KARAKAS
FRANÇAIS

ZSoil Day 2026

Design and monitoring of an unsymmetrical deep excavation based on ZSoil predictions

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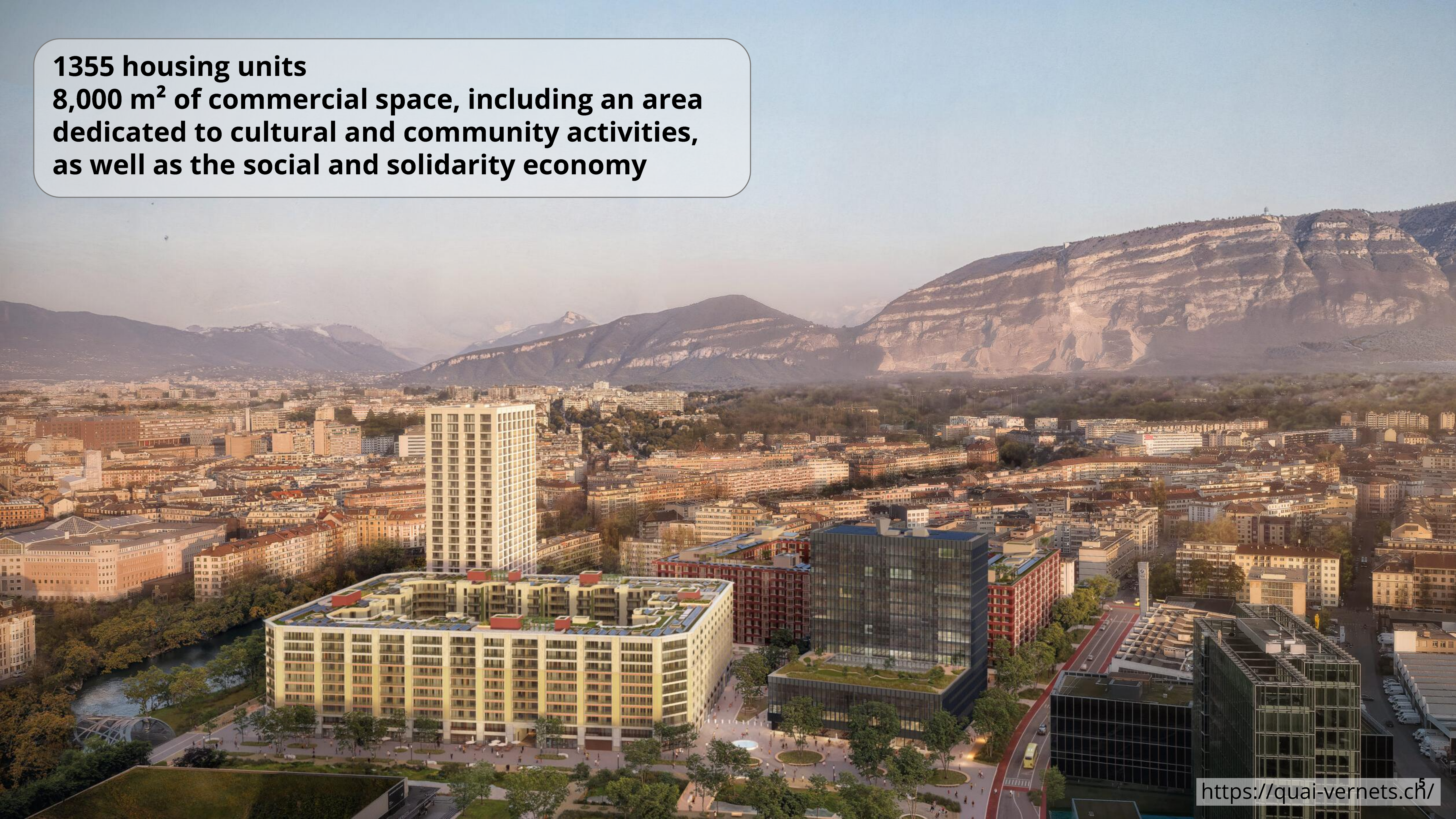
Outline

- Quai Vernets
- Unsymmetrical deep excavation
  - Objectives
  - Modelling challenges
  - Design
  - Savings
- Monitoring
- Final remarks

01 Quais Vernets project

1355 housing units
8,000 m² of commercial space, including an area dedicated to cultural and community activities, as well as the social and solidarity economy



https://quai-vernets.ch/

BUILDINGS – 1 INTAGRATED NUMERICAL APPROACH

Quai Vernets

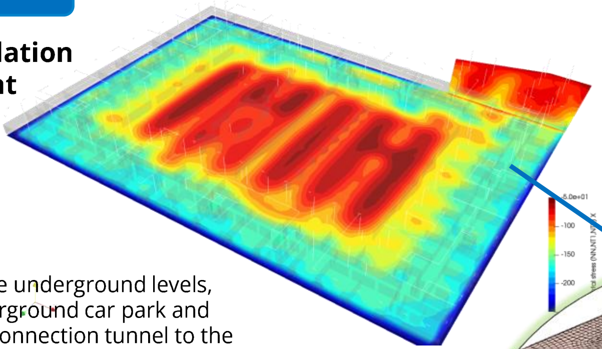
- 4 main lots in Geneva city :
  - A – 9 storey
  - B – 9 storeys
  - C - mixed-use residential block combining rental housing with active ground-floor commercial and community spaces, 14 storeys
  - D – residential tower 86m, 26 above-ground storeys
- Final realisation : 2026 – 2028
- Real estate developer and general contractor : LOSINGER MARAZZI
- Geotechnical engineer : KARAKAS FRANÇAIS

Quai Vernets with ZSoil

4 BUILDINGS – 1 INTAGRATED NUMERICAL APPROACH

BUILDING A

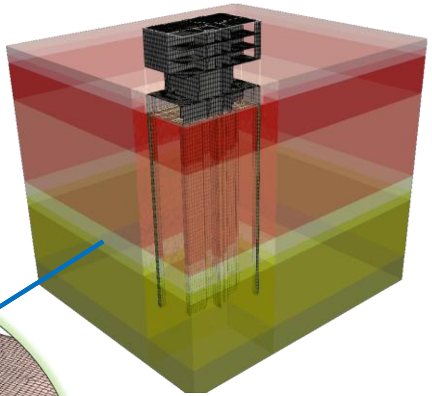
Full raft foundation and settlement



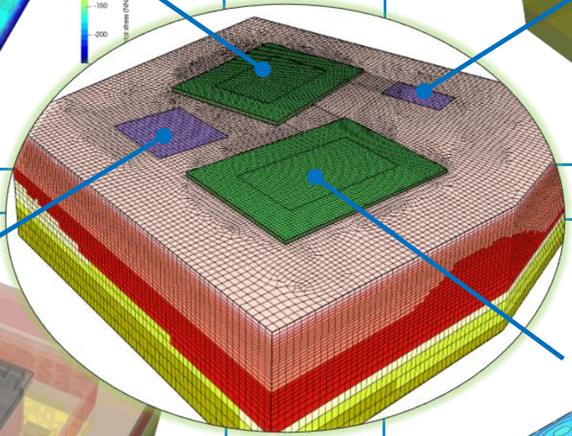
3D modelling of the underground levels, including the underground car park and the underground connection tunnel to the adjacent building B

BUILDING D

High-rise tower on barrette foundation

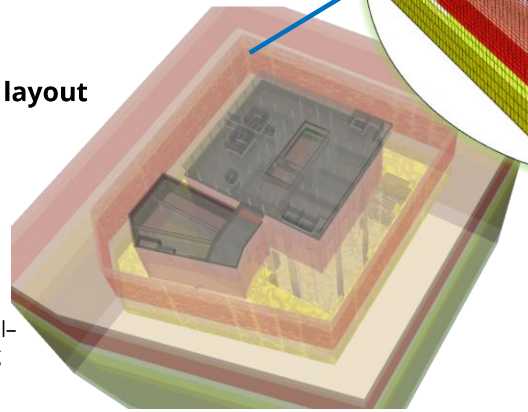


Soil-structure interaction of the deep foundation design



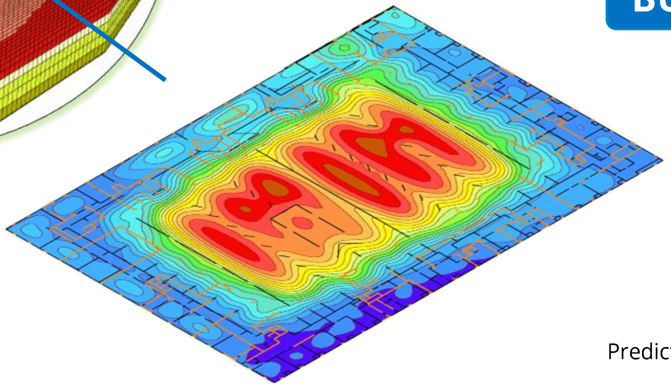
BUILDING C

Complex underground layout



3D analysis of the complex underground structure and soil–structure interaction, including the design of the diaphragm walls and barrettes

BUILDING B



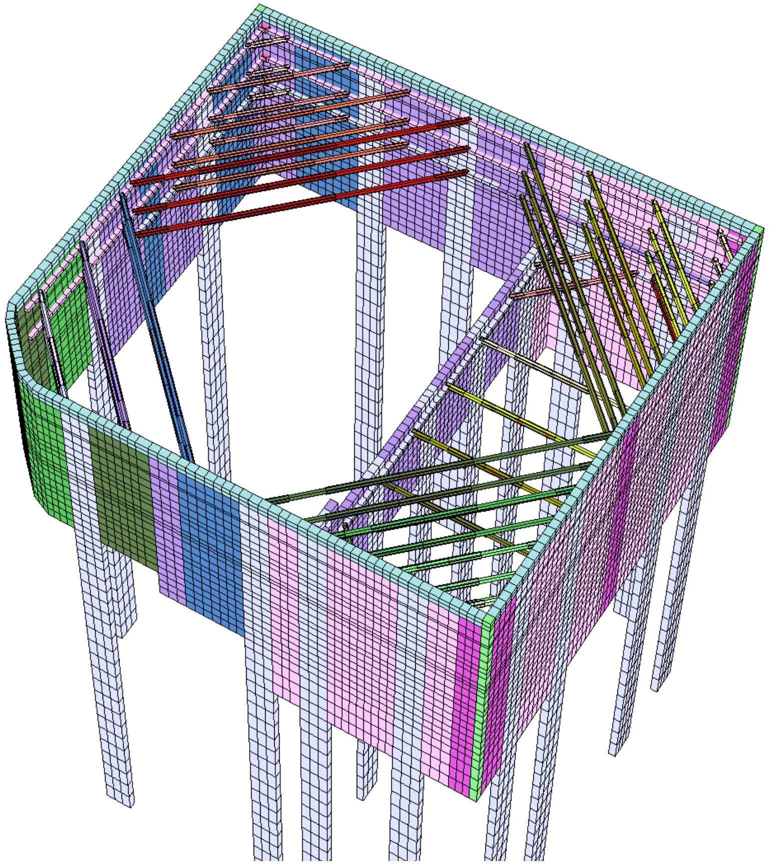
Prediction of settlements of the building

02 Unsymmetrical deep excavation

Objectives

Objectives

1. **Develop a robust and reliable design of the retaining walls**, ensuring safety during both the excavation works and the service life of the structure, while avoiding unnecessary optimisation that could reduce resilience to unforeseen ground conditions.



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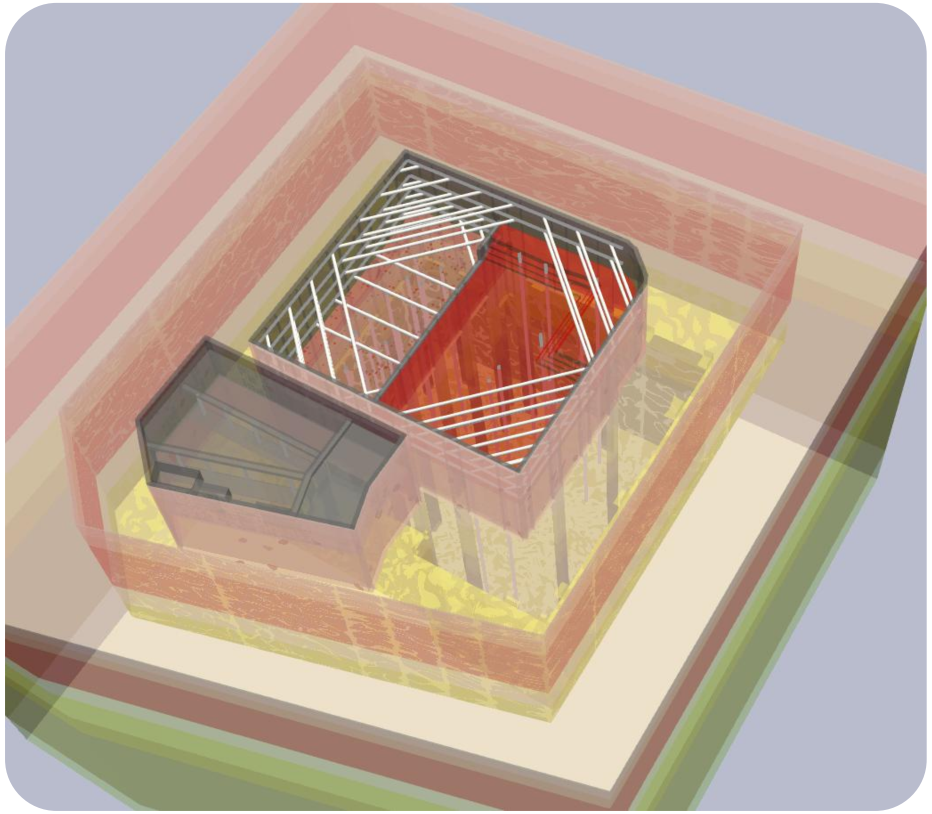
2. **Design the deep excavation support system** for the critical unsymmetrical condition associated with the progressive removal of the struts during the construction of the underground levels.



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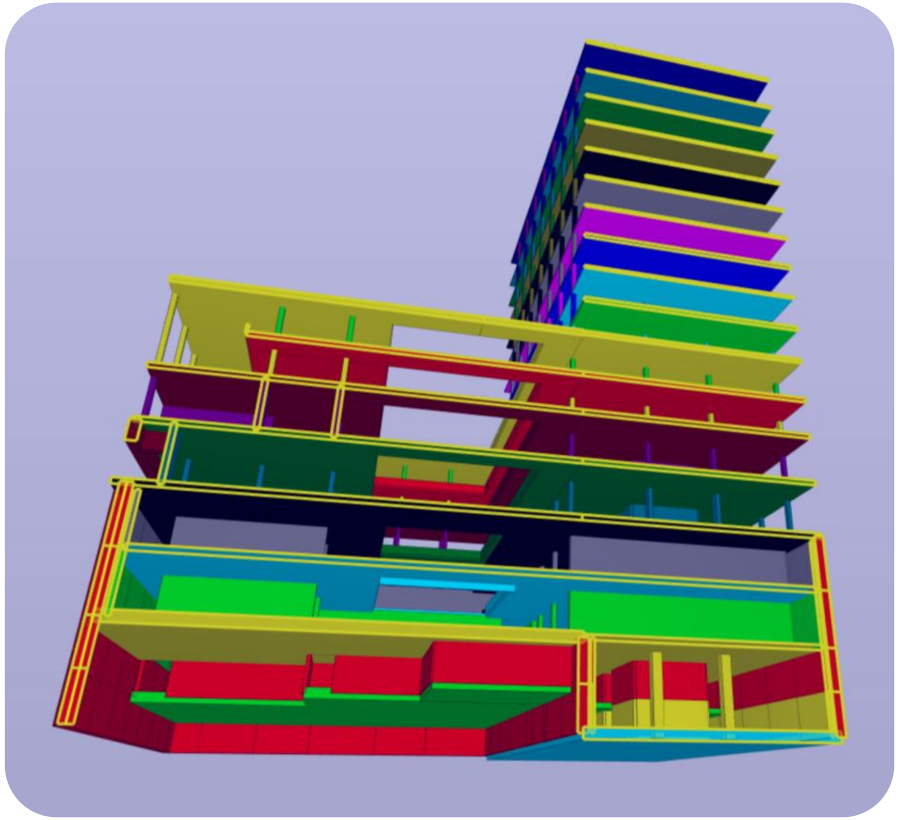
2. **Design the deep excavation support system** for the critical unsymmetrical condition associated with the progressive removal of the struts during the construction of the underground levels.

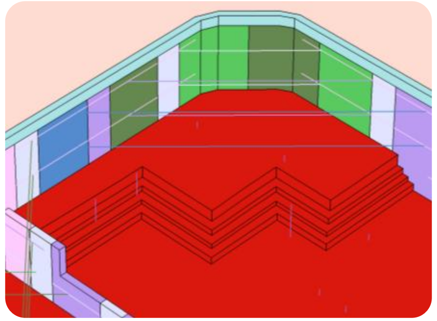
3. **Design the foundation system** for a multi-storey building with highly unsymmetrical loading and a complex underground structural layout, taking full account of soil–structure interaction.

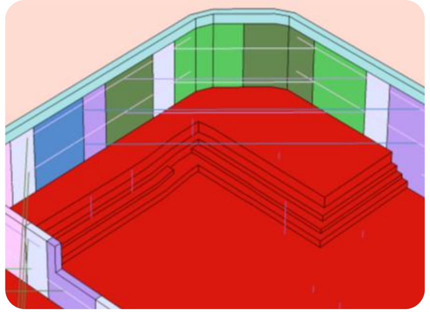


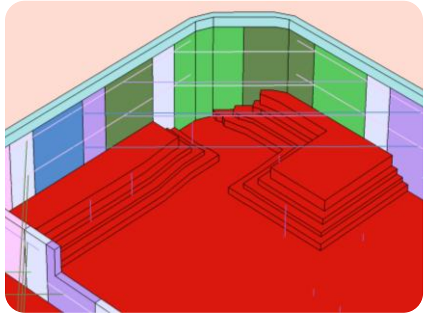
Objectives

1. …
2. …
3. …
4. **Evaluate alternative design scenarios** using numerical analyses to identify the governing conditions for excavation performance, structural behaviour and foundation response.

   e.g. modified excavation geometry checks,
   removal of sub-raft stiffening slab,
   phasing issues





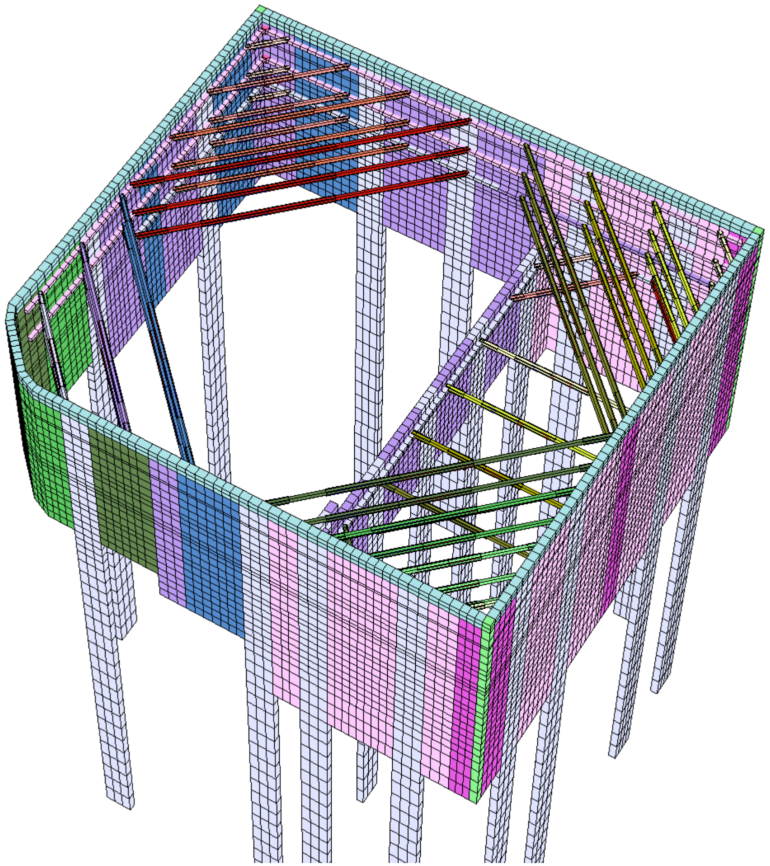


02 Unsymmetrical deep excavation

Modelling challenges

Modelling challenges

1. **Stratigraphy and geological conditions**
2. **Modelling of barrettes**
3. **Modelling of slurry walls**
4. Modelling of the underground concrete construction phases
5. Optimisation of the model size



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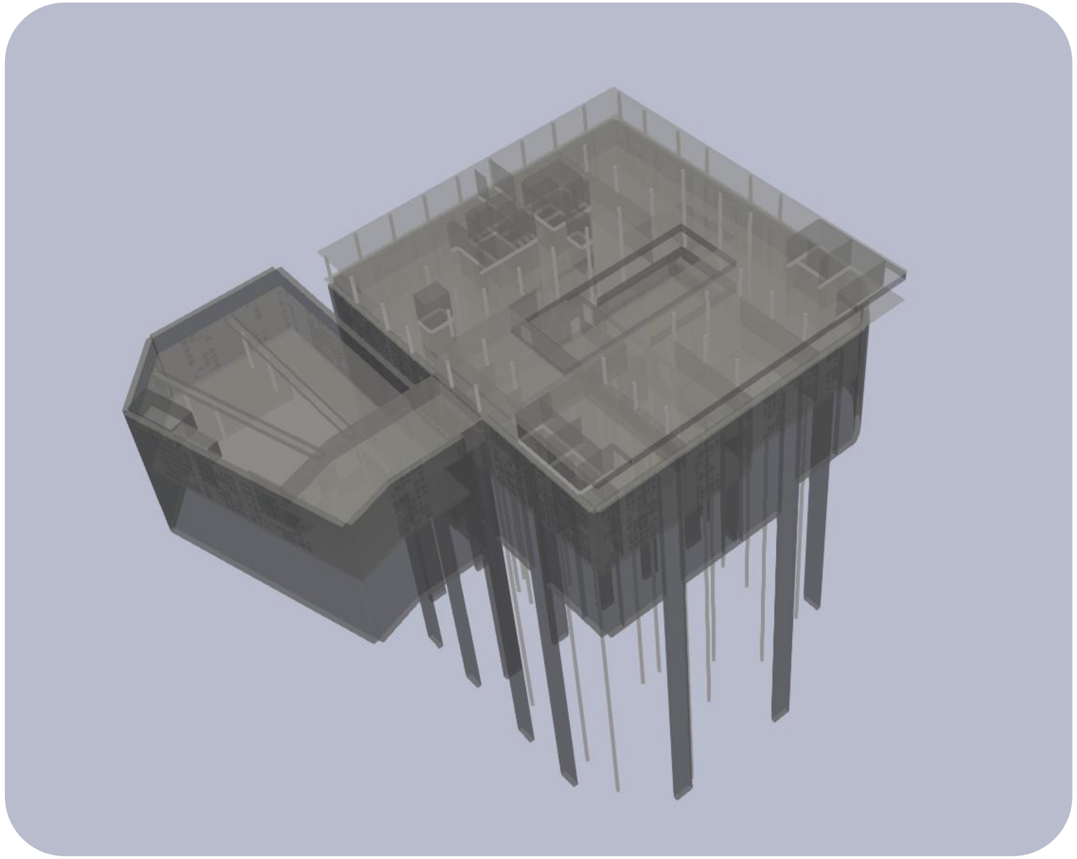
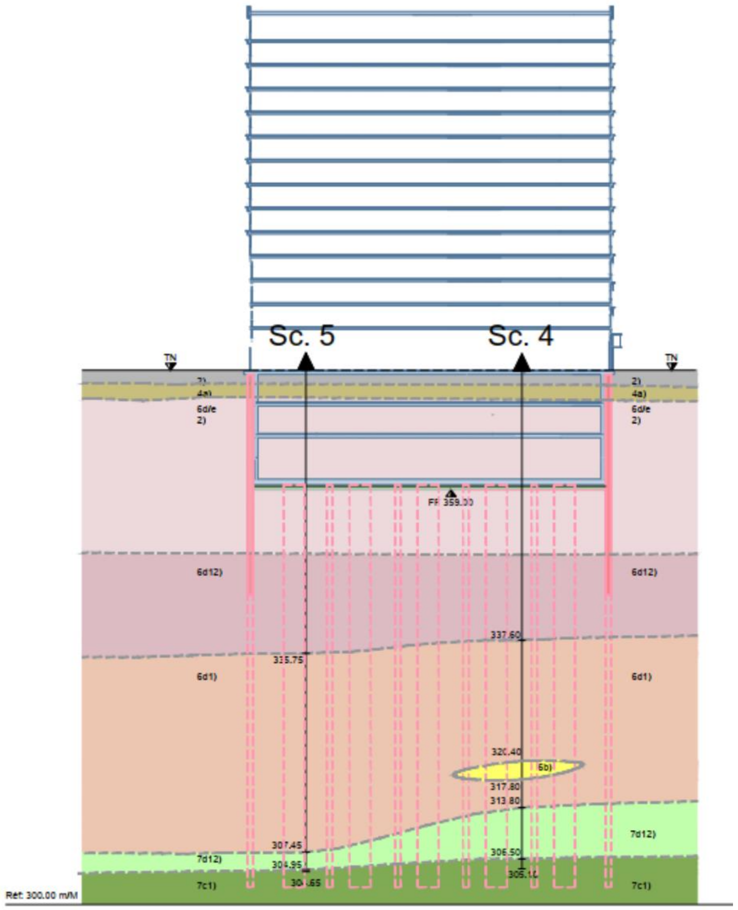


Modelling challenges

STRATIGRAPHY



Geneva geology

- Thin superficial deposits
- Thick sequence of Quaternary glacial sediments (soft clayey soils)
- Alternating glacial till, glaciofluvial sands and gravels, and glaciolacustrine silts/clays

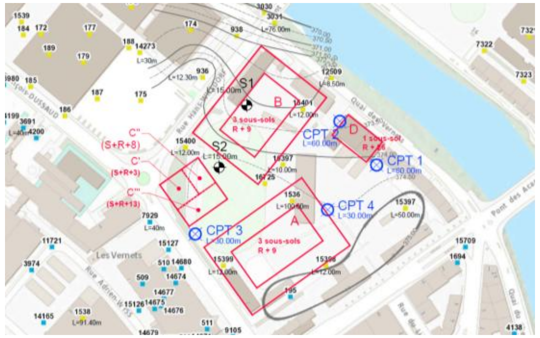
Modelling challenges

STRATIGRAPHY

2017

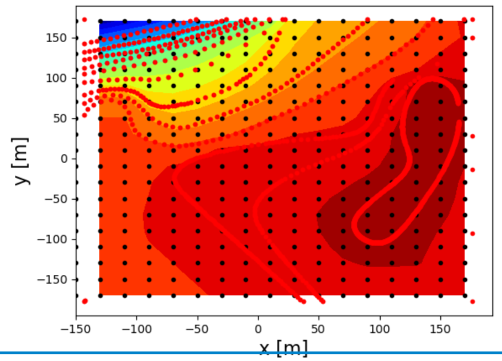
1 Formation levels
Surfer

Generating formation level contours based on existing boreholes



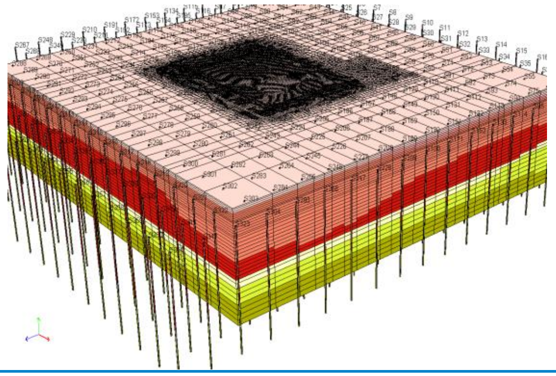
2 Auxiliary boreholes
Python

Interpolation and generating auxiliary boreholes



3 Geological model
ZSoil

3D geological model based on auxiliary boreholes

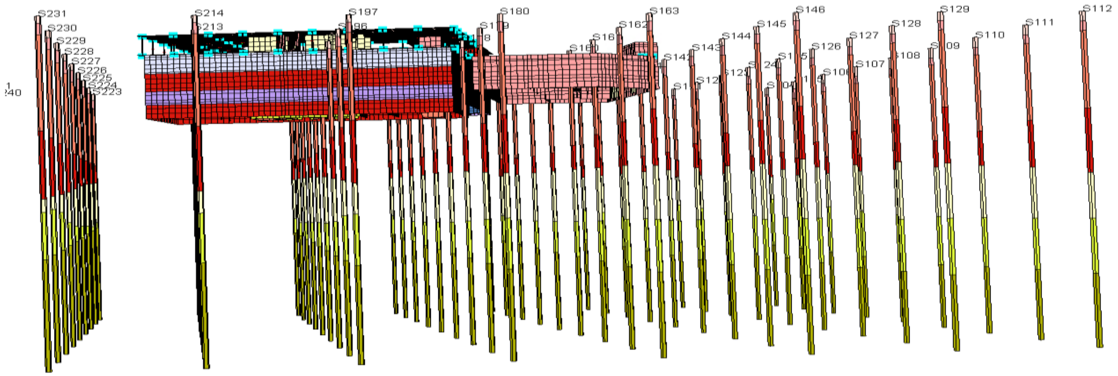


2025

BUILDING B

Input borehole database

Retrieved auxiliary boreholes applied to the new model



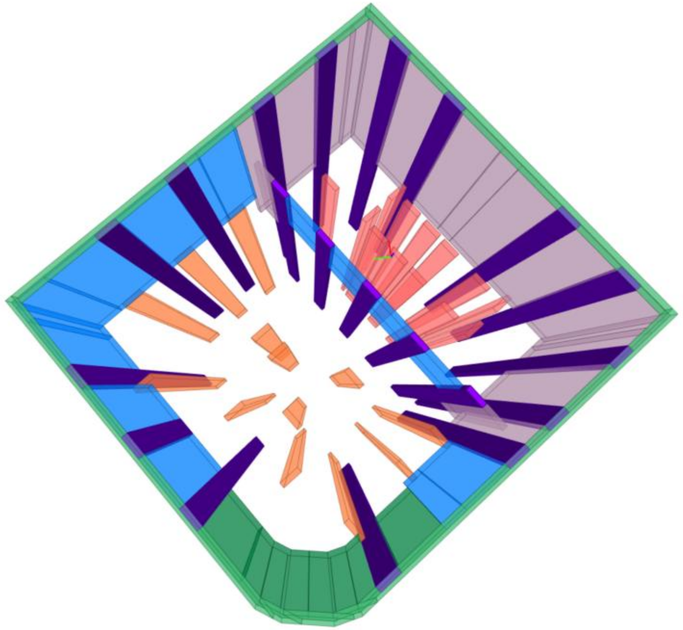
Modelling challenges

HYBRID MODELLING OF BARRETTES

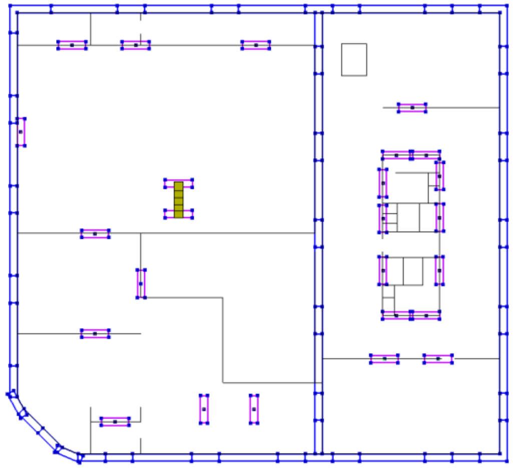
Dual role of the barrettes in the retaining and foundation systems

External barrettes

- Retaining wall
- Deep foundation
- **Explicit thick-shell elements**

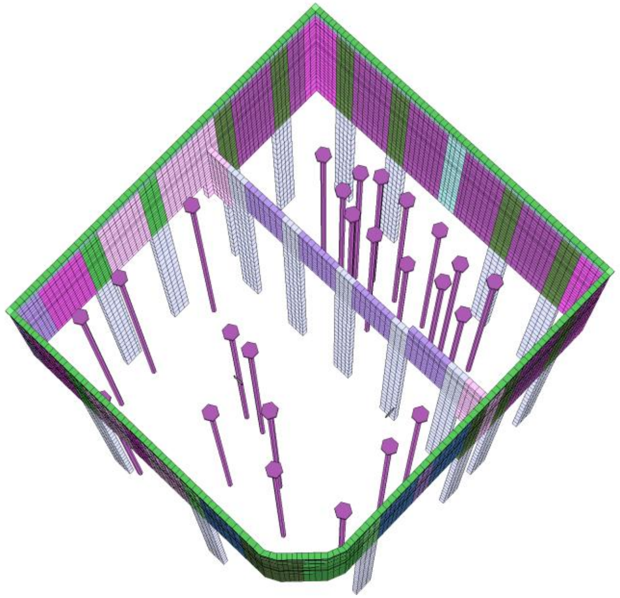


Plan view



Internal barrettes

- Deep foundation
- **Macro-pile elements with non-local formulation developed by Truty (2023)**



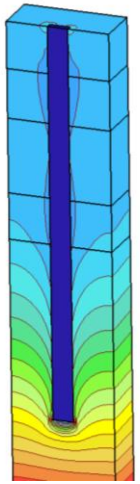
Modelling challenges

HYBRID MODELLING OF BARRETTES

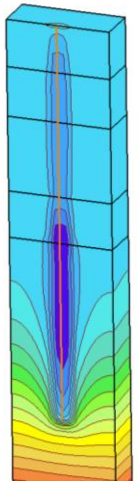
Calibration of Macro-Pile Barrettes

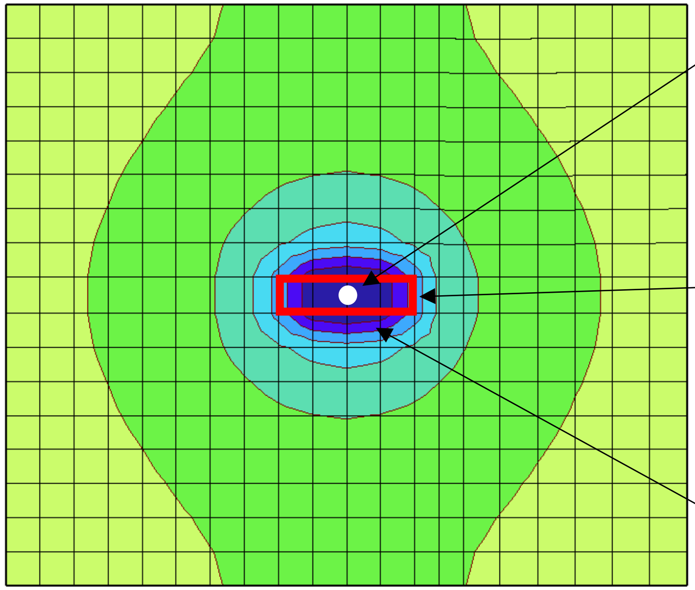
Non-local Macro-Pile formulation: the Macro-Pile element influences the finite element mesh by accounting for the effective cross-sectional area and geometry of the barrette.

Explicit geometry approach



Macro-Pile approach





Location of the Macro-Pile element with the explicit cross-section of a barrette

Outline of the explicit barrette geometry

Zone of influence obtained with the non-local formulation

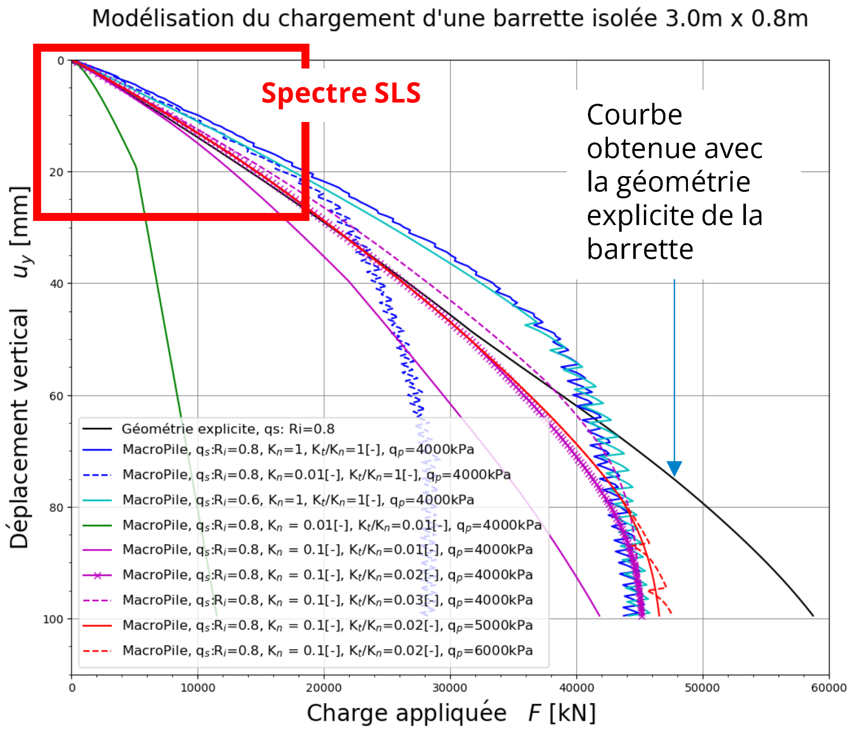
Modelling challenges

HYBRID MODELLING OF BARRETTES

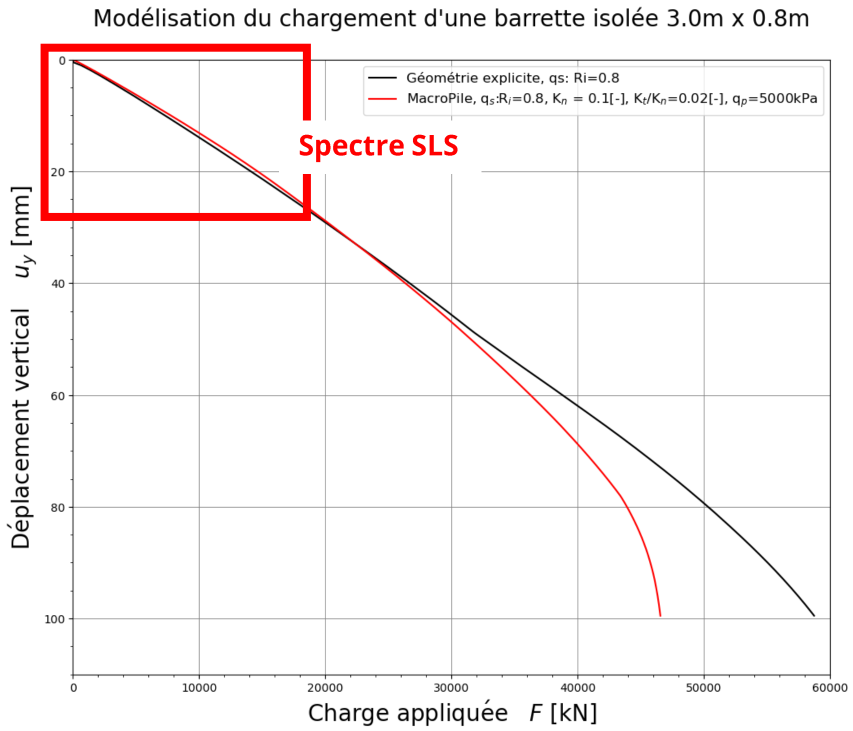
Calibration of Macro-Pile Barrettes

Single barrette load test simulation

1 PARAMETRIC STUDIES



2 BEST FIT



Modelling challenges

MODELLING OF SLURRY WALLS

Discontinuous panel layout

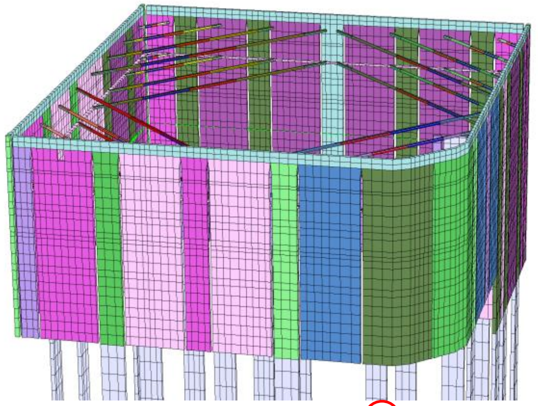
Modelling of diaphragm walls in ZSoil

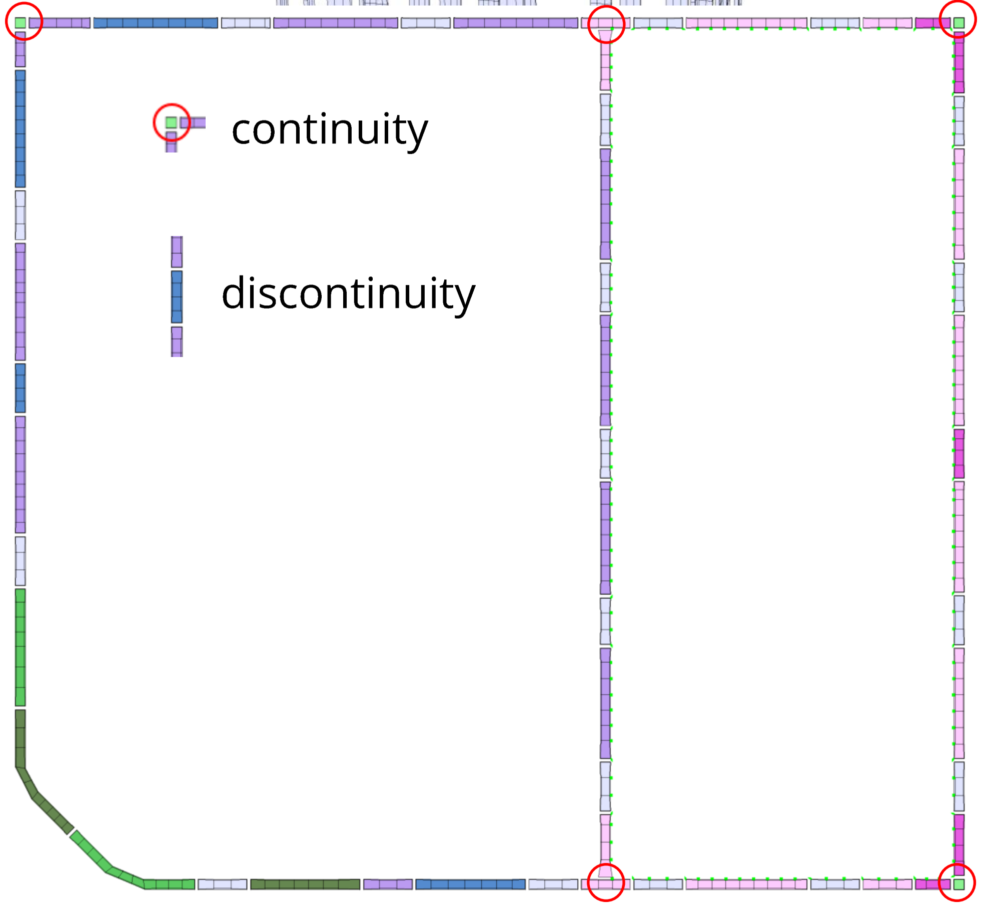
Approach 1 :
- *one-layer shells* for panels without or with *ideal or elasto-plastic hinges* for connexions

Approach 2 :
- *thick shells* for panels without discontinuities between panels

Approach 3 :
- ***thick shells* for panels with *frictional interfaces* representing discontinuities between panels**

See ZSoilDay 2023, Obrzud & Maye. Application of thick shells to model diaphragm walls in large scale 3D models.



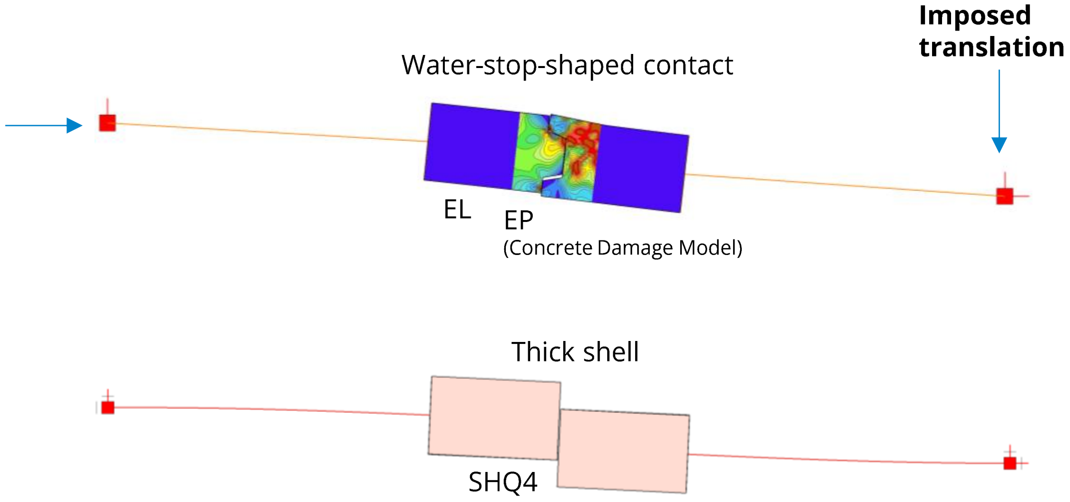


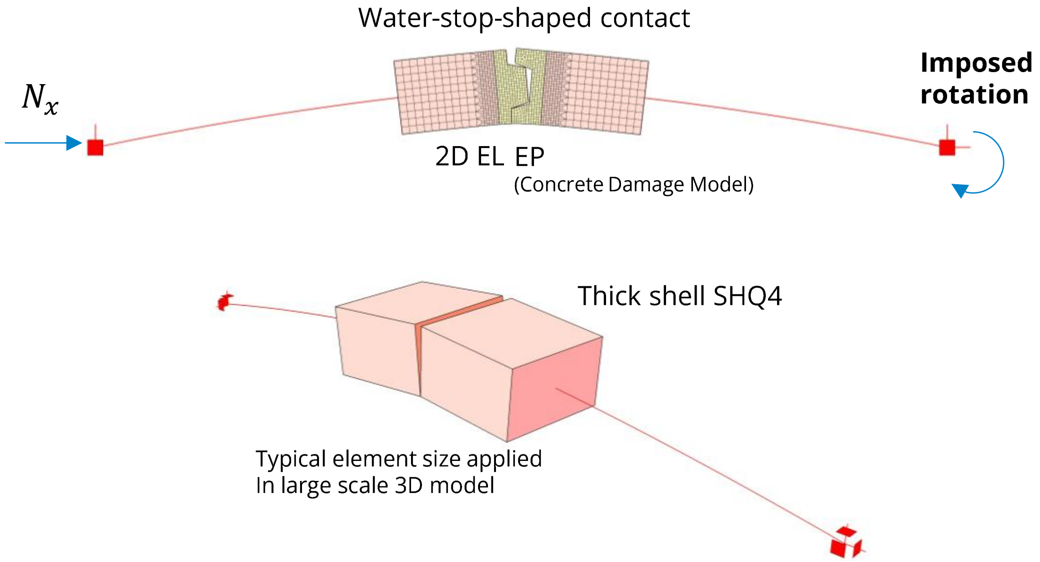
Modelling challenges

MODELLING OF SLURRY WALLS

Discontinuous panel layout

Joints are between wall panels modelled using frictional contact between thick-shell elements.





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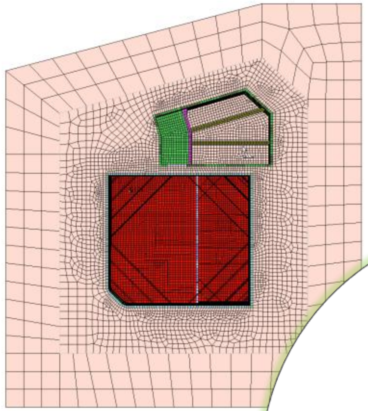
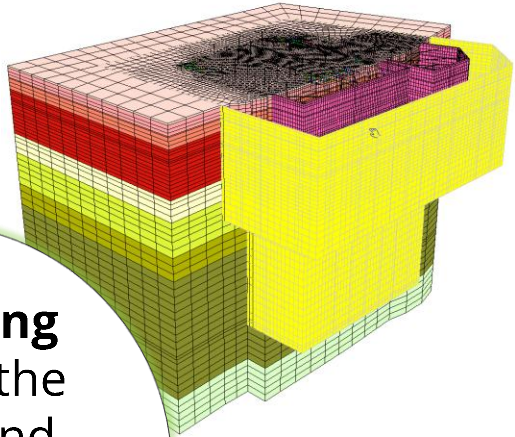
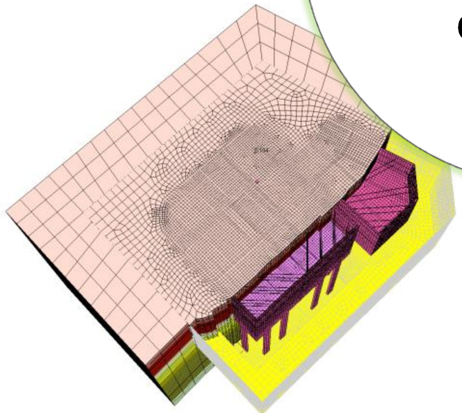
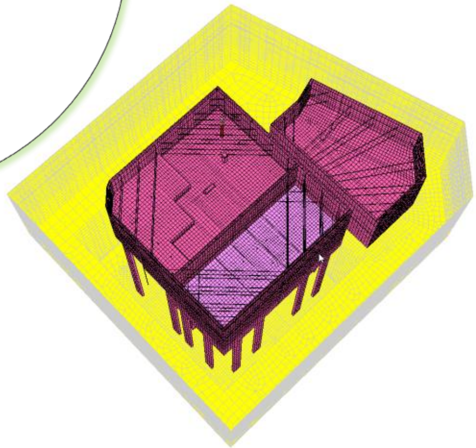
Modelling challenges

MODEL SIZE OPTIMISATION





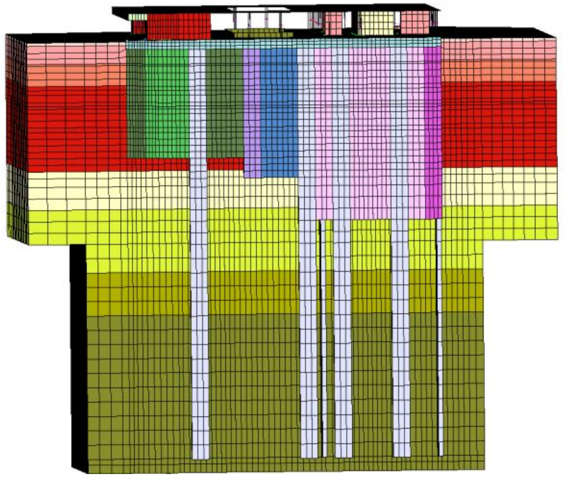




Mesh tying between the refined and coarse finite element meshes

ZONES OF INTEREST

Excavation design



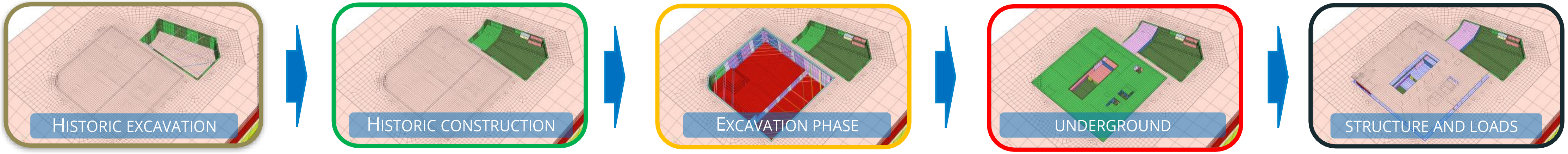
Foundation design

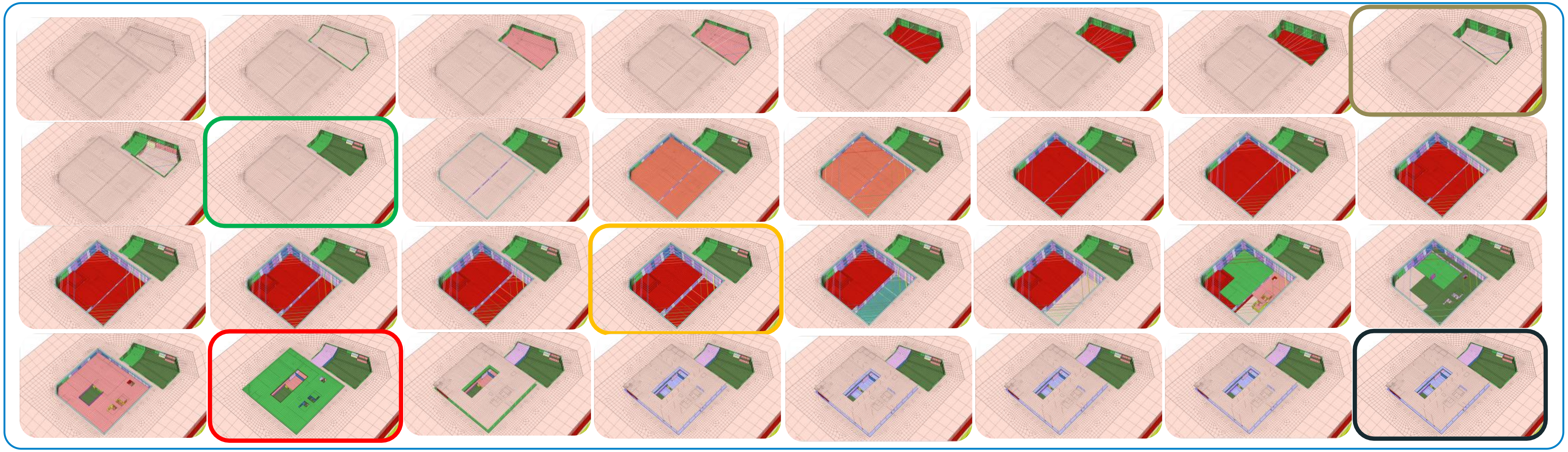
Modelling challenges

MODEL SIZE OPTIMISATION

Model size optimisation → Reasonable computing time

MORE THAN 32 CONSTRUCTION STAGES SIMULATED

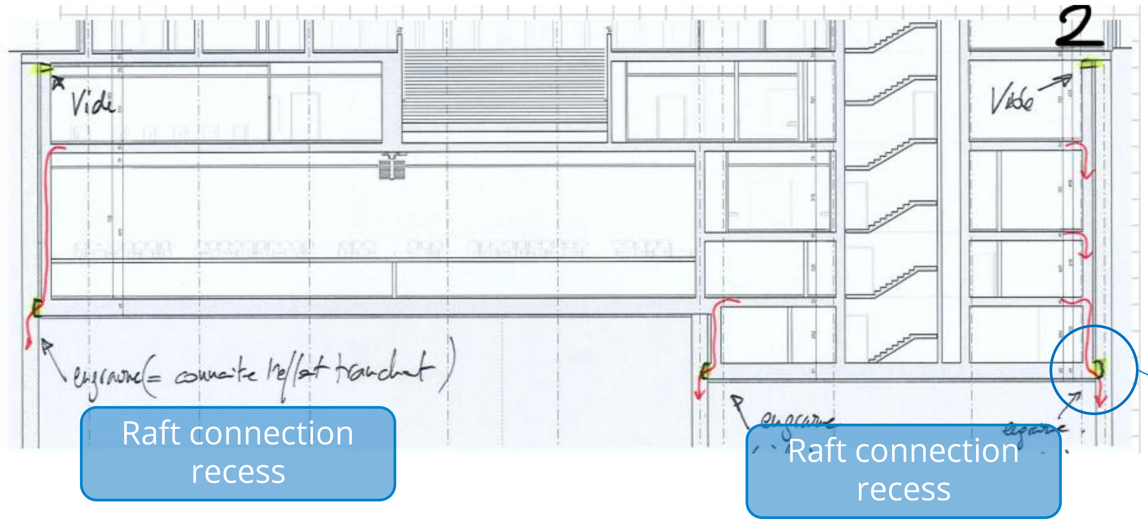


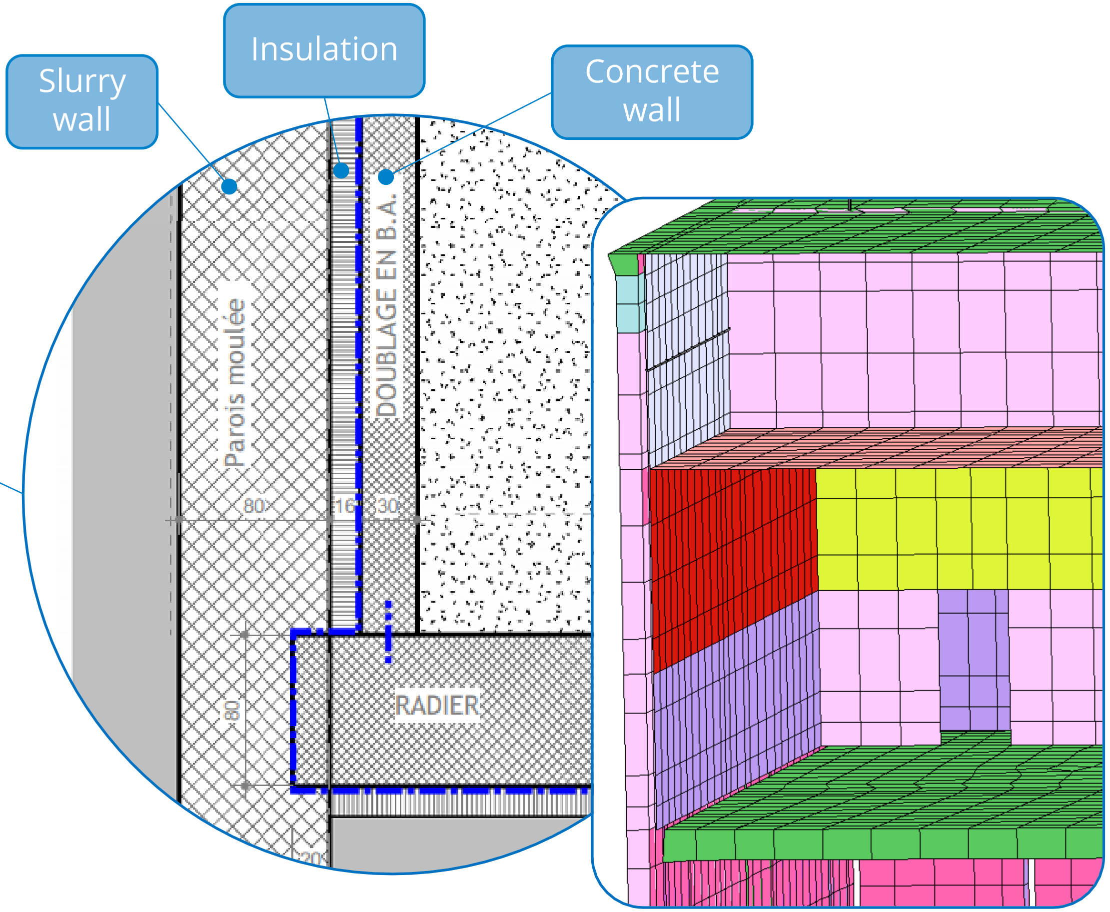


Modelling challenges

UNDERGROUND STRUCTURE

Complex load path from the superstructure to the foundations

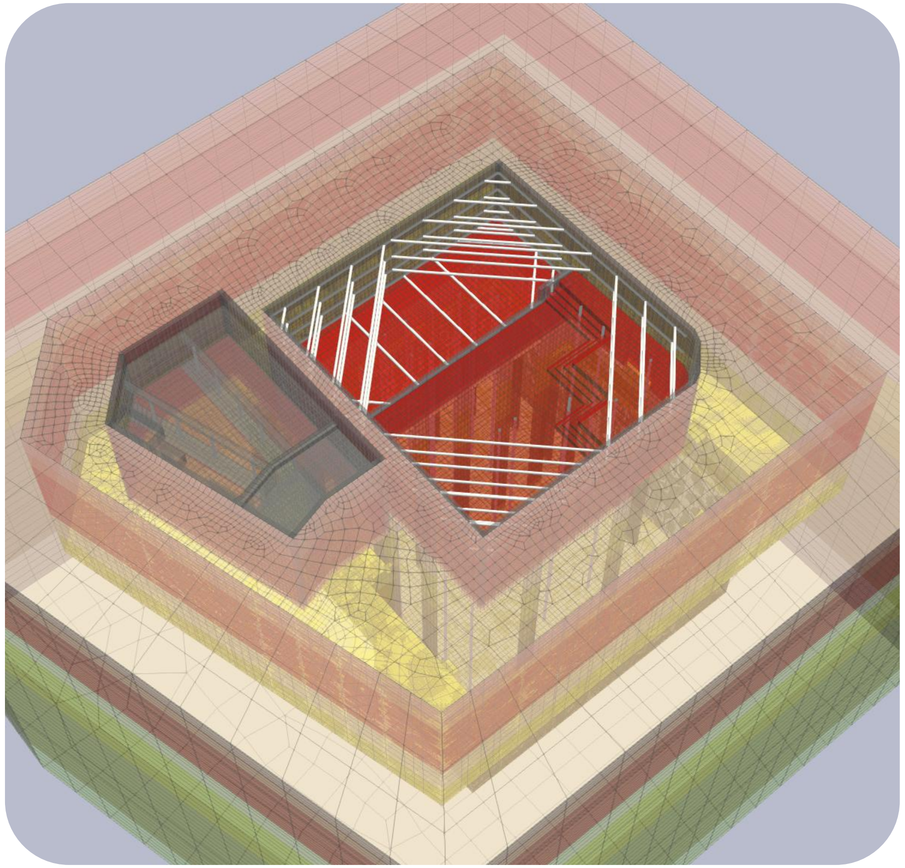


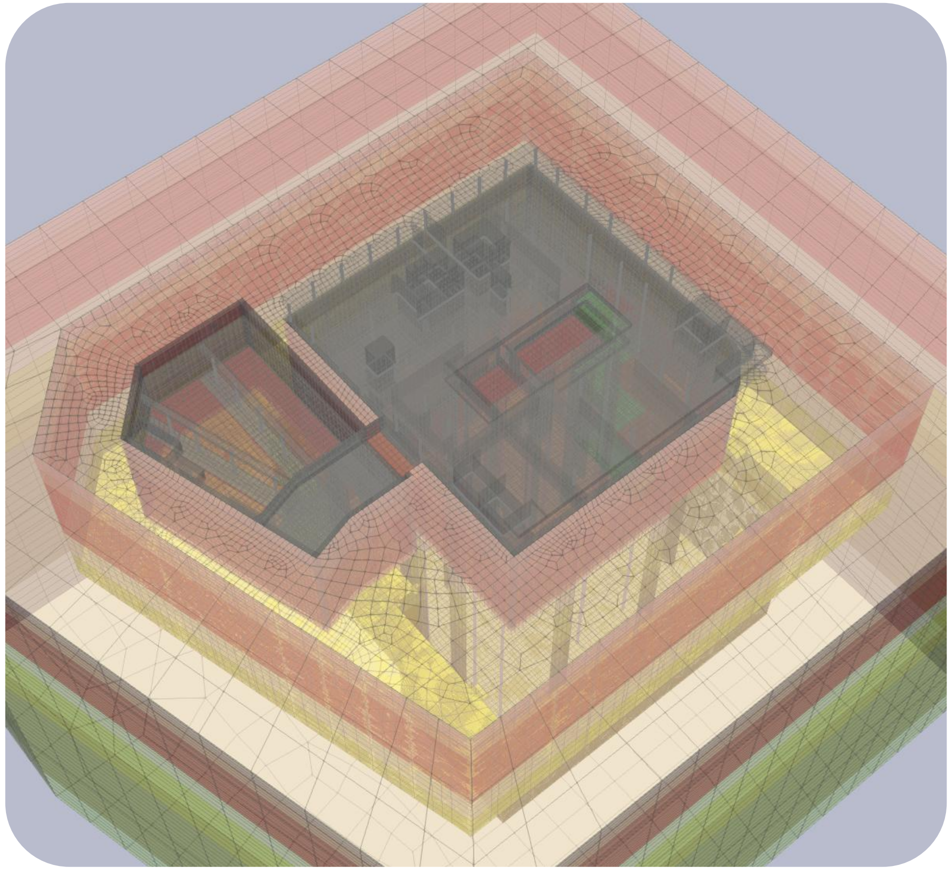


Modelling challenges

UNDERGROUND STRUCTURE

Soil-structure interaction for construction stages and long-term behaviour





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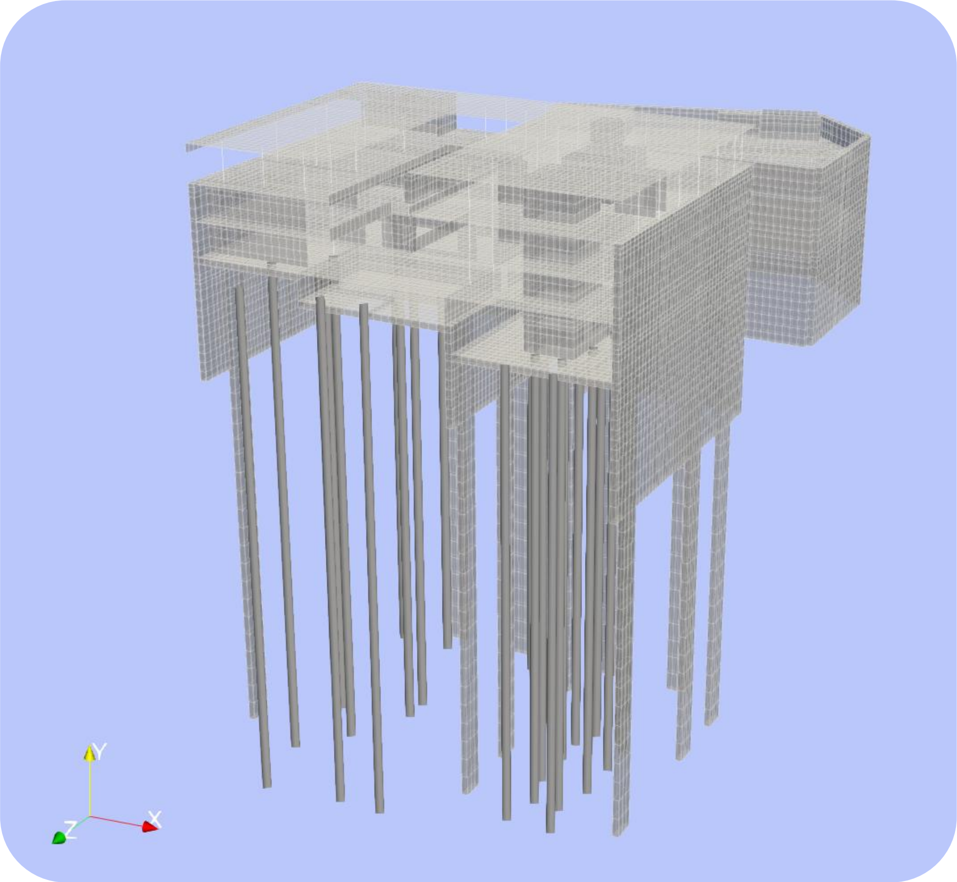
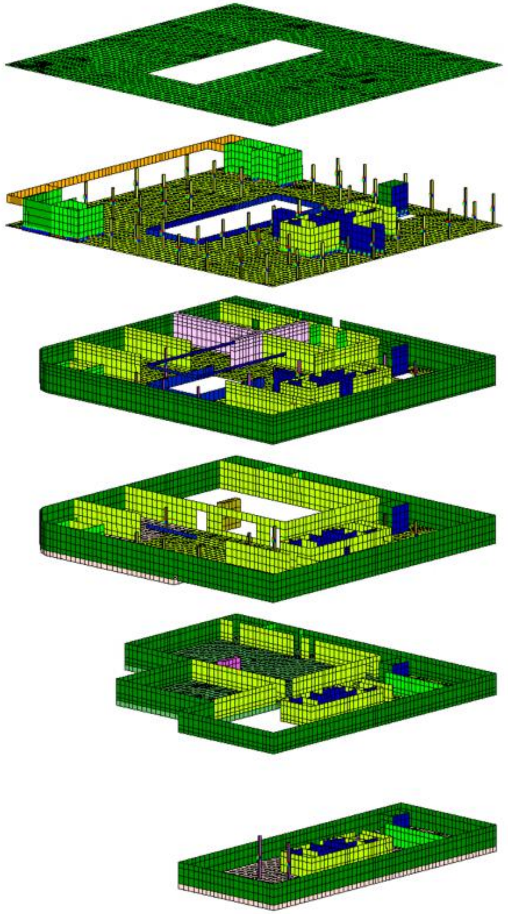


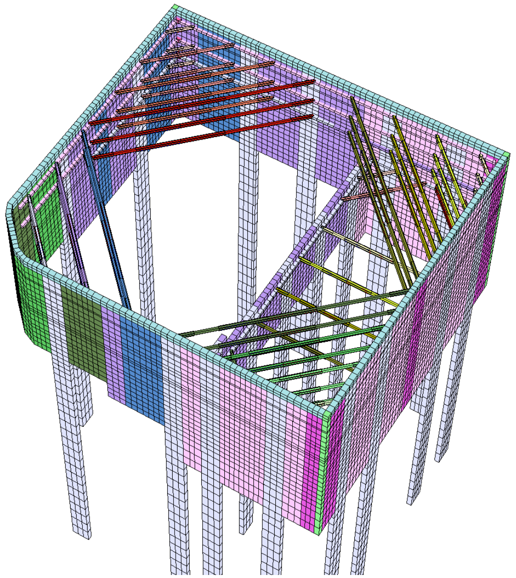


02 Unsymmetrical deep excavation

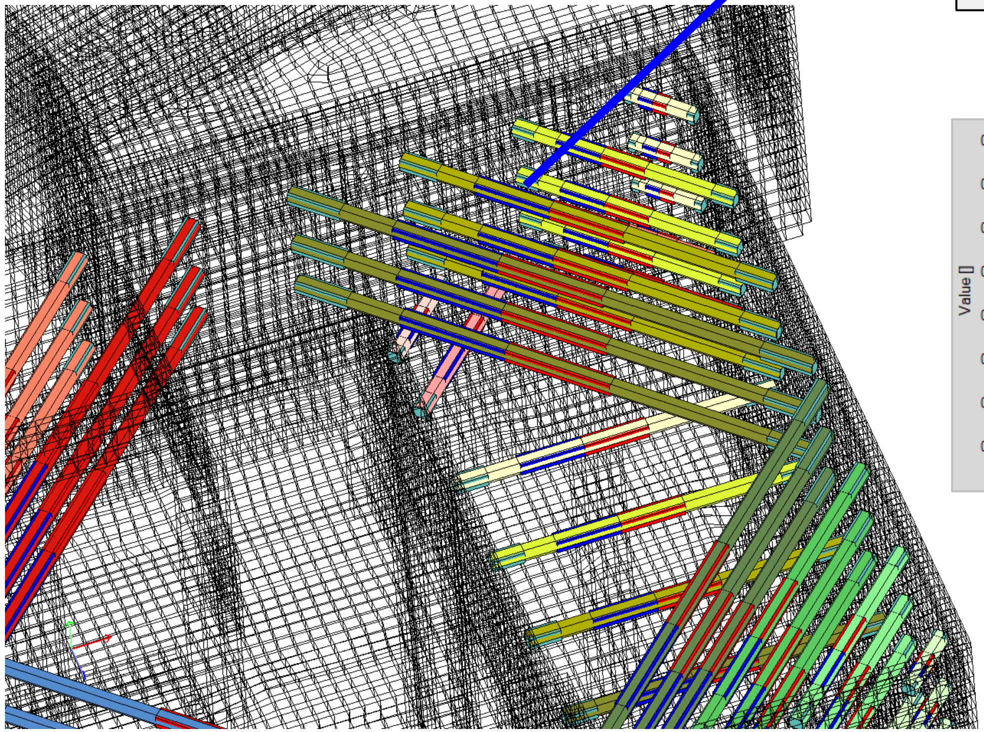
Design

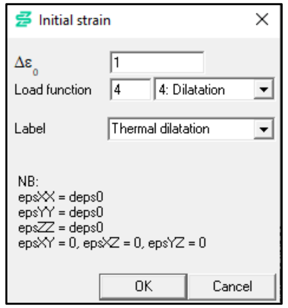
Design

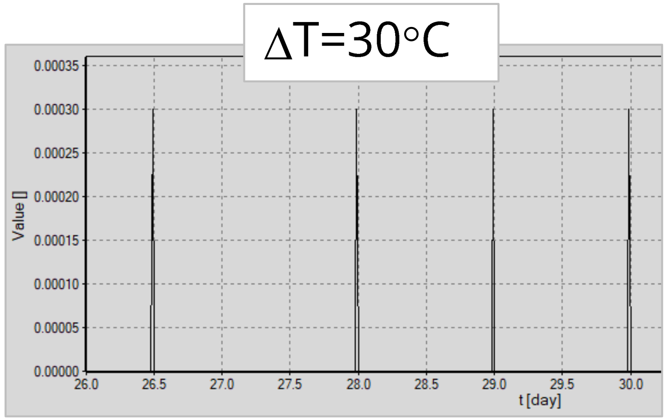
RETAINING SYSTEM



Accounting for temperature-induced forces in the strutting system

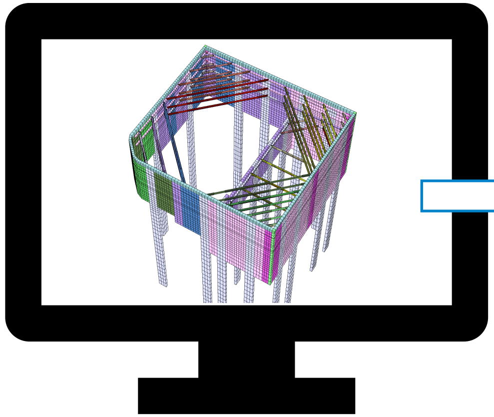


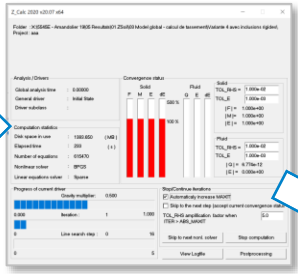




Design

RETAINING SYSTEM





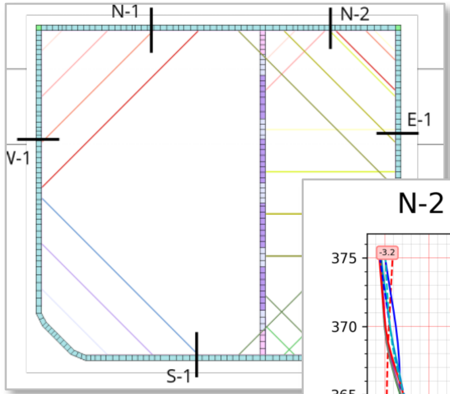
Problem-dedicated procedure

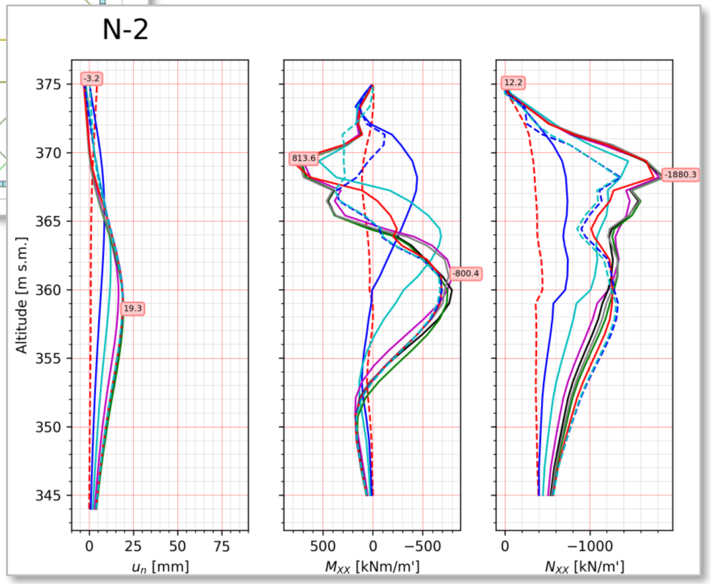
Python

ZSoil SDK

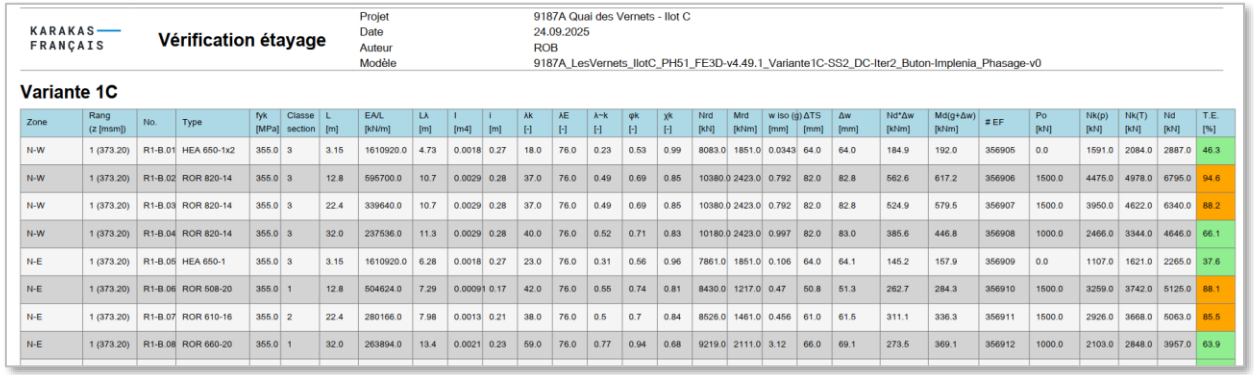
Automatic reporting

Wall design





Strut design



KARAKAS FRANÇAIS

Vérification étayage

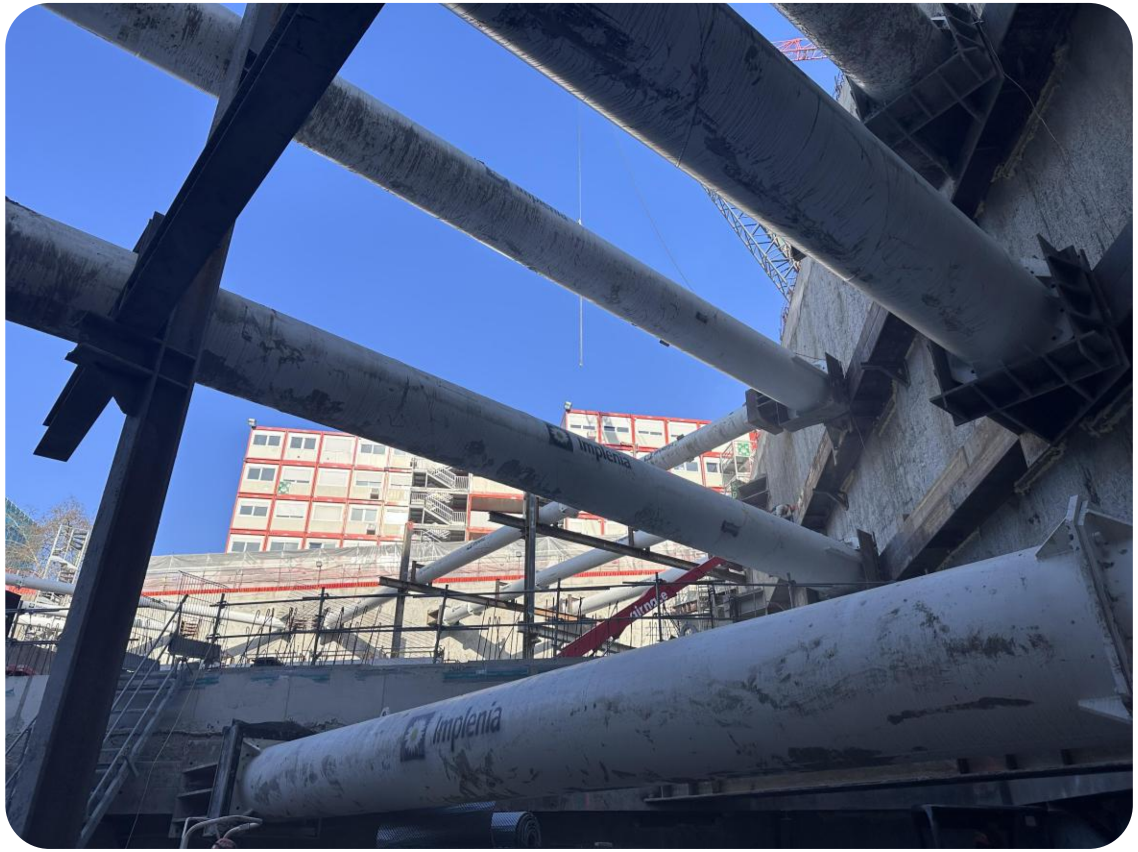
Projet 9187A Quai des Vernets - Ilot C
Date 24.09.2025
Auteur ROB
Modèle 9187A_LesVernets_IlotC_PH51_FE3D-v4.49.1_Variante1C-SS2_DC-Iter2_Buton-Implenia_Phasage-v0

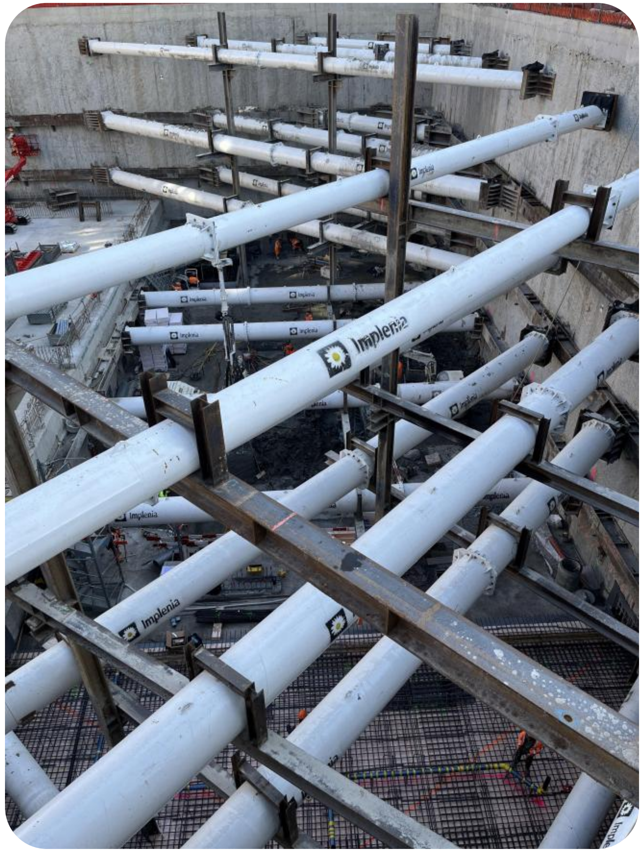
Variante 1C

Zone	Rang (z [msm])	No.	Type	fyk [MPa]	Classe section	L [m]	EA/L [kN/m]	Lλ [m]	I [m4]	i [m]	λk [-]	λE [-]	λ~k [-]	φk [-]	χk [-]	Nrd [kN]	Mrd [kNm]	w iso (g) [mm]	ΔTS [mm]	Δw [mm]	Nd*Δw [kNm]	Md(g+Δw) [kNm]	# EF	Po [kN]	Nk(p) [kN]	Nk(T) [kN]	Nd [kN]	T.E. [%]
N-W	1 (373.20)	R1-B.01	HEA 650-1x2	355.0	3	3.15	1610920.0	4.73	0.0018	0.27	18.0	76.0	0.23	0.53	0.99	8083.0	1851.0	0.0343	64.0	64.0	184.9	192.0	356905	0.0	1591.0	2084.0	2887.0	46.3
N-W	1 (373.20)	R1-B.02	ROR 820-14	355.0	3	12.8	595700.0	10.7	0.0029	0.28	37.0	76.0	0.49	0.69	0.85	10380.0	2423.0	0.792	82.0	82.8	562.6	617.2	356906	1500.0	4475.0	4978.0	6795.0	94.6
N-W	1 (373.20)	R1-B.03	ROR 820-14	355.0	3	22.4	339640.0	10.7	0.0029	0.28	37.0	76.0	0.49	0.69	0.85	10380.0	2423.0	0.792	82.0	82.8	524.9	579.5	356907	1500.0	3950.0	4622.0	6340.0	88.2
N-W	1 (373.20)	R1-B.04	ROR 820-14	355.0	3	32.0	237536.0	11.3	0.0029	0.28	40.0	76.0	0.52	0.71	0.83	10180.0	2423.0	0.997	82.0	83.0	385.6	446.8	356908	1000.0	2466.0	3344.0	4646.0	66.1
N-E	1 (373.20)	R1-B.05	HEA 650-1	355.0	3	3.15	1610920.0	6.28	0.0018	0.27	23.0	76.0	0.31	0.56	0.96	7861.0	1851.0	0.106	64.0	64.1	145.2	157.9	356909	0.0	1107.0	1621.0	2265.0	37.6
N-E	1 (373.20)	R1-B.06	ROR 508-20	355.0	1	12.8	504624.0	7.29	0.00091	0.17	42.0	76.0	0.55	0.74	0.81	8430.0	1217.0	0.47	50.8	51.3	262.7	284.3	356910	1500.0	3259.0	3742.0	5125.0	88.1
N-E	1 (373.20)	R1-B.07	ROR 610-16	355.0	2	22.4	280166.0	7.98	0.0013	0.21	38.0	76.0	0.5	0.7	0.84	8526.0	1461.0	0.456	61.0	61.5	311.1	336.3	356911	1500.0	2926.0	3668.0	5063.0	85.5
N-E	1 (373.20)	R1-B.08	ROR 660-20	355.0	1	32.0	263894.0	13.4	0.0021	0.23	59.0	76.0	0.77	0.94	0.68	9219.0	2111.0	3.12	66.0	69.1	273.5	369.1	356912	1000.0	2103.0	2848.0	3957.0	63.9

Design

RETAINING SYSTEM

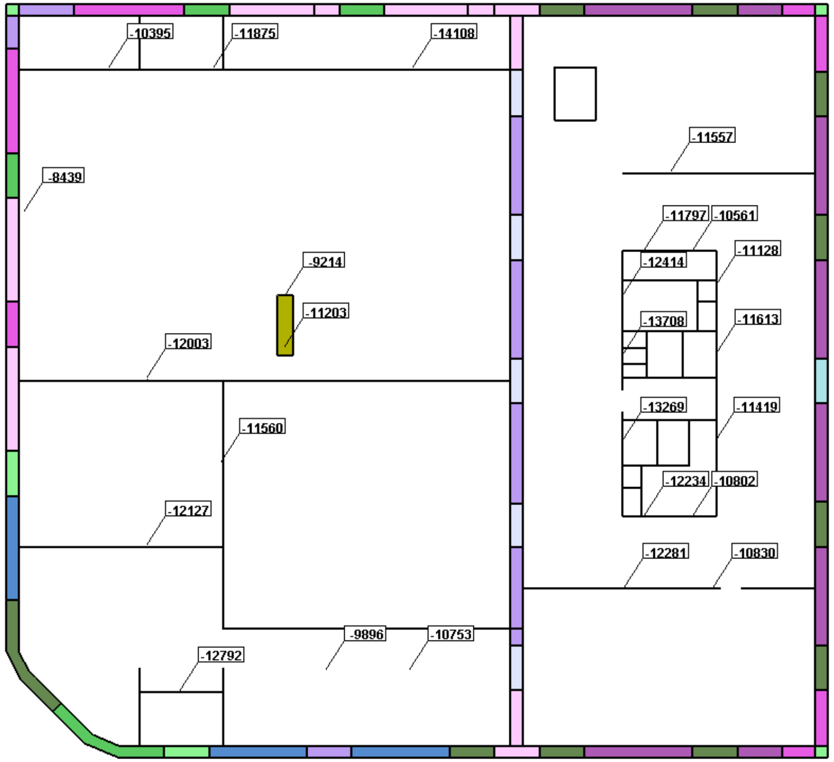


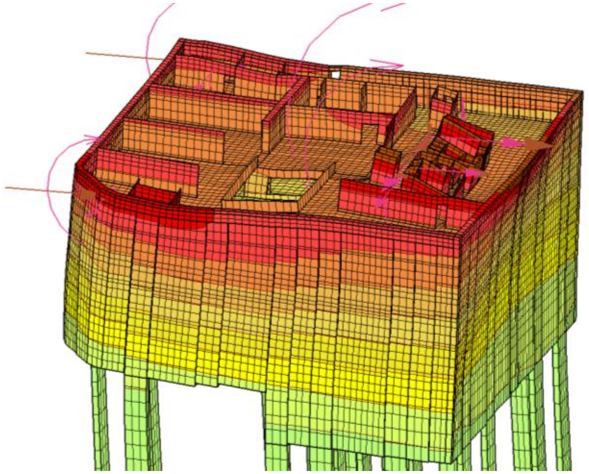


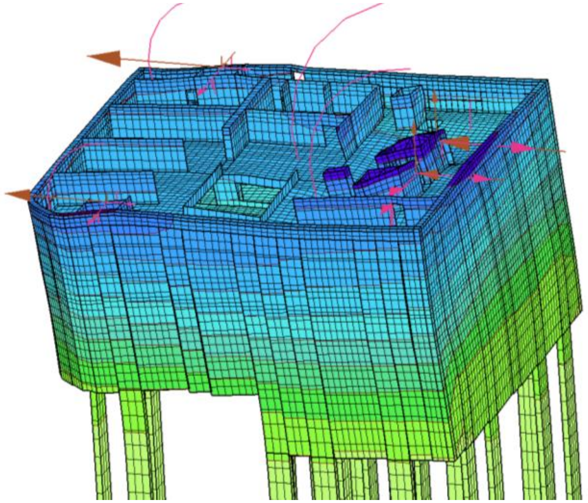
Design

BARRETTES

- Application of different load combinations including seismic effects







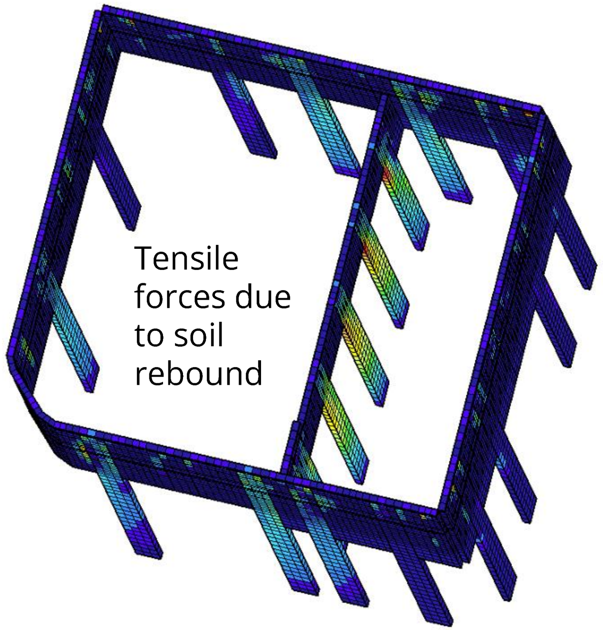
Design

BARRETTES

- Barrettes executed from the terrain surface

⇩

- Design for tensile forces induced by soil elastic heave and shaft friction

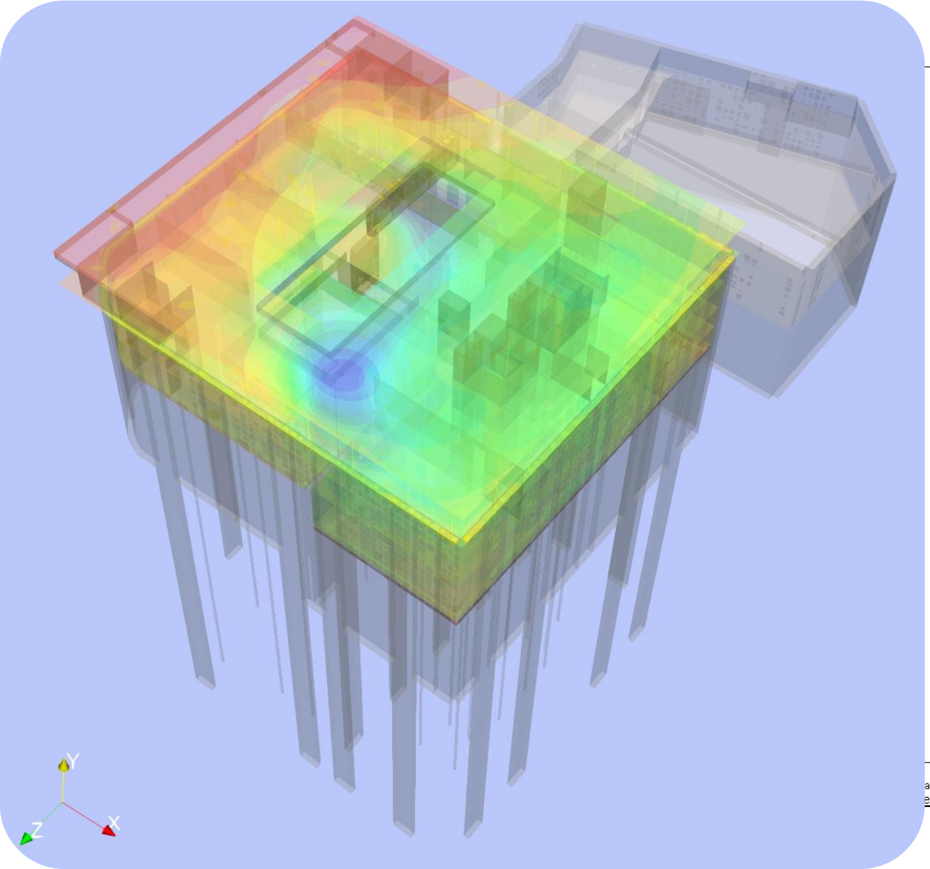


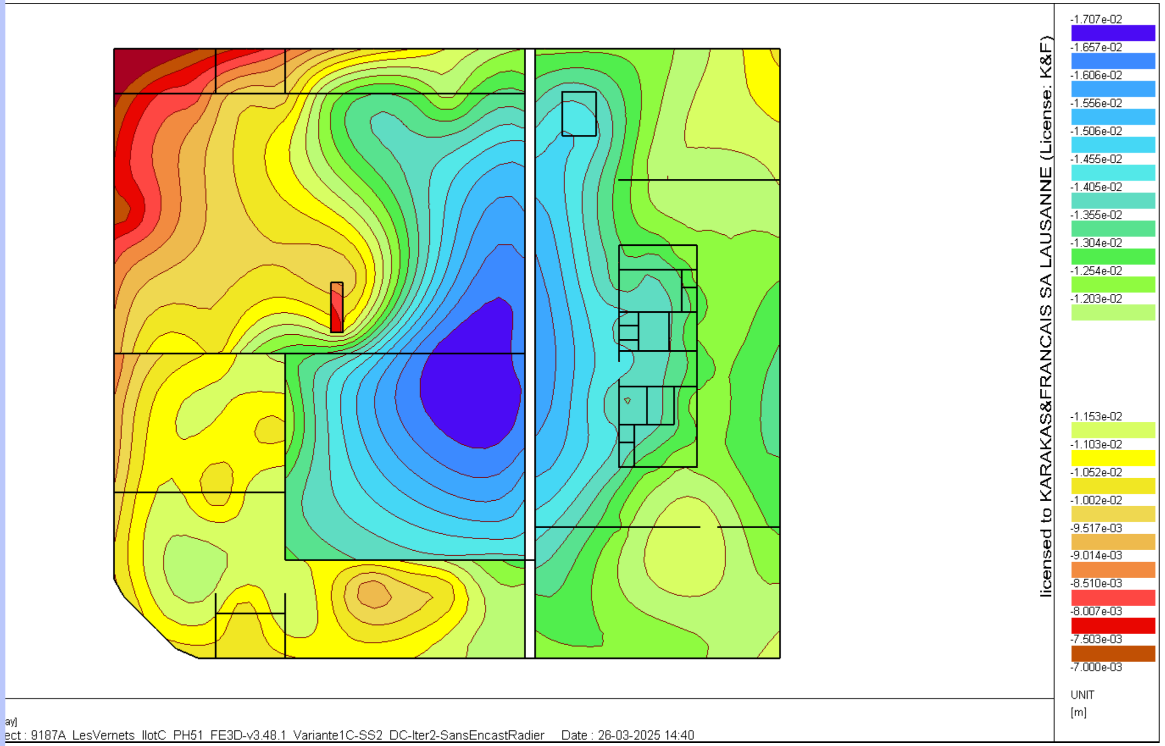
Barrette with exposed reinforcement after trimming to the cut-off level

Design

SETTLEMENT

Soil-structure interaction for construction stages and long-term behaviour





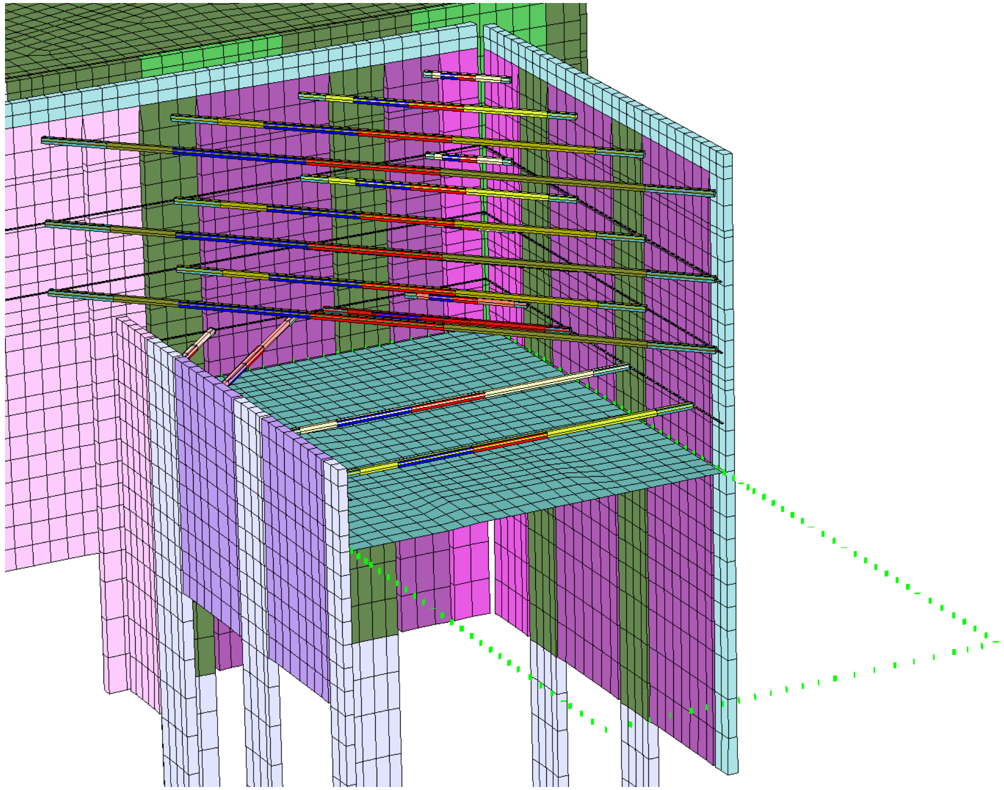
02 Unsymmetrical deep excavation

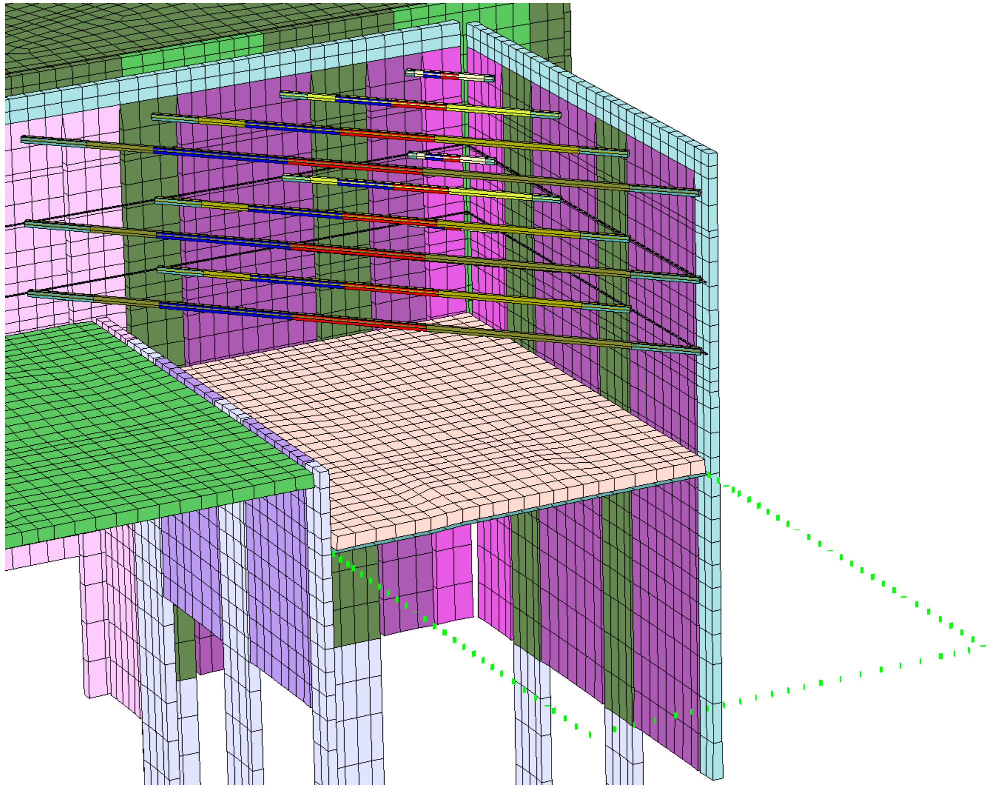
Savings

Savings

SUB-RAFT STIFFENING SLAB

Is the stiffening slab necessary ?

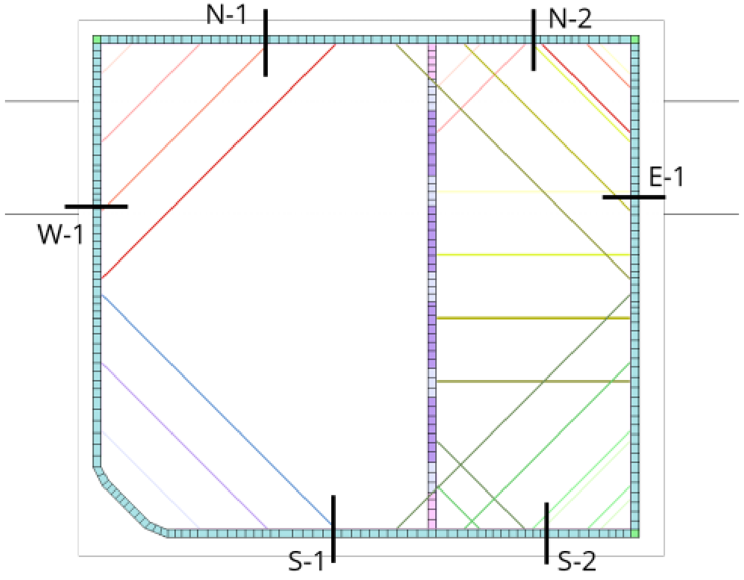




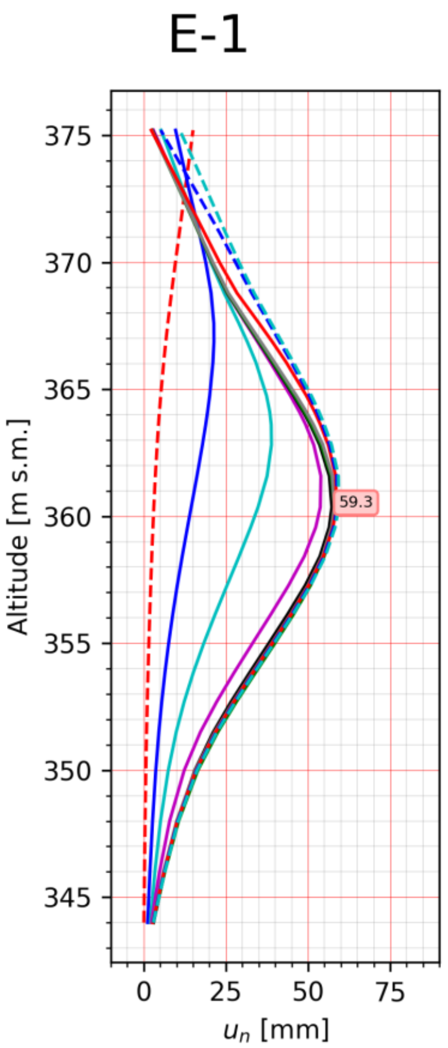
Savings

SUB-RAFT STIFFENING SLAB

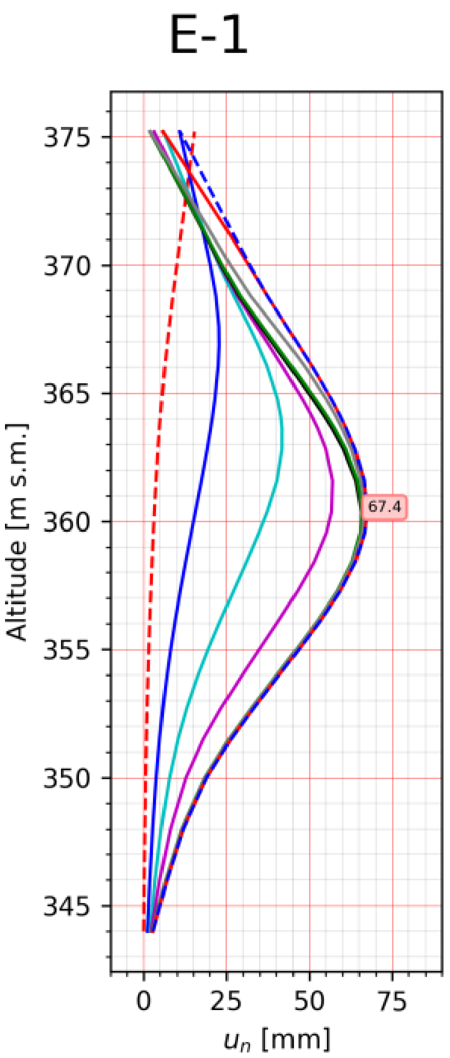
Is the stiffening slab necessary ?



with



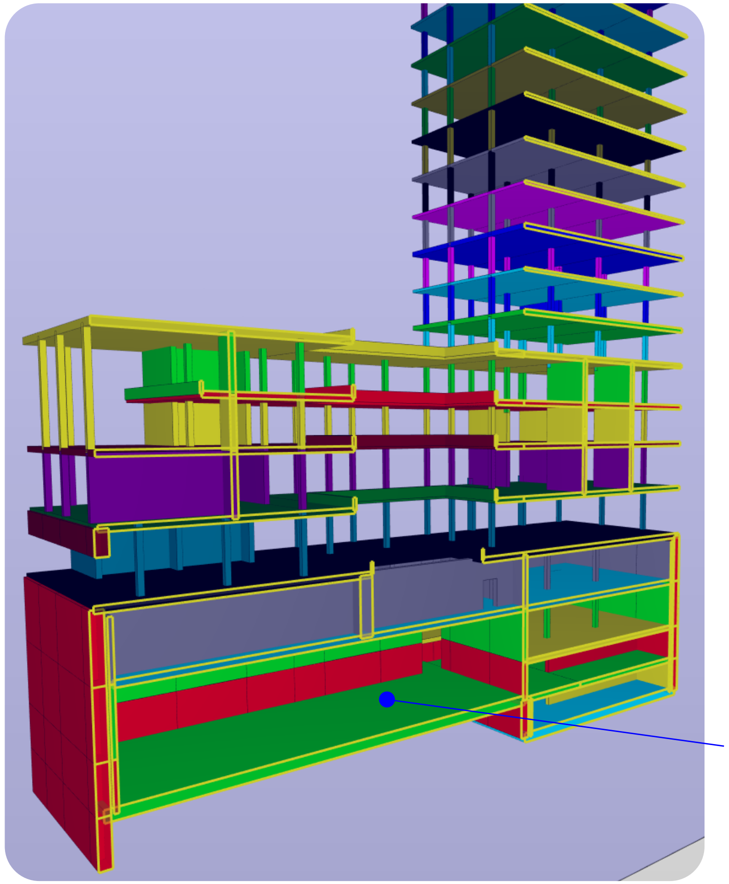
w/o



Savings

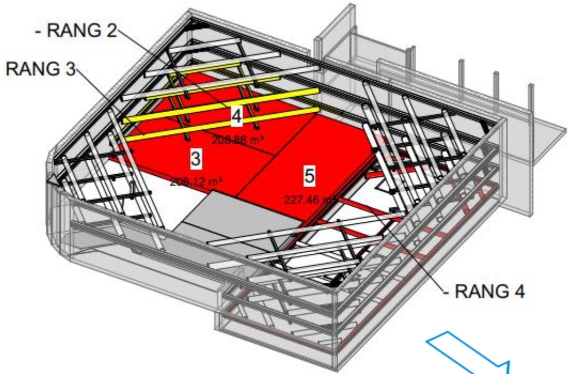
PLANNING

Can strut removal be executed earlier in the north corner ?

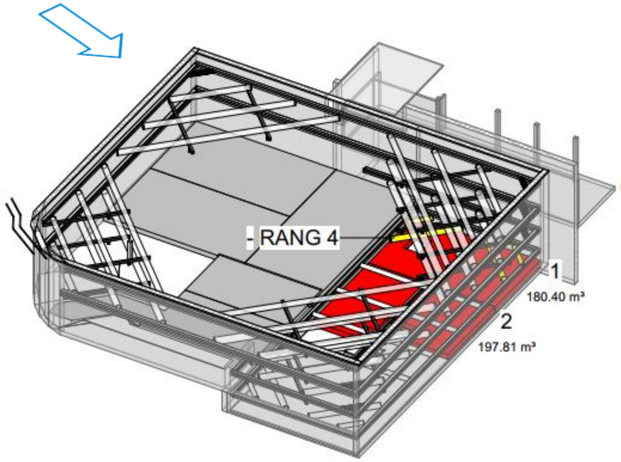


2 level-high
auditorium

Intended strut removal – Levels 2 & 3 – North corner



Asymmetric active
earth pressure

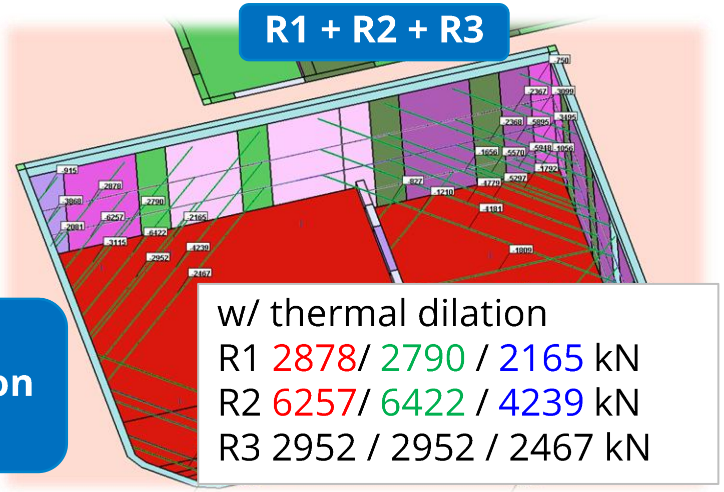


Savings

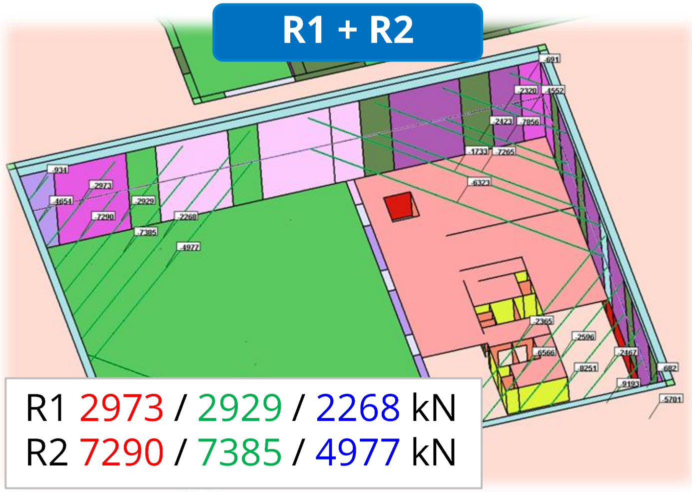
PLANNING

R1 + R2 + R3 | **R1 + R2** | **R1**

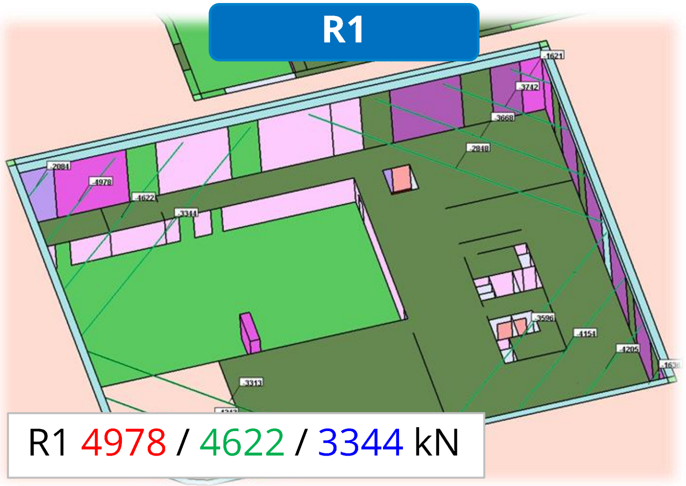
Original construction sequence



w/ thermal dilation
R1 2878/ 2790 / 2165 kN
R2 6257/ 6422 / 4239 kN
R3 2952 / 2952 / 2467 kN

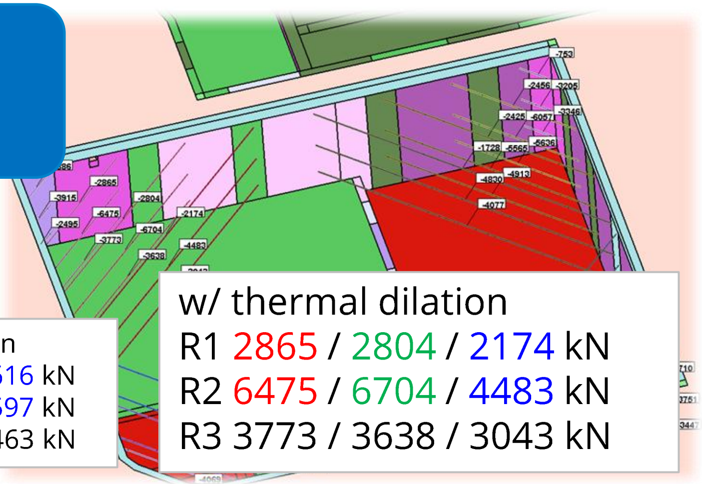


R1 2973 / 2929 / 2268 kN
R2 7290 / 7385 / 4977 kN



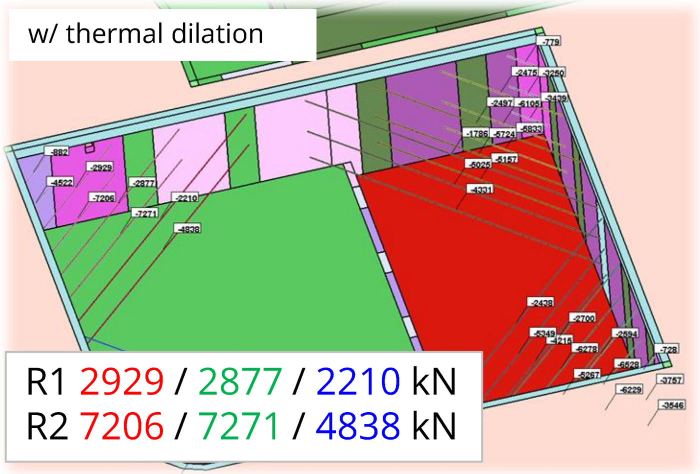
R1 4978 / 4622 / 3344 kN

Optimized sequence

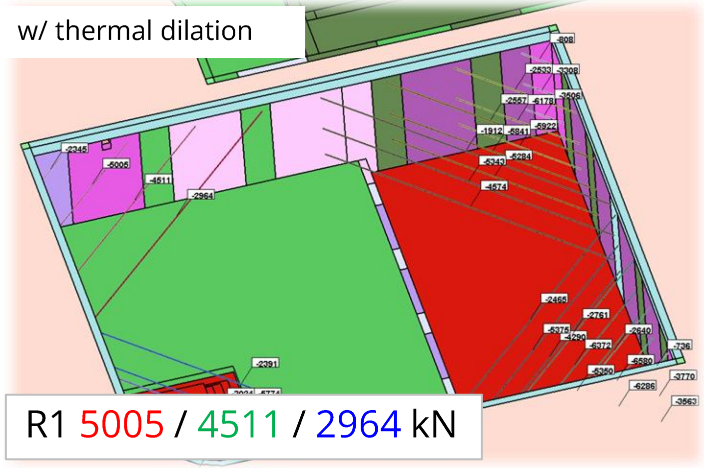


w/o thermal dilation
R1 2574 / 2421 / 1616 kN
R2 6101 / 6016 / 3597 kN
R3 2454 / 2120 / 1463 kN

w/ thermal dilation
R1 2865 / 2804 / 2174 kN
R2 6475 / 6704 / 4483 kN
R3 3773 / 3638 / 3043 kN



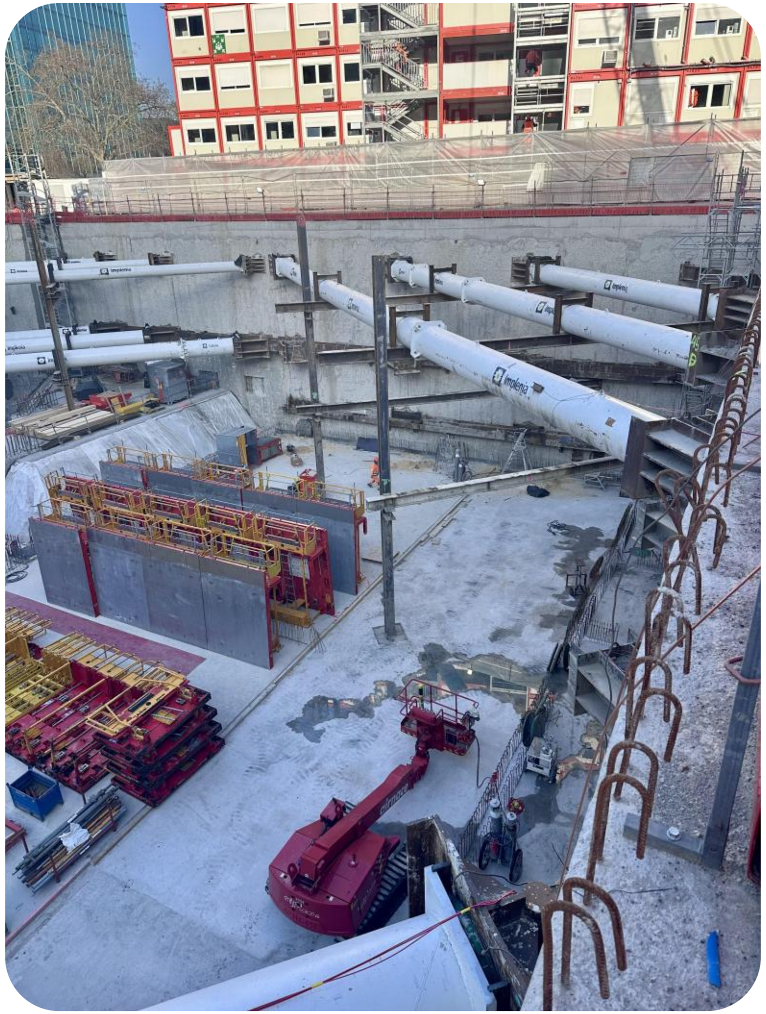
w/ thermal dilation
R1 2929 / 2877 / 2210 kN
R2 7206 / 7271 / 4838 kN

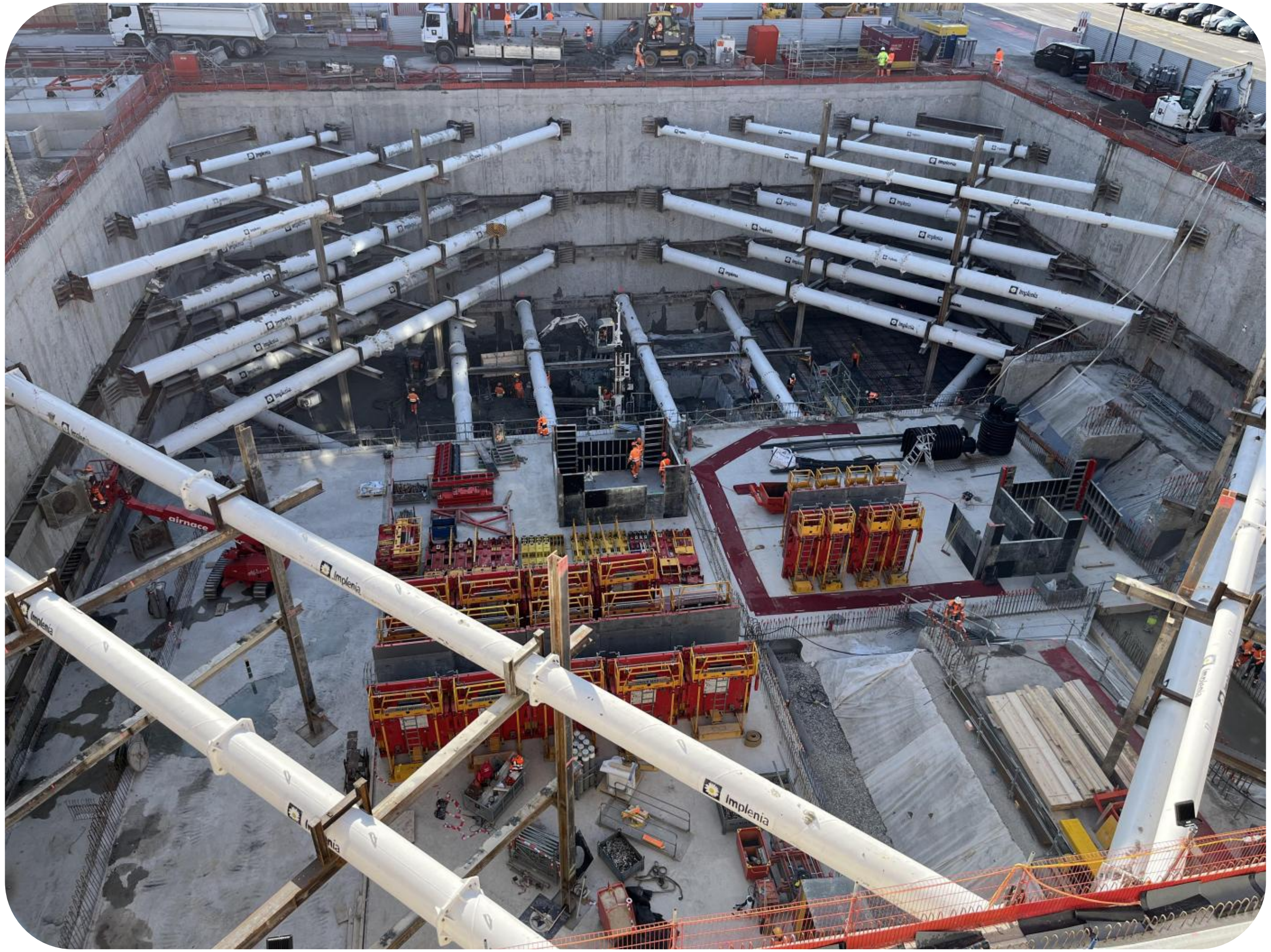


w/ thermal dilation
R1 5005 / 4511 / 2964 kN

Savings

PLANNING





03 Monitoring

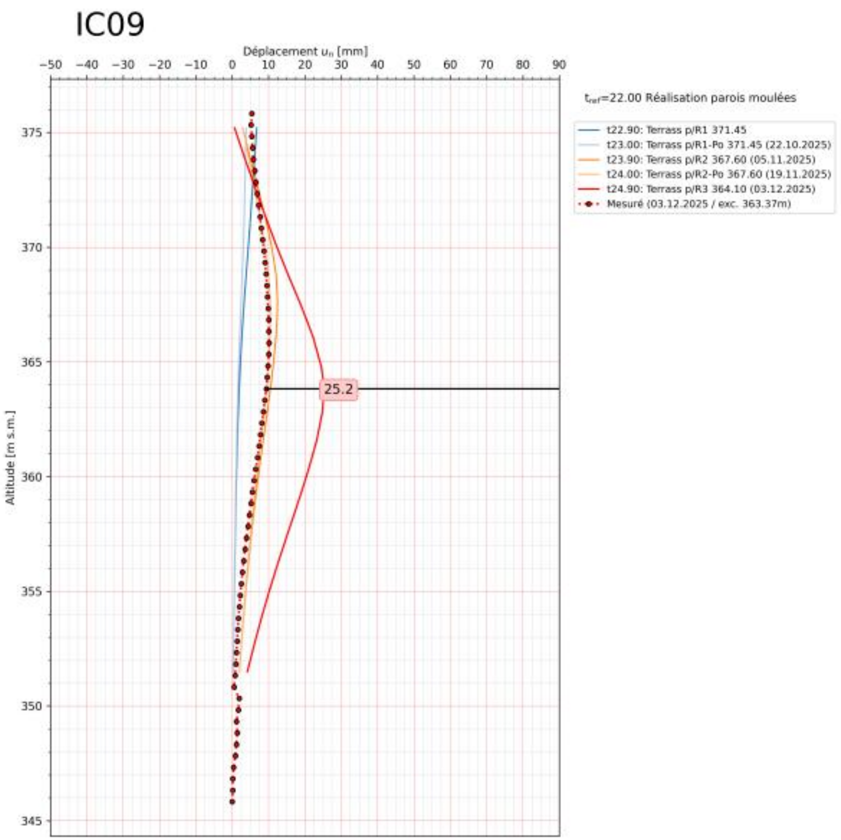
Monitoring

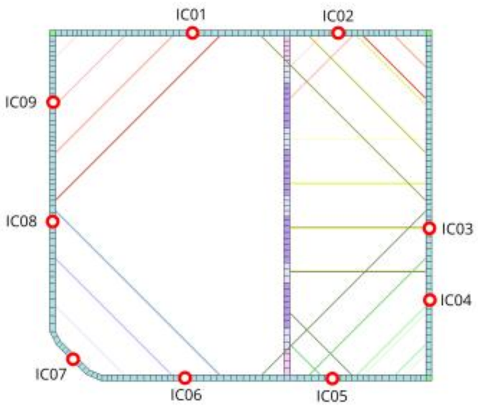
- **9 inclinometers**
  → Monitoring of diaphragm wall displacements
- **Pressure cells at strut supports**
  → Manual monitoring of strut forces and their evolution over time
- **Automatic strain-gauge measurements on the struts**
  → Continuous monitoring of axial forces during excavation and construction

Monitoring

INCLINOMETERS

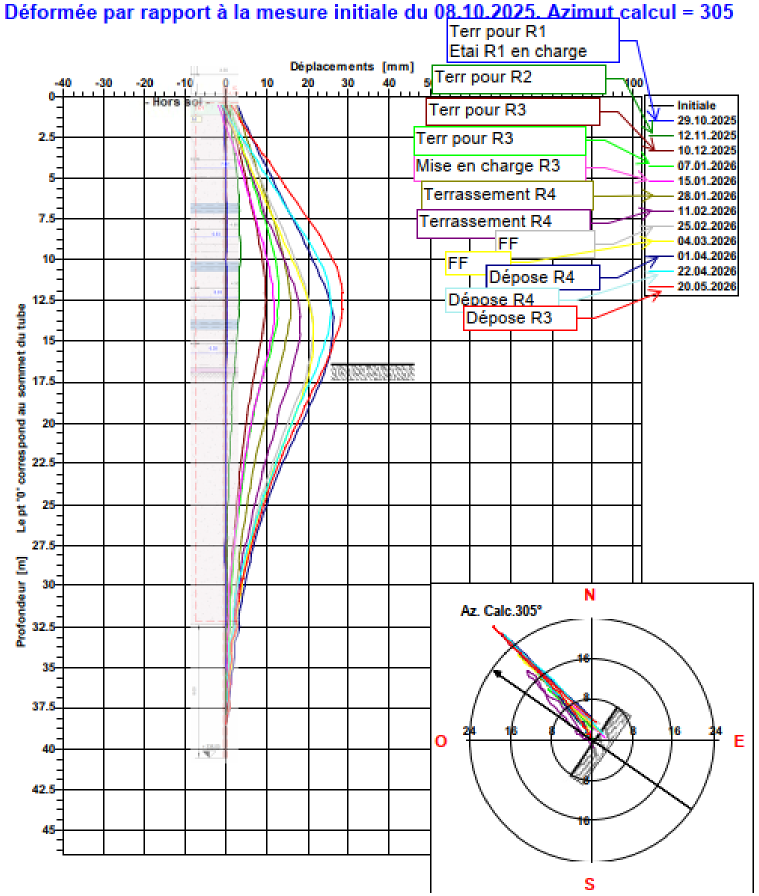
KARAKAS— FRANÇAIS	Auscultation de déformation des parois	Projet	9187A Quai de Vernets - Ilot C
		Date	10.12.2025
		Auteur	ROB
		Modèle	v4.49.2 QVC-Variante 1C-Phasage 1

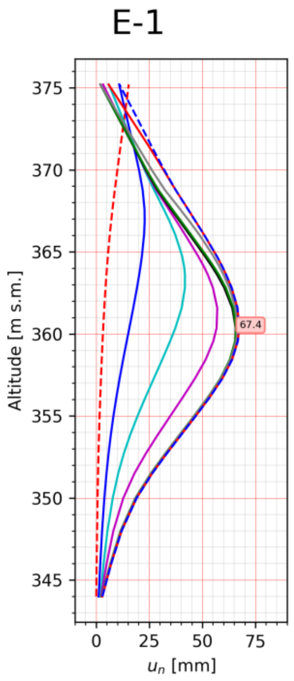




Monitoring

INCLINOMETERS





04 Final remarks

Conclusions

FROM NUMERICAL MODEL TO ENGINEERING DECISION

01 **Integrated 3D modelling**
Complex geometry and construction stages in a unified framework
→ **RELIABLE DESIGN**

02 **Multiple interacting phenomena**
Soil, structure, excavation and foundations in a single model
→ **CONSISTENT ASSESSMENT**

03 **Numerical analysis**
Understanding mechanisms, critical stages and load transfer
→ **ENGINEERING INSIGHT**

04 **Alternative scenarios**
Comparison and optimisation before implementation
→ **OPTIMISATION & SAVINGS**

05 **Predictions + monitoring**
Numerical predictions confronted with field measurements
→ **CONFIDENCE IN PERFORMANCE**

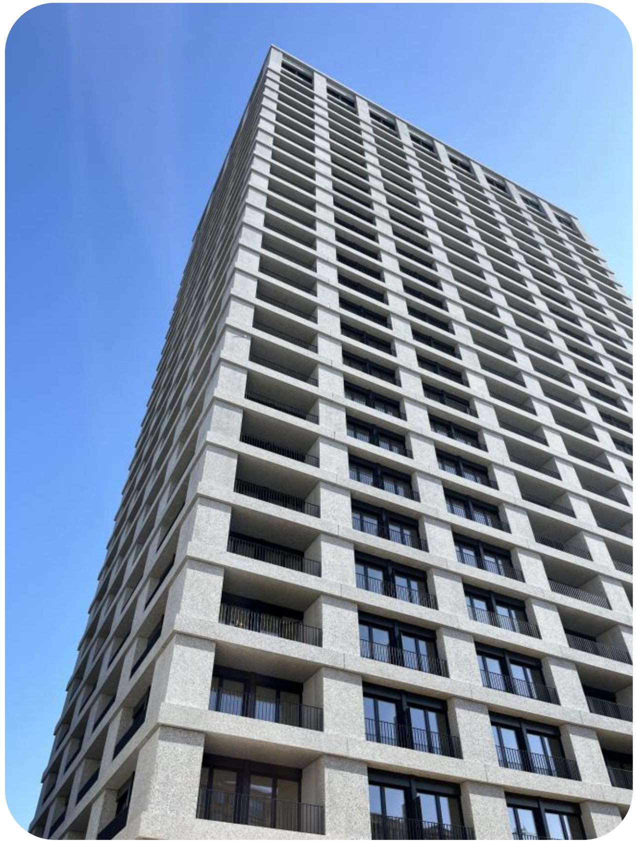
ZSoil **as a design and decision-support tool — not only a verification tool.**

Acknowledgment

Our sincere thanks to LOSINGER MARAZZI for their trust in KARAKAS FRANÇAIS and for giving us the opportunity to provide geotechnical support for this challenging project from design through construction.

My sincere thanks to **Matthias Lanza** for his expertise, support and excellent collaboration throughout this part of the project.

Special thanks to **Thibaud Meynet** for his exceptional project leadership and coordination of the geotechnical design for all four buildings.



merci

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