

# XVIII EUROPEAN CONFERENCE ON SOIL MECHANICS AND GEOTECHNICAL ENGINEERING

August 26th to August 30th 2024 – Lisbon, Portugal

## Session A9

Theme A: Piles

593 Combined pile-raft and raft foundation modelling and design for three distinct office buildings in Lisbon, Portugal

A. Sousa, A. Pinto, N. Silva; Presenting Author: André Sousa

## Session A10

Theme A: Modelling; Education

233 Use of BIM methodology in Geotechnical Projects – Construction of underground reservoirs

A. Henriques, N. Silva, M. Lopes; Presenting Author: André Henriques

770 Deep excavation solutions for the construction of a logistic park in Loures (Lisbon)

A. Henriques, R. Tomásio, F. Ramalho, J. Dias; Presenting Author: Rui Tomásio

## Session D1

Theme D: Metro tunnels and excavations

545 Lisbon new circular Metro underground line: Centenary buildings underpinning

C. Fartaria, A. Henriques, C. Martins, A. Pinto, R. Tomásio; Presenting Author: Catarina Fartaria

540 Lisbon new circular metro line: interconnection section between new line and existing terminus

P. Marques, C. Martins, C. Fartaria, R. Tomásio, A. Pinto; Presenting Author: Carlos Martins

530 Lisbon new circular Metro line: Buildings underpinning

C. Martins, C. Fartaria, R. Tomásio, A. Pinto; Presenting Author: Carlos de Oliveira Martins

## Session D3

Theme D: Ground improvement

457 Ground improvement solutions at the plot 14 of the Northern Lisbon logistic platform

M. Lopes, A. Pinto, A.L. Gonçalves, J. Moreno; Presenting Author: Miriam Lopes

## Session D5

Theme D: Excavations; Tunnelling; Monitoring

489 Excavation, retaining wall and deep foundations solutions for an office building at Alcântara

R. Tomásio, F. Veloso, N. Rosa; Presenting Author: Rui Tomásio

987 Solutions of excavations and peripheral earth retaining walls in dense urban área

L. Fernandes, R. Justiniano

Session D10

Theme D: Excavations; Tunnelling; Monitoring

53 Solution of excavation and peripheral earth retaining walls near sensitive structures – O’Living Development, Lisbon

R. Justiniano, A. Pinto

243 Deep excavation solutions in an urban environment - Distrikt residential project, Lisbon

J. Silva, I. Braz, A. Pinto; Presenting Author: Joana Silva

948 Earth retaining solutions and facades underpinning, for the refurbishment an historic building, in Lisbon

I. Braz, A. Pinto, D. Henriques, R. Santos; Presenting Author: Inês Braz

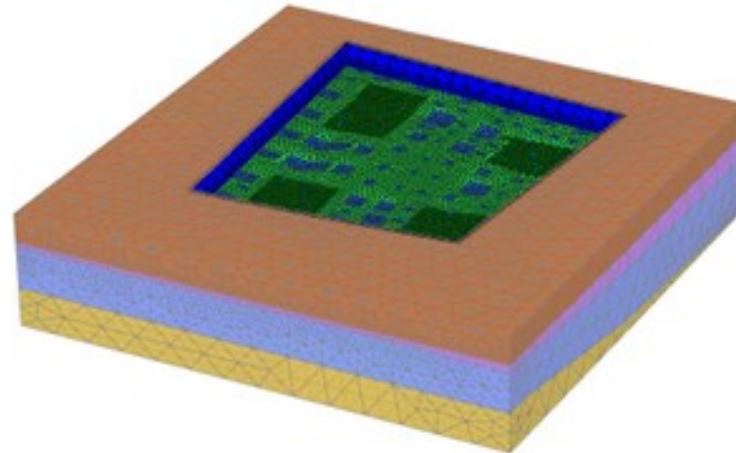
Session E2 Theme E: Flood protection structures

978 Temporary cofferdam at Caniçada Dam, Portugal

A.Pinto, L. Caldeira, F. Cerqueira, N. Plasencia, F. Gomes; Presenting Author: Alexandre Pinto

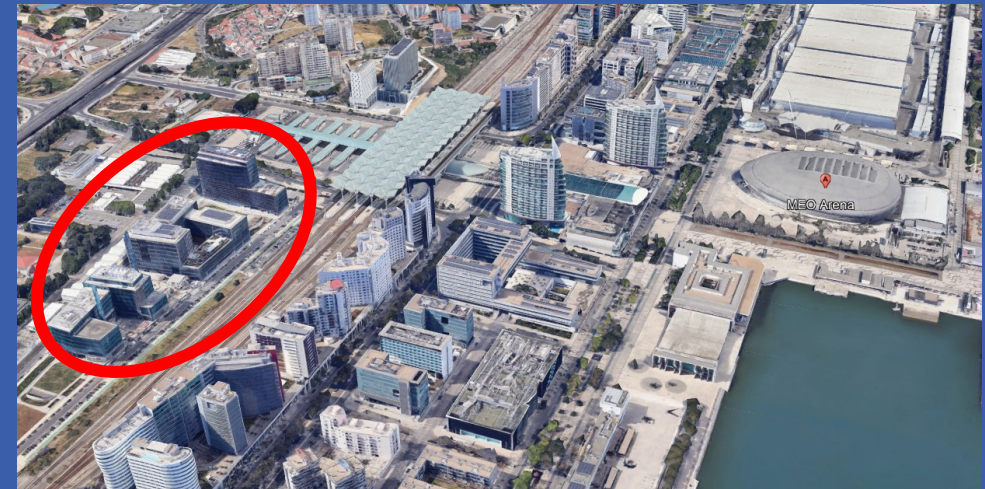
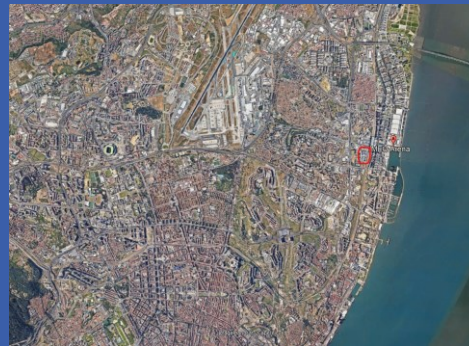
# COMBINED PILE-RAFT AND RAFT FOUNDATION MODELLING AND DESIGN FOR THREE DISTINCT OFFICE BUILDINGS IN LISBON, PORTUGAL

**André Sousa/** JETsj Geotecnia  
**Alexandre Pinto/** JETsj Geotecnia  
**Nuno Silva/** JETsj Geotecnia



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- **GEOTECHNICAL CONSTRAINTS**
- SOLUTIONS ADOPTED – RAFT PILE
- IN SITU TESTS AND 3D FE MODELLING / CALIBRATION
- FOUNDATION DESIGN
- FINAL REMARKS



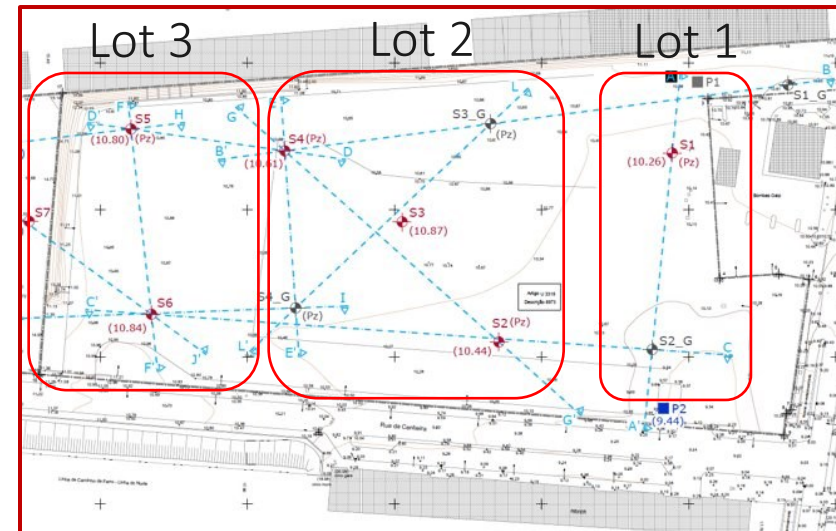
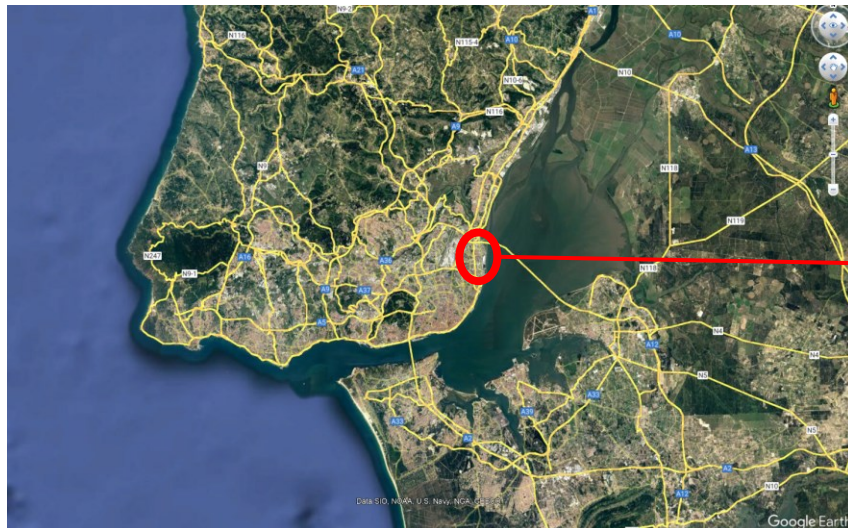
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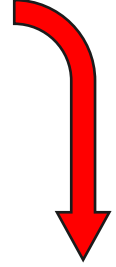
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26 - 30 August      Lisbon Portugal

## → GEOTECHNICAL CONSTRAINTS

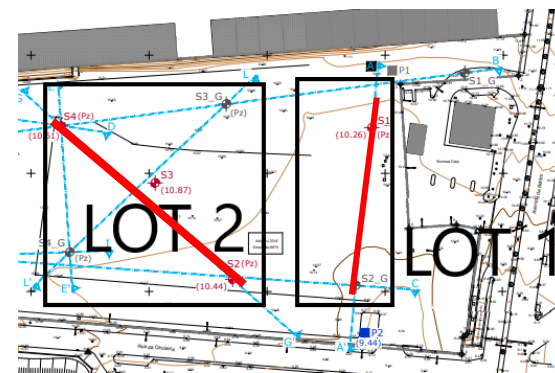
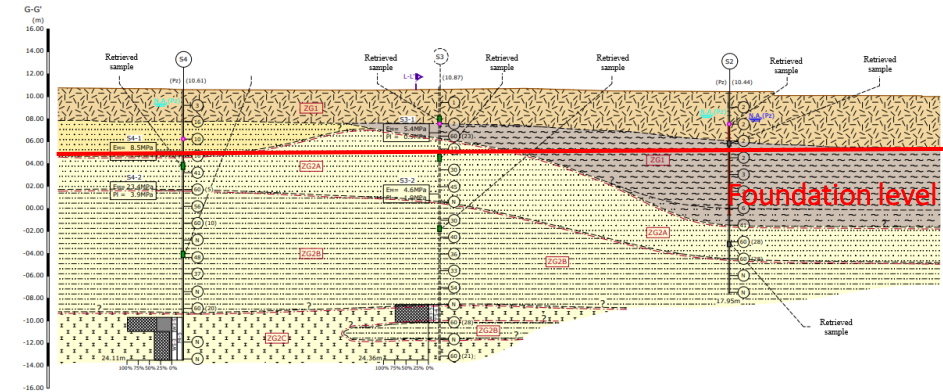
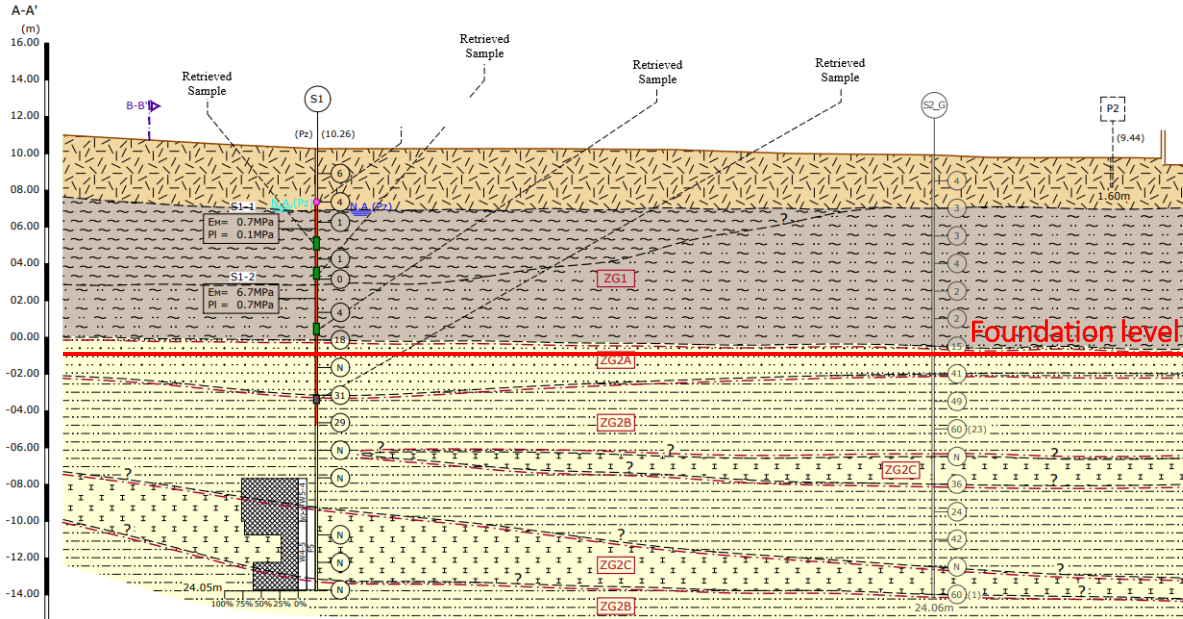
- **Foundations** for 3 office buildings in Lisbon, Portugal:
  - Lot 1 with 12 stories and 3 basements (2000m<sup>2</sup>);
  - Lot 2 with 9 stories and 2 basements (6350m<sup>2</sup>);
  - Lot 3 with 8 stories and 2 basements (5000m<sup>2</sup>).
- **Site investigation campaign** with a total of 12 boreholes:
  - 2 for Lot 1
  - 5 for Lot 2
  - 5 for Lot 3




 Samples were retrieved and sent to a lab for testing.

- Slug tests (**soil permeability test**)

# → GEOTECHNICAL CONSTRAINTS



- Landfill
- Alluvial Deposits
- Miocene Sands and Clays

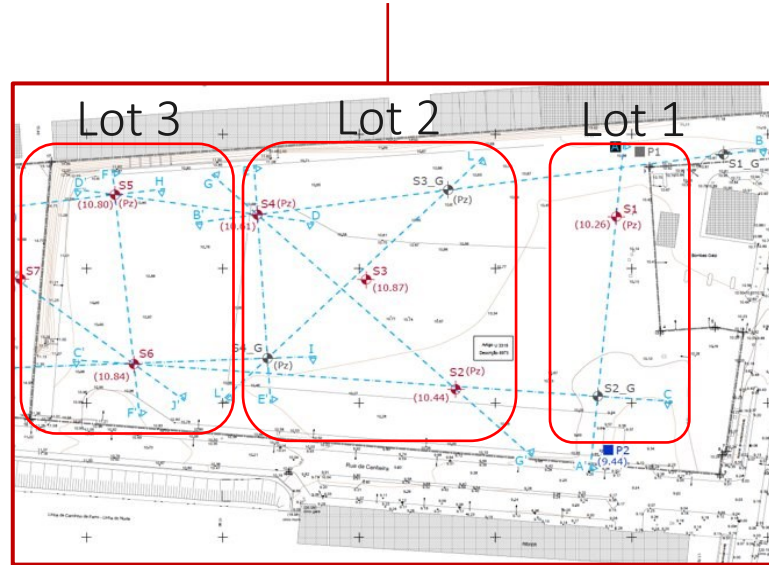


## → GEOTECHNICAL CONSTRAINTS - SUMMARY

LOT 3  
Outcropping Miocene  
compact layer



**Direct Foundations**



LOT 1  
Deeper foundation  
level due to having  
one more basement



**Direct Foundations**

LOT 2  
Thick alluvial deposits detected in  
the whole foundation area



**Need for Indirect Foundations**

## → SOLUTIONS ADOPTED – RAFT PILE

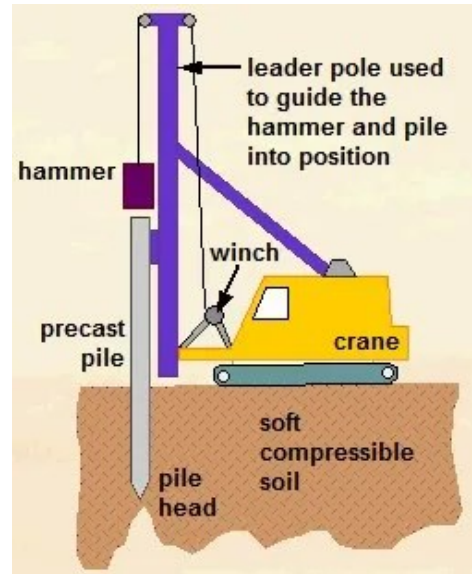
Soft compressible soil



Integrity of the piles



Economy, speed and safety



*Bored Piles (?)*

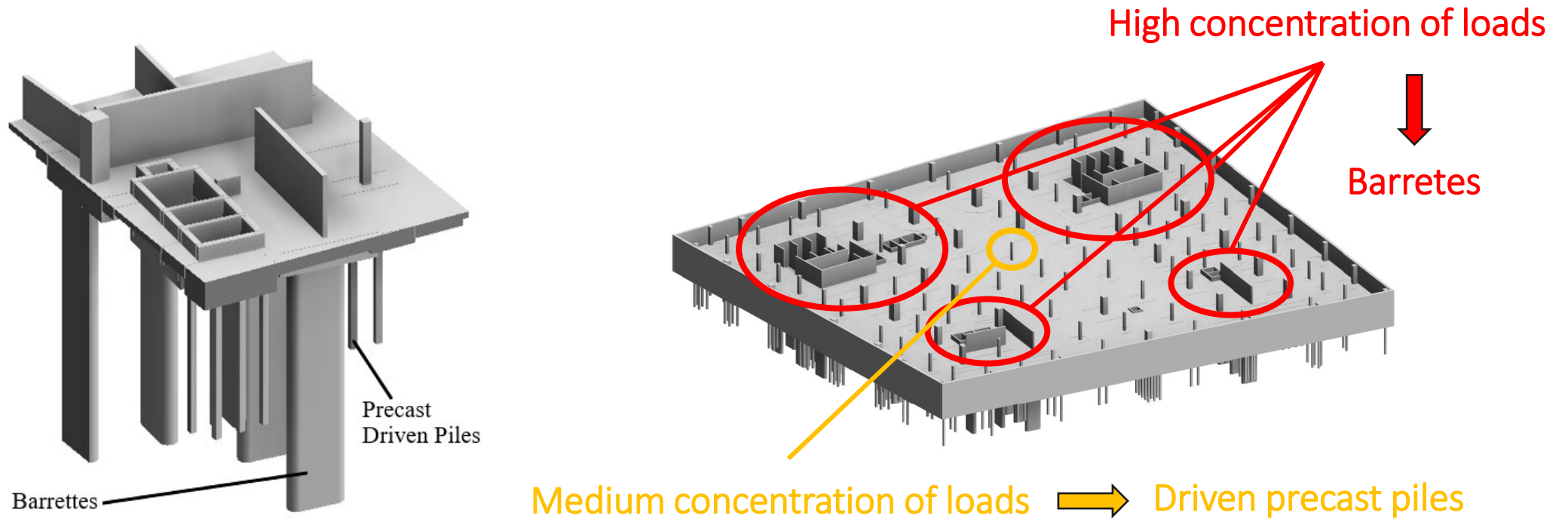


*Driven Precast Piles*

*Micro Piles (?)*

## → SOLUTIONS ADOPTED – RAFT PILE

- Soil inclusions (**Barretes** and **Driven Precast Piles**) in areas with higher loads to control differential settlements;



## → INSITU TESTS AND 3D FE MODELLING/CALIBRATION



- **9 dynamic load tests** with PDA method;
- Shaft resistance **lower than 90kN/m<sup>2</sup>** ranging from 2.9m to 13.1 meter depths;
- Tip resistances, under this layer, was between **14.6 and 18.2 MPa**.

8 meter precast driven pile

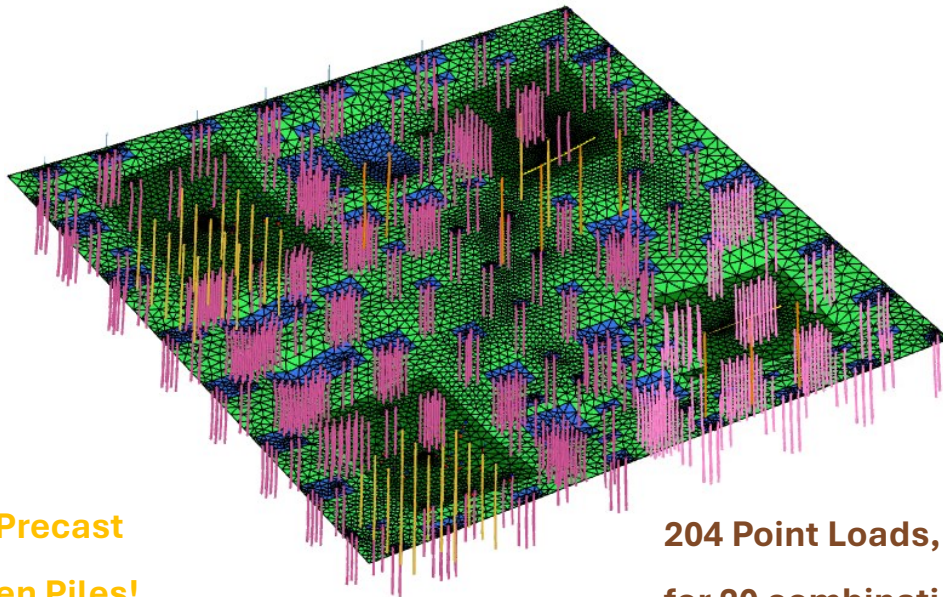


~800kN Shaft resistance  
~450kN Tip resistance at 5MPa



## → INSITU TESTS AND 3D FE MODELLING/CALIBRATION

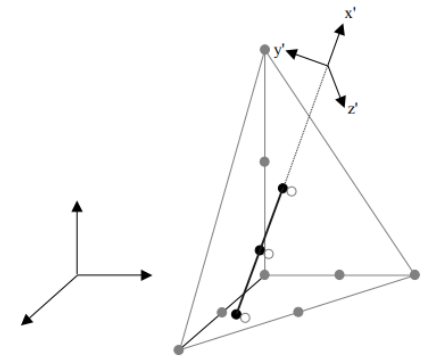
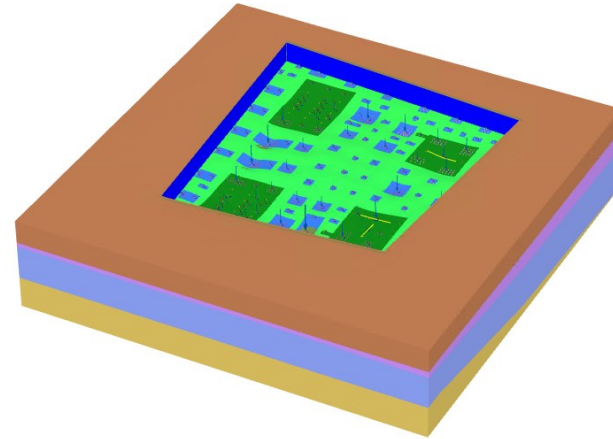
- **Driven Precast Piles** and **Barretes** were modelled with **Embedded Beam** elements.



**622 Precast  
Driven Piles!**

**41 Barretes!**

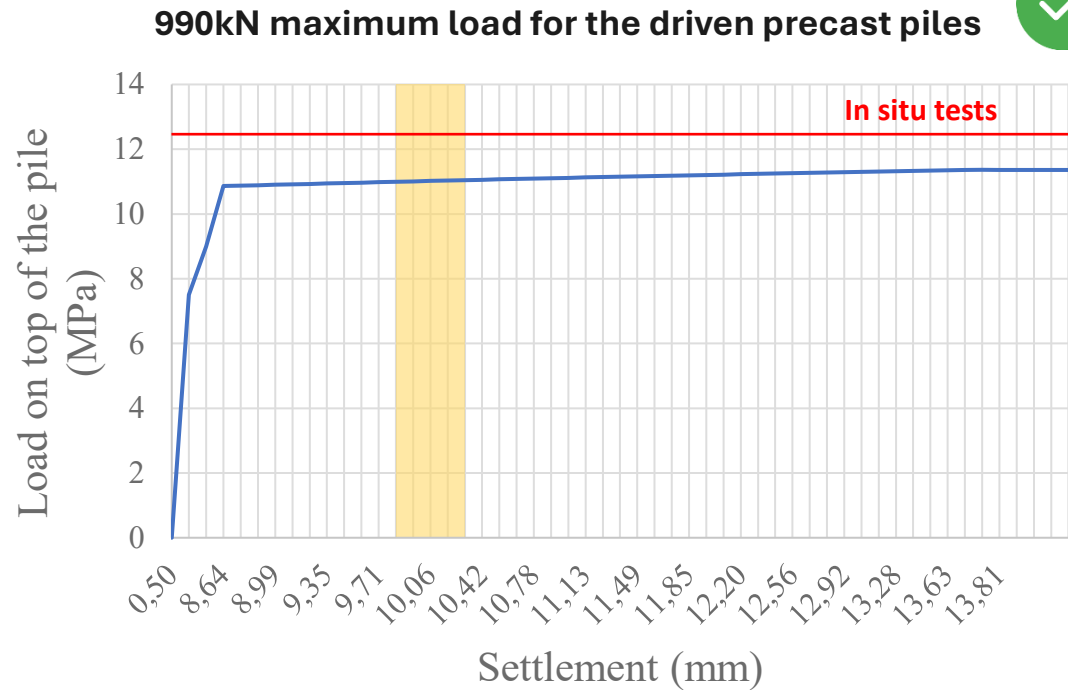
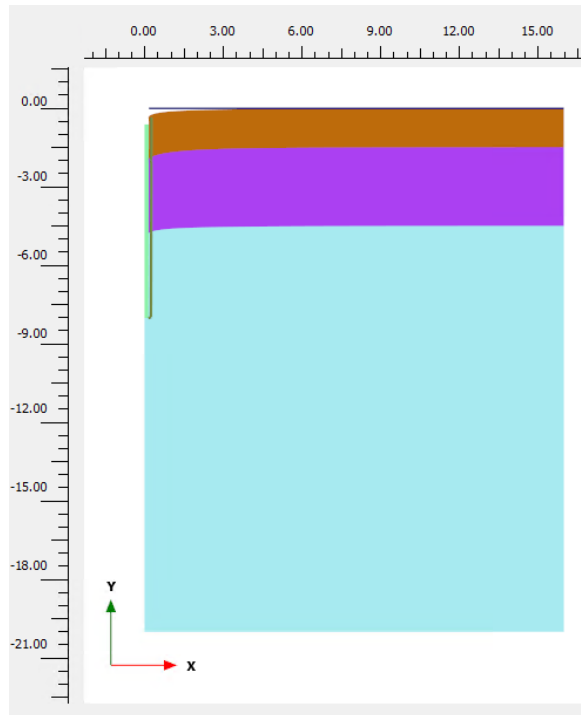
**204 Point Loads,  
for 20 combinations!**



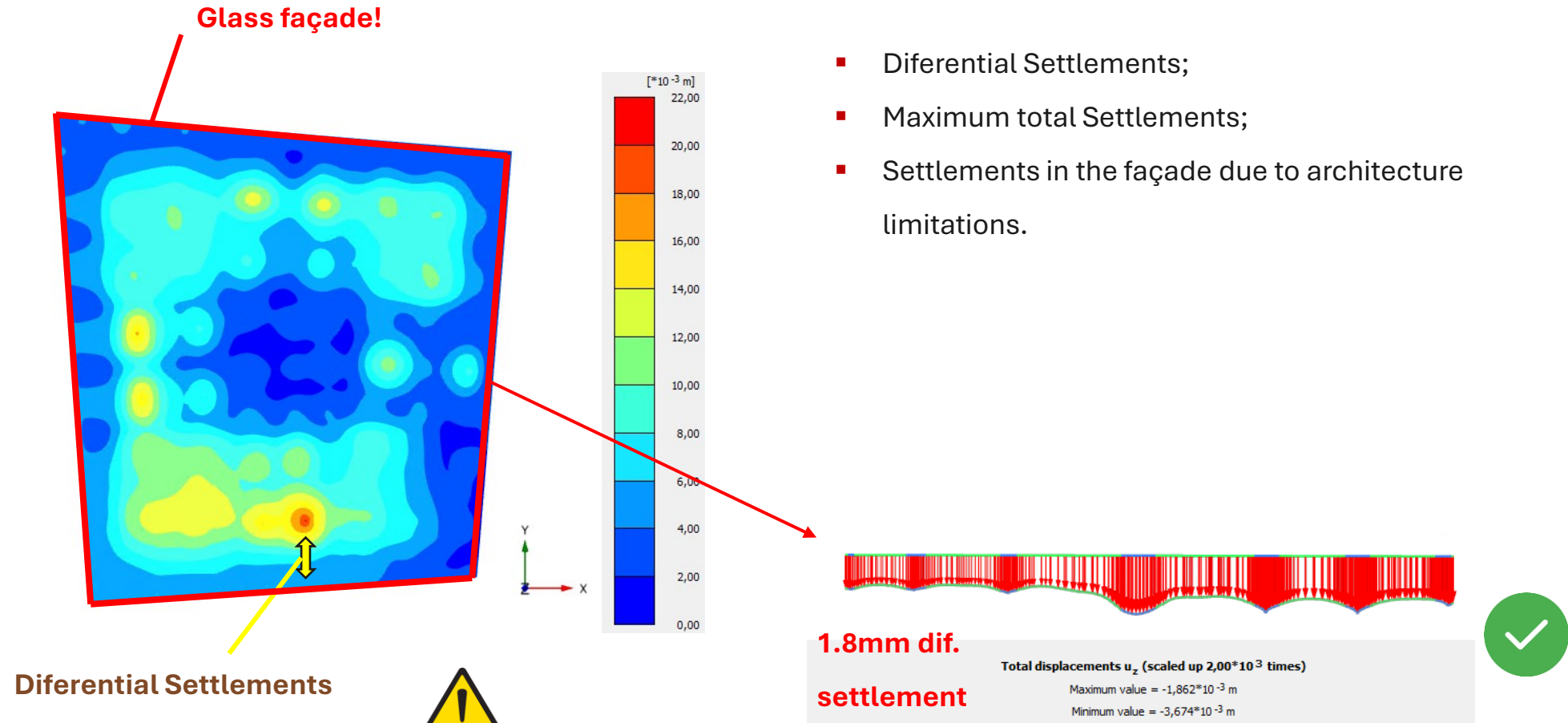
With a refined mesh, the model took  
**several hours** to run...

## → INSITU TESTS AND 3D FE MODELLING/CALIBRATION

- PLAXIS 2D Axissimetric model for **embedded beam calibration**;
- Results show an agreement between in situ tests and the model results.



## → INSITU TESTS AND 3D FE MODELLING/CALIBRATION



## → INSITU TESTS AND 3D FE MODELLING/CALIBRATION

### 3D FE MODELS VS EMPIRICAL METHODS

#### PROS

- Able to **capture complex soil-structure interactions**;
- Easier to re-do all calculations when there are changes to the structural system;
- Provides **high quality result presentation** for the projects.

#### CONS

- **High amount of time to run** the calculation;
- **Difficult to calibrate** due to high calc. time;
- **Difficulty building large models.**

*As processing power increases... the balance starts to shift towards computational methods...*



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Acknowledgements  
**Thank you for your attention!**

# Use of BIM methodology in geotechnical projects

## Construction of underground reservoirs

**André Henriques** / JETsj Geotecnia  
**Nuno Braz Silva** / JETsj Geotecnia  
**Miriam Lopes** / JETsj Geotecnia

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- Introduction
- Structural solution
- Use of BIM tools
  - Geotechnical modelling
  - Numerical modelling
  - Geometrical and rebar modelling
- Final remarks



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## → Introduction

- Brasil – Minas Gerais – Belo Horizonte
- Venda Nova – Region with the highest incidence of **flood records**
- Implementation of a **flood control system**



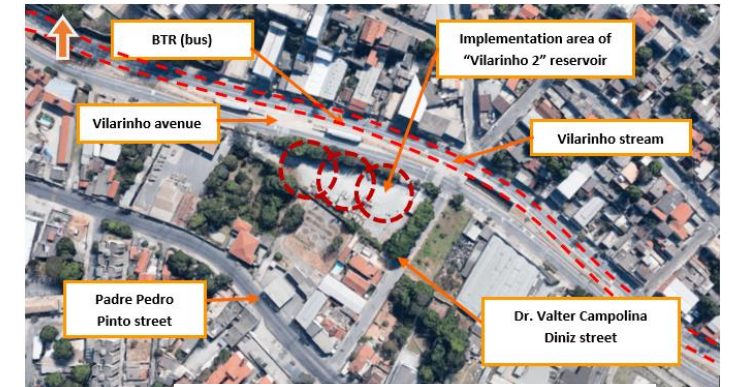
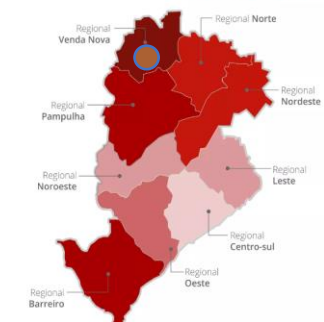
- Execution of two reservoirs in the city:
  - Nado
  - Vilarinho
- **3 intersecting circular shafts** with 40 m diameter
- 100 m length
- 35 m depth
- Area = 3500 m<sup>2</sup>
- Volume = 122 500 m<sup>3</sup>



### Áreas com risco de inundação em Belo Horizonte

Carta de Inundações de Belo Horizonte/PBH

Quantidade de pontos de inundação: 3 6 8 10 13 20



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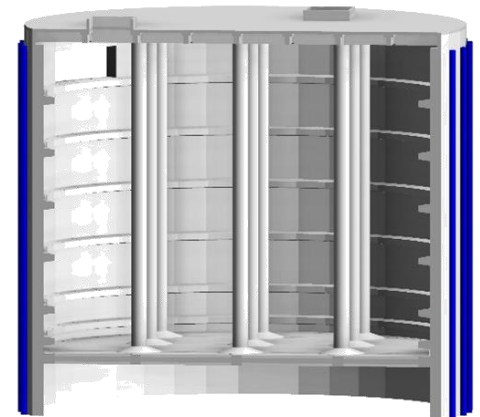
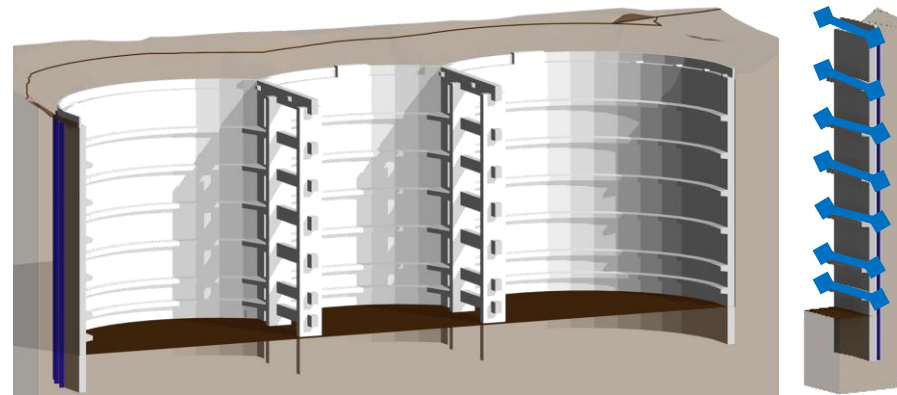
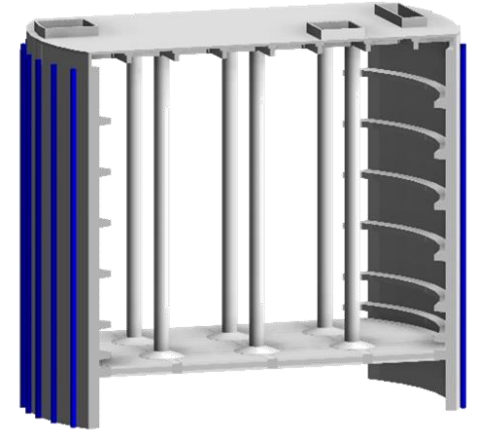
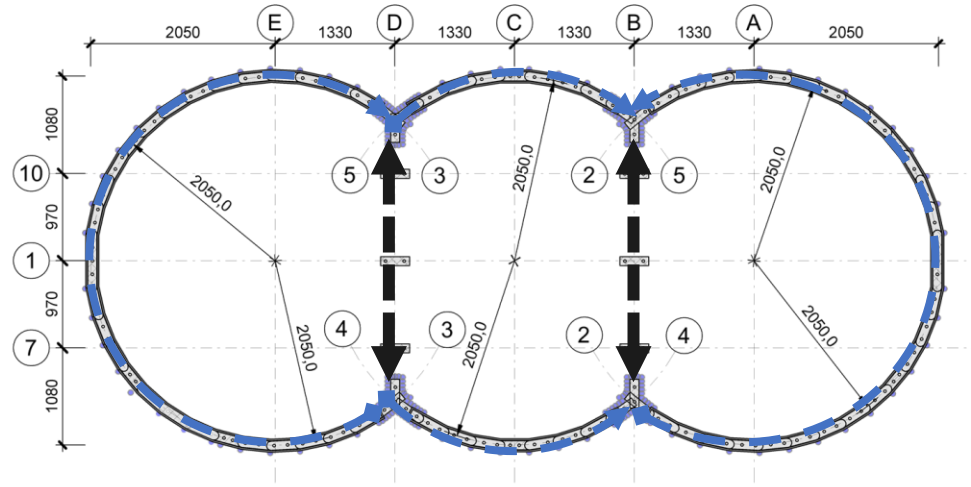
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## → Structural solution

### Retaining structure

- **Control of deformations** in the influence area of the excavation
- 1 m thick **diaphragm wall**
- **Circular shape** – Compression
- Two reinforced concrete frames, materialized by a set of columns and struts
- 7 levels of bracing rings (struts)
- **Jetgrouting columns** between panels



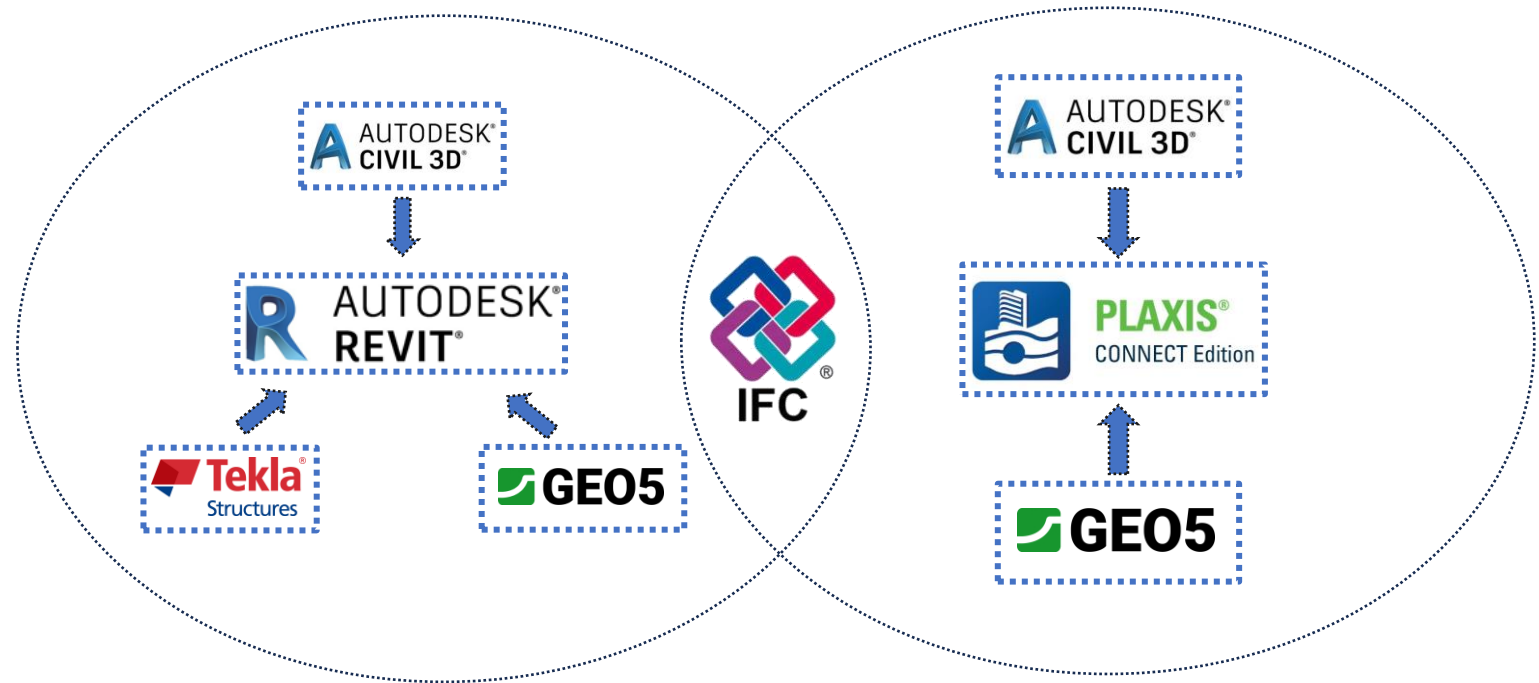
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## → Use of BIM tools

- Use of BIM **was not mandatory!**
- All the other designers developed their projects using CAD methodologies
- Integration of geotechnical, numerical and geometric models:
  - **More realistic and accurate results** in terms of stresses and deformations
  - **Identify incompatibilities** among the different structures of the reservoir
  - Facilitate the extraction of **material quantities**
- Integration of the models using open format **IFC**

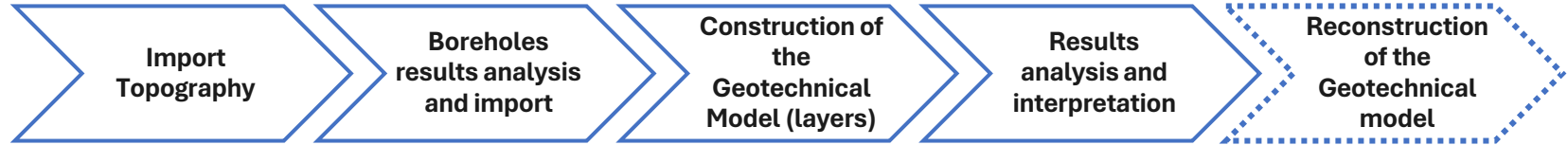


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## → Geotechnical modelling

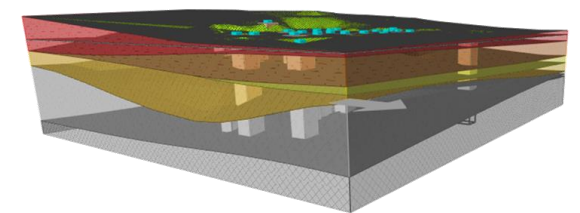
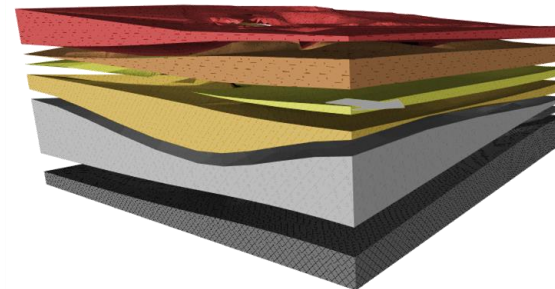
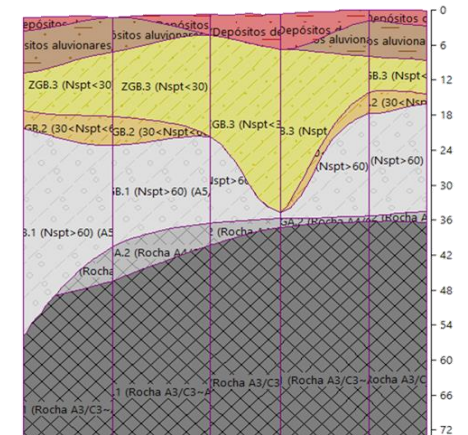
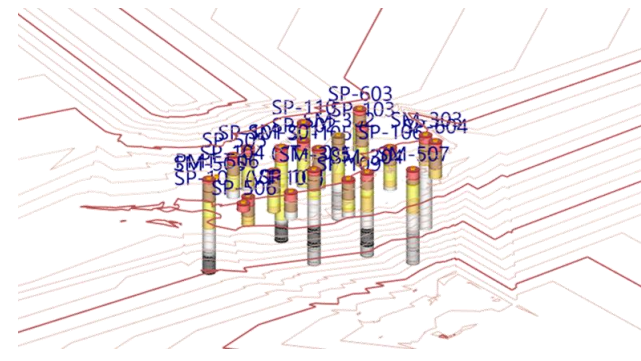


– Geotechnical campaigns:

- Mechanical drilling;
- Geophysical surveying
- In-situ tests
- Laboratory tests

– Definition of 7 geological layers:

1. Fill deposits
2. Alluvial deposits
3. Residual soils/saprolites
4. Gneiss rock mass



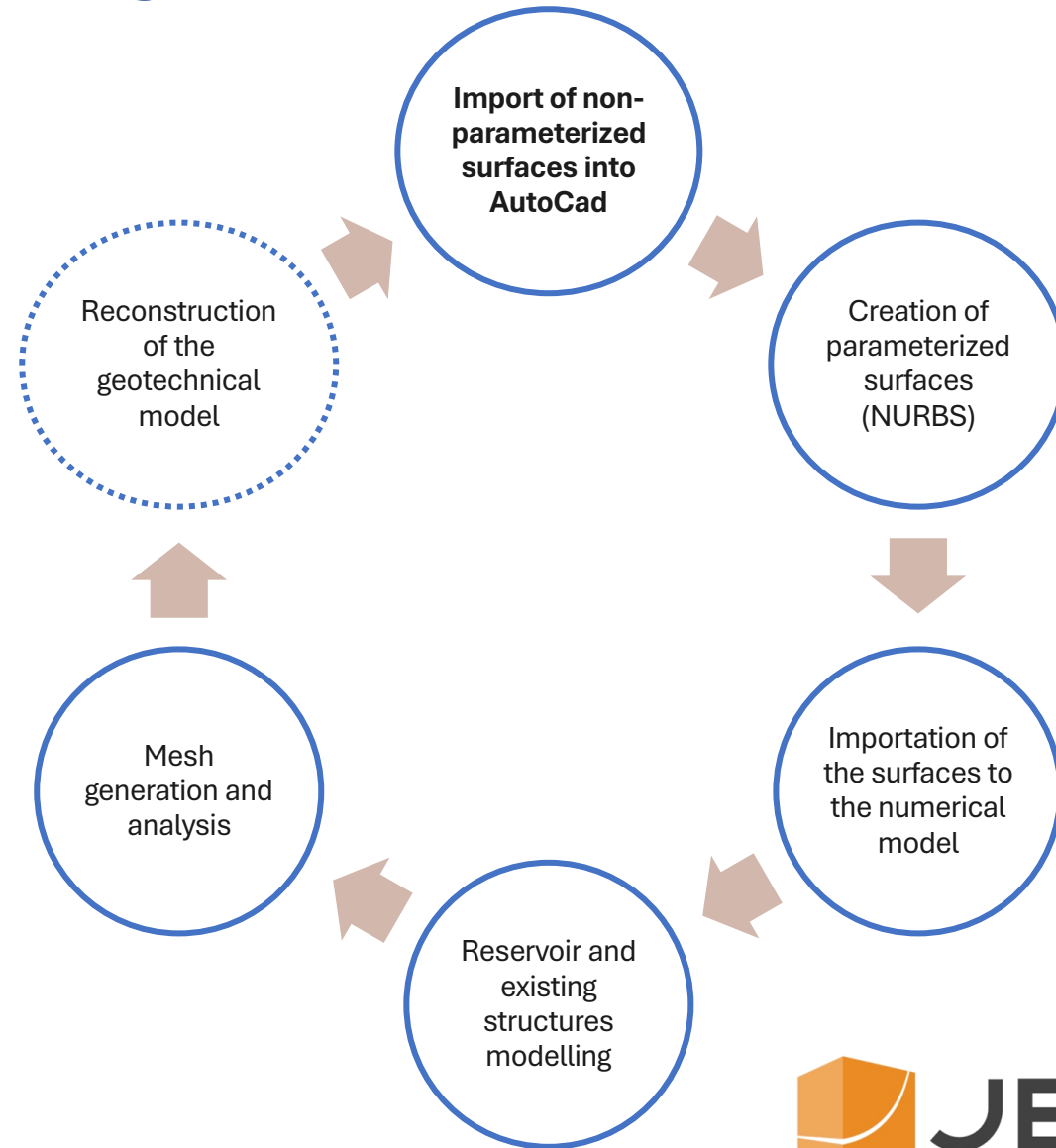
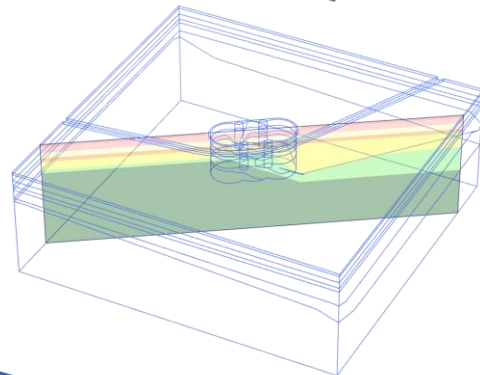
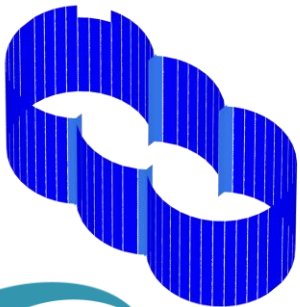
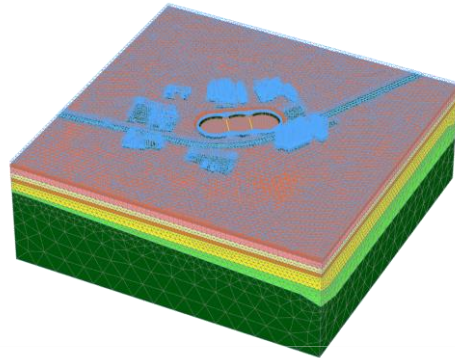
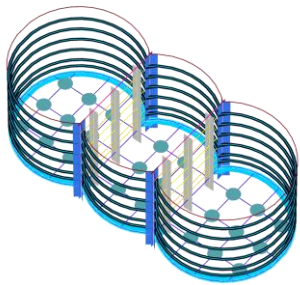
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## → Numerical modelling

- 3D model in Plaxis 3D [385m x 365m x 133m]
- Estimate **accurate stresses and deformations**:
  - Geological-geotechnical asymmetry
  - Structural symmetry
  - Existing structures and infrastructures



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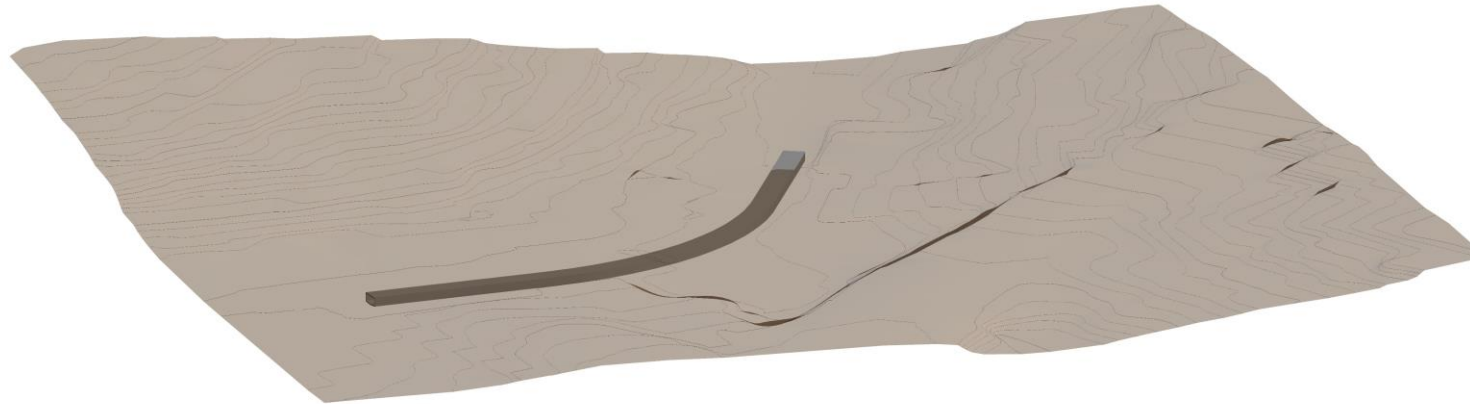
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## → Geometrical and rebar modelling

Several construction phases to simulate the reservoir construction process:

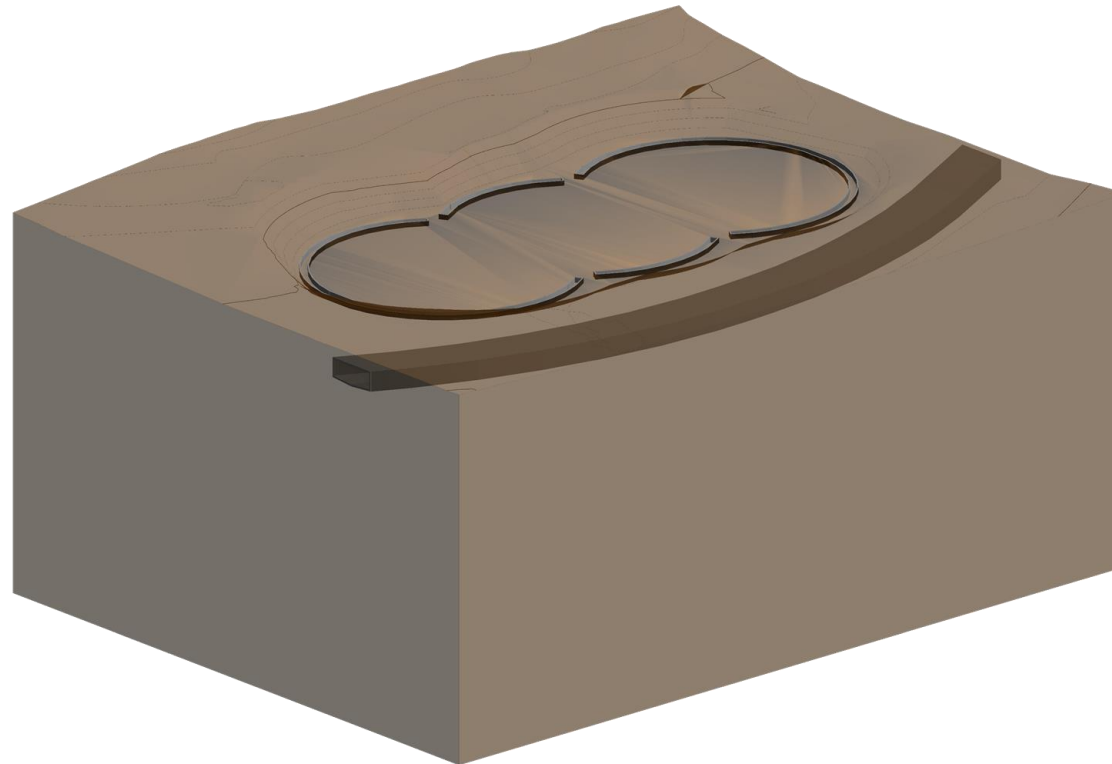
1. Existing topography



## → Geometrical and rebar modelling

Several construction phases to simulate the reservoir construction process:

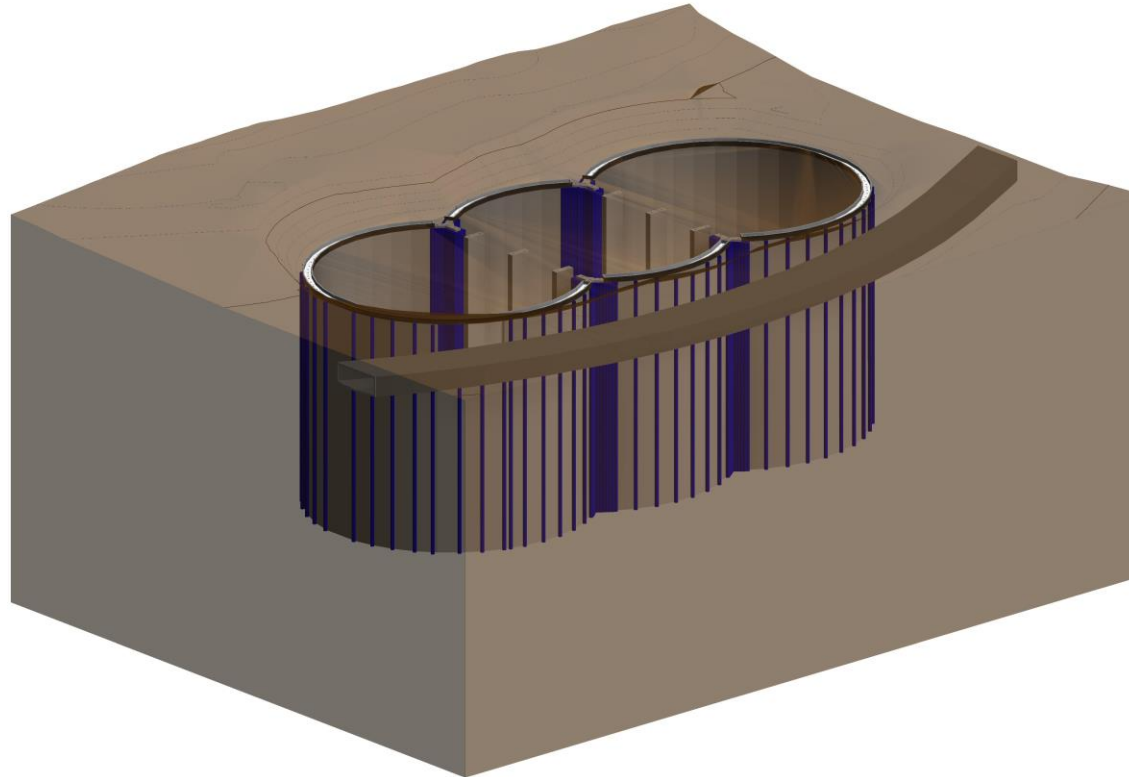
1. Existing topography
2. Excavation to the work platform



## → Geometrical and rebar modelling

Several construction phases to simulate the reservoir construction process:

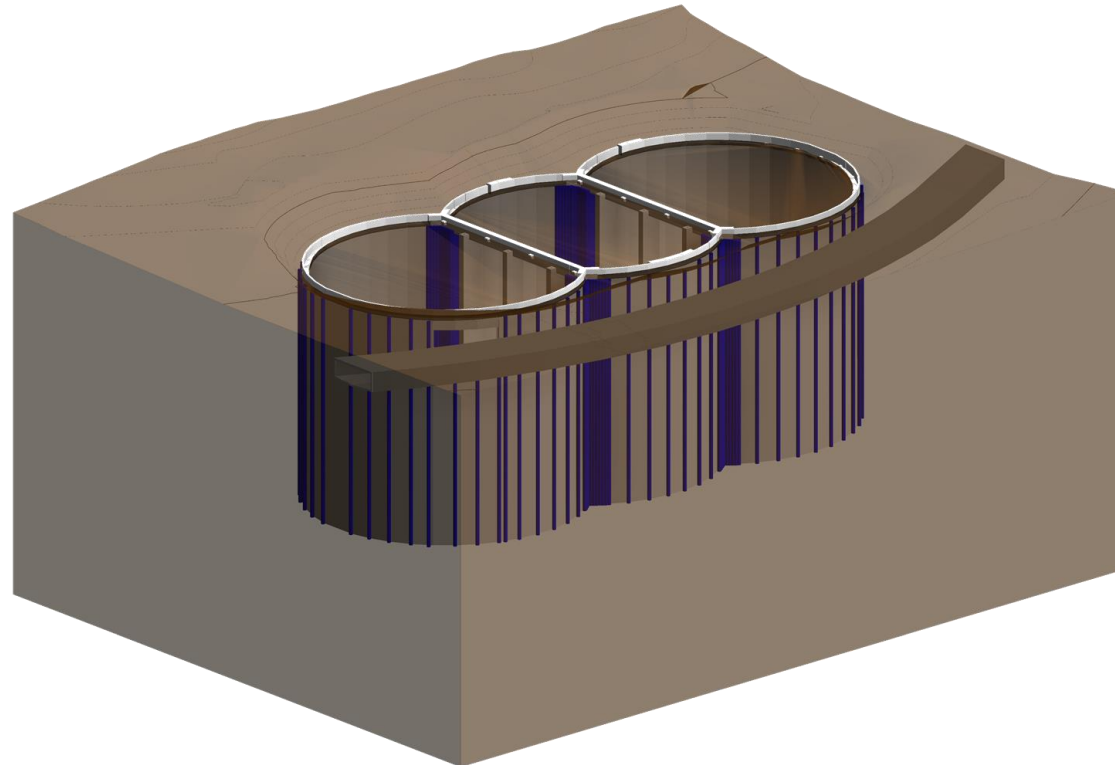
1. Existing topography
2. Excavation to the work platform
3. Execution of the diaphragm wall panels and Jetgrouting columns



## → Geometrical and rebar modelling

Several construction phases to simulate the reservoir construction process:

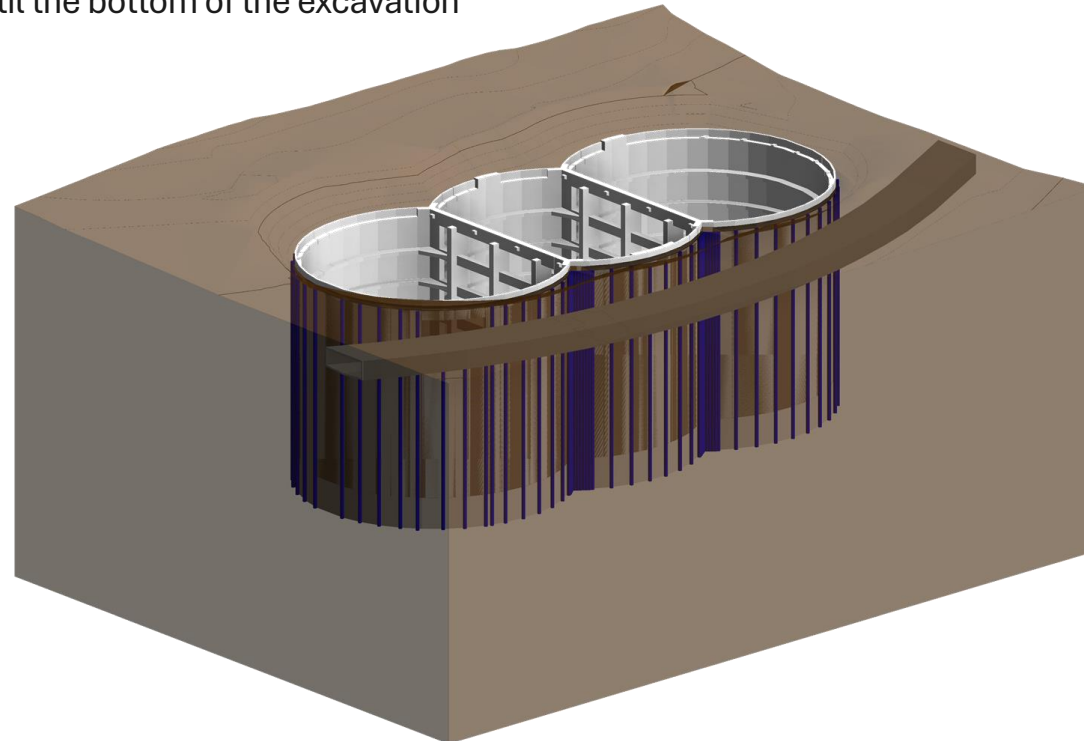
1. Existing topography
2. Excavation to the work platform
3. Execution of the diaphragm wall panels and Jetgrouting columns
4. Execution of the first beam



## → Geometrical and rebar modelling

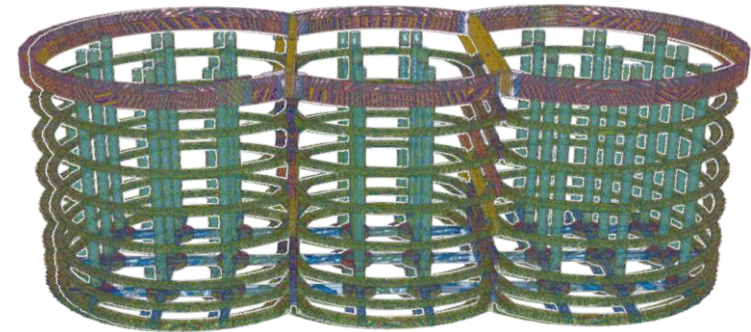
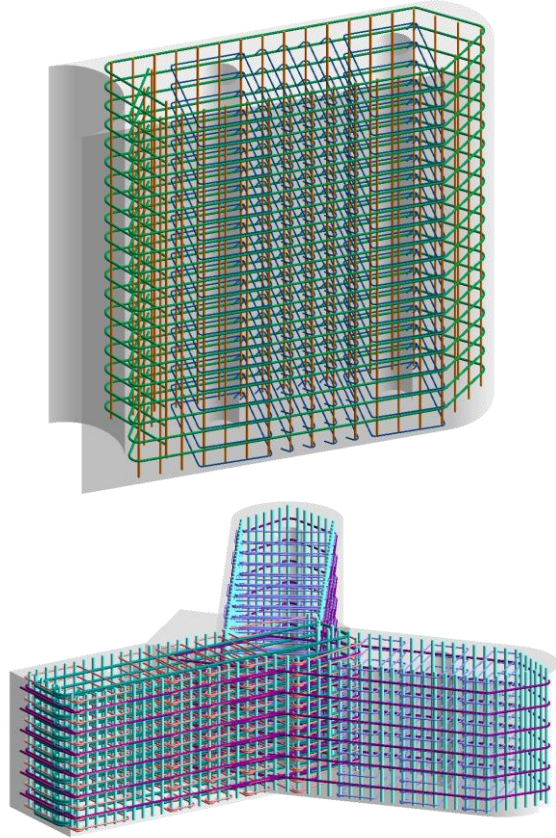
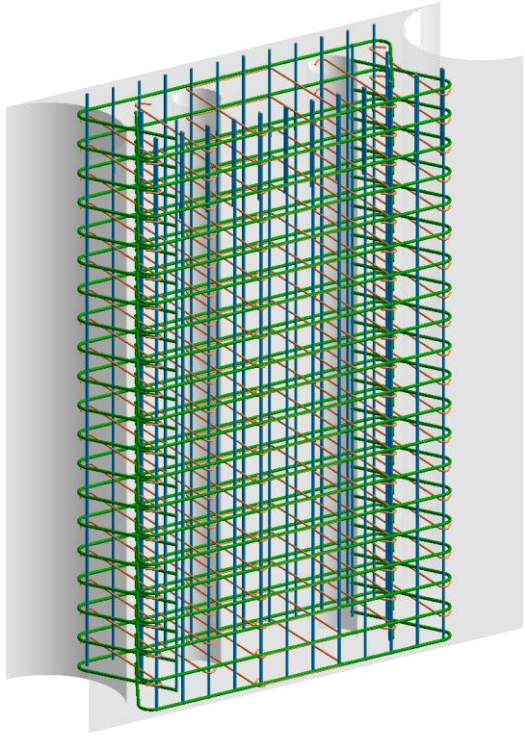
Several construction phases to simulate the reservoir construction process:

1. Existing topography
2. Excavation to the work platform
3. Execution of the diaphragm wall panels and Jetgrouting columns
4. Execution of the first beam
5. Execution of the rings and struts until the bottom of the excavation



## → Geometrical and rebar modelling

- Using **of different software** to rebar modelling
- **Revit** – diaphragm wall panels
- **Tekla** – other elements of the reservoir



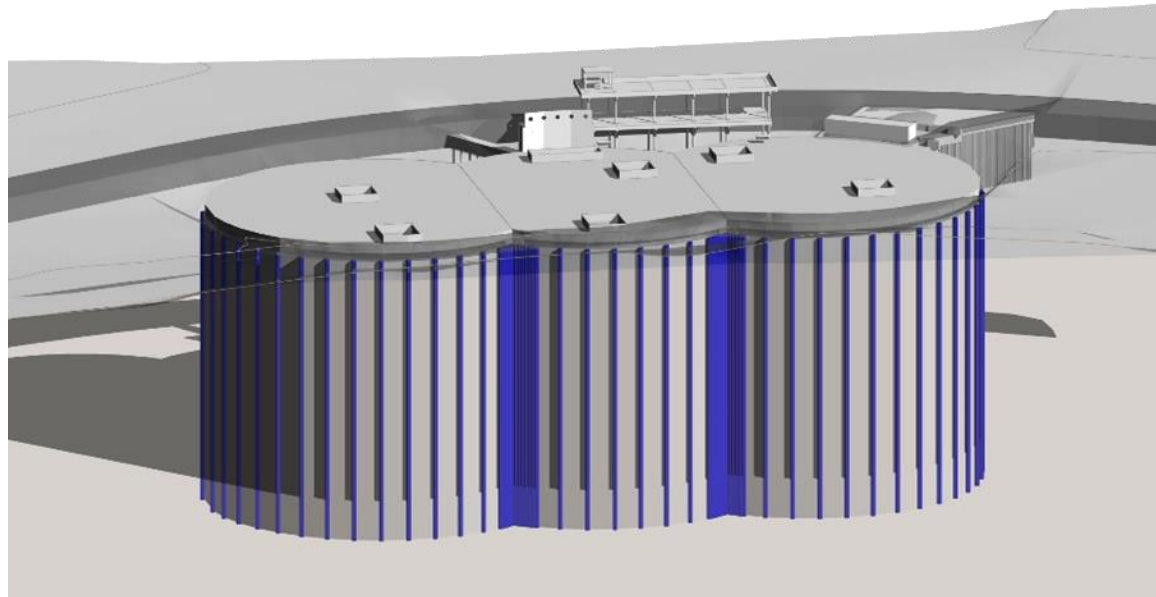
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## → Final remarks

- Geometric modeling and integration of all structures allowed for the **verification of intersections and conflicts in an early design stage**, as well as the effective **interpretation of the different construction phases**.
- Rebar modeling, although **time-consuming**, presents **numerous advantages** for the various entities involved, especially in this type of project where the required detail is greater.
- Integration of geological, numerical, and geometric models allowed for a **more comprehensive analysis of the available geotechnical data**, leading to a better simulation of soil-structure interaction **and more reliable and realistic results**.





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# Deep excavation solutions for the construction of a logistic park in Loures (Lisbon)

**Rui Tomásio** / JETsj Geotecnia

**André Henriques** / JETsj Geotecnia

**Filipa Ramalho** / NORTON Edifícios Industriais

**João Dias** / Triaxial – Engenharia Geotécnica



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- Geotechnical Scenario
- Proposed solutions
- Design methods
- Monitoring plan
- Conclusions



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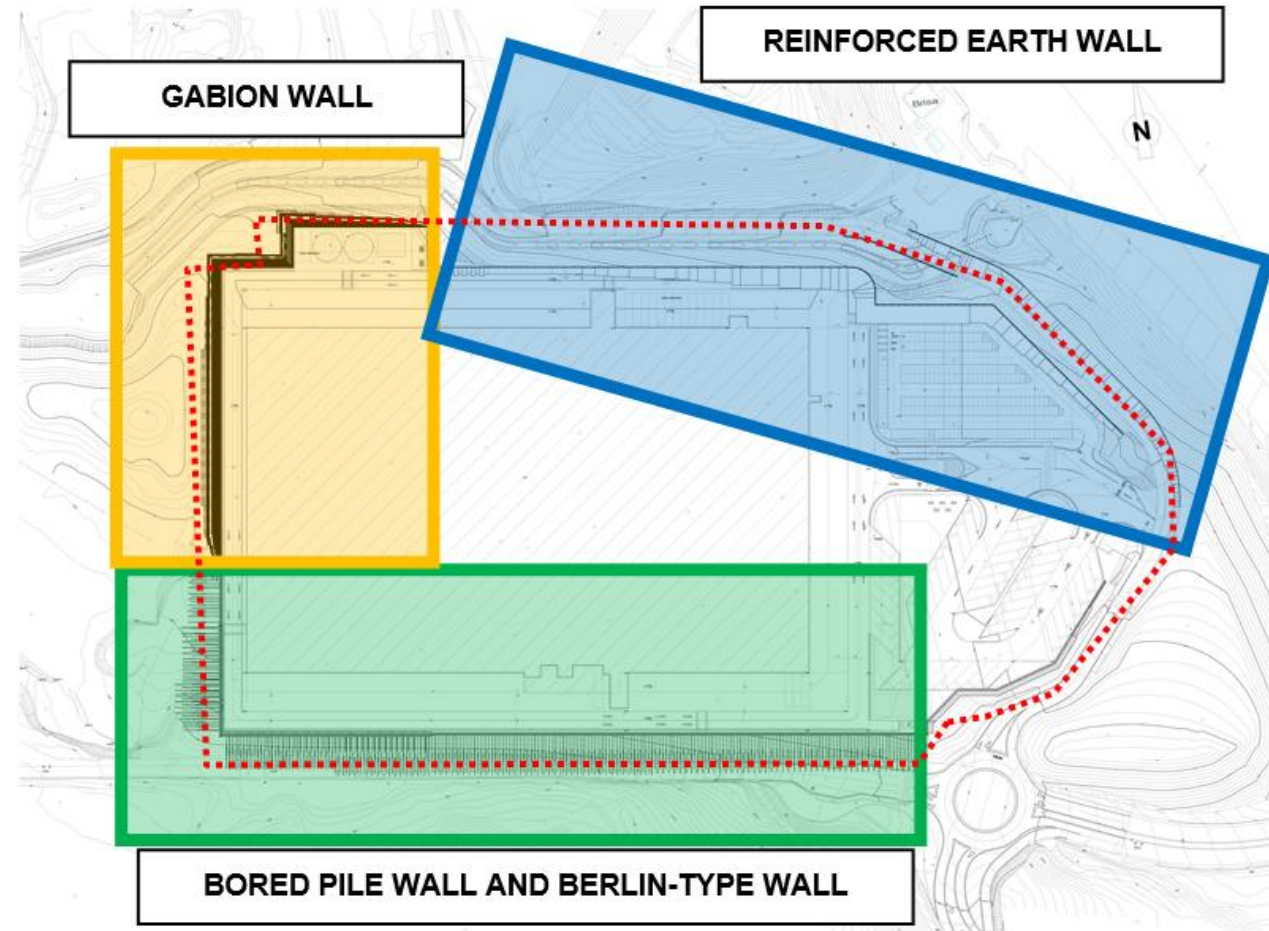
## → Introduction

- Loures municipality
- Construction of a logistic park
- 107 000 m<sup>2</sup> site area
- 55 000 m<sup>2</sup> footprint area
- Old limestone quarry
- Old landfill site
- Very abrupt geotechnical behaviour over short distances
- Excavation and embankment areas



## → Introduction

- Bored pile wall permanently anchored – 450 m length - 20 m height
- Berlin type wall – 1250 m<sup>2</sup> area - 12 m height
- Gabion wall – 250 m length – 16 m height
- Reinforced earth wall with facing precast reinforced concrete panels – 600 m length – 18 m height
- Soil excavation – 370 000 m<sup>3</sup>
- Rock excavation – 47 500 m<sup>3</sup>



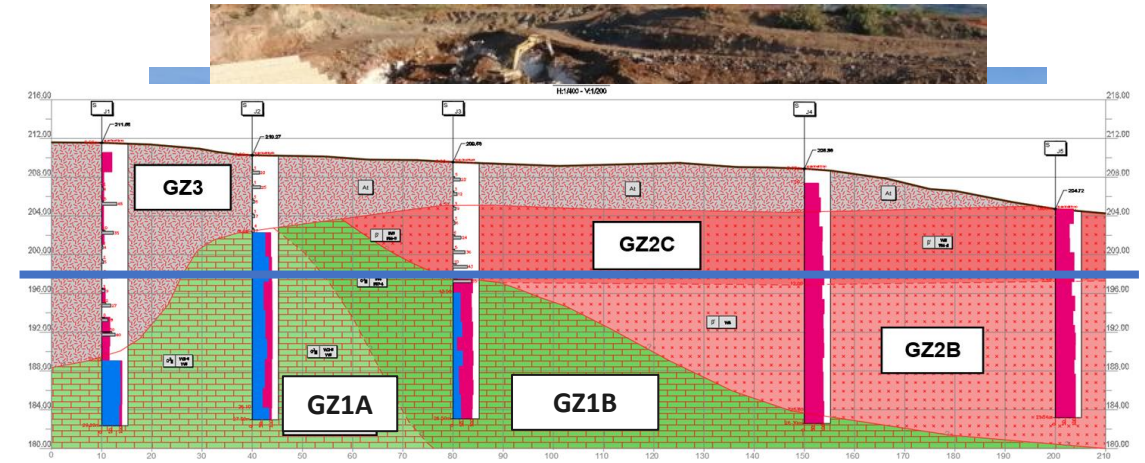
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## → Geotechnical Scenario

- 4 geotechnical surveys from 2019 to 2021
- 50 boreholes with SPT tests
- 24 exploratory pits
- 10 seismic profiles
- Direct shear tests
- Drained triaxial tests
- Unconfined compression tests
- High level of uncertainty about the composition of the fill materials
- High level of uncertainty about the location configuration and inclination of the old quarry cuts

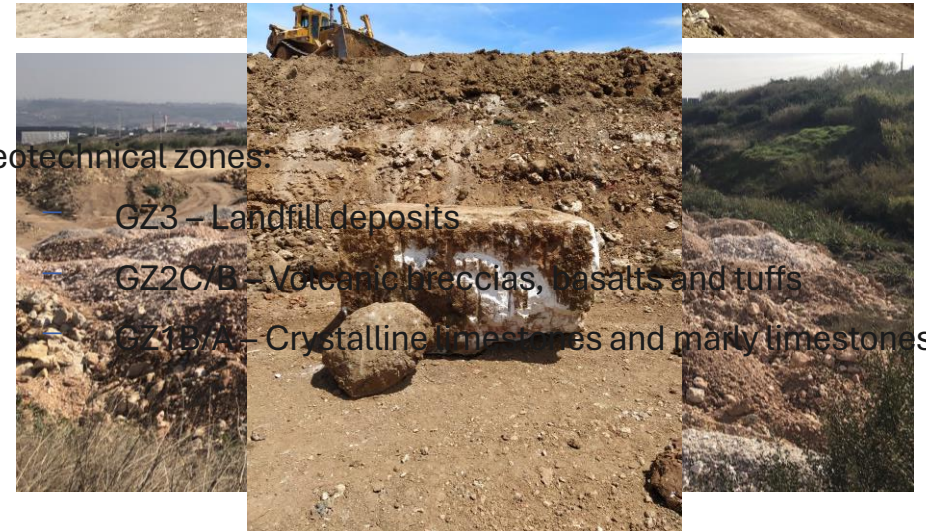


5 geotechnical zones:

GZ3 – Landfill deposits

GZ2C/B – Volcanic breccias, basalts and tuffs

GZ1B/A – Crystalline limestones and marly limestones



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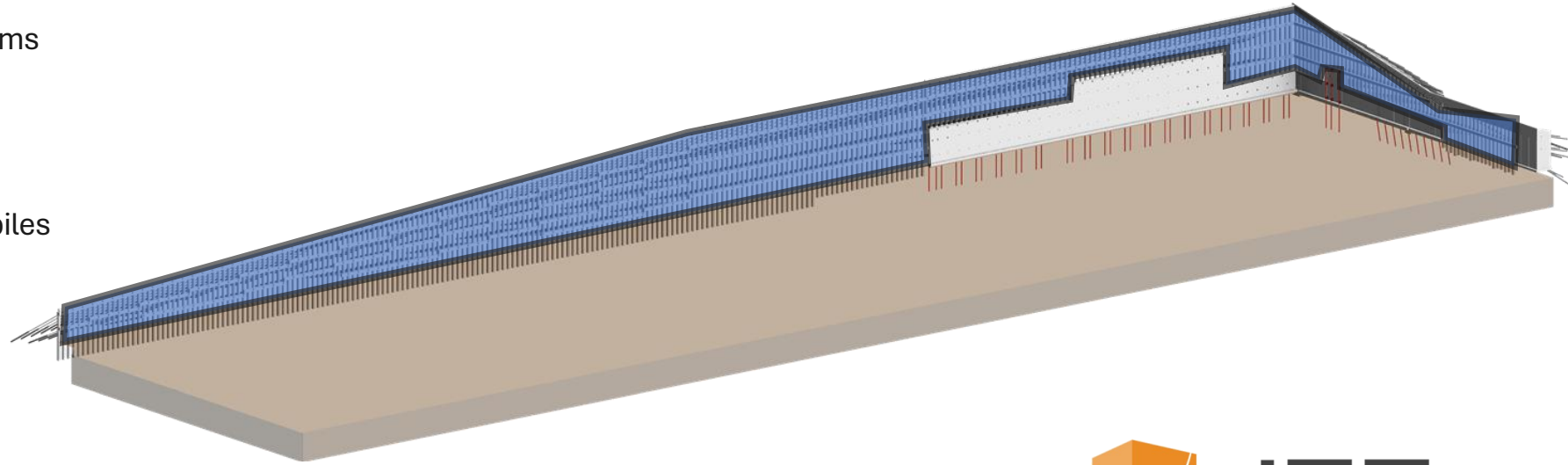
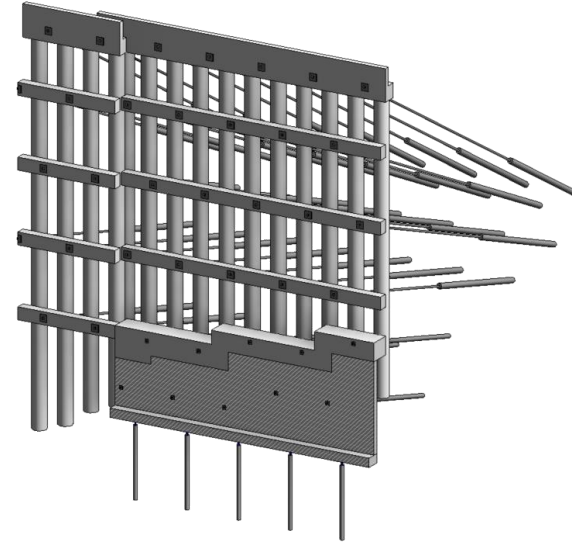
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- Geotechnical Scenario
- **Proposed solutions**
- Design methods
- Monitoring plan
- Conclusions



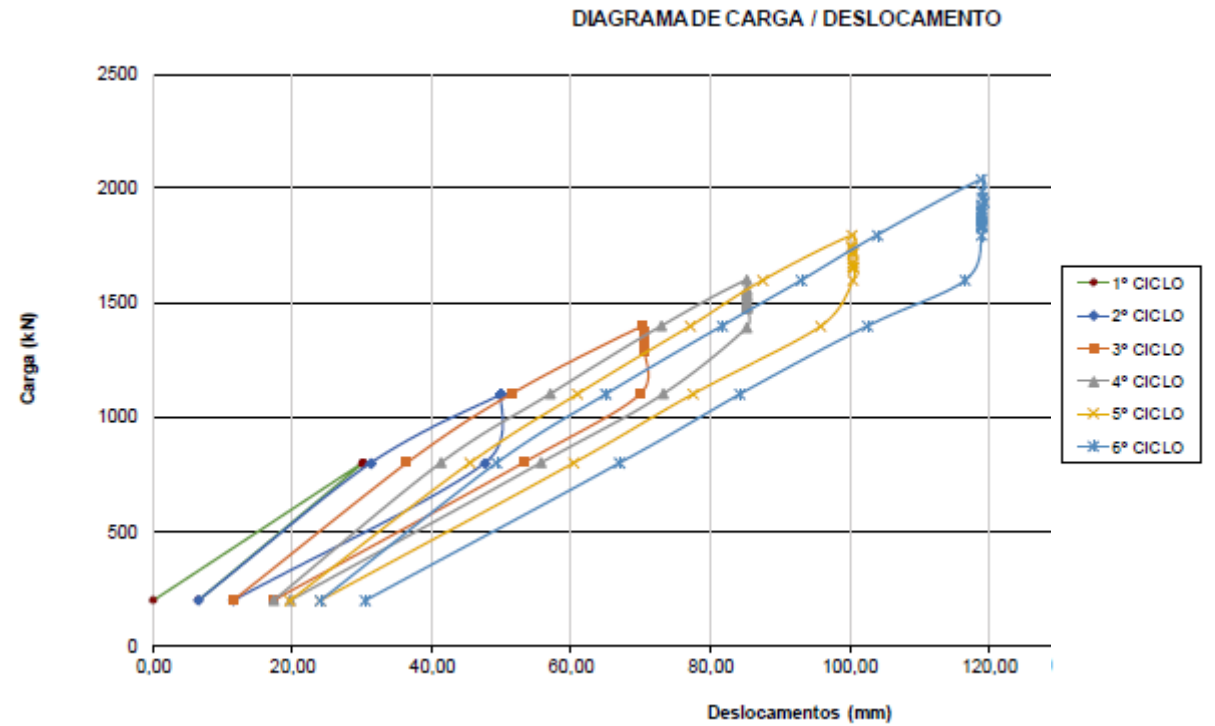
## → Proposed solutions

### Bored pile retaining wall

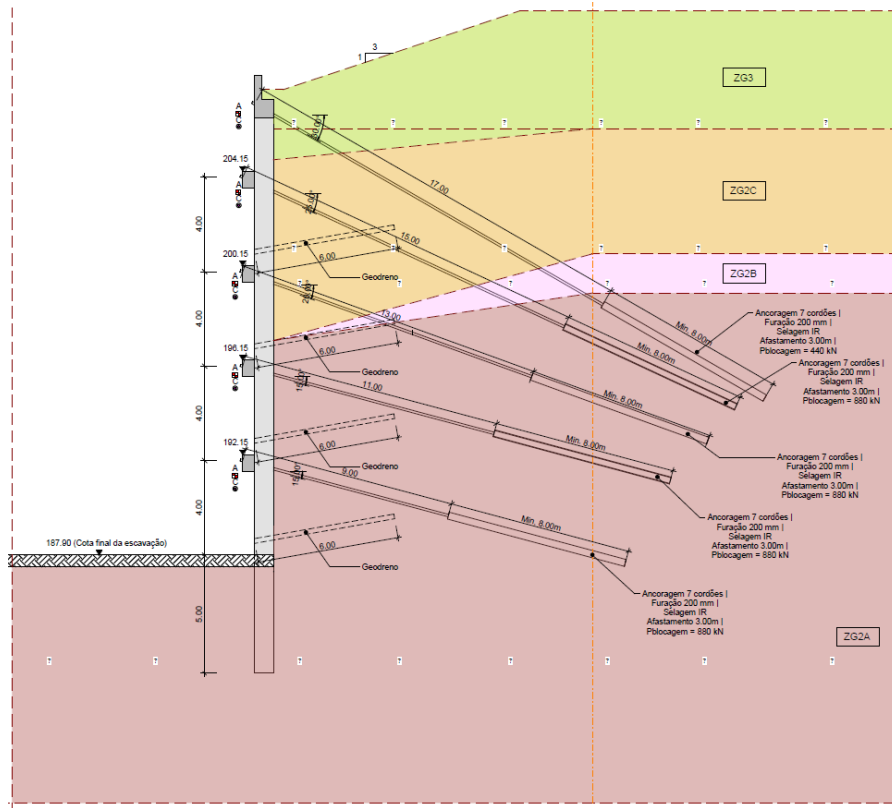
- 800 mm piles spaced 1.5 m, center-to-center
- 20 m of maximum height
- 2 to 5 levels of permanent ground anchors spaced 3.0 m – design to static and seismic conditions
- Reinforced concrete distribution beams
- Prestress load on anchors of 900 kN
- Shotcrete protection layer between piles



Testing of 2 sacrificial ground anchors



## → Proposed solutions



## → Proposed solutions



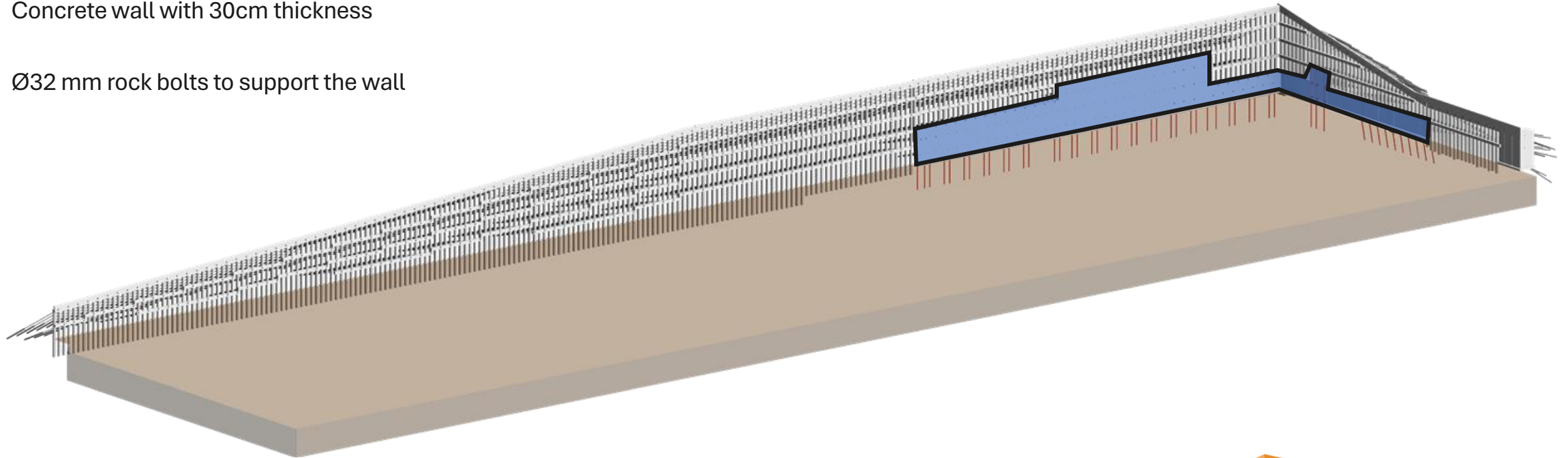
## → Proposed solutions



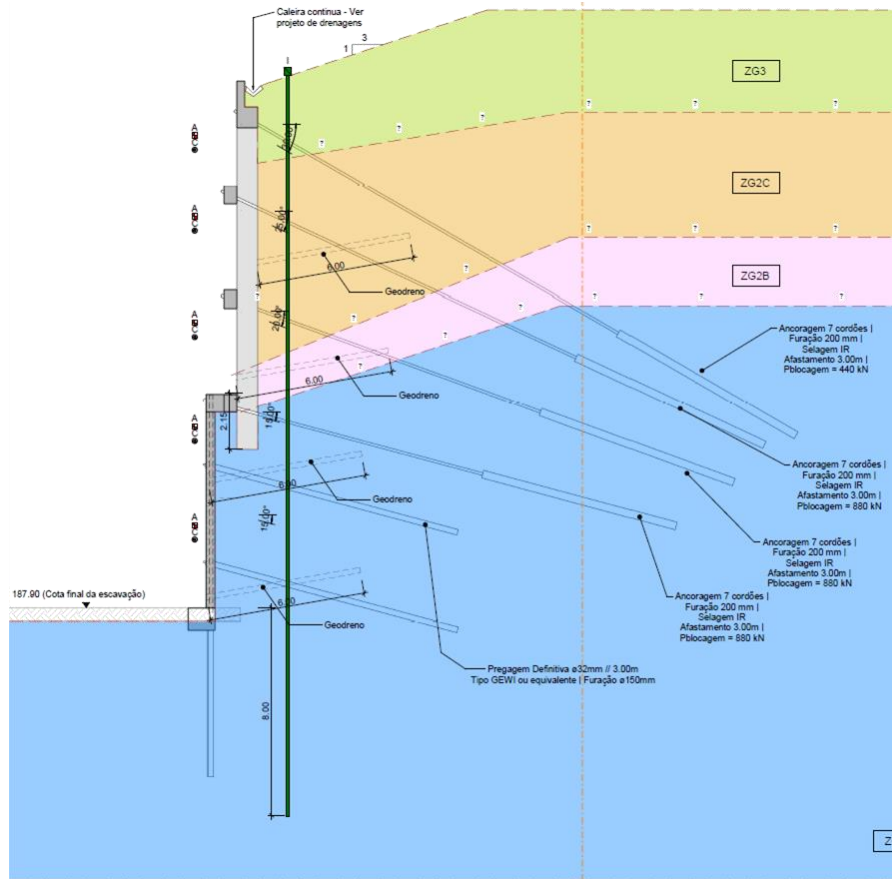
## → Proposed solutions

### Concrete Berlin-type retaining wall

- Zones with slightly altered limestone
- Pile wall underpinned using micro-piles – 3 m spacing
- Concrete wall with 30cm thickness
- Ø32 mm rock bolts to support the wall



## → Proposed solutions



## → Proposed solutions



→ Proposed solutions



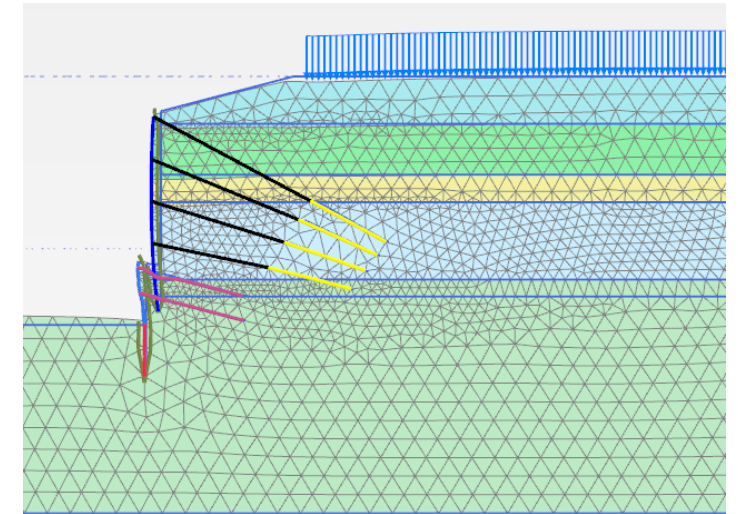
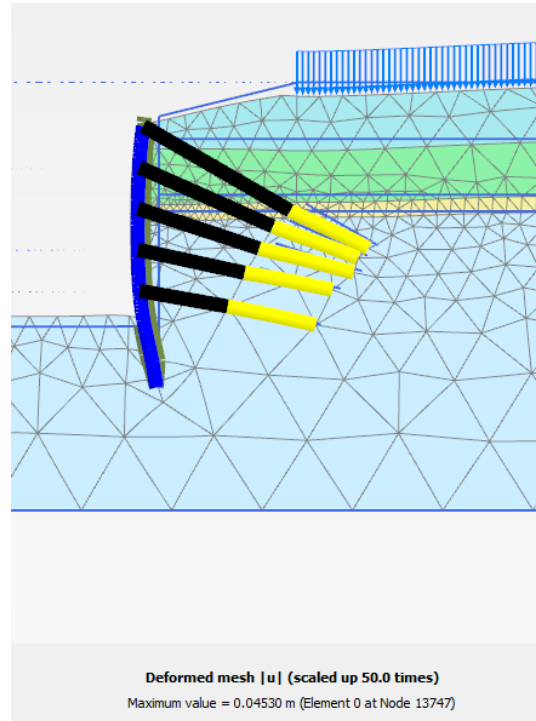
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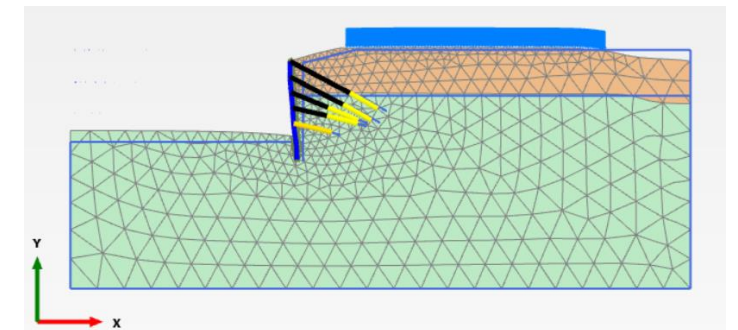


## → Design methods

- Plaxis 2D models – stresses and deformations
- Several cross-sections
- Soils - Hardening soil constitutive model
- Rock – Mohr-Coulomb constitutive models
- Assessment of the maximum global safety factor for static and seismic conditions



Deformed mesh |u| (scaled up 40.0 times)  
Maximum value = 0.02613 m (Element 0 at Node 14939)



Deformed mesh |u| (scaled up 50.0 times)  
Maximum value = 0,07682 m (Element 453 at Node 496)

Models	Height	Horizontal deformation
Bored pile wall	20 m	15 mm to 26 mm
Concrete Berlin-type retaining wall	20 m	26 mm

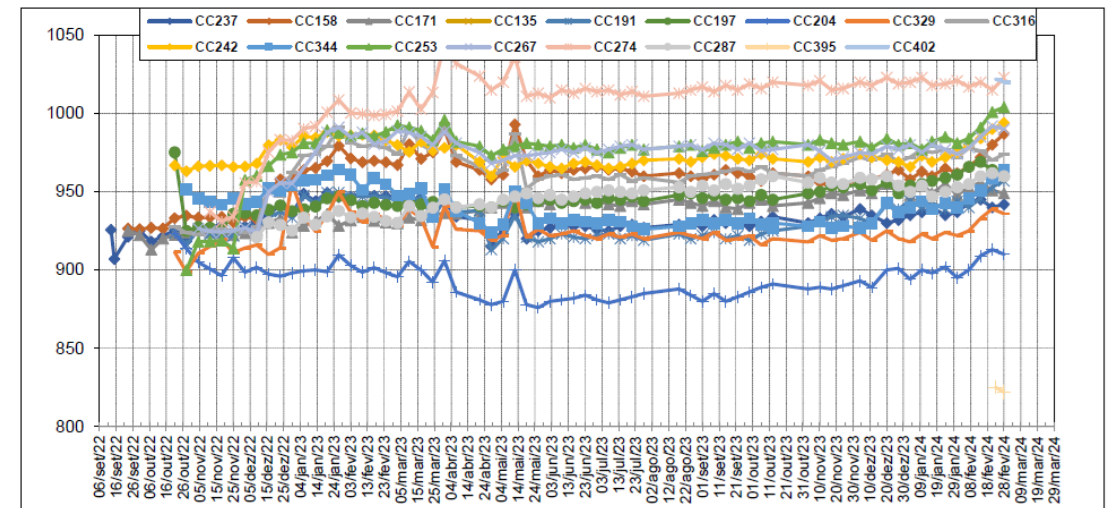
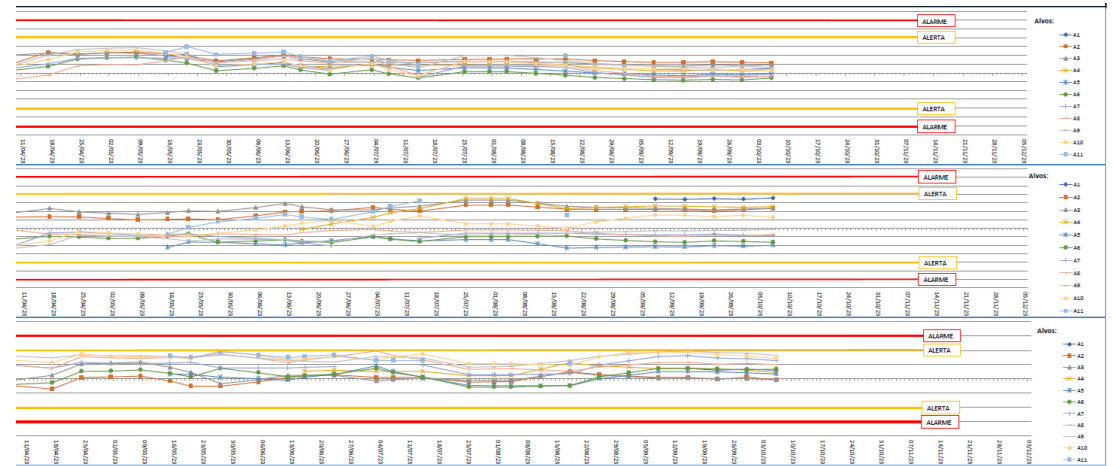
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- **Monitoring plan**
- Conclusions



## → Monitoring plan

- Ensure the safe and cost-effective execution of the retaining structures
- Horizontal and vertical displacements – Topographic targets
- Horizontal displacements – Inclinometers
- Tension load in the anchors – Load cells
- Maximum horizontal displacement - 15 mm/20 m height
- Anchor load increments of less than 10%



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- Introduction
- Geotechnical Scenario
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- Monitoring plan
- **Conclusions**



## → Conclusions

The alternative solution developed in the context of the design and construction contract carried out in collaboration between the designer (JETSJ) and the contractor (Norton EI), have proven to be extremely versatile and well-suited to local constraints





**ECSMGE 24**  
XVIII EUROPEAN CONFERENCE  
ON SOIL MECHANICS AND  
GEOTECHNICAL ENGINEERING

Acknowledgements  
**Thank you for your attention!**

# Lisbon new circular Metro line: Buildings underpinning

**Carlos de Oliveira Martins** / JETsj, Geotecnia

**Catarina Fartaria** / JETsj, Geotecnia

**Rui Tomásio** / JETsj, Geotecnia

**Alexandre Pinto** / JETsj, Geotecnia



**coba**  
Portugal



MOTAENGIL

spie batignolles



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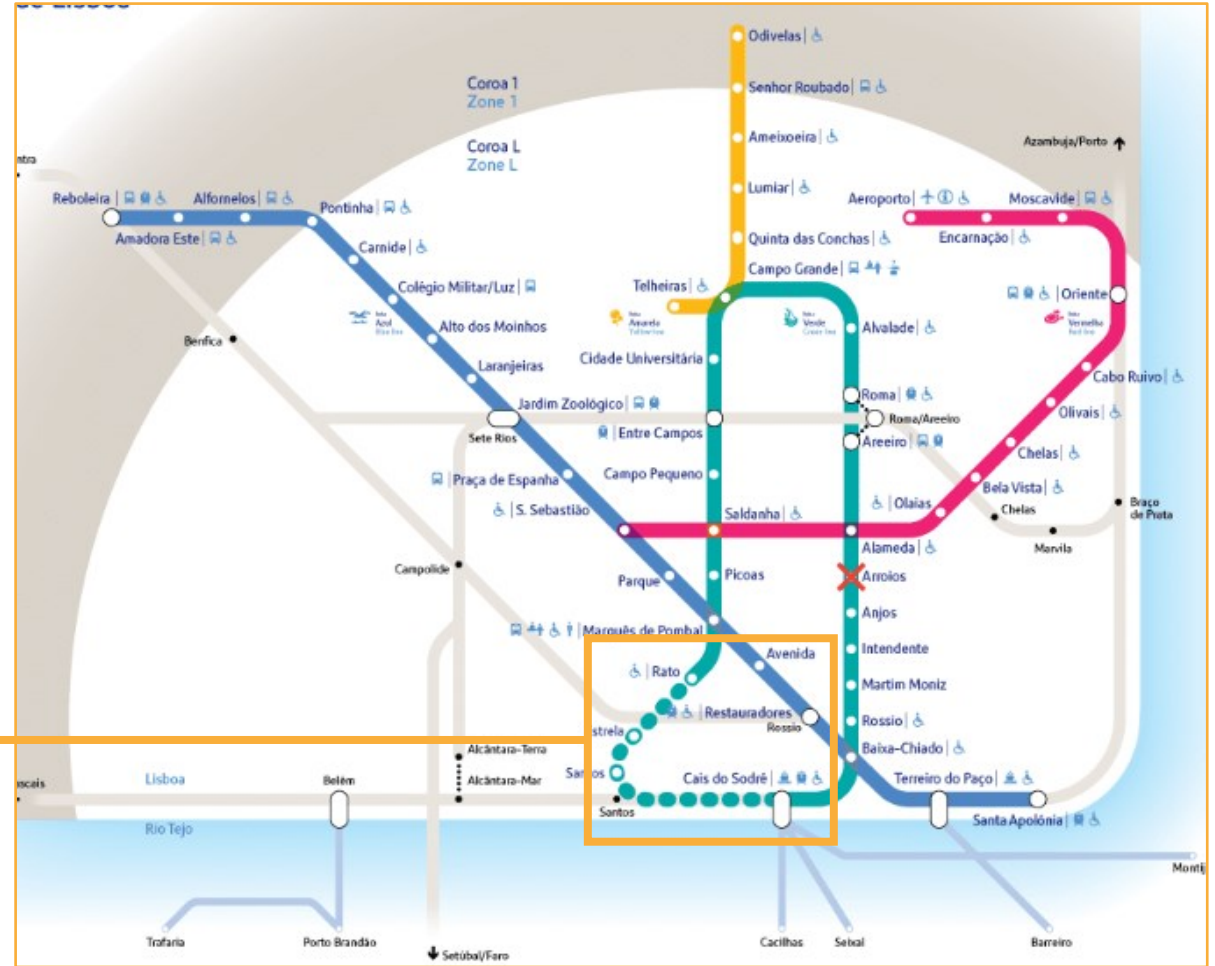
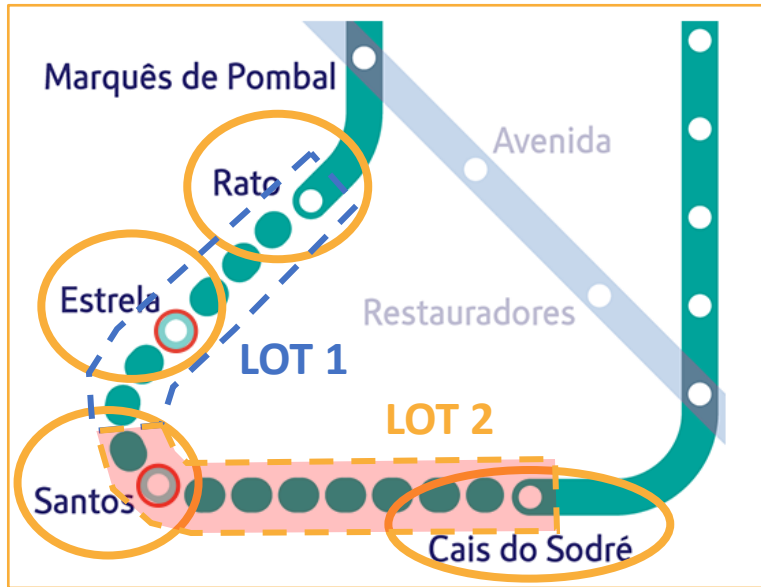
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- Main Challenges and Constraints
- Solution Description
- Solution Design
- Construction Phases and Load Transfer Operation
- Construction Works



# → Introduction

## LISBON NEW CIRCULAR METRO LINE:

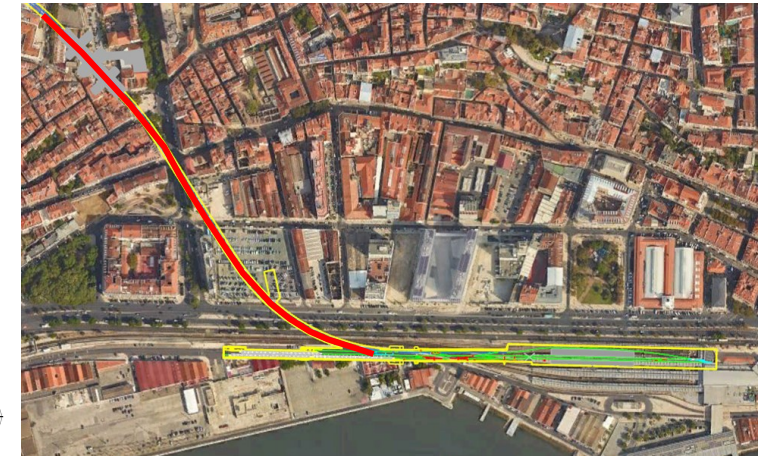
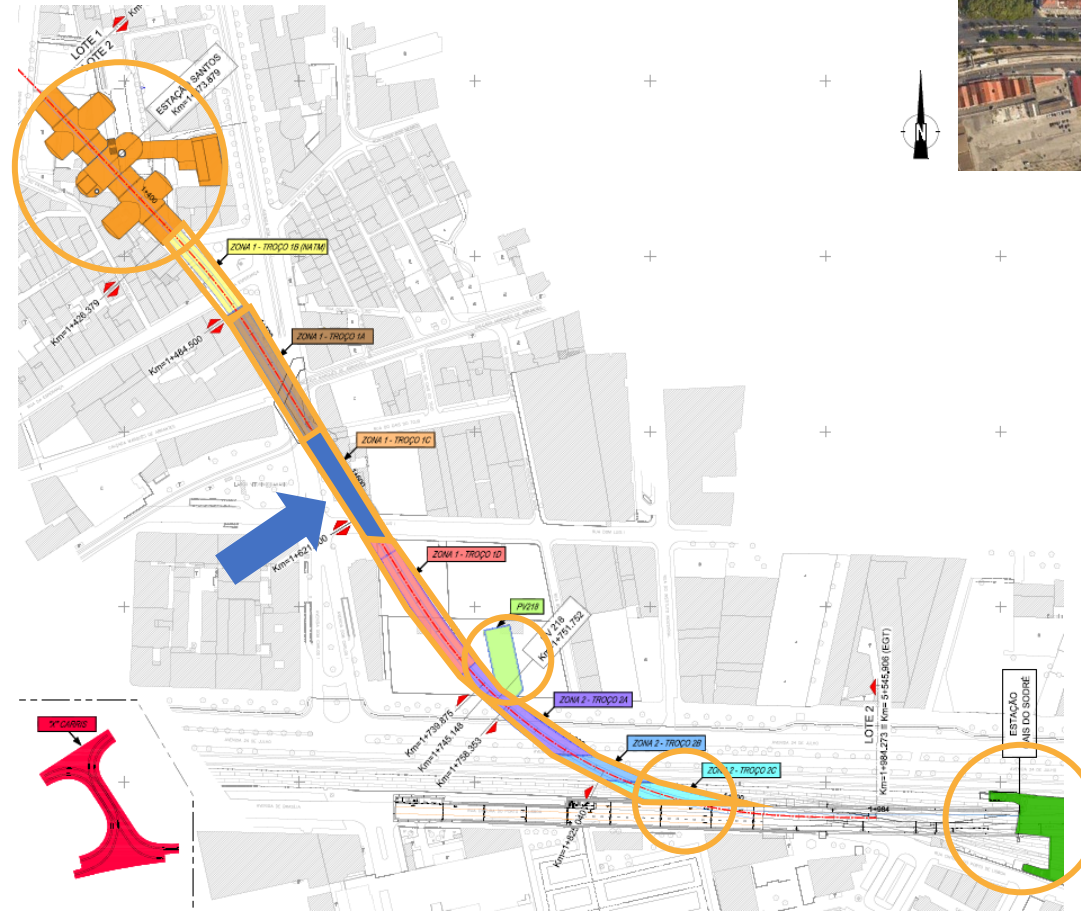
- Rato station interconnection
- Estrela station
- Santos station
- Cais do Sodré station interconnection



## → Introduction

### ROUTE OF LOT 2 AND MAIN WORKS:

- New Santos Station
- NATM Tunnel
- Cut&Cover Tunnel
- Buildings Underpinning
- Cut&Cover Tunnel
- PV218 Ventilation Shaft
- Interconnection to Cais do Sodré Terminus
- Refurbishment of Cais do Sodré Station



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- Solution Description
- Solution Design
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- Construction Works



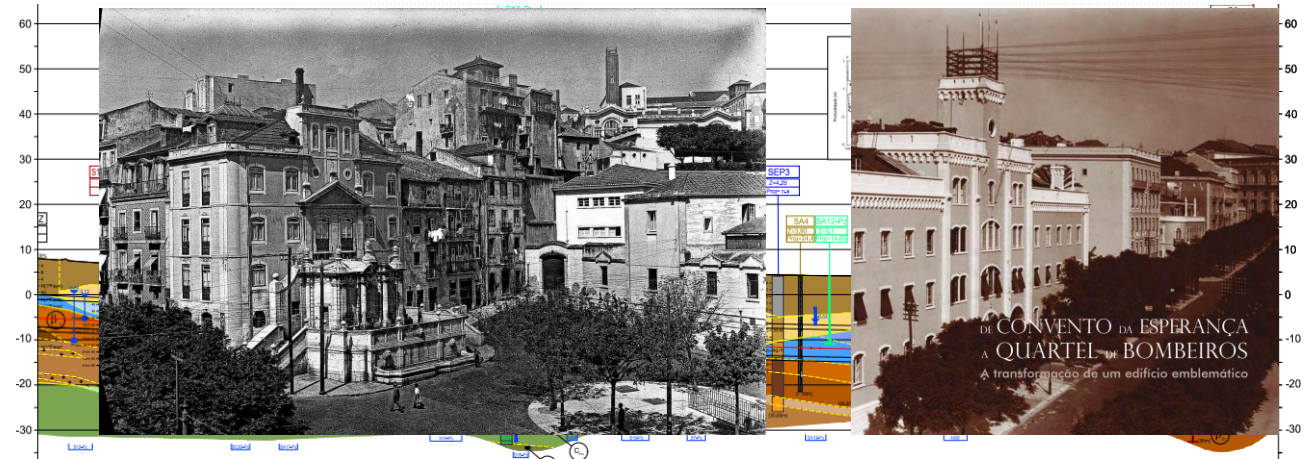
## → Main Challenges and Constraints

### CHALLENGES:

- Densely urbanized area
  - Density of structures and services
- Complex geological, geotechnical and hydrogeological scenario:
  - Maritime landfill area
  - Raised water level
  - Tide effect
- Historic part of the city
  - Centenary buildings
  - Former Convent of Esperança

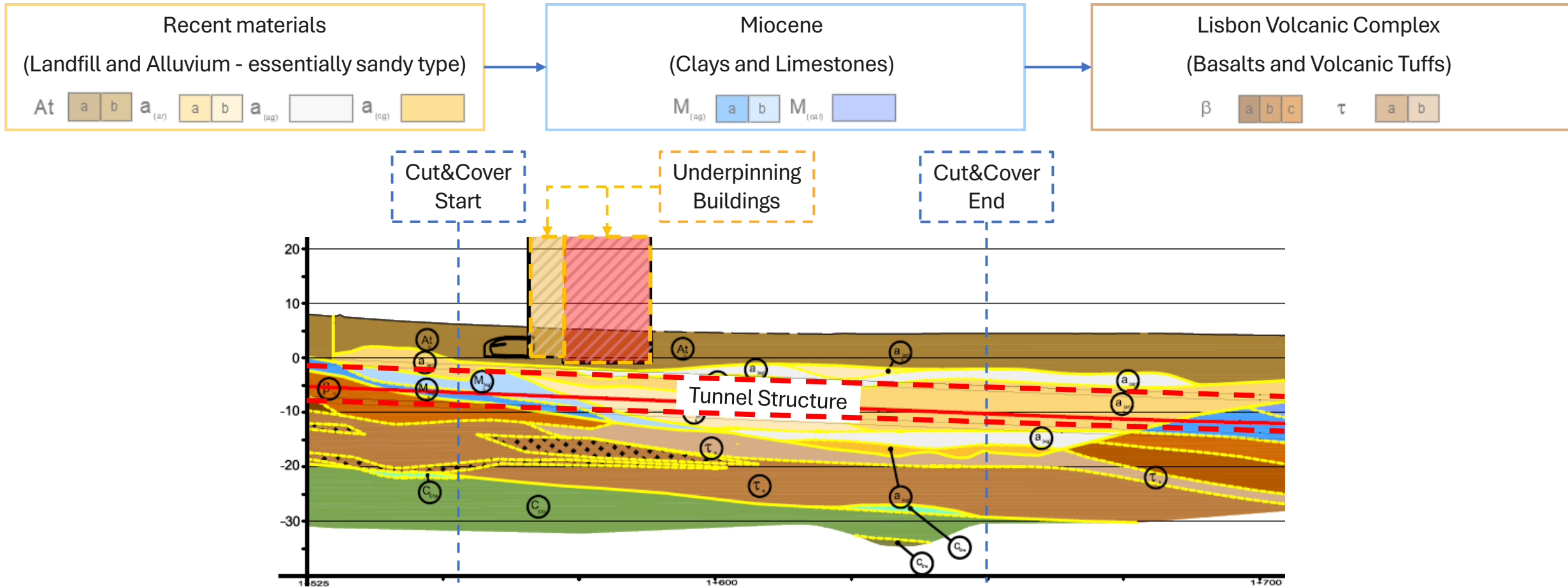


1780 - PLANTA TOPOGRAPHICA



## → Main Challenges and Constraints

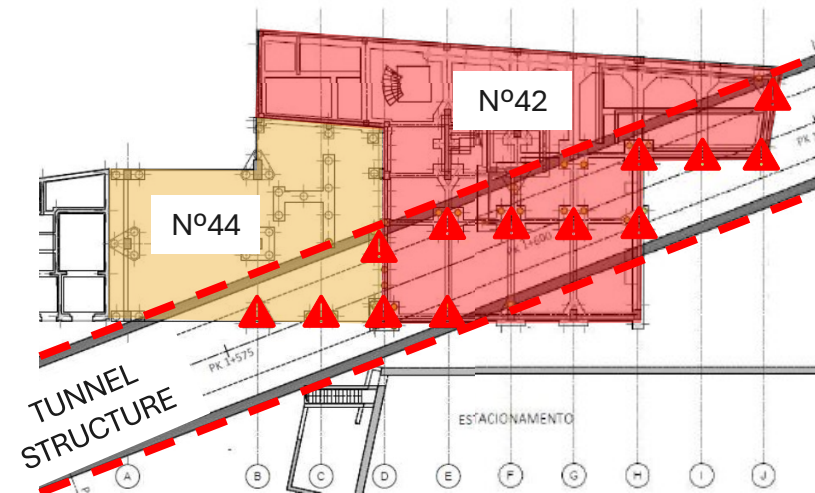
### GEOLOGICAL AND GEOTECHNICAL CONSTRAINTS:



## → Main Challenges and Constraints

### AFFECTED BUILDINGS:

- Buildings nº 42 and nº 44 at Avenida D. Carlos I (XX century):
  - Reinforced concrete structure
  - Pile foundations.
  - 9 elevated floors and 1 basement.
  
- Building nº42 was recently subject to rehabilitation works for conversion into residential use.
  
- Building nº44 is in its original conditions, used for offices, and showing a good state of conservation.
  
- Need to underpin several columns over intervention area:
  - Solution compatible with equipment that can operate inside the building's basements (ceiling height of about 3,0m )



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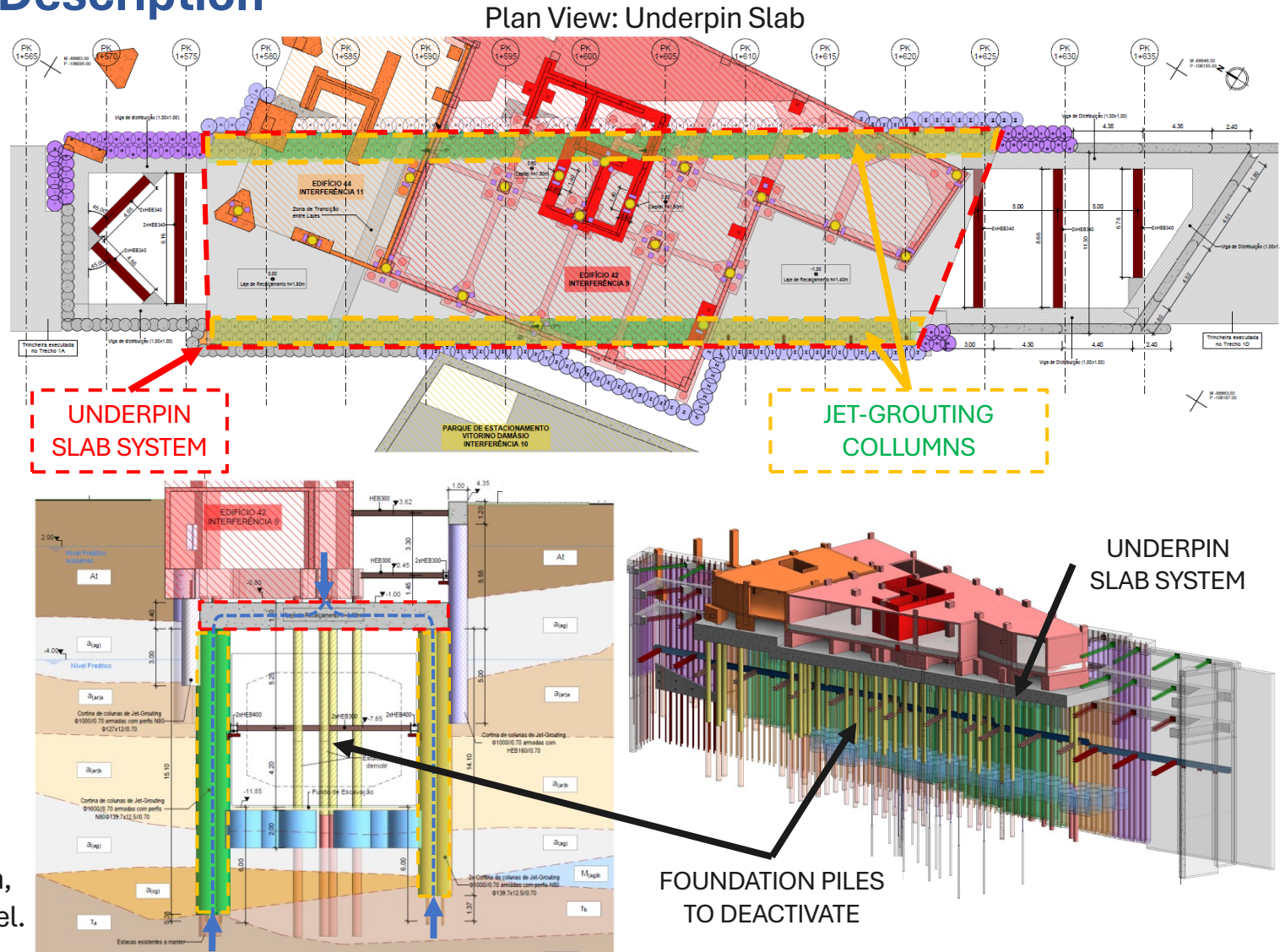
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## → Solution Description

### UNDERPINNING SOLUTION:

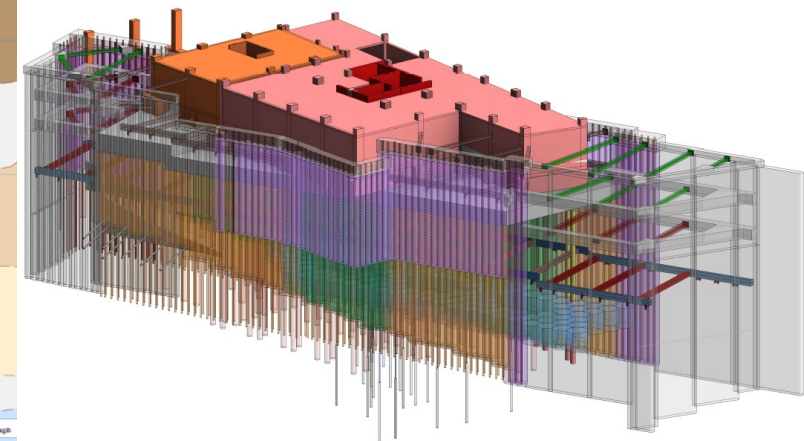
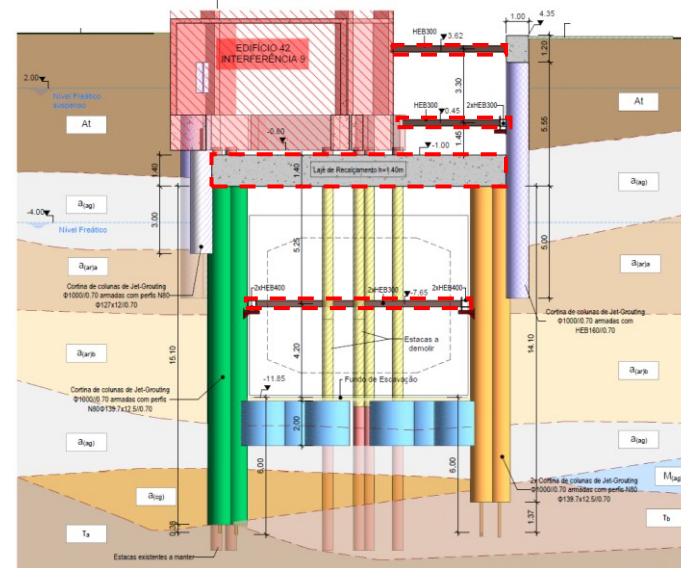
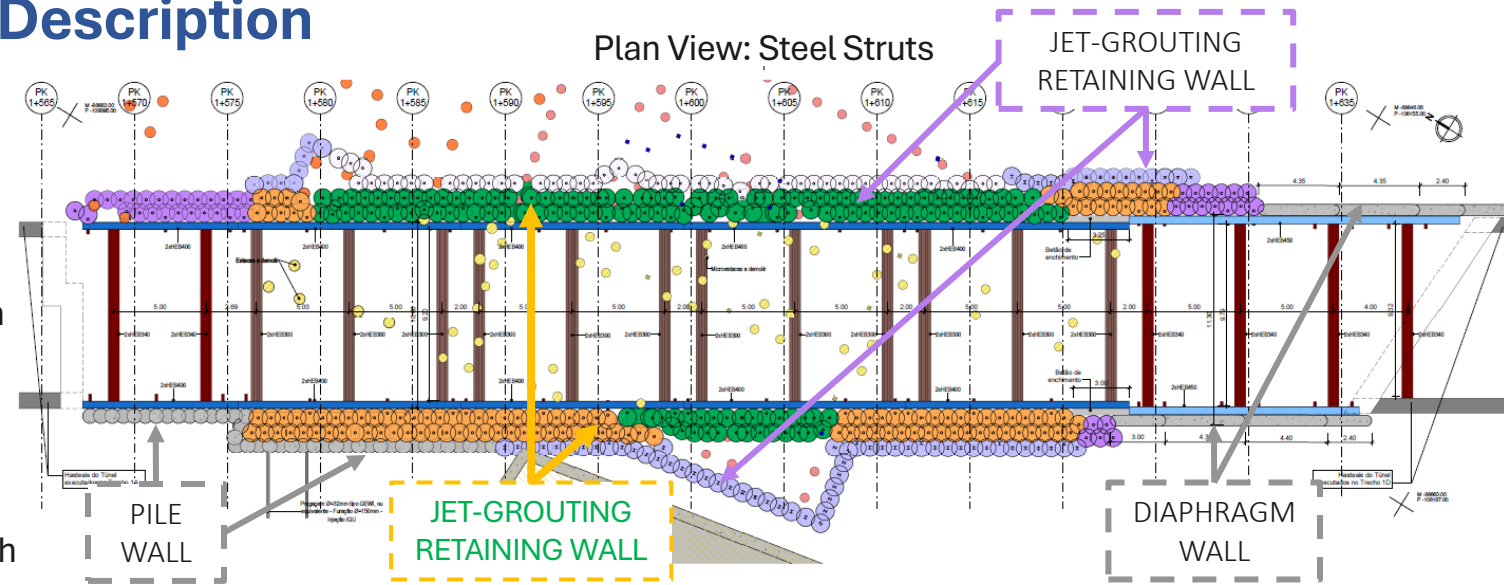
- Reinforced concrete slab, not prestressed:
  - Below the existing pile caps and above the tunnel
  - Geometry of approximately 50,0m by 13,0m
  - Thickness between 1.40m and 1.80m
- Supported on two rows of jet-grouting columns, reinforced with steel profiles
- Change the foundation system of the buildings:
  - Structural columns
  - Slab (cylindrical bending)
  - Jet-grouting columns
  - Competent ground layers (below the tunnel)
- Possible to deactivate the existing piles over the tunnel area, to proceed with the excavation works to build the new tunnel.



## → Solution Description

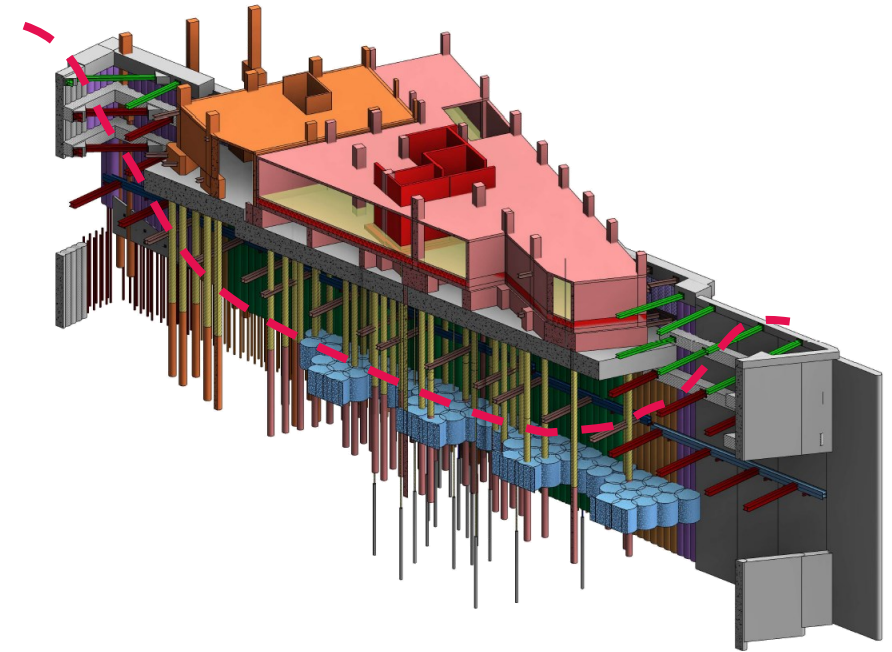
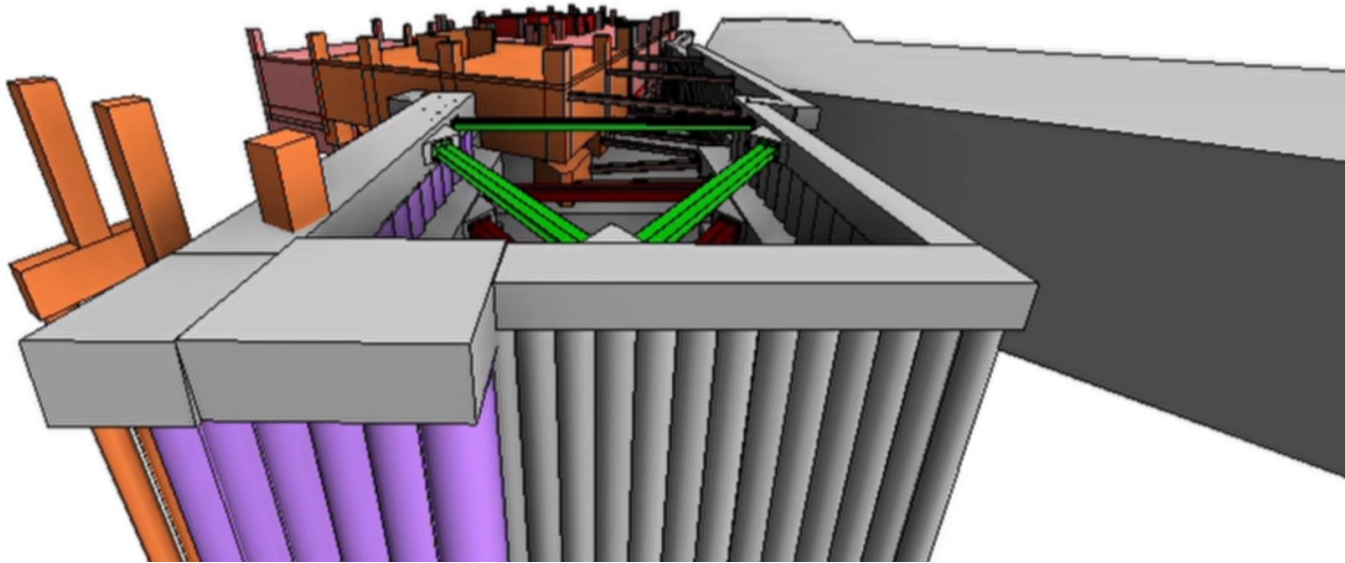
### CUT&COVER EXCAVATION SOLUTION

- Double jet-grouting retaining wall  $\varnothing 1.0\text{m}/700\text{mm}$ 
  - Reinforced with tubular steel profiles
- To reach the underpinned slab level:
  - Third row of jet-grouting columns, also reinforced with steel profiles
- Interconnection with neighboring trenches:
  - Pile wall, in the north side
  - Diaphragm wall, on the south side
- Temporary propped each other with:
  - 4 levels of steel struts, 5.0m apart
  - Steel and reinforced concrete distribution beams
  - Reinforced concrete slab as the third strut level



## → Solution Description

### QUICK WALK THROUGH THE REVIT MODEL



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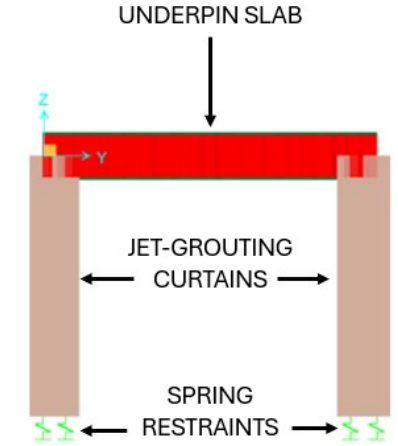
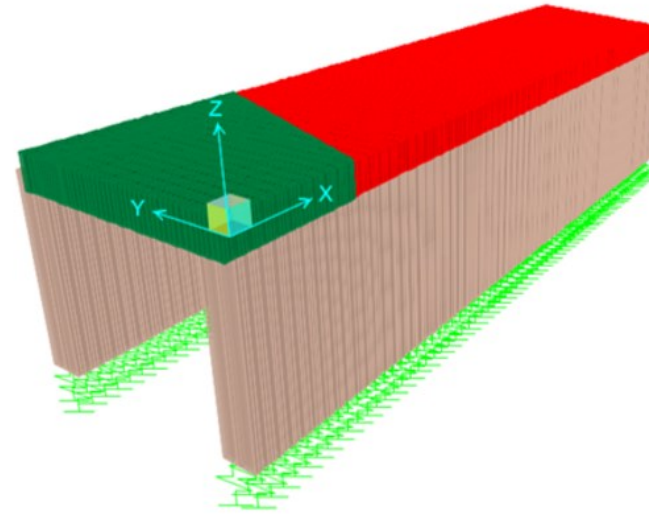
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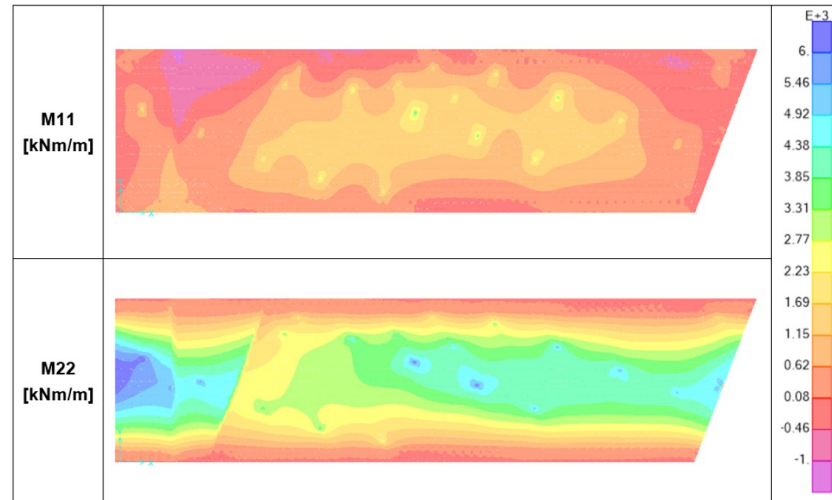
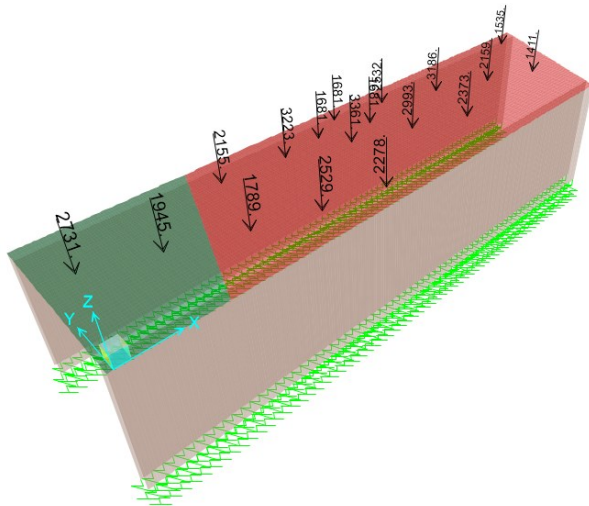
## → Solution Design

### UNDERPINNING SLAB:

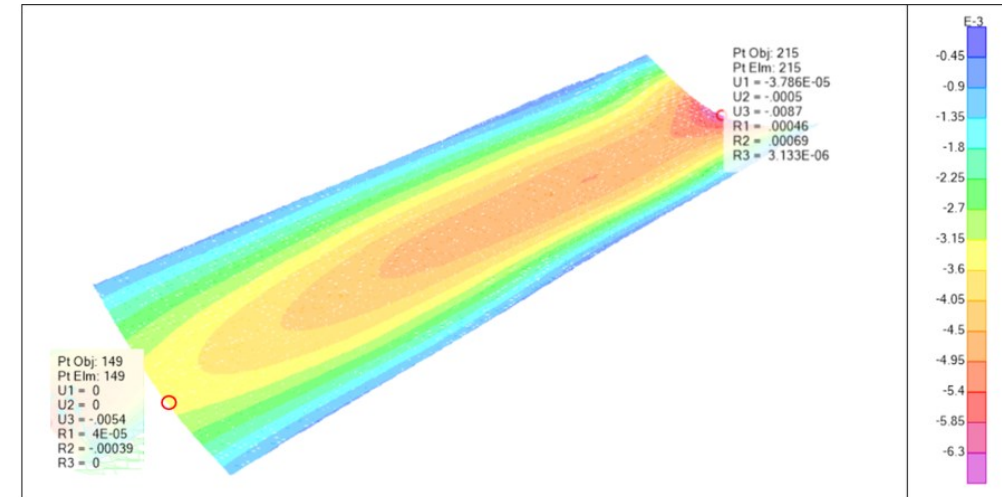
- Design using structural finite element analysis software *SAP2000*:
  - Shell type elements
  - Springs type restraint
  - Estimate slab forces and elastic deformation



Bending Moments (ULS)



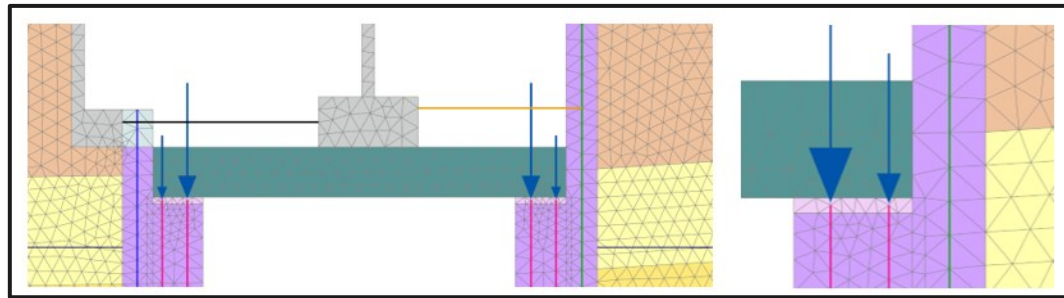
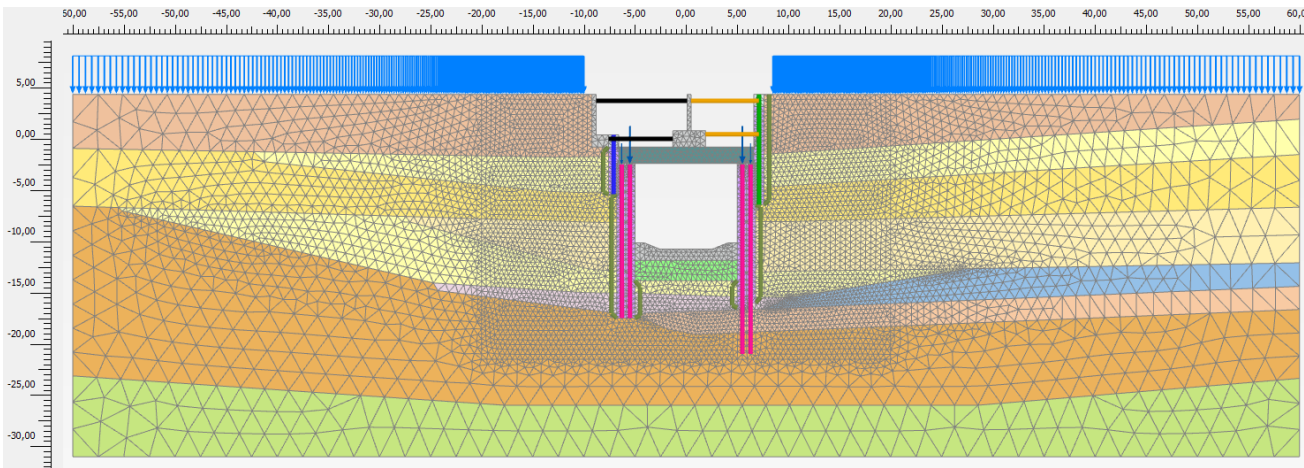
Elastic Deformation (SLS)



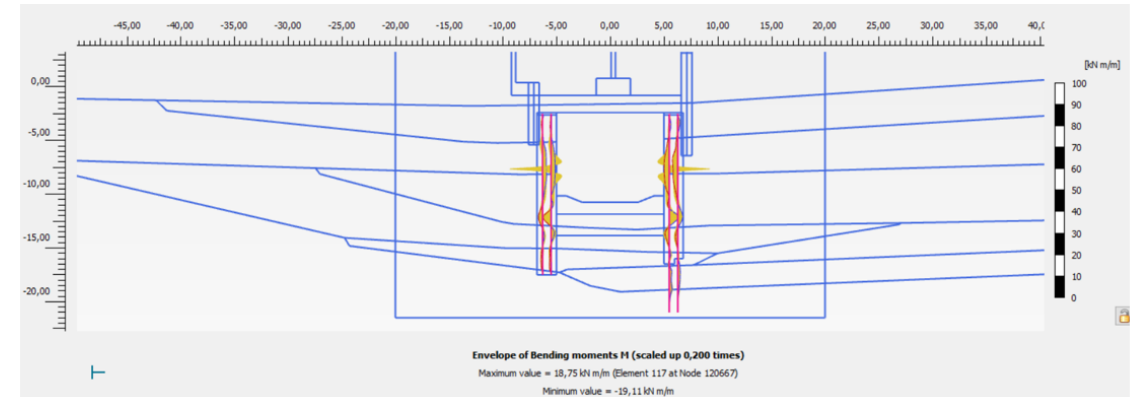
# → Solution Design

## UNDERPINNING SLAB AND CUT&COVER:

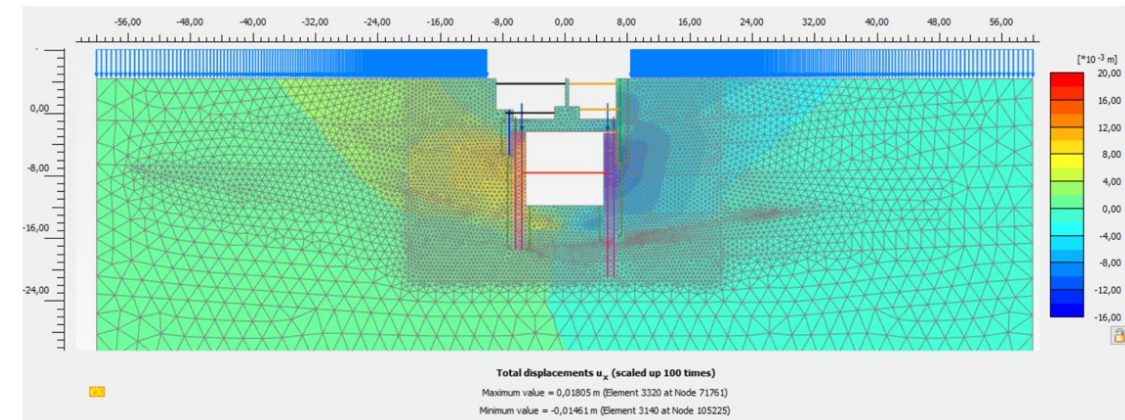
— Design using geotechnical finite element analysis software *PLAXIS 2D*



## Forces at the steel reinforcement of the jet-grouting columns



## Horizontal Deformation ( $U_{x,max} = 18\text{mm}$ )



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- Construction Works

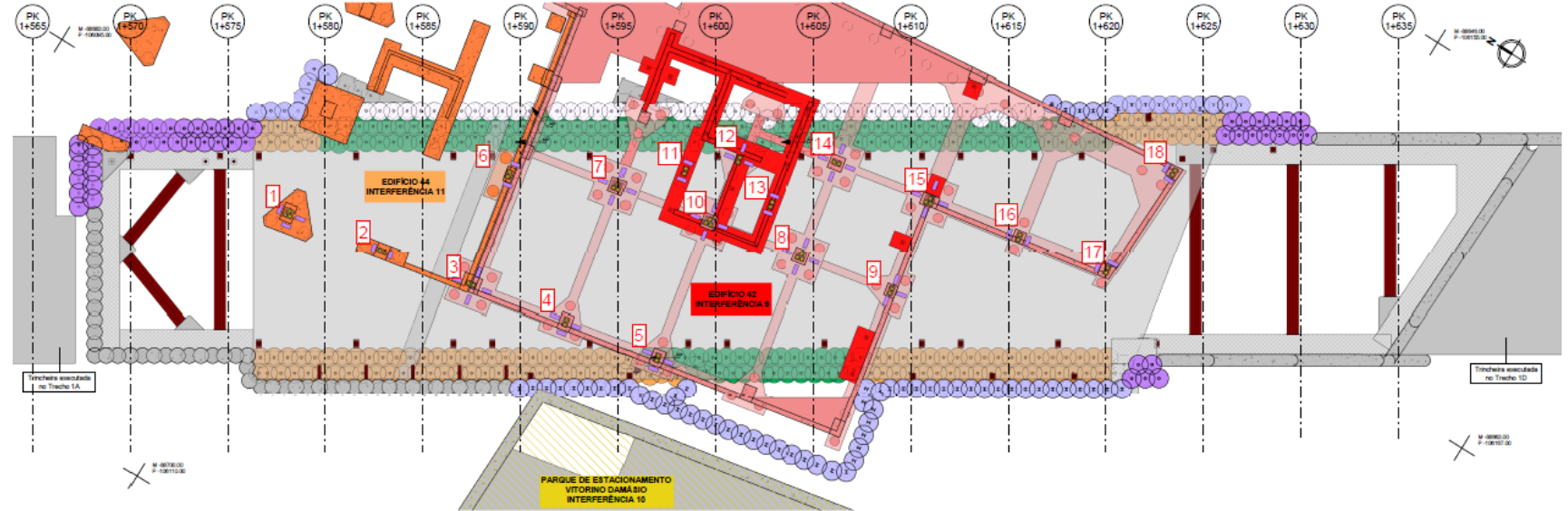


# → Construction Phases and Load Transfer Operation

## LOAD TRANSFER OPERATION

- 18 Columns and Walls
- 41 Hydraulic Jacks
- 18 Load Steps (20 to 50 bars each step)

ENERPAC LPL-2002



### Monitoring devices

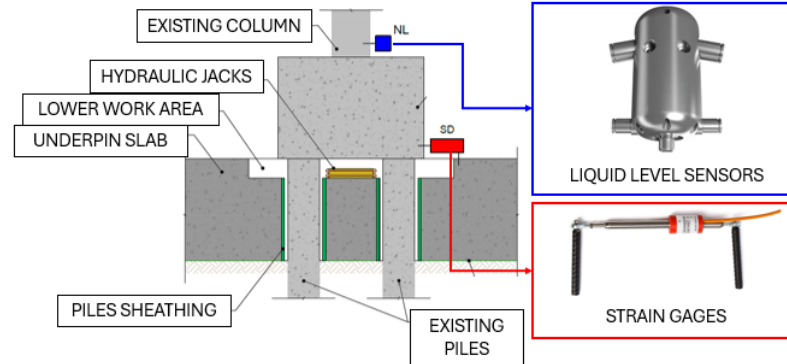


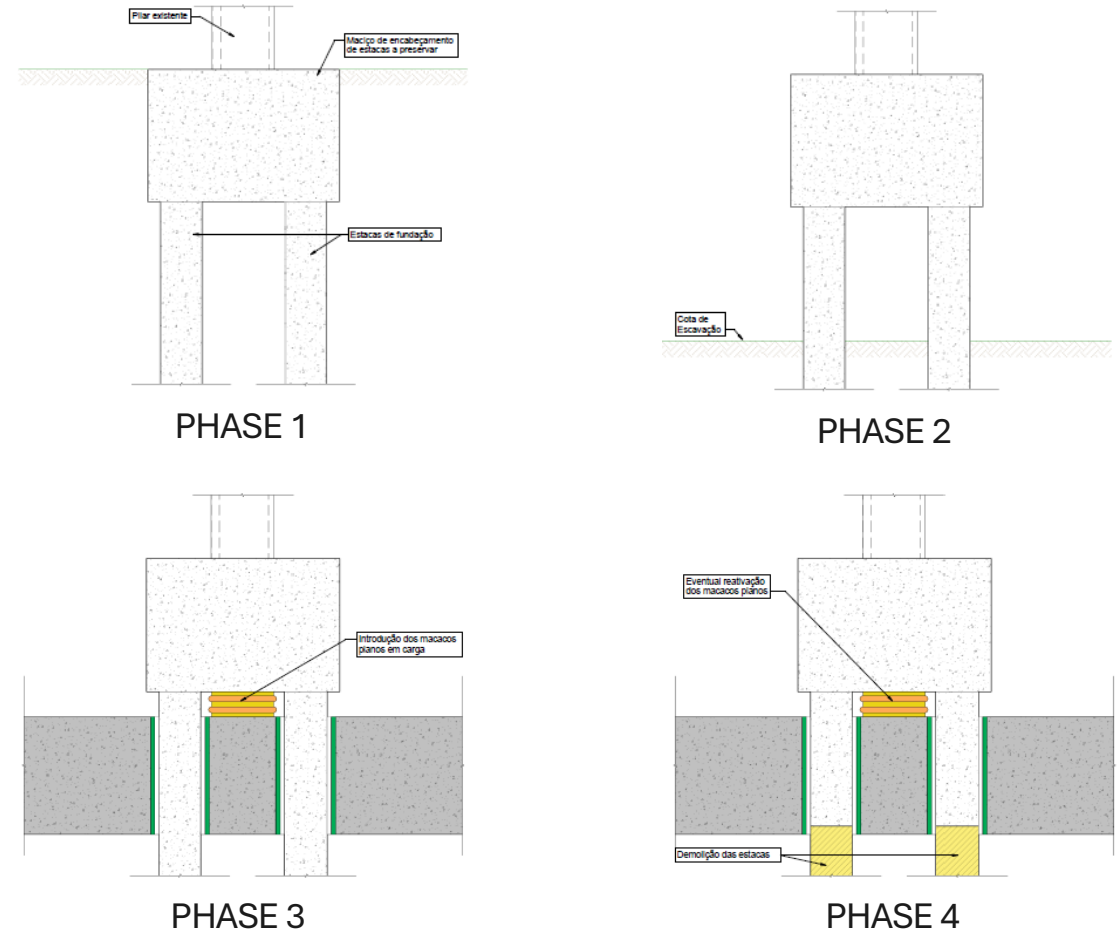
Table of deformation control criteria for each step

Macaco	Carga máxima estimada (quase permanente)	Quantidade de Cilindros	Patamar de pressão	Pressão / cil [bar]	Pressão [bar]	Carga instalada [kN]	Porcentagem de carga instalada [%]	Deformação vertical [mm]		
								Limite de alerta	Limite de referência	Limite de alarme
7	3223,0	3	1	50	150	425,3	13,2%	0,42	0,53	0,69
			2	100	300	850,5	26,4%	0,73	0,91	1,19
			3	150	450	1275,8	39,6%	1,04	1,30	1,68
			4	170	510	1445,9	44,9%	1,16	1,45	1,88
			5	180	540	1530,9	47,5%	1,22	1,53	1,98
			6	200	600	1701,0	52,8%	1,34	1,58	2,18
			7	220	660	1871,1	58,1%	1,47	1,83	2,38
			8	240	720	2041,2	63,3%	1,59	1,99	2,58
			9	250	750	2126,3	66,0%	1,65	2,06	2,68
			10	270	810	2296,4	71,2%	1,77	2,22	2,88
			11	300	900	2551,5	79,2%	1,96	2,45	3,18
			12	320	960	2721,6	84,4%	2,05	2,57	3,34
			13	350	1050	2976,8	92,4%	2,19	2,74	3,56
			14	380	1140	3231,9	100,3%	2,32	2,90	3,77
			15					2,34	2,93	3,80
			16					2,36	2,95	3,83
			17					2,37	2,96	3,85
			18					2,38	2,98	3,88

## → Construction Phases and Load Transfer Operation

### LOAD TRANSFER OPERATION (SUMMARY VERSION)

- **Phase 1:**
  - Installation of the instrumentation system at the existing columns;
- **Phase 2:**
  - Excavation to the bottom level of the slab;
- **Phase 3:**
  - Sheathing of the piles followed by slab construction
  - Hydraulic jacks installation;
- **Phase 4:**
  - Excavation under the slab, followed by hydraulic jacks activation
  - Finally existing piles demolition, managed by monitoring data analysis



## → Construction Phases and Load Transfer Operation

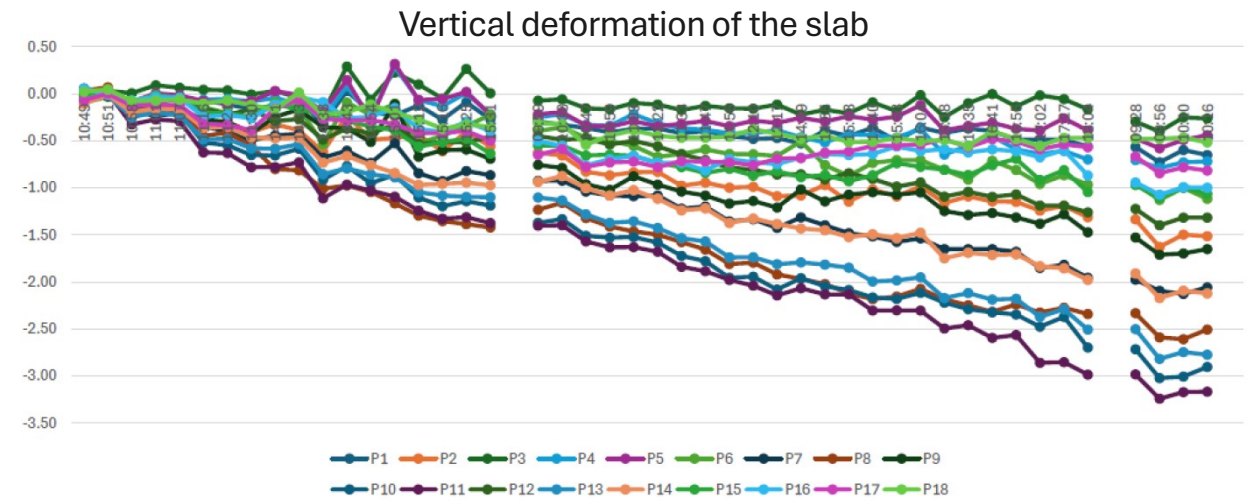
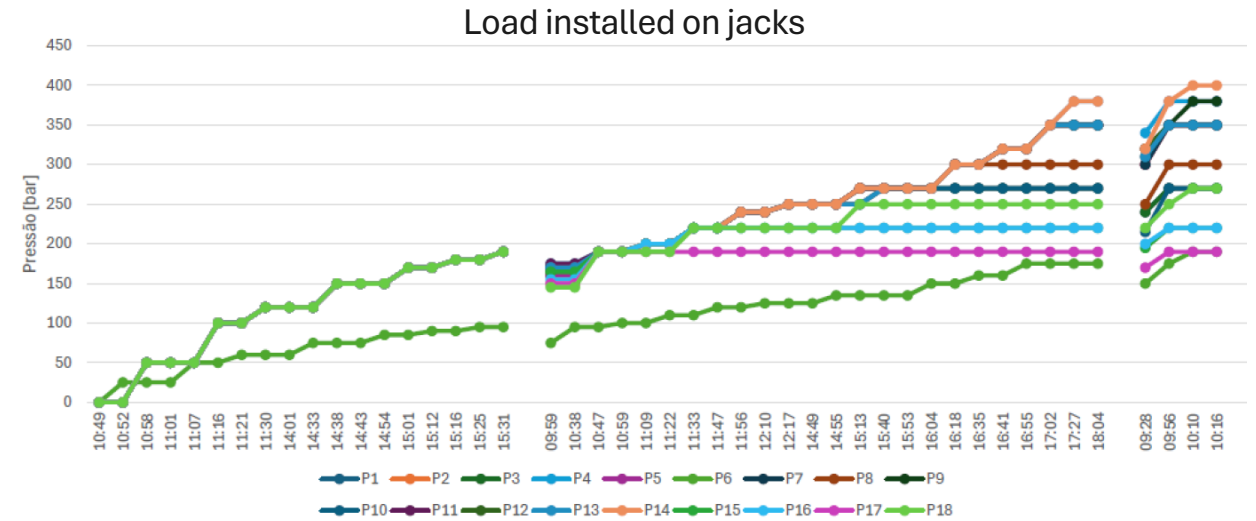
### LOAD TRANSFER OPERATION - PHASE 3: HYDRAULIC JACKS ACTIVATION AND APPLICATION OF LOAD TRANSFER

#### Estimated loads:

- Generally adequate and consistent with the recorded ones;
- Some applied loads were below or above the estimated value (adjusted to avoid differential settlements):
  - Column P10: installed load lower than estimated (67.5% applied load with a vertical deformation of 1.3mm);
  - Columns P11, P12 and P13: installed load higher than estimated (118.1% applied load with a vertical deformation of 1.3mm to 3.1mm);

#### Estimated deformations:

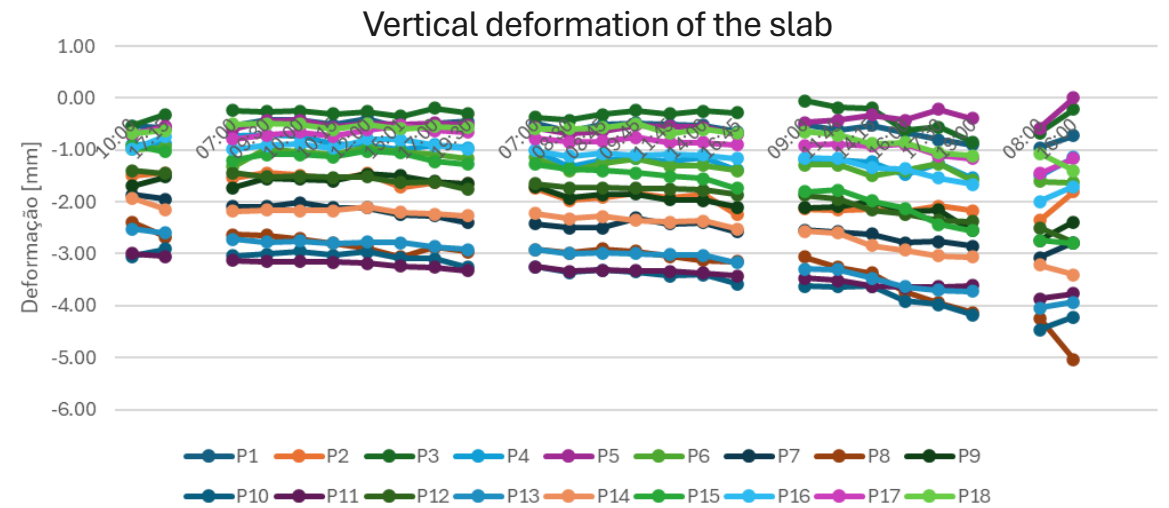
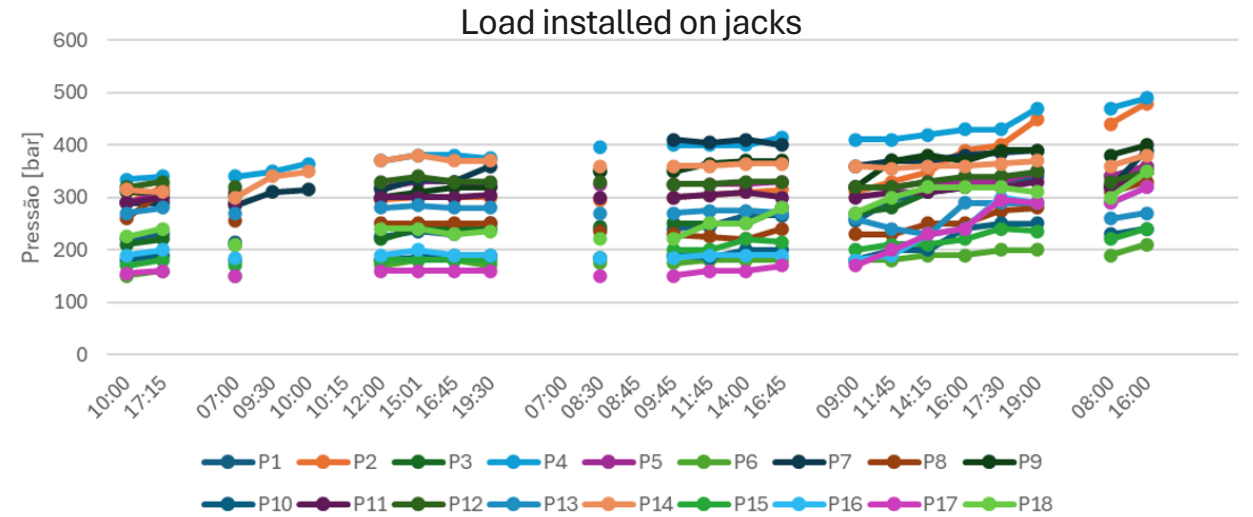
- Generally higher than the recorded values;
- Close to the estimate in columns P2 (1.50mm), P10 (3.00mm) and P14 (2.09mm)



## → Construction Phases and Load Transfer Operation

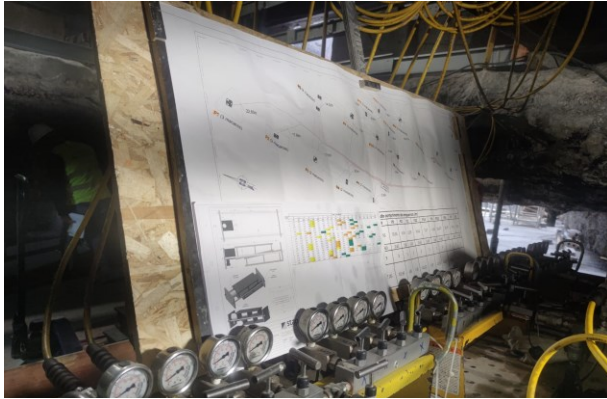
### LOAD TRANSFER OPERATION - PHASE 4: DEMOLITION OF THE PILES

- Load increases occurred on the jacks in all columns:
  - Loads were not fully actively transferred, in Phase 3 of the process
  - Increased safety: avoided tensioned piles by the application of excessive loads, minimizing dynamic effects resulting from the release of this energy in the demolition phase
  
- Estimated deformations:
  - Below the criteria defined for possible reactivation of the hydraulic jacks (settlements lower than 5mm)



# → Construction Phases and Load Transfer Operation

## LOAD TRANSFER OPERATION



Pressure control on the jacks



Hydraulic jacks



Fitting temporary chocks



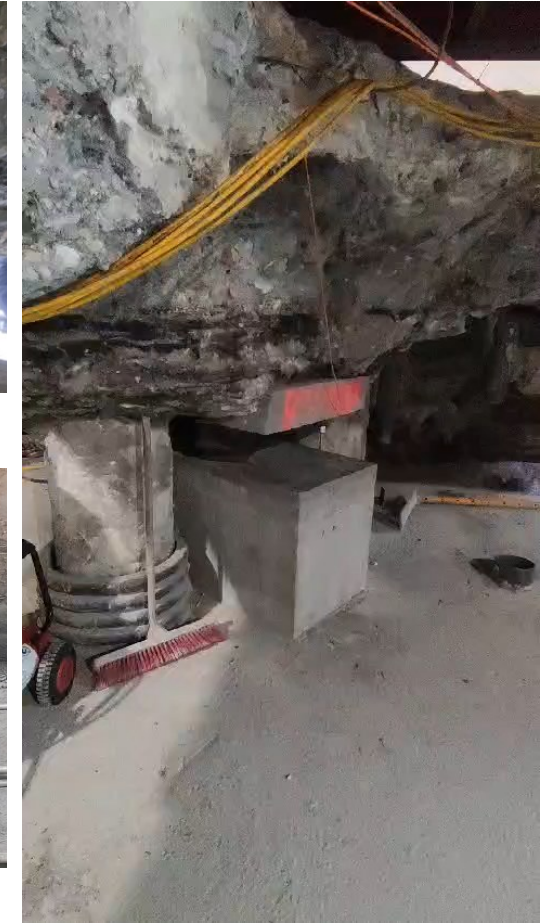
Hydraulic jacks activation and application of load transfer



Sheathing of the piles



Demolition of the piles



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- Construction Phases and Load Transfer Operation
- **Construction Works**



## → Construction Works



Execution of jet-grouting columns



Installation of the first level of steel struts



Excavation work in the area of the existing foundation piles



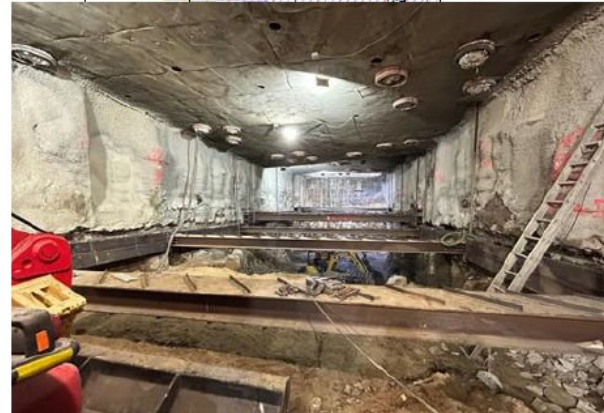
→ **Construction Works**



Second and third strut level in the pile wall and in the diaphragm wall section



Steel reinforcement of the slab



Installation of the fourth level of steel struts

## → Construction Works: Current Phase



Special Acknowledgements to:



**Thank you for your attention!**



# Lisbon new circular Metro line: Interconnection section between new line and existing terminus

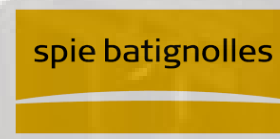
**Carlos de Oliveira Martins** / JETsj, Geotecnia

**Pedro Marques** / JETsj, Geotecnia

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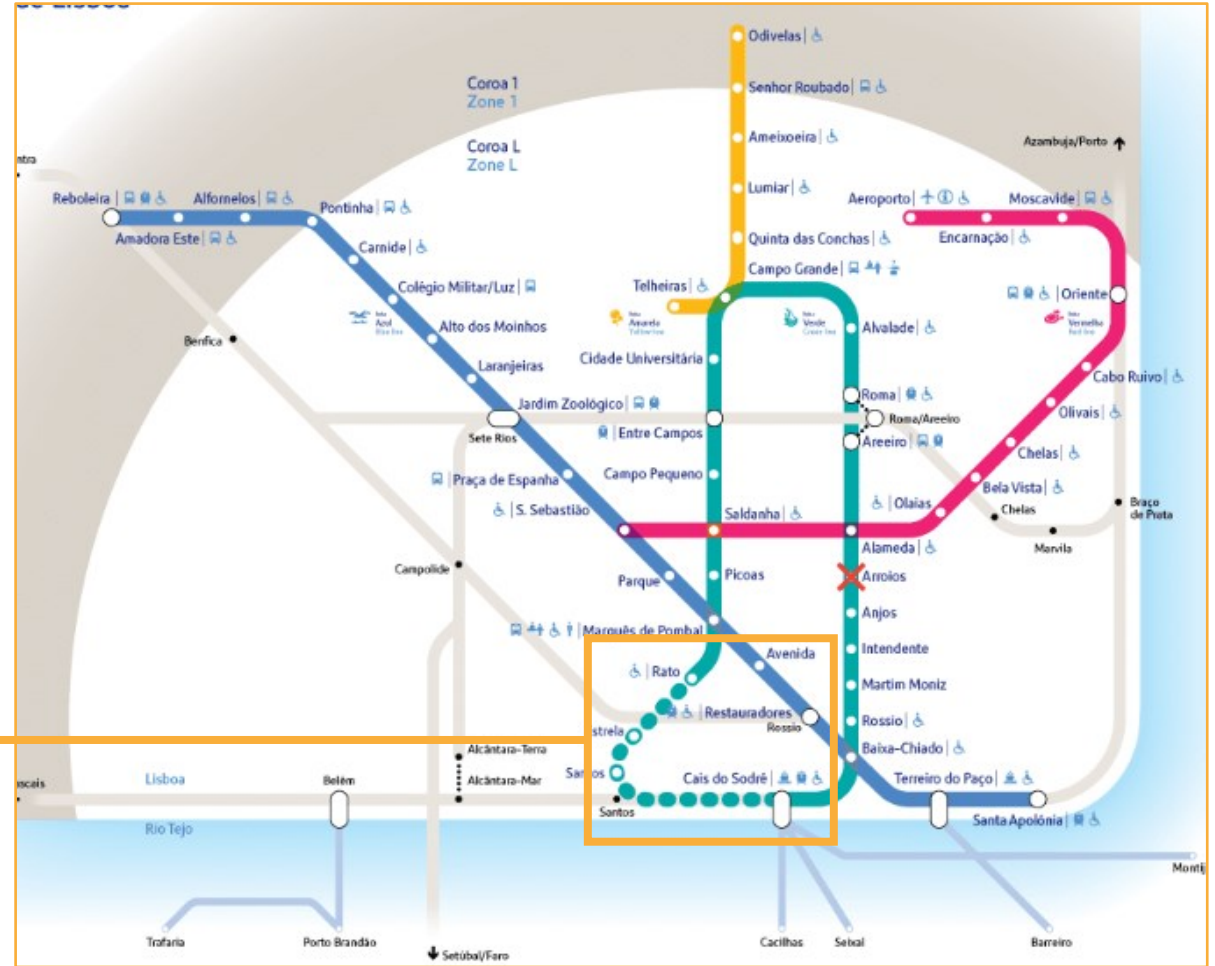
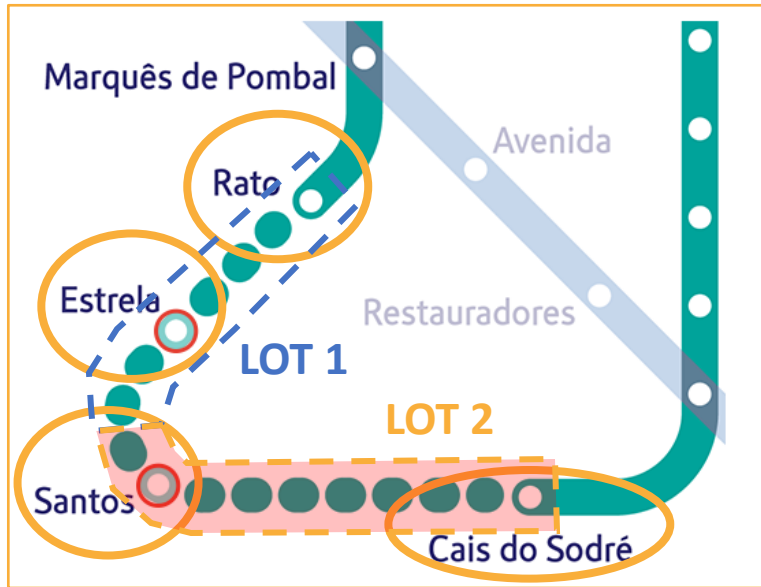
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# → Introduction

## LISBON NEW CIRCULAR METRO LINE:

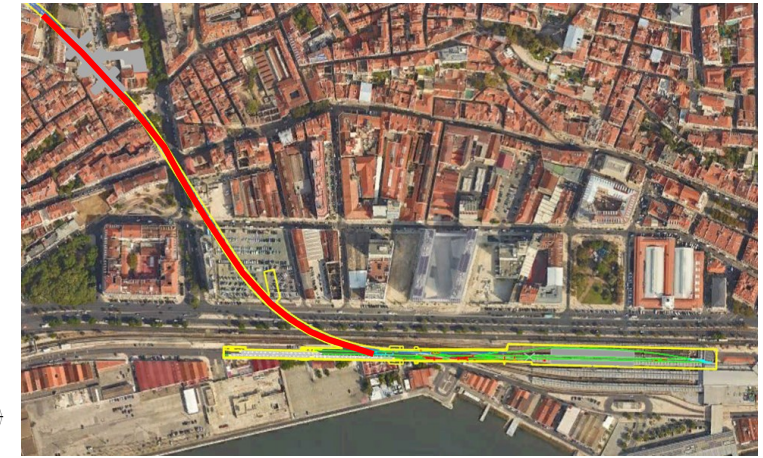
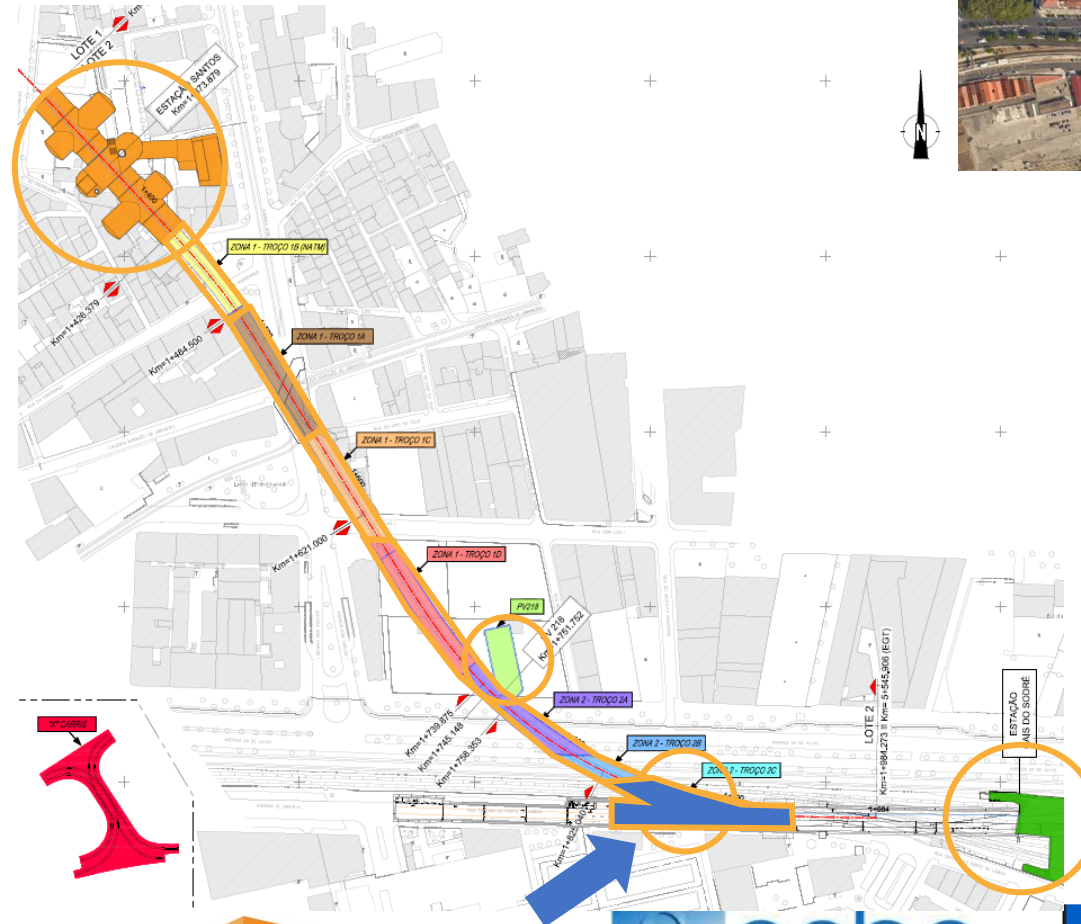
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# → Introduction

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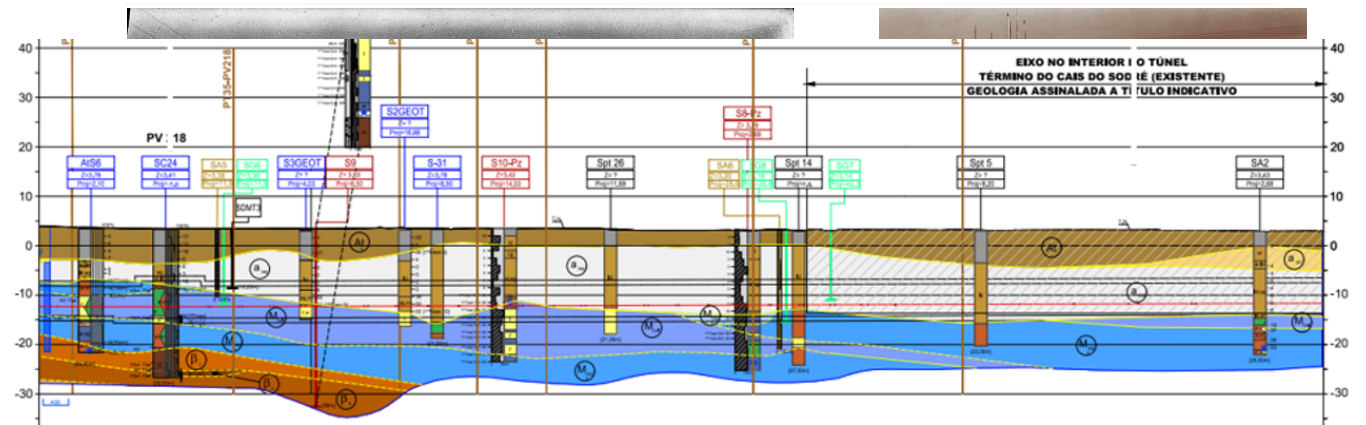
## → Main Challenges and Constraints

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  - Density of structures and services
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  - Maritime landfill area
  - Raised water level
  - Tide effect
- Historic part of the city
  - Centenary buildings
  - Former Convent of Esperança



1780 - PLANTA TOPOGRAPHICA



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**coba**  
Portugal



MOTA-ENGIL



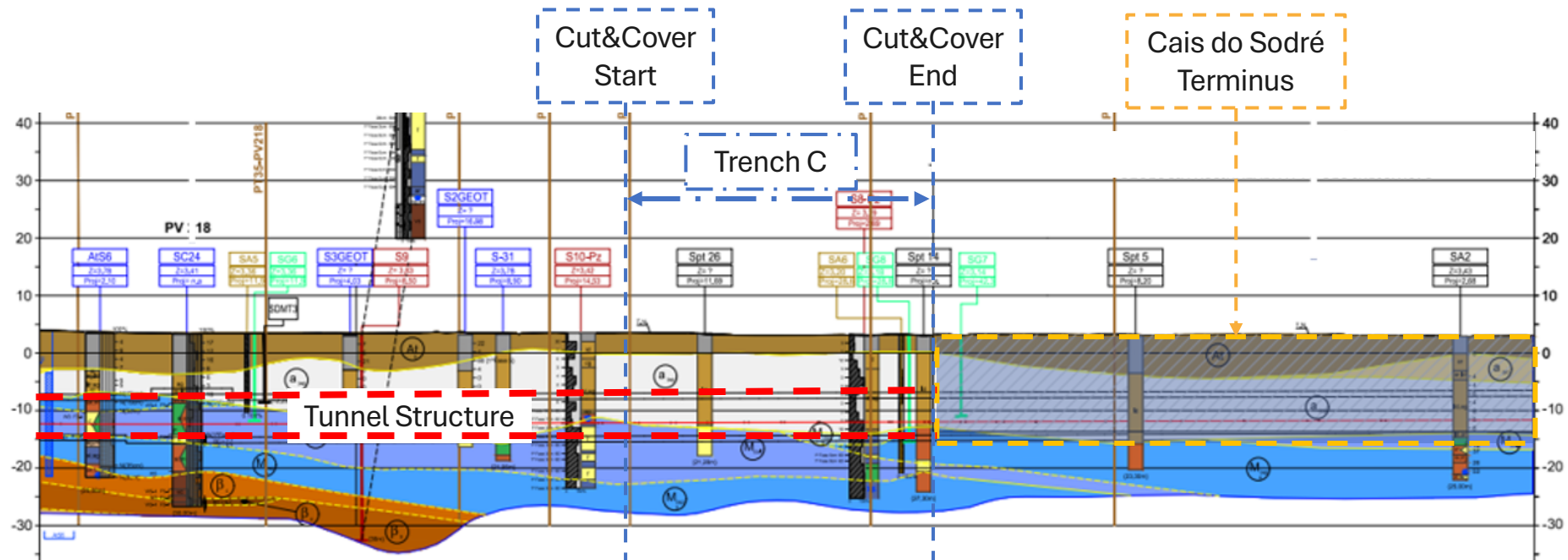
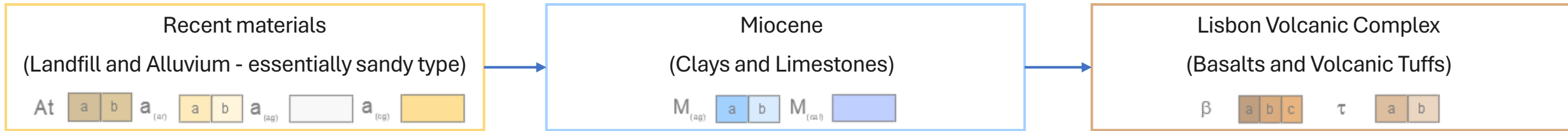
spie batignolles



metro

## → Main Challenges and Constraints

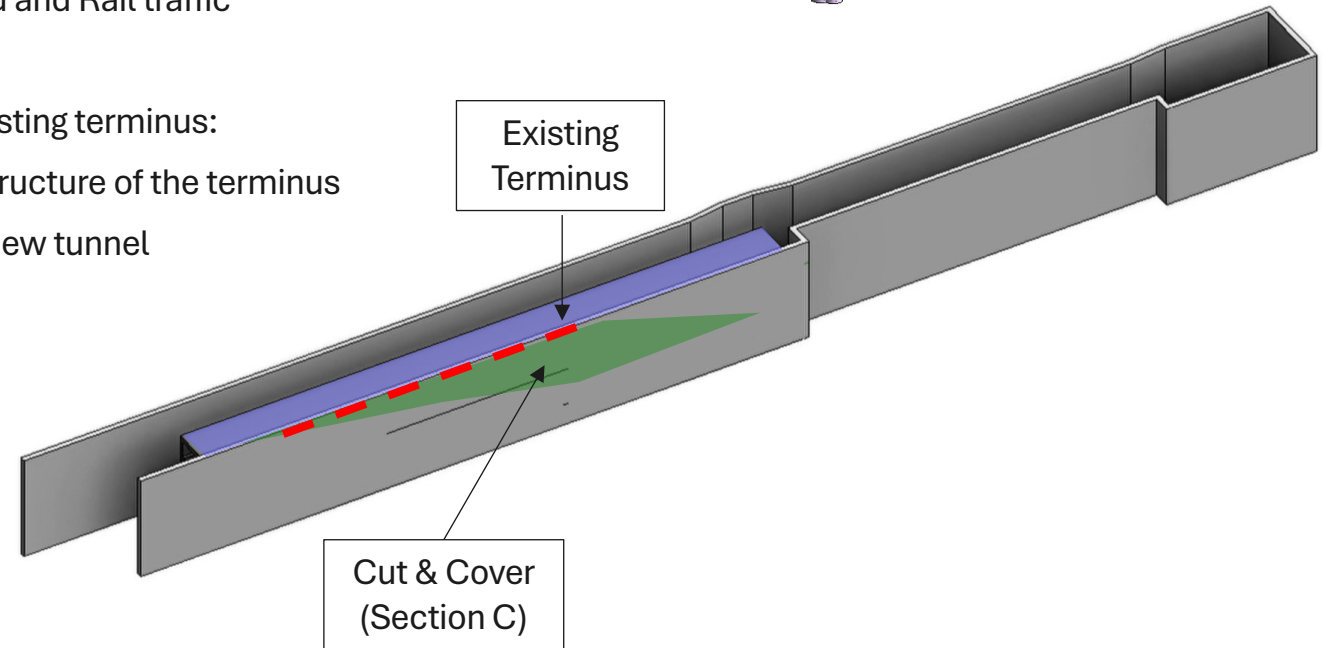
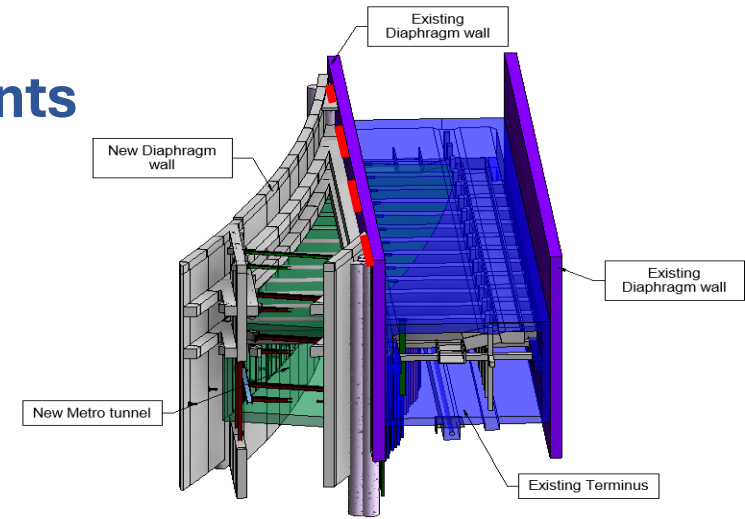
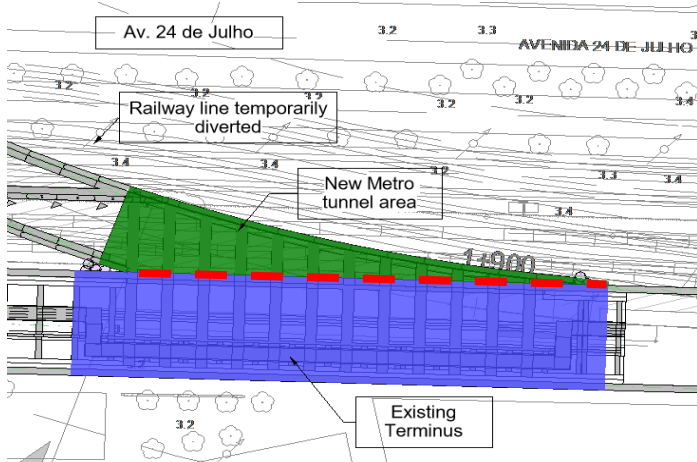
### GEOLOGICAL AND GEOTECHNICAL CONSTRAINTS:



## → Main Challenges and Constraints

### AFFECTED INFRASTRUCTURE AND CONSTRUCTION CONSTRAINTS: AV. 24 DE JULHO

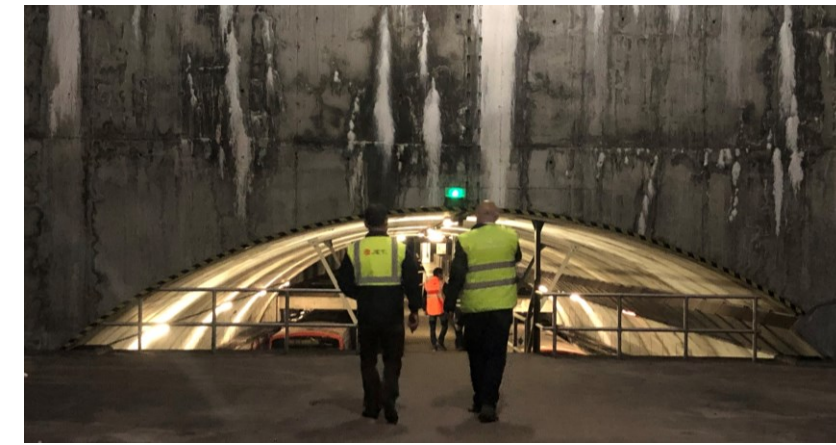
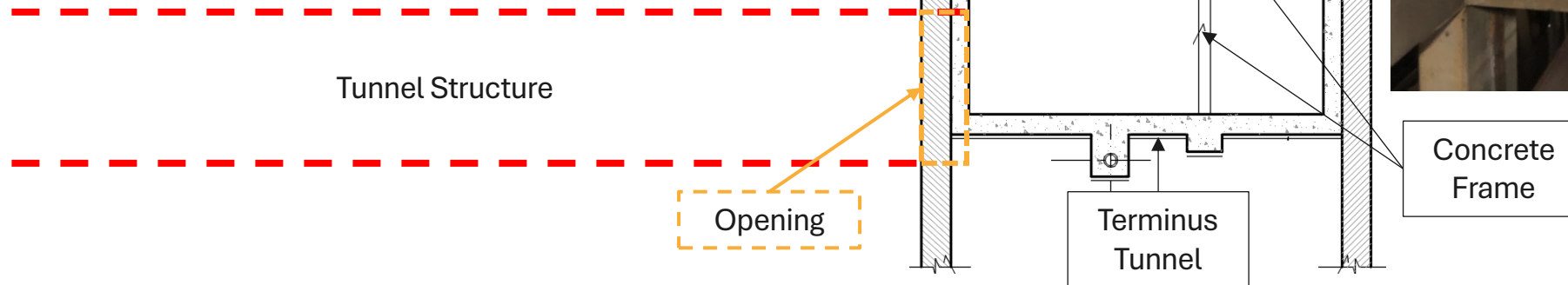
- Crossing the Av. 24 de Julho:
  - Definition of Cut&Cover excavation in 3 phases
  - Infrastructure diversions: Water pipes and collectors, Road and Rail traffic
  
- Last Cut&Cover section (section C), intersects Cais do Sodré existing terminus:
  - Design Cut&Cover solution compatible with the existing structure of the terminus
  - Need to opening the the existing structure to connect the new tunnel



## → Main Challenges and Constraints

### AFFECTED BUILDINGS: CAIS DO SODRÉ EXISTING TERMINUS

- Built in 90's using the Cut&Cover method:
  - Retaining structure composed for two alignments of diaphragm walls.
  - Definitive structure composed for a box section tunnel with an interior reinforced concrete frame.
- Need to opening the existing structure to connect the new tunnel:
  - Solutions compatible with equipment that can operate inside the terminus.



# Index

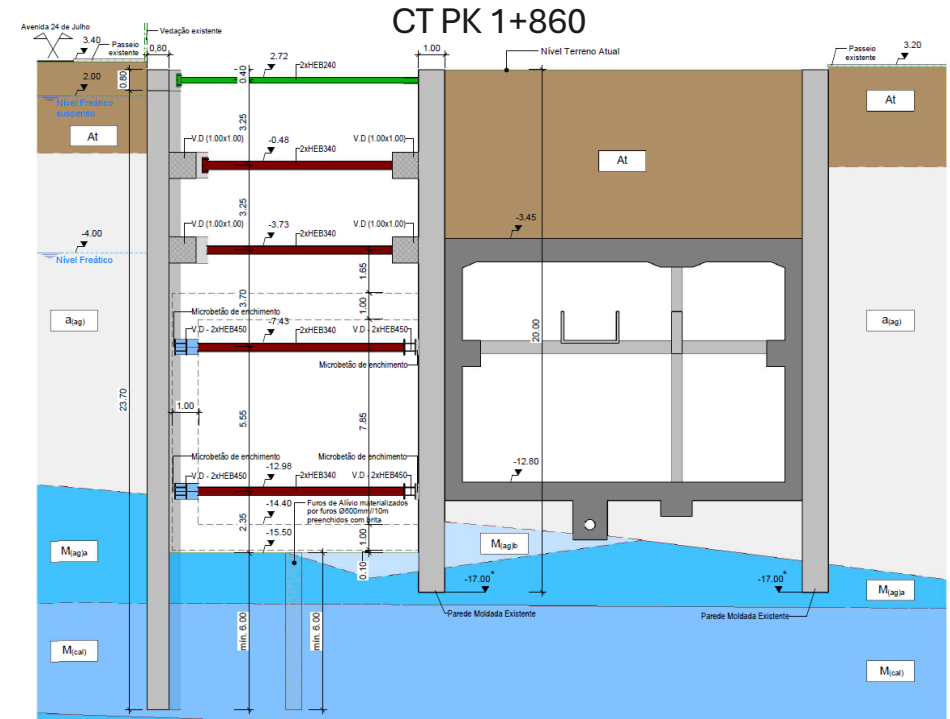
- Introduction
- Main Challenges and Constraints
- **Solution Description**
- Construction Phases
- Solution Design
- Construction Works



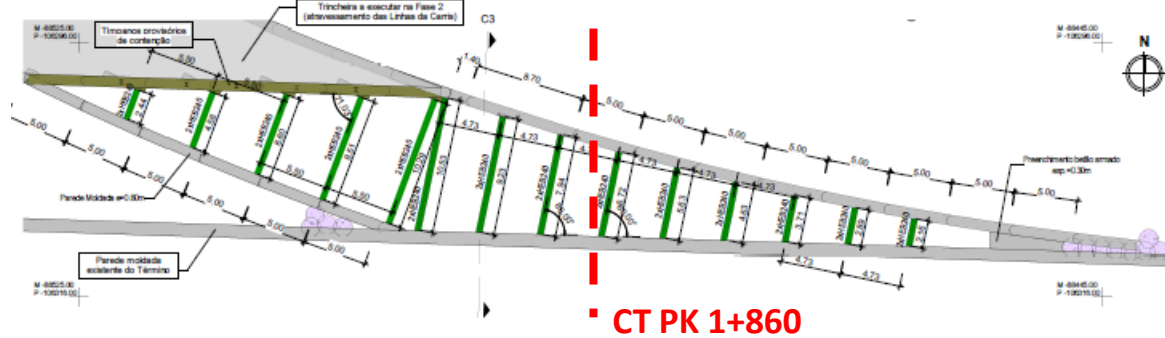
## → Solution Description

### CUT&COVER EXCAVATION SOLUTION:

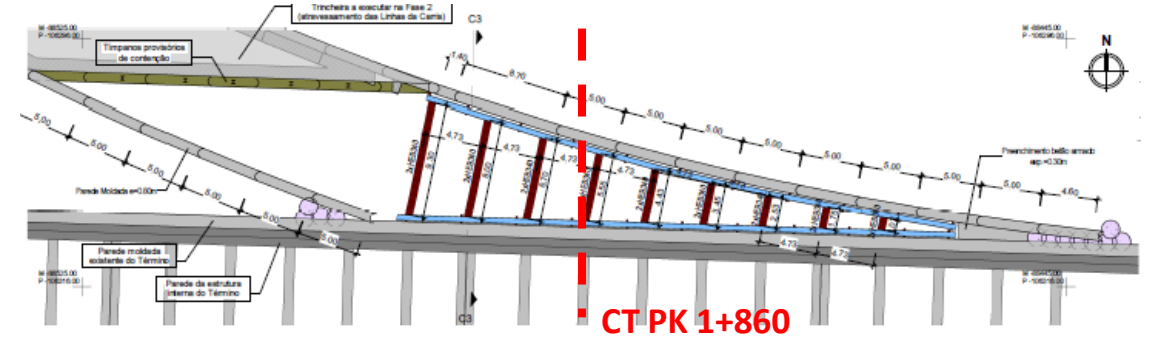
- Diaphragm wall 80cm thick
- Temporary propped to the existing Terminus with:
  - 5 levels of steel struts, 5.0m apart
  - Steel and reinforced concrete distribution beams
  - 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> strut levels aligned with the Terminus structure.



Plan View: 1<sup>st</sup> Strut Level



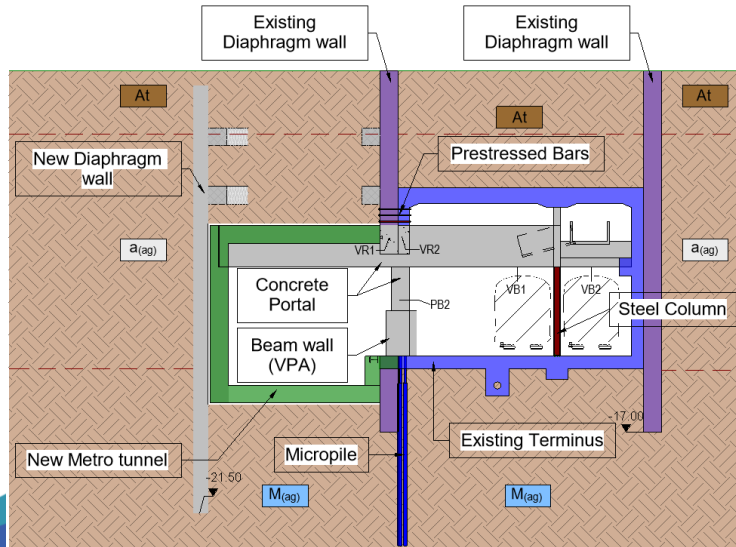
Plan View: 4<sup>th</sup> Strut Level



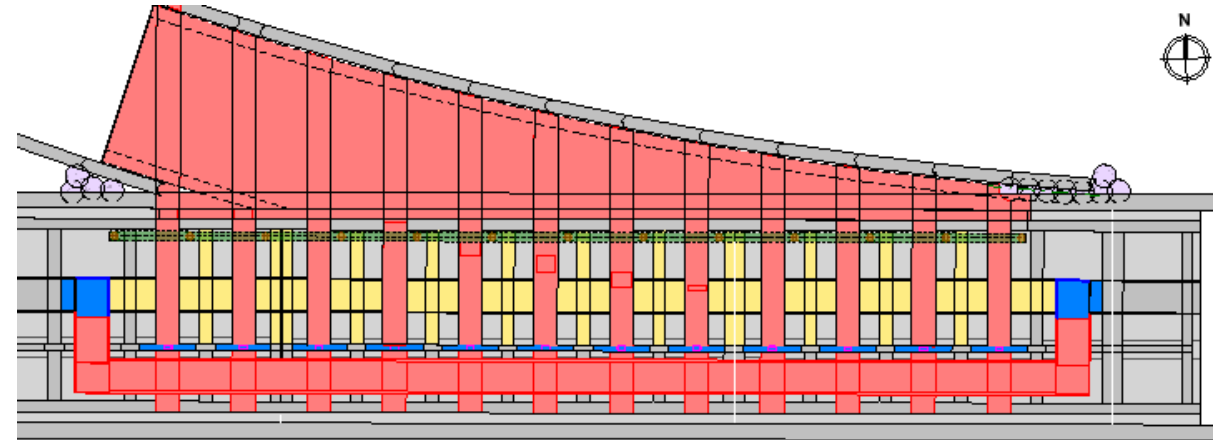
## → Solution Description

### FINAL STRUCTURAL SOLUTION FOR TERMINUS:

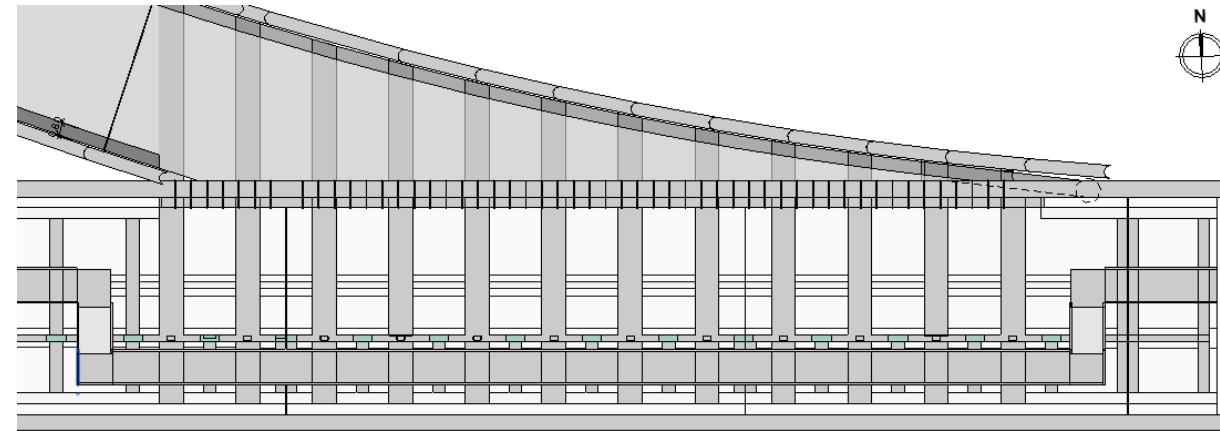
- Construction of a new **reinforced concrete frame** between the **existing one**, which will be later demolished.
- New frame composed by beams and columns has the capacity for:
  - Loads placed in the existing north side wall, after the opening execution
  - Loads from the new tunnel roof slab
  - Strut effect between the south wall and the new north wall
- Micropiles foundation



Plan View: Structural elements to be **demolished** and **built**



Plan View: Final structural solution for Terminus



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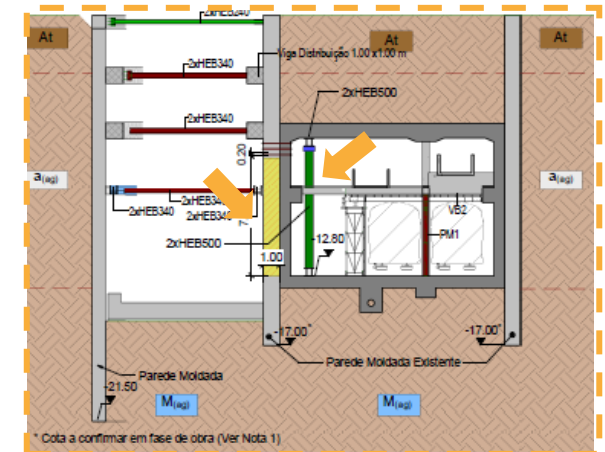
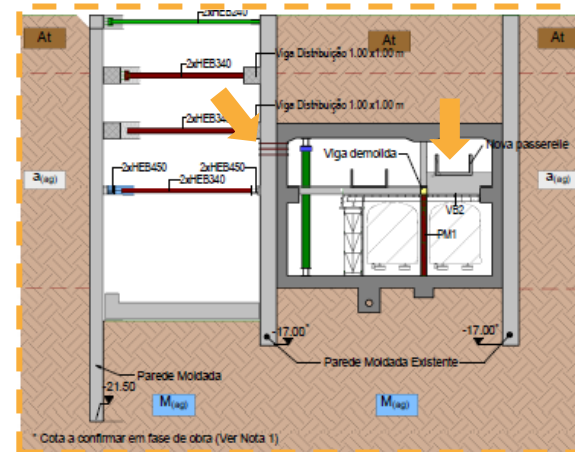
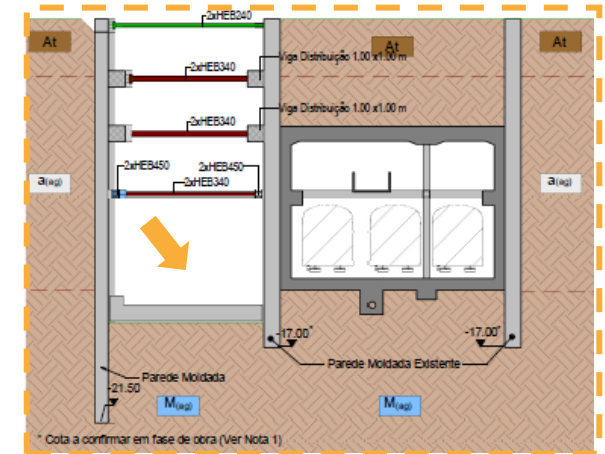
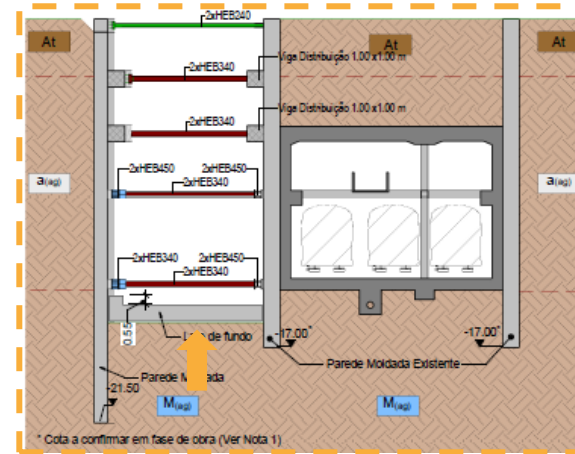
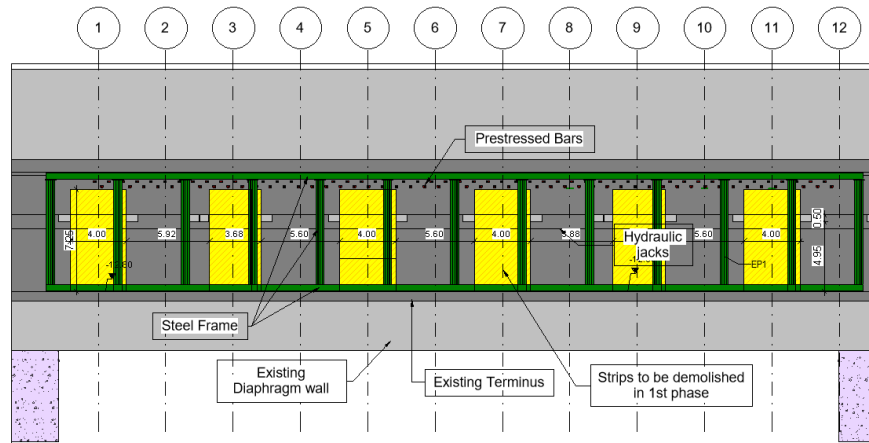
- Introduction
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## → Construction Phases

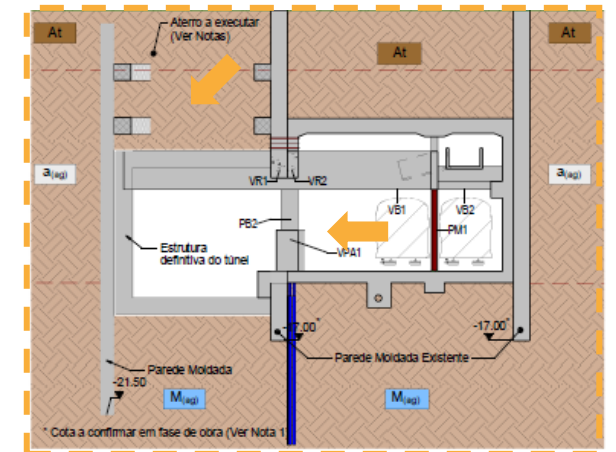
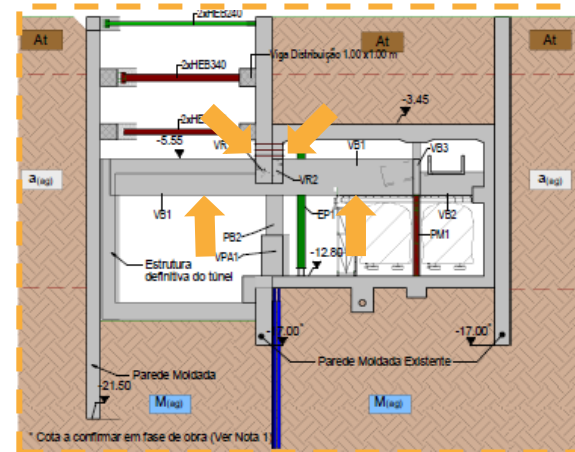
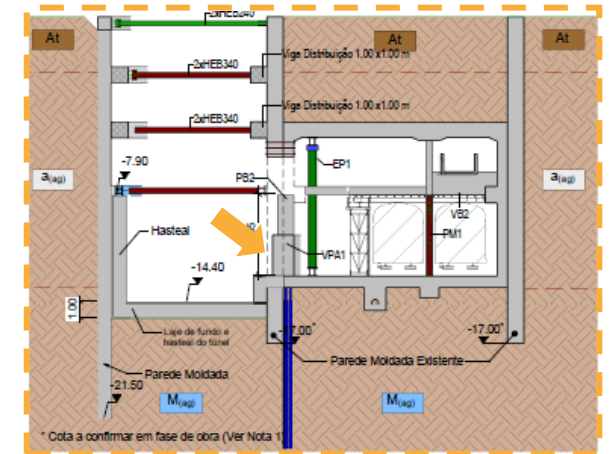
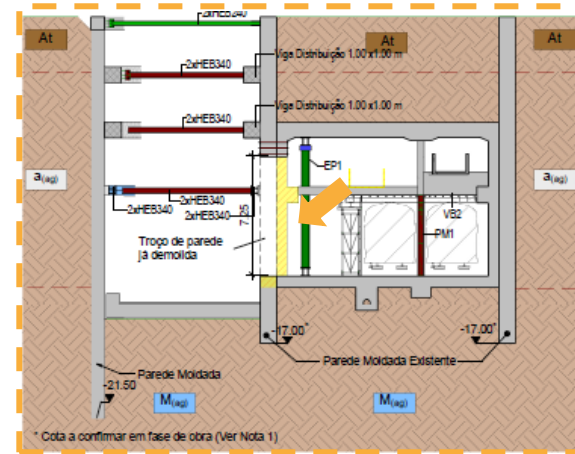
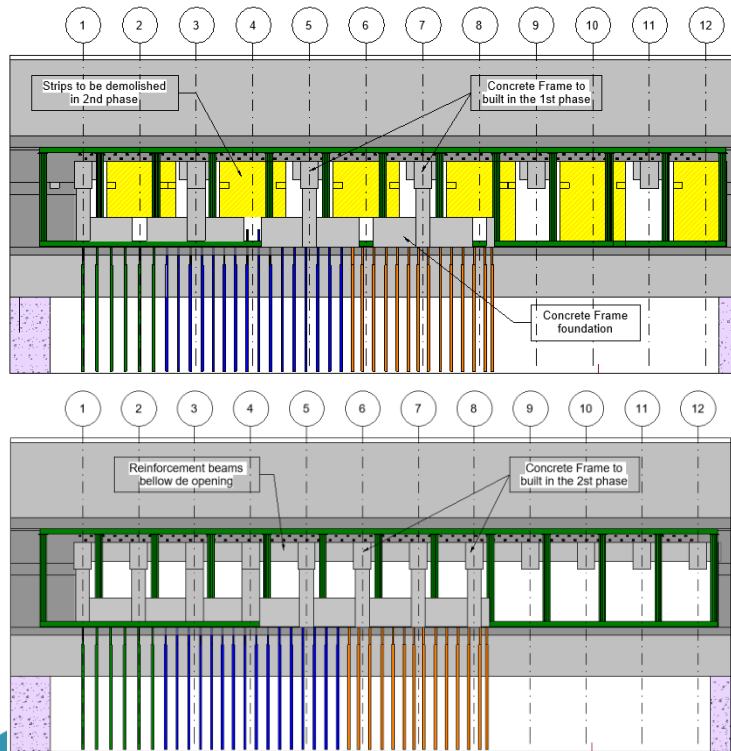
1. Cut&Cover excavation works to the bottom of the new tunnel
2. Foundation slab of the new tunnel
3. Deactivation of the 5th strut level
4. Construction of the new concrete frame next to the south existing wall
5. Reinforcement of the connection between the existing diaphragm wall and the Terminus tunnel wall, with DYWIDAG prestressed bars
6. Installation of the temporary steel propping frame
7. Start of demolition works to make the opening

- Small openings: 4m strips in 1<sup>st</sup> phase



## → Construction Phases

8. Continuation of demolition works to make the opening
9. Micropiles for the new concrete frame foundation
10. Reinforcement beams in the opening
11. Close the new reinforced concrete frame structure
12. Deactivation of the temporary propping steel frame and landfill



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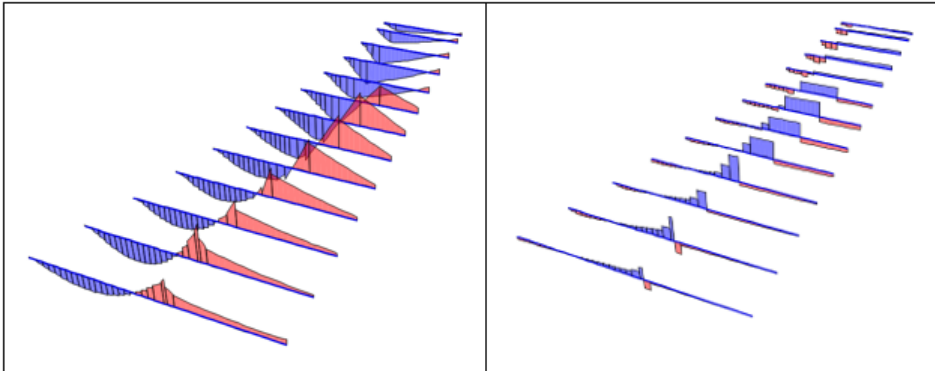


→ **Solution Design**

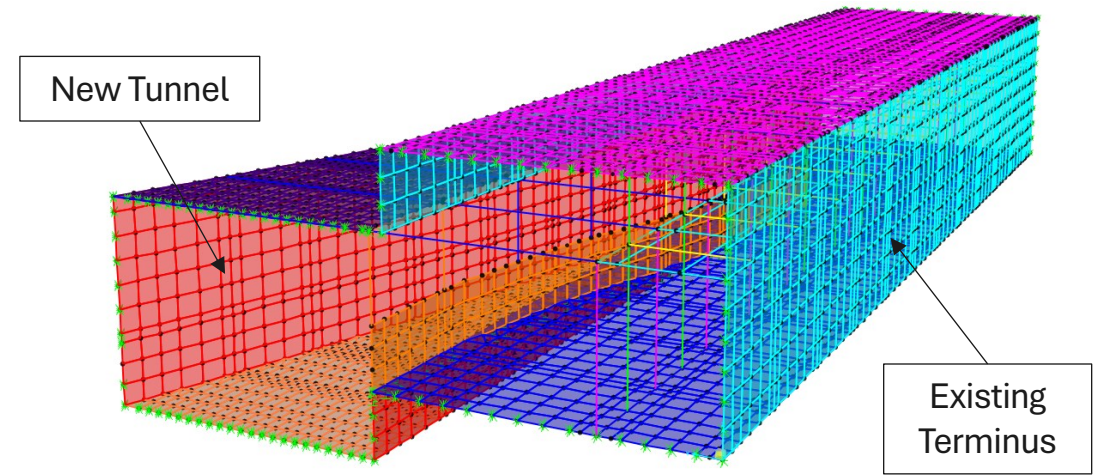
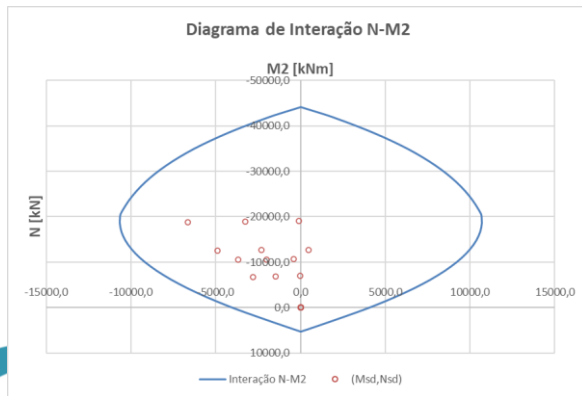
**FINAL STRUCTURAL SOLUTION FOR TERMINUS:**

- Design using structural finite element analysis software *SAP2000*:

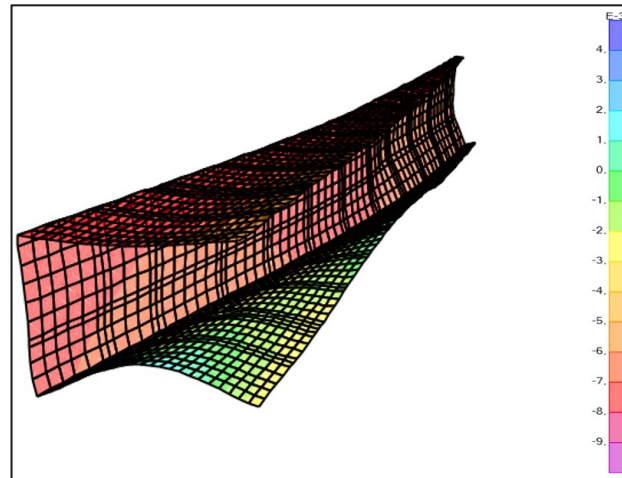
Bending moments and Shear of beams



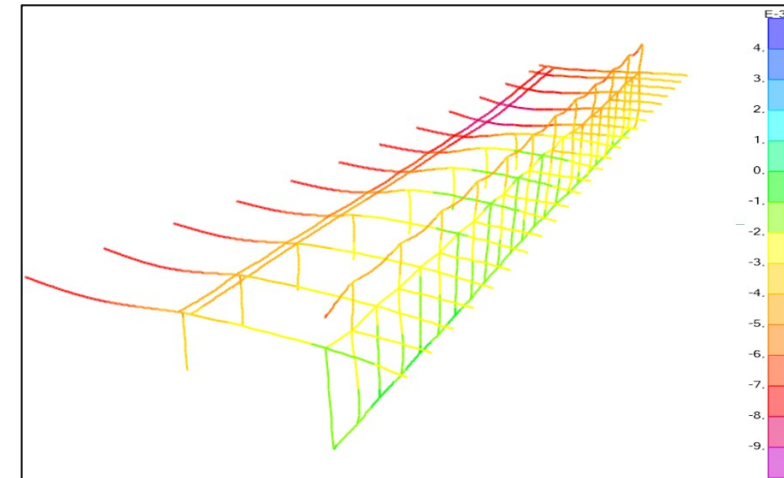
M-N interaction of columns



Vertical Deformation of new tunnel



Vertical Deformation of new concrete frame



**JET** SJ



**coba**  
Portugal



MOTA-ENGIL



spie batignolles

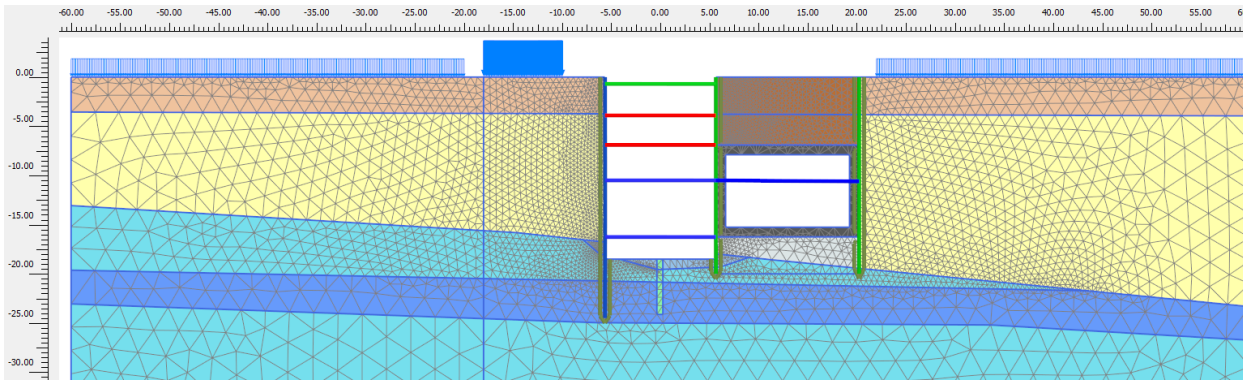


metro

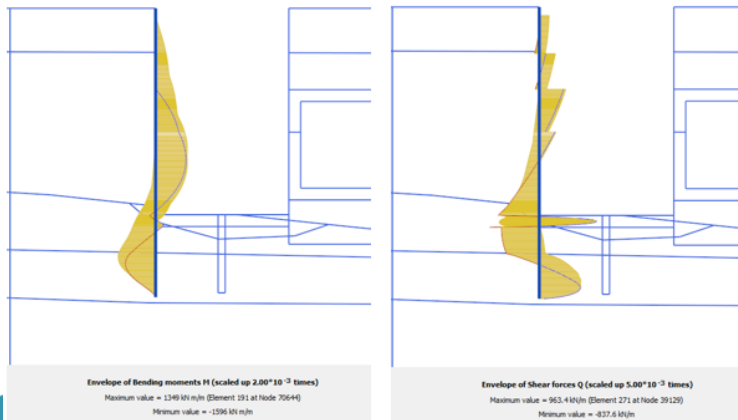
→ Solution Design

**CUT&COVER EXCAVATION SOLUTION:**

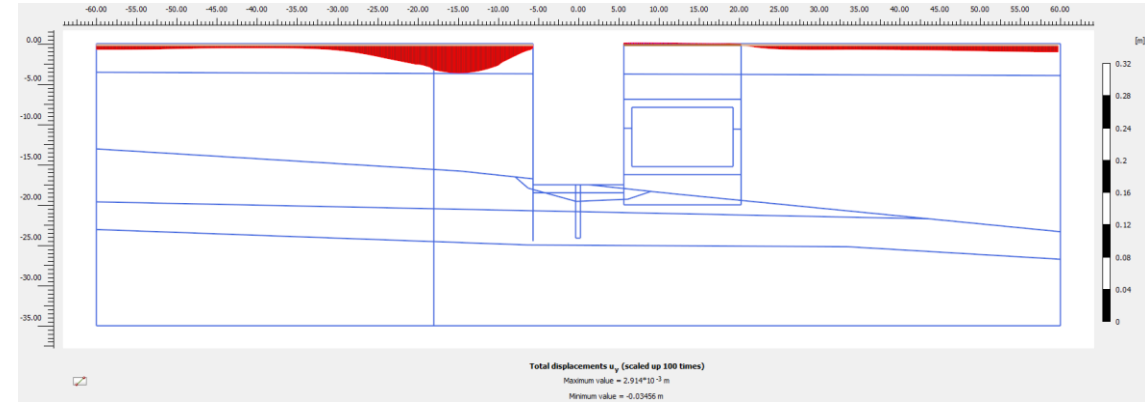
Design using geotechnical finite element analysis software *PLAXIS 2D*:



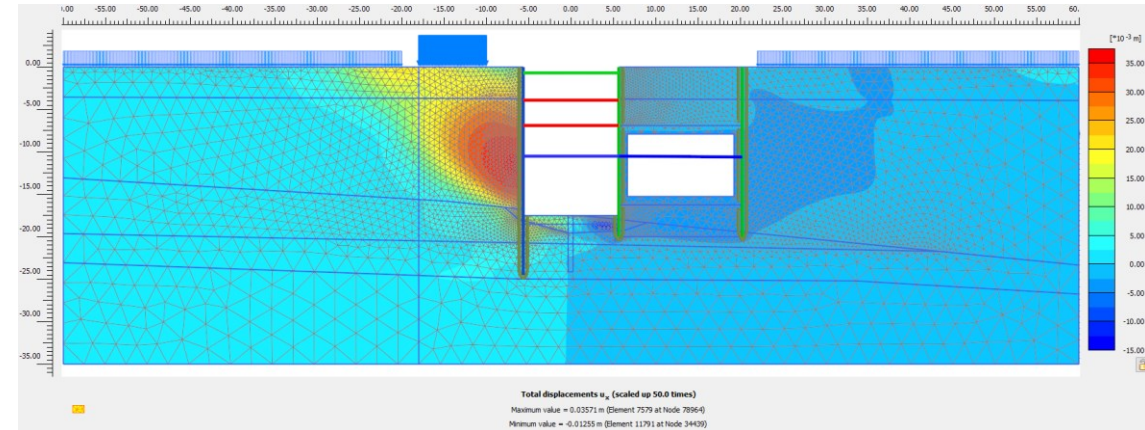
Bending moments and Shear forces of plate



Vertical Deformation ( $U_{y,max} = 34\text{mm}$ )



Horizontal Deformation ( $U_{x,max} = 36\text{mm}$ )



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ON SOIL MECHANICS AND  
GEOTECHNICAL ENGINEERING

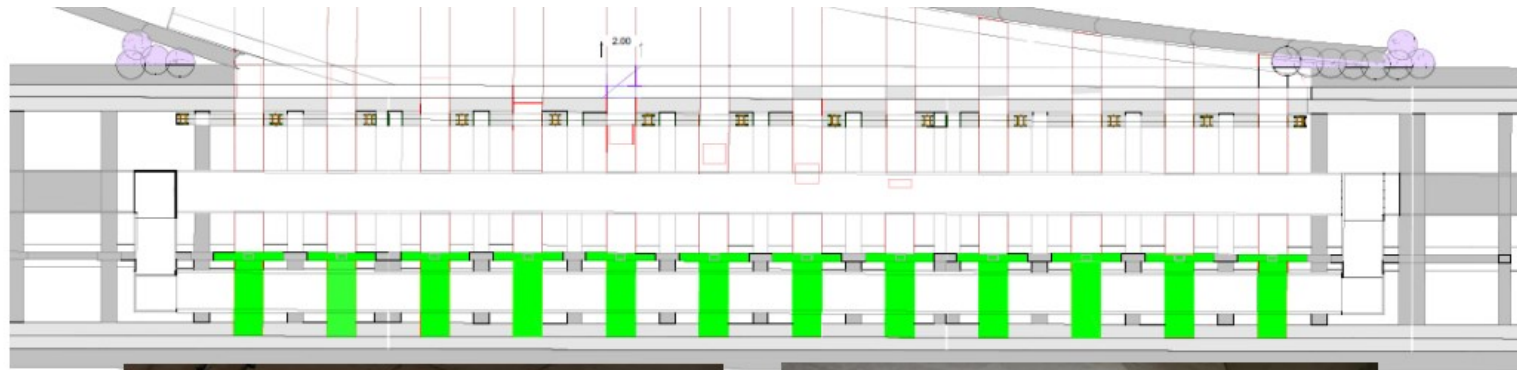
26 - 30 August

Lisbon Portugal

## → Construction Works

### WORKS AT A VERY EARLY STAGE:

- Construction of the new reinforced concrete frame next to the south side Terminus existing wall



Special Acknowledgements to:

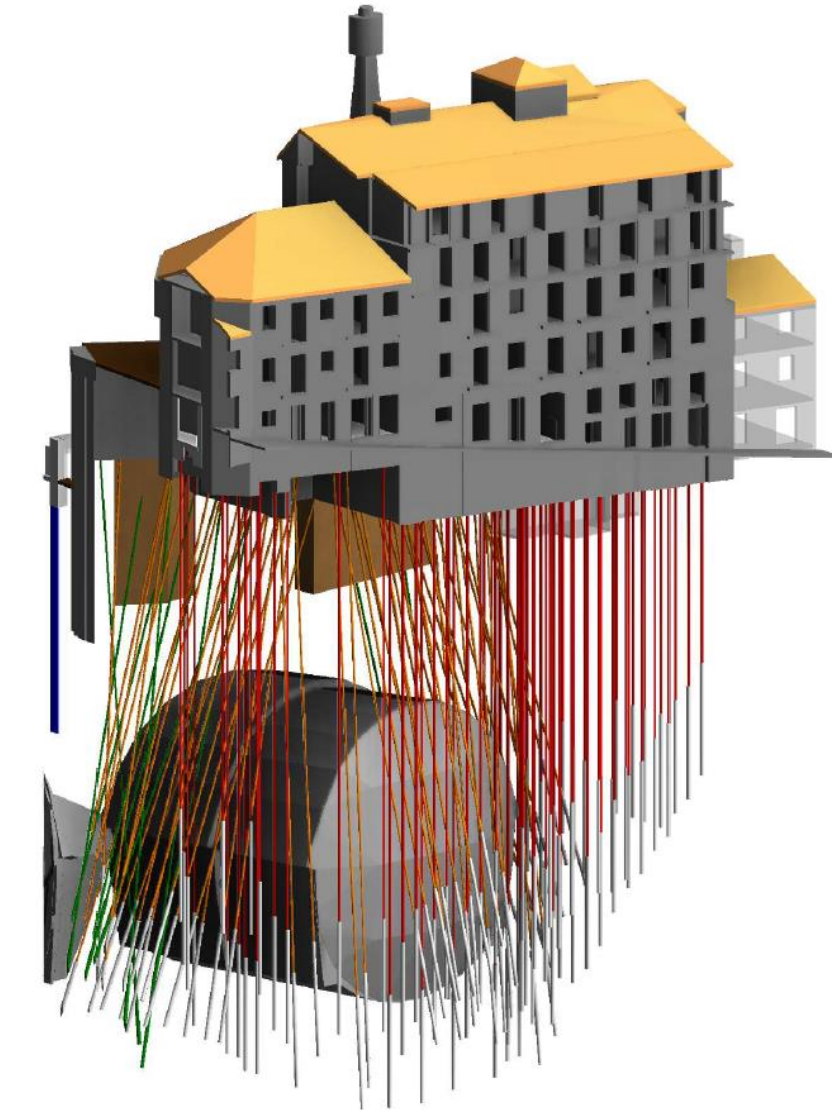


**Thank you for your attention!**



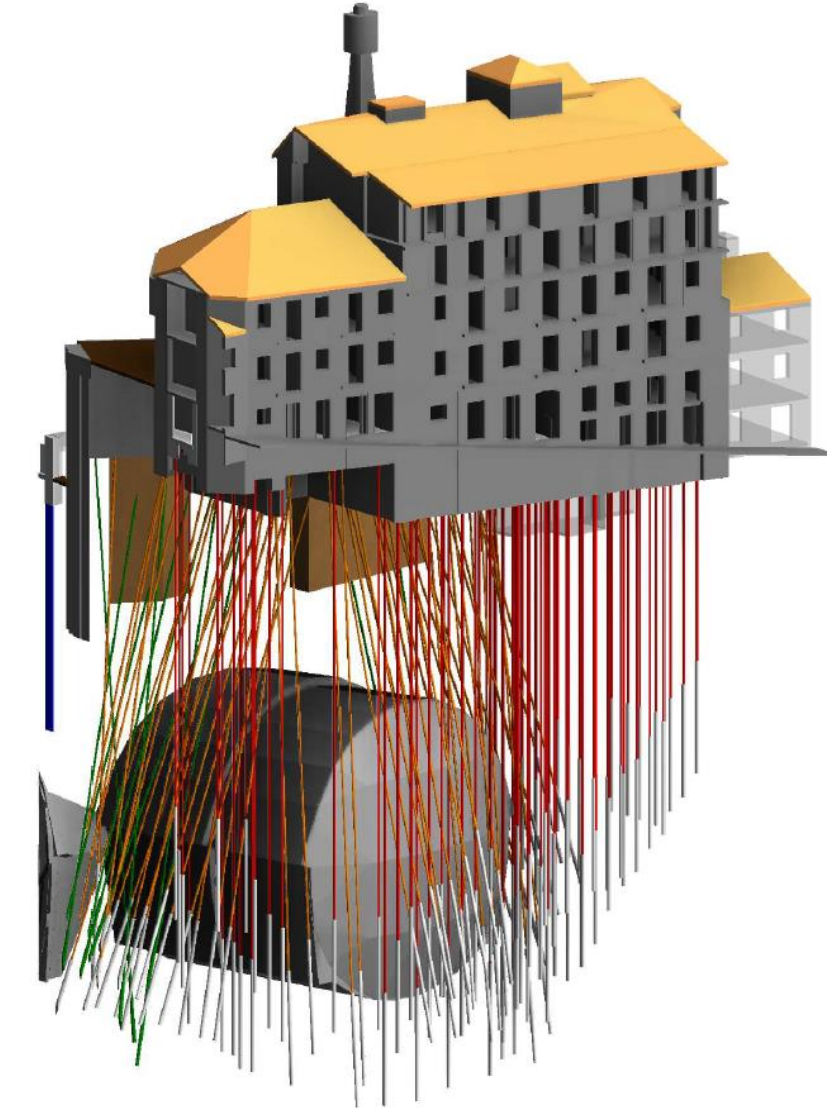
# Lisbon new circular Metro underground line: Centenary buildings underpinning

**Catarina Fartaria** / JETsj, Geotecnia  
**Carlos Martins** / JETsj, Geotecnia  
**André Henriques** / JETsj, Geotecnia  
**Rui Tomásio** / JETsj, Geotecnia  
**Alexandre Pinto** / JETsj, Geotecnia



# Lisbon new circular Metro underground line: Centenary buildings underpinning

- TECHNICAL VISIT TO LISBON METRO
- FRIDAY, 30 AUGUST 2024



# Index

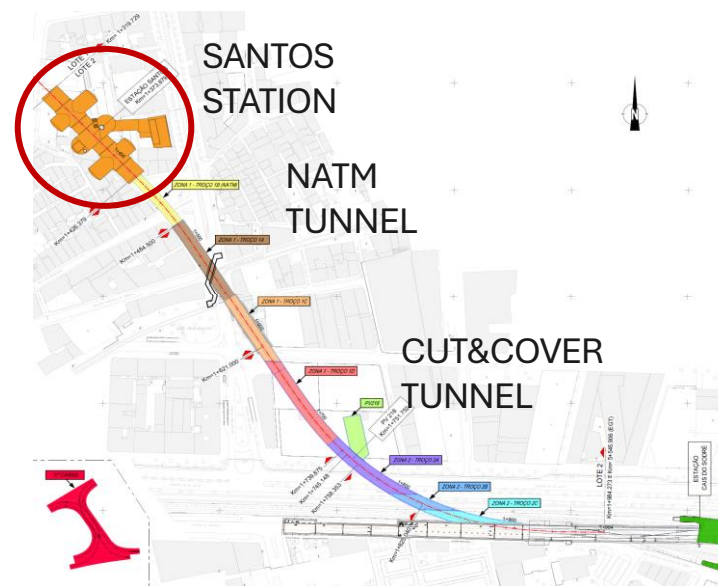
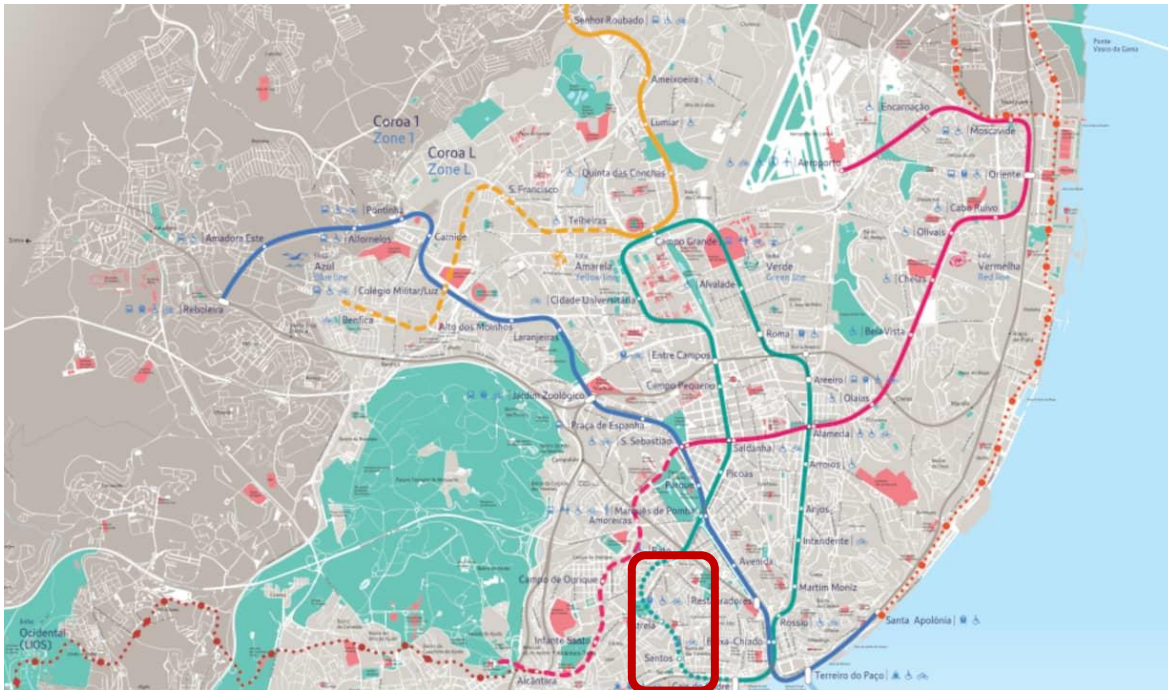
- **Introduction**
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- Conclusions



# → Introduction

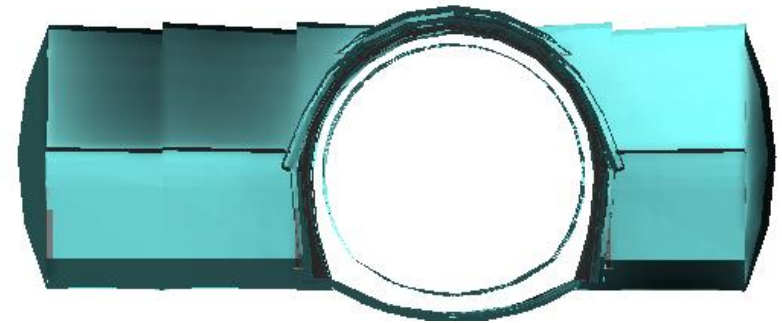
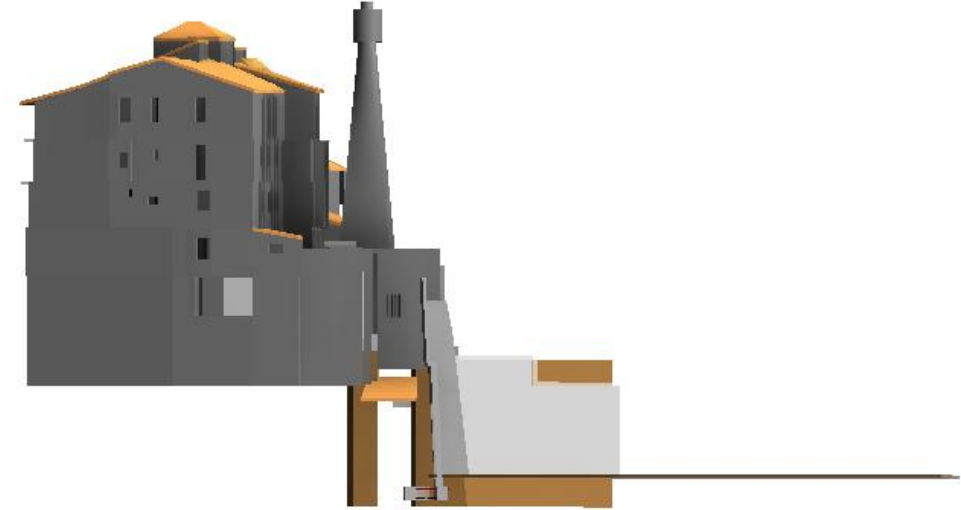
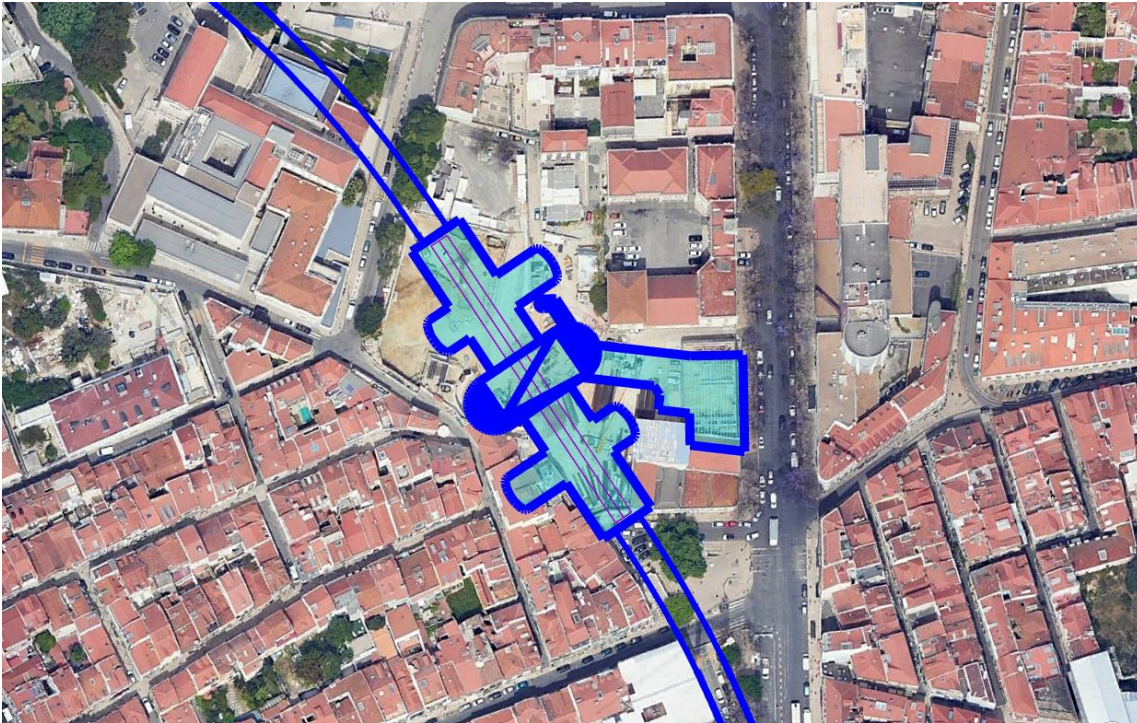


- NEW CIRCULAR LISBON METRO LINE
- + ~2 KM LINE
- + 2 NEW STATIONS



## → Introduction

- ❑ SANTOS STATION
- ❑ DENSE URBAN AREA
- ❑ HISTORICAL CITY AREA



- ❑ NATM METHODOLOGY
- ❑ TUNNEL WITH SHALLOW DEPTH
- ❑ NEED TO MITIGATE CENTENARY BUILDINGS STRUCTURAL DAMAGE

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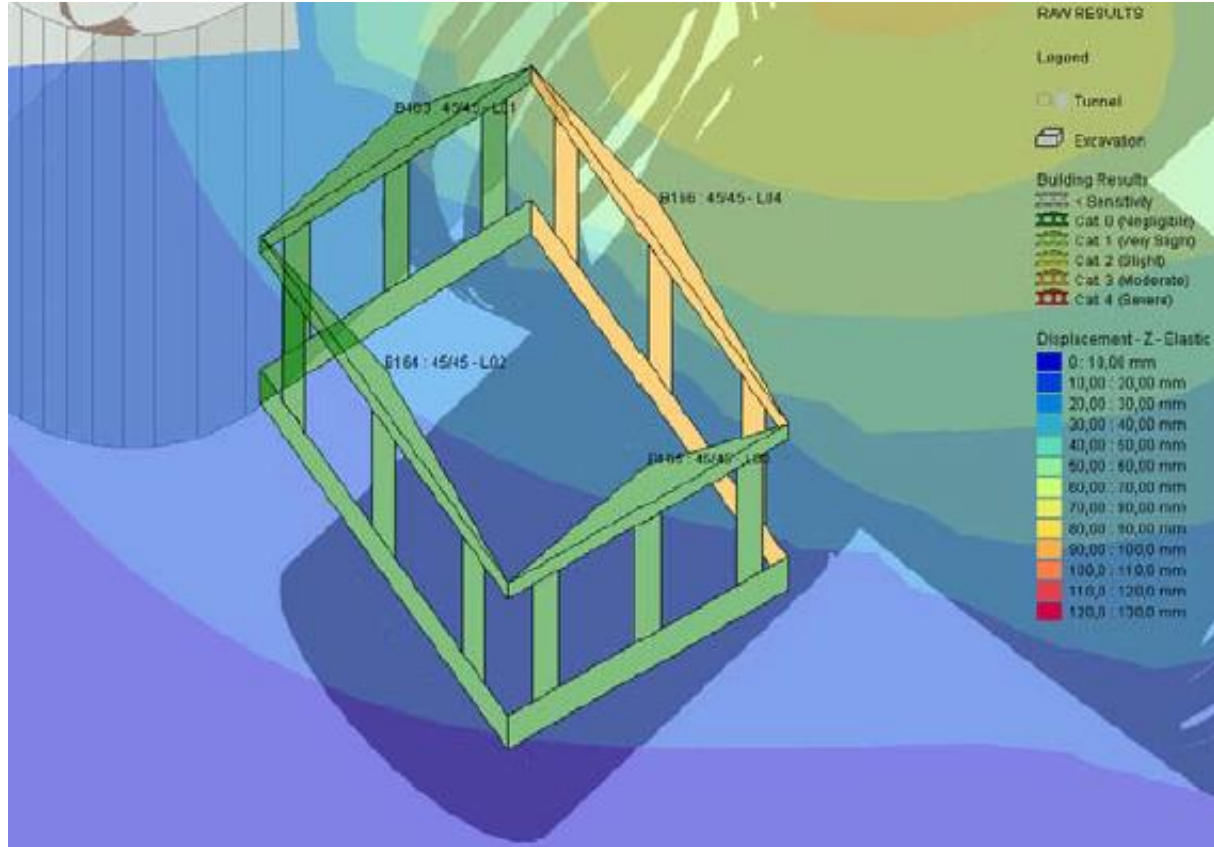


## → Affected Buildings



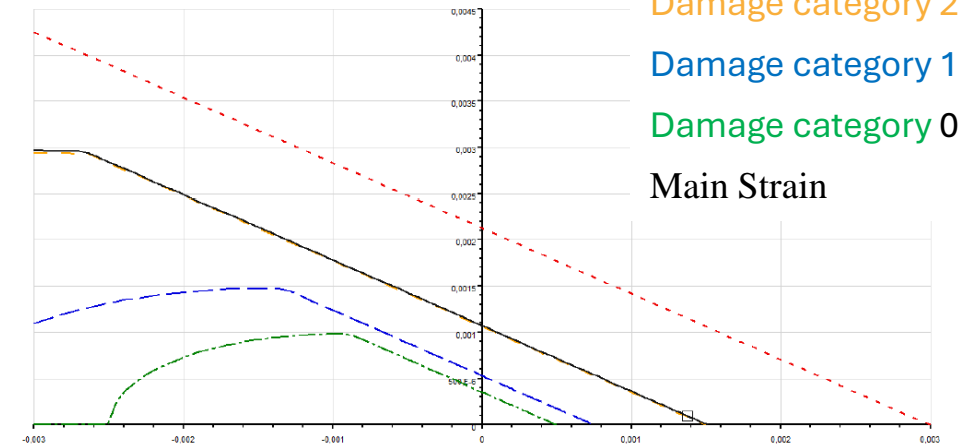
- XIX CENTURY BUILDINGS
- MASONRY WALLS
- TIMBER FLOORS
- RESIDENTIAL USE

## → Affected Buildings



## DAMAGE INTERACTION CHART

Deflection Ratio



Damage category 3

Damage category 2

Damage category 1

Damage category 0

Main Strain

Horizontal Ground Strain

## NUMERICAL ANALYSIS ESTIMATED SETTLEMENT



**BURLAND'S (1997)**



**MODERATE TO SEVERE DAMAGE**



**REINFORCEMENT MEASURES NEEDED**

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## → Main Constrains

### ☐ GEOTECHNICAL CONSTRAINS

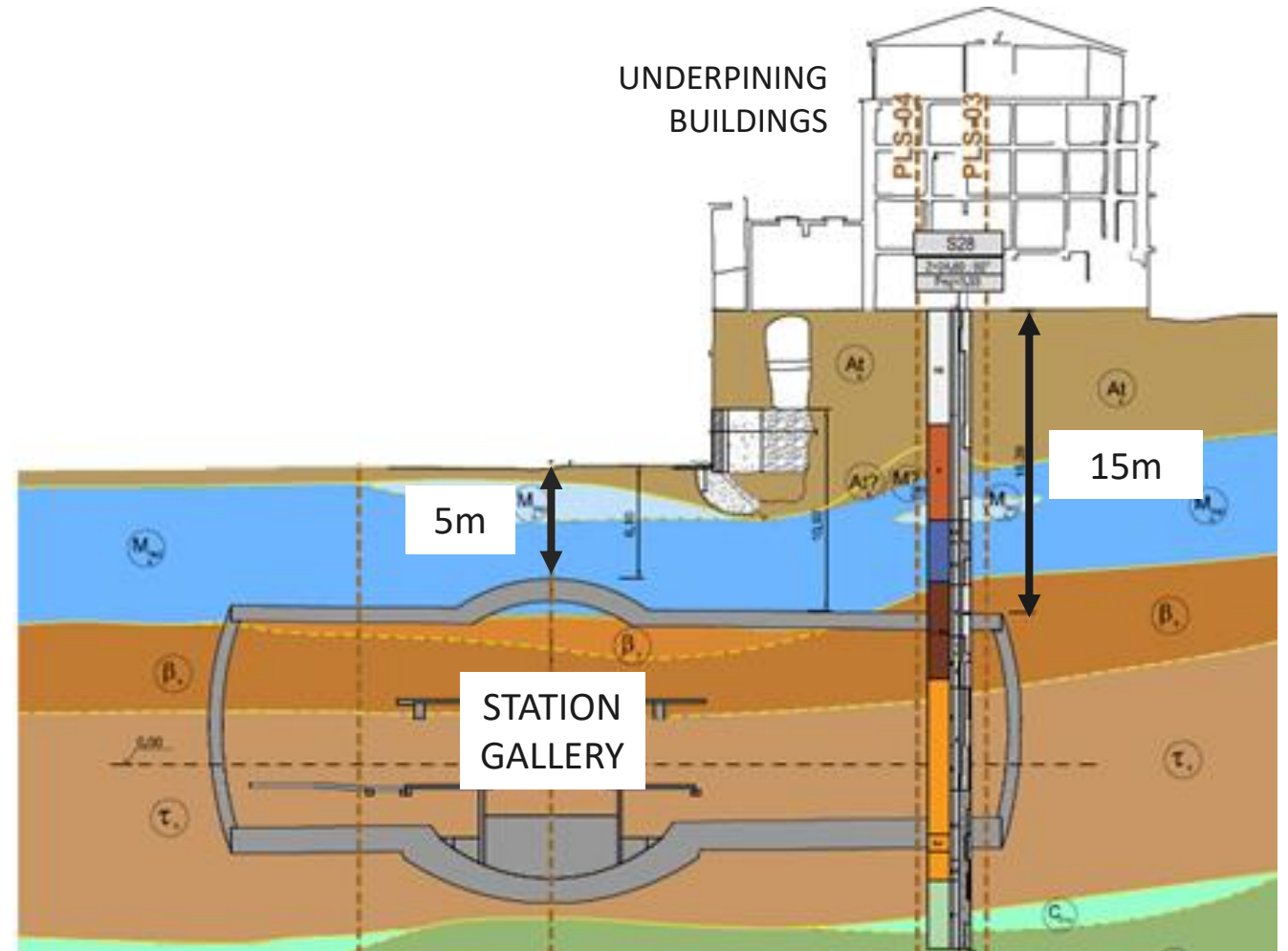
- ❖ BUILDINGS SUPERFICIAL FOUNDATION
- ❖ 10 m THICKNESS LANDFILL
- ❖ UNDERGROUND EXCAVATION ON
- ❖ LISBON VULCANIC COMPLEX MATERIALS

### ☐ CONSTRUCTIVE CONSTRAINS

- ❖ EQUIPMENT ACCESSIBILITY INSIDE THE BUILDINGS
- ❖ OPERATE WITH A MINIMAL CEILING HEIGHT OF 2,5 m

### ☐ UNDERGROUND EXCAVATION CONSTRAINS

- ❖ NATM TEMPORARY SUPPORT ELEMENTS



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## → Underpinning Solution



- WALLS REINFORCEMENT SOLUTION
  - ❖ SPRAYABLE MORTAR AT MASONRY WALLS REINFORCED WITH CARBON FIBRE MESH

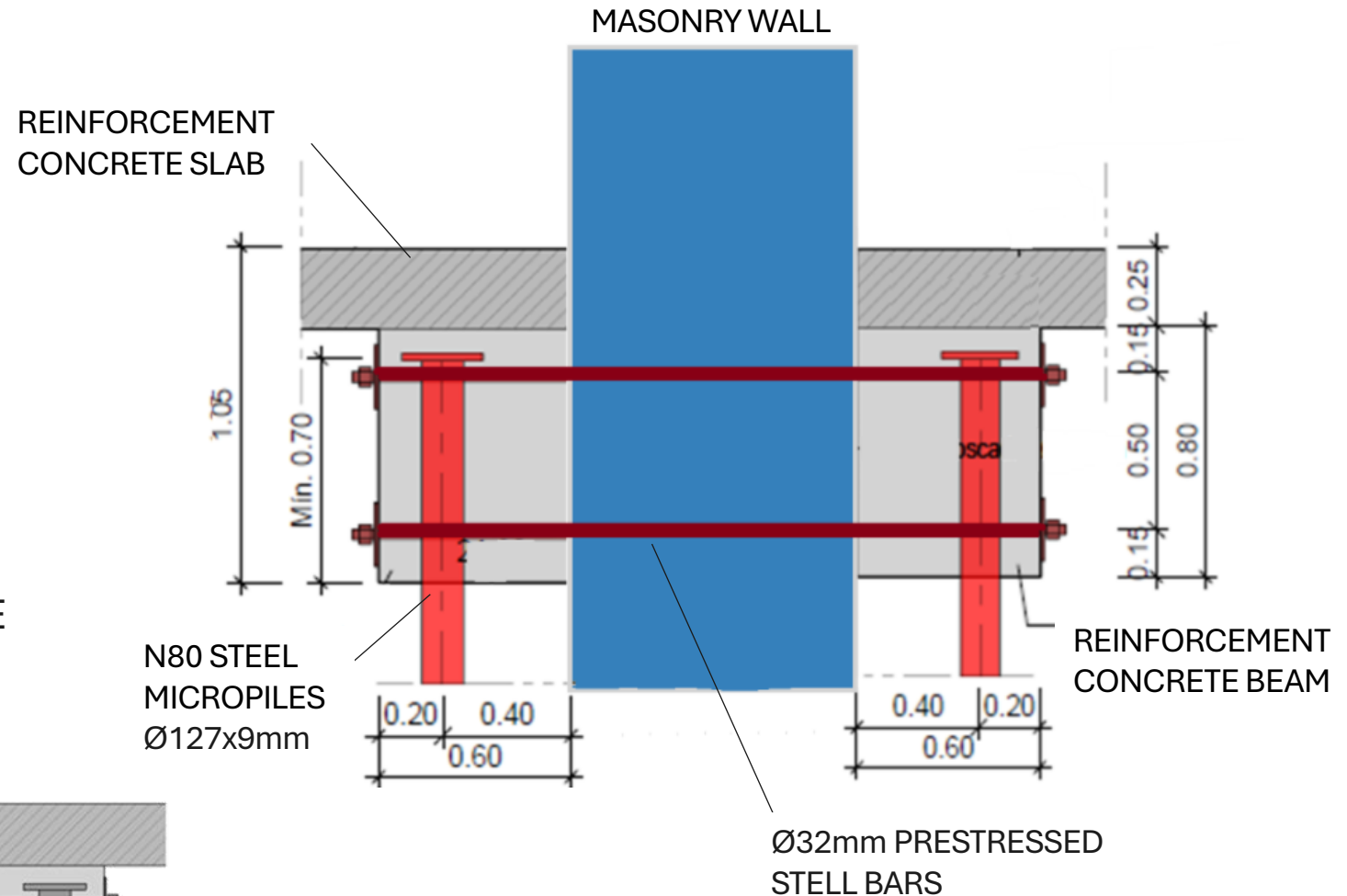
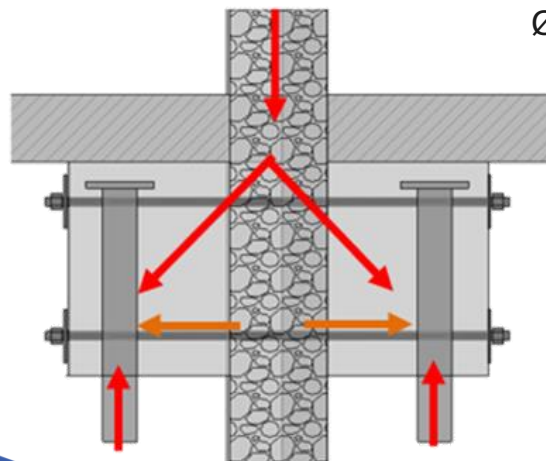
MASONRY WALLS REINFORCEMENT

[S&P ARMO-mesh | S&P ARMO-crete w]

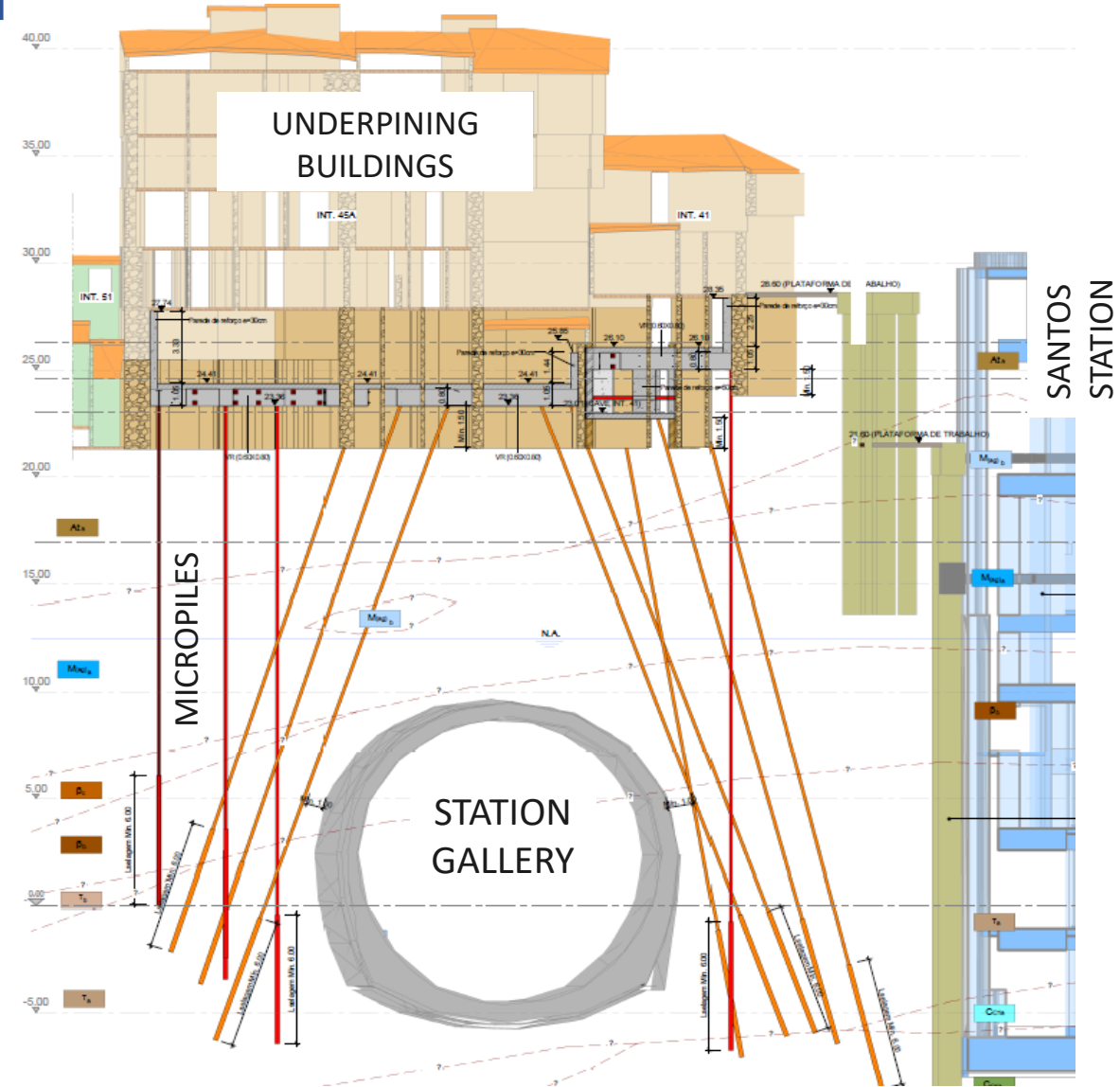
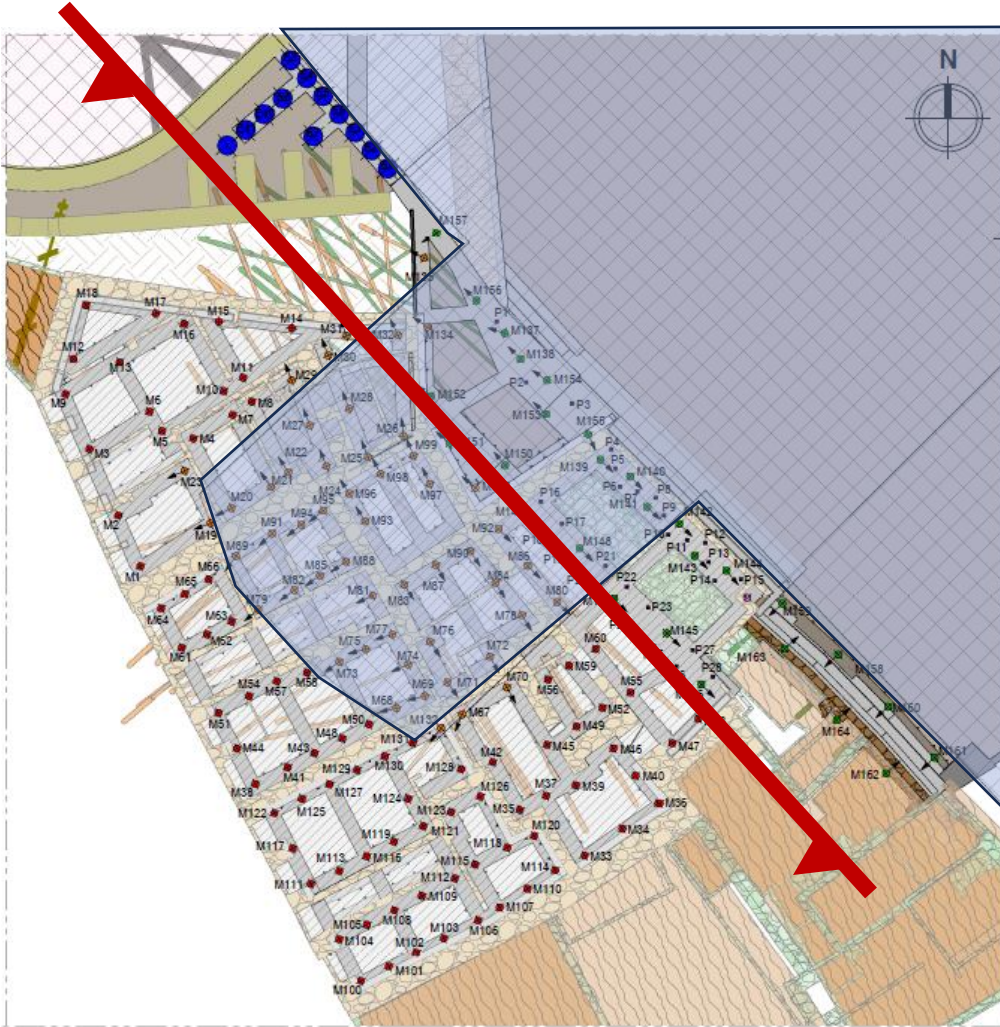
## → Underpinning Solution

### □ UNDERPINNING SOLUTION

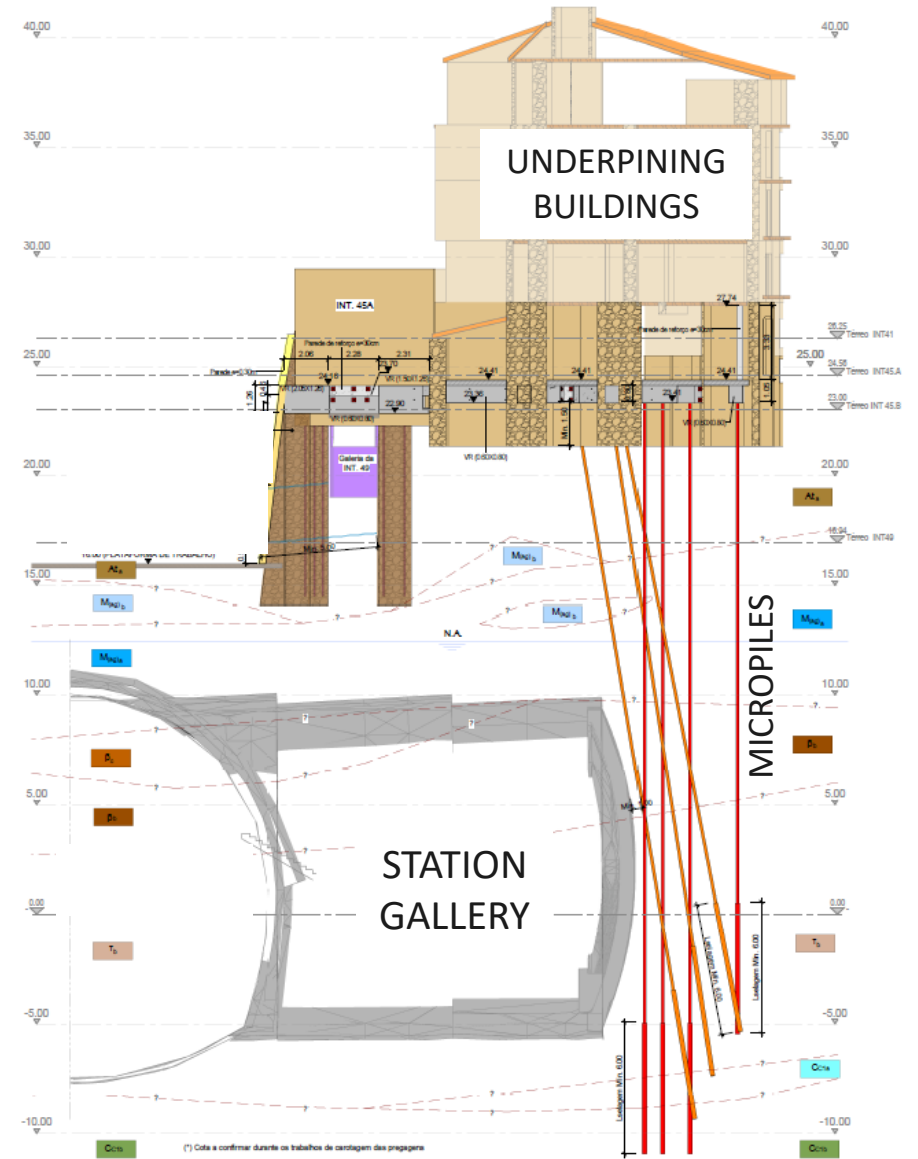
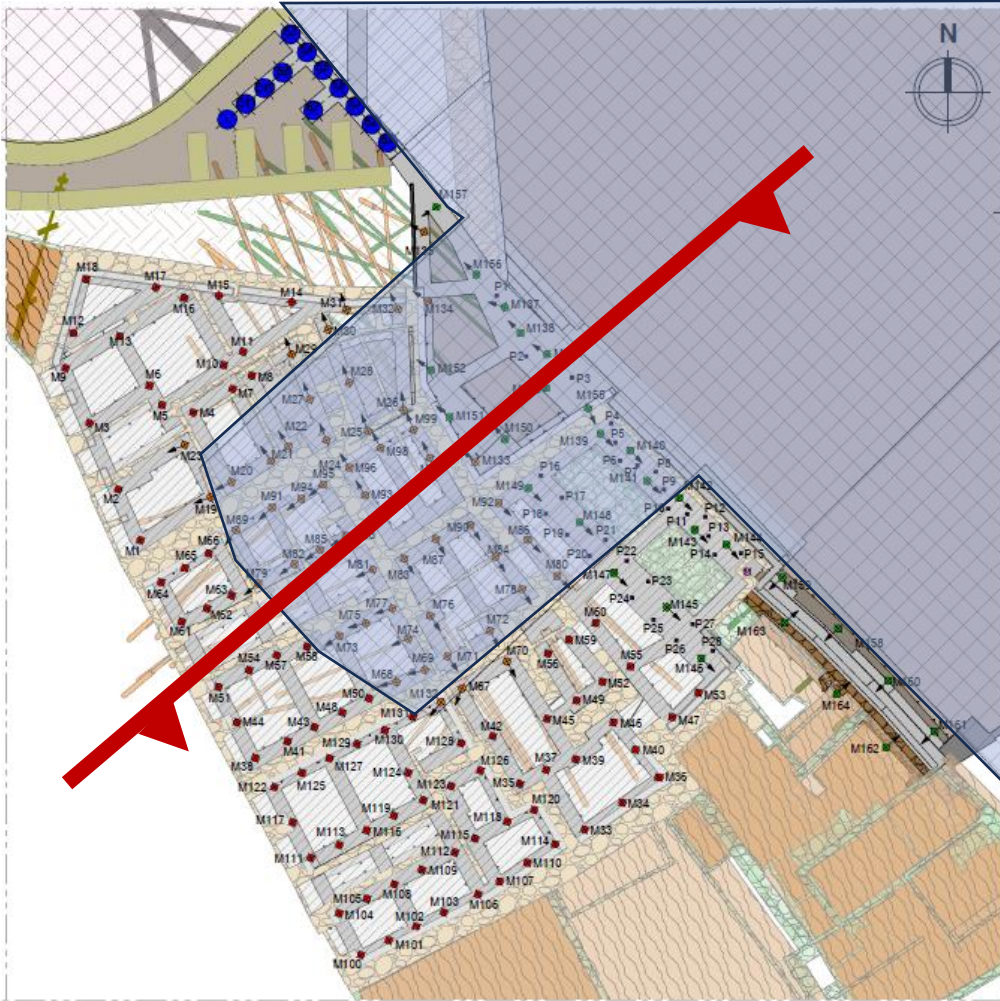
- ❖ REINFORCED CONCRETE BEAMS AT BASE LEVEL CONNECTED TO MASONRY WALLS WITH PRESTRESSED STEEL BARS
- ❖ STEEL MICROPILES; VERTICAL AND SUBVERTICAL, CONNECTED TO BEAMS TO TRANSFER BUILDINGS LOAD BELOW THE UNDERGROUND EXCAVATION



# → Underpinning Solution

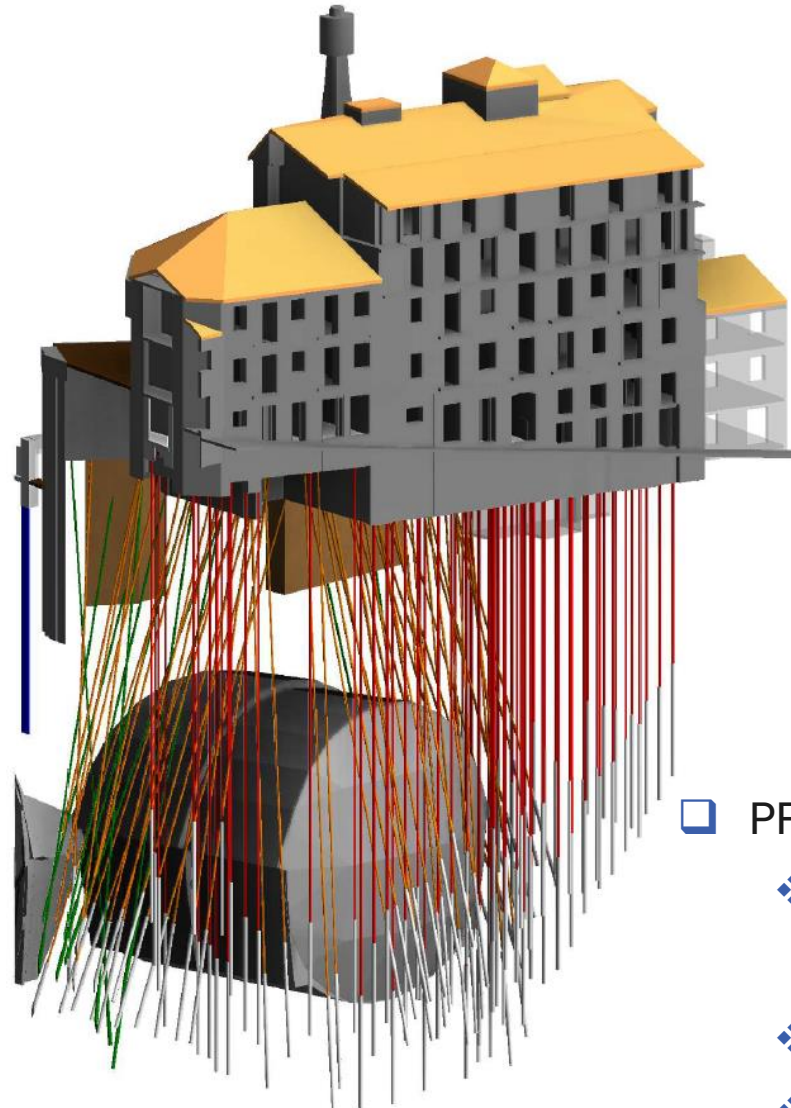
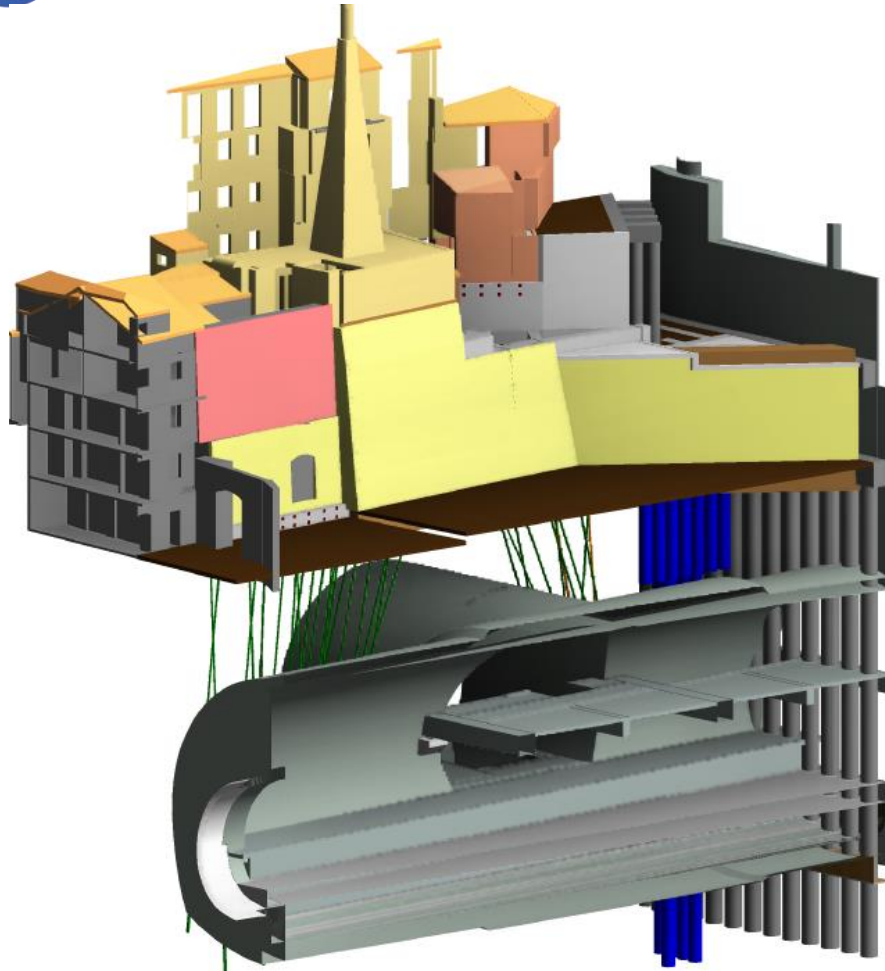


# → Underpinning Solution



(\*) Cota a confirmar durante os trabalhos de cartagens das pregagens

## → Underpinning Solution



- ❑ PROJECT QUANTITIES
  - ❖ MICROPIPLES LENGTH  
20 to 25m
  - ❖ ~ 170 MICROPILES
  - ❖ TOTAL LENGTH  
~ 4.000m

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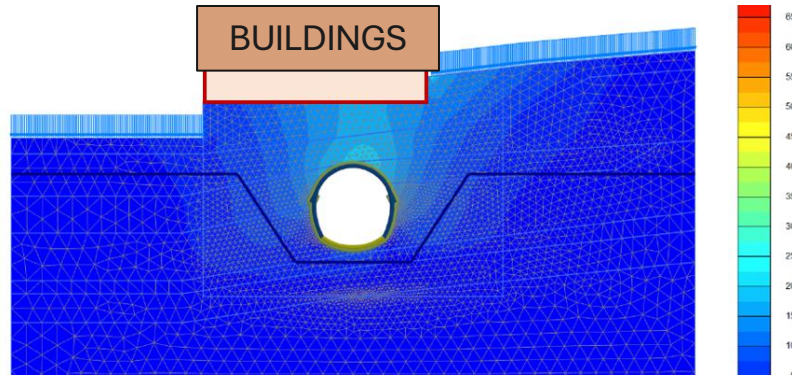
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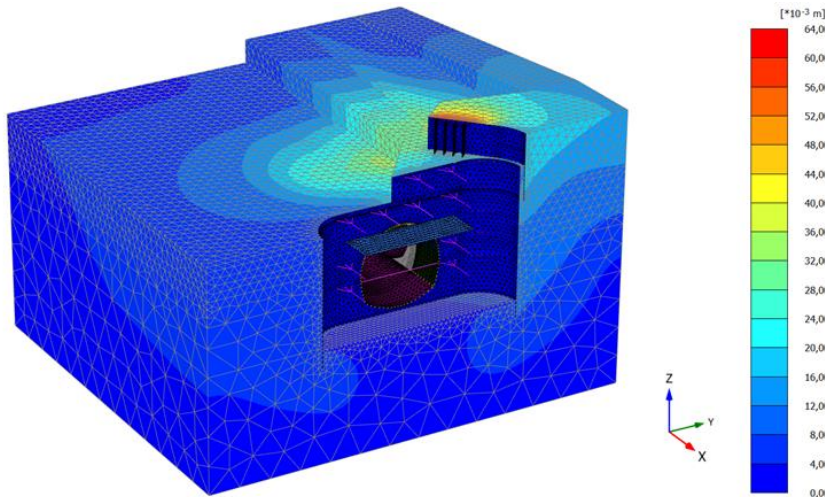
## → Solution Design

### □ DESIGN CALCULATIONS

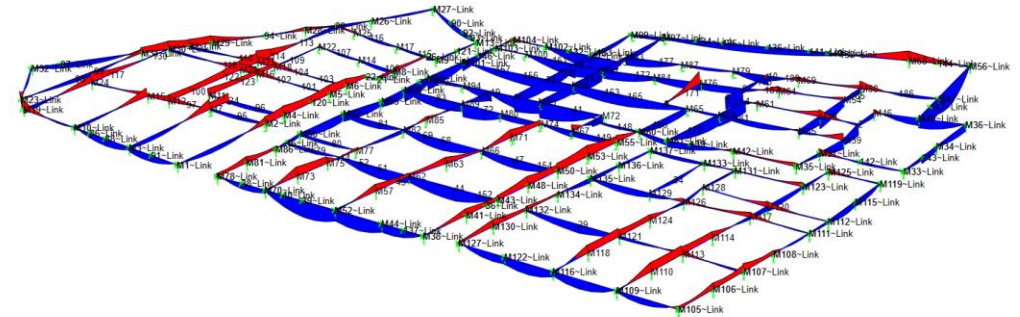
- ❖ STRUCTURAL MODELS (SAP2000)
- ❖ SOIL STRUCTURE INTERACTION USING NUMERICAL MODELS (PLAXIS 2D AND 3D)



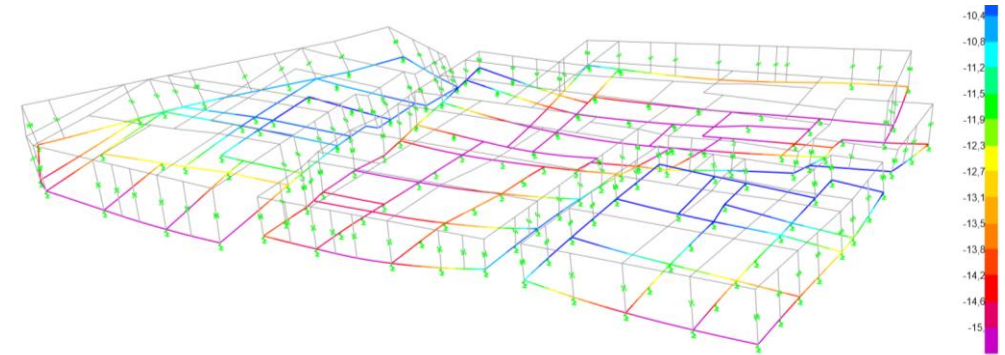
PLAXIS 2D – GROUND DISPLACEMENTS



PLAXIS 3D – SURFACE SETTLEMENT



SAP 2000 – BEAM GRID BENDING MOMENTS



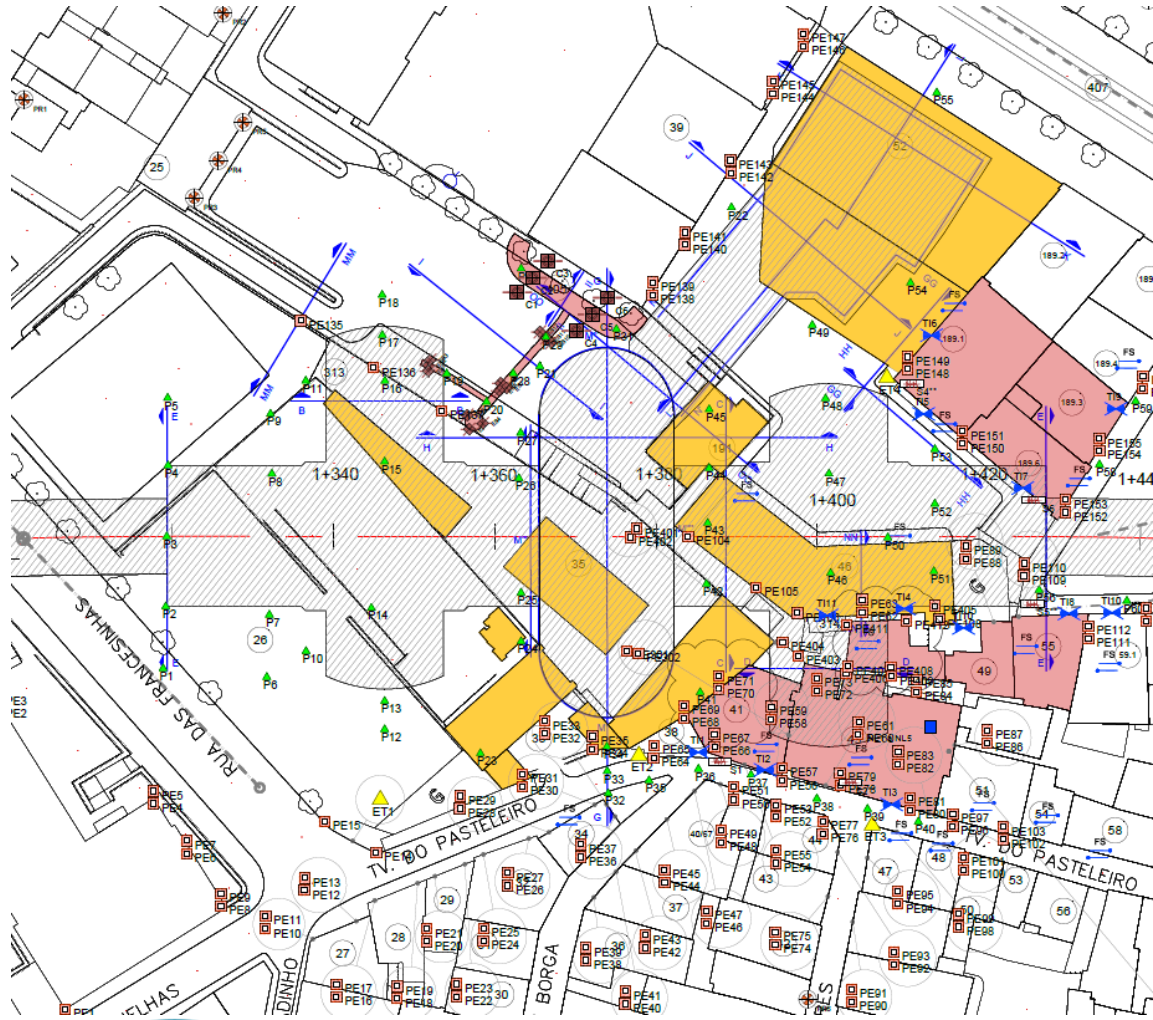
SAP 2000 – VERTICAL DISPLACEMENTS

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- Conclusions



## → Monitoring and Survey Plan



- RISK MANAGEMENT
  - ❖ ALARM THRESHOLDS
  - ❖ DAILY MEASURES WITH AUTOMATED TOTAL STATIONS
  
- MONITORING DEVICES
  - ❖ INCLINOMETER
  - ❖ TOPOGRAPHIC TARGETS
  - ❖ TILTMETERS
  - ❖ CRACK METERS

## → Monitoring and Survey Plan



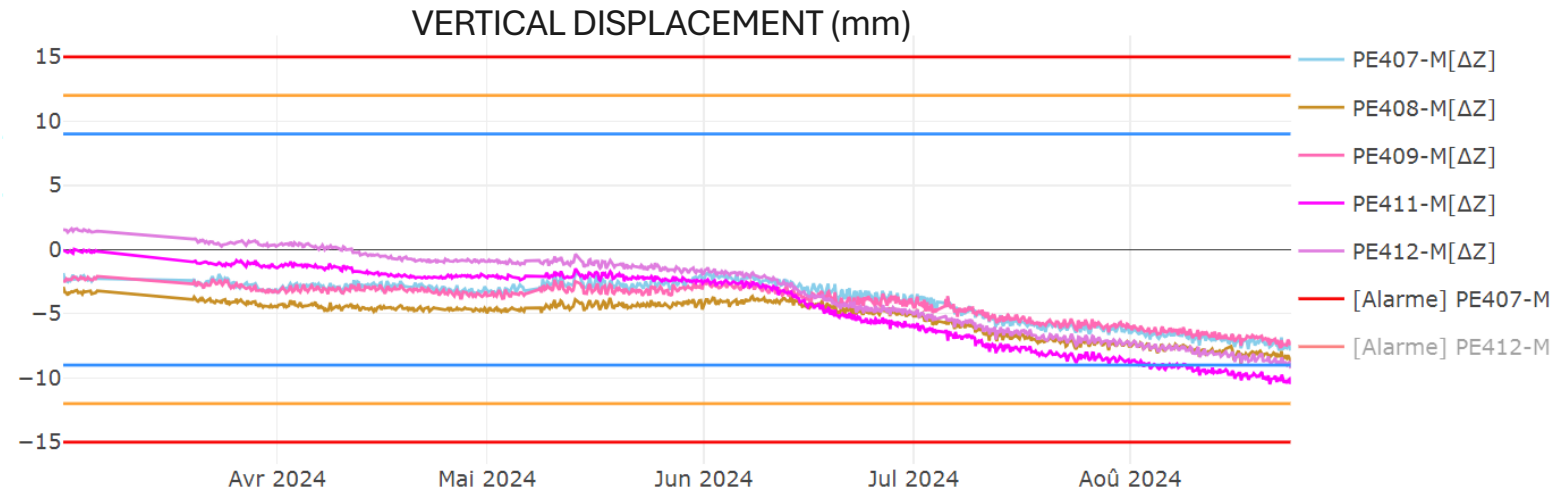
TOPOGRAPHIC TARGETS



AUTOMATED TOTAL STATION

### VERTICAL SETTLEMENT ALARM THRESHOLDS

- WARNING – 80% RV
- VALUE -RV
- ALARM – 130% RV



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- **Conclusions**



## → Conclusions

- ❑ EXTREME SCENARIO POTENTIAL BUILDINGS DAMAGE INDUCED BY AN UNDERGROUND EXCAVATION
- ❑ REINFORCEMENT MEASURES NEEDED
- ❑ MONITORING PLAN AS RISK MANAGEMENT TOOL



## → Conclusions



## → Conclusions





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ON SOIL MECHANICS AND  
GEOTECHNICAL ENGINEERING



METRO SANTOS SODRÉ ACE  
METROPOLITANO DE LISBOA



**Metropolitano de Lisboa**

The authors are grateful to Metropolitano de Lisboa  
for permission to present this paper

**Thank you for your attention!**

# Ground improvement solutions at the plot 14 of the Northern Lisbon Logistic Platform

**Miriam Lopes** / JETsj Geotecnia Lda.  
**Alexandre Pinto** / JETsj Geotecnia Lda.  
**António Levita Gonçalves** / Terratest  
**Javier Moreno** / JM Ingeniería Geológica



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- Introduction
- Ground improvement solutions
- Design
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- Final remarks



## → Introduction

### □ LOCATION

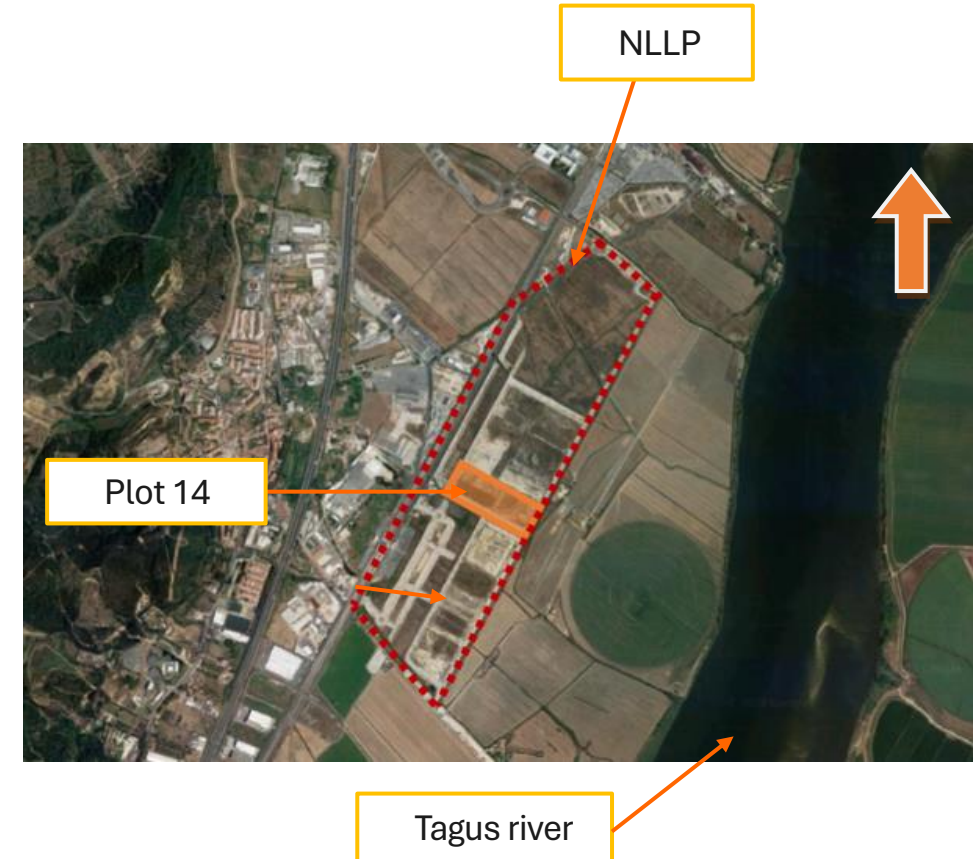
- ❖ Northern Lisbon Logistic Platform, at Castanheira do Ribatejo, Vila Franca de Xira, Portugal
- ❖ Right bank of the Tagus river

### □ GEOLOGICAL CONDITIONS

- ❖ Presence of alluvial deposits, essentially made up of **soft silts and very soft high plasticity clays** (approximately 20 m thick)

### □ OBJECTIVE

- ❖ New industrial building
- ❖ Expected **high magnitude live loads** for ground pavements (50/20 kPa)
- ❖ Embankments to **raise the ground pavement level**



Risk of accentuated and evolving deformable behaviour over time.

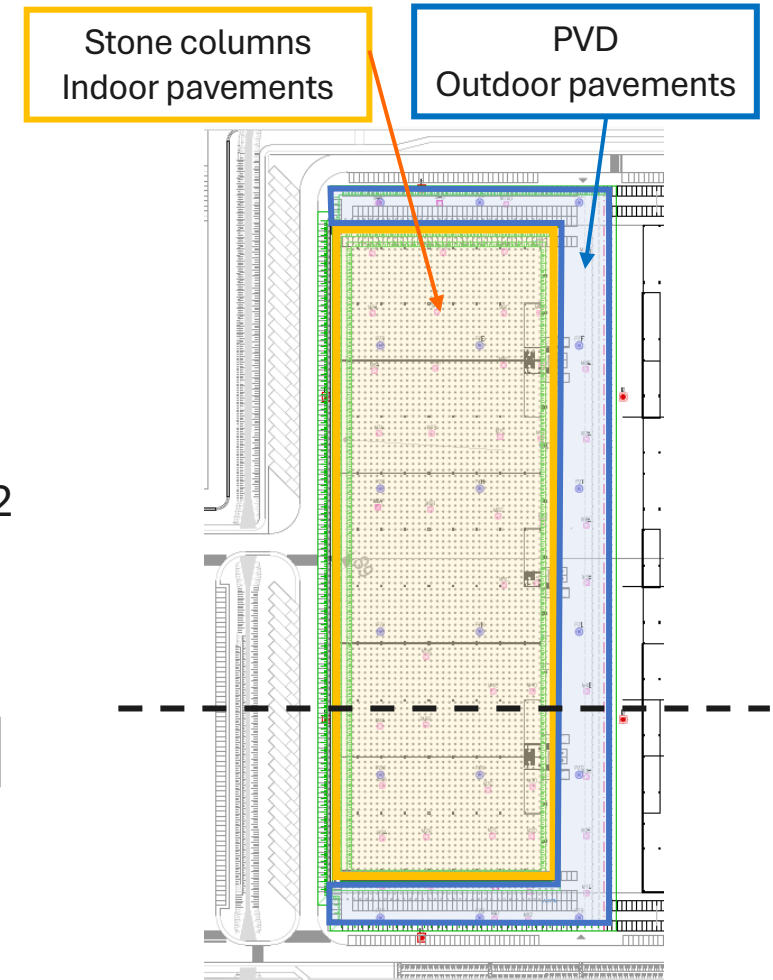
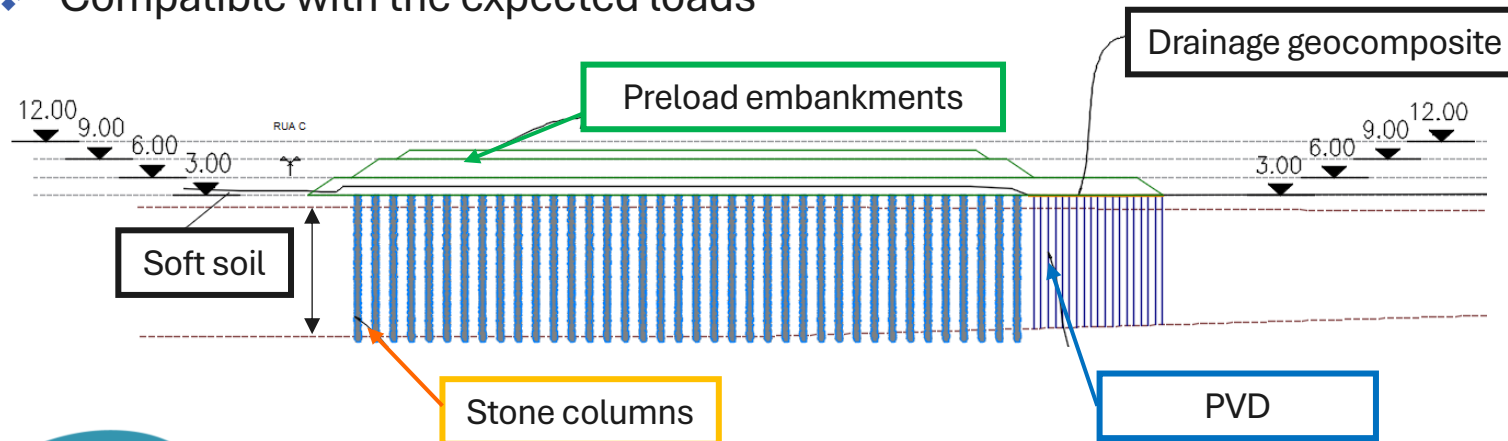
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- Design
- Monitoring and survey plan
- Final remarks



## → Ground improvement solutions

- ❑ Accelerate the process of hydrodynamic consolidation of the compressible materials (soft clayey soils)
- ❑ Introduction of drainage elements
  - ❖ Stone columns (Ø900 mm), at the area of the warehouse indoor pavements (3.0 x 3.0 m square array)
  - ❖ Prefabricated vertical drains (PVD), at the area of the outdoor pavements (1.2 m triangular mesh)
- ❑ Build 8.0 m and 4.0 m high preload embankments, with slopes H=1.5; V=1.0
  - ❖ Compatible with the expected loads



## → Ground improvement solutions



Prefabricated vertical drains installation

Preload embankment construction over drainage geocomposite



Conclusion of preload embankment construction

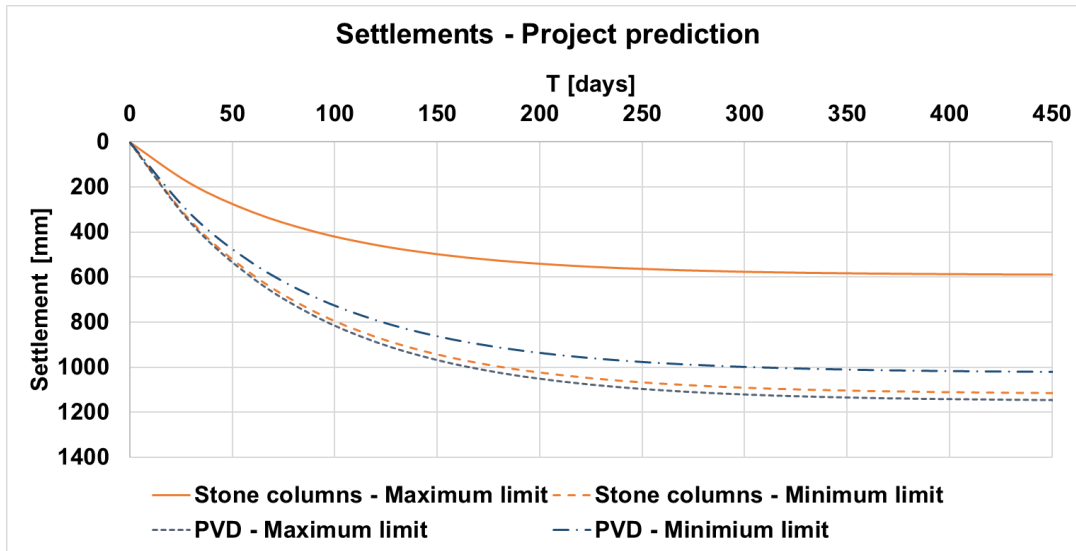
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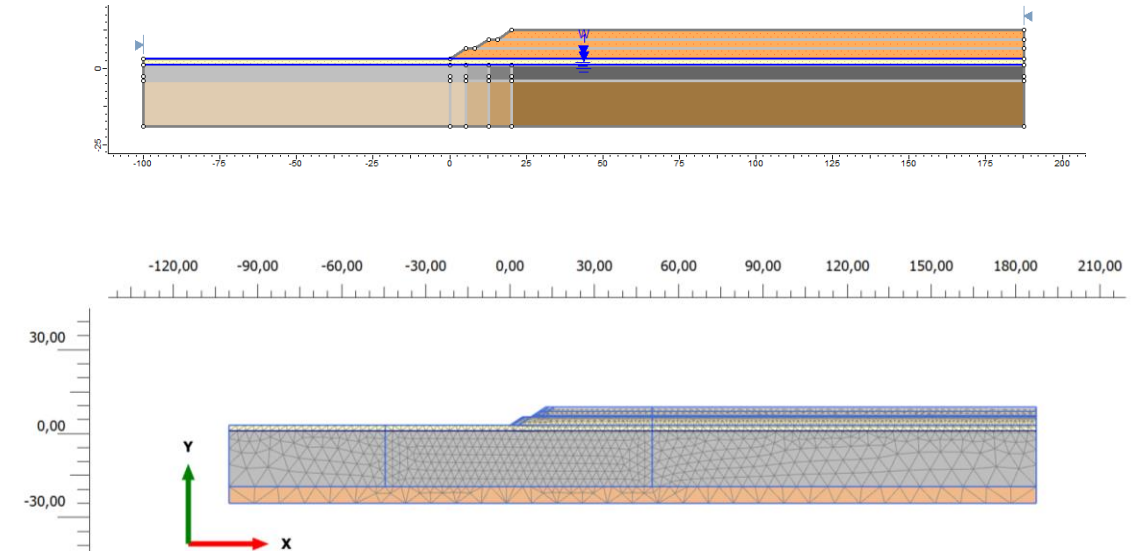
## □ SETTLEMENT EVOLUTION OVER TIME ESTIMATE

- ❖ Compressibility of alluvial soft clays
- ❖ Presence of the stone columns and prefabricates vertical drains



## □ SLOPE STABILITY

- ❖ Foundation soils characterized by low shear strength
- ❖ Limit equilibrium and finite element calculation



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- Final remarks



## → Monitoring and survey plan

### ☐ MONITOR EVOLUTION OF THE CONSOLIDATION PROCESS

- ❖ Topographic marks supported on settlement plates (Surface settlements)
- ❖ Vibrating wire piezometers (Water levels/Pore pressure)

M...

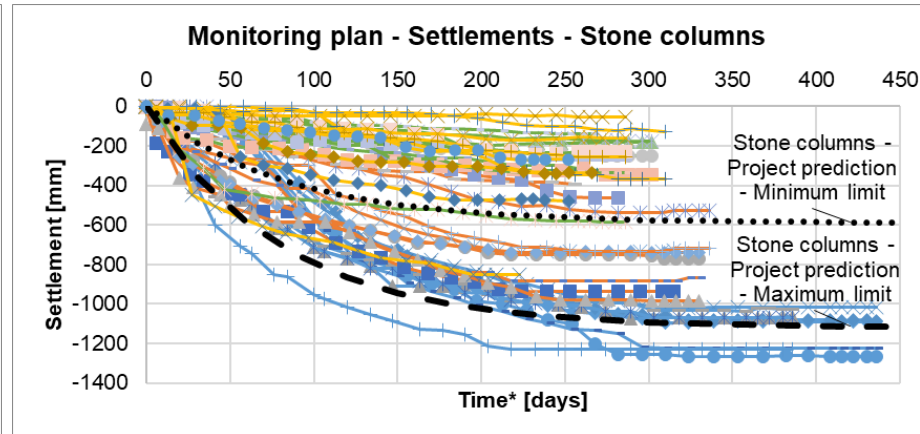
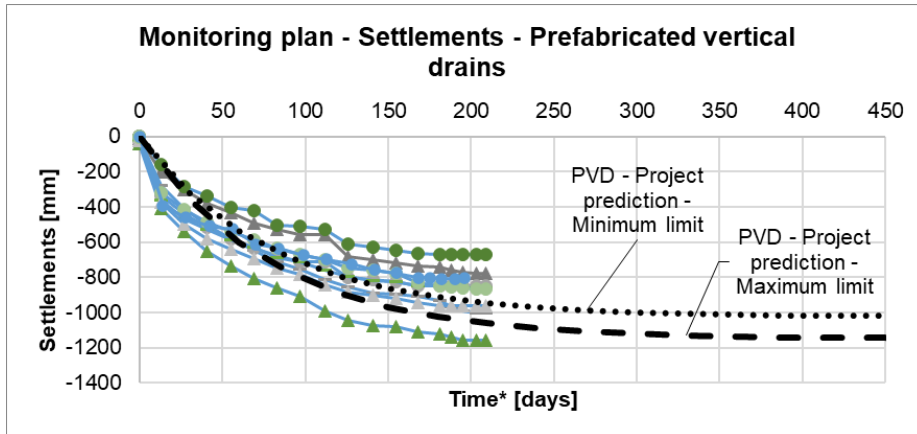
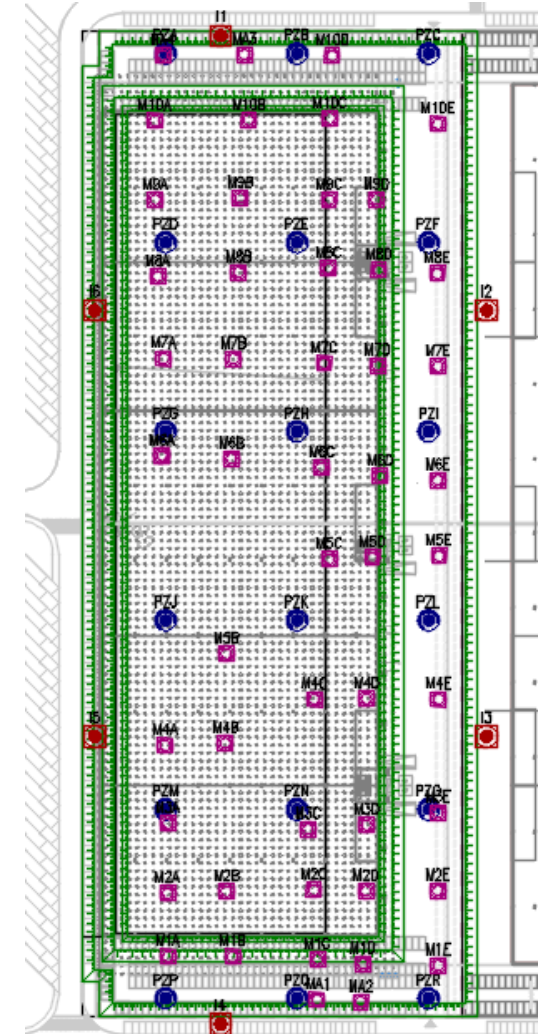


Pz...



### ☐ SLOPE STABILTY

- ❖ Inclinometers (Horizontal movements of the ground)



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## → Final remarks

- ❑ The framework of the work described, including **the available time**, determined the need to develop **ground improvement** solutions aiming to provide favourable conditions for the future employment of **economic foundation solutions**, compatible with the structure serviceability
- ❑ The adopted solutions make it possible to **mitigate**, during the life of the future industrial structure, **high magnitude settlements, resulting from the primary consolidation process**, developed at the level of soft clayey alluvial layers
- ❑ The **Monitoring and Survey Plan** plays an essential role in managing the behaviour of the work, allowing the interpretation of the observed settlements and the establishment, with greater accuracy, of the time necessary to obtain the specified degree of consolidation
- ❑ The magnitude of settlements estimated at the project stage, in general, was in line with the values measured on site



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**Thank you for your attention!**



**JET**<sub>SJ</sub>



**TERRATEST**

# Excavation, retaining wall and deep foundations solutions for an office building at Alcântara – Lisbon

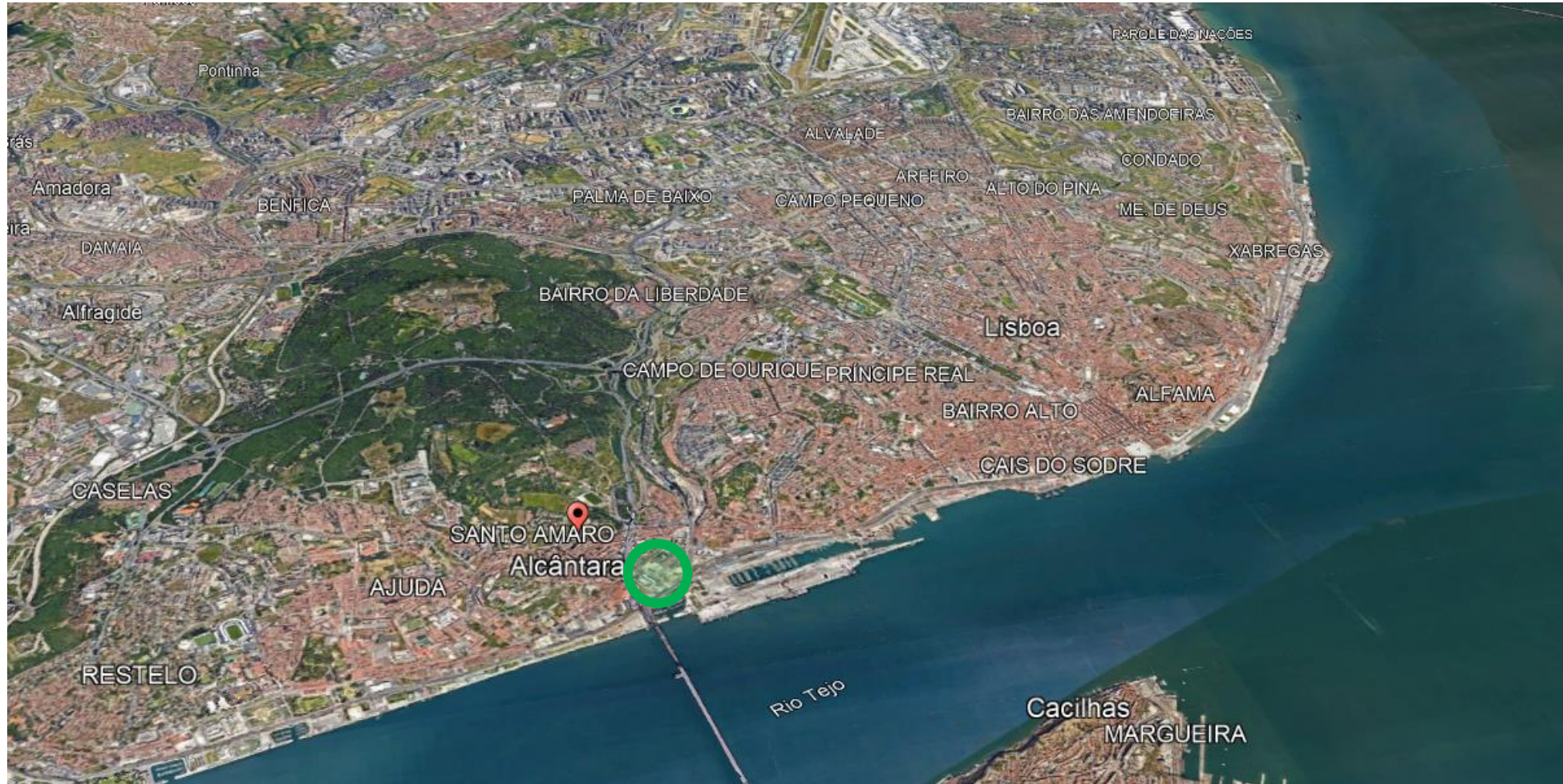
Rui Tomásio / JETsj Geotecnia  
Filipe Veloso / Rockbuilding  
Nuno Rosa / Alves Ribeiro



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- Main Constrains
- Adopted Solutions
- Design Models
- Monitoring





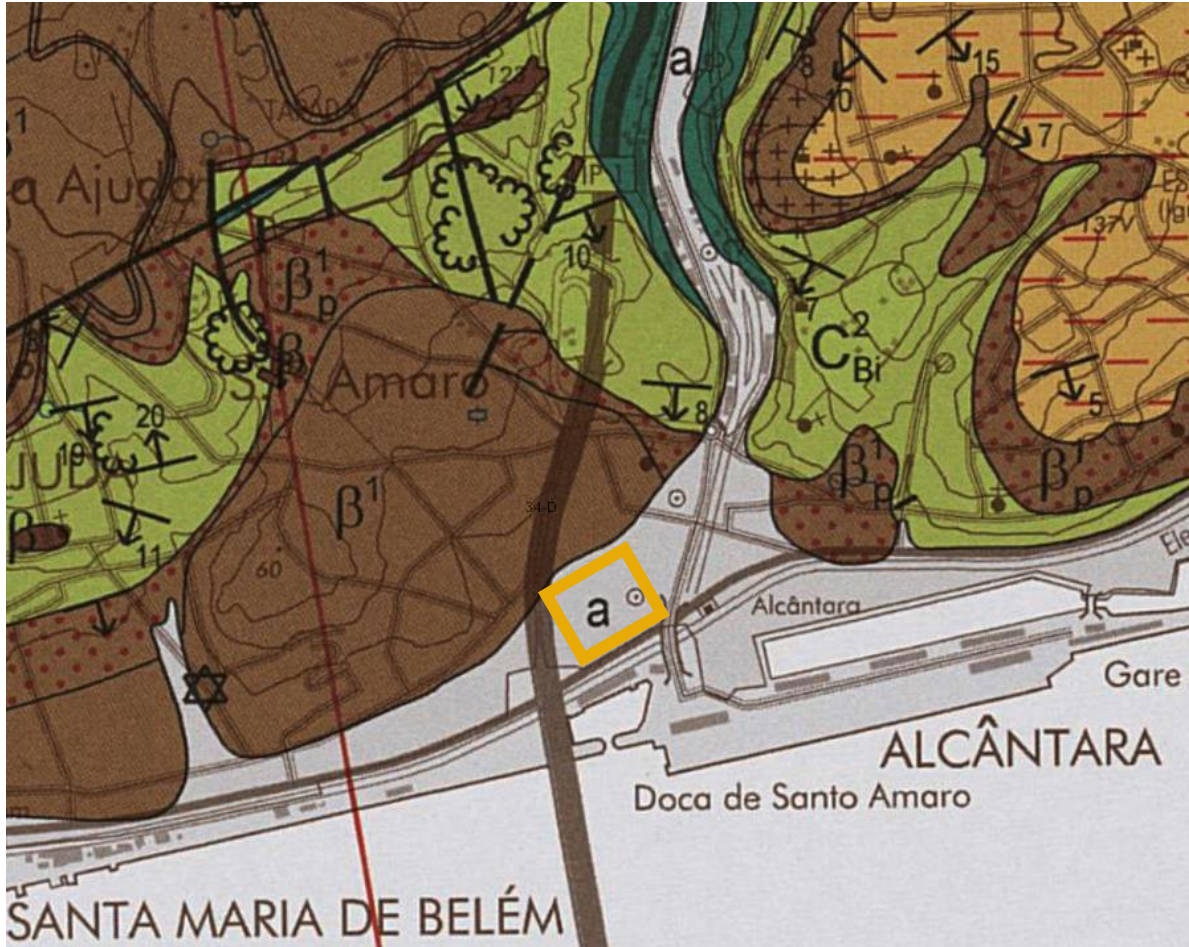


- Office building
- 6.300m<sup>2</sup> plot area (90mx70m)
- 4 underground levels
- 13m excavation depth
- 2m depth water table
- High permeability sandy alluvium layers
- Very close to Tagus river

# Index

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- **Main Constrains**
- Adopted Solutions
- Design Models
- Monitoring





- 9 boreholes combined with SPT tests
- 6 Seismic CPTu tests
- Lefranc permeability tests
- Direct shear tests
- Triaxial tests



0,00 m - 23,00 m

Heterogenous Fill  
 Sandy alluvium



23,00 m - 37,50 m

Silty alluvium  
 Clayey alluvium  
 Gravel



37,50 m - 40,30 m

Weathered Basalt



40,30 m - 43,15 m

Basalt





Industrial archaeological remains from  
20<sup>th</sup> century



Maritime archaeological remains  
from the 18<sup>th</sup> and 19<sup>th</sup> centuries

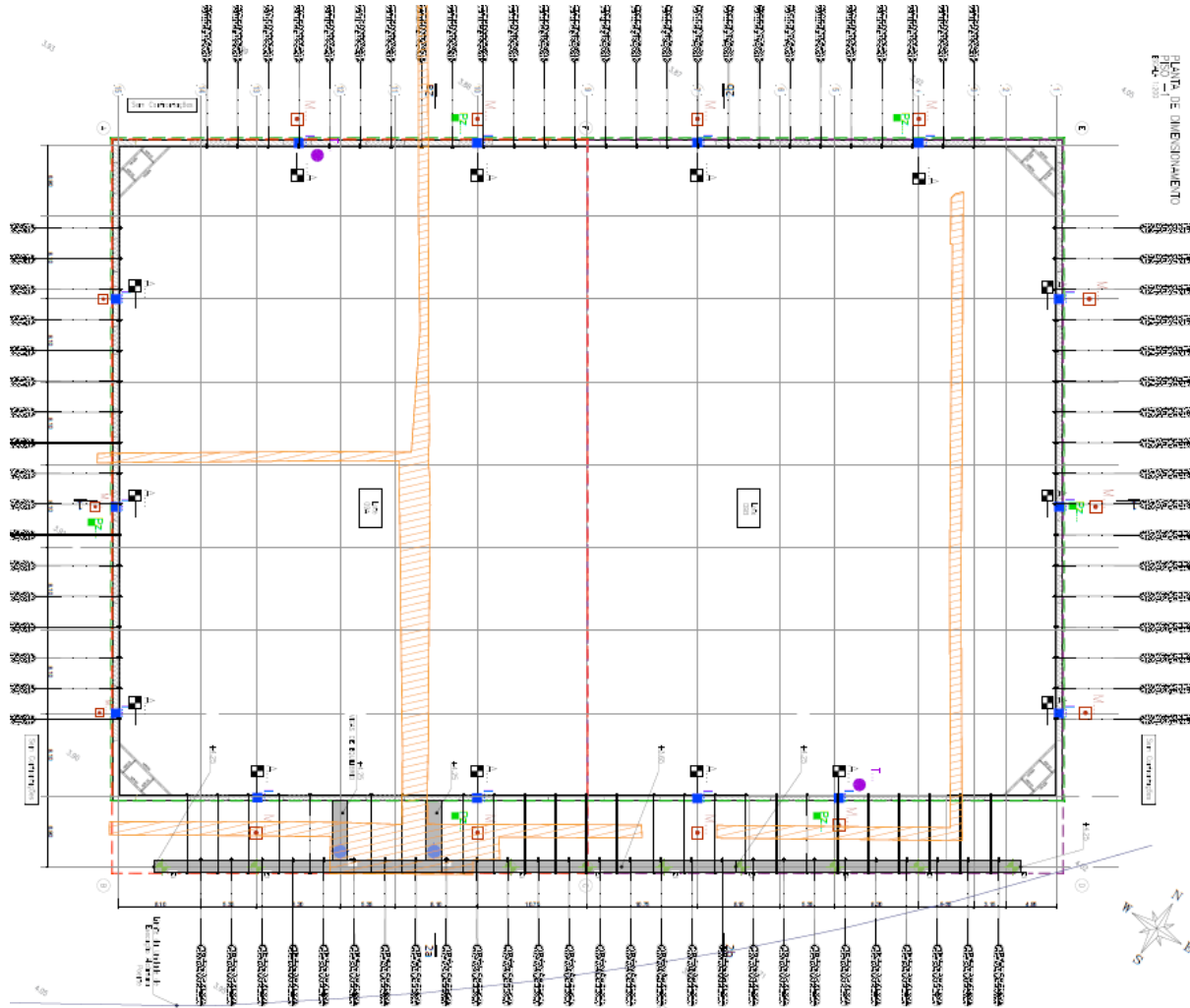


Maritime archaeological remains  
from the 18<sup>th</sup> and 19<sup>th</sup> centuries

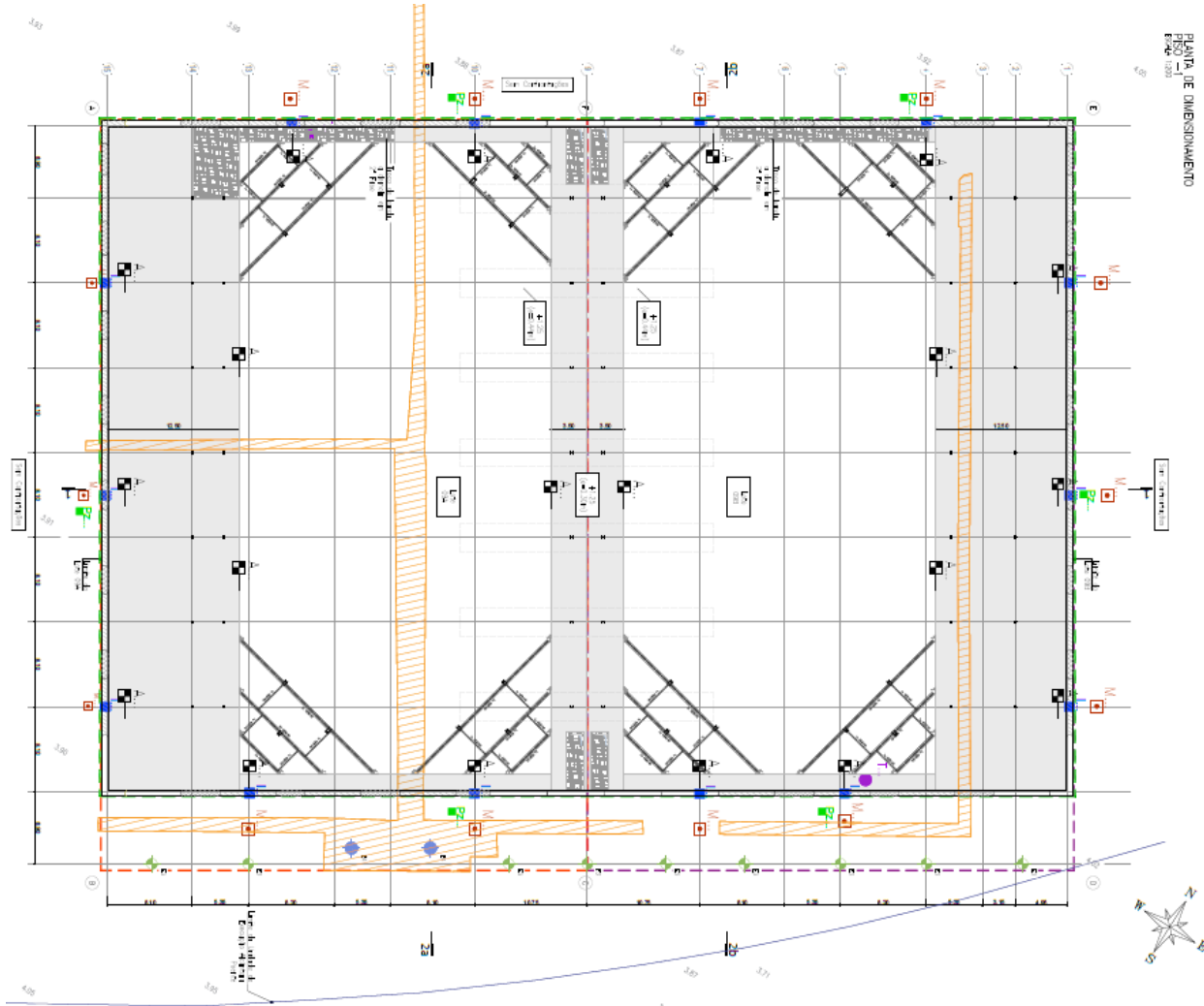
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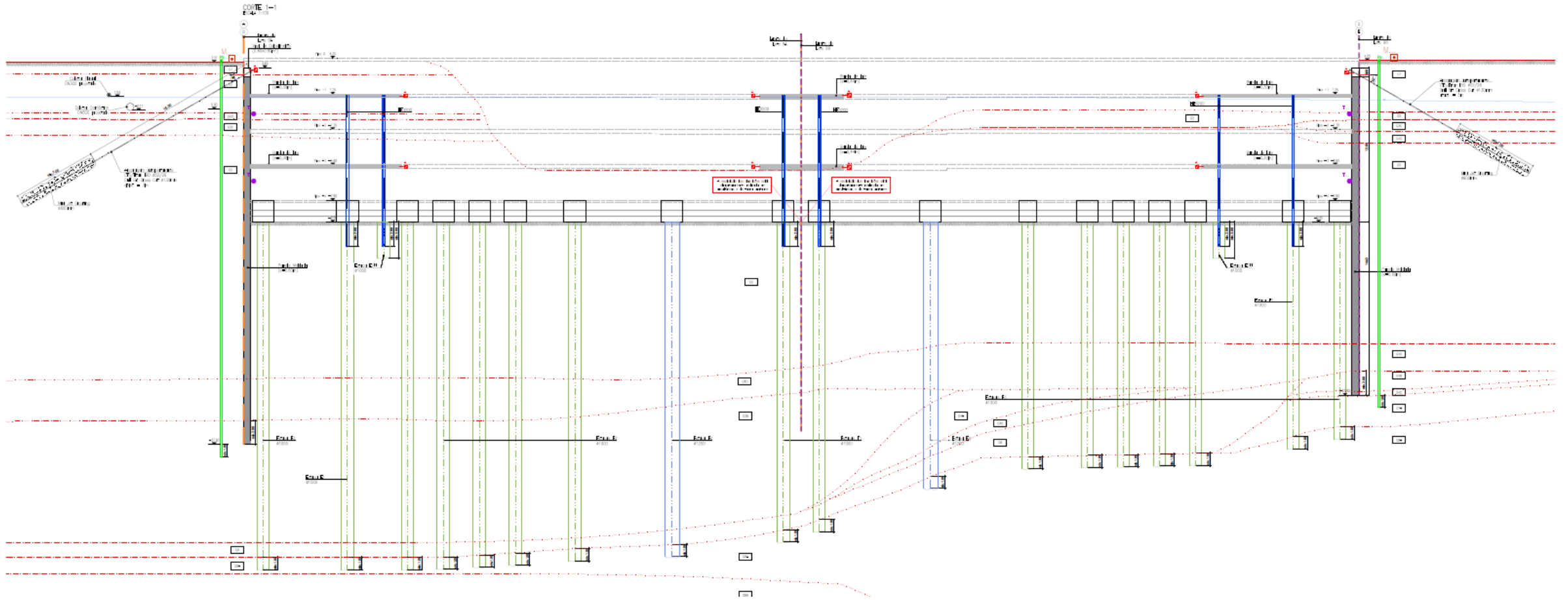




1. Diaphragm Wall
  - 60cm thickness
  - 32m maximum depth
  - 1m embedded length on clayey alluvium layer
  
2. Self-drilling temporary ground anchors at capping beam level to allow an undisturbed archaeological excavation over a depth of 6m in the entire plot and 9m in the centre part



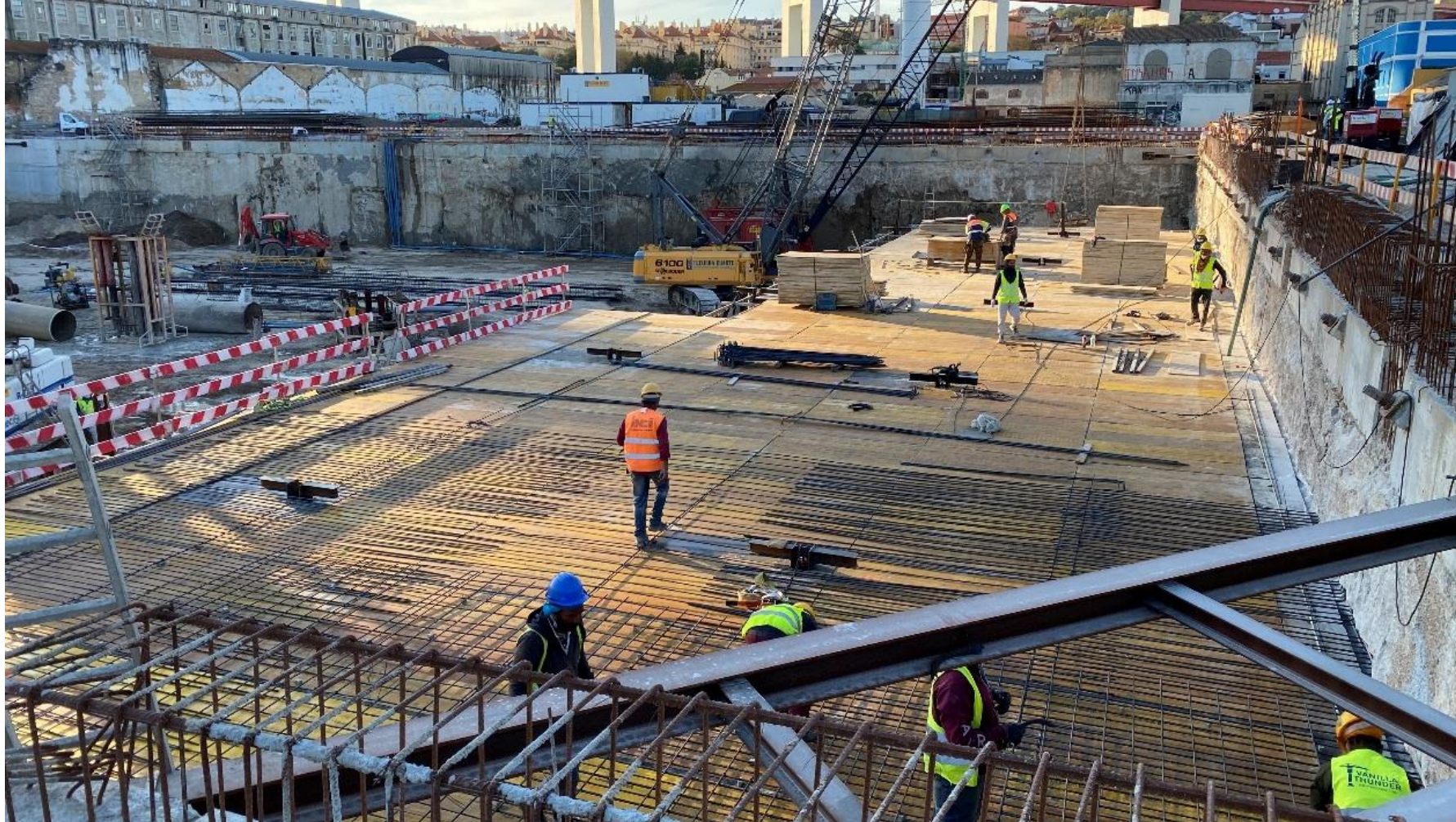
3. Top-down slab for temporary support of the diaphragm walls at level -1
4. Excavation until level -3
5. Top-down slab for temporary support of the diaphragm walls at level -3
6. Excavation until foundation level













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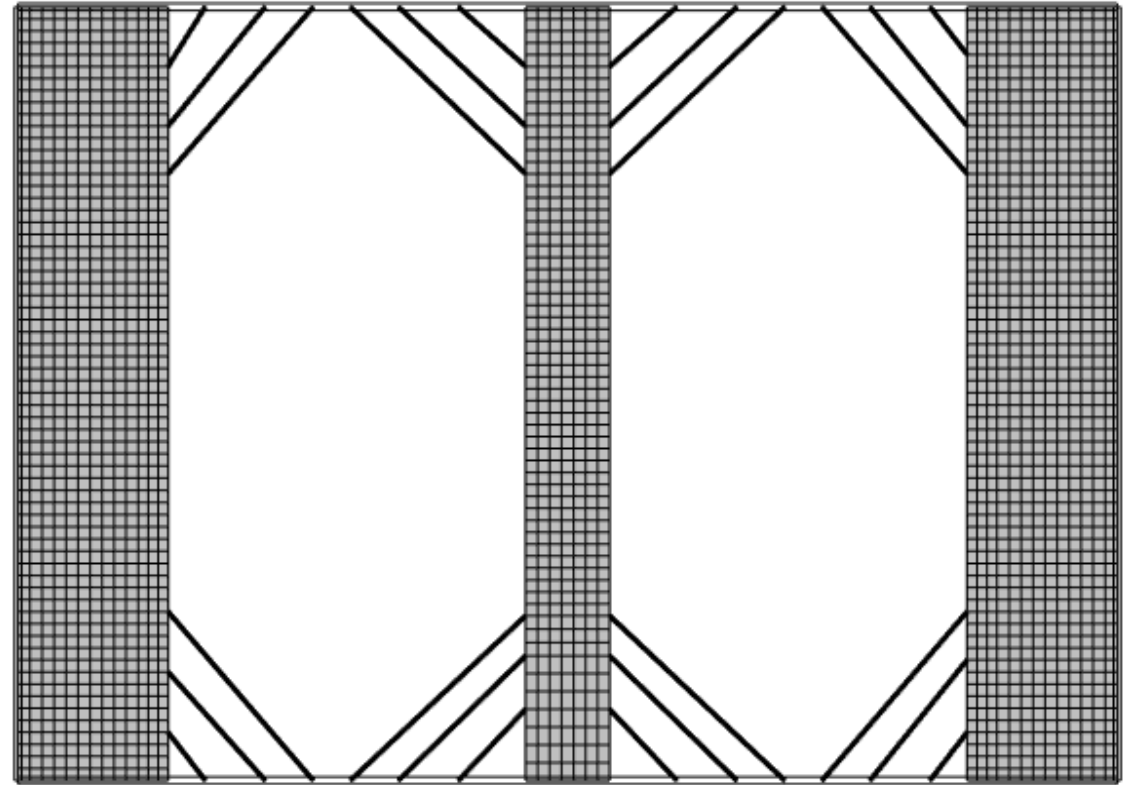
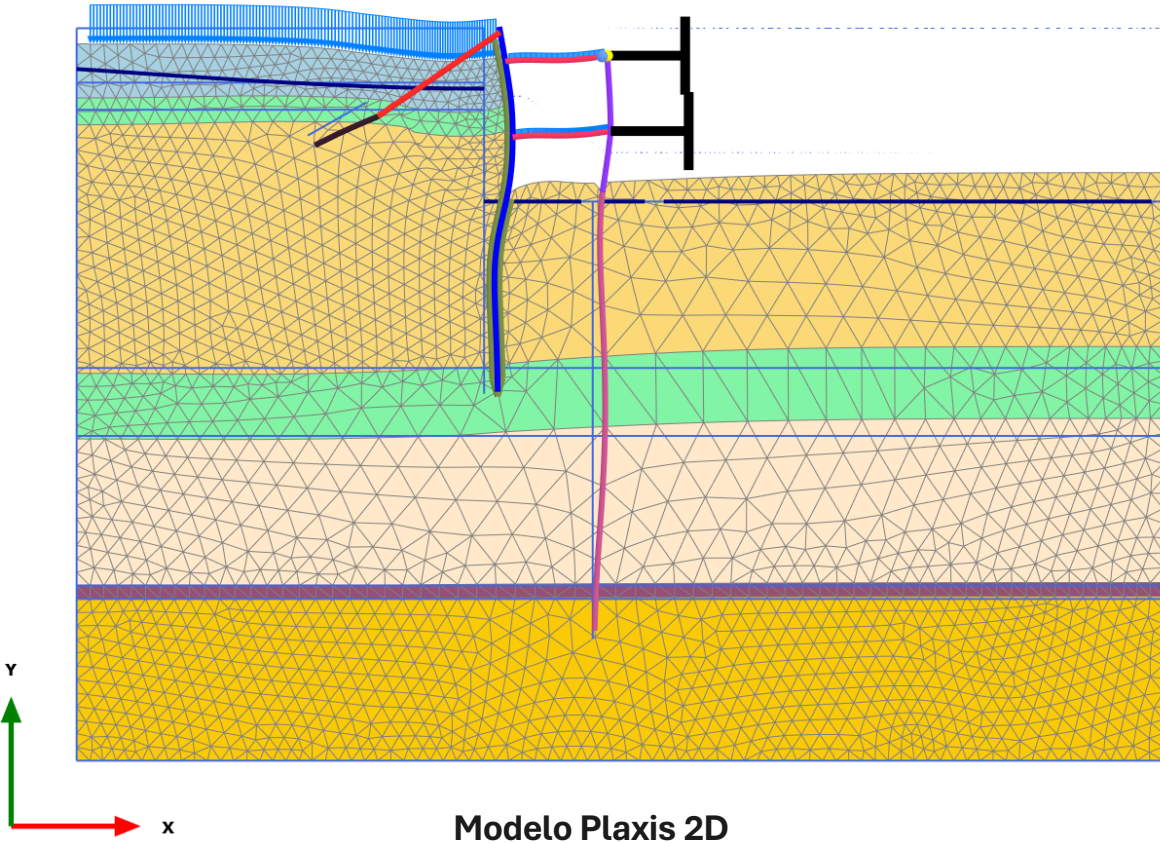


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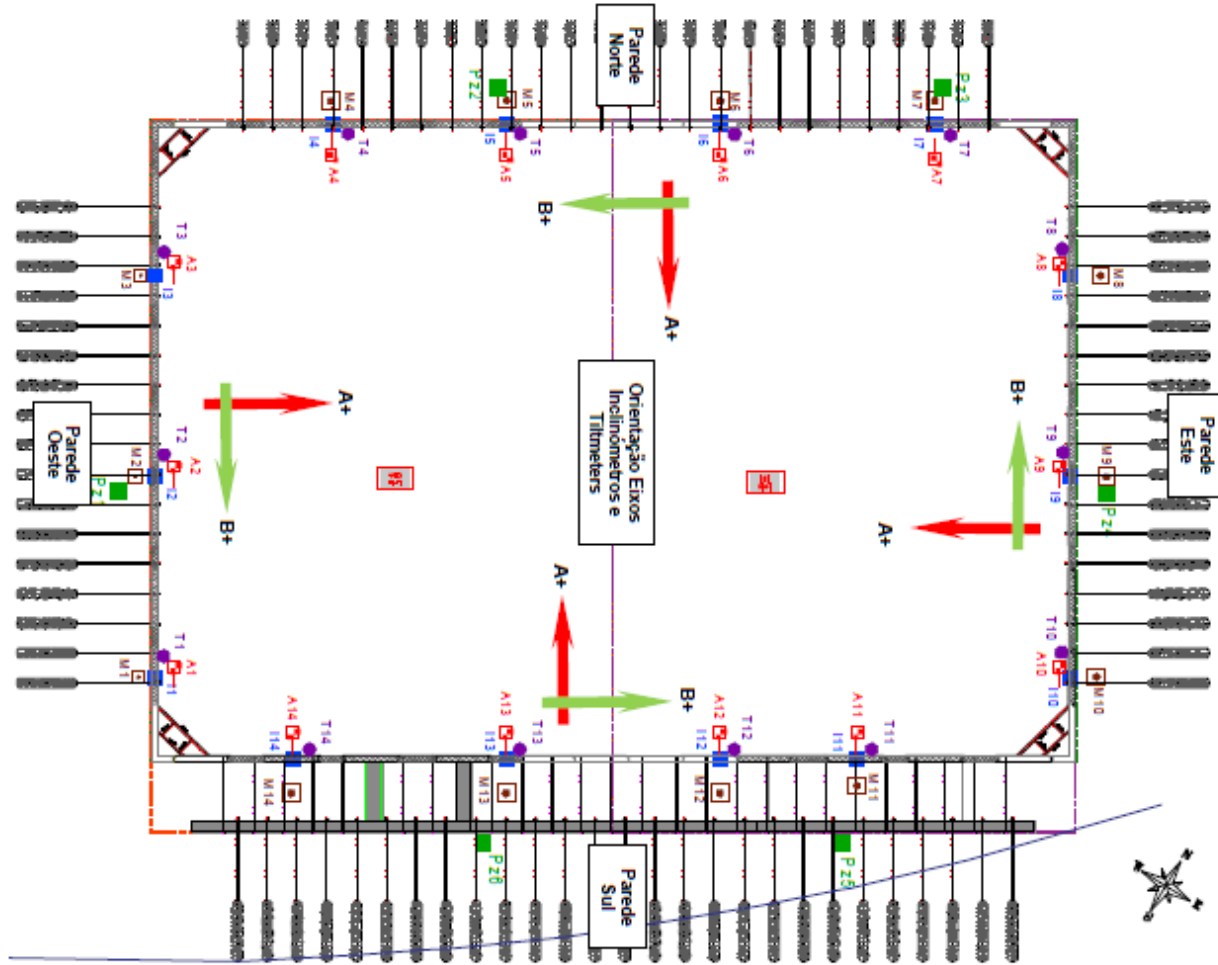
Lisbon Portugal



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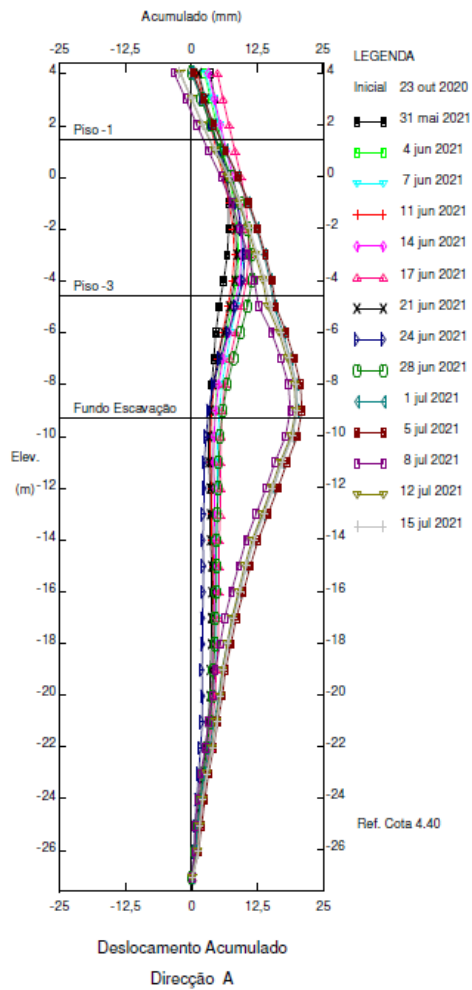
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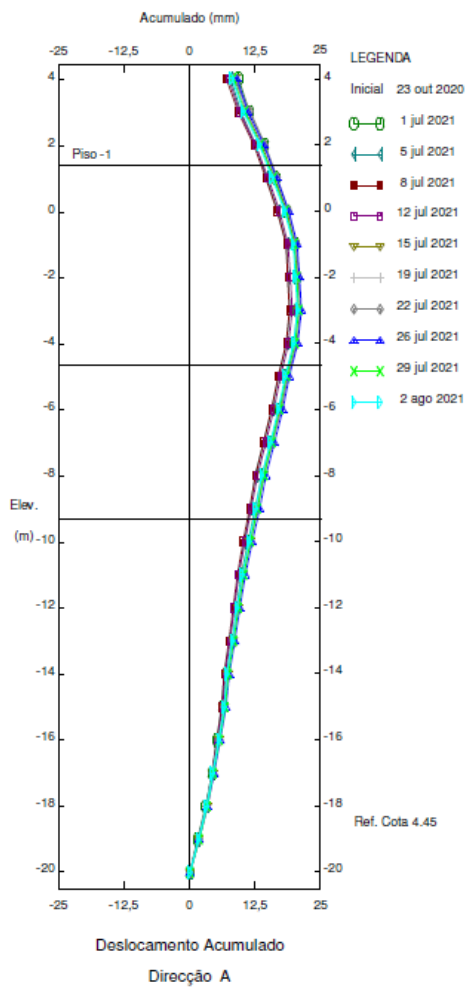


- 14 Inclínômetros
- 6 Piezômetros
- 14 Topographic targets
- 14 Settlement marks
- 28 Tiltmeters

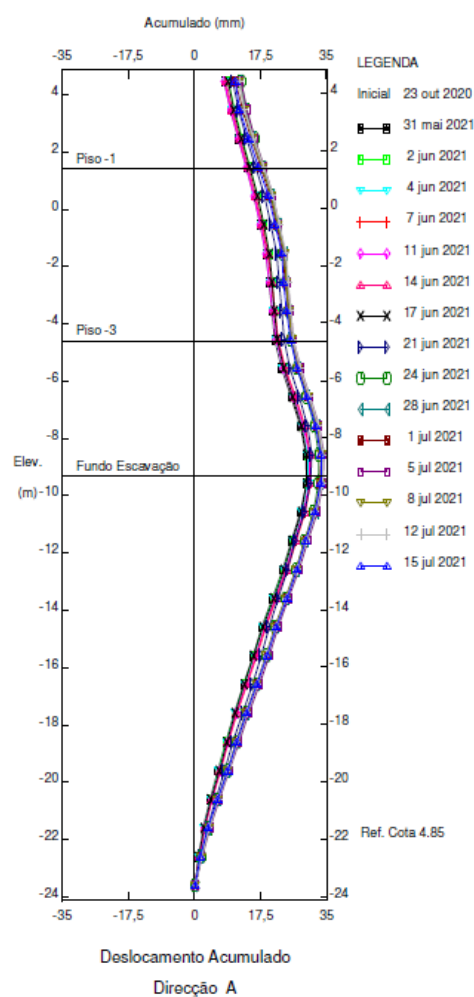
### INCLINOMETER I3



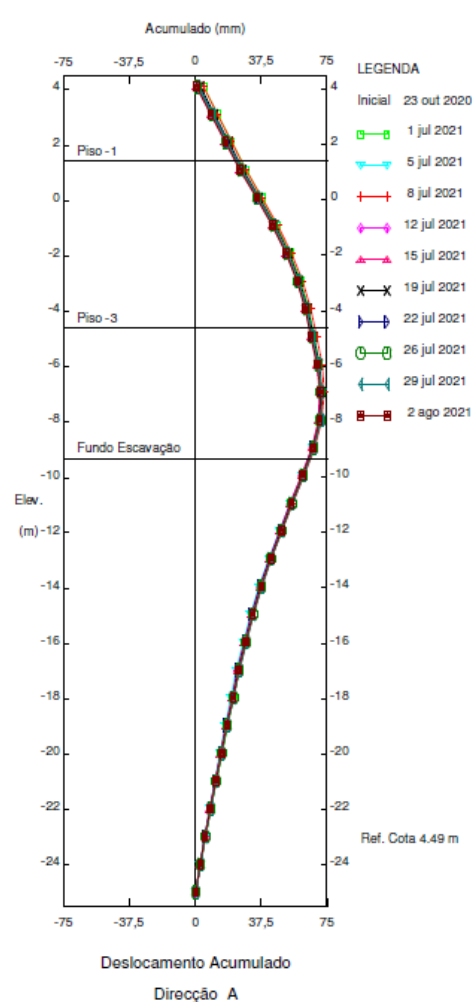
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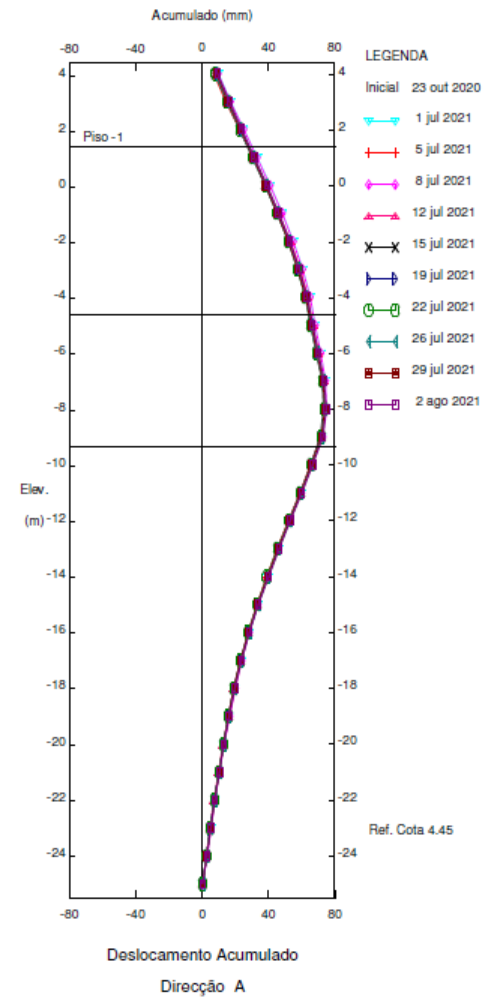
### INCLINOMETER I10



### INCLINOMETER I11



### INCLINOMETER I12





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# Acknowledgements

## Thank you for your attention!

Developer



**BEDROCK**  
CAPITAL PARTNERS<sup>LDA</sup>

Supervision

**Rockbuilding**  
Solid Project Management

Contractor



**hci**  
CONSTRUTORA

**ar**  
ALVES RIBEIRO, S.A.

Geotechnical Contractor

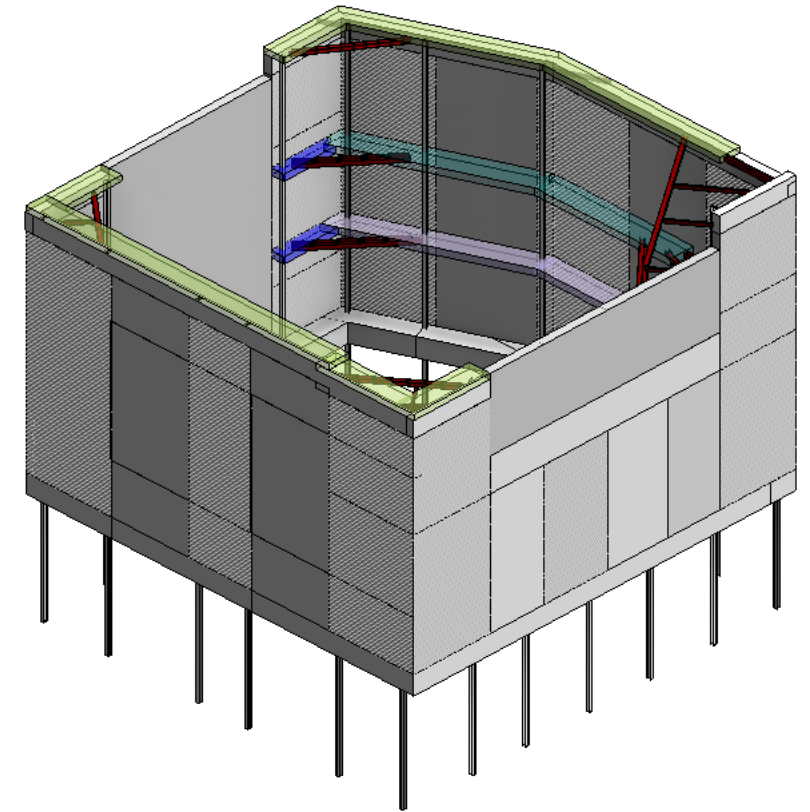


**TEIXEIRA DUARTE**  
ENGENHARIA E CONSTRUÇÕES, S.A.

# Solutions of excavations and peripheral earth retaining walls in dense urban area

**Lourenço Fernandes** / Jetsj – Geotecnia Lda.

**Ricardo Justiniano** / Jetsj – Geotecnia Lda.



**SOSIDIS**  
ACTIVIDADE HOTELEIRA, LDA.

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- **Introduction**
- Main Constrains
- Excavation and Peripheral Earth Retaining Solutions
- Geotechnical and Structural Design
- Monitoring and Survey Plan
- Conclusions



## → Introduction

### ❑ PROPOSED BUILDING

- ❖ Multi-family residential building
- ❖ 3 underground floors + 7 elevated floors
- ❖ Footprint area of approximately 200 square meters.



# Index

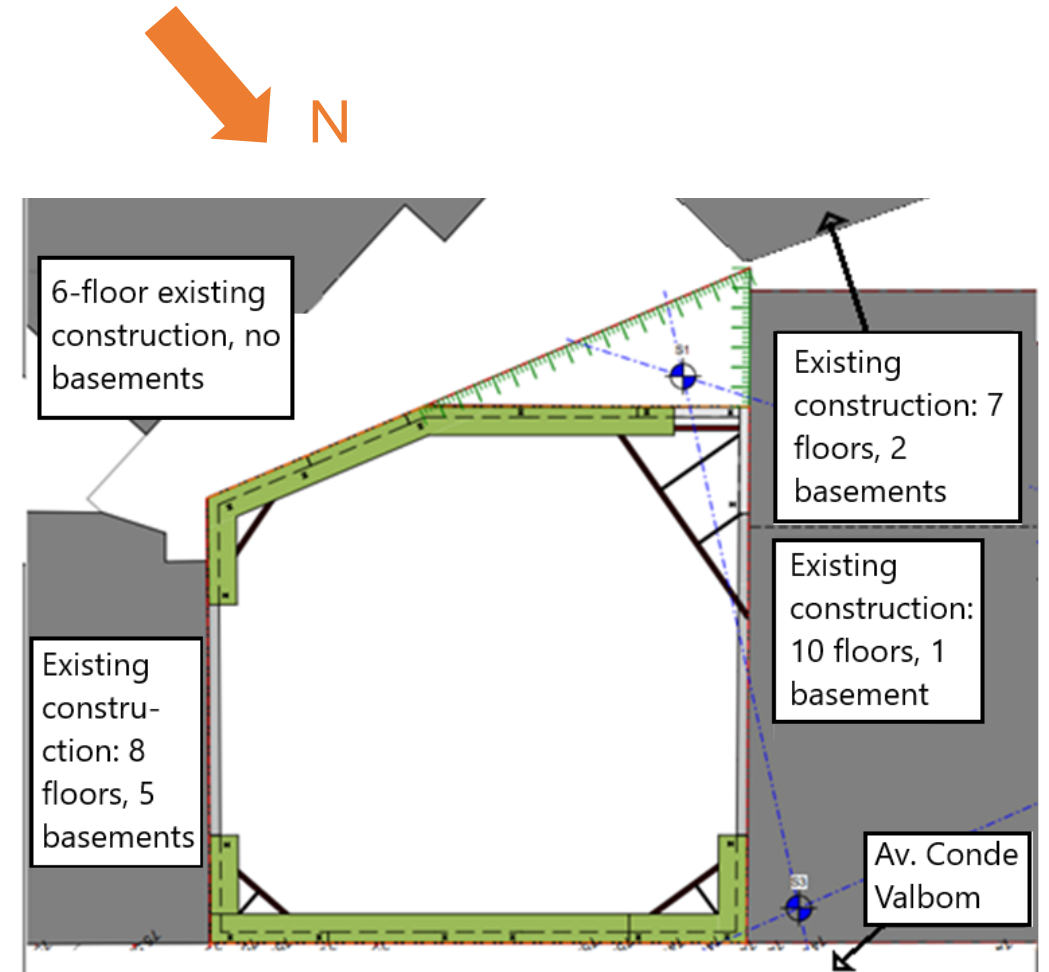
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## → Main Constrains

### □ NEIGHBOURHOOD MAIN CONSTRAINS:

- Conde Valbom Avenue side: +/- level of floor 0.
- Northern side: Existing building with 10 floors and 1 basement floor.
- Southern side: Existing building with 8 elevated floors and 5 basement floors.
- Rear side: Boundary with the existing backyard.

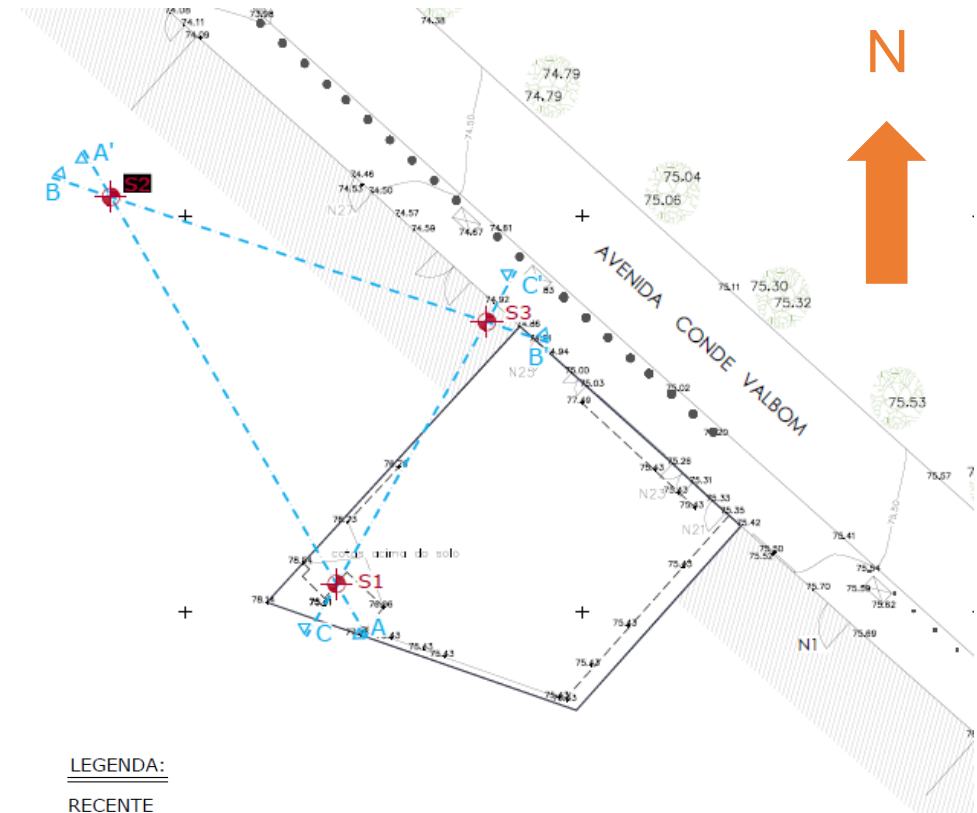
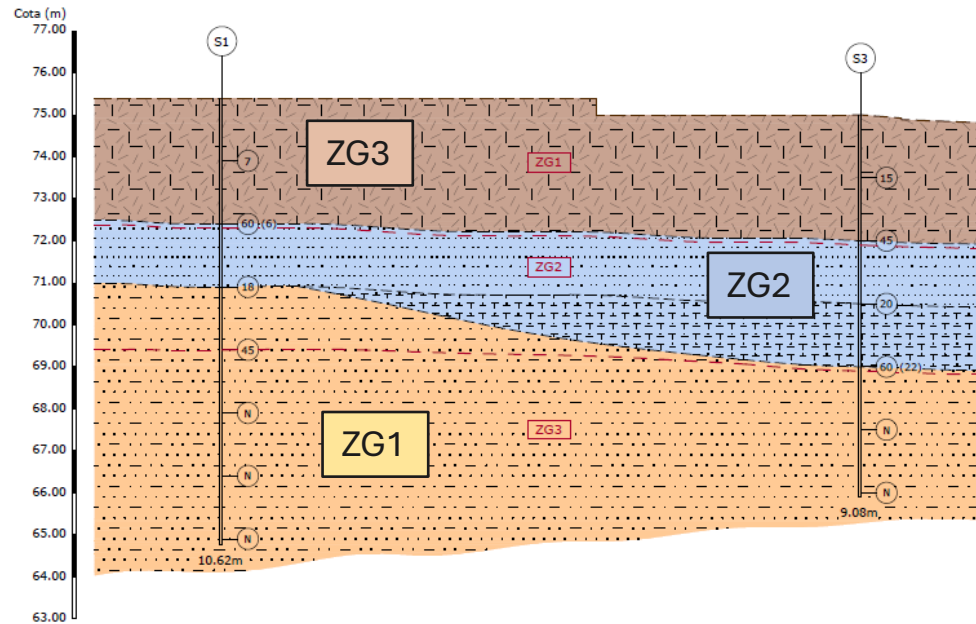


## → Main Constrains

### ☐ GEOLOGICAL AND GEOTECHNICAL PROSPECTION

- 3 mechanical boreholes:
- Standard Penetration Tests (SPT)

Cross section C-C'



LEGENDA:

RECENTE

ZG3 Loosely compact clayey

MIOCÉNICO

ZG2 Moderately compact Silts and Sandy clays

ZG1 Compact claye sands

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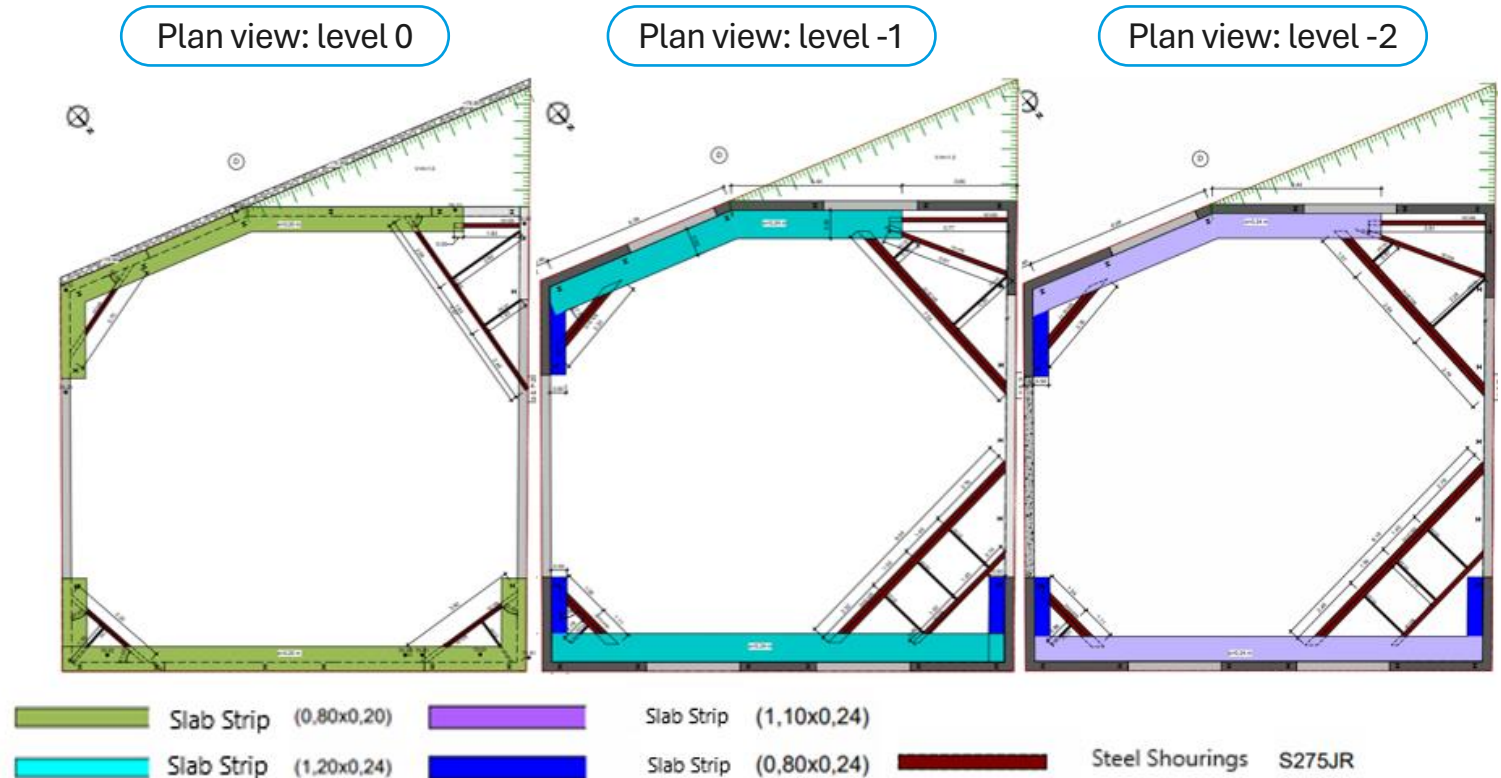
## → Excavation and Peripheral Earth Retaining Solutions

### □ OBJECTIVE:

- Manage soil deformation
- Minimize disruptions to adjacent structures and infrastructures

### □ ADOPTED SOLUTION

- King post wall ( $t=0,30$  m)
- Concrete slab bands ( $t=0,24$  m)
- Shorings (HEB 140, IPE 120)
- Vertical steel profiles (HEB 120)



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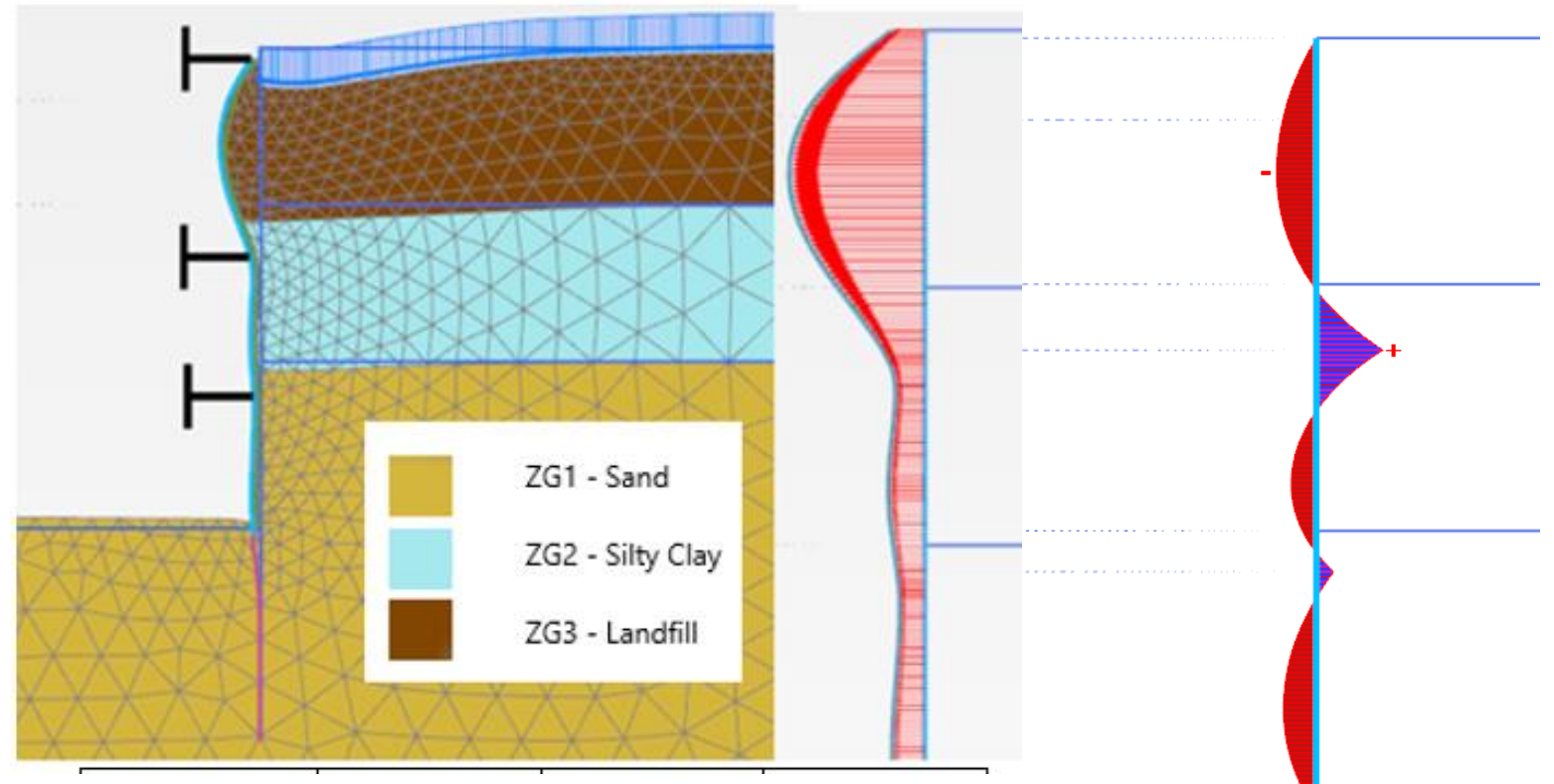
## → Geotechnical and Structural Design

### □ FINITE ELEMENT ANALYSIS SOFTWARES:

#### ➤ PLAXIS 2D

Soil Type	ZG <sub>3</sub>	ZG <sub>2</sub>	ZG <sub>1</sub>
N <sub>SPT</sub>	7-15	18-45	45-60
γ [kN/m <sup>3</sup> ]	18	18	20
Φ [°]	27	30	38
E <sub>50</sub> <sup>ref</sup> [MPa]	10	40	90
E <sub>ur</sub> <sup>ref</sup> [MPa]	30	120	270

ZG<sub>1</sub> – Loosely compact clay fill; ZG<sub>2</sub> – moderately compact silt soil and clayey sandy soil; ZG<sub>3</sub> – compact clayey sand soil.



U.max.y = 0,008  
(m)

U.max.x = 0,018  
(m)

M.max = 40,6  
(kN m/m)

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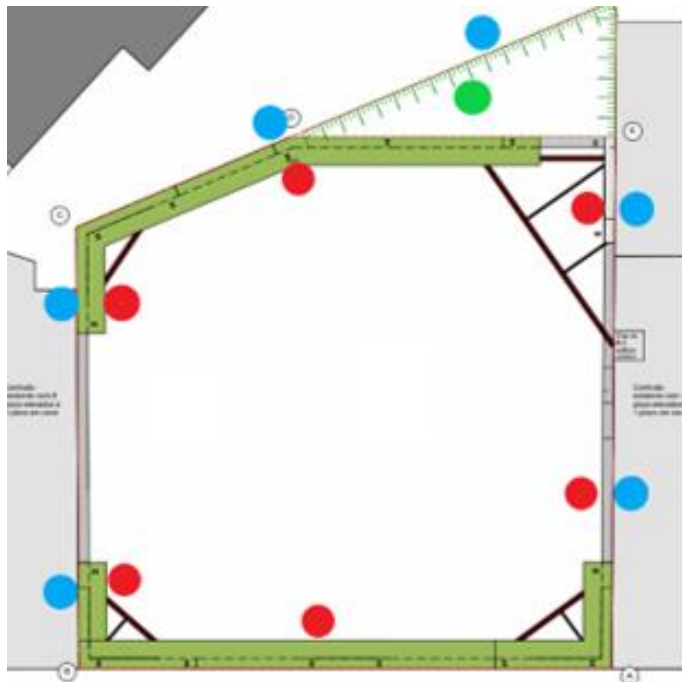
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## → Monitoring and Survey Plan

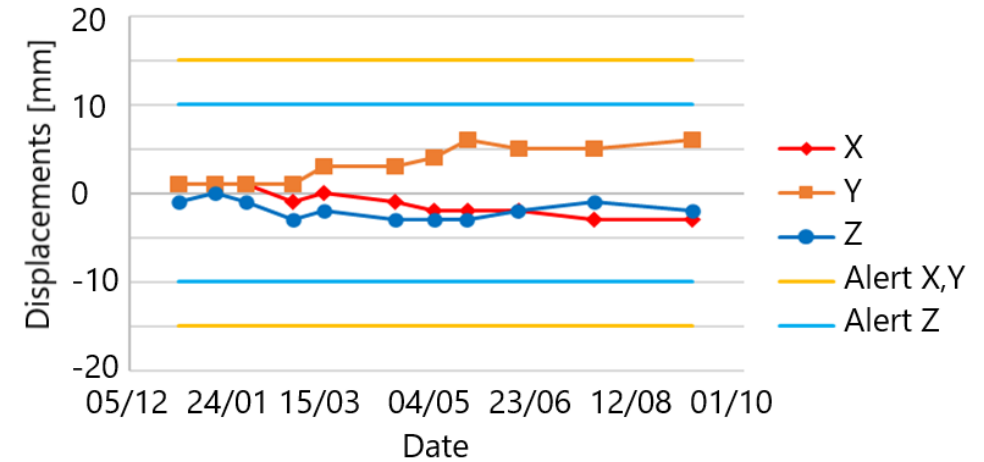
### □ INSTRUMENTATION:

- 20 topographic targets
- 1 inclinometer

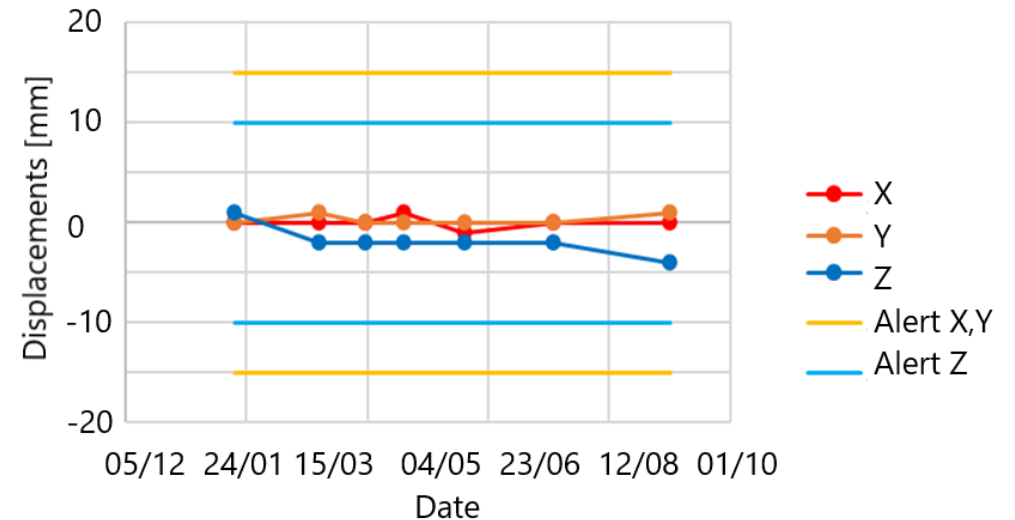


- Topographic targets on:
- (a) peripheral earth retaining solution
  - (b) neighbouring structures
  - Inclinometers

Station A4 - Neighboring buildings



Station C8 - Peripheral earth retaining solution



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## → Conclusions

### □ CONCLUDING COMMENTS:

- Technical efficiency of king post wall braced by various structural elements such as struts, and mini slab stripes.
- Displacements lower than those estimated in project and displayed a highly stable behaviour during the excavation works.
- Economic efficiency using mini slab bands, it incorporated elements of the final structure.

**Thank you for your attention!**



Acknowledgements:



**SOSIDIS**  
ACTIVIDADE HOTELEIRA, LDA.

# Solution of excavation and peripheral earth retaining walls near sensitive structures – O'Living Development, Lisbon

**R. Justiniano** / JETsj Geotecnia / Lisbon, Portugal

**A. Pinto** / JETsj Geotecnia / Lisbon, Portugal

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- Conclusion



## → Introduction

- Residential Development
  - Lot 1 – 2 floors underground
  - Lot 2 – 3 floors underground
- Metro Gallery cross Lot 1 and Lot 2 about 4m under bottom excavation



## → Main Constrains

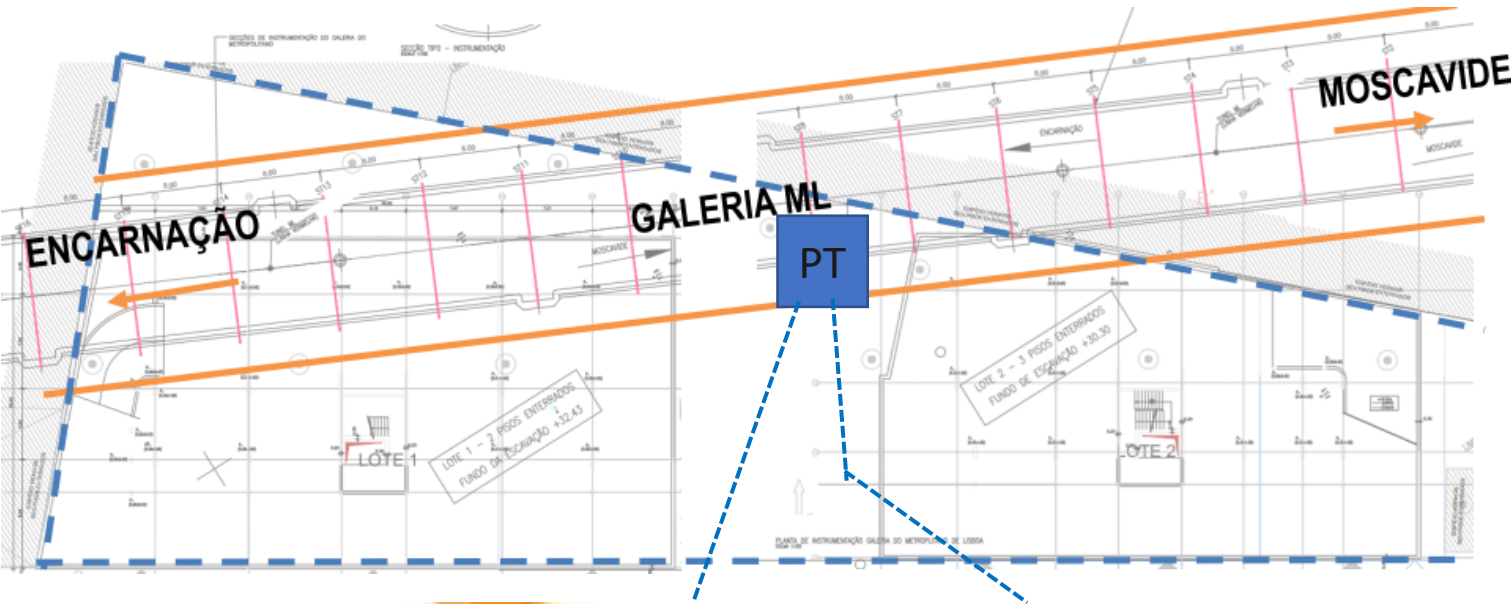
- Metro Gallery under Lot 1 and Lot 2
- Existing buildings at north with foundation above floor 0 of new develop
- Existing PT (Transformation Post) crossing Lot 2



Lot 1 North side

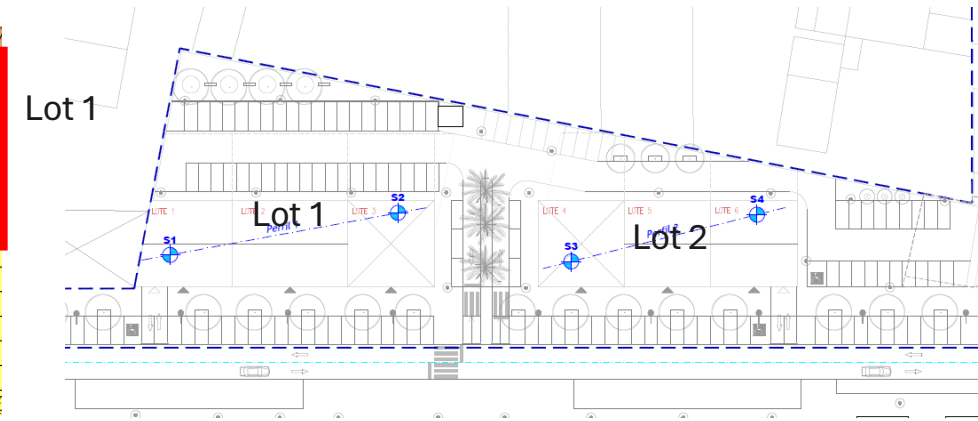
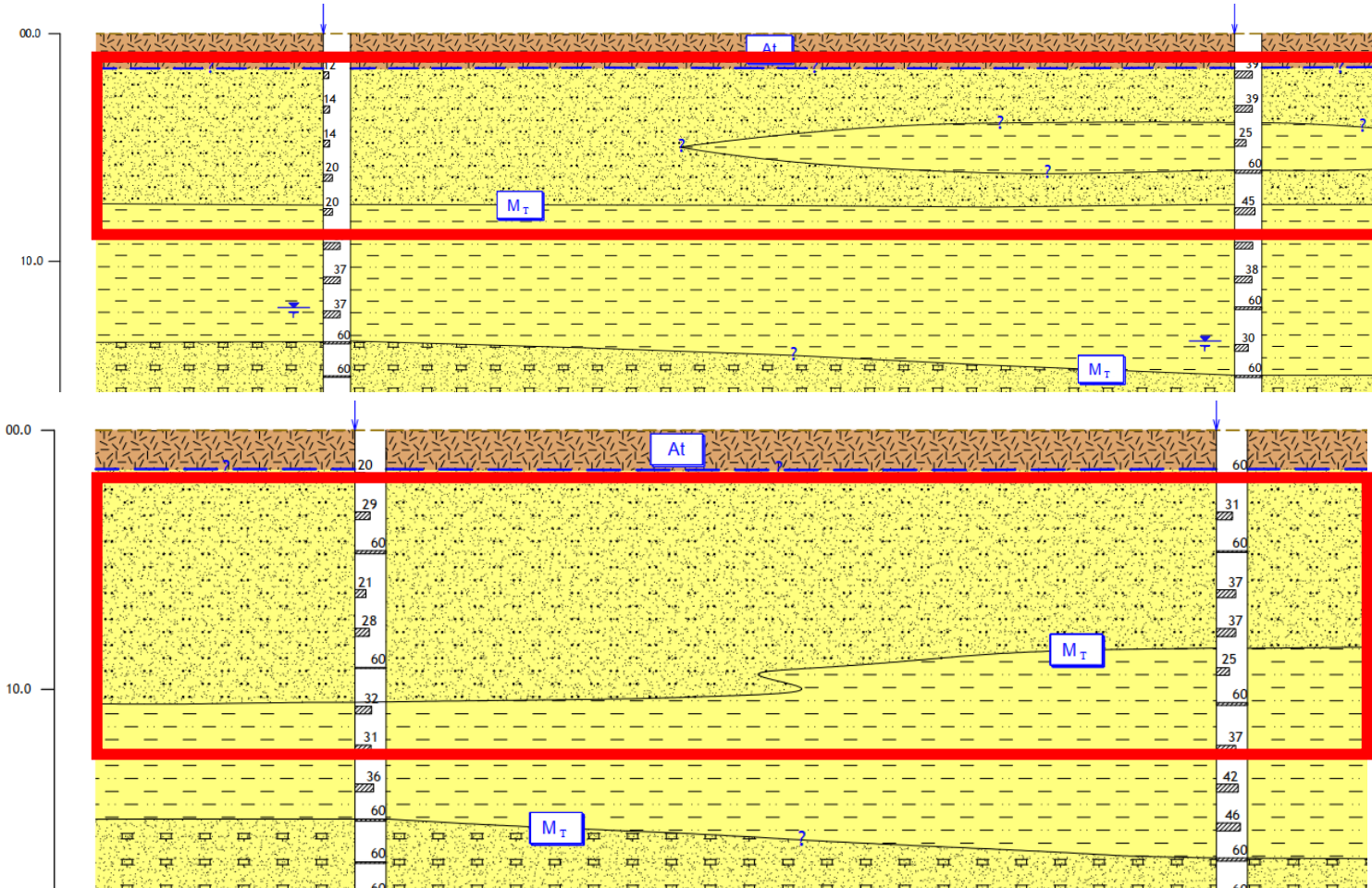


Lot 2 North side



**JET**<sub>SJ</sub>

## → Main Constrains



### RECENTE

**At** Depósitos de aterro

Aterro heterogêneo associando restos líticos e cerâmicos em matriz silto-areno-argilosa

### MIOCÊNICO

**M<sub>T</sub>** Sequência deposicional T "Mt"

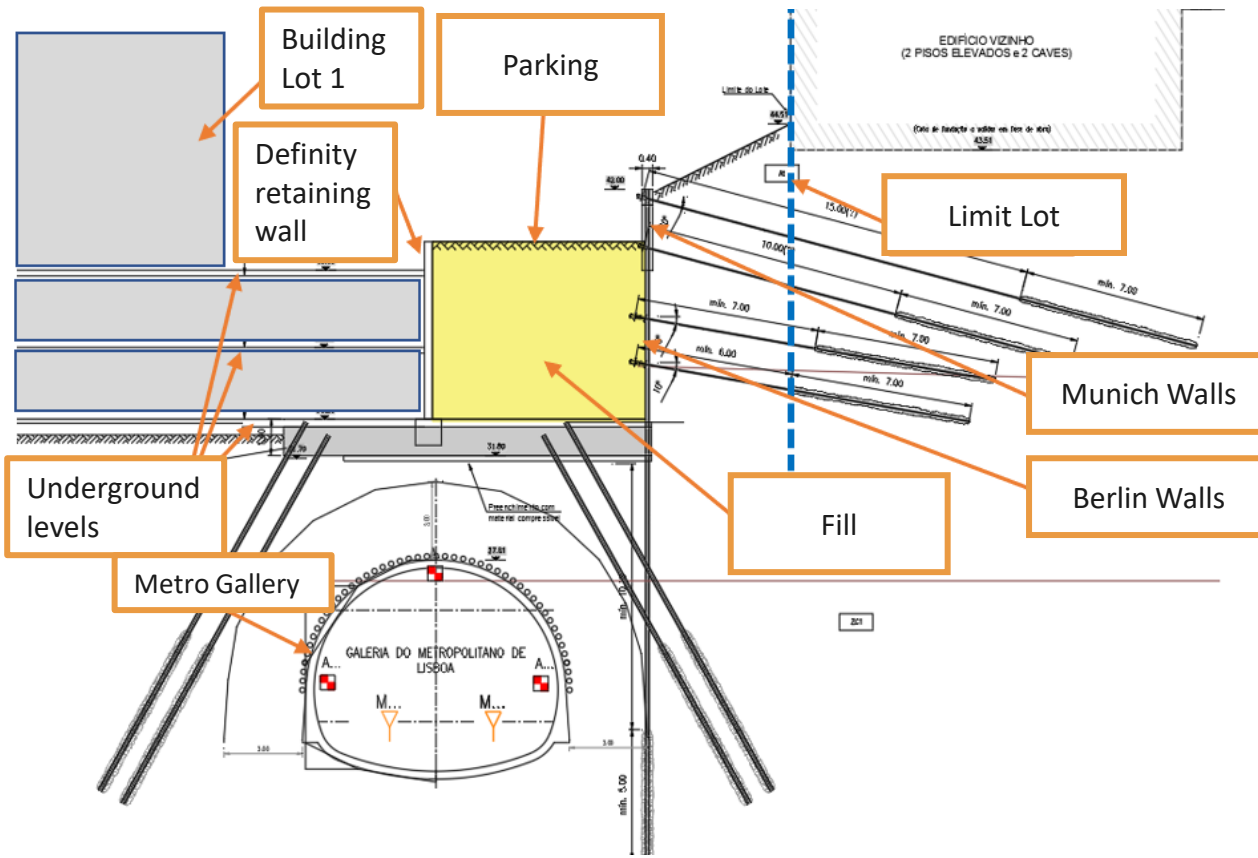
Silte fortemente arenoso (areolas), por vezes com níveis de argila siltosa

Argila fortemente siltosa com níveis associando restos coníferos frequentes e por vezes com pequenas concreções greso-carbonatadas

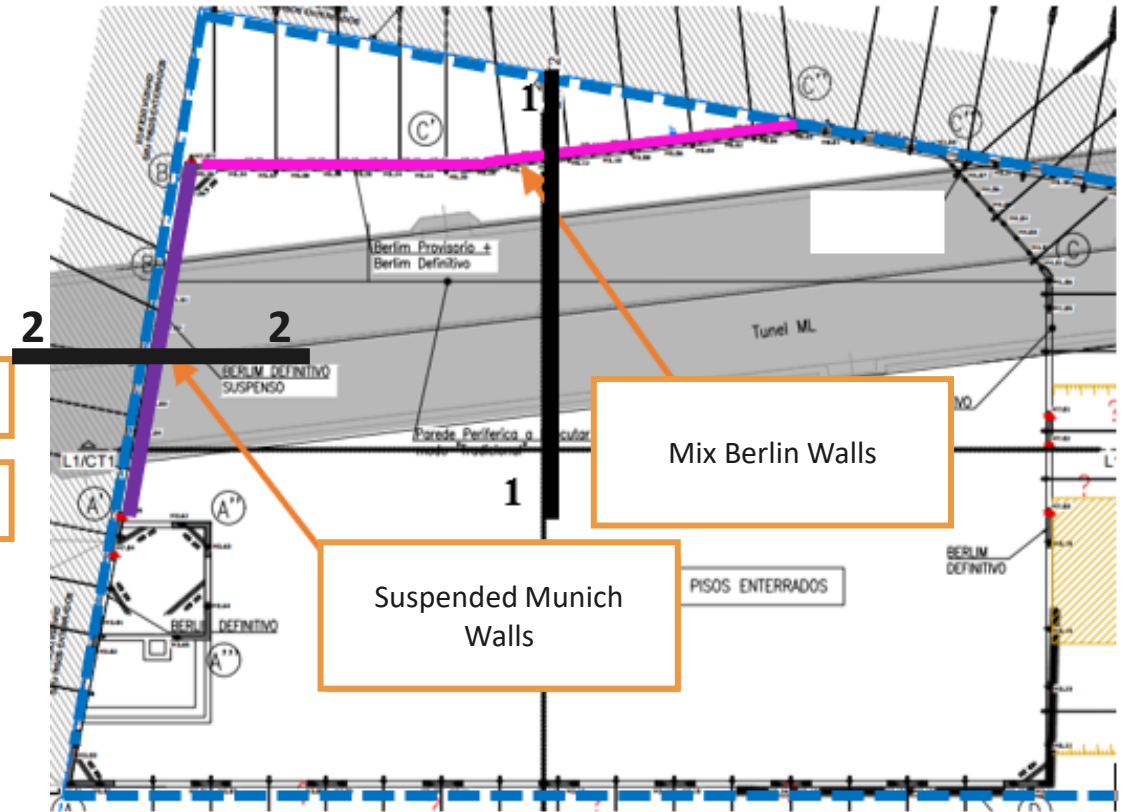
Areia levemente siltosa com níveis de cascão greso-carbonatado

## → Solutions – Lot 1

- Suspended Munich Walls;
- Mix Berlin Walls (top area with Munich walls, bottom area with Berlin Walls)

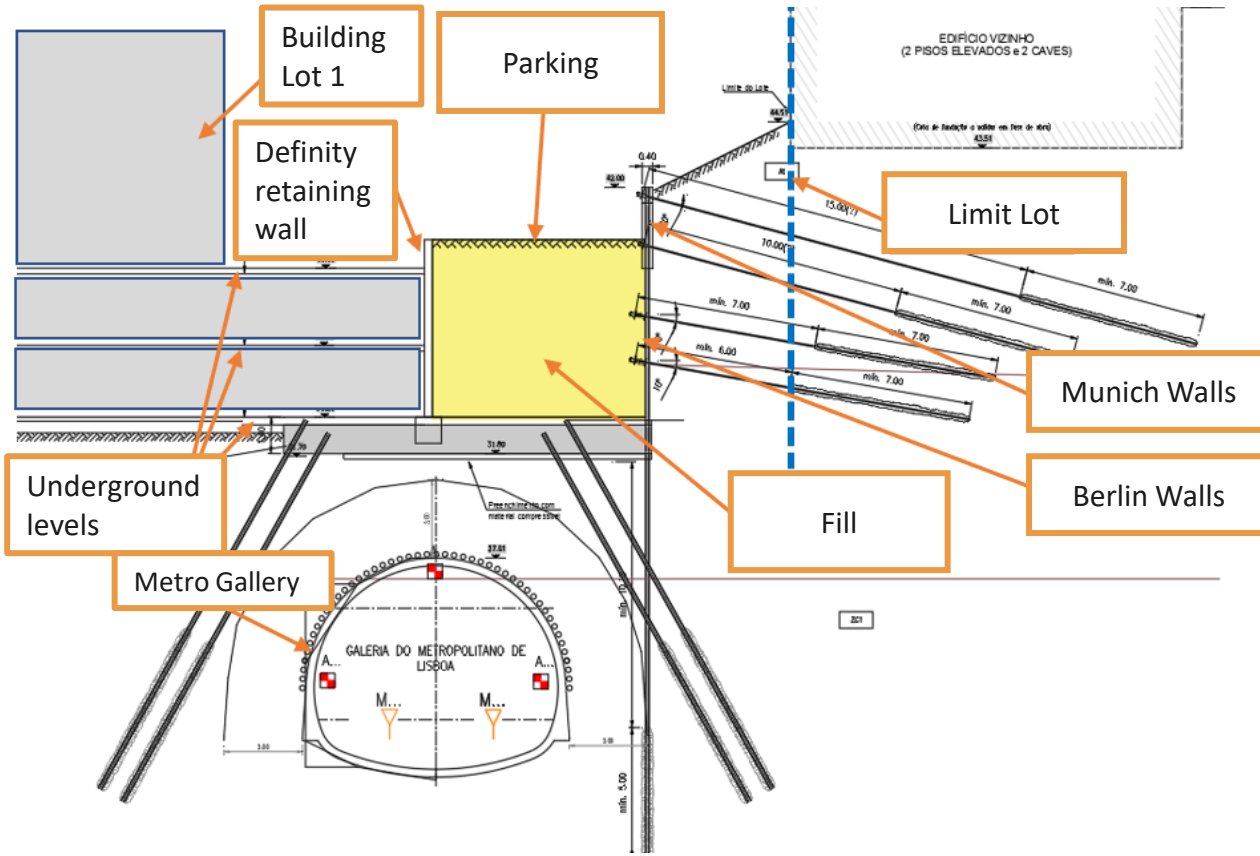


1-1



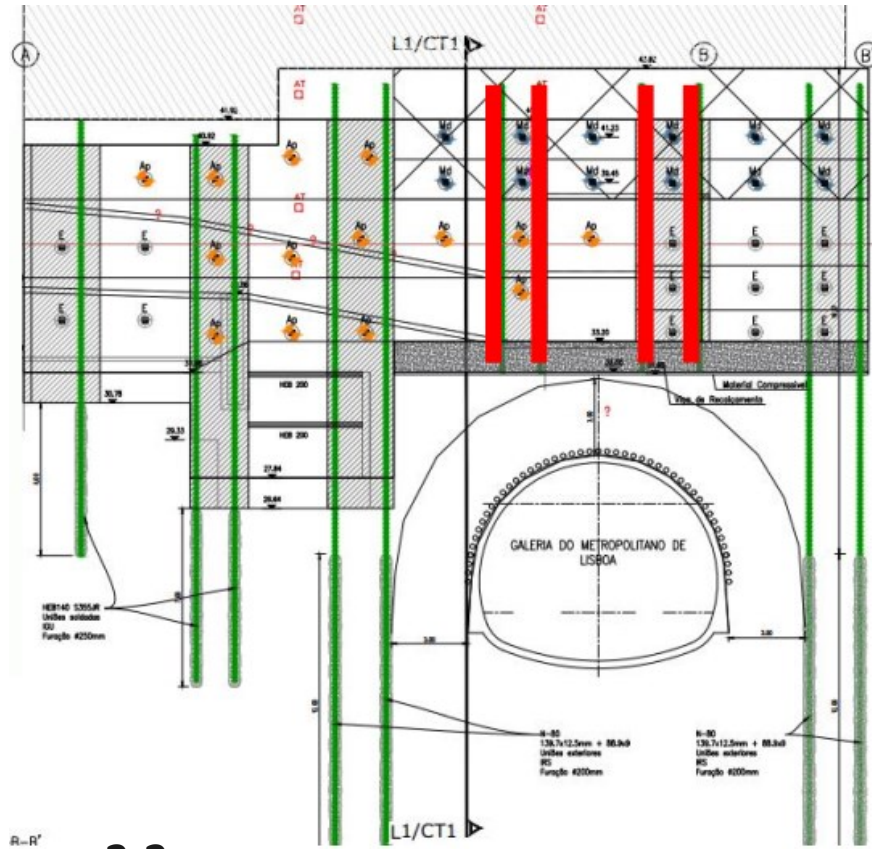
## → Solutions – Lot 1

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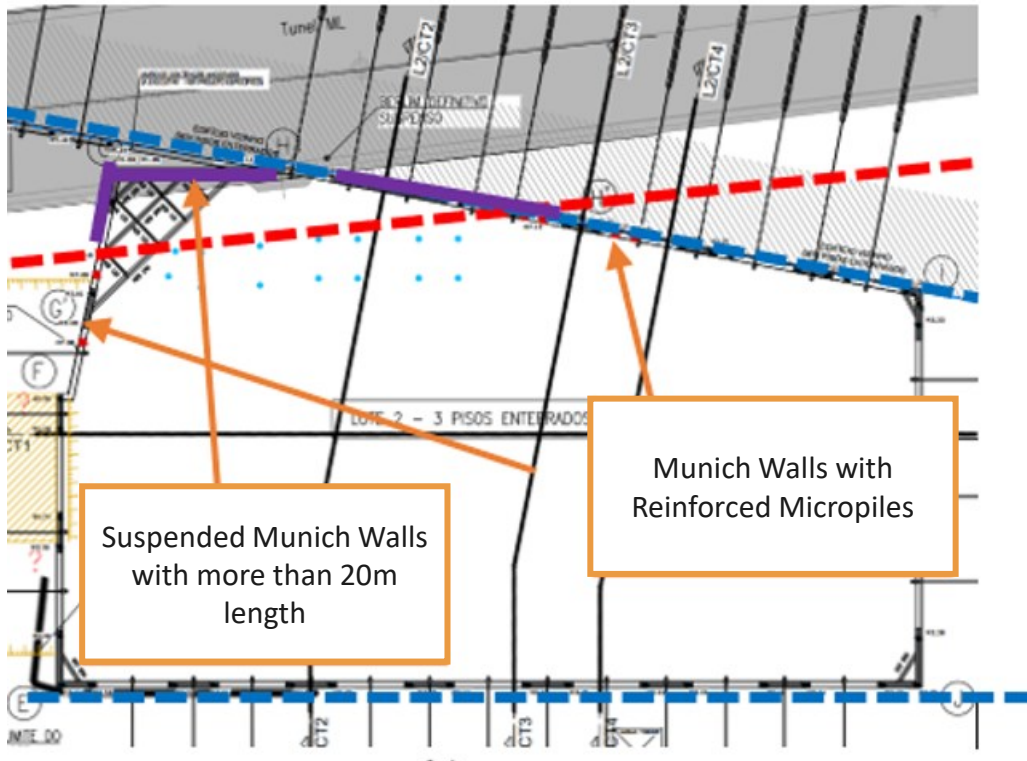


2-2



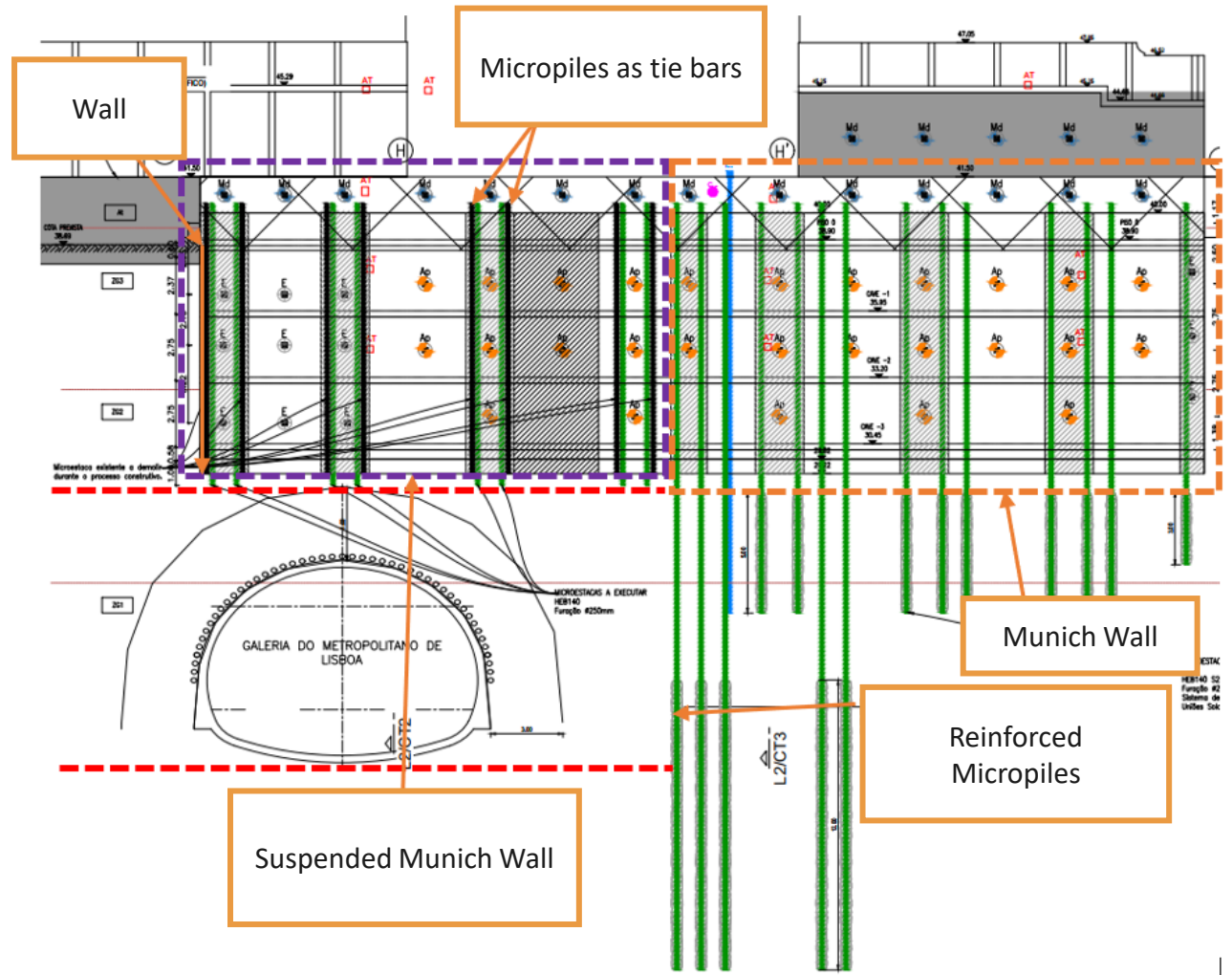
## → Solutions – Lot 2

### – Suspended Munich Walls



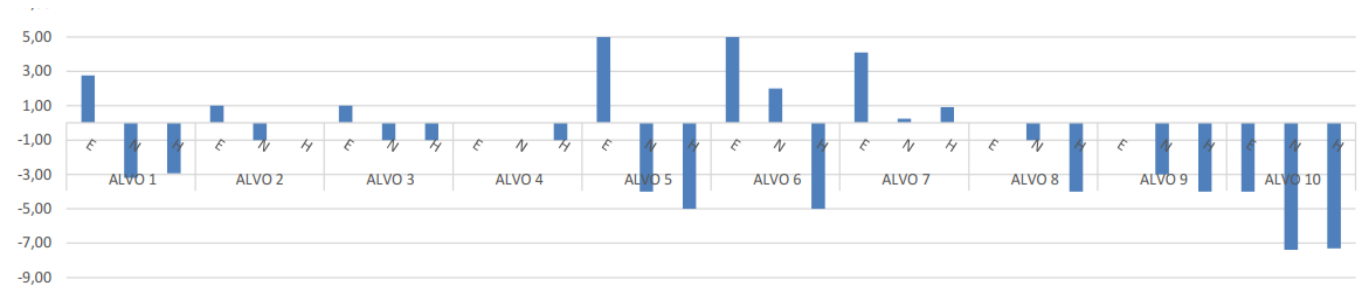
## → Solutions – Lot 2

### – Suspended Munich Walls

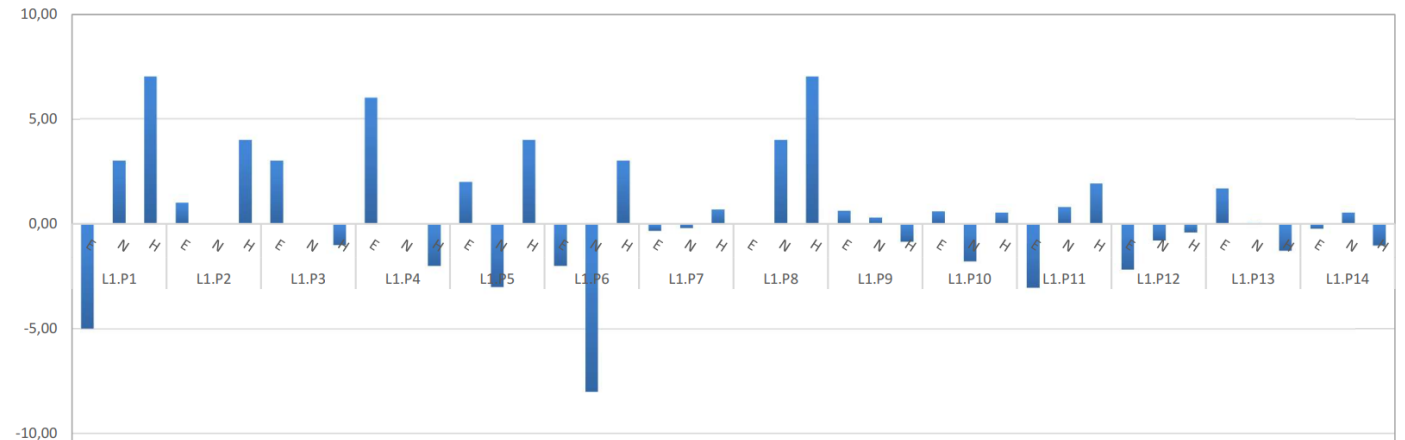


## → Monitoring and Observation Plan

- Topographic Targets on Existing Buildings;
- Topographic Targets on Retaining Walls;
- Topographic Targets on Metro Gallery;
- Topographic Marks on Metro Ralls;
- Piezometers;
- Load Cells;



Deformation on existing buildings (mm)



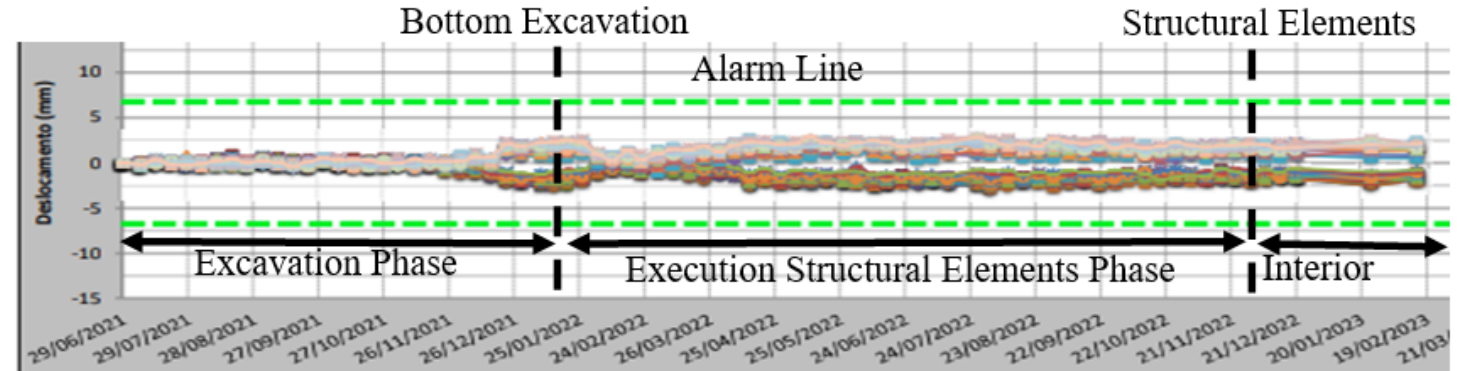
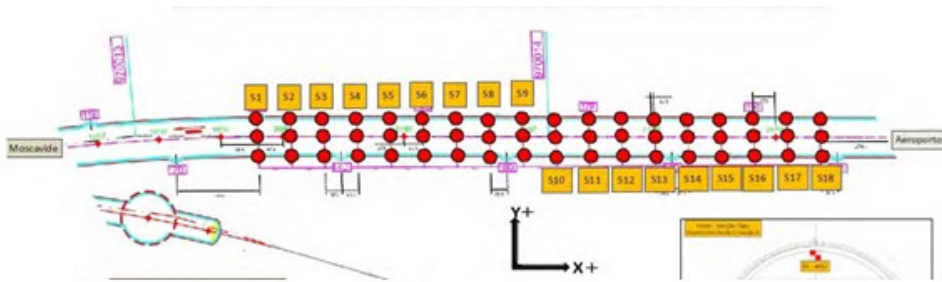
Deformation on Peripheral Retaining Walls – Lot 1 (mm)



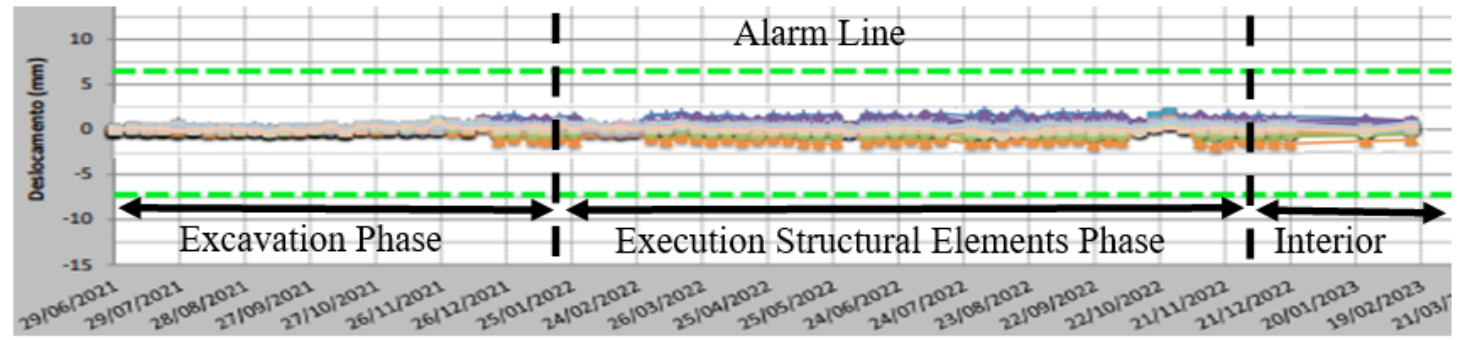
Deformation on Peripheral Retaining Walls – Lot 2 (mm)

## → Monitoring and Observation Plan

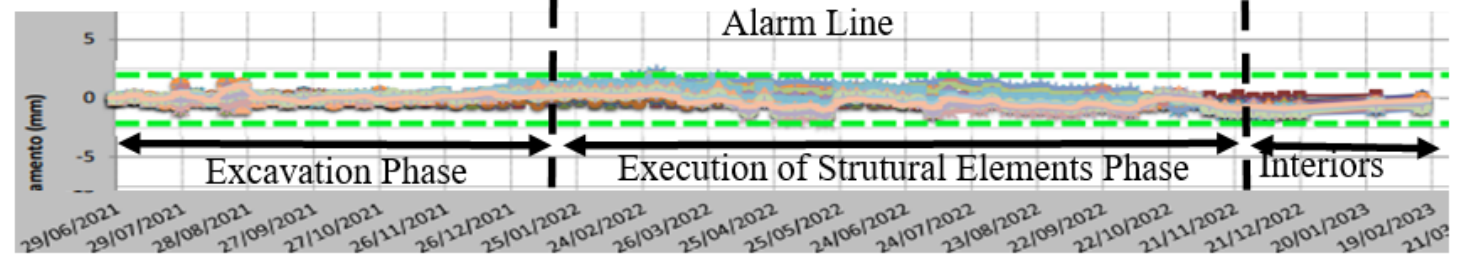
- Topographic Targets on Existing Buildings;
- Topographic Targets on Retaining Walls;
- Topographic Targets on Metro Gallery;
- Topographic Marks on Metro Rails;
- Piezometers;
- Load Cells;



Deformation on Topographic targets (xx – mm)



Deformation on Topographic targets (yy – mm)



Deformation on Topographic targets on Rails (zz – mm)

## → Conclusion

- Monitoring and Observation Plan is a critical tool;
- Coordination between promoters, contractors and design team is key to success;





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**Thank you for your attention!**

# Deep excavation solutions in an urban environment - Distrikt residential project, Lisbon

**J. Silva**/ Jetsj – Geotecnia, Lda. / Portugal

**I. Braz** / Jetsj – Geotecnia, Lda. / Portugal

**A. Pinto**/ Jetsj – Geotecnia, Lda. / Portugal



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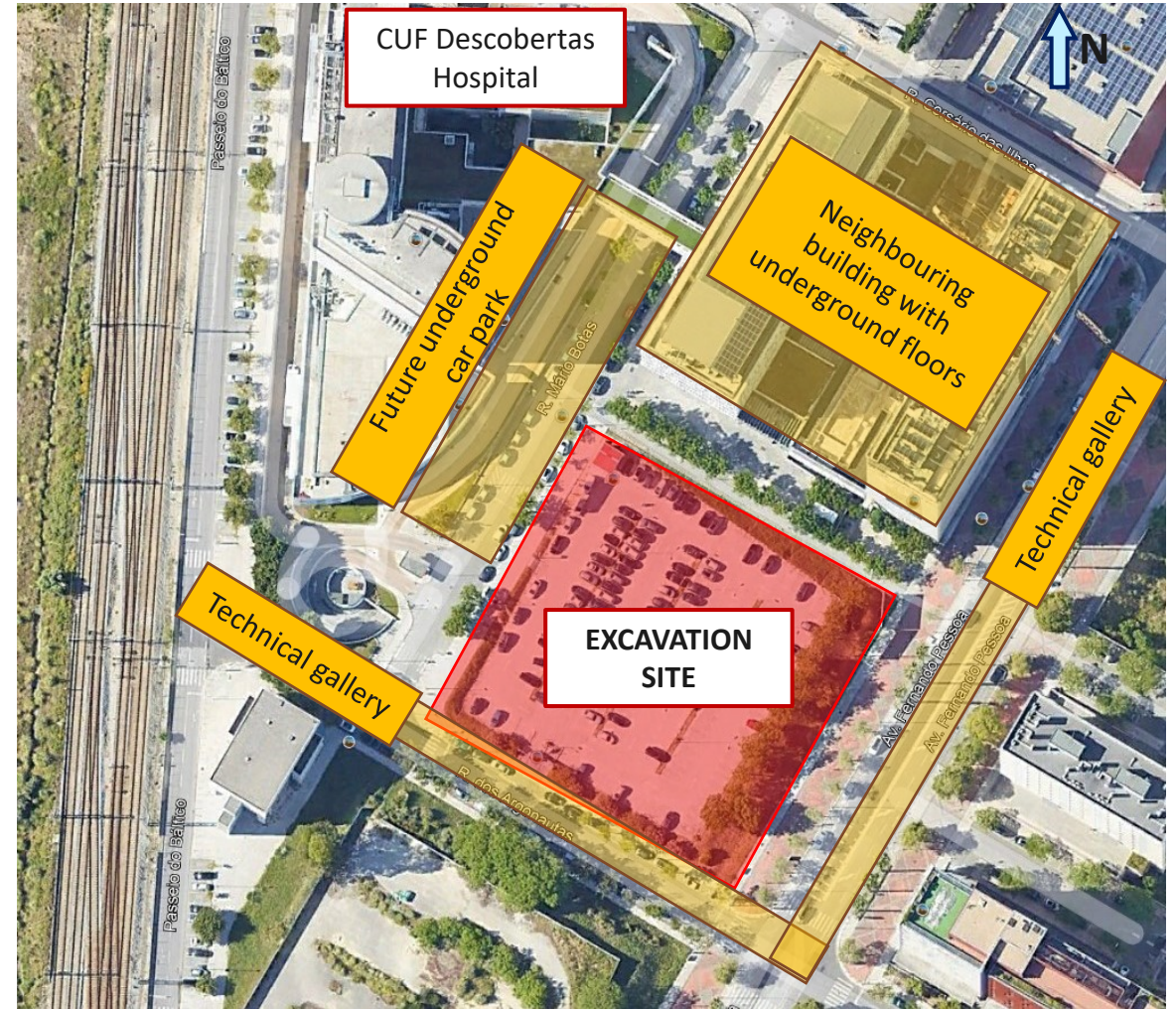
- **Introduction**
- Main constraints
- Excavation and peripheral earth retaining solutions
- Numerical Analyses
- Monitoring and survey plan
- Conclusion



## → Introduction

### DISTRIKT DEVELOPMENT PROJECT

- Location: Parque das Nações, Lisbon
- Total plot area: 5945 m<sup>2</sup>
- Development project: 4 towers with 13 elevated floors and 3 underground floors



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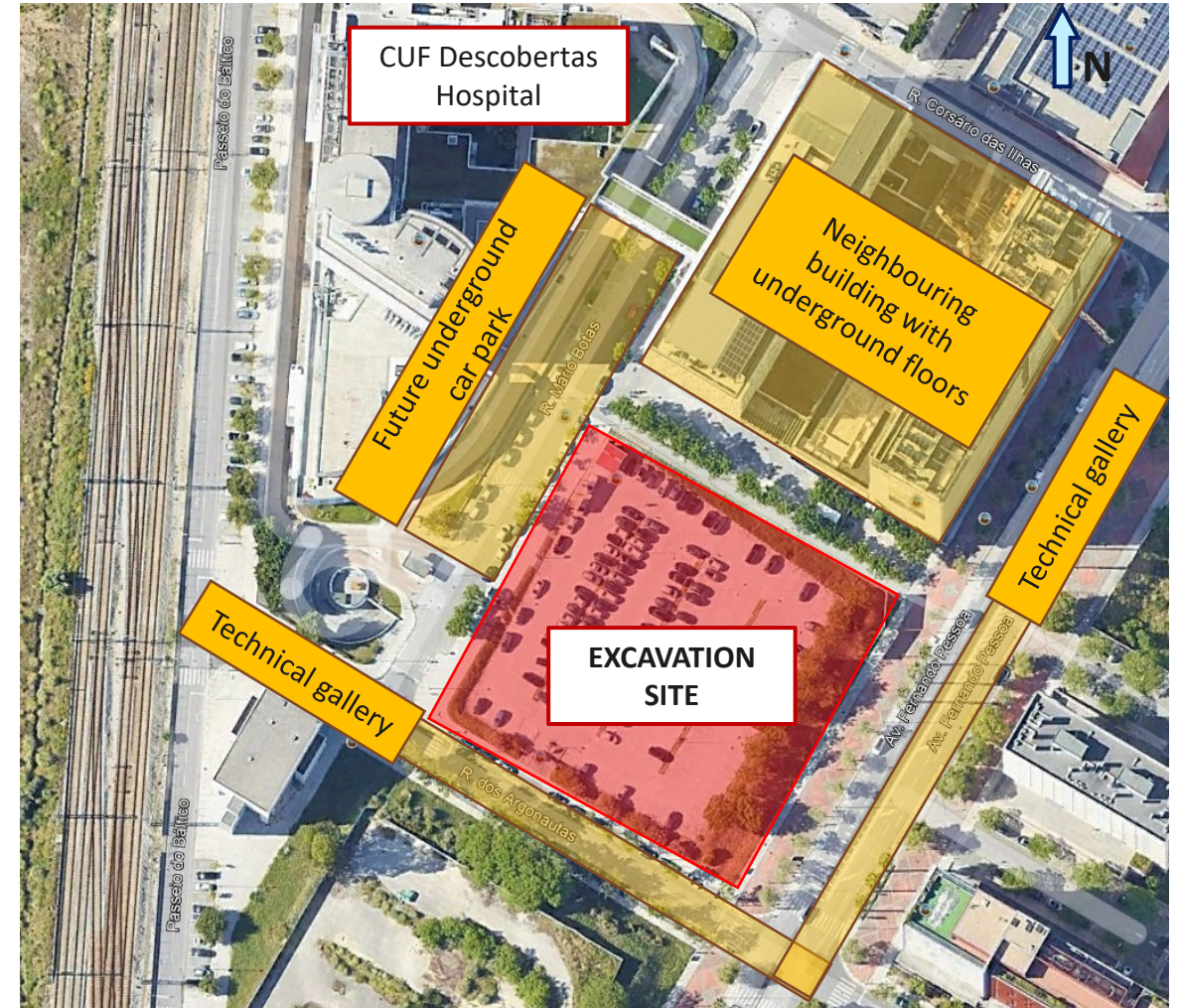
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## → Main constraints

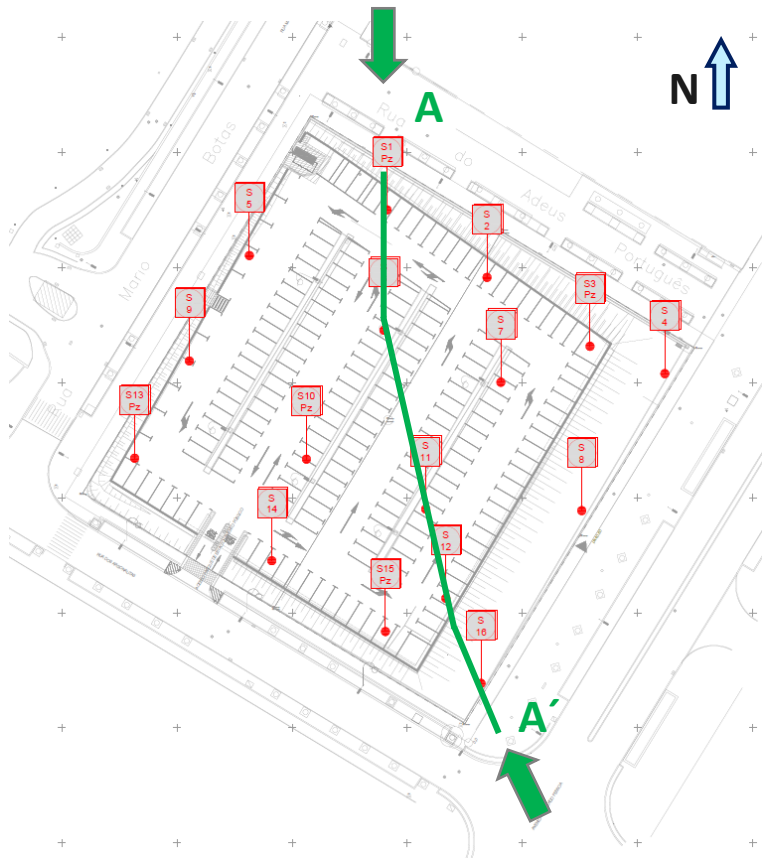
### DISTRIKT ENTERPRISE

- Heavily urbanized area
- Future constructions adjacent to the plot
- Excavation with 11 meters of maximum depth
- Water level located in highly permeable layers
- Total dependence on geological and geotechnical conditions

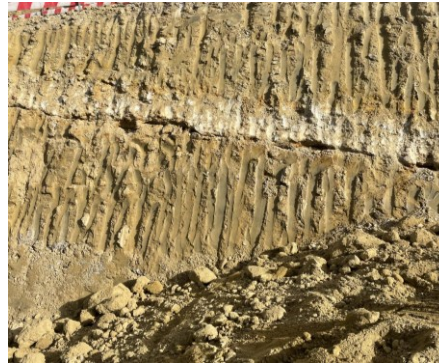
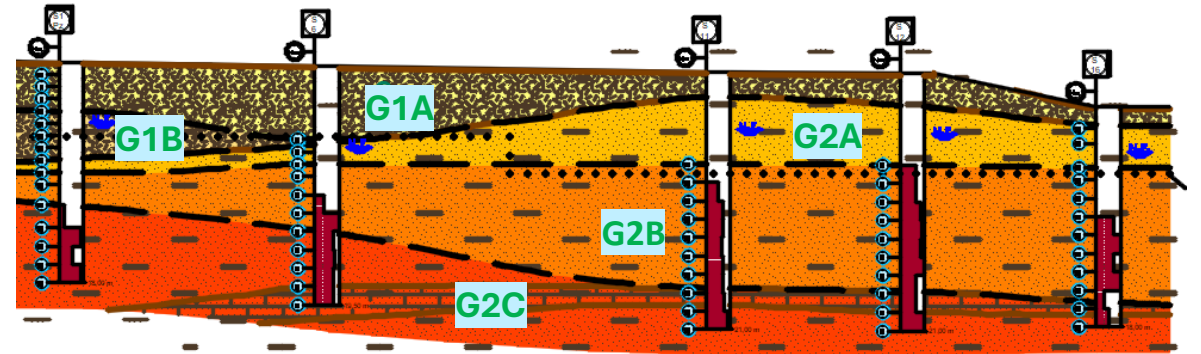


→ Main constraints

**GEOLOGICAL AND GEOTECHNICAL CONDITIONS**



Cross section A-A'



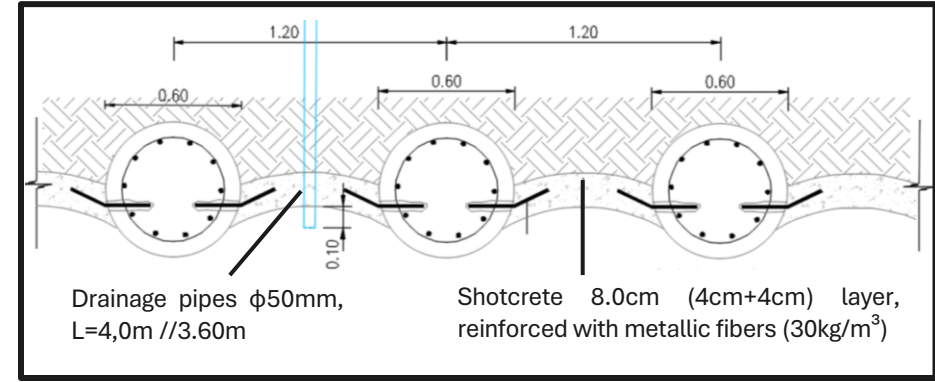
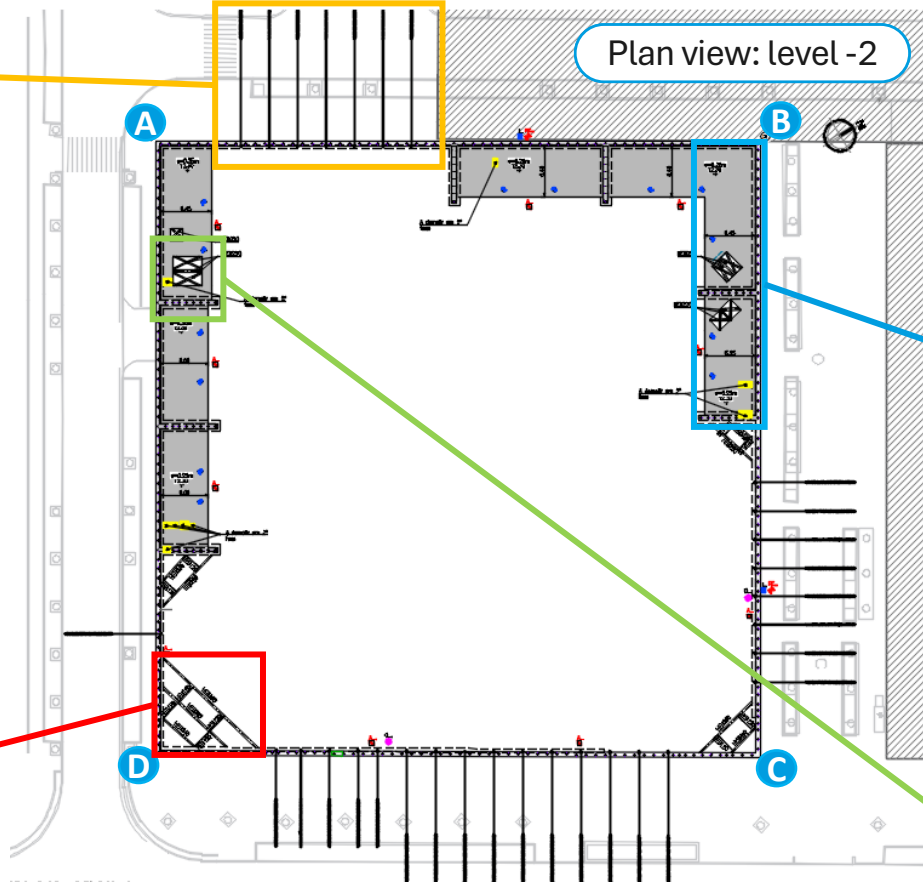
Geotechnical zone	Geology
G1A	Loosely compact sandy-clay landfill
G1B	Moderately compact sandy-clay landfill
G2A	Moderately compact sandy-silt soil
G2B	Compact sandy-silt soil
G2C	Very compact sandy-silt soil

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- Main constraints
- **Excavation and peripheral earth retaining solutions**
- Numerical Analyses
- Monitoring and survey plan
- Conclusion



## → Excavation and peripheral earth retaining solutions



## → Excavation and peripheral earth retaining solutions



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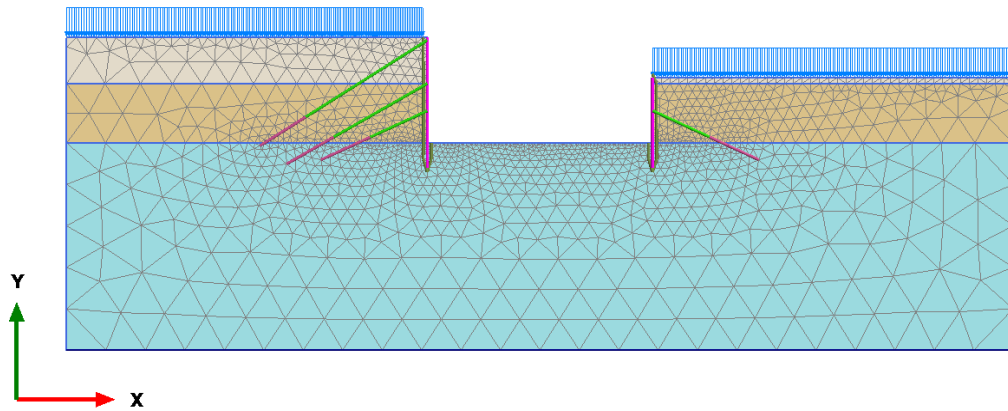
- Introduction
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- Excavation and peripheral earth retaining solutions
- **Numerical Analyses**
- Monitoring and survey plan
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## → Numerical Analyses

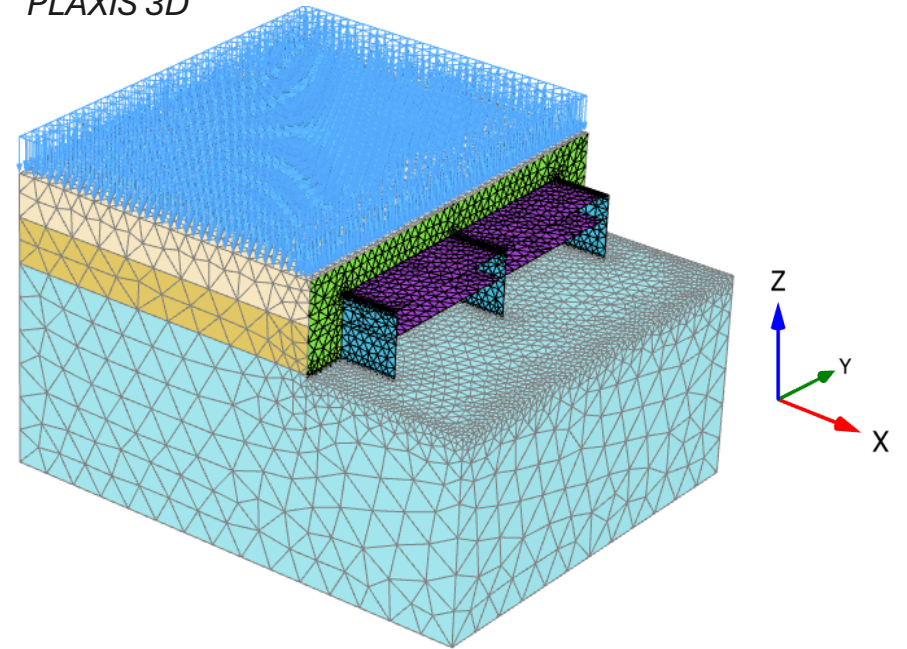
### FINITE ELEMENT ANALYSIS SOFTWARES

*PLAXIS 2D*



+

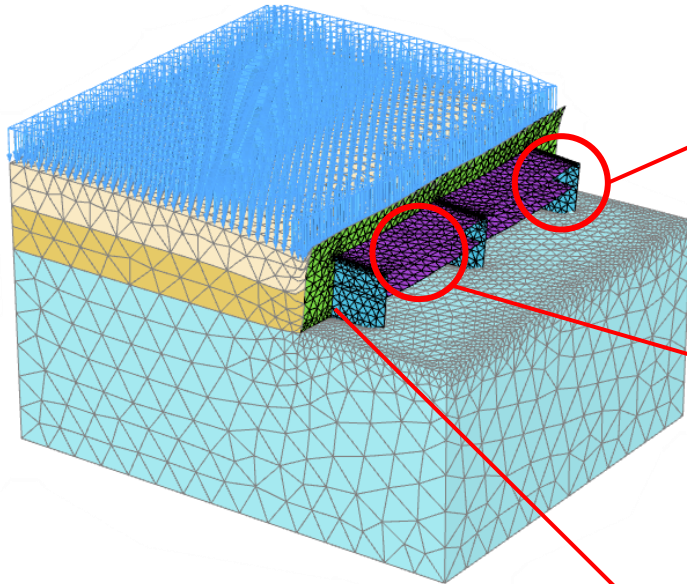
*PLAXIS 3D*



## → Numerical Analyses

### FORCES AND DEFORMATIONS

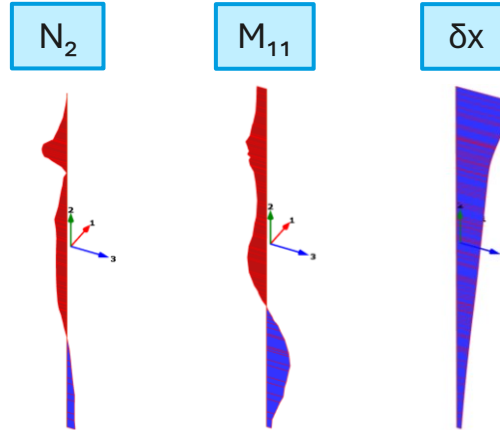
PLAXIS 3D



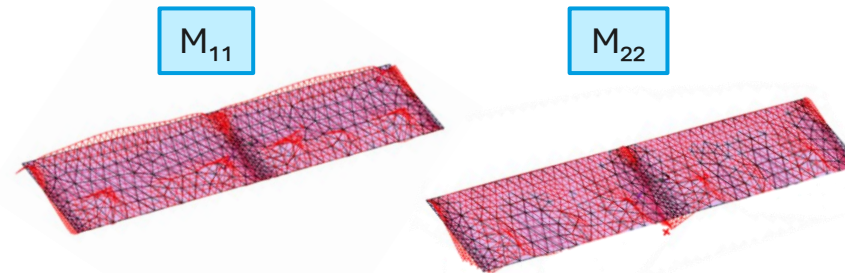
**Buttresses**

**Slab bands**

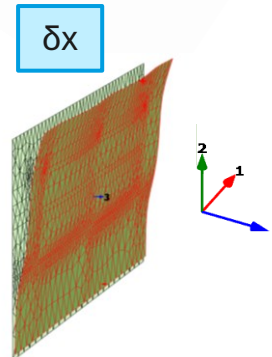
**Curtain Wall**



$N_2$ [KN/m]	$M_{11}$ [KNm/m]	$\delta x$ [mm]
-221,0	209,1 -183,6	50,30



$M_{11}$ [KNm/m]	$M_{22}$ [KNm/m]
22,81 -53,49	70,36 -68,37



$\delta x$ [mm]
55,54

# Index

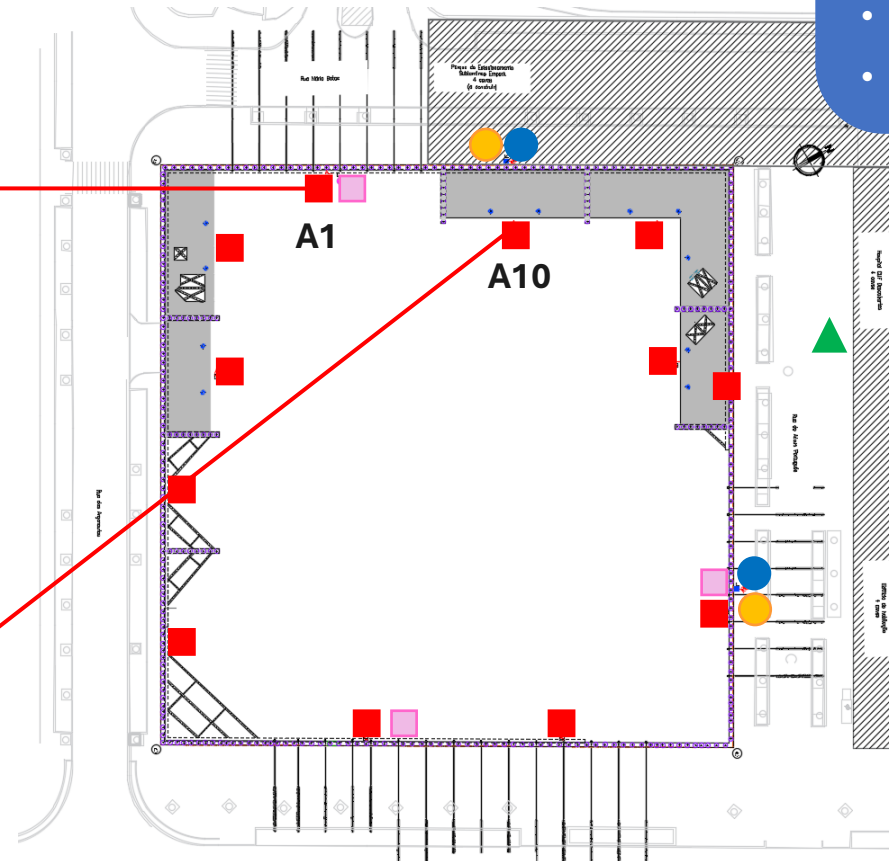
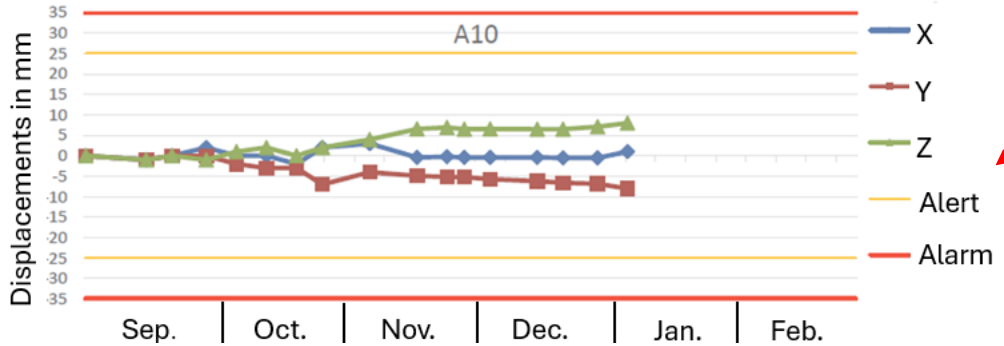
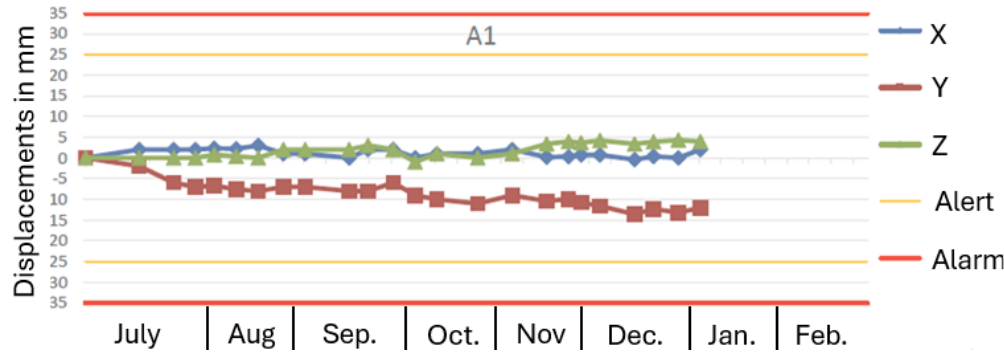
- Introduction
- Main constraints
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- Numerical Analyses
- **Monitoring and survey plan**
- Conclusion



## → Monitoring and survey plan

### MONITORING INSTRUMENTS:

- 27 Topographic targets ■
- 4 Load cells ■
- 2 Inclinometers ●
- 2 Piezometers ○
- 1 Seismograph ▲



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- Introduction
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- Excavation and peripheral earth retaining solutions
- Numerical Analyses
- Monitoring and survey plan
- **Conclusions**



## → Conclusion

### FINAL REMARKS

- Technical efficiency of the implemented peripheral earth retaining solutions
- Economic efficiency achieved by using slab bands
- The observed displacements of the adopted solutions were less pronounced than those estimated in project





**Thank you for your attention!**

Acknowledgements:



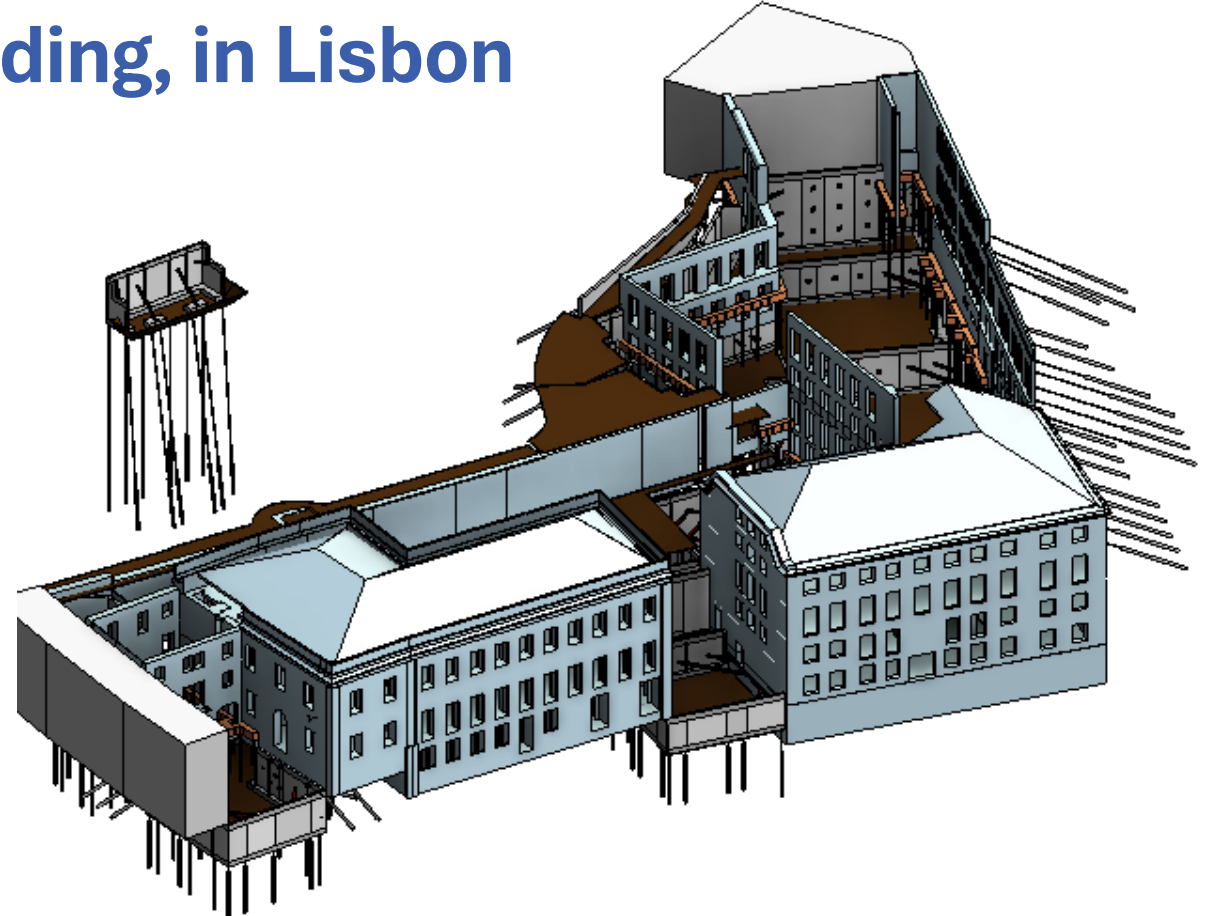
# Earth retaining solutions and facade underpinning for the refurbishment of a historic building, in Lisbon

**Inês Braz/** JETsj Geotecnia Lda.

**Alexandre Pinto/** JETsj Geotecnia Lda.

**David Henriques/** PPE – Planeamento e Projetos de Engenharia Lda.

**Rogério Santos/** PPE – Planeamento e Projetos de Engenharia Lda.



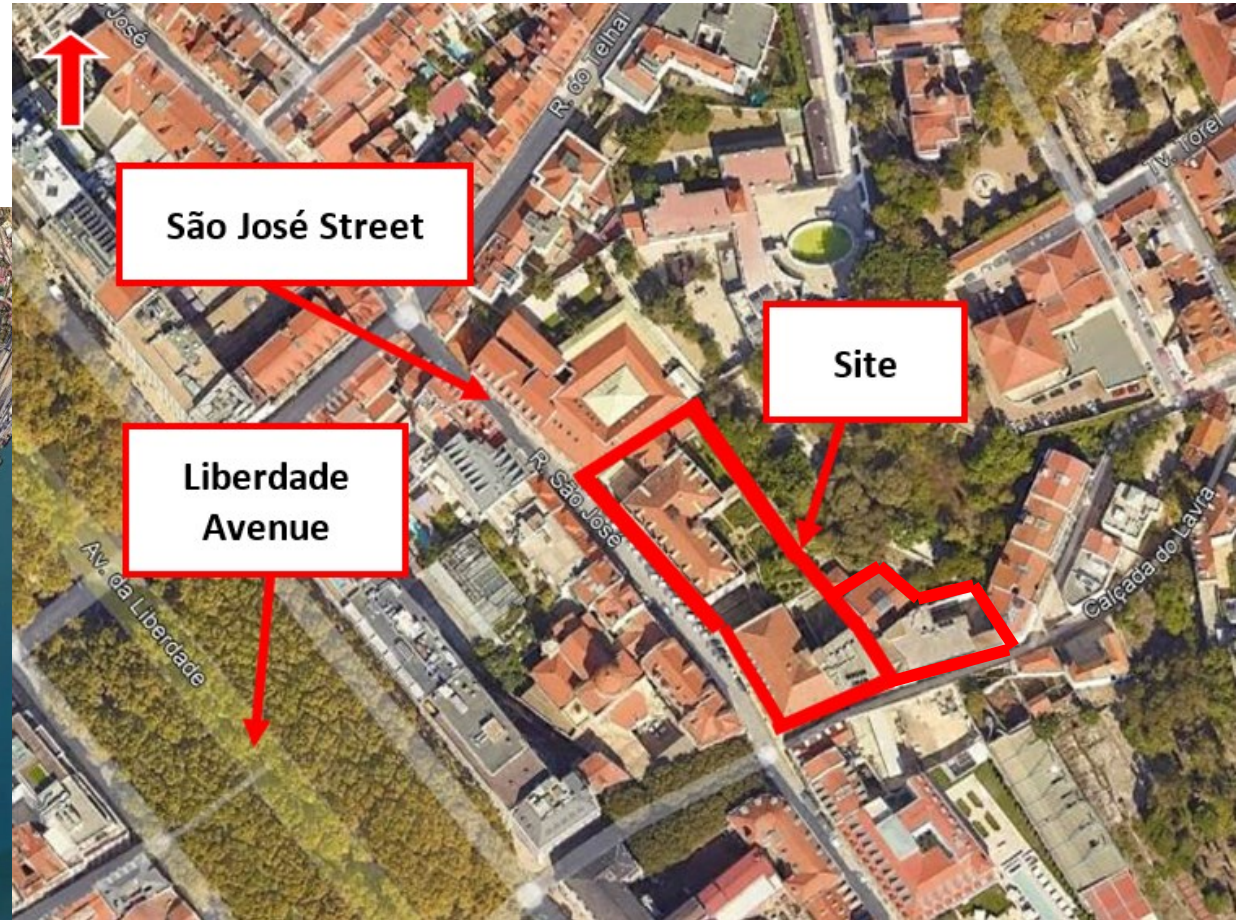
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- Design
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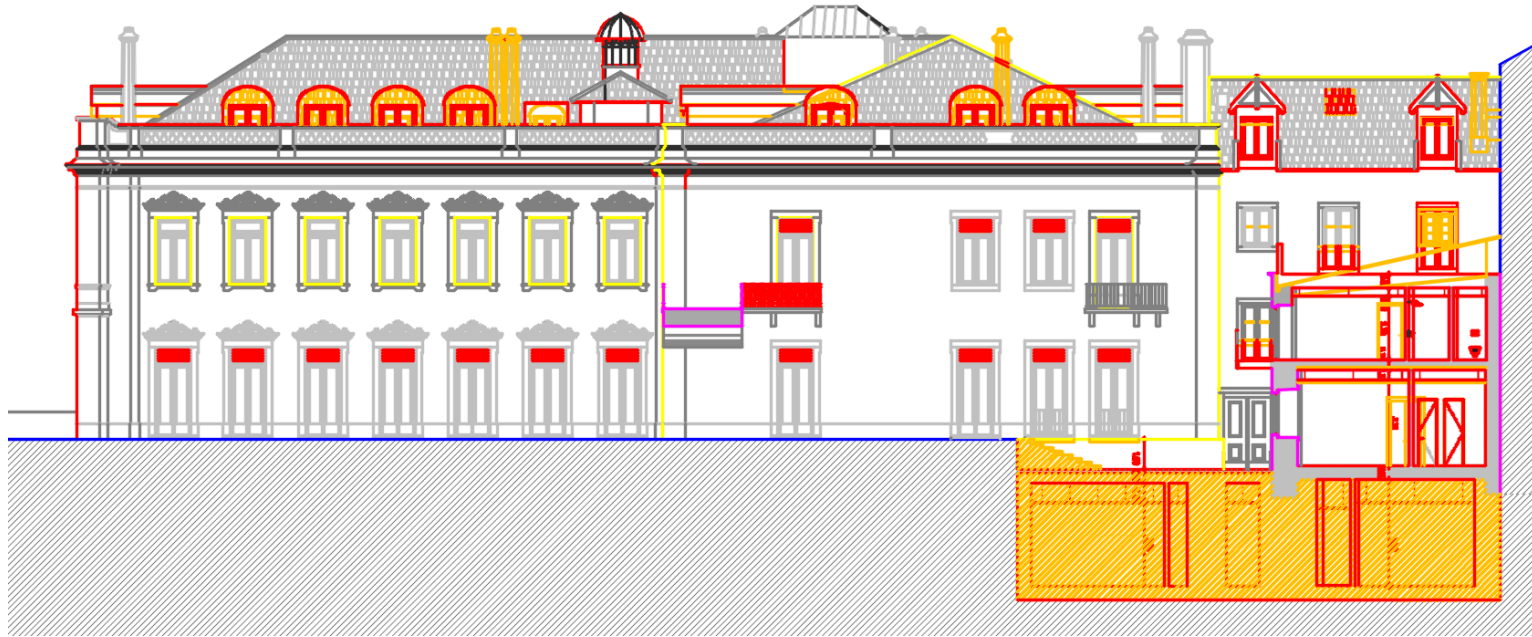


## → Introduction

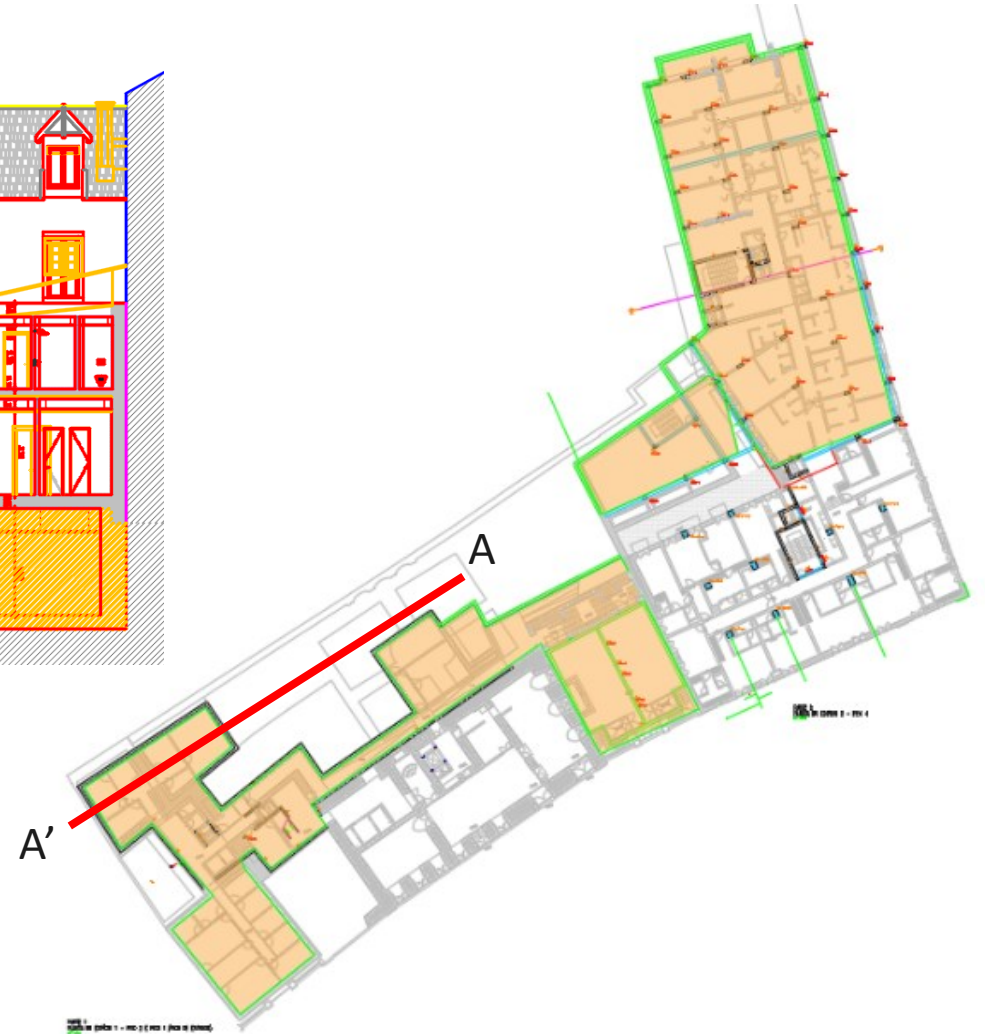
### Location



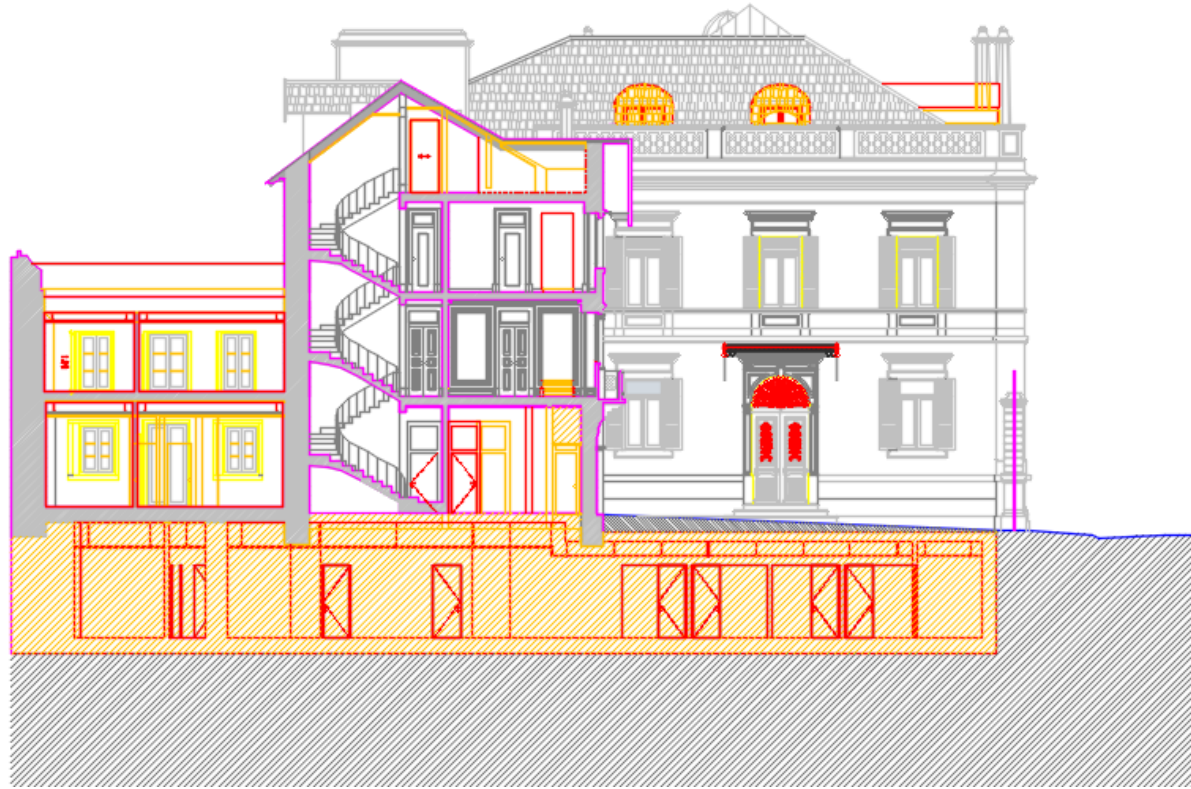
# → Introduction



Cross section AA'



# → Introduction



Cross section BB'



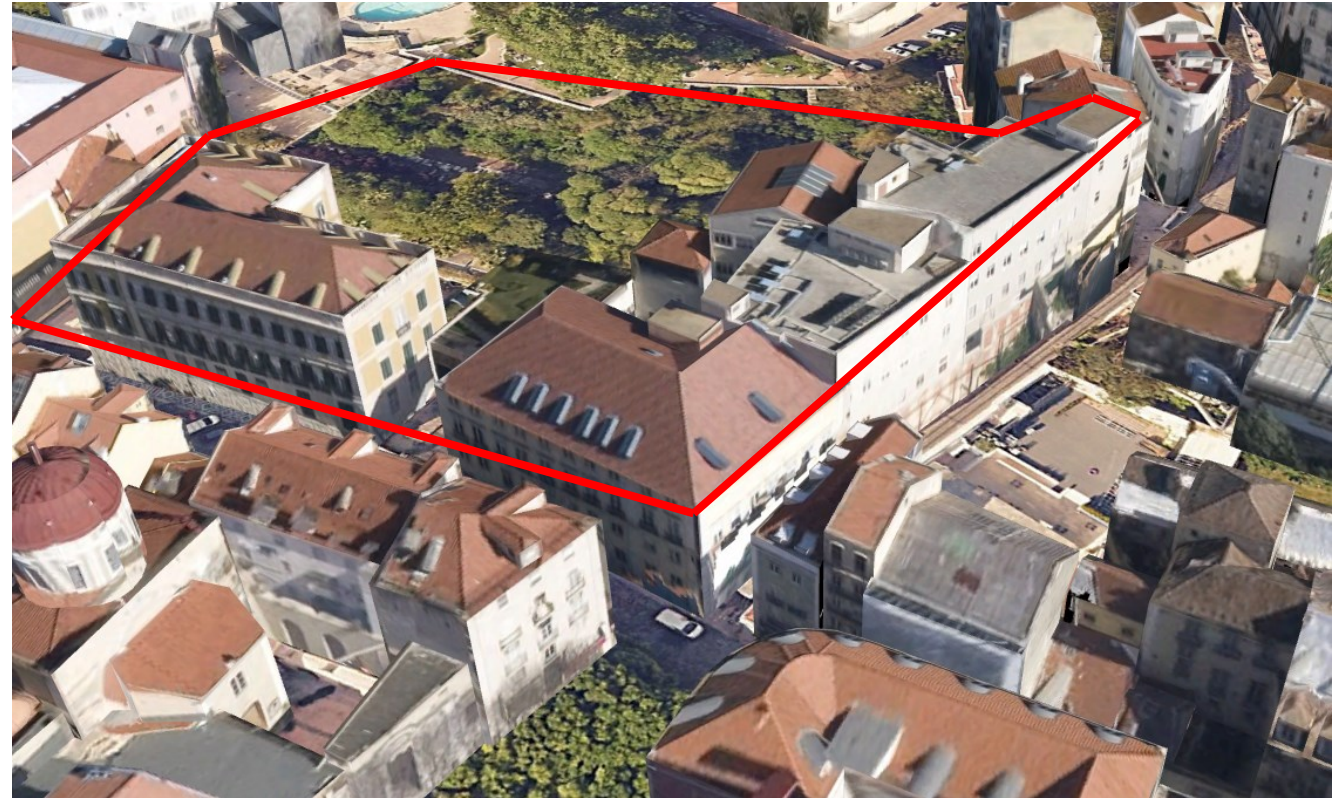
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## → Main constraints

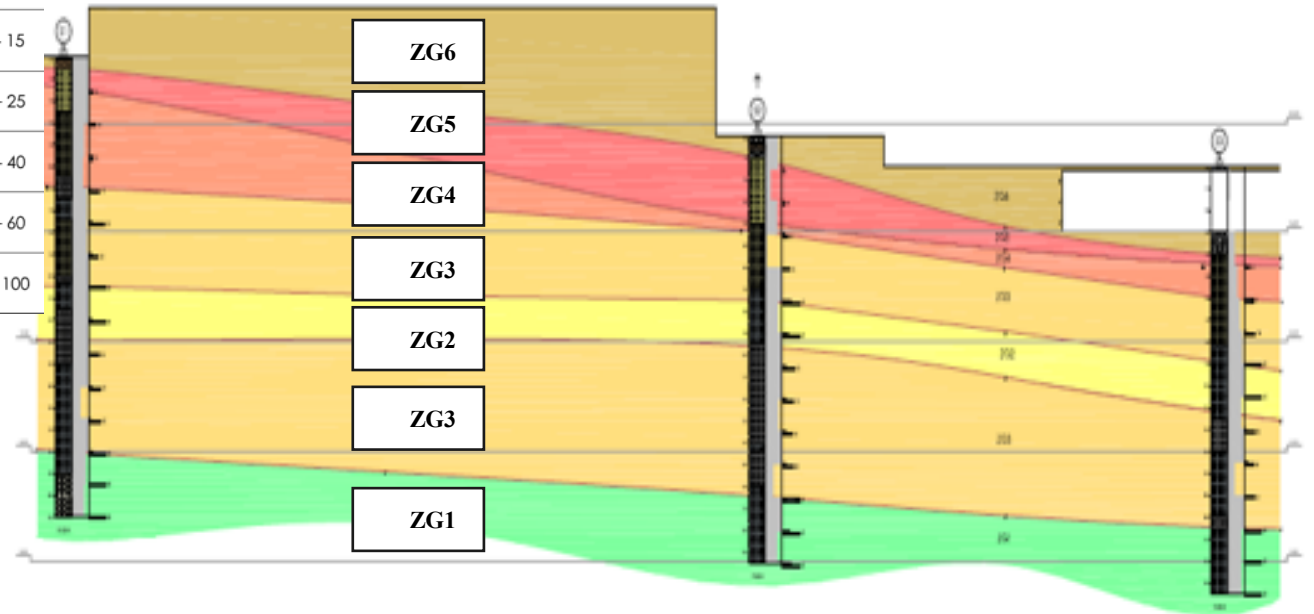
- Constraints related to the building's boundaries



## → Main constraints

### — Geological and geotechnical constraints

Geotechnical zone	N <sub>SPT</sub>	Lithology	$\phi'$ (°)	C' (kPa)	$\gamma$ (kN/m <sup>3</sup> )	E' (MPa)
ZG6	-	Silt-sandy embankments with masonry fragments, all-in-one, concrete, and pavements	5 - 10	-	16 - 17	5 - 10
ZG5	2 - 9	Clayey silts and silty clays	10 - 15	5 - 15	17 - 18	10 - 15
ZG4	16 - 26 (16 - 18)*	Clayey silts and silty clays	15 - 20	15 - 20	18 - 19	20 - 25
ZG3	21 - 56 (21 - 42)*	Clayey silts and silty clays	20 - 25	20 - 30	19 - 20	30 - 40
ZG2	>60	Clayey silts and silty clays	25 - 30	40 - 60	20 - 21	50 - 60
ZG1	>60	Clayey silts, silty clays, calcareous marts/marly limestones	25 - 35	60 - 80	21 - 23	60 - 100



## → Main constraints

- Architecture constraints related to the need to preserve facades



## → Main constraints

- Architecture constraints related to the need to preserve facades



## → Main constraints

- Architecture constraints related to the need to preserve facades



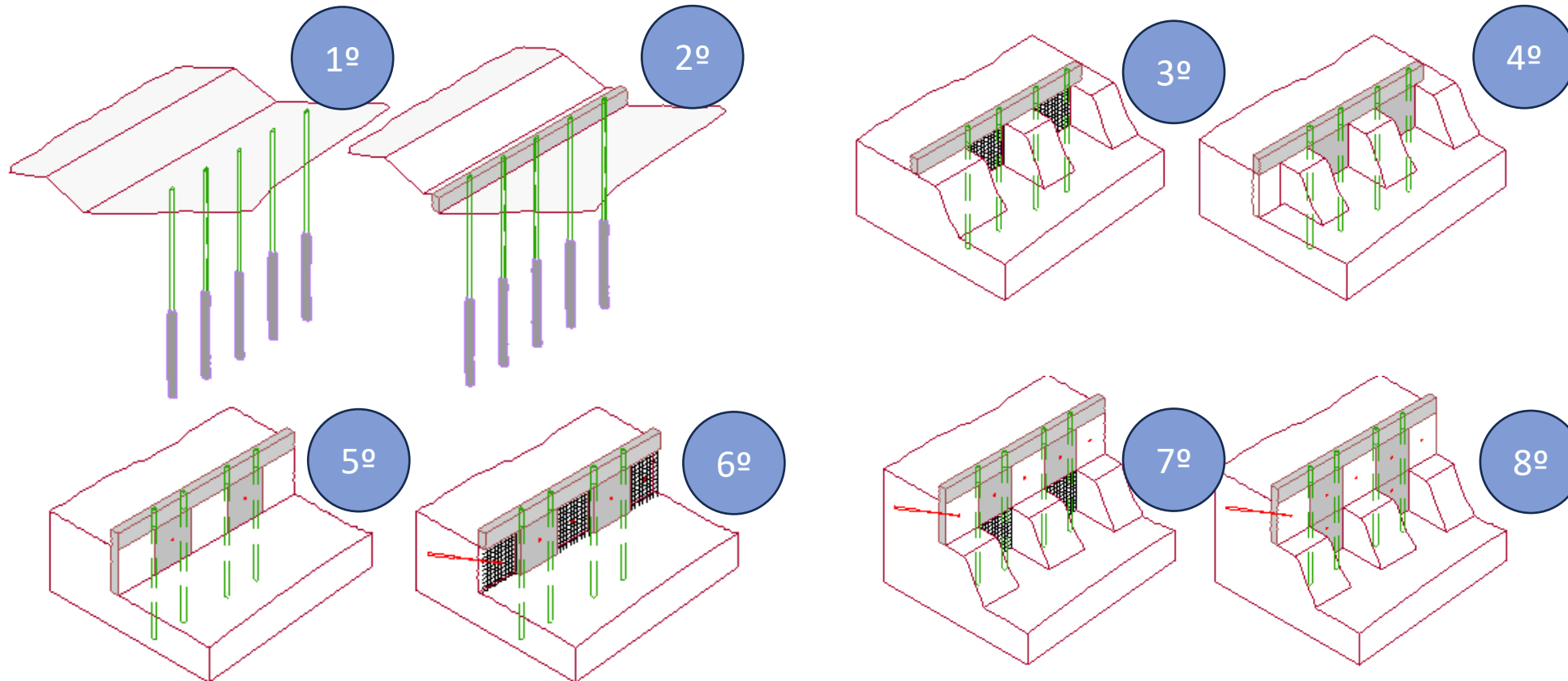
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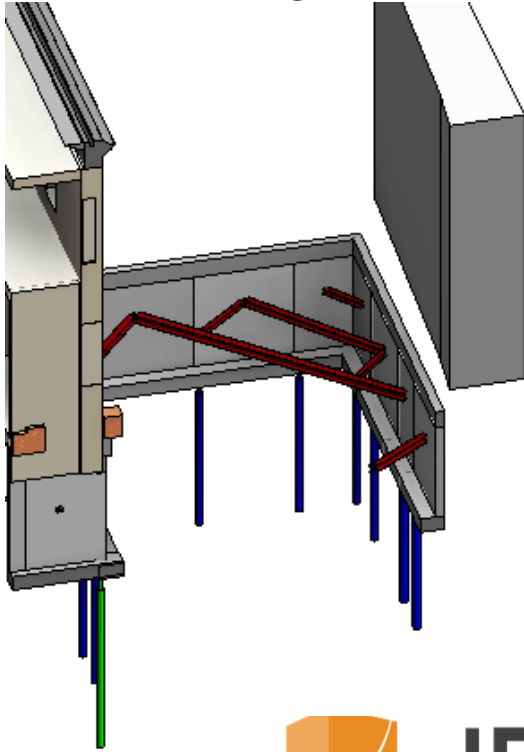
→ Adopted solution

— Retaining wall: King post wall technology



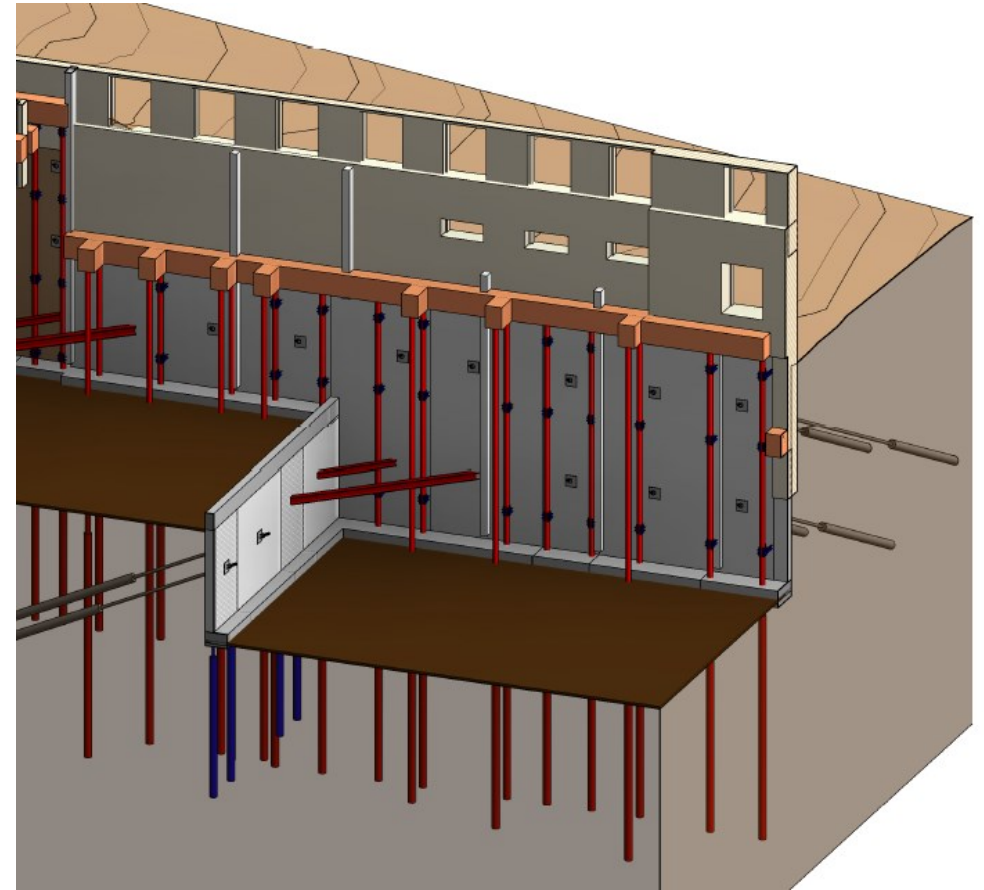
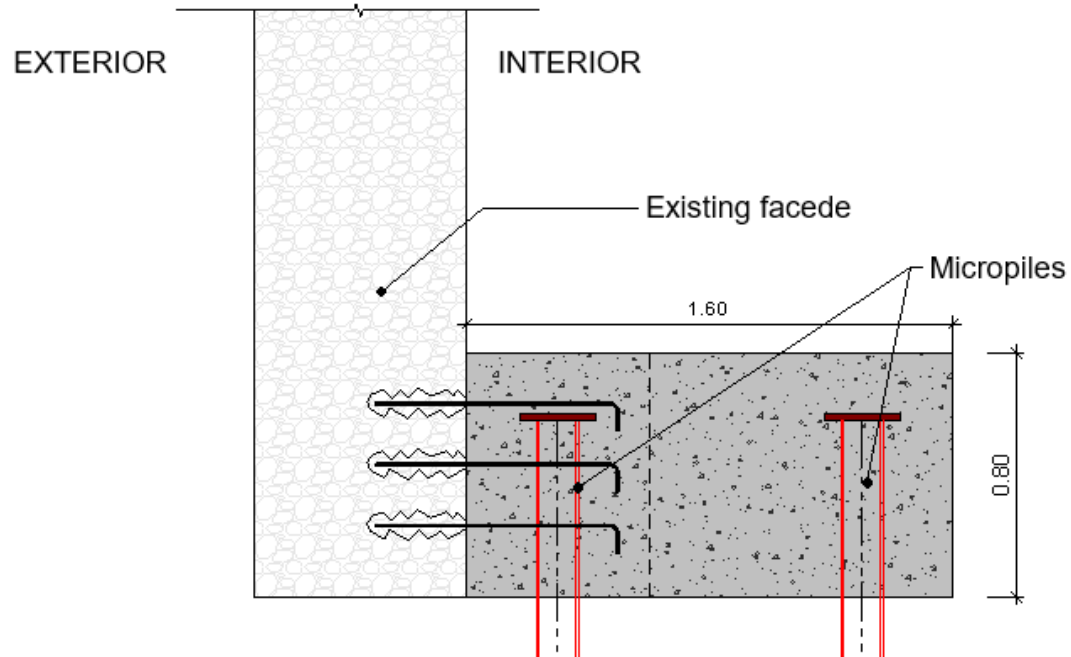
## → Adopted solution

- ❖ Horizontal supports
  - ❖ Anchors
  - ❖ Shoring



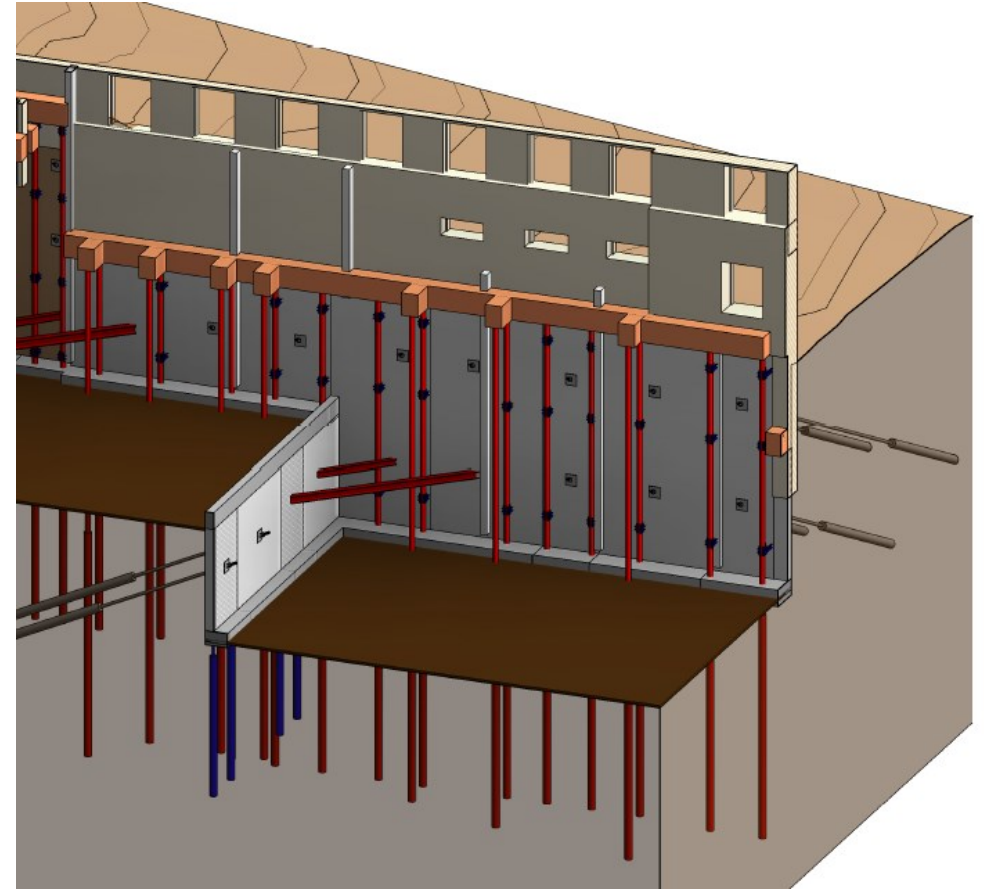
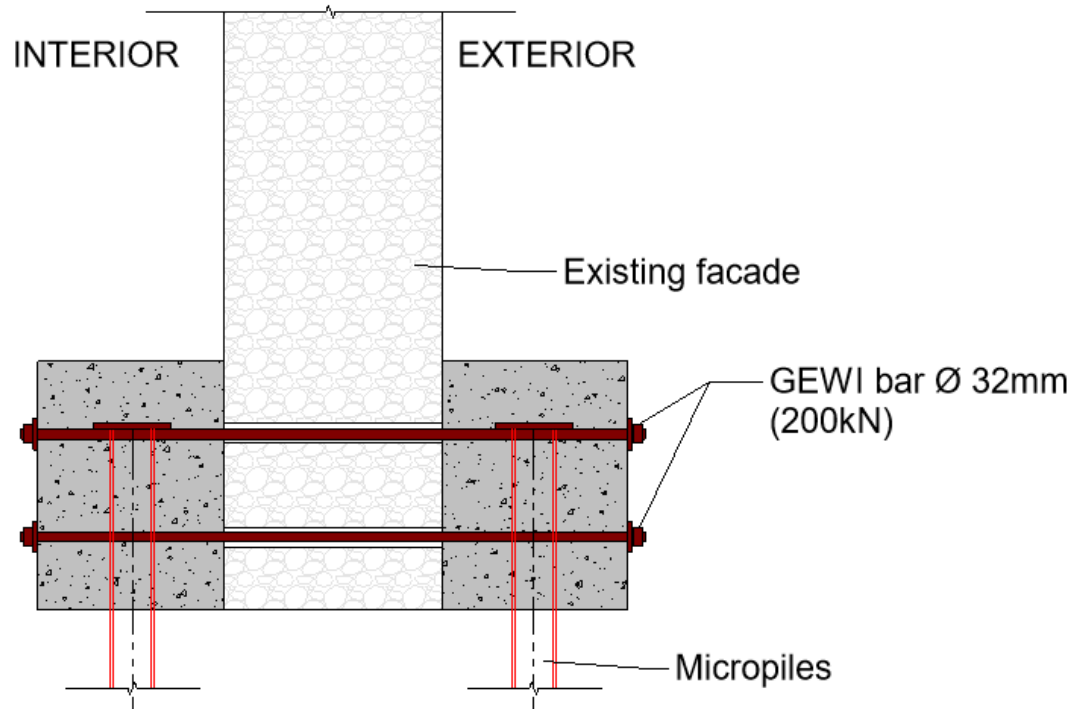
## → Adopted solution

- Underpinning with micropiles

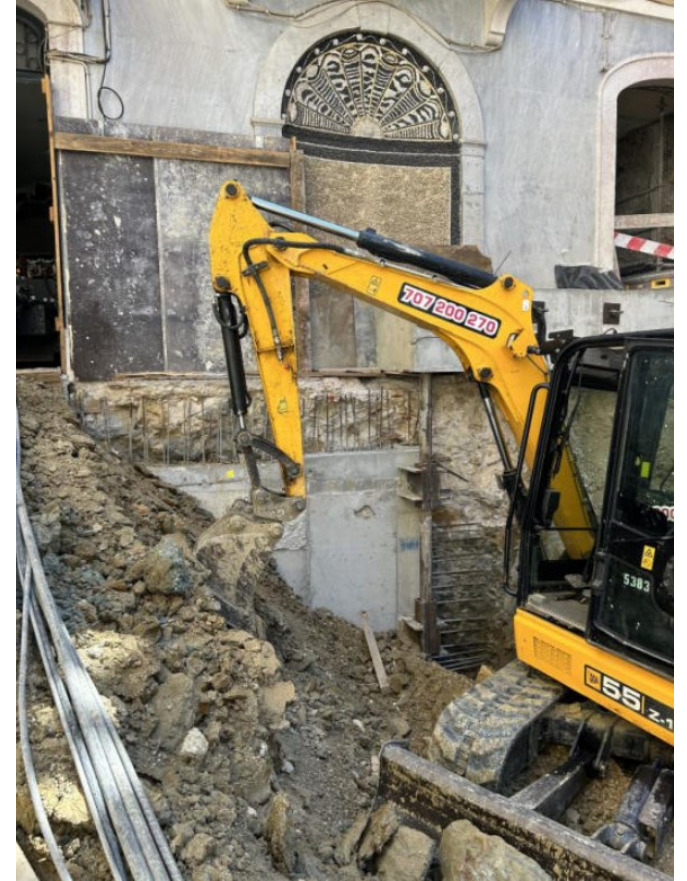


## → Adopted solution

- Underpinning with micropiles



→ Adopted solution

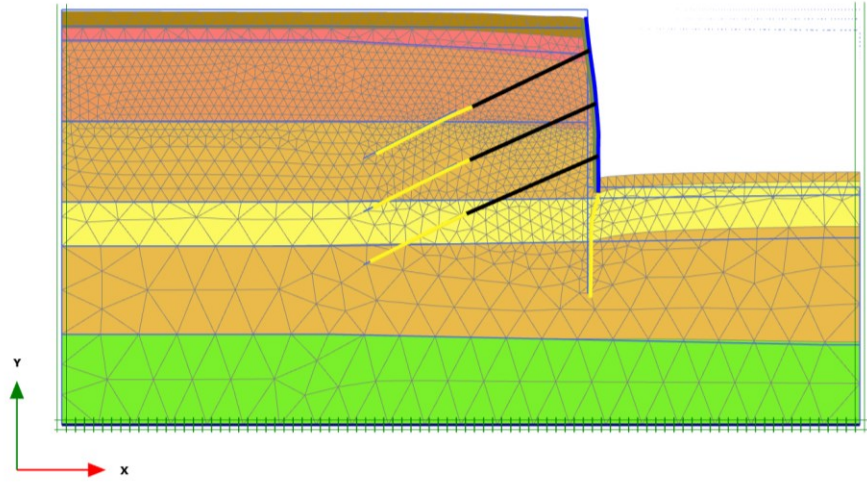


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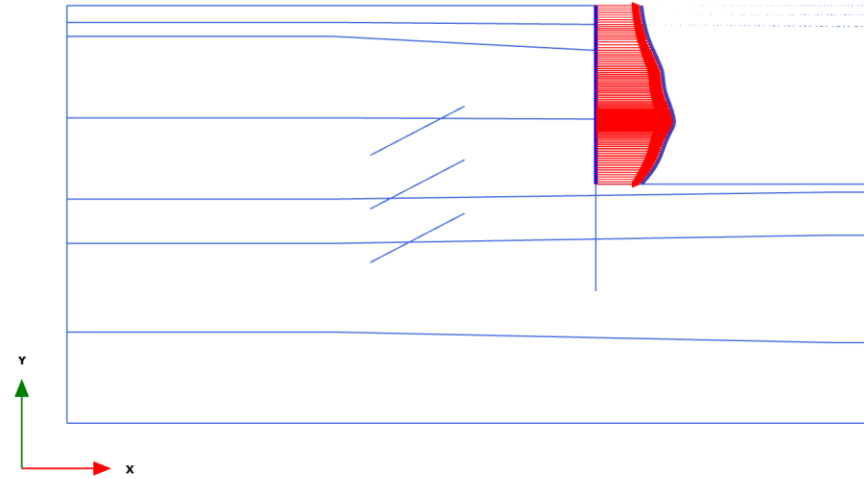
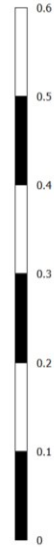
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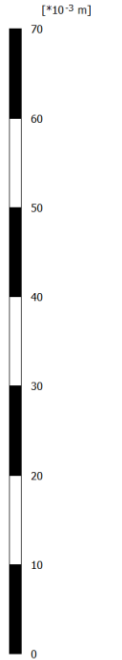
→ Design



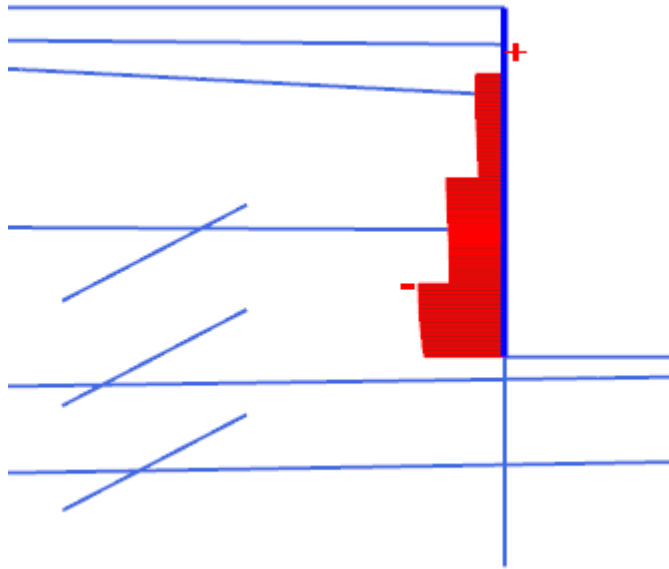
**Deformed mesh  $|u|$  (scaled up 50.0 times)**  
 Maximum value = 0.01769 m (Element 0 at Node 41817)



**Sum phase displacements  $\Sigma Pu_x$  (scaled up 500 times)**  
 Maximum value =  $8,794 \cdot 10^{-3}$  m (Element 15 at Node 15063)  
 Minimum value =  $5,085 \cdot 10^{-3}$  m (Element 1 at Node 14379)

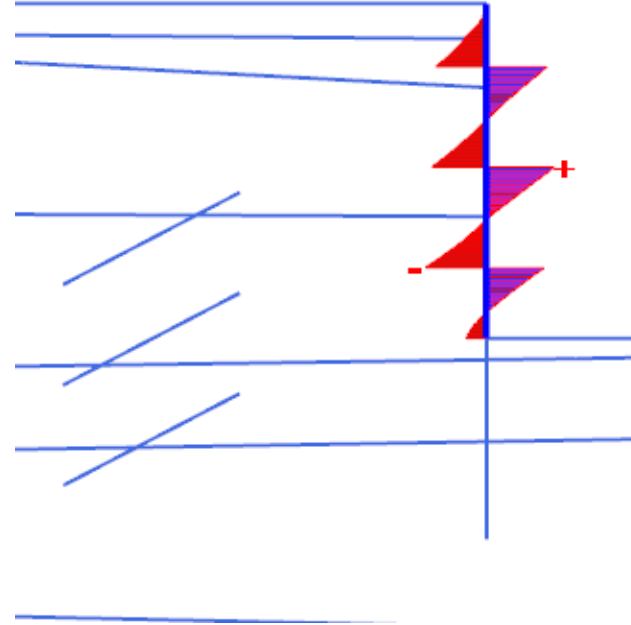


→ Design



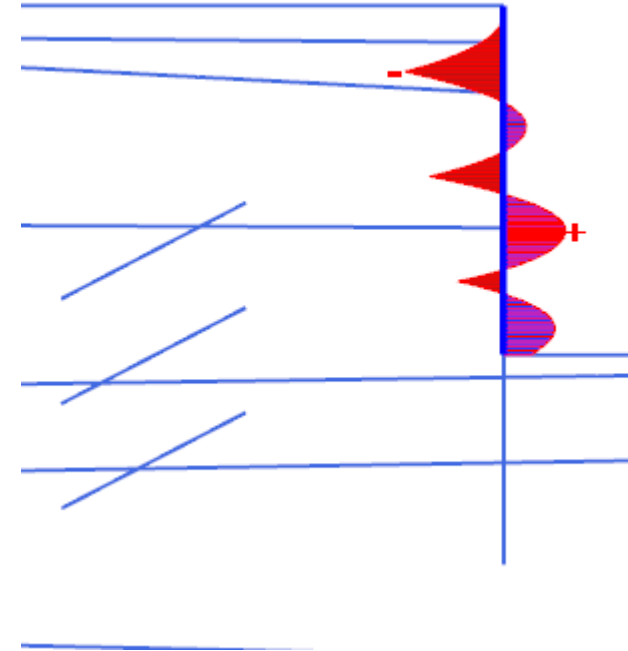
**Axial forces N (scaled up 0.0100 times)**

Maximum value = 2.827 kN/m (Element 3 at Node 22662)  
 Minimum value = -247.2 kN/m (Element 20 at Node 13845)



**Shear forces Q (scaled up 0.0200 times)**

Maximum value = 101.4 kN/m (Element 11 at Node 20612)  
 Minimum value = -91.70 kN/m (Element 19 at Node 13845)



**Bending moments M (scaled up 0.0500 times)**

Maximum value = 35.44 kN m/m (Element 15 at Node 16442)  
 Minimum value = -56.73 kN m/m (Element 5 at Node 22932)

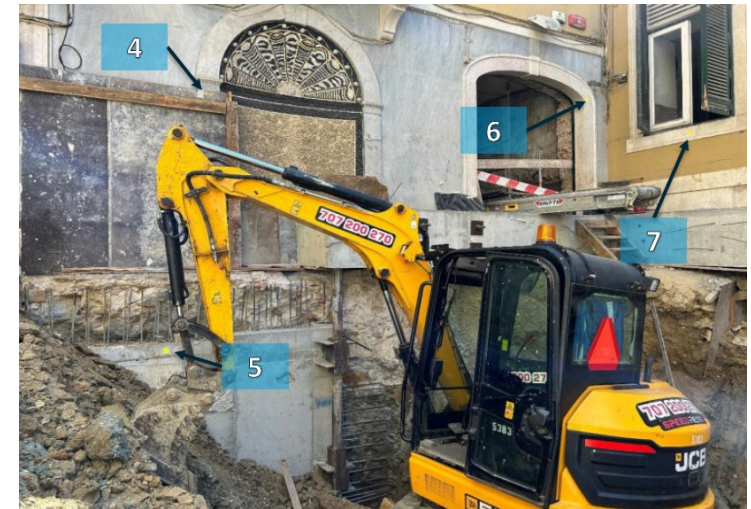
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## → Monitoring and Survey Plan

- ❖ Topographic targets
- ❖ Load cells
- ❖ Inclinometers



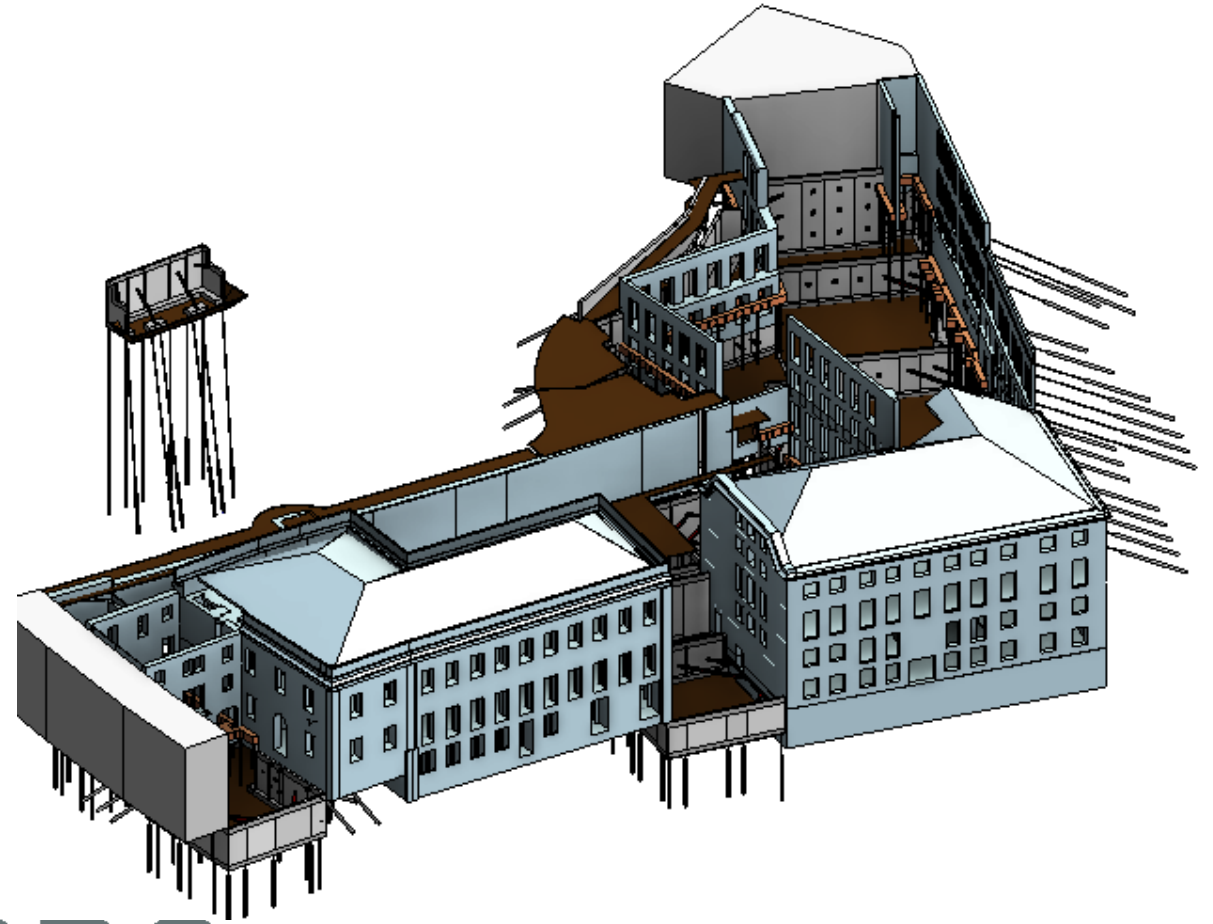
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## → Final remarks

- ❖ This project faced significant challenges in:
  - ❖ The urban location
  - ❖ The need to protect both the historic building and surrounding structures
- ❖ By employing advanced excavation and underpinning techniques, along with continuous monitoring, we are ensuring the safety and stability of the site
- ❖ Our tailored approach addresses the specific demands of this refurbishment, and we remain focused on preserving the building's integrity throughout the construction process





**ECSMGE 24**  
XVIII EUROPEAN CONFERENCE  
ON SOIL MECHANICS AND  
GEOTECHNICAL ENGINEERING

**Thank you for your attention!**



THE GROUND IS OUR CHALLENGE



# Temporary cofferdam at Caniçada Dam, Portugal

Alexandre Pinto / JETsj Geotecnia / IST – Technical University of Lisbon

Laura Caldeira / LNEC

Filipe Cerqueira/ EDP

Nadir Plasência / EDP

Fernando Gomes / Mota Engil



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- **Geological Scenario**
- **Cofferdam Solution**
- **Final Remarks**

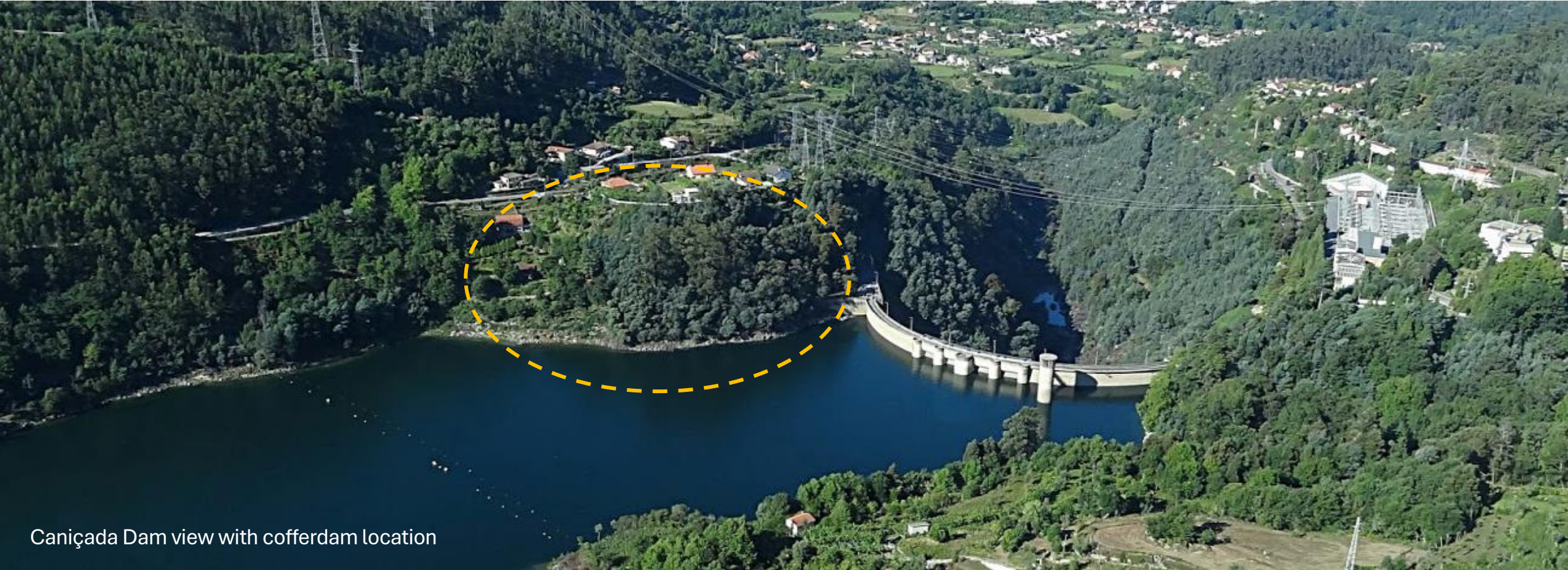




Caniçada Dam location



Caniçada Dam construction (1955)



Caniçada Dam view with cofferdam location

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→ Cofferdam Solution

→ Final Remarks

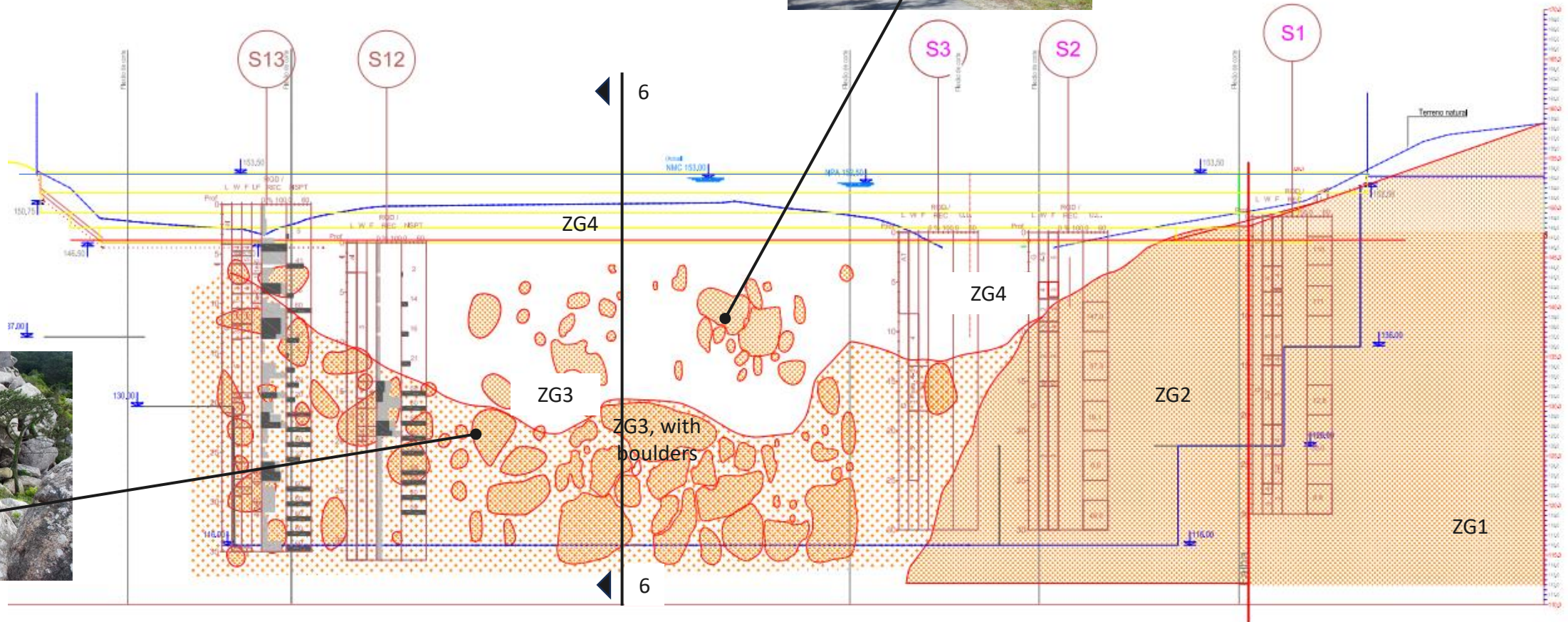


**ECSMGE 24**

XVIII EUROPEAN CONFERENCE  
ON SOIL MECHANICS AND  
GEOTECHNICAL ENGINEERING

26 - 30 August

Lisbon Portugal



Cofferdam geological elevation



LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

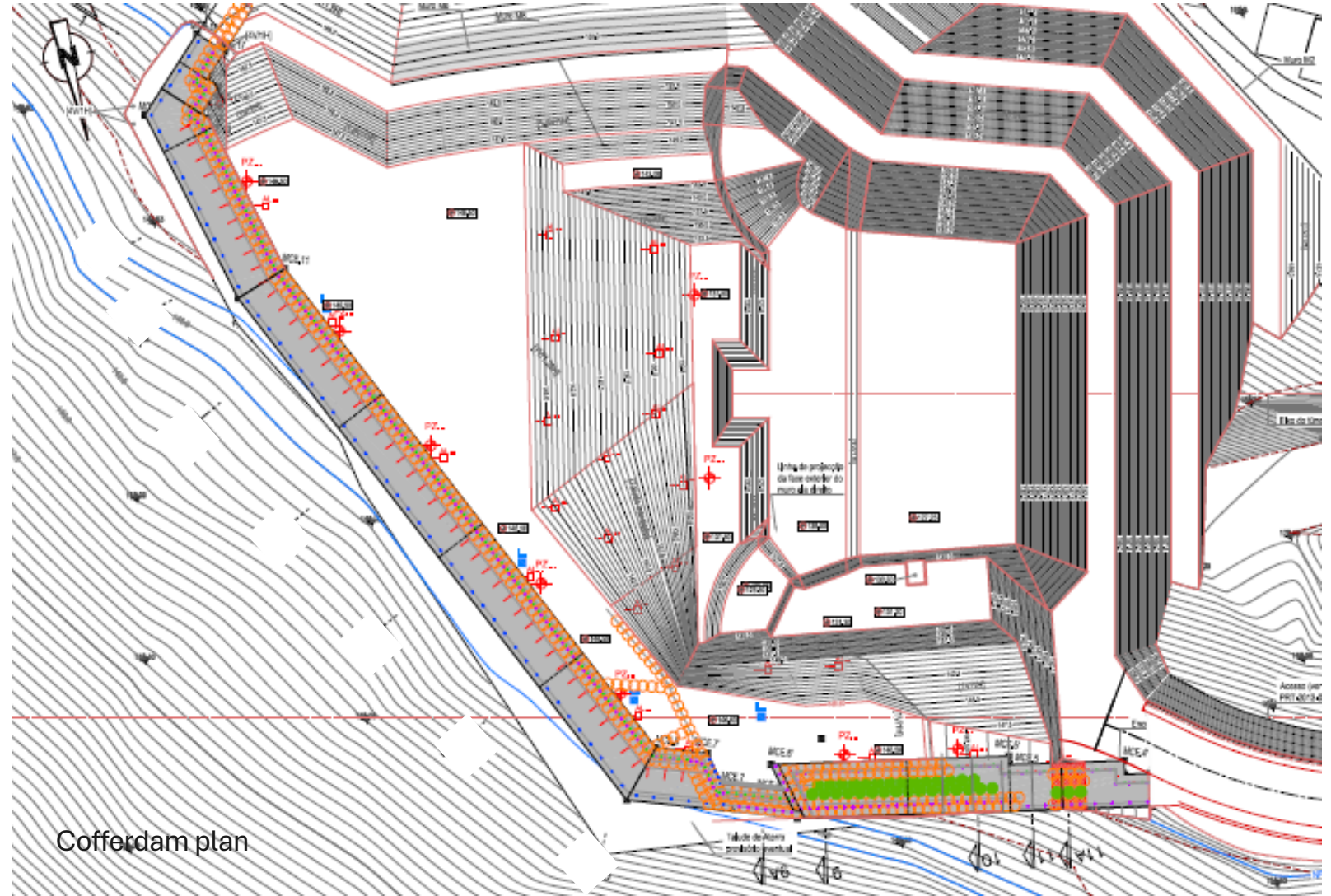
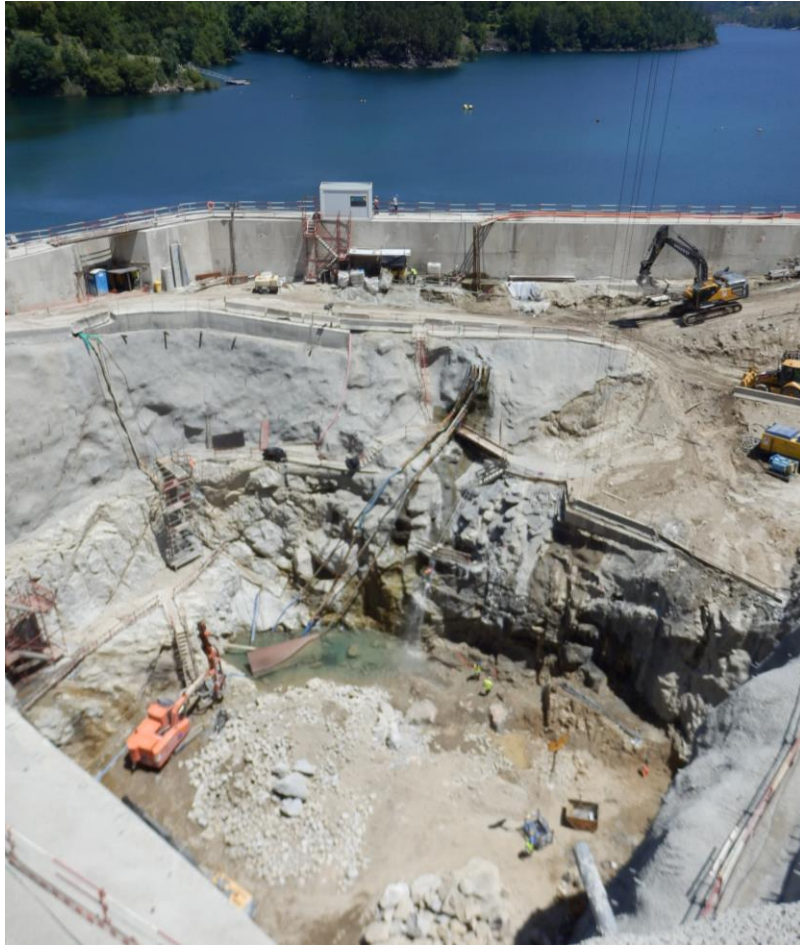


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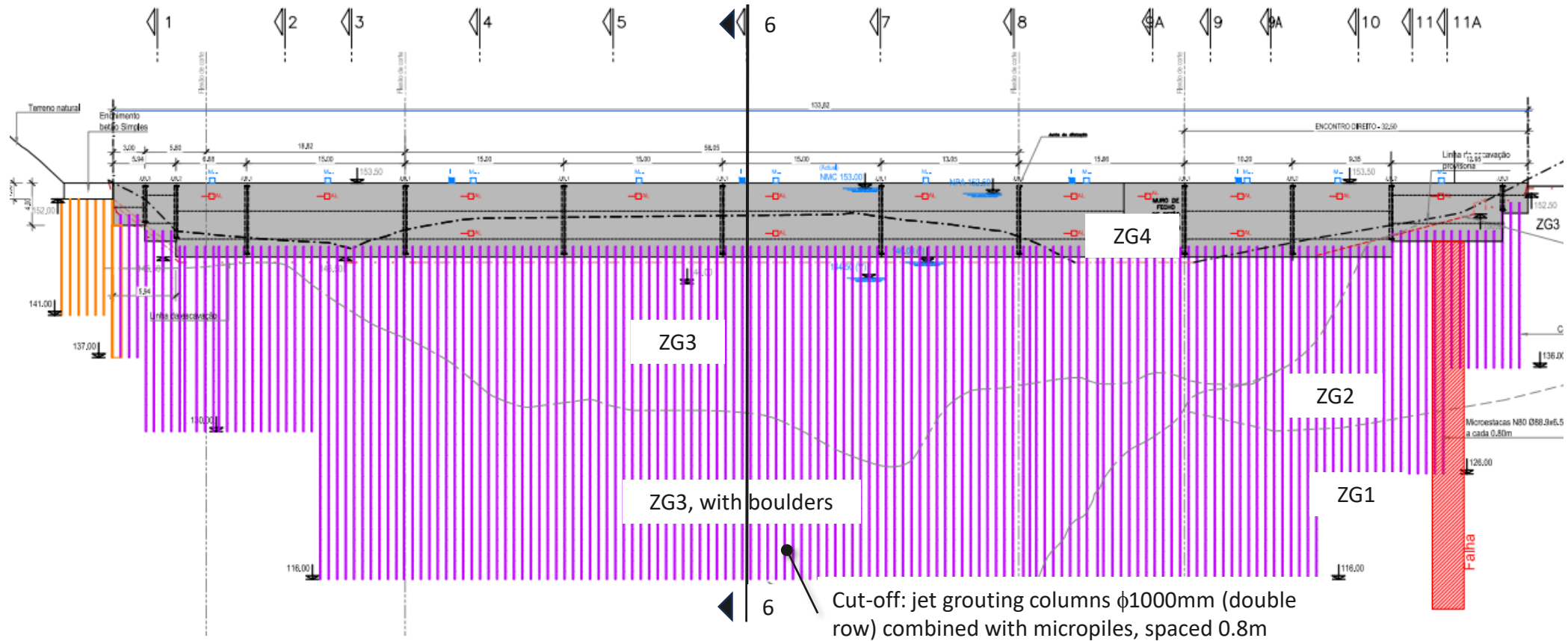


# → Cofferdam Solution



Cofferdam plan

# → Cofferdam Solution

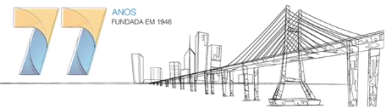


6 Cut-off: jet grouting columns  $\phi 1000\text{mm}$  (double row) combined with micropiles, spaced 0.8m

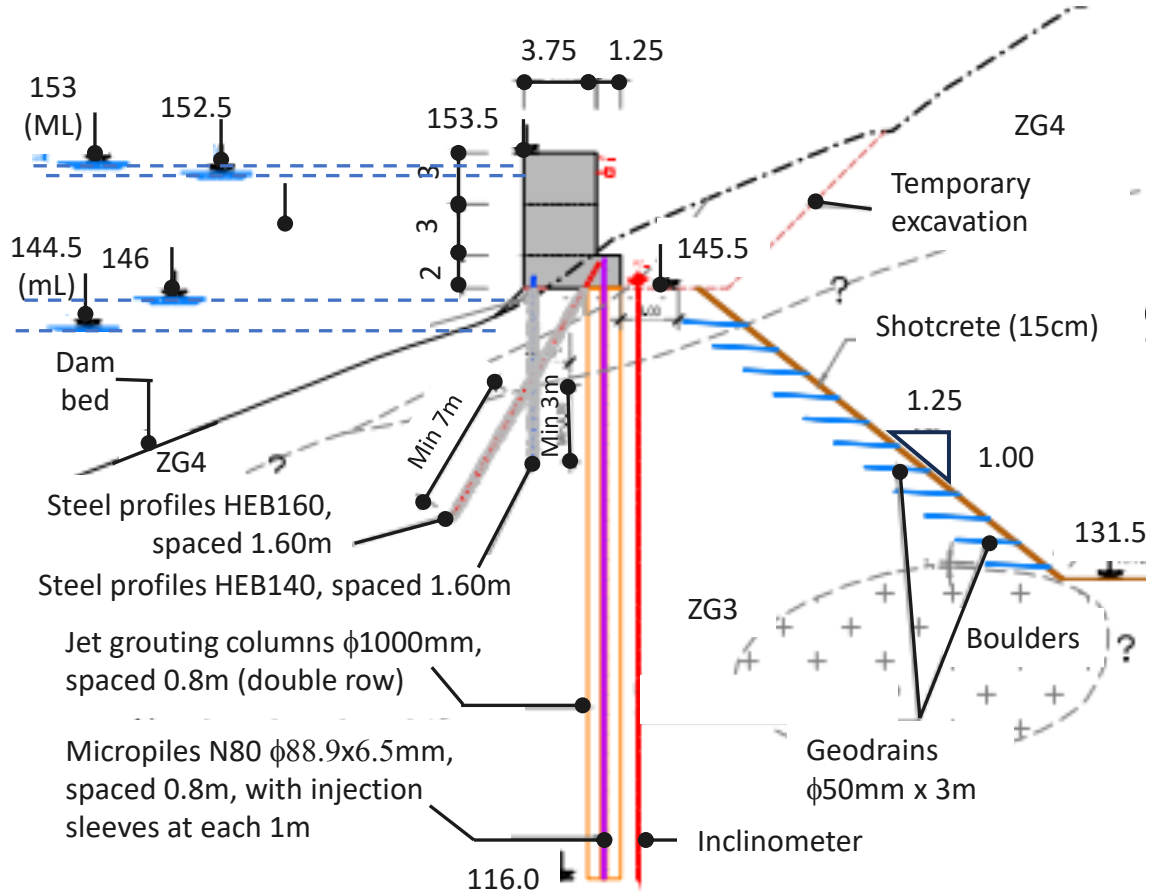
Cofferdam solution elevation



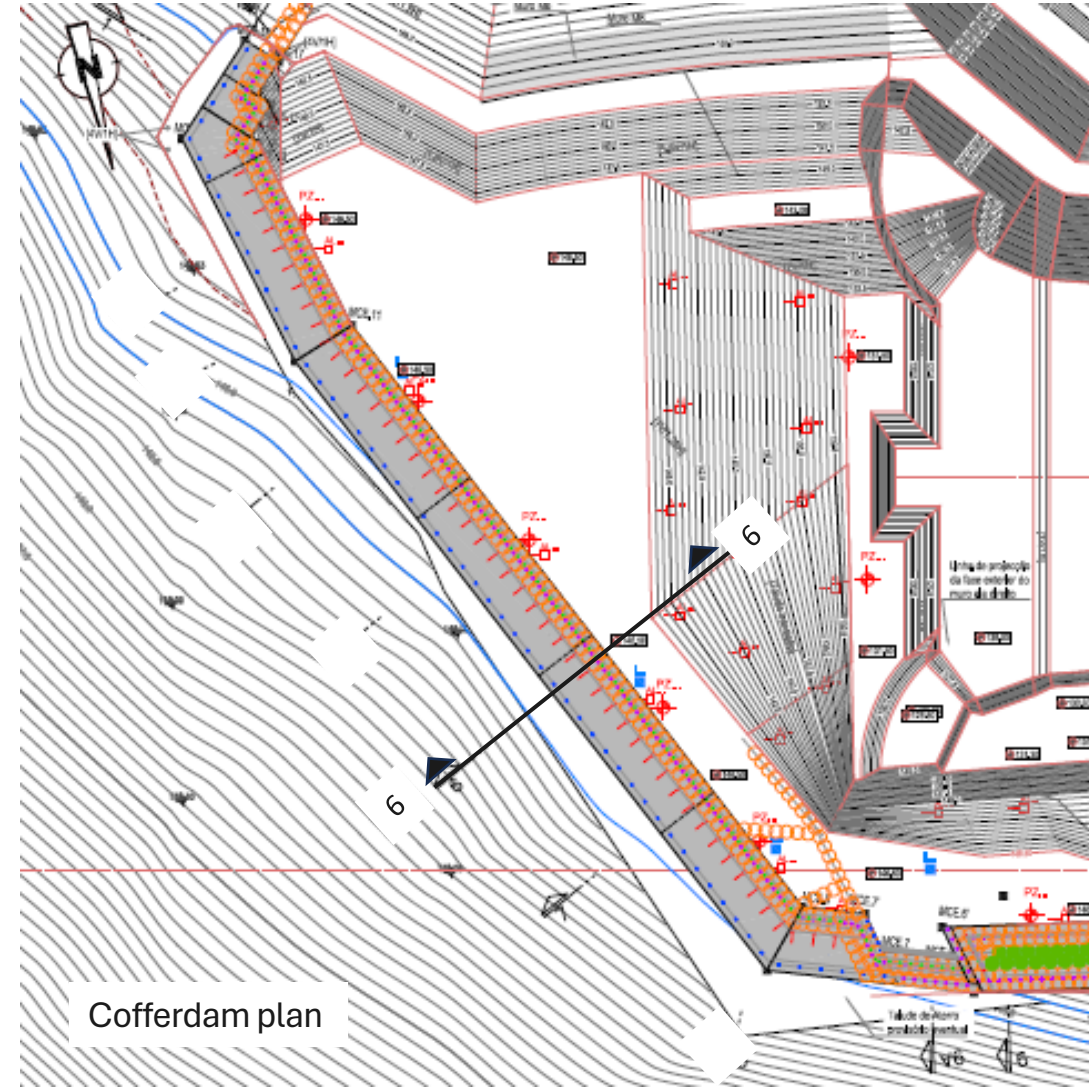
LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL



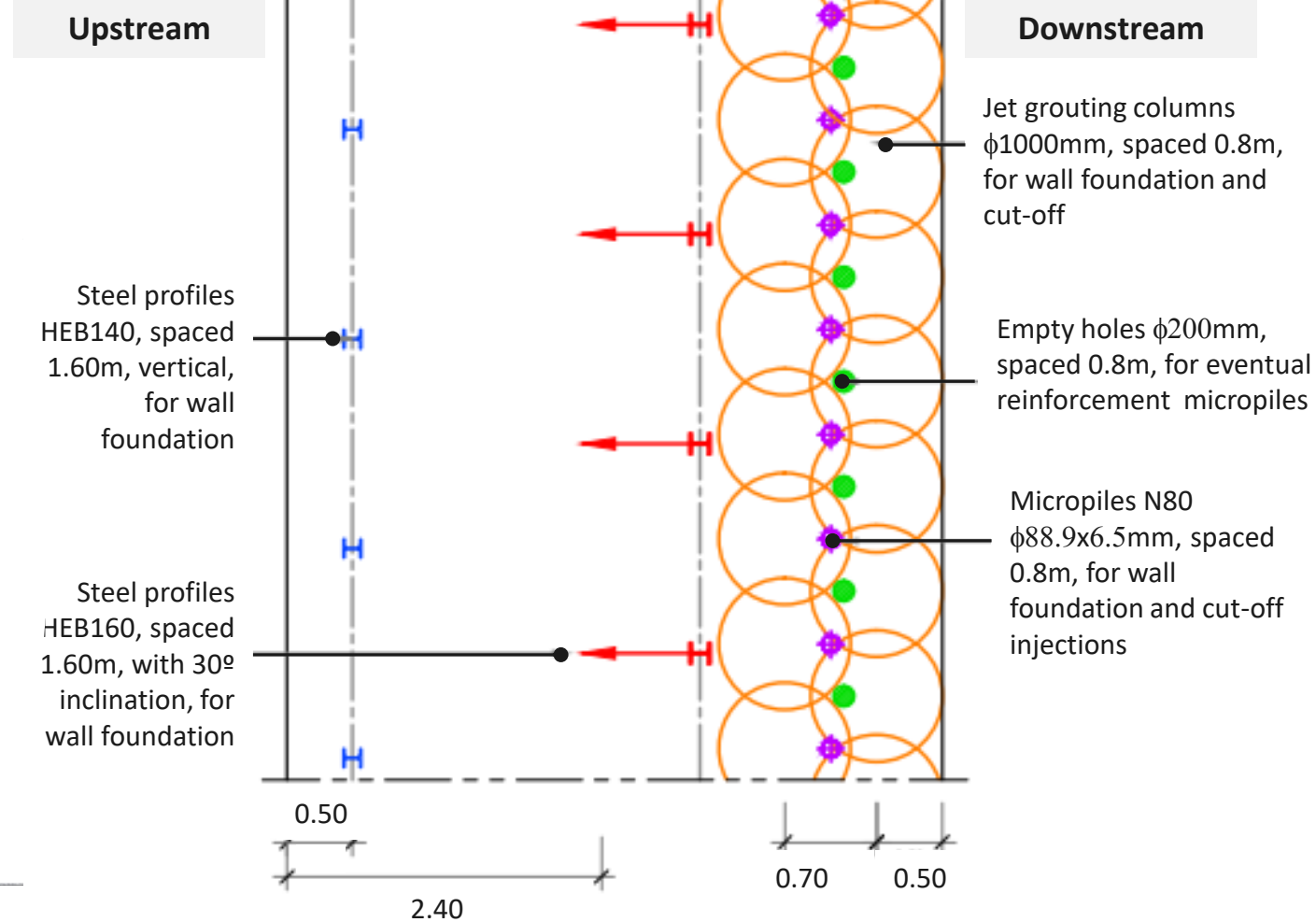
# → Cofferdam Solution



Cofferdam solution cross section 6-6 (ZG3 intersection)



## → Cofferdam Solution



Cofferdam solution detailed plan

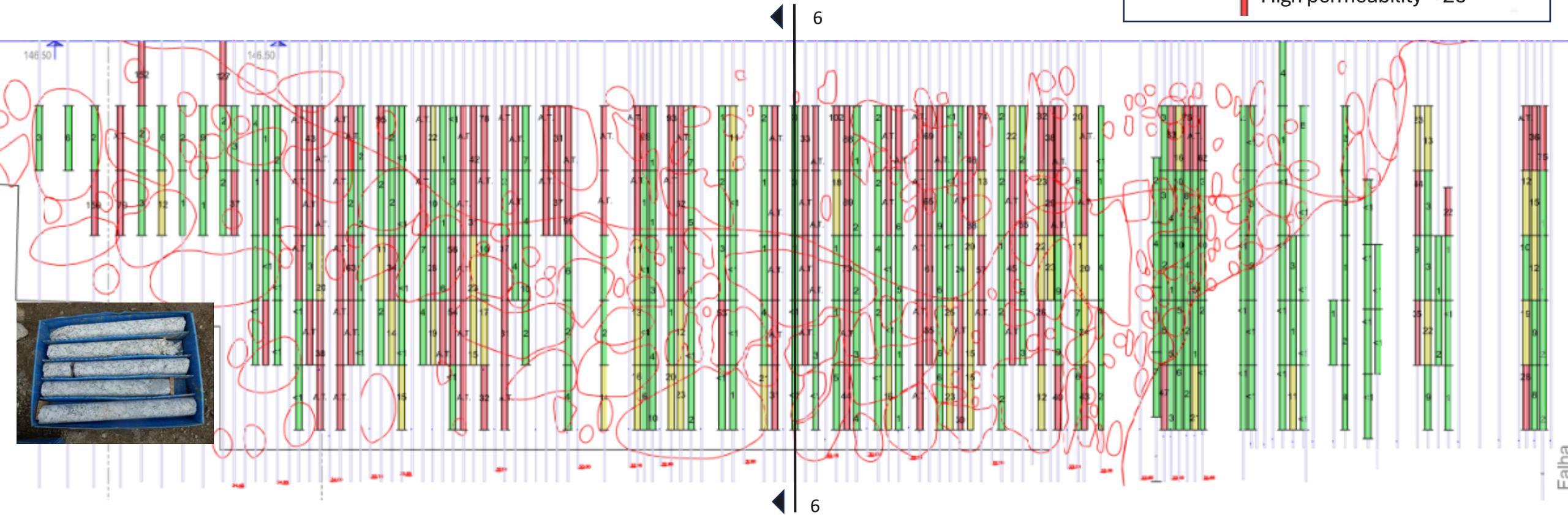
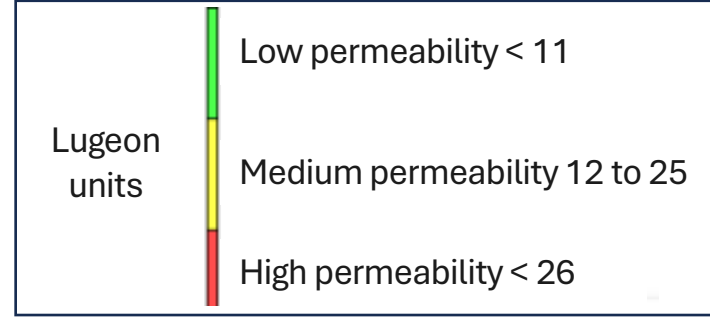
## → Cofferdam Solution: QC/QA



Cofferdam solution: trial jet grouting columns



# → Cofferdam Solution: QC/QA



Cofferdam solution elevation: permeability control

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- **Final Remarks**



## → Final Remarks

- ❑ Water cut-off solutions for temporary cofferdams using jet grouting columns combined with micropiles in a complex geological and hydrogeological scenario



## → Final Remarks

- ❑ Water cut-off solutions for temporary cofferdams using jet grouting columns combined with micropiles in a complex geological and hydrogeological scenario
  
- ❑ Adopted solutions main advantages:
  - ✓ minimum ground extraction
  - ✓ behavior predictability
  - ✓ ease demolition



The authors are grateful to EDP (Owner)

The geotechnical works were performed by Keller



Vhils portrait portrays a “*face inspired by the workers who gave their body and soul to the building of the dam, surrounded by a group of children and tree elements*”

**Thank you for your attention!**

# XVIII EUROPEAN CONFERENCE ON SOIL MECHANICS AND GEOTECHNICAL ENGINEERING

August 26th to August 30th 2024 – Lisbon, Portugal

## Poster Session

587 Foundation solutions near Trancão river, in Lisbon

I. Braz, A. Pinto, C. Simões, T. Gomes, C. Caxias

870 Coastal cliff stabilization and access stair reconstruction at Peneco beach, Algarve, Portugal

C. Fartaria, A. Pinto, J. Dinis, P. Nunes, M. Silva; Presenting Author: Catarina Fartaria

904 Ground improvement and special foundations at North Lisbon Logistic Platform, plot 1, Portugal

A. Pinto, M. Lopes, P. Marques, A.L. Gonçalves, A. Perez, J. Moreno, J. Moreno; Presenting Author: Miriam Lopes

972 Special foundations at the cycle-pedestrian bridge over the Trancão river, Portugal

A. Pinto, A. Rodrigues A. Rodrigues, P. Santos, C. Caxias; Presenting Author: Ana Teresa Rodrigues

981 Deep and complex excavation in an urban environment in Miraflores, Oeiras

R. Justiniano, A. Pinto; Presenting Author: Ricardo Justiniano

986 Excavation, earth retaining solutions and facades underpinning of a historic building in Estoril, Portugal

J. Silva, C. Martins, A. Pinto; Presenting Author: Joana Silva

988 Industrial warehouse retaining walls and pavements strengthening at Quinta do Adarse, Alverca, Portugal

T.M.L. Paludeto, M. Lopes, A. Pinto; Presenting Author: Thaís Maria Paludeto



## Foundation solution near Trancão river, in Lisbon

I. Braz, JETsj Geotecnia Lda  
A. Pinto JETsj Geotecnia Lda  
C. Simões, Oliveiras S.A.  
T. Gomes, Geosol S.A.  
C. Caxias, ANP Systems

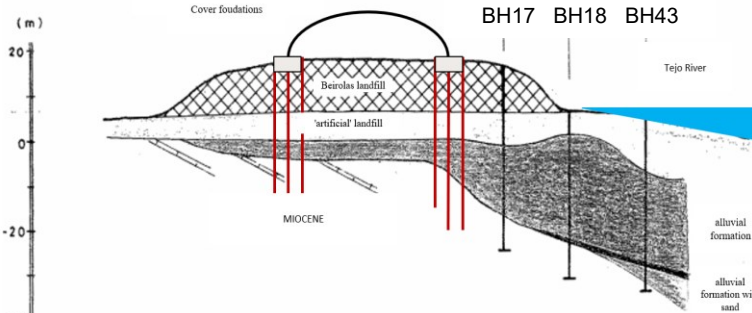


### REFERENCE SCENARIO

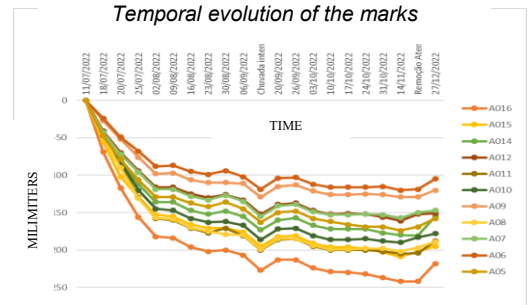
For the World Youth Day 2023 event, pope mass, a mega stage was built at Parque Tejo, Lisbon

### GEOTECHNICAL SCENARIO

### PRELOADING EMBANKMENT (SHALLOW FOUNDATIONS)

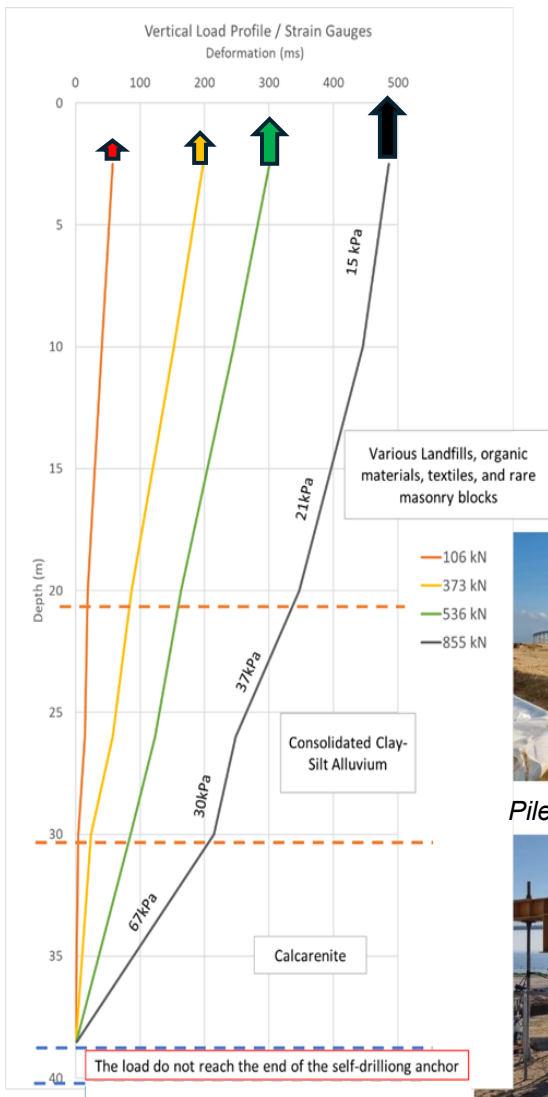


Geological cross section at the stage



Stage foundation preloading embankment

### DUCTILE IRON DRIVEN PILES (BACK STAGE AND STAGE COVER FOUNDATIONS) LOAD TESTS

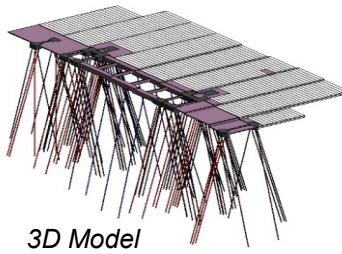


No end bearing loads at -41m!

Load vs depth - Tension load test



Ductile iron piles driven



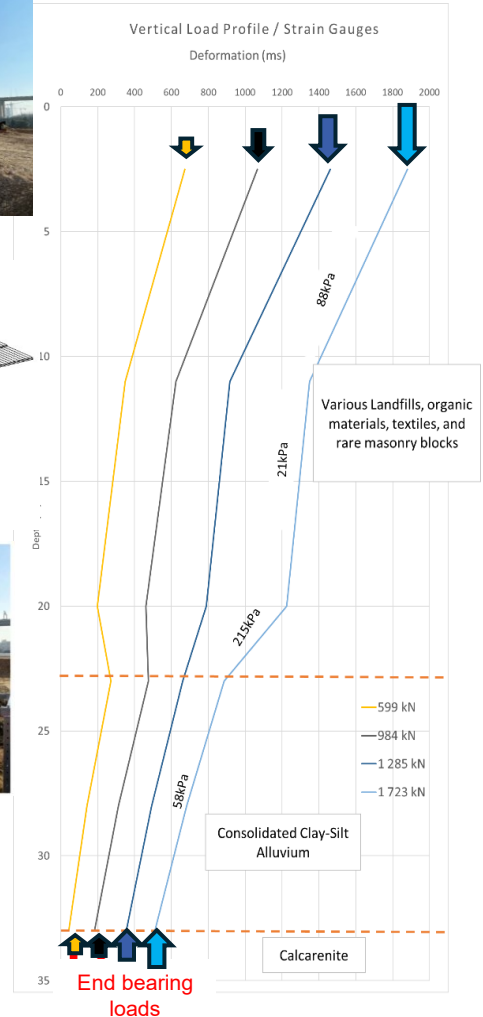
3D Model



Pile tension full scale load test



Pile compression full scale load test



Load vs depth - Compression load test





# Coastal Cliff Stabilization and Access Stairs Reconstruction at Peneco Beach, Algarve

C. Fartaria, JETsj, Geotecnia, Lisbon, Portugal

A. Pinto, JETsj, Geotecnia, Lisbon, Portugal

J. Dinis, P. Nunes, Teixeira Duarte, Lisbon, Portugal

M. Silva, Câmara Municipal de Albufeira, Albufeira, Portugal

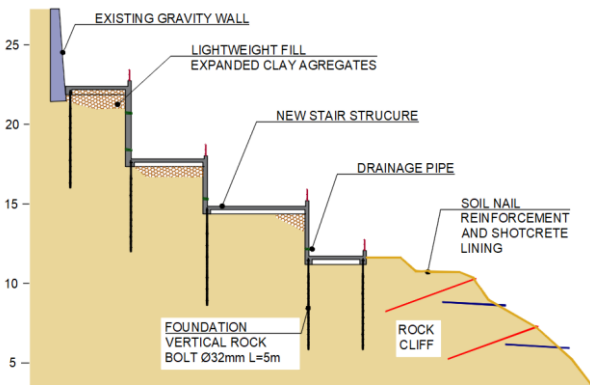
## REFERENCE SCENARIO

- Coastal Cliff:
  - Erosion and local mass movements;
  - Natural geological hazard;
  - High exposure to atmospheric actions;
  - Risk increase by high exposure of people accessing and using beach public space;
- Access Stairs:
  - Structural pathologies;
  - Poor foundation conditions;
  - Pavement and walls cracks.



Overall view before intervention

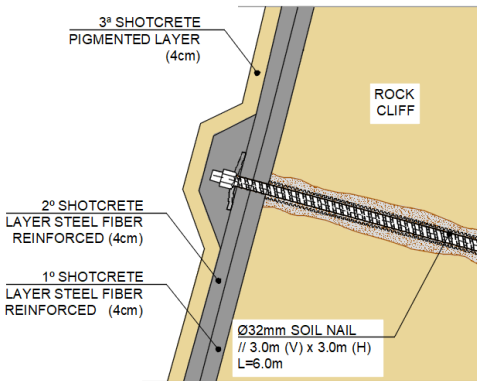
## CLIFF STABILIZATION AND ACCESS STAIRS RECONSTRUCTION



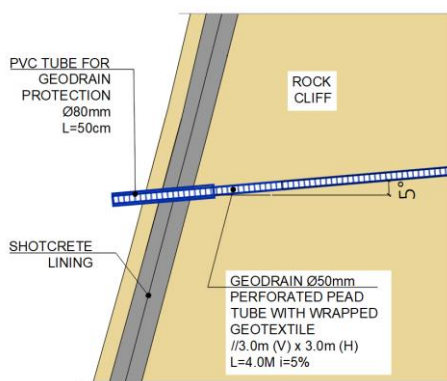
Access Stairs Reconstruction – Cross Section



Access Stairs Reconstruction – Plan View



Shotcrete lining and soil nail detail



Geodrain detail



Rock cliff after intervention



Overall view after intervention

- Coastal Cliff:
  - Soil nail stabilization;
  - Shotcrete lining for erosion control with steel fibre reinforcement;
  - Pigmented shotcrete for landscape integration;
  - Drainage using geodrains;
- Access Stairs:
  - Structure reconstruction;
  - Vertical rock bolts as foundation elements.





## Ground improvement and special foundations at North Lisbon Logistic Platform, plot 1, Portugal

A. Pinto, JETsj, Geotecnia, Lisbon, Portugal  
M. Lopes, JETsj, Geotecnia, Lisbon, Portugal  
P. Marques, JETsj, Geotecnia, Lisbon, Portugal  
A. L. Gonçalves, Terratest, Lisbon, Portugal  
A. Perez, Terratest, Madrid, Spain  
J. Moreno, Terratest, Madrid, Spain  
J. Moreno, JM Ingeniería Geológica, Madrid, Spain

### PILE FOUNDATIONS

Reinforced concrete driven piles (TERRA®) for the building resistant structure.



### GROUND IMPROVEMENT

Rigid inclusions (GCC®) and stone columns (GRAVA IMPACT®) for interior and exterior pavements, respectively.

Geosynthetics-reinforced load transfer platforms.



### MONITORING AND TESTING

Static and dynamic load tests on vertical prefabricated driven piles.

Static vertical load tests on rigid inclusions and stone columns.

Full scale load test: embankment over rigid inclusions.



### OBJECTIVE

Building a new industrial building with an area of approximately 100.000 m<sup>2</sup> in Castanheira do Ribatejo, Portugal, with expected high magnitude pavements live loads.



### GEOLOGICAL CONDITIONS

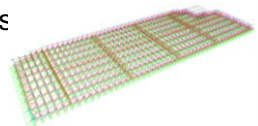
Alluvial soils: very loose to loose sandy-silty horizons and very soft to soft silty clays.



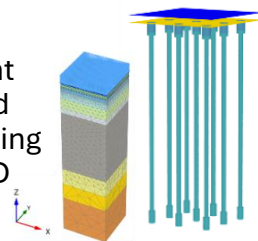
Risk of accentuated and evolving deformable behaviour over time.

### DESIGN AND ANALYSIS

The foundations as well as the building's structure were modelled using the SAP2000 finite element software.



The study of the ground improvement solutions was based on finite element using the Plaxis 2D and 3D software.



### CONCLUSIONS

More economic foundation solutions compatible with the structure serviceability:

- ground improvement solutions allow for the reduction, in the foundation structural elements, of the design seismic horizontal forces originating from the expected high magnitude pavements live loads.
- possible to reduce shear stresses and bending moments at the floor slab.





# Special foundations at the cycle-pedestrian bridge over the Trancão river, Portugal

A. Pinto, JETsj Geotecnia, Lisbon, Portugal  
A. Rodrigues, P. Santos, RODIO, Lisbon, Portugal  
C. Caxias, ANP Systems GmbH, Lisbon, Portugal

## MAIN REASONS FOR THE CONSTRUCTION

- World Youth Day 2023 (WYD)
- Connect already existent cycle-pedestrian paths at both banks of the Trancão river (Loures and Lisbon)

## THE SOLUTION

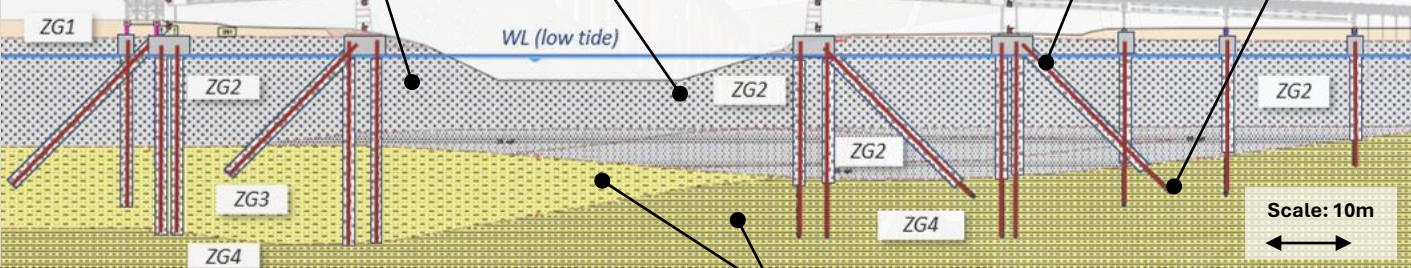
- Layout: 3 spans (28m+65m+28m, 121m overall length) cable stayed bridge, to be built without any river occupancy
- Structural: laminated wood deck, steel towers and cables, resting over reinforced concrete columns and abutments
- Foundations: micropiles steel hollow bars, with sacrificial grouting bits, associated to up-bottom self drilling  $\phi 500\text{mm}$  mini jet grouting columns

Zone	Description	N <sub>SPT</sub> blows
ZG1	Heterogeneous landfills	<12
ZG2	Very soft alluvial soils (Su < 20KPa)	0 < N <sub>SPT</sub> < 2
ZG3	Miocene loose sandy and clay soils	12 < N <sub>SPT</sub> < 47
ZG4	Miocene bedrock	N <sub>SPT</sub> >60

### Geotechnical zones

South riverbank (Lisbon)

### Bridge longitudinal profile



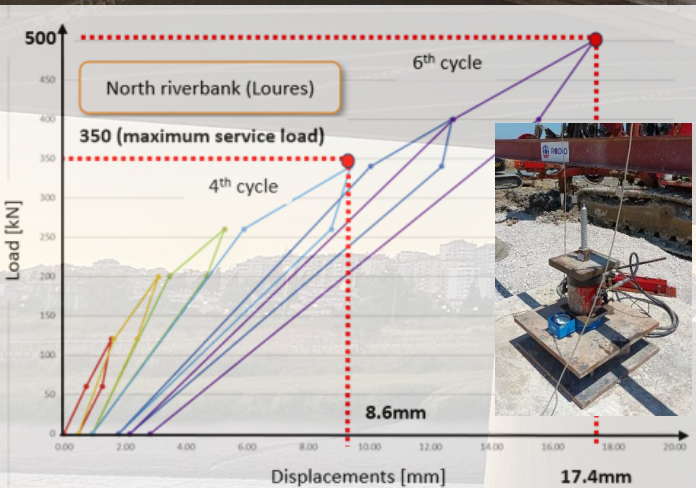
Micropiles hollow bars



Sacrificial bits

Scale: 10m

## MICROPILES TENSION FULL SCALE LOAD TESTS



ZG3 + ZG4 samples

### QC / QA

- Jet grouting trial columns
  - Cores (integrity)
  - UCS tests: 3MPa (28 days)
- Parameters recorder





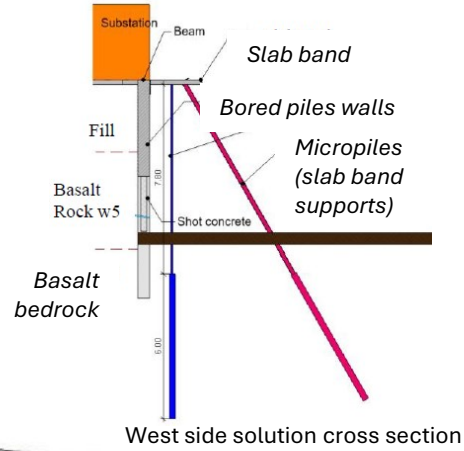
# Deep and complex excavation in an urban environment at Miraflores, Oeiras

R. Justiniano , JETSj Geotecnia, Lisbon, Portugal

A. Pinto , JETSj Geotecnia, Lisbon, Portugal

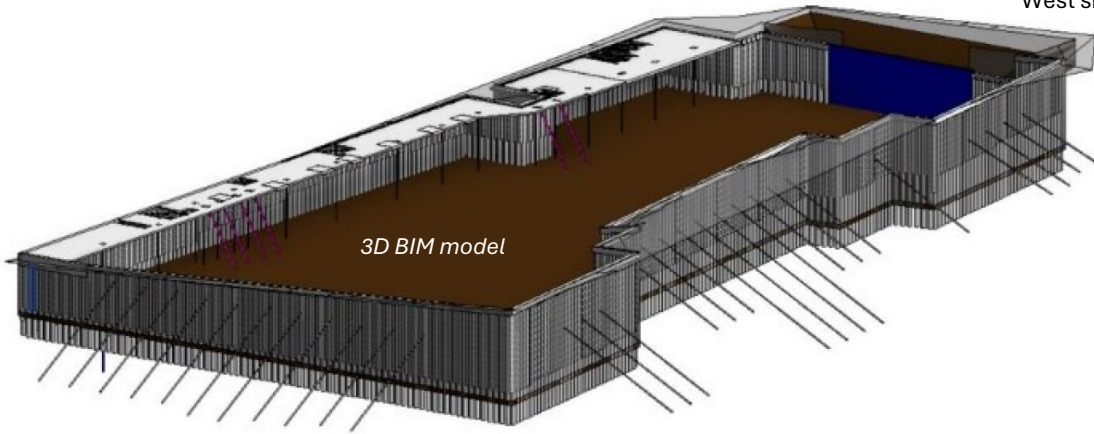
## REFERENCE SCENARIO

- Geological and geotechnical:
  - Weak fill with 4 to 8 meters deep
  - Basalt bedrock with UCS » 120 MPa
- Time of Execution:
  - 6 months for 60 000 m<sup>3</sup> excavation peripheral earth retaining wall
- Existing Construction:
  - West to the site an excavation with 12 meters depth



## CONCEPTUAL SOLUTION

- Bored piles walls
  - Braced at the West side by slab bands
  - Braced at the other sides by temporary ground anchors

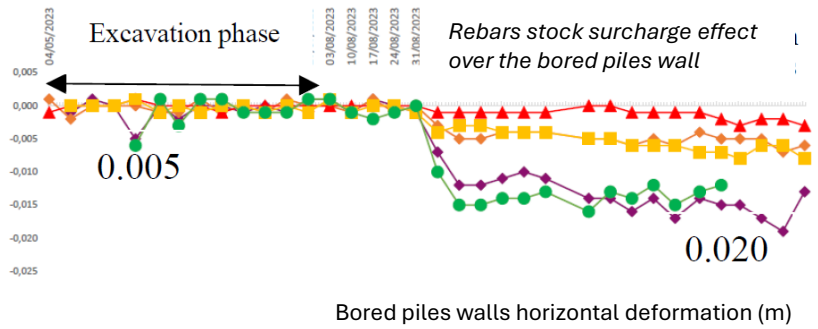


## EXECUTION



West side excavation works (under slab band)

## MONITORING AND SURVEY PLAN



East side excavation works





# Excavation, earth retaining solutions and facades underpinning of a historic building in Estoril, Portugal

J. Silva, C. Martins & A. Pinto, JETsj – Geotecnia Lda, Lisbon, Portugal



Overall view before intervention

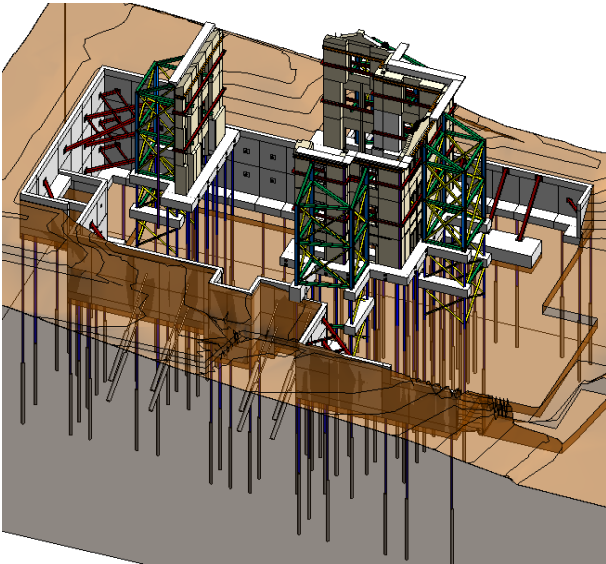
➤ Facades solution:

- Injection of grout into existing cracks;
- Interior reinforced concrete layer;
- Underpinning beams with prestressed bars;
- Temporary structural system of steel beams and trusses.

➤ Peripheral earth retaining solution:

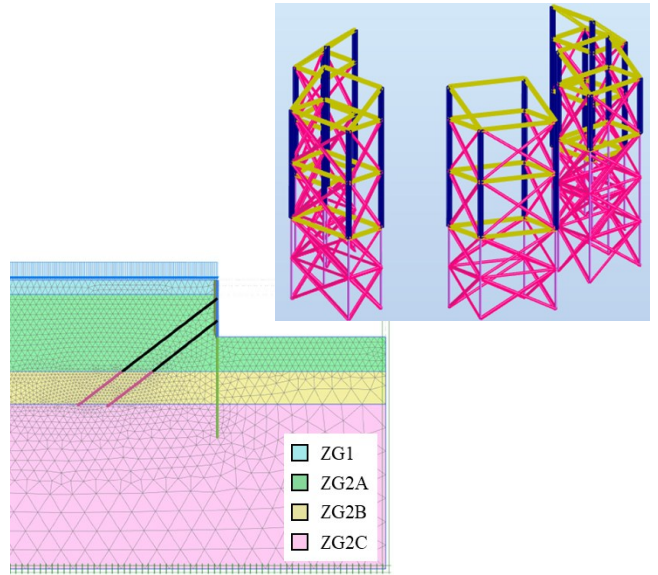
- 9,0 m depth excavation;
- King Post Wall technology, horizontally braced by prestressed ground anchors and steel props.

## ADOPTED SOLUTION



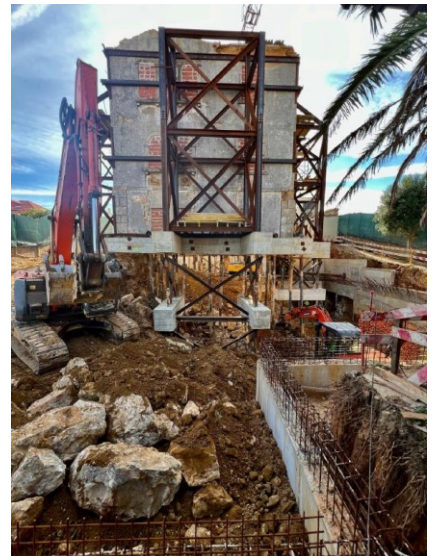
BIM model developed using Revit software

## GEOTECHNICAL AND STRUCTURAL DESIGN



Structural analysis models developed using Robot and Plaxis 2D softwares

## CONSTRUCTION SITE



Overall view of the construction works



# Industrial warehouse retaining walls and pavements strengthening at Quinta do Adarse, Alverca, Portugal

T. M. L. Paludeto, M. Lopes, A. Pinto  
JETsj Geotecnia, Lisbon, Portugal

## INTRODUCTION

- Industrial warehouse with 20.250 m<sup>2</sup>
- Retaining walls with 6m height and 320m length
- Industrial pavements built with 10cm concrete reinforced with steel mesh AR 30



Overall view before intervention

## MAIN PATHOLOGIES

- **Retaining walls:**
  - Excessive deformations
  - Cracks



Retaining walls pathologies

- **Pavements:**
  - Cracks
  - Differential settlements, mainly around pile caps and underground water pipes



Pavements pathologies

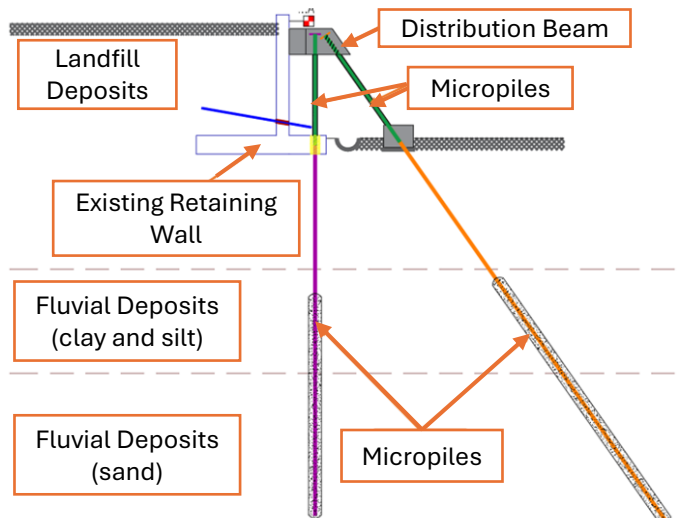
## STRENGTHENING SOLUTIONS

- **Pavements:**
  - Ground consolidation solution using the Uretek - Floor Lift (expansive resin)

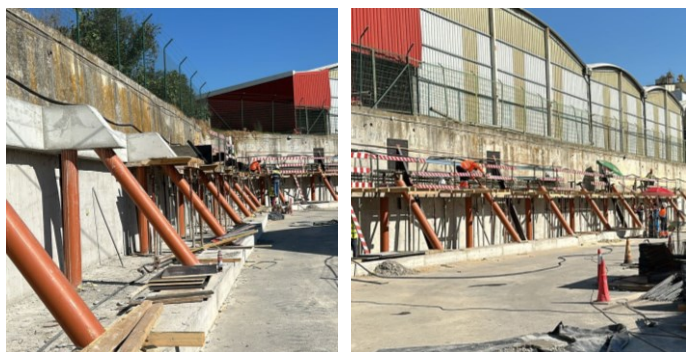


Injection system - Uretek Floor Lift (<https://www.uretek.pt>)

- **Retaining walls:**
  - Construction of a bracing elements
  - Horizontal forces transfer to micropiles



Cross section of both geological scenario and walls reinforcement solution



Walls reinforcement construction works

