavation

- Depths 4,5 m
- 850 Big Bags of material
- Thickness of frozen body ca. 3,5 m
- Frost body with sealing and structural function



Phase 4: Civil works

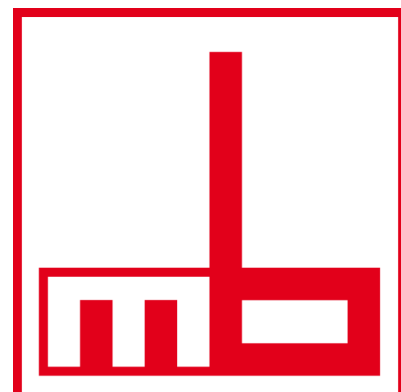
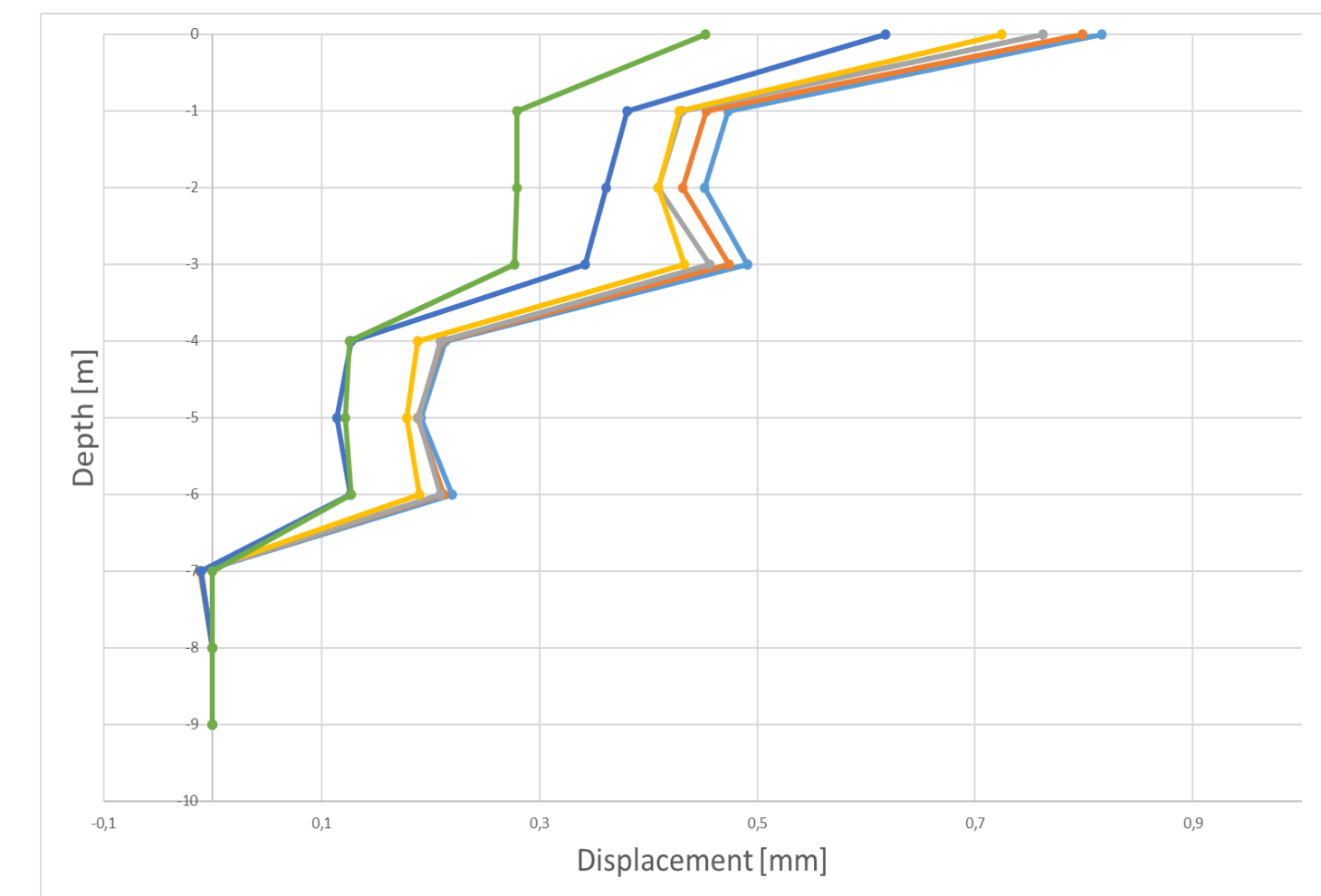
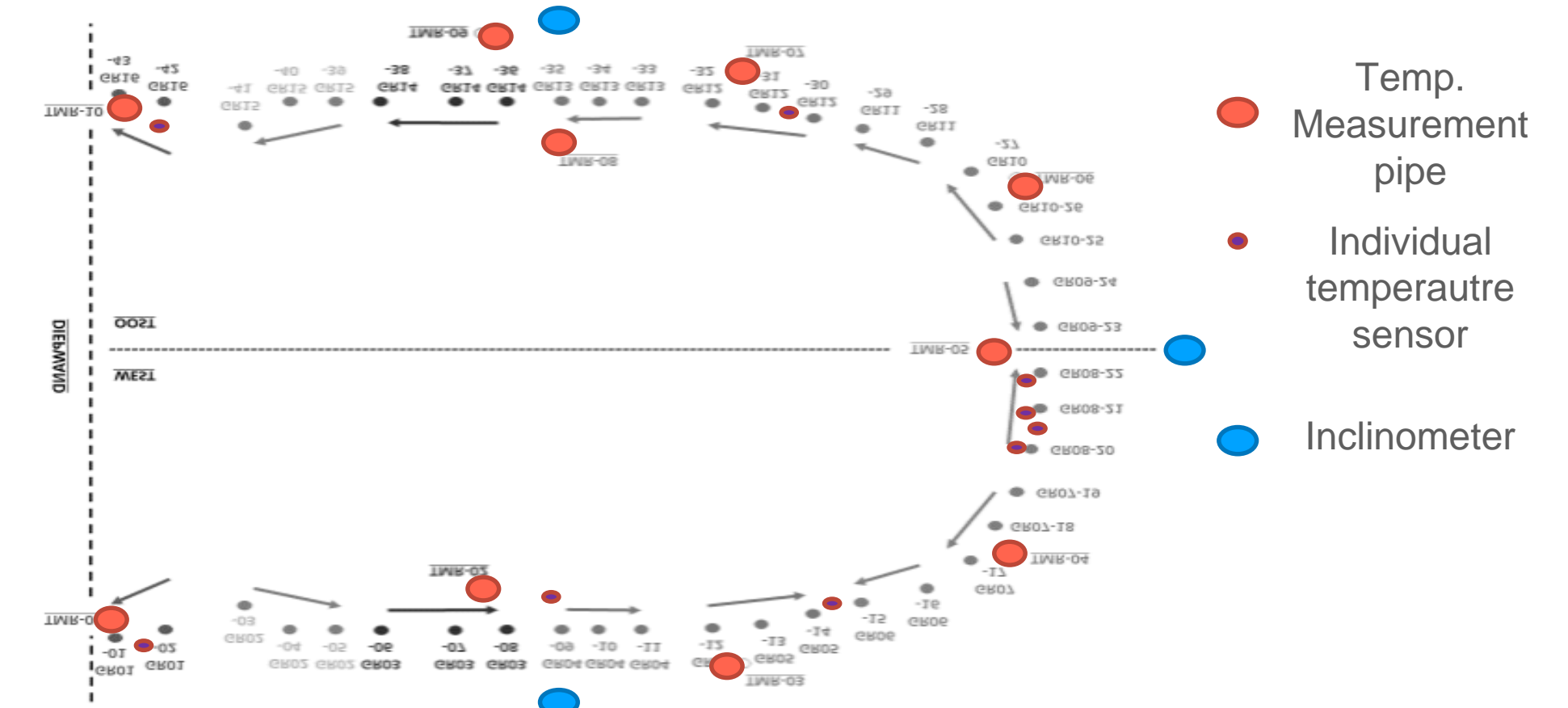
- Concrete works
- Cutting of the diaphragm wall



Cuyperstrap – Amsterdam Central

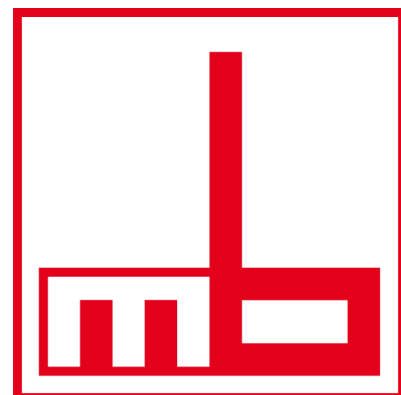
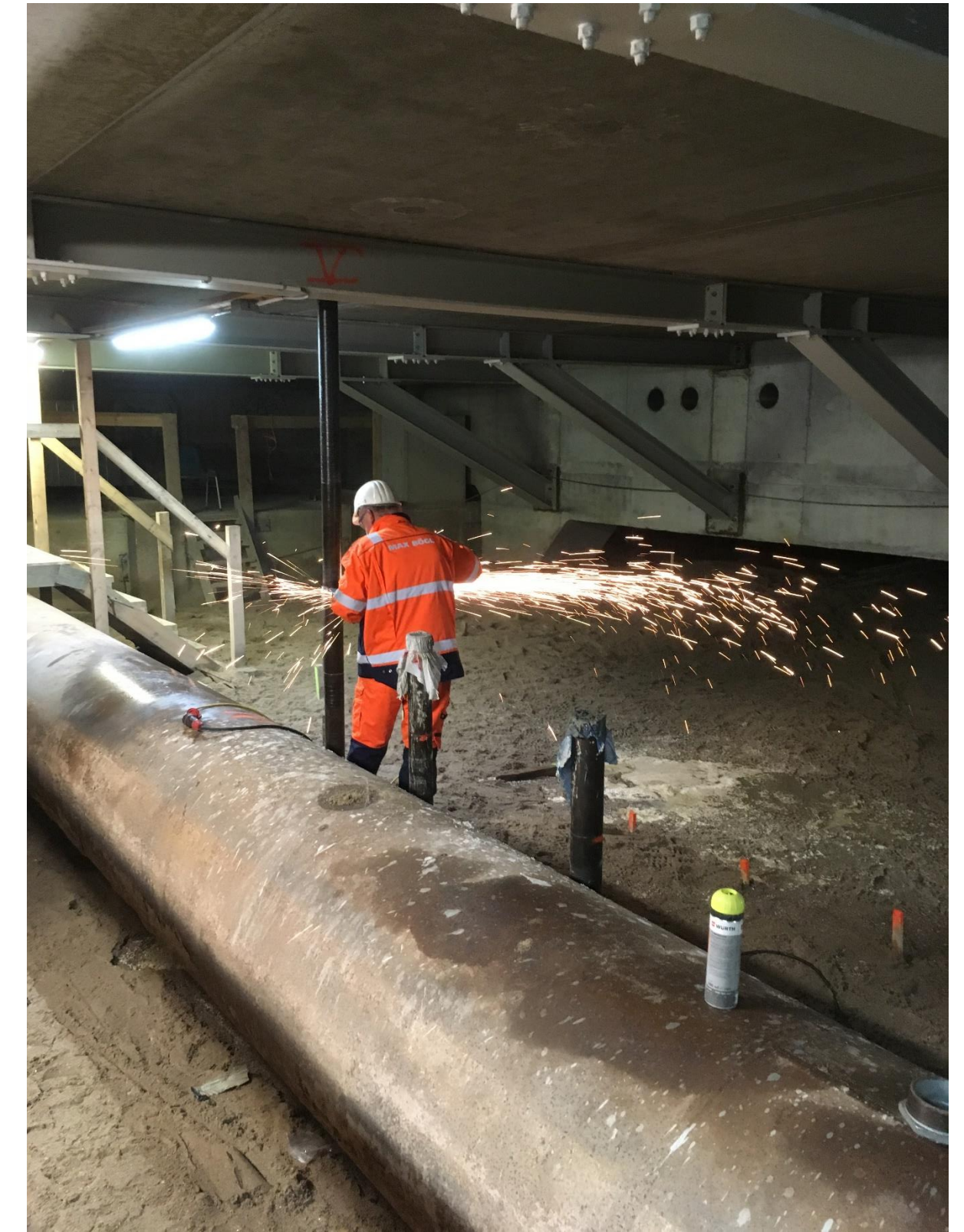
Execution - monitoring

- 10 temperature measurement pipes with 11 sensors each
- 9 flushed-in individual sensors on the top of the tunnel ceiling
- 45 sensors in the distribution circuit
- Continuous measurement of temperatures in the ground
- Assessment of frost body growth
- Monitoring of connection to diaphragm wall
- Comparison with thermal calculations
- Monitoring of the displacement with 3 inclinometers



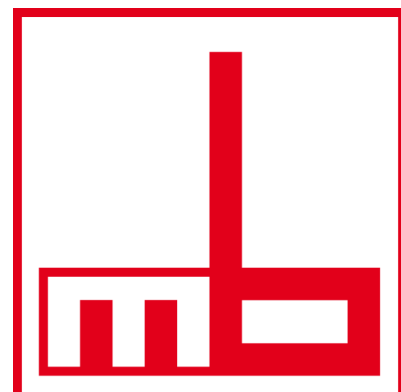
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Execution - Drillings



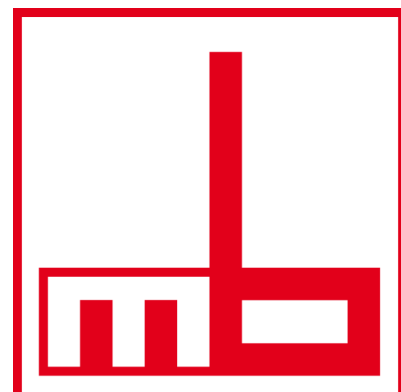
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Execution - Distribution circuit for brine



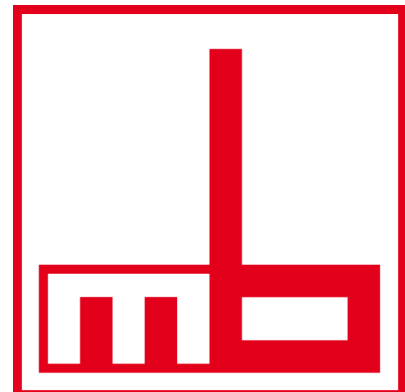
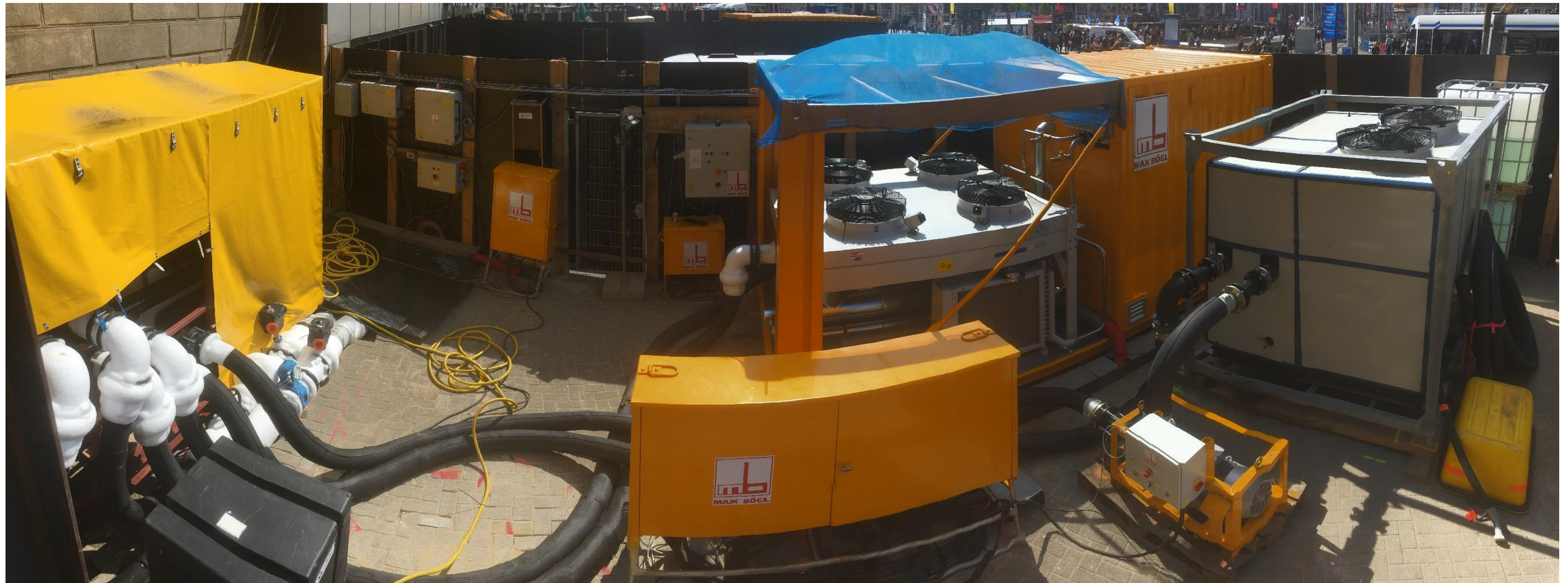
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Execution – Freezing and excavation



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Freezing plant in front of the station building

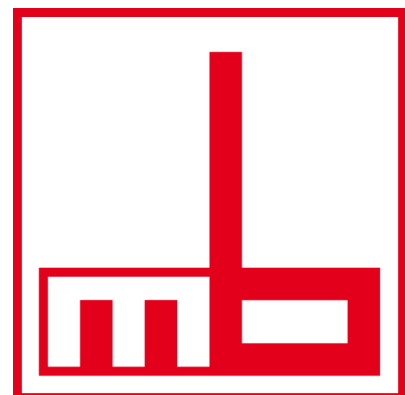
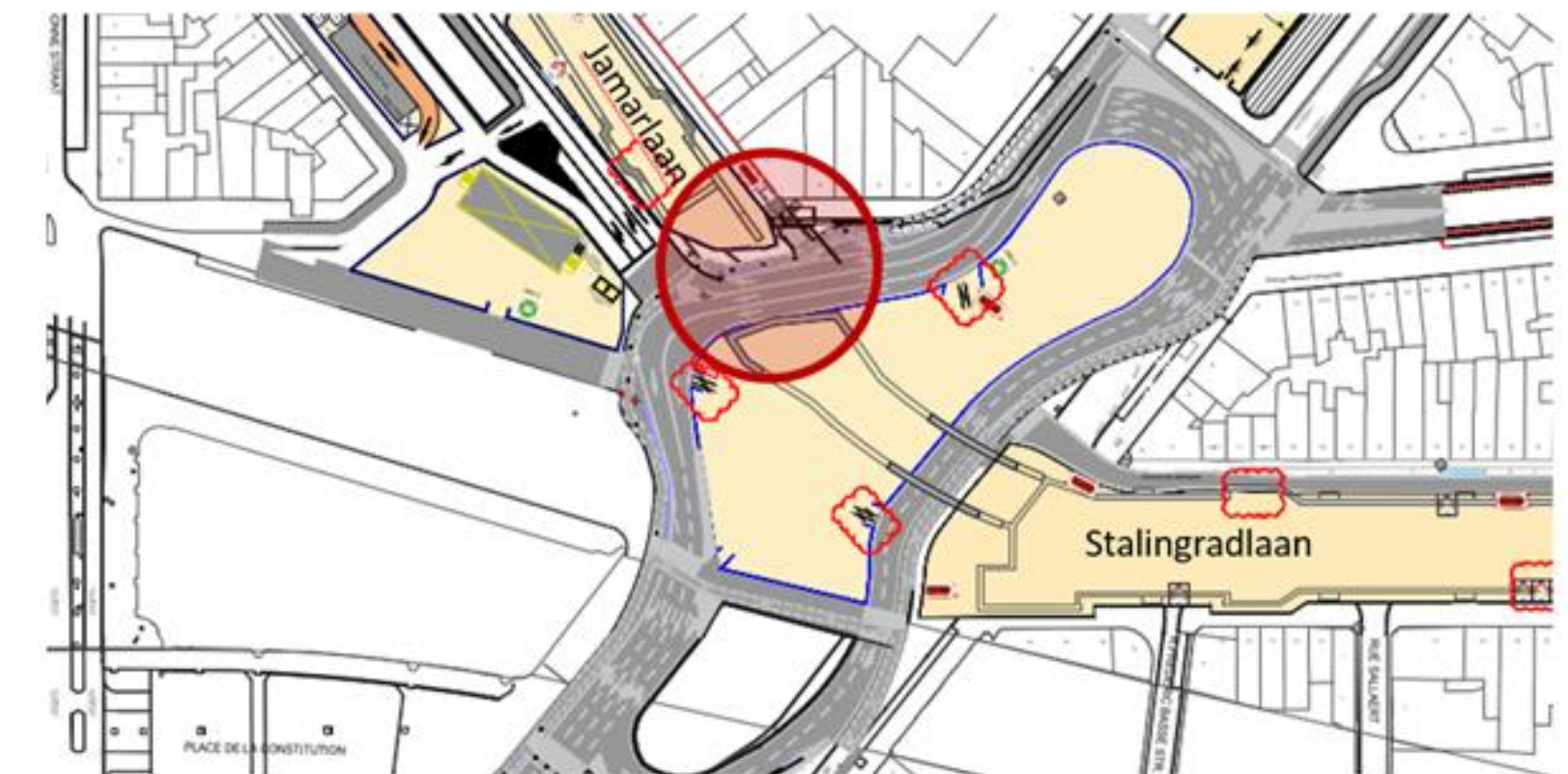
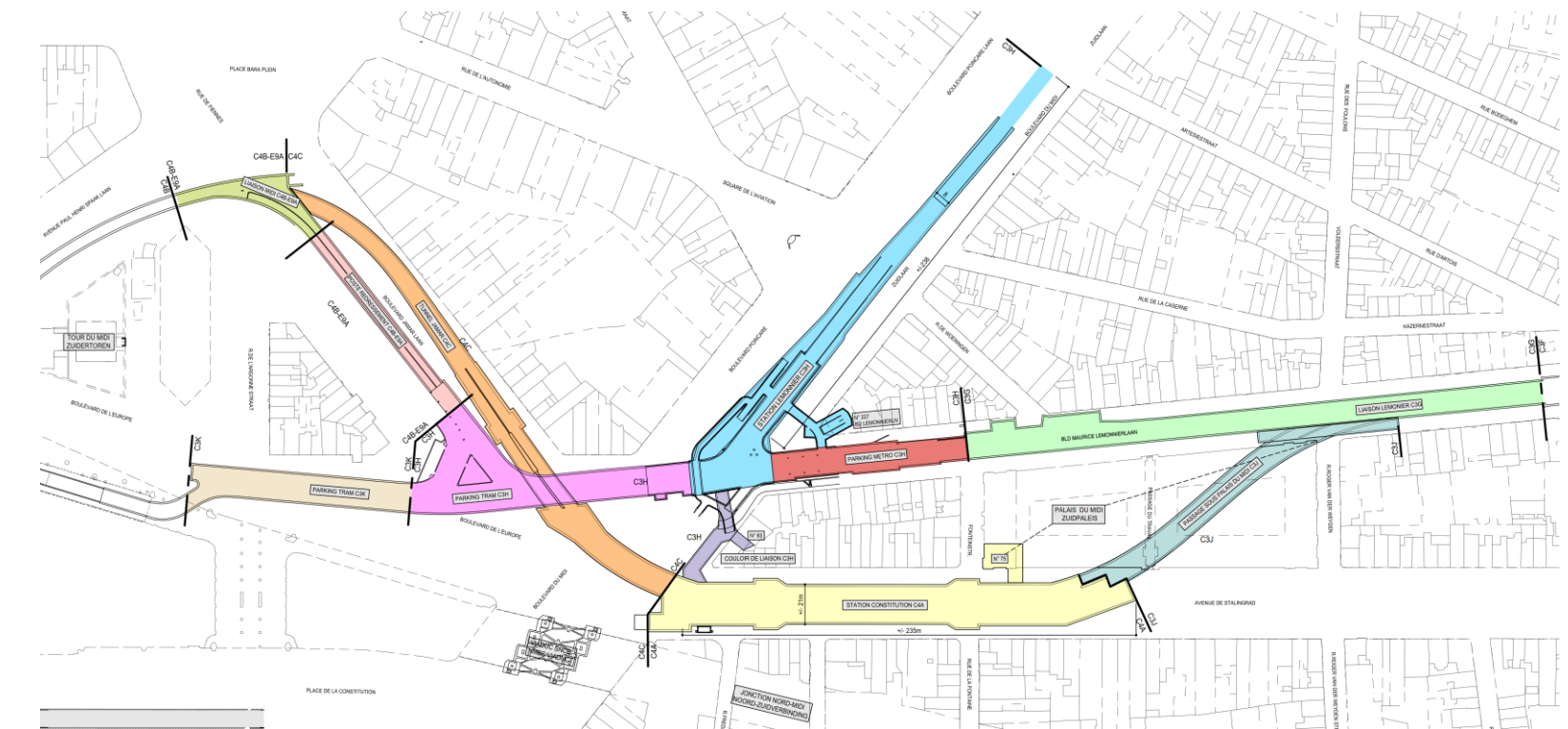


Metro – Brussels

Overview

- Part of the Project « Constitution - Metro & Pre-Métro Gare Du Midi – Lemonnier »
- Tunnel section of 25 m under an existing tramway tunnel.
- Connection between two cut-and-cover sections
- Drilling, freezing works and monitoring

- | | |
|-----------------------|--|
| Client: | SM Toots |
| Owner: | STIB/MIV |
| Start of Constructio: | 06/2023 |
| Freezing Methode: | Combined, primary freezing with LN2, maintenance freezing with brine |



Metro – Brussels

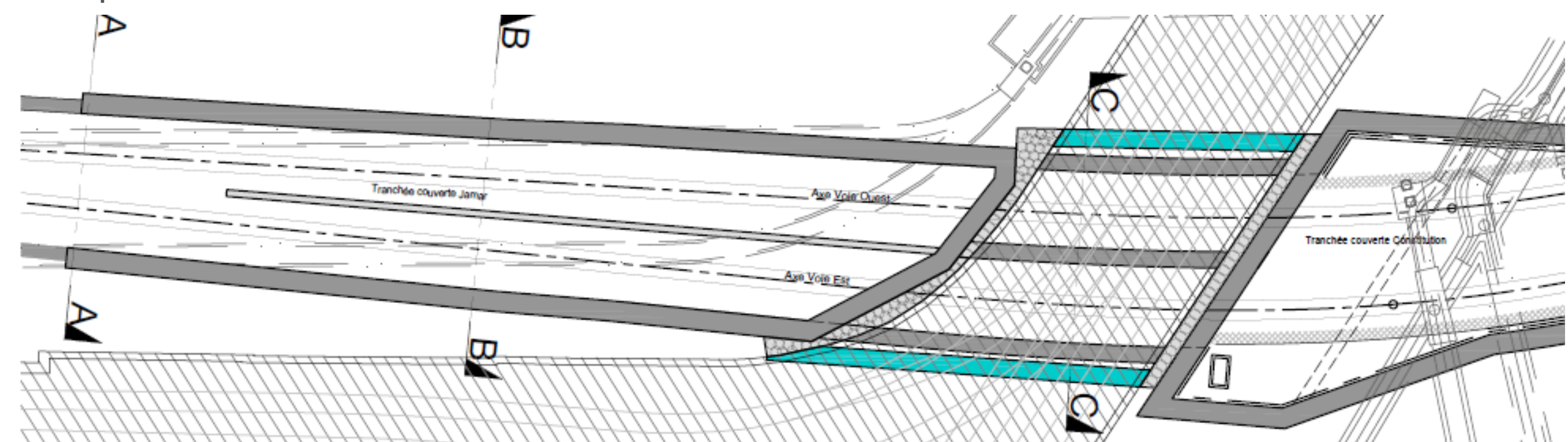
Tunnel section tramway tunnel - design

- Frost body as water tightening element, no structural function
- No overburden between existing tram tunnel and new tunnel section
- Intensive monitoring of the existing tram tunnel and adjacent structures
- Execution of the tunnel with fouilles blindées

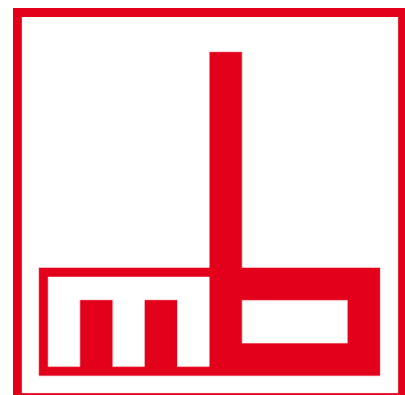
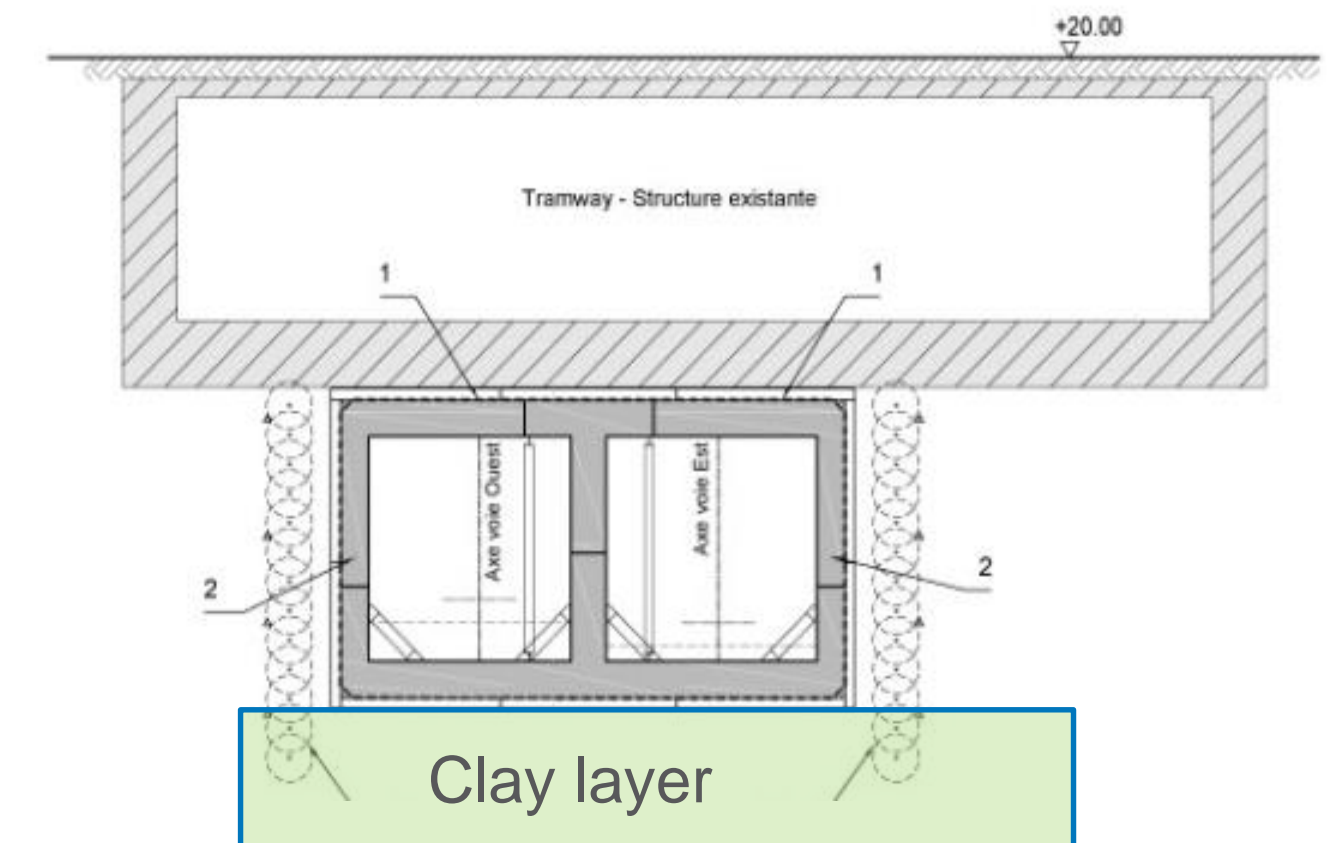
Légende

- Paroi moulée
- Congélation
- ▨ Structure existante tramway midi

Top view



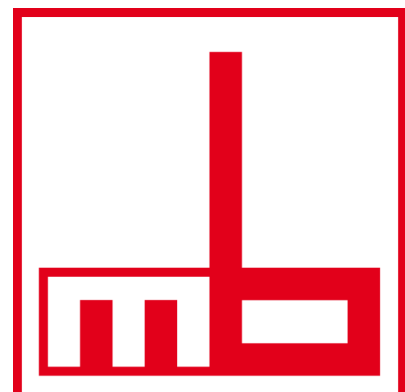
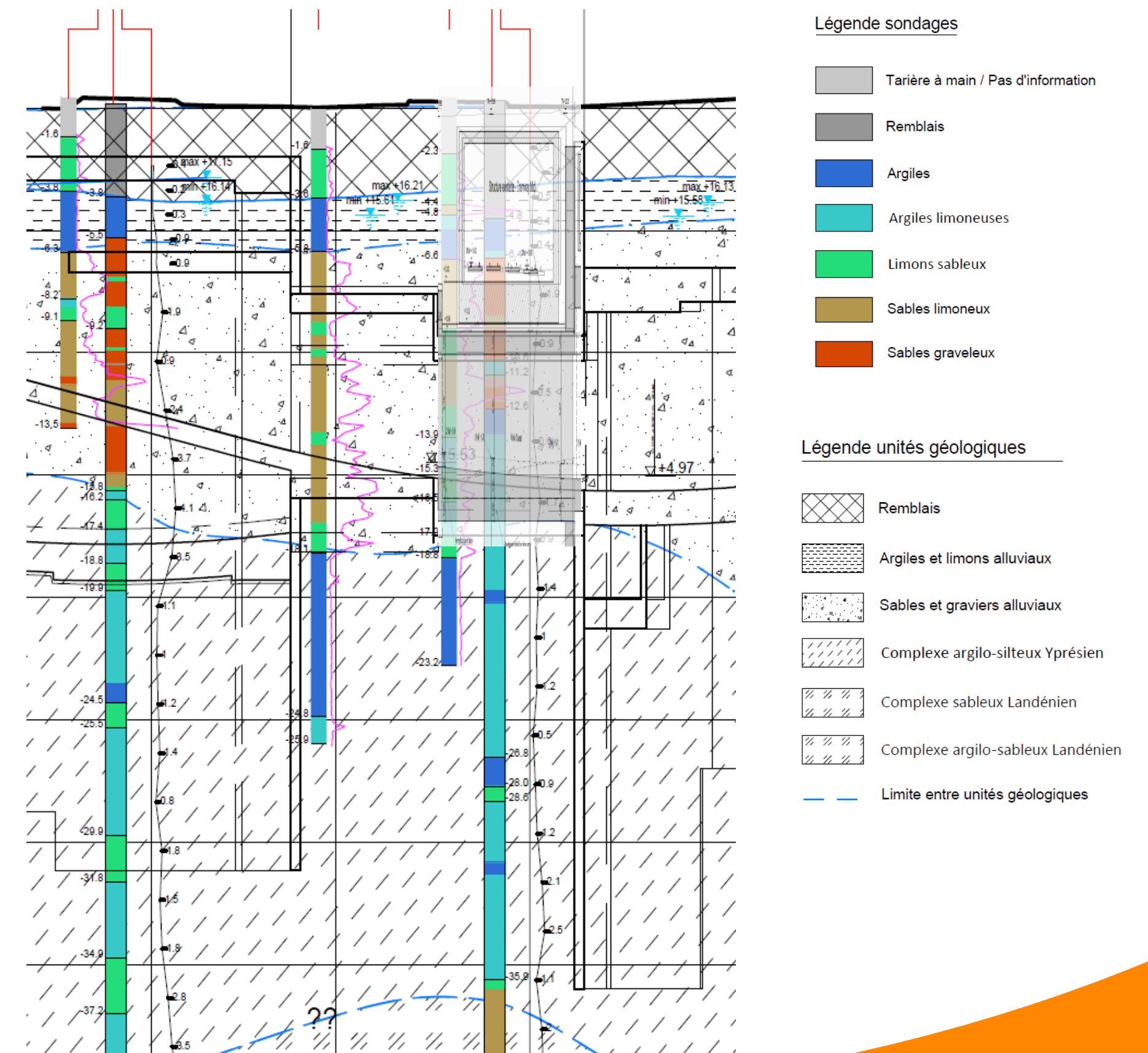
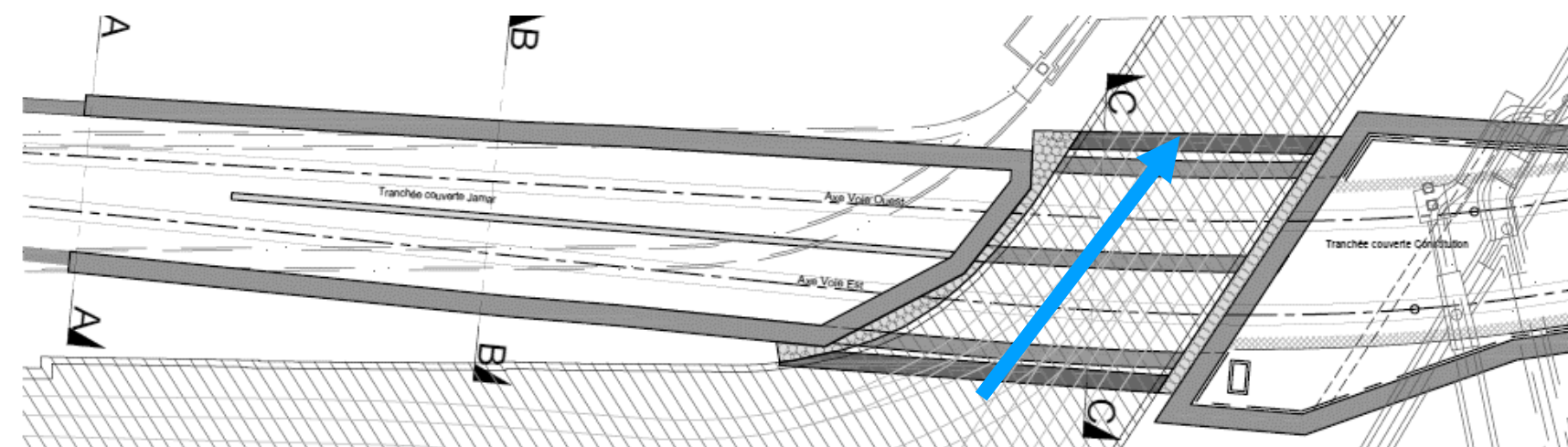
Crosssection C-C



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Site conditions and constraints - geology

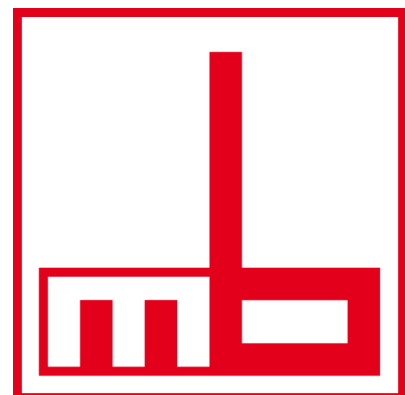
- Heterogenous ground conditions with alternating layers of sand, silt and gravel
- Underlying clay layer lower then originally foreseen
- Build-up of groundwater level on the south side due to the cut and cover tunnel sections
- Groundwater flow in the permeable layers



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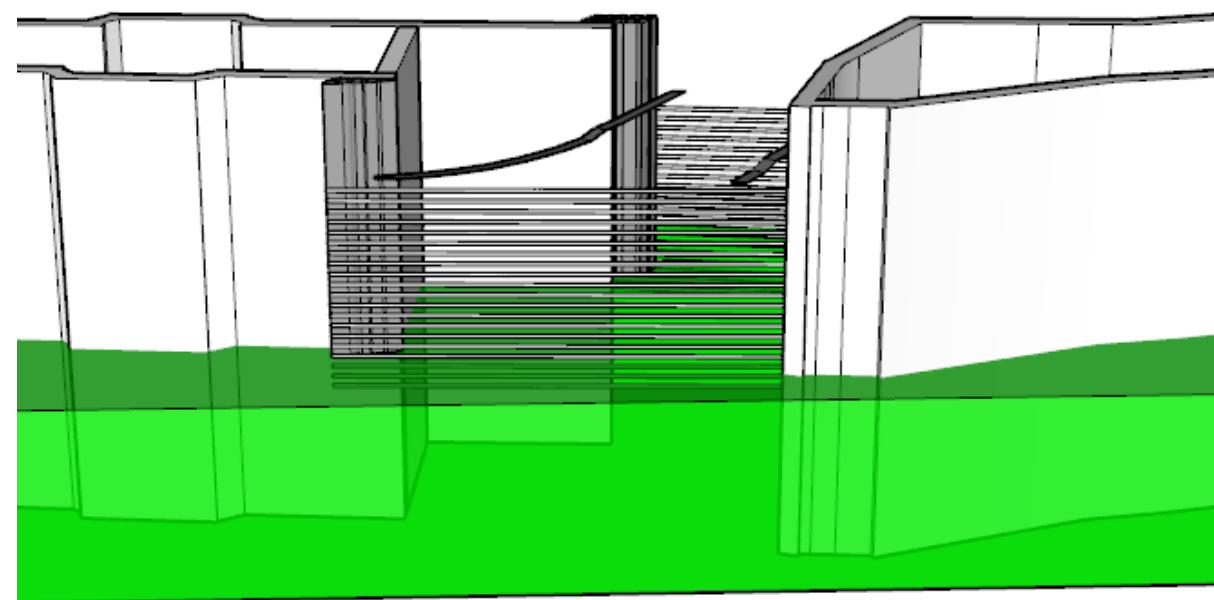
Site conditions and constraints

- Highly populated inner-city area, close to Gare du Midi
- Restraints for the delivery of liquid nitrogen (LN2)



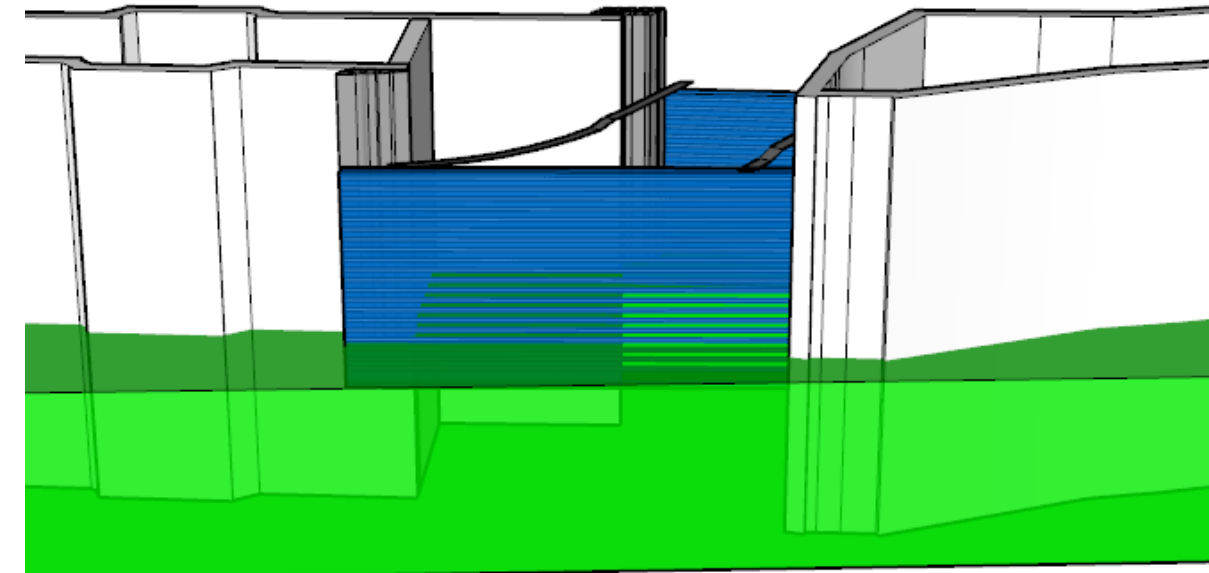
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Execution



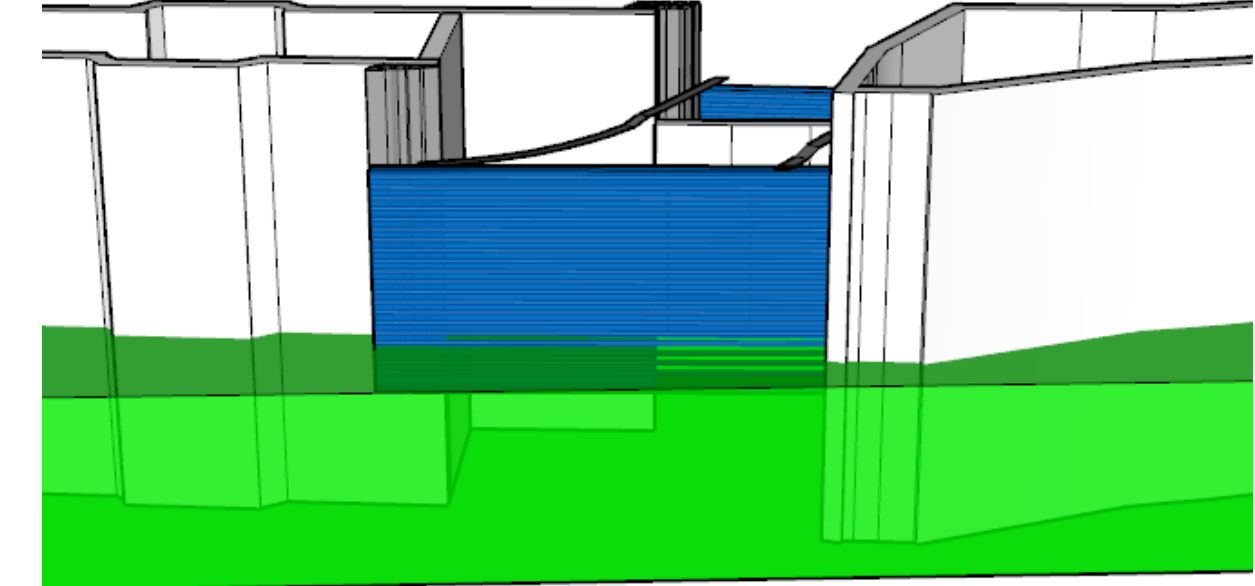
Phase 1: Excavation of the pit and drillings

- 41 (horizontal) Freeze pipes
- 10 (inclined)
- Temperature pipes
- Length up to 35 m
- Welded inox freeze pipes



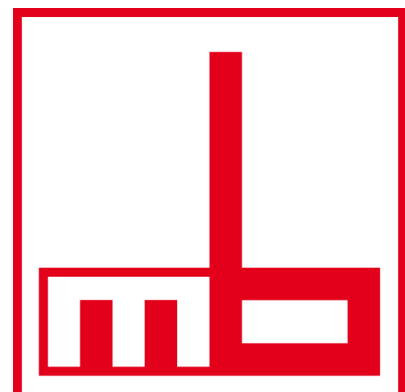
Phase 2: Primary freezing

- Liquid nitrogen installation
- Switch to brine freezing
- Monitoring



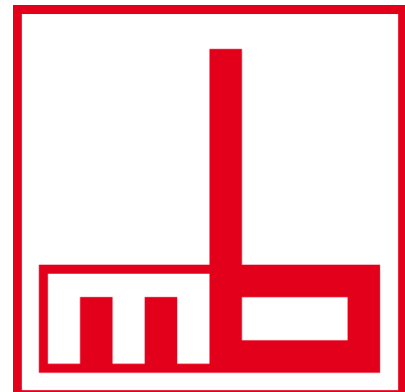
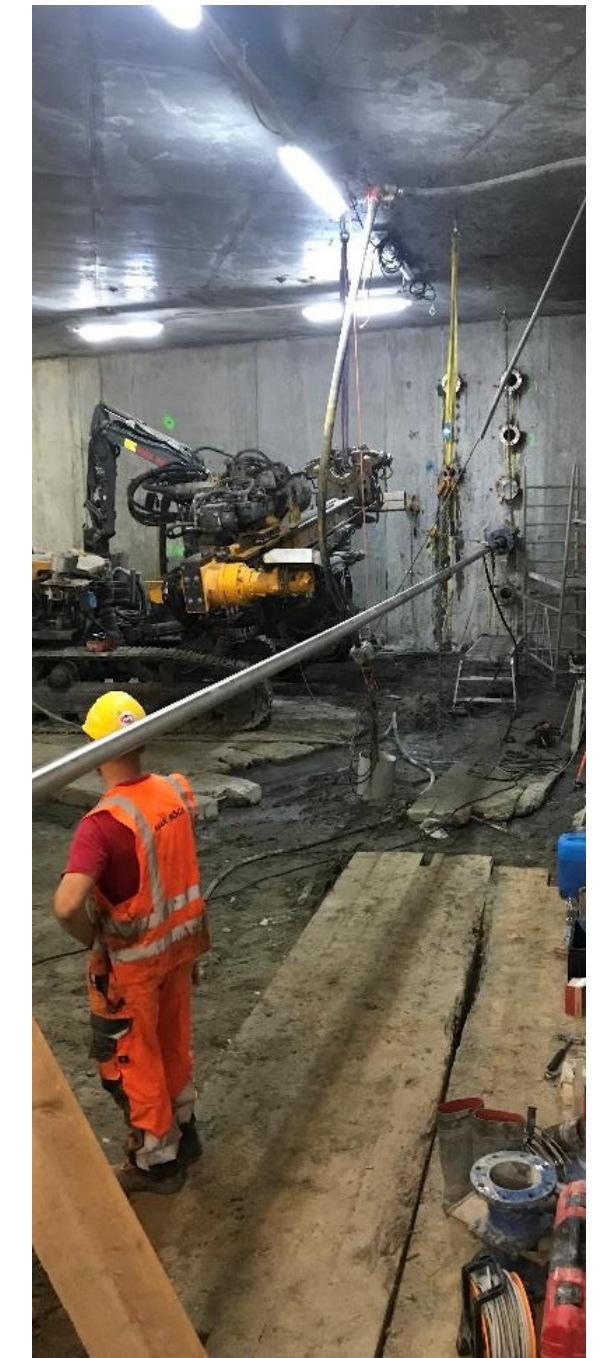
Phase 3: Maintenance, excavation and civil works

- Freezing with brine
- Monitoring



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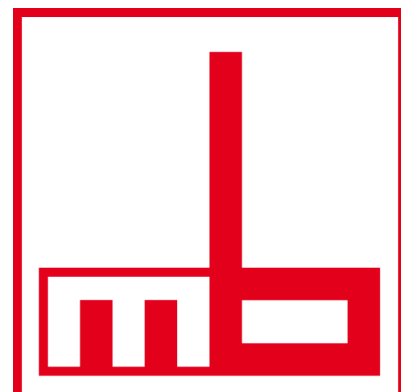
Phase 1: Excavation of the pit and horizontal drillings



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Outlook

- Completion of drilling works
- Installation of freezing equipment and distribution circuits for liquid nitrogen and brine
- Start of freezing foreseen for Q3 2024
- Duration of freezing approximately 1.5 years



Thank You

Questions ?

cnellessen@max-boegl.de

bmuellet@max-boegl.de

www.ground-freezing.com / www.congelation-des-sols.fr

