ECSMGE 2019
Reykjavík

SIMSG ISSMGE

GEOTECHNICAL ENGINEERING,

FOUNDATION OF THE FUTURE

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XVII EUROPEAN CONFERENCE ON SOIL MECHANICS AND GEOTECHNICAL ENGINEERING

4 SEPTEMBER – SESSION TC207 – Soil-Structure

NUMERICAL ANALYSIS OF AN UNSYMMETRICAL RAILCAR UNLOADING PIT AND CONNECTION TRENCH

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- INTRODUCTION
- STRUCTURE GEOMETRY
- SITE CONDITIONS
- NUMERICAL MODELS
- NUMERICAL MODELS RESULTS
- MAIN CONCLUSIONS

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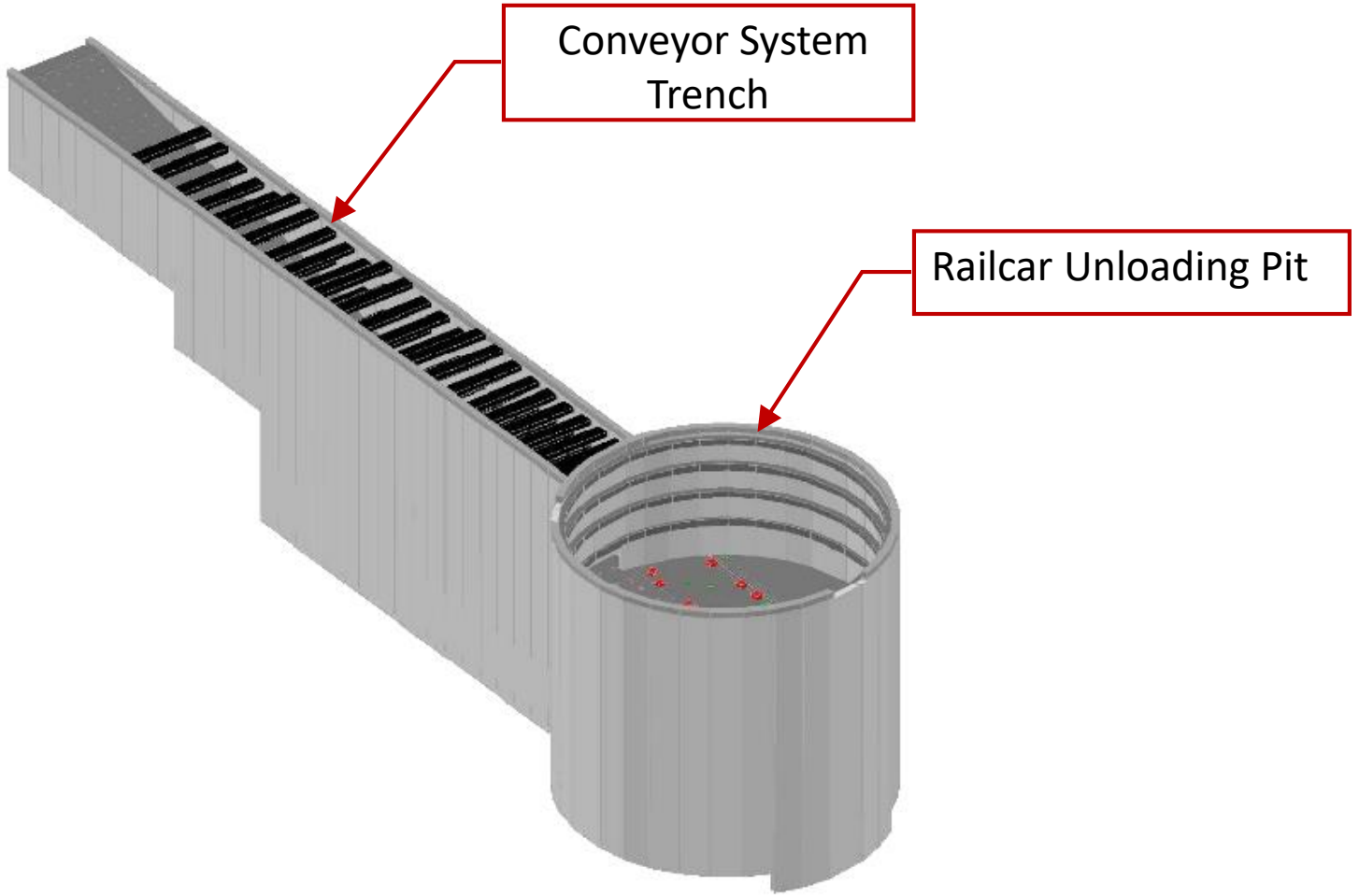
INTRODUCTION

INTRODUCTION

INFRASTRUCTURE FOR BAUXITE CRUSHING



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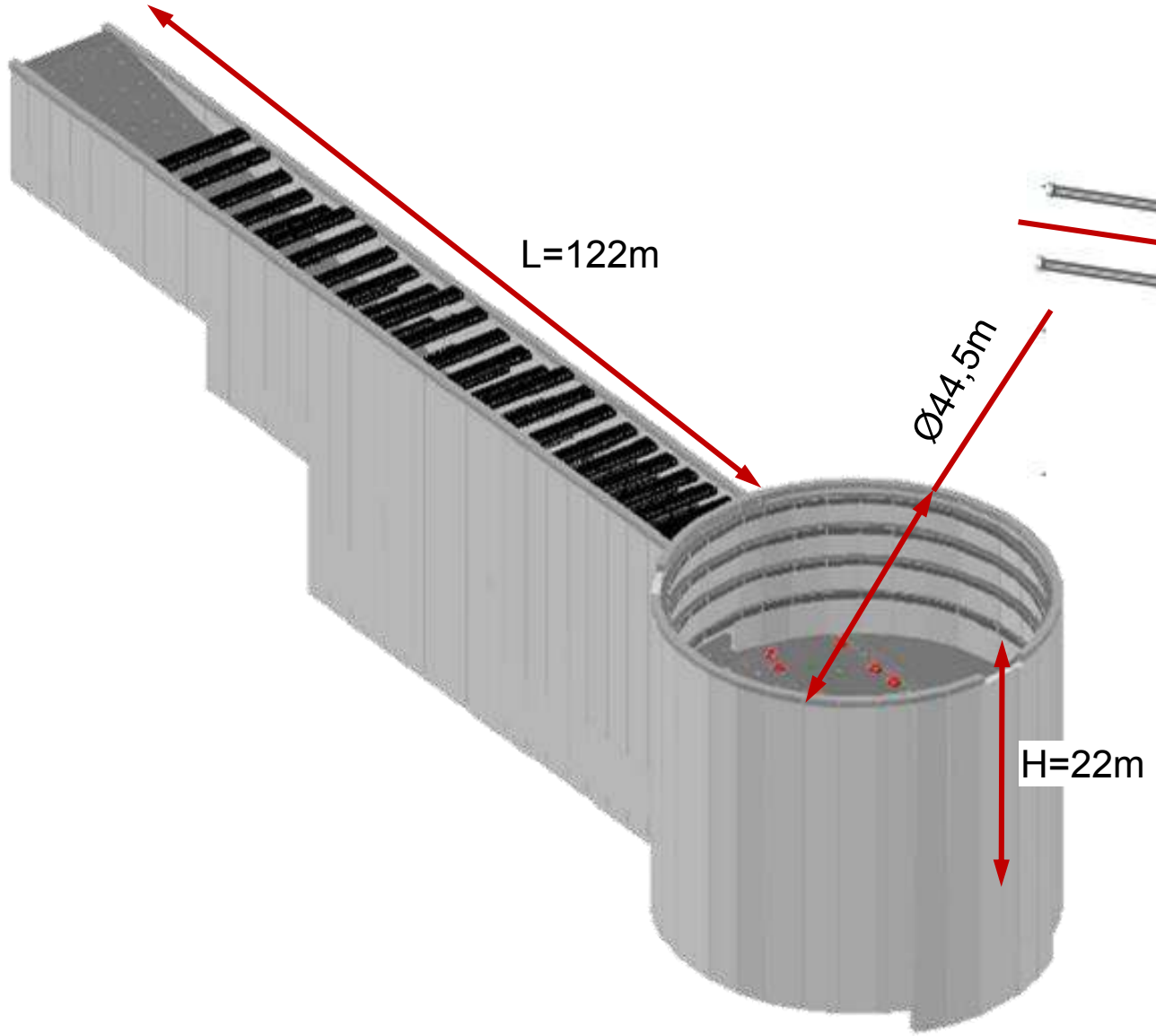
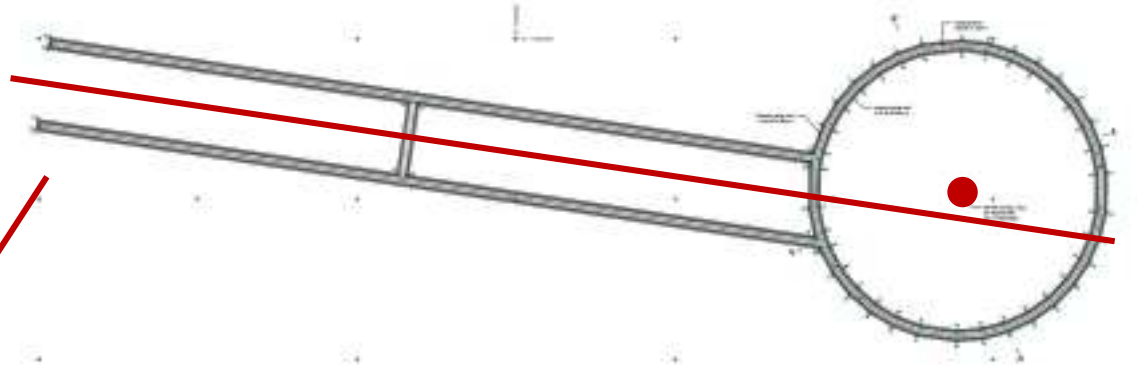
STRUCTURE GEOMETRY

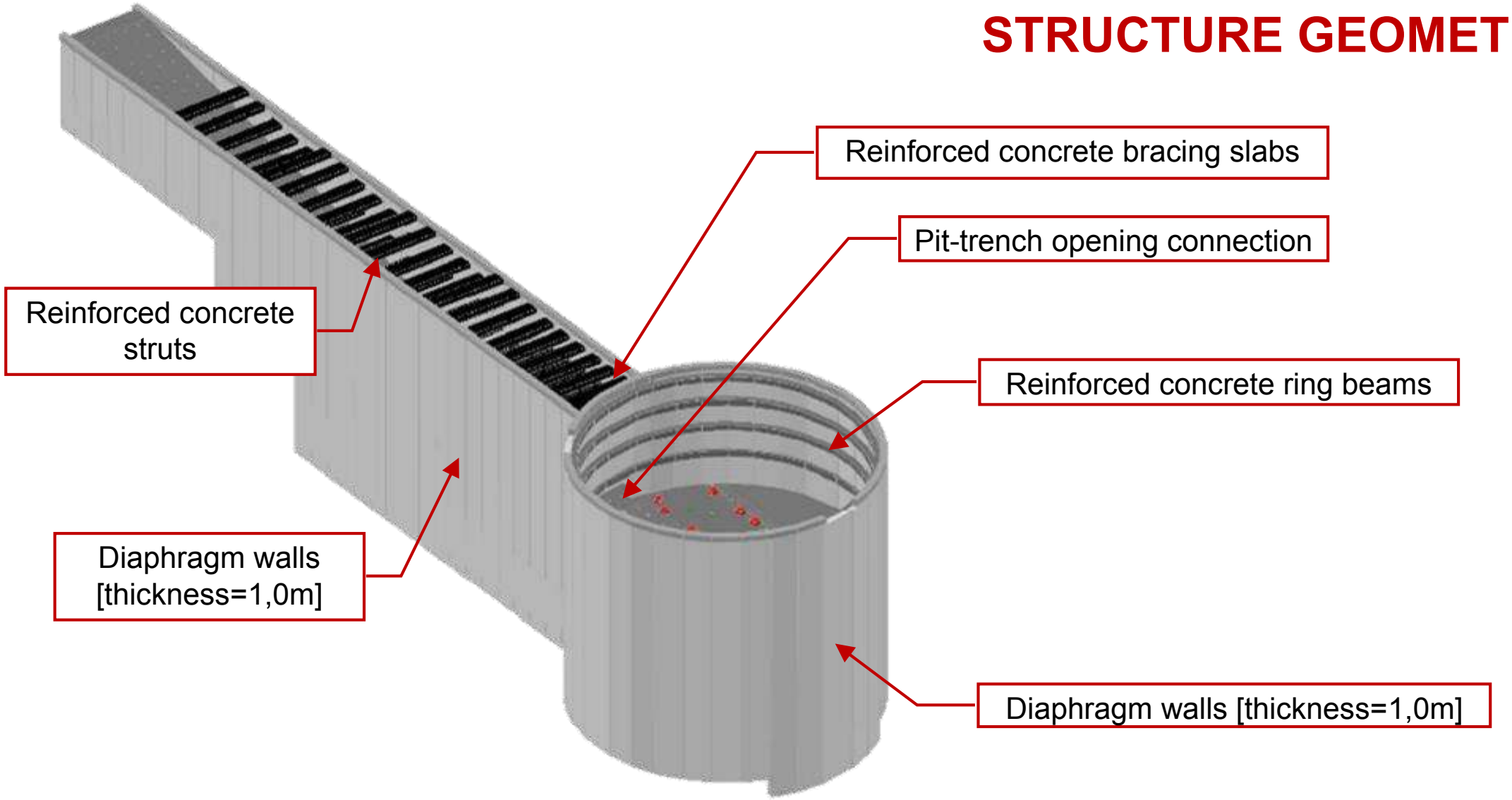




TRENCH AND PIT ARE NOT COCENTRIC

PIT –TRENCH CONNECTION AND OPENING

STRUCTURE GEOMETRY



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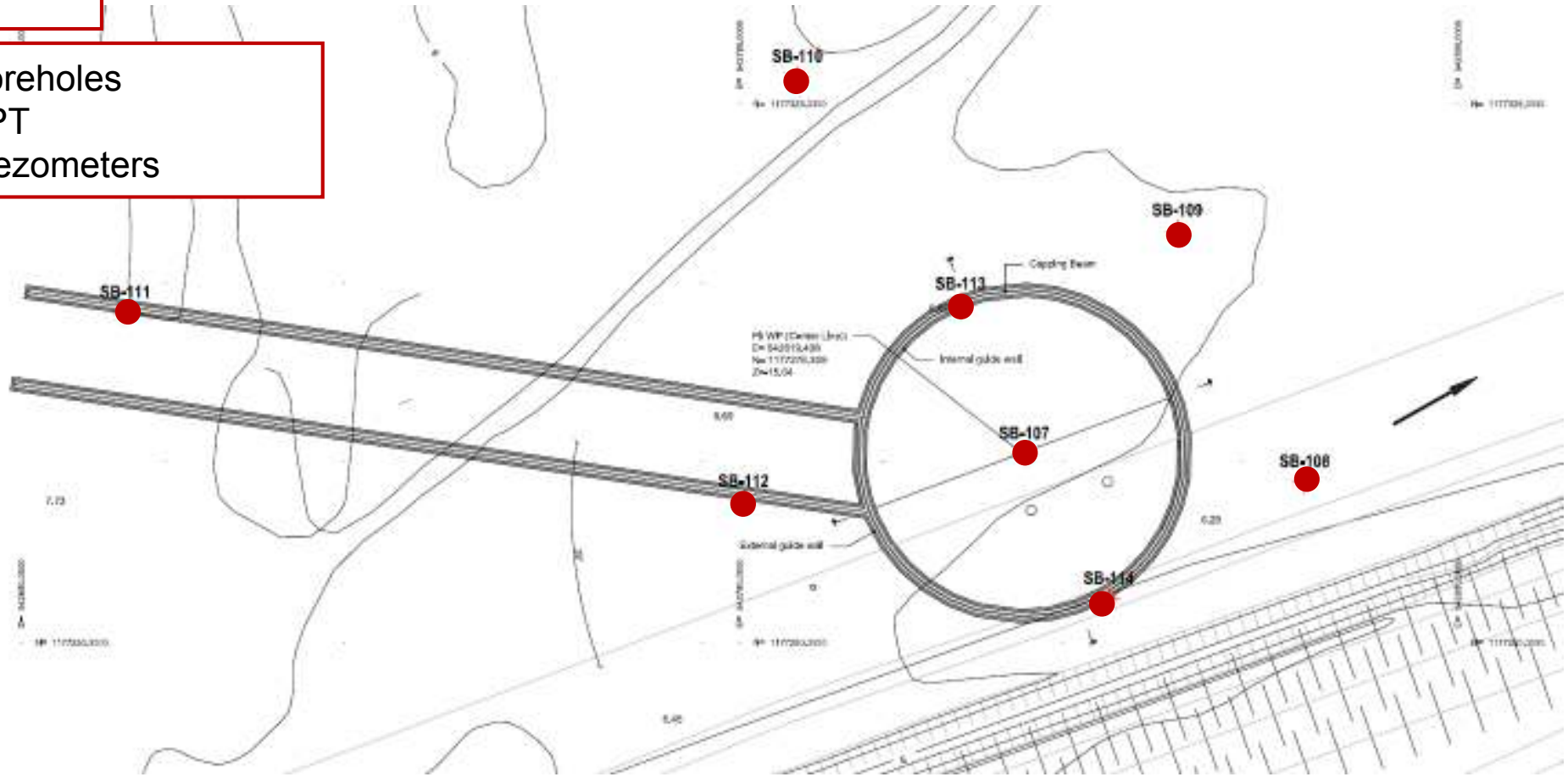
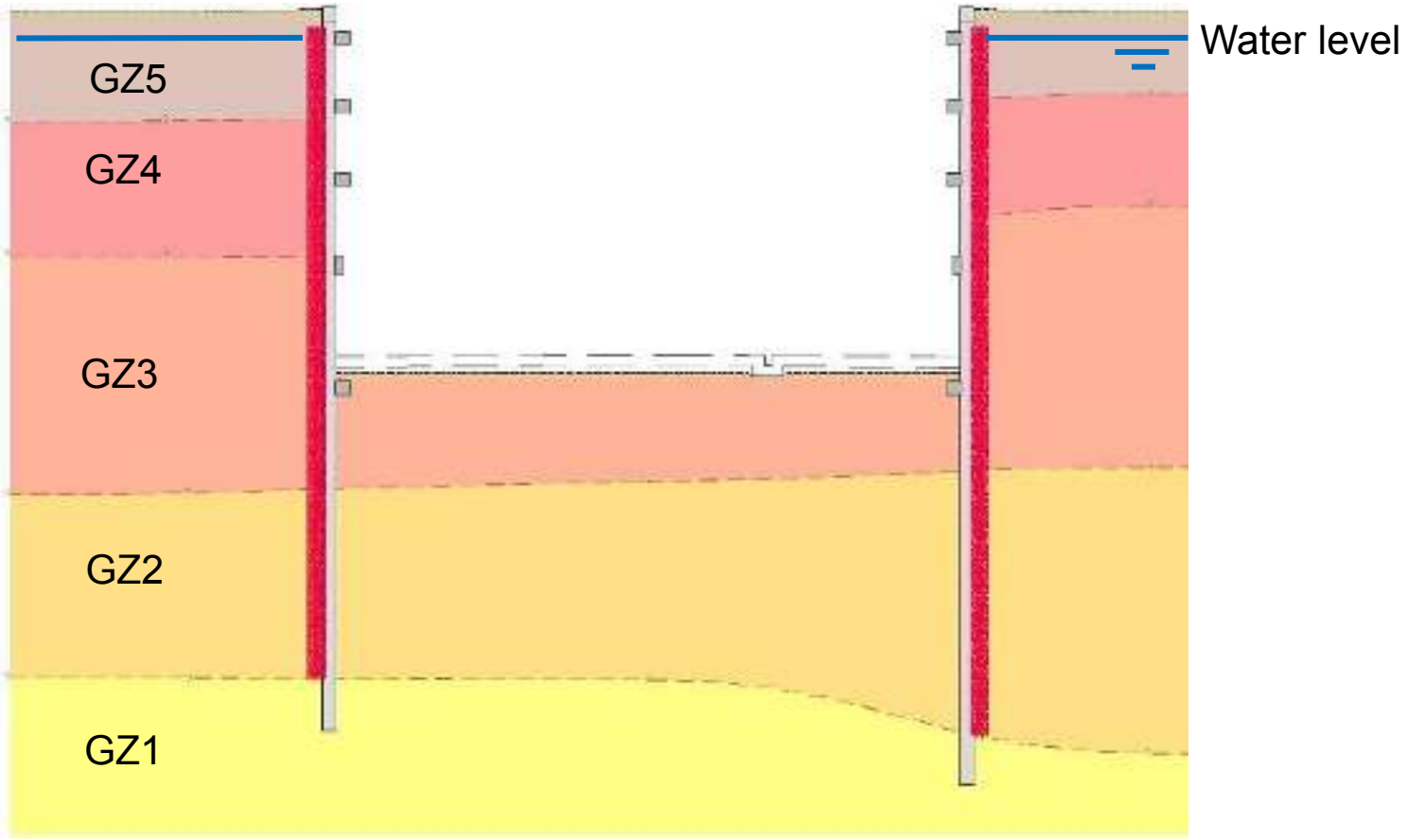
SITE CONDITIONS

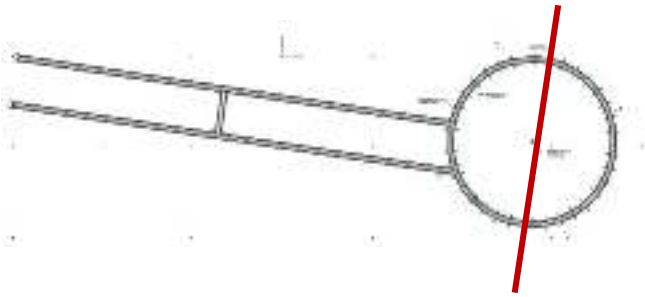
Site investigation

- Boreholes
- SPT
- Piezometers



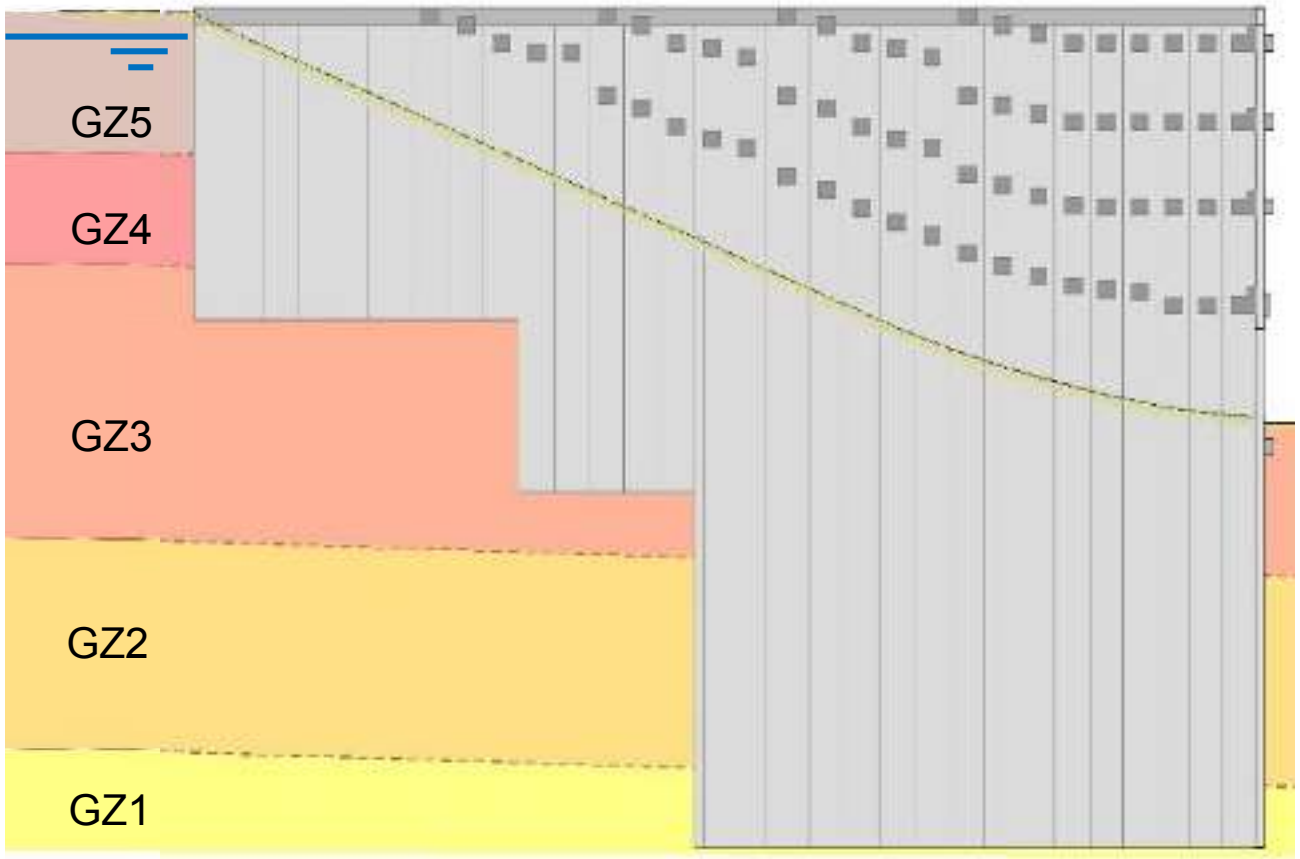
SITE CONDITIONS

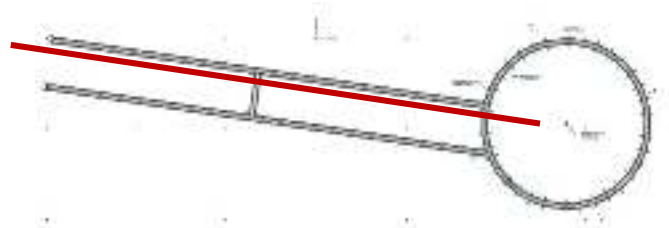




Soil Layers	
GZ5	Alluvium
GZ4	Silty clay 1
GZ3	Silty clay 2
GZ2	Medium sand
GZ1	Claystone

SITE CONDITIONS





Soil Layers	
GZ5	Alluvium
GZ4	Silty clay 1
GZ3	Silty clay 2
GZ2	Medium sand
GZ1	Claystone

SITE CONDITIONS

Soil Layers		Depth [m]	K_0 [-]	γ_{sat} [kN/m^3]	c' [kPa]	ϕ' [°]	E_{50}^{ref} [MPa]	E_{oed}^{ref} [MPa]	E_{ur}^{ref} [MPa]	m [-]	k [ms^{-1}]
GZ5	Alluvium	0 - 7,5	0,64	17	3	21	6	6	18	0,8	10^{-6}
GZ4	Silty clay1	7,5 - 15,5	0,44	22	8	34	30	30	90	0,8	10^{-10}
GZ3	Silty clay2	15,5 - 29,0	0,58	20	35	25	20	20	60	0,8	10^{-10}
GZ2	Medium sand	29,0 - 41,0	0,38	21	0	38	100	100	300	0,5	10^{-5}
GZ1	Claystone	> 41.0	0,38	22	40	38	150	150	450	1,0	10^{-7}

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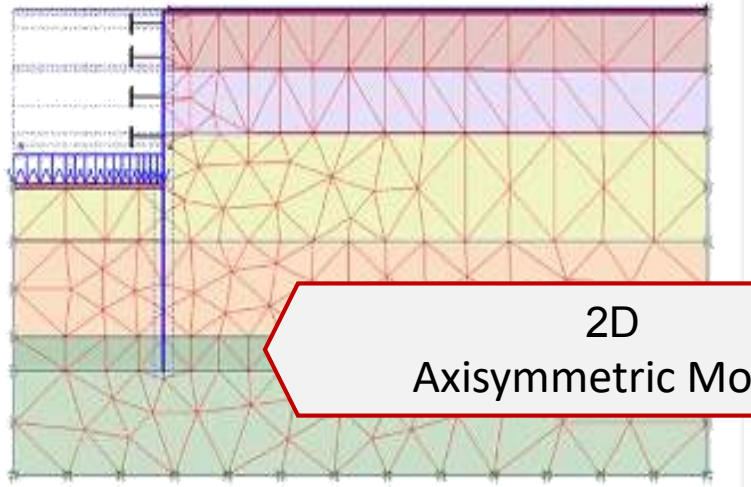
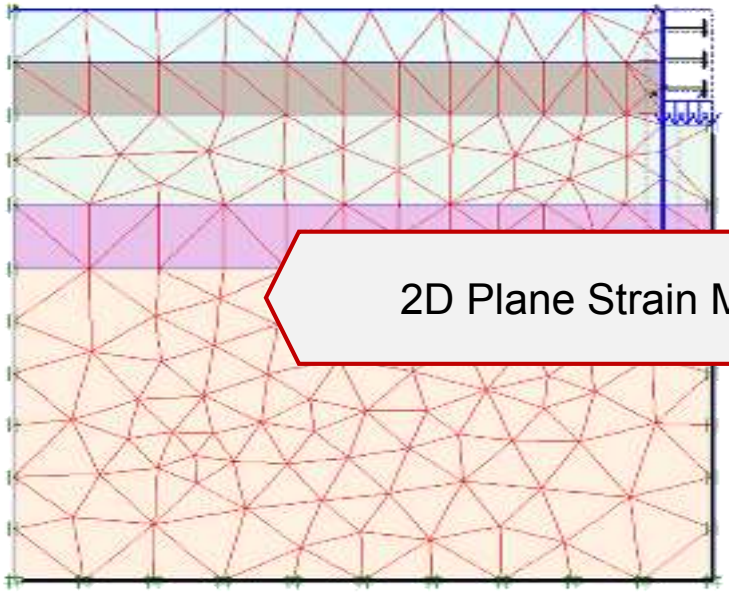
NUMERICAL MODELS



2D
Axisymmetric Model



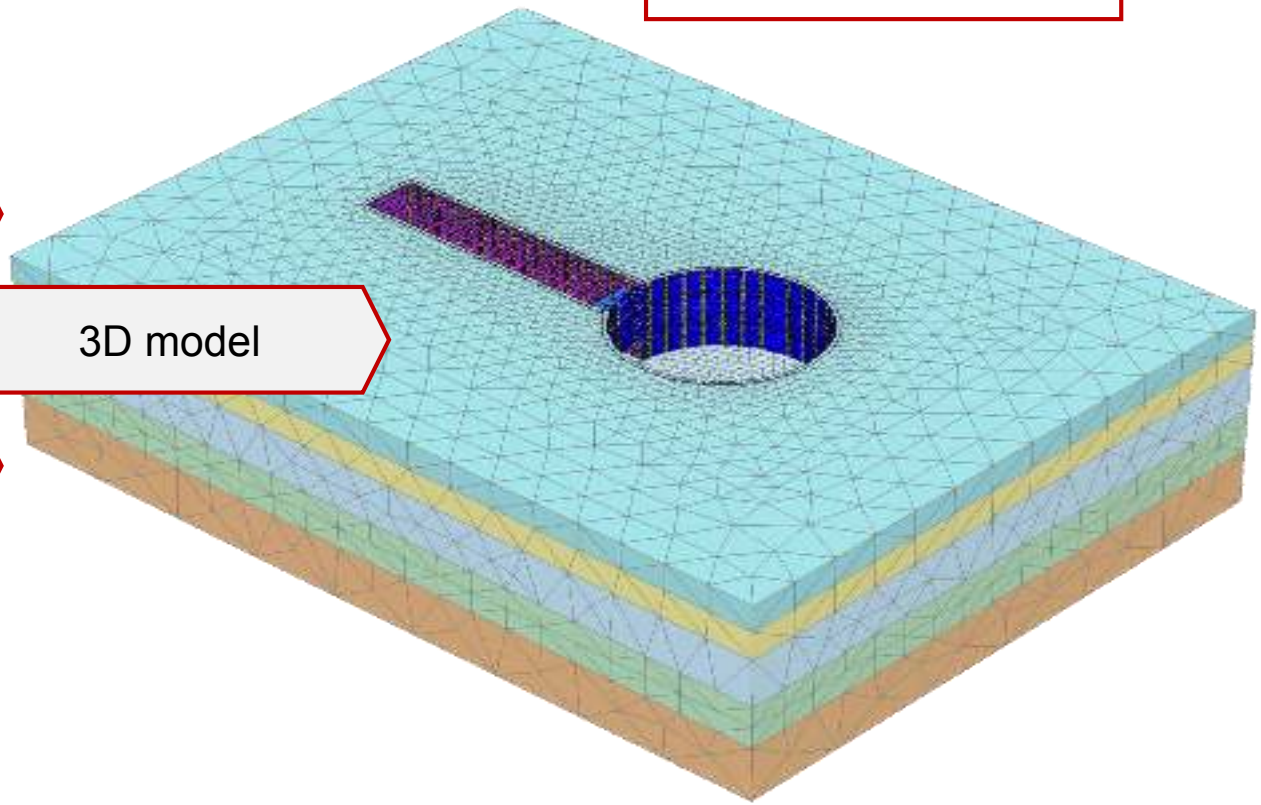
2D Plane Strain Model

PIT

TRENCH

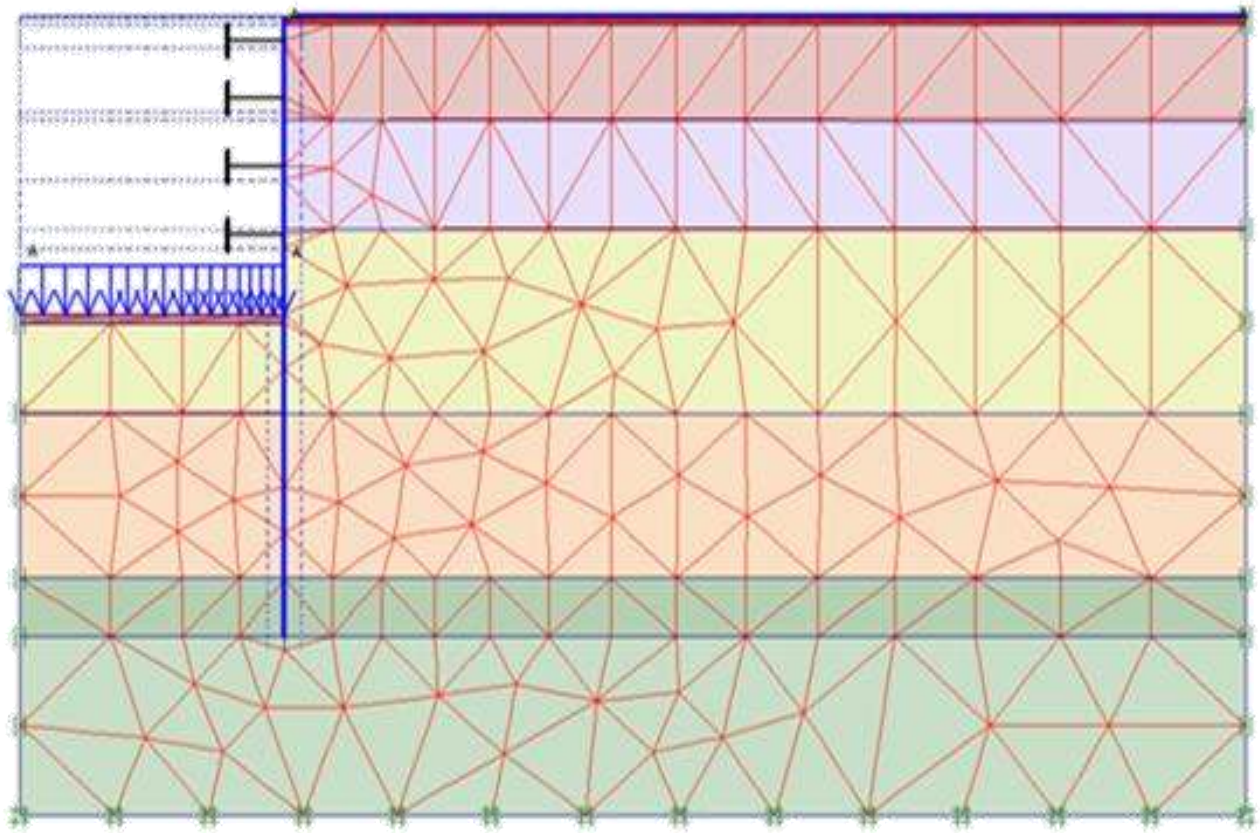
Software: PLAXIS

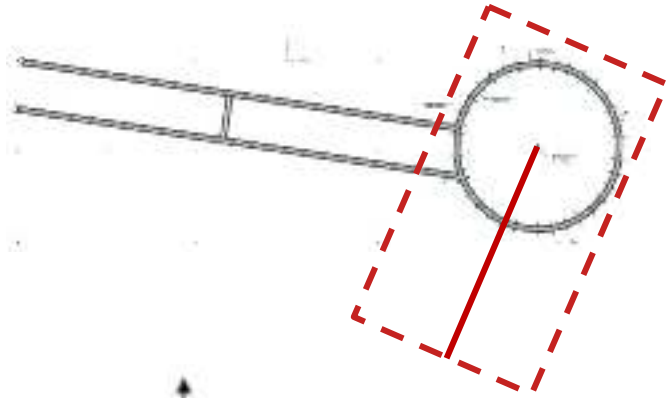
3D model

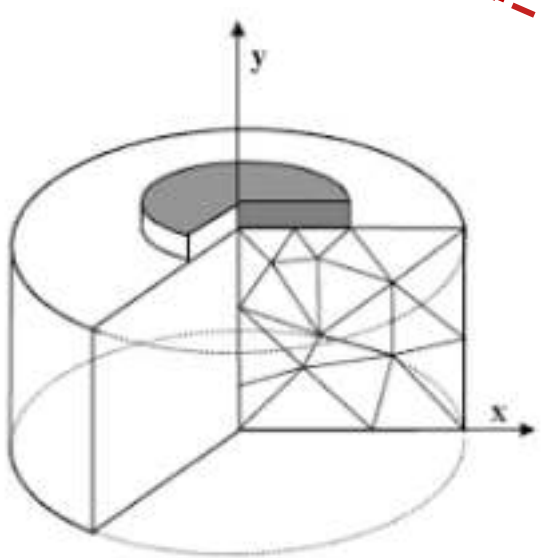


2D Axisymmetric Model - Pit

- Constitutive model: *Hardening-Soil*
- Diaphragm wall ↔ *plate*
- Ring beams ↔ *fixed-end-anchor*





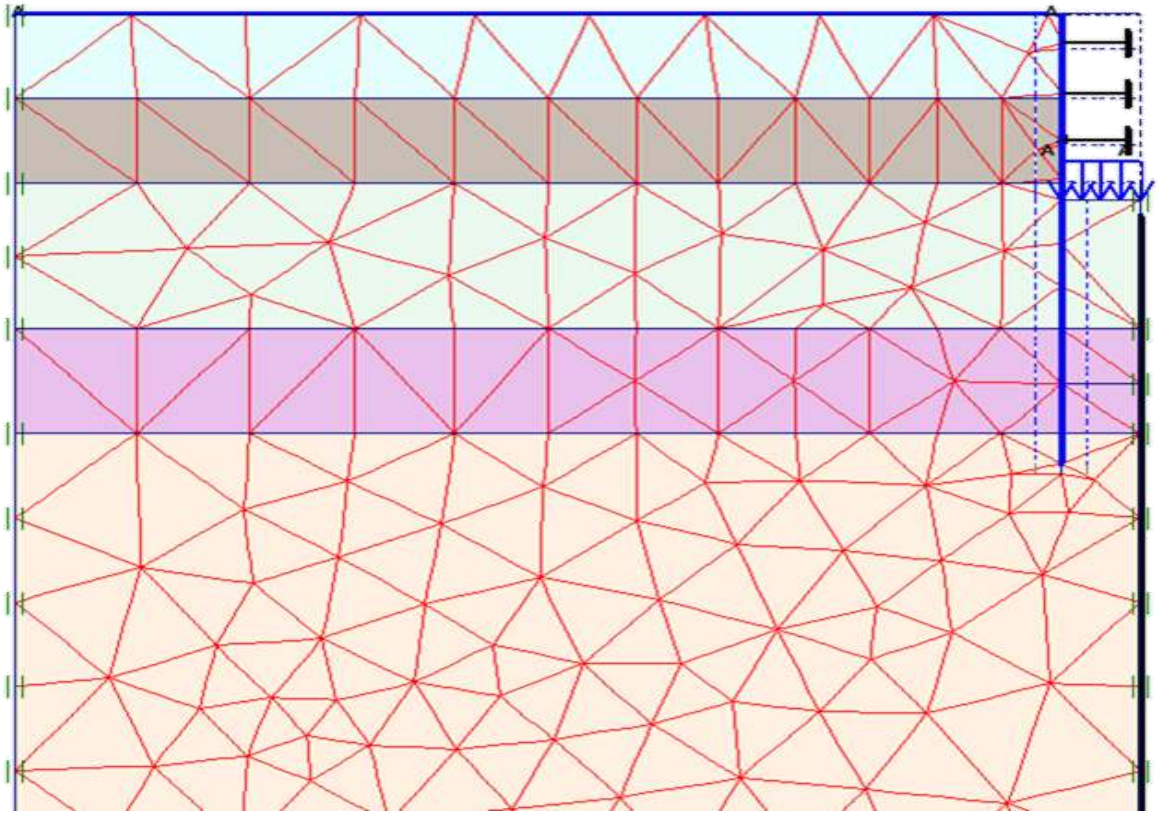


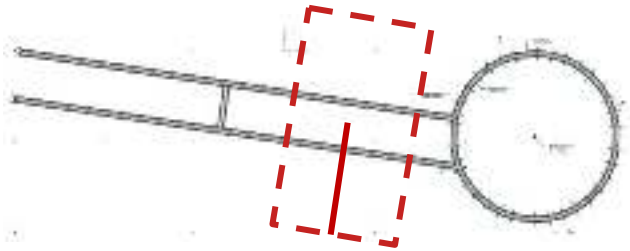
2D Plane Strain Model - Trench

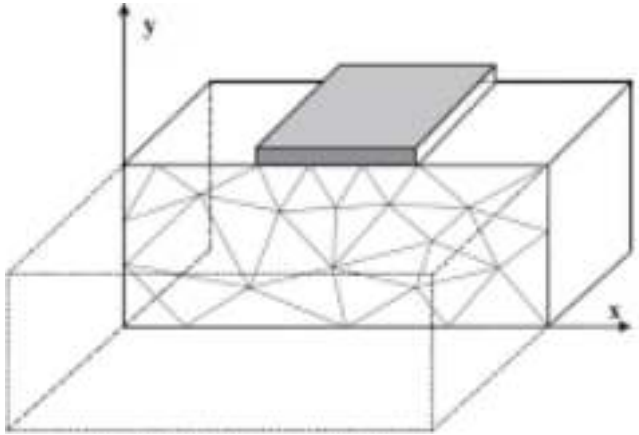
Constitutive model: *Hardening-Soil*

Diaphragm wall ↔ *plate*

Struts ↔ *fixed-end-anchor*





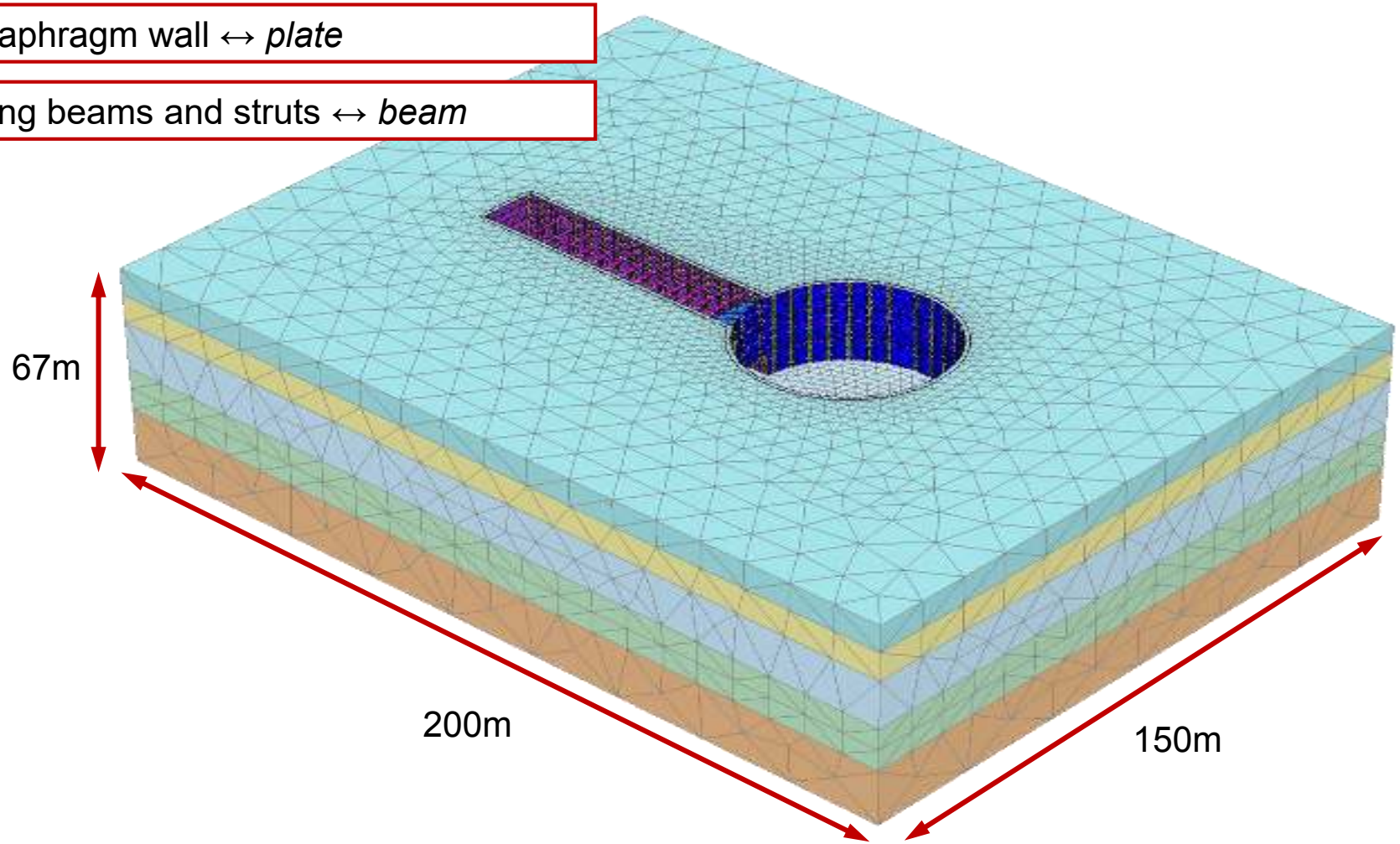


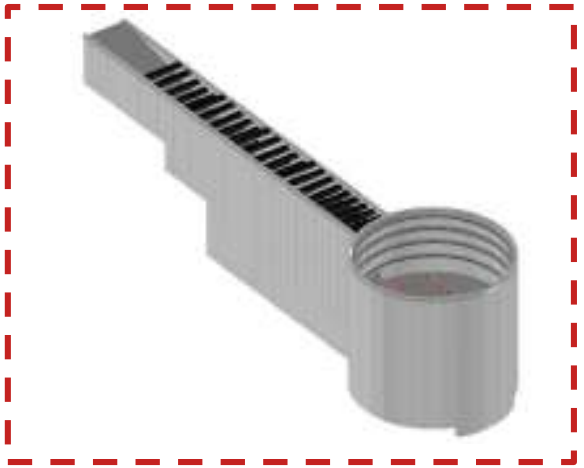
3D Model – Pit + Trench

Constitutive model: *Hardening-Soil*

Diaphragm wall ↔ *plate*

Ring beams and struts ↔ *beam*





MESH

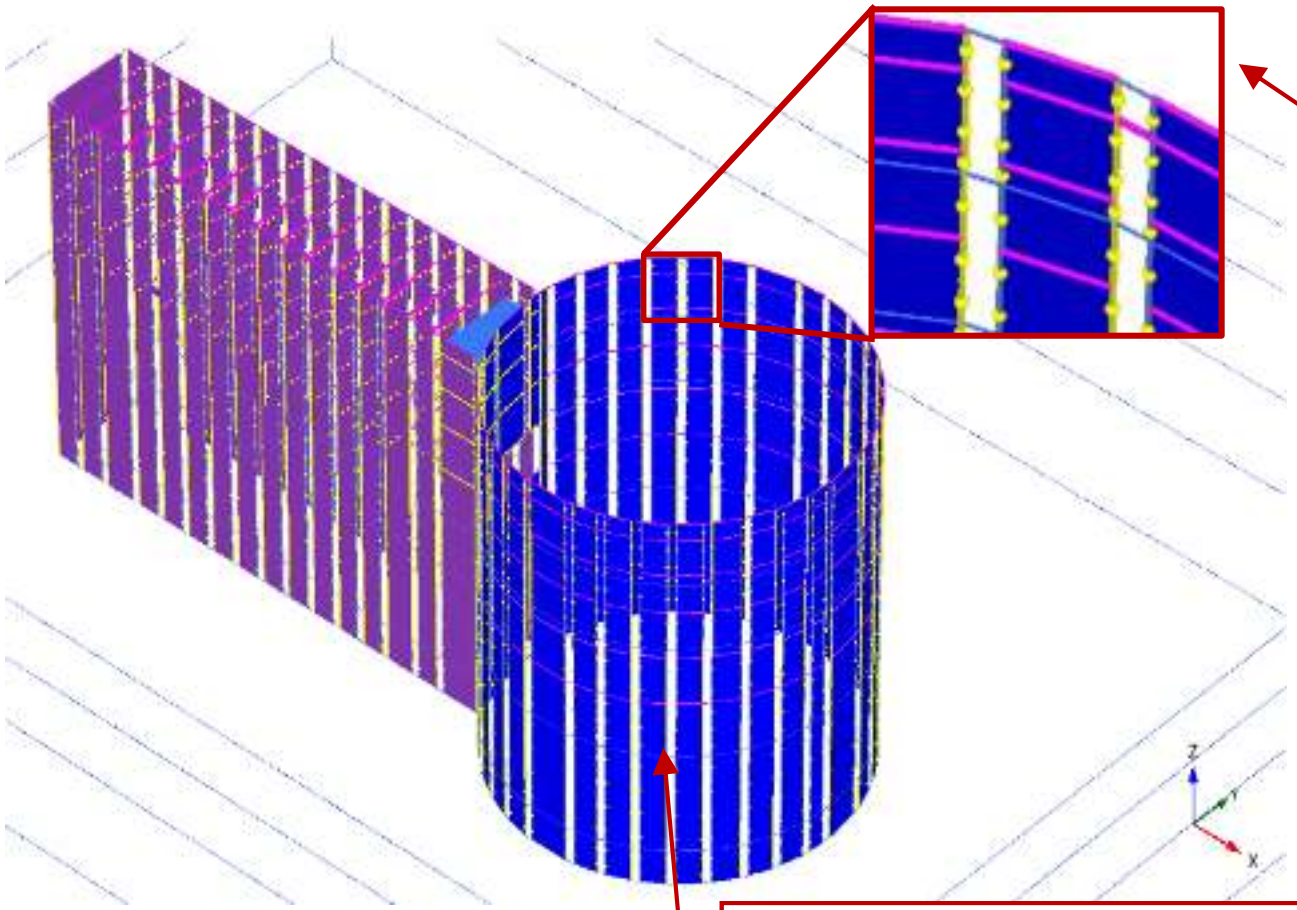
Finite Elements

137 692

Nodes:

2 065 380

3D Model – Pit + Trench



Hinged connection between diaphragm wall panels

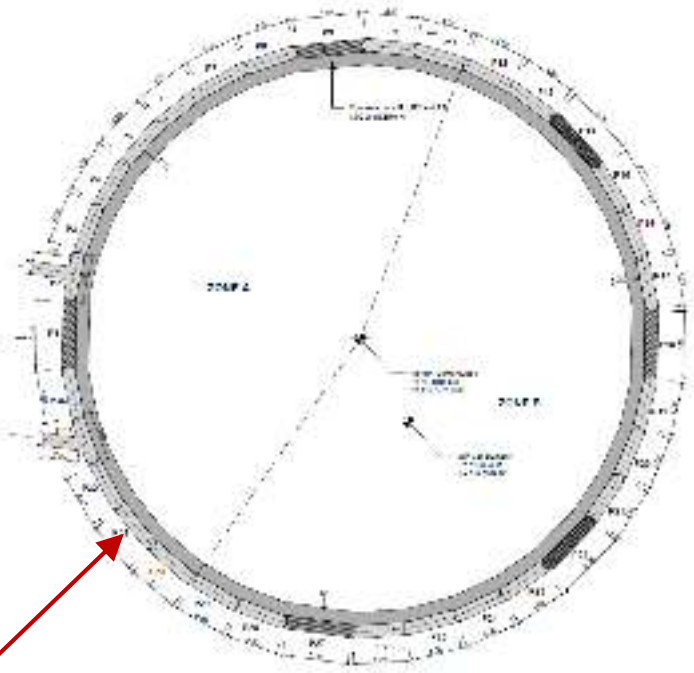
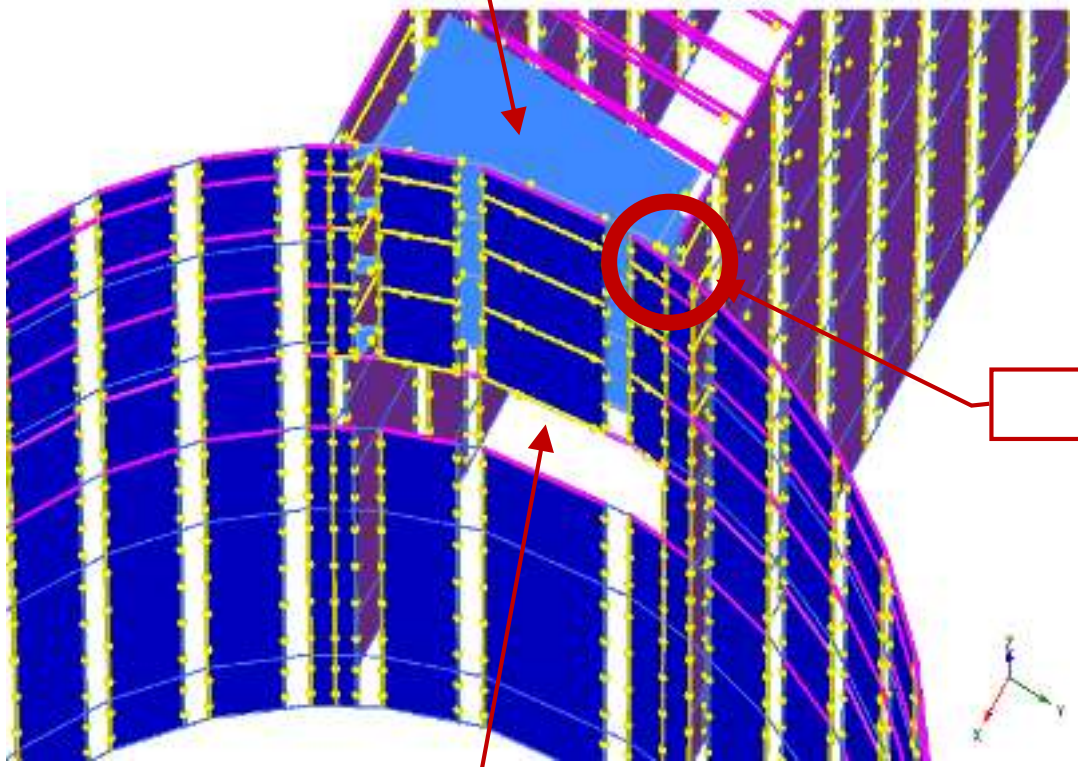


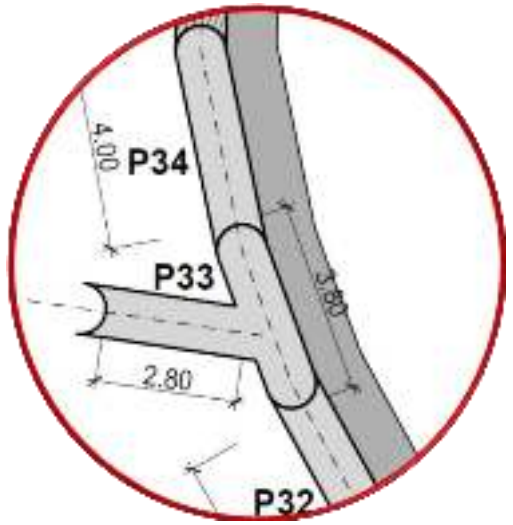
Plate ↔ Diaphragm wall panel

3D Model – Pit + Trench

Reinforced concrete bracing slabs



'T' Panel



Pit-trench opening connection

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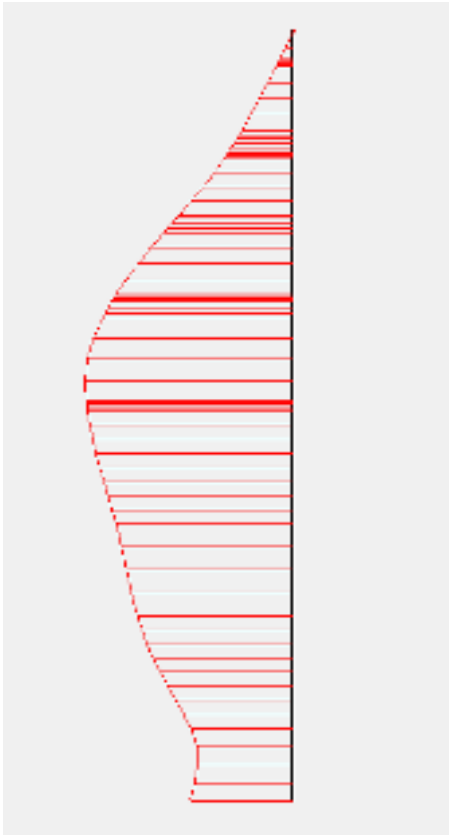
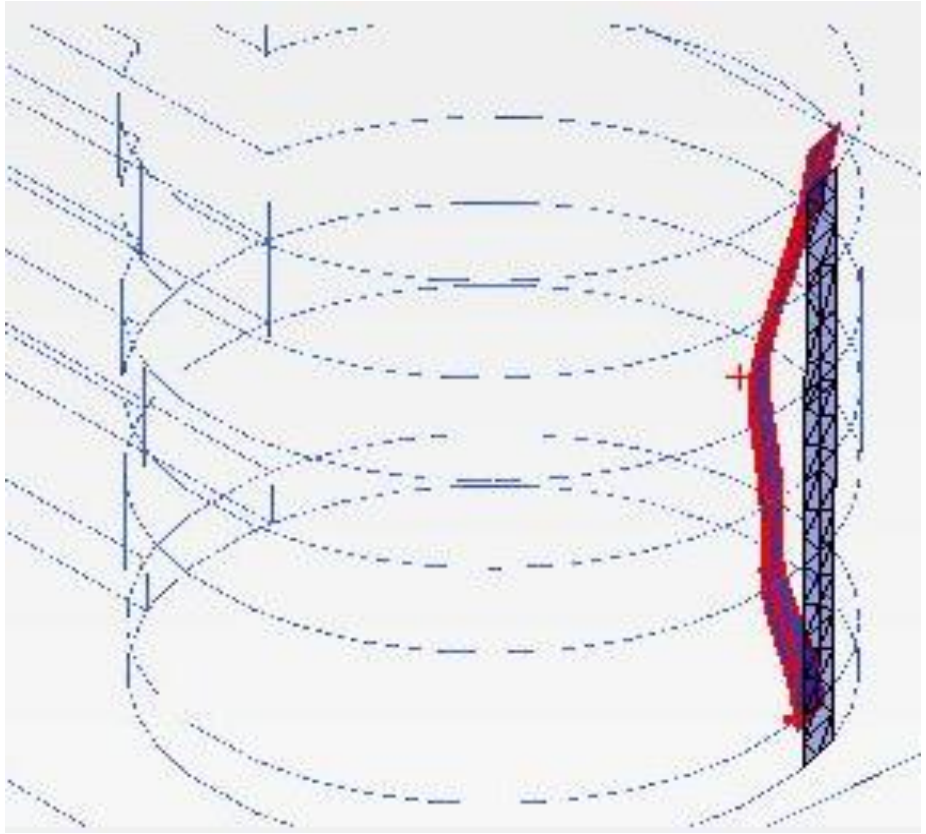
NUMERICAL MODELS RESULTS

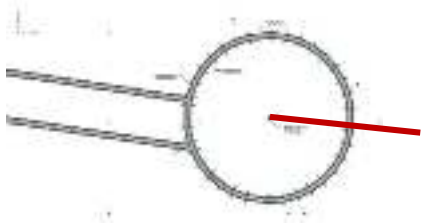
Pit Retaining Wall Horizontal Displacements

2D



3D





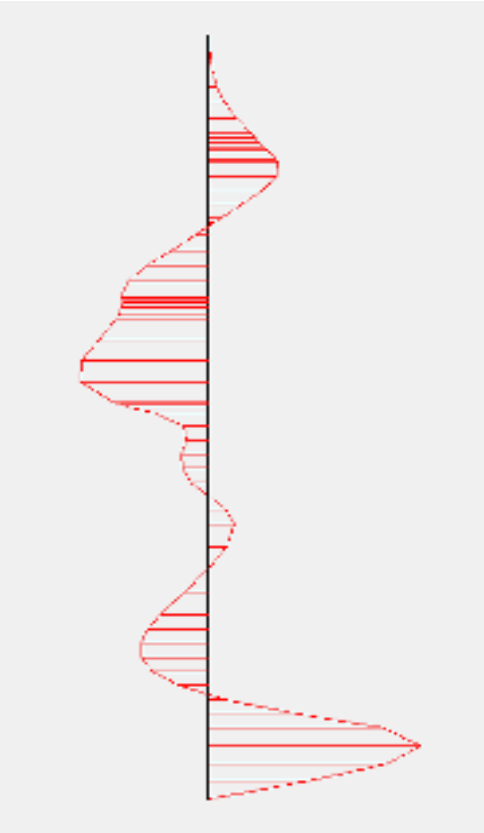
2D
u=5 mm

3D
u =6 mm

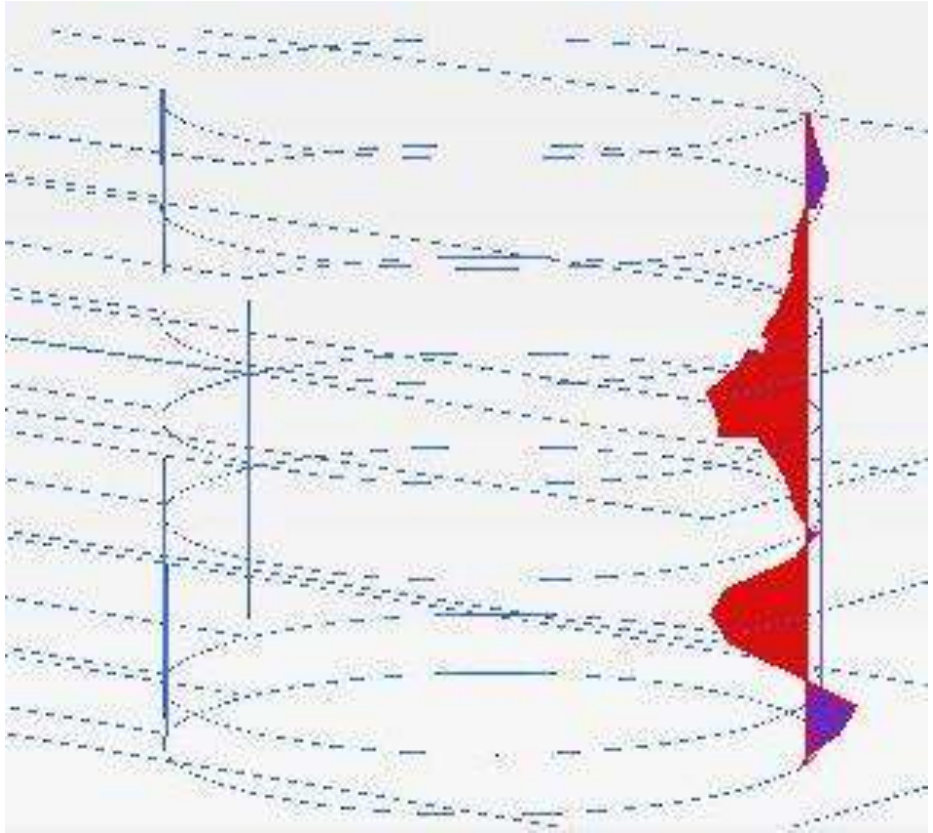
NUMERICAL MODELS RESULTS

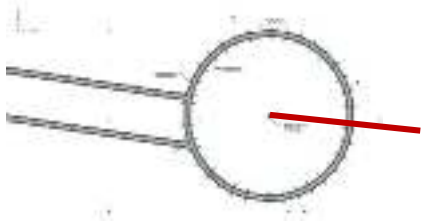
Pit Retaining Wall Bending Moments

2D Model



3D Model





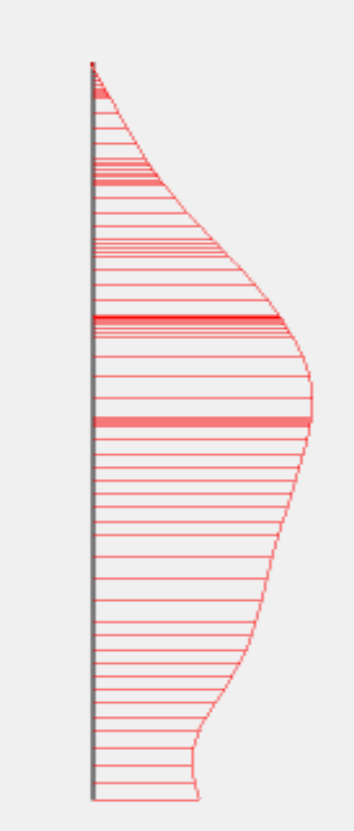
2D
M=272 kNm/m

3D
M=345 kNm/m

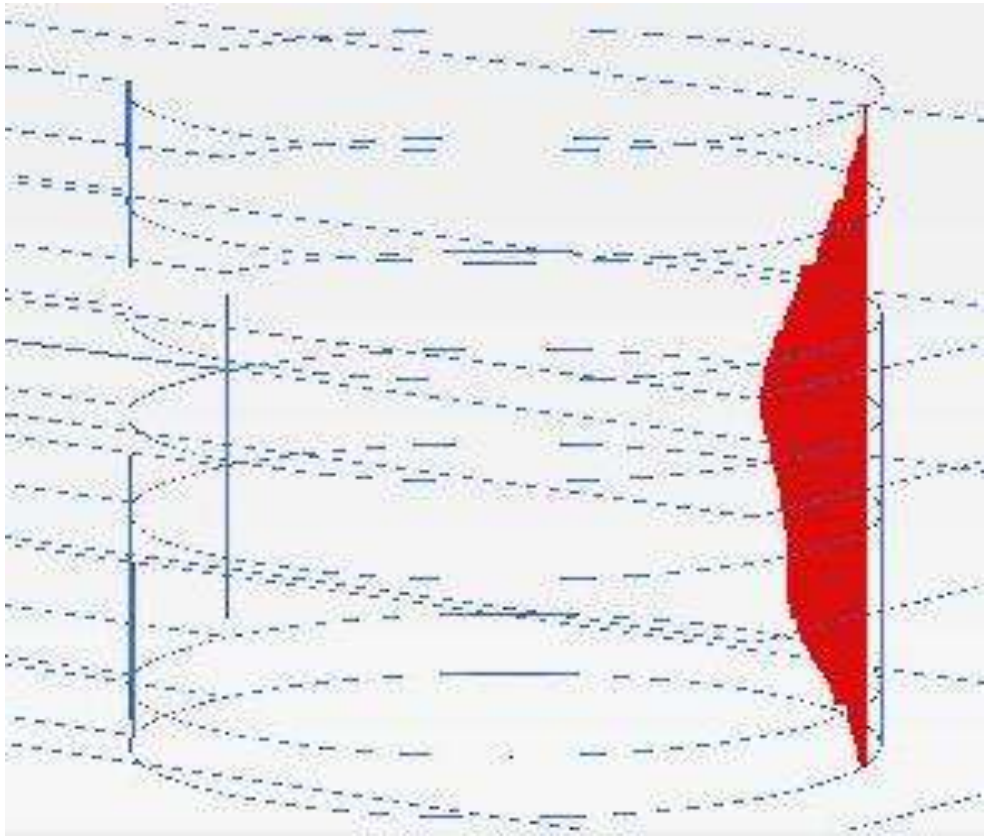
NUMERICAL MODELS RESULTS

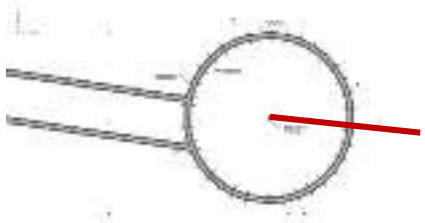
Pit Retaining Wall Hoop Stresses

2D Model



3D Model





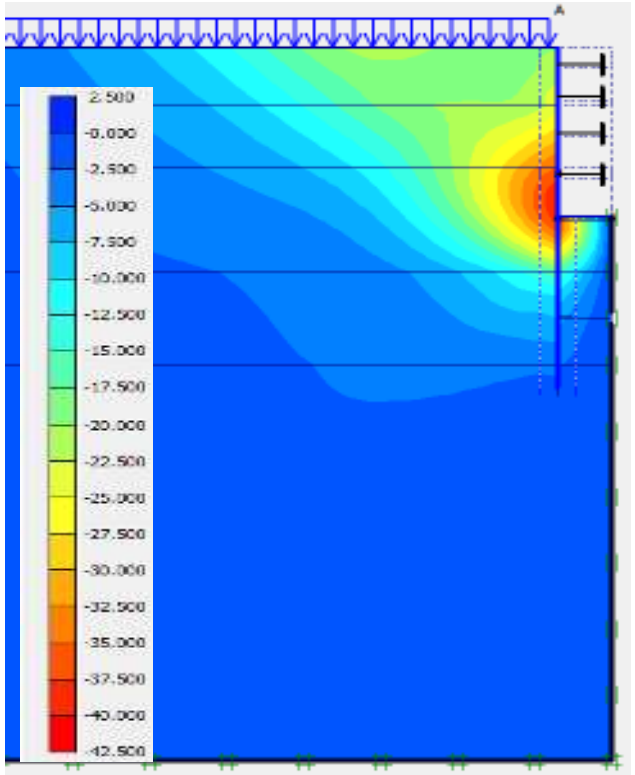
2D
N=7864 kN/m

3D
N=6270 kN/m

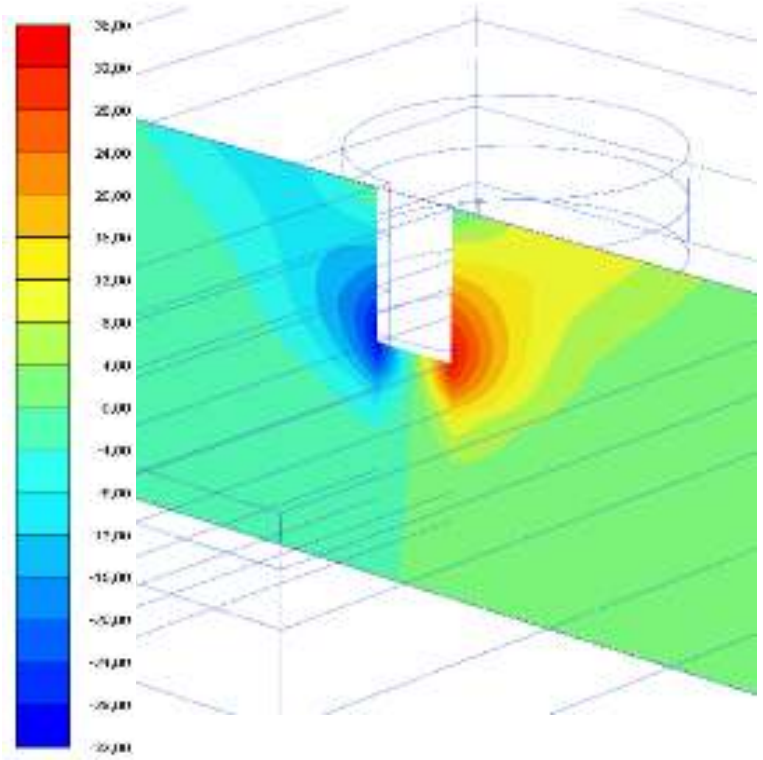
NUMERICAL MODELS RESULTS

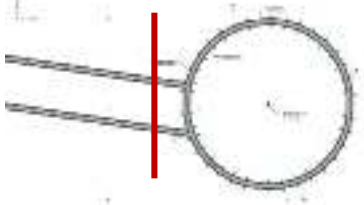
Trench Retaining Wall Horizontal Displacements

2D Model



3D Model





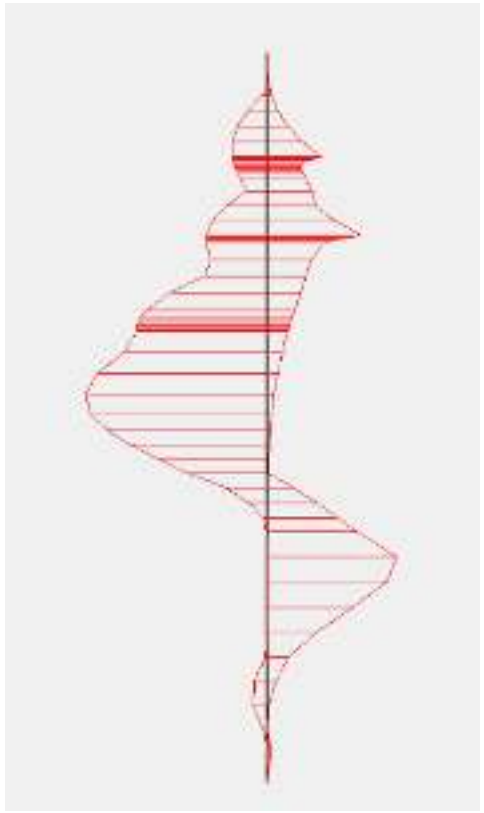
2D
u=41mm

3D
u=35mm

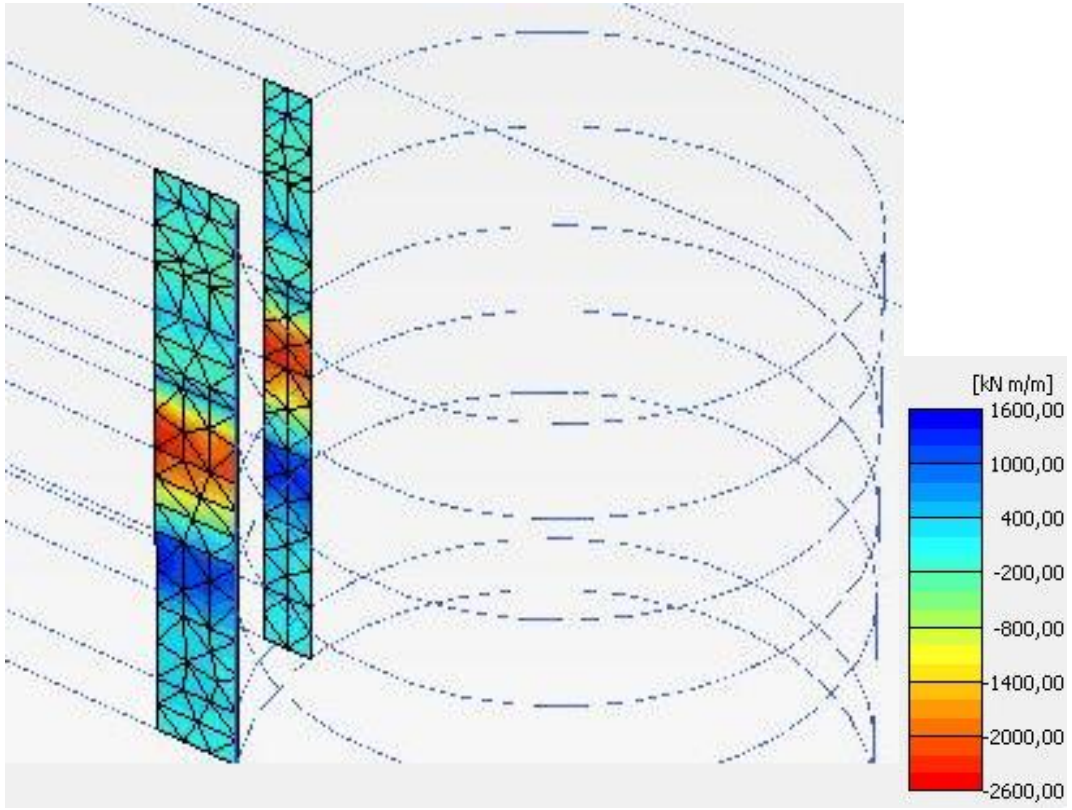
NUMERICAL MODELS RESULTS

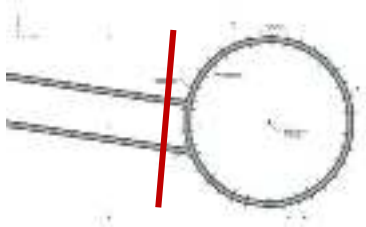
Trench Retaining Wall Bending Moments

2D Model



3D Model





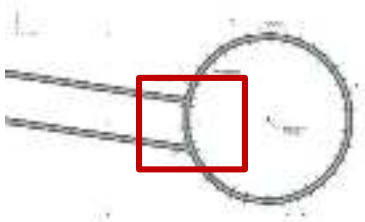
2D
M=2381 kNm/m

3D
M=2552 kNm/m

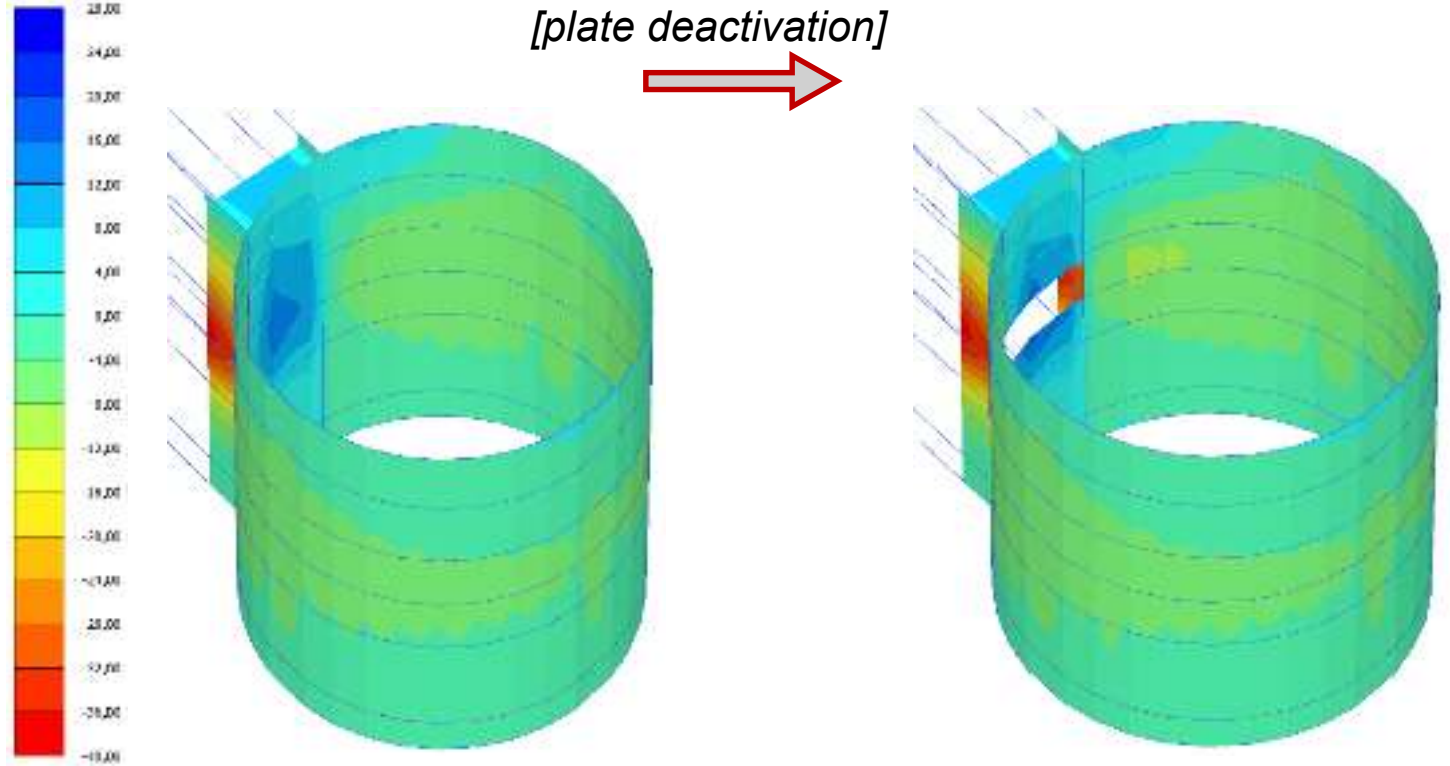
NUMERICAL MODELS RESULTS

Retaining Wall Horizontal Displacements

3D Model



Pit-Trench connection opening
[plate deactivation]



No increase in horizontal displacements

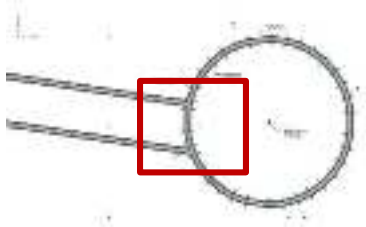
Efective brancig slab system

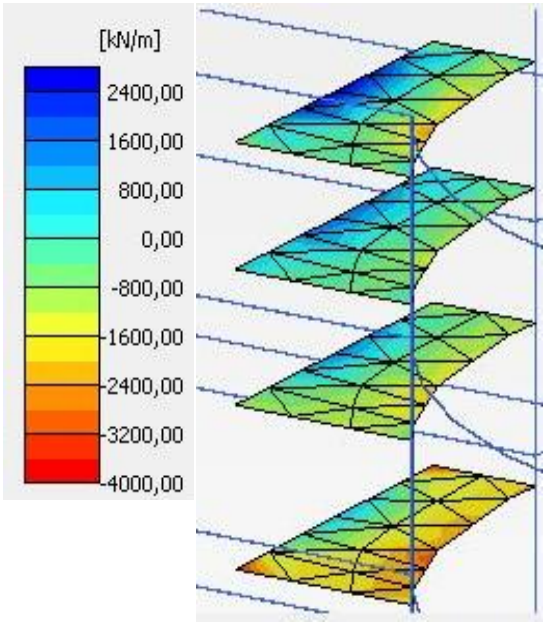
NUMERICAL MODELS RESULTS

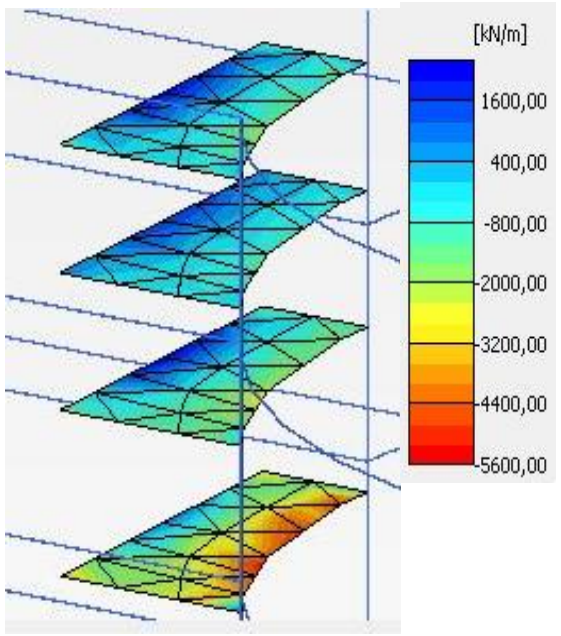
Bracing Slab Axial Stresses

3D Model

Pit-Trench connection opening
[plate deactivation]







$N_{compression}$

3665kN/m

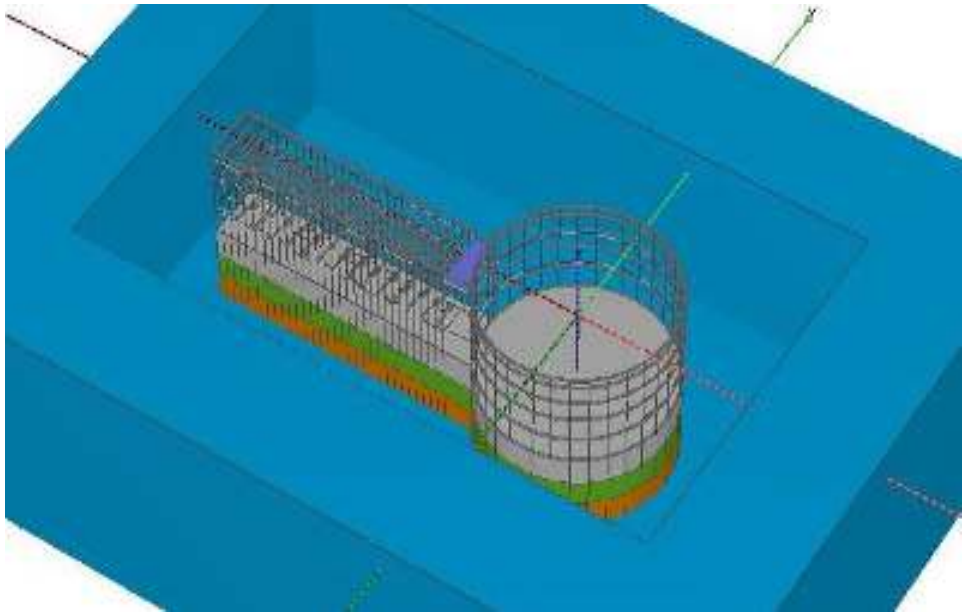
↓

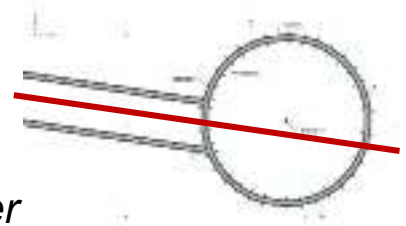
5232kN/m

NUMERICAL MODELS RESULTS

Hydrostatic Pressures

3D Model

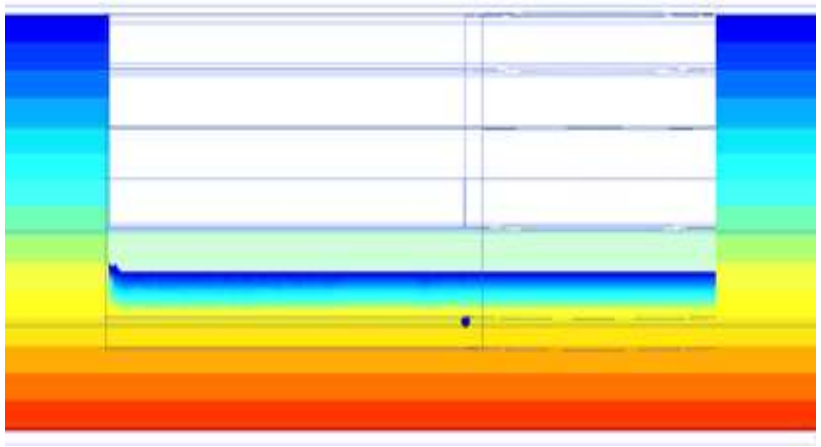




Permeable sand layer with groundwater under positive pressure located bellow the excavation level

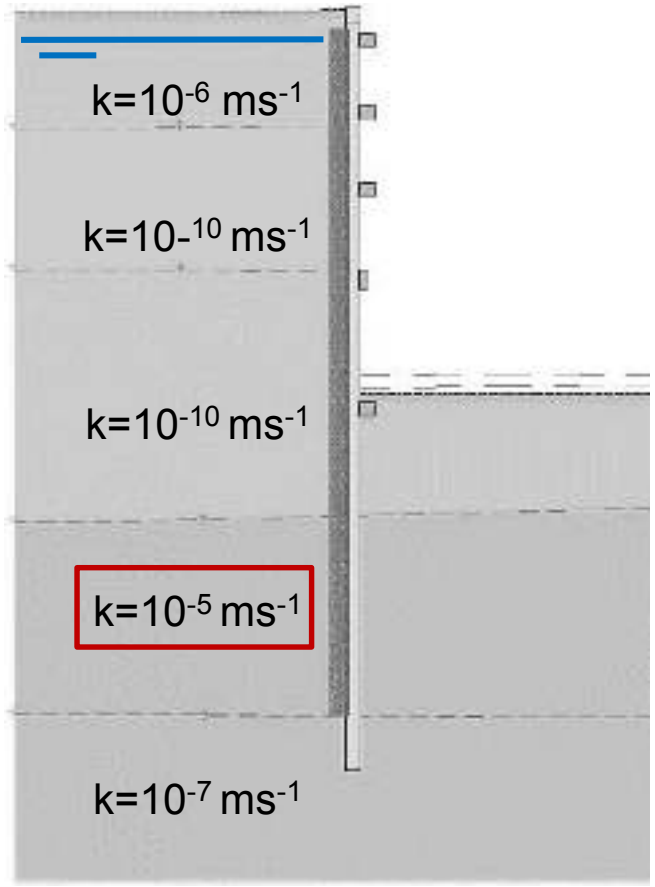
↓

Water head of the permeable layer was lowered to the level of its centre line simulating the dewatering effects of the pressure relief drills

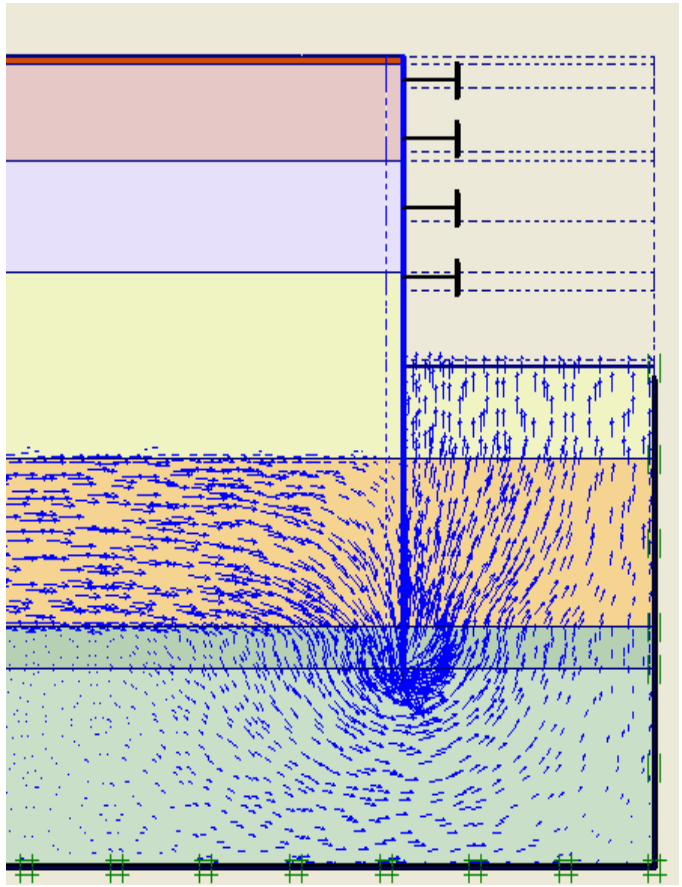


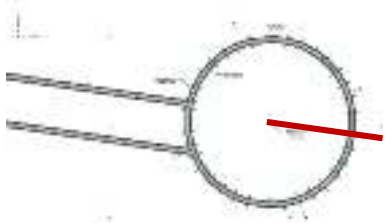
NUMERICAL MODELS RESULTS

Water flow analysis



2D Axisymmetric





Objective:
Optimization of the retaining wall length bellow excavation level aiming inflow control

Inflow estimative:
Q=95L/day

- INTRODUCTION
- STRUCTURE GEOMETRY
- SITE CONDITIONS
- NUMERICAL MODELS
- NUMERICAL MODELS RESULTS
- MAIN CONCLUSIONS

MAIN CONCLUSIONS

Structural design
Soil structure interaction
Soil behaviour

2D

- Preliminary analysis of pit and trench;
- Simple models with some level of symmetry or infinite length normal to the plane section of the analysis;
- Low computing time;
- Easy use iterative on iterative analysis and sensitivity analysis.

3D

- General structure behaviour assessment;
- Pit-Trench connection opening modelling;
- Overall effects of earth pressure imbalance due to trench excavation.

MAIN CONCLUSIONS

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4 SEPTEMBER – SESSION TC207 – Soil-Structure

NUMERICAL ANALYSIS OF AN UNSYMMETRICAL RAILCAR UNLOADING PIT AND CONNECTION TRENCH

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4 SEPTEMBER – SESSION TC208 - I - Slope Stability

URGENT STABILIZATION, RECONSTRUCTION AND REINFORCEMENT SOLUTIONS OF HIGH RETAINING WALLS IN LISBON, PORTUGAL

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João Farinha, HTecnic, joao.farinha@htecnic.com
Gonçalo Lopes, HTecnic, joao.farinha@htecnic.com

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- INTRODUCTION
- EARTH RETAINING WALLS COLLAPSE POSSIBLE CAUSES
- URGENT REINFORCED MEASURES
- GEOLOGICAL AND GEOTECHNICAL SCENARIO
- RETAINING WALL INVESTIGATION
- STABILIZATION, RECONSTRUCTION AND REINFORCEMENT SOLUTIONS
- CONSTRUCTION CONDITIONS
- MONITORING PLAN
- FINAL REMARKS

- **INTRODUCTION**
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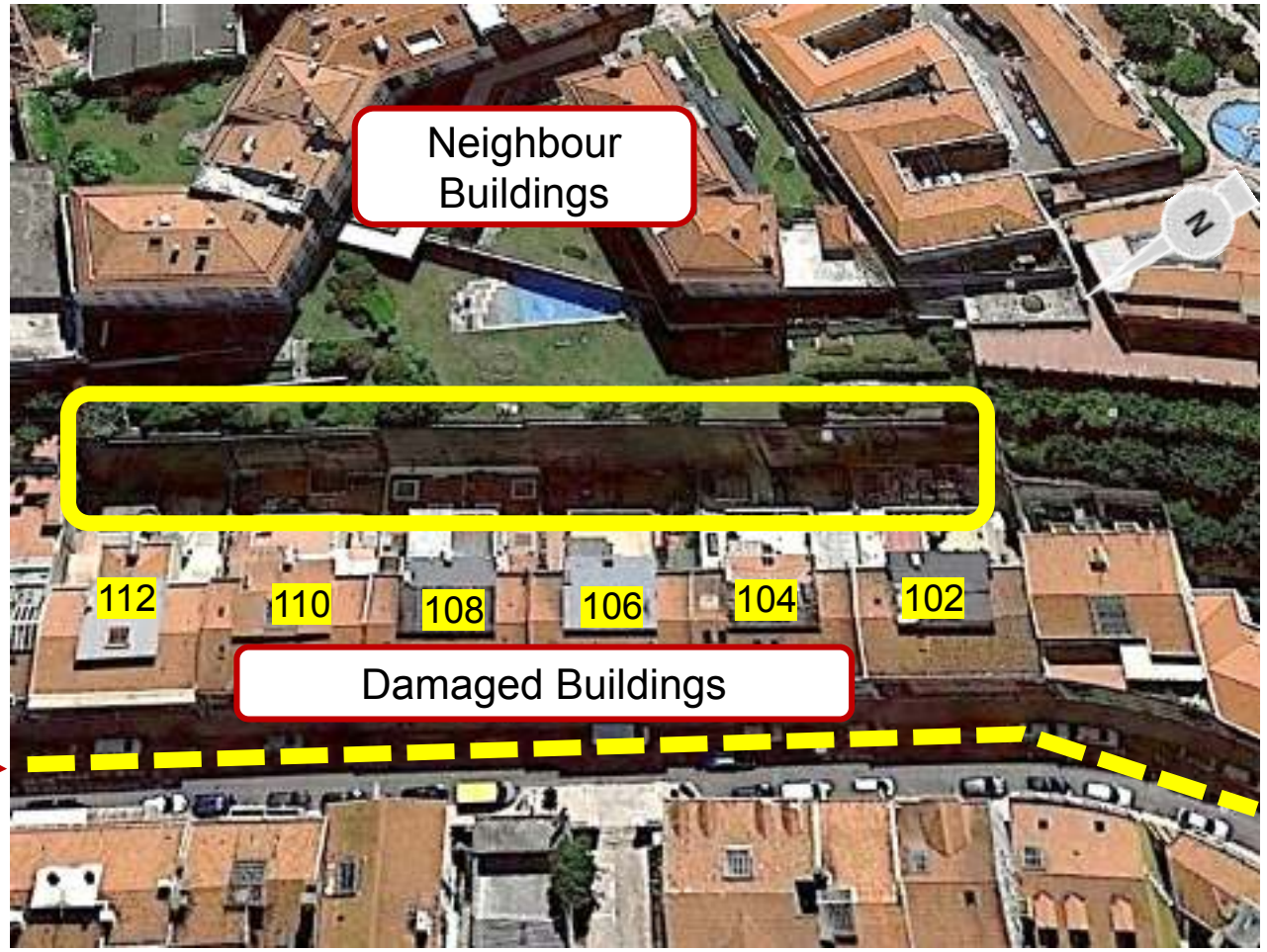
- FINAL REMARKS

INTRODUCTION

Graça, Lisbon, Portugal



INTRODUCTION

27th february 2017

Partial Collapse of Central Retaining Walls

Retained Soil Landslide

Buildings Severe Structural Damage

Building Residents Re-housing

Urgent Measures Undertaken

INTRODUCTION

INTRODUCTION

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- INTRODUCTION
- **EARTH RETAINING WALLS COLLAPSE POSSIBLE CAUSES**
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- FINAL REMARKS

EARTH RETAINING WALLS COLLAPSE POSSIBLE CAUSES

Retaining Wall Height ≈19m | Lenght ≈ 90m

Partial Collapse of Central Retaining Walls

Hydrostatic Horizontal Pressure

+

Weak Reinforced Concrete Resistance

High Rainfall

Garden Watering

Inefficiency of Drainage Systems

Reinforced concrete dated of 1955

EARTH RETAINING WALLS COLLAPSE POSSIBLE CAUSES

Existence of a soil layer with very low permeability above which was probably installed a hydrostatic horizontal pressure on the wall leading to its rupture

- INTRODUCTION
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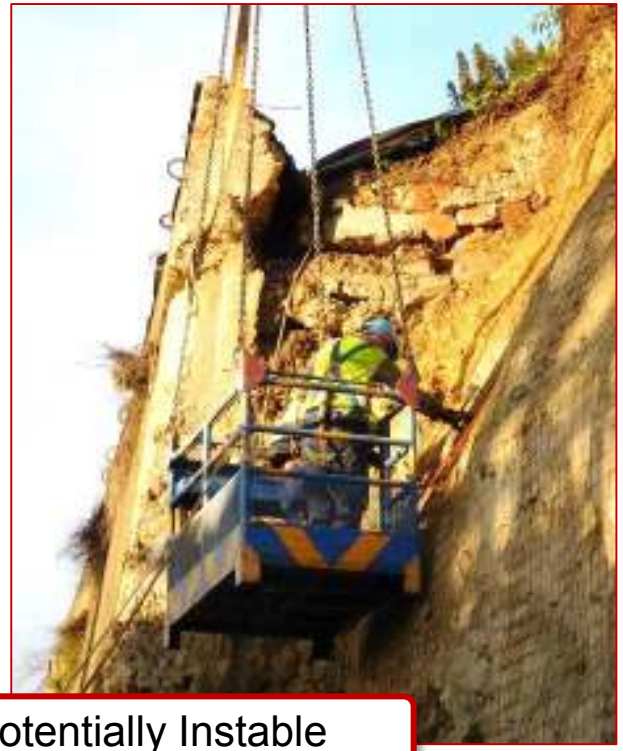
URGENT REINFORCED MEASURES



Potentially Instable Blocks Removing

Reinforced Shotcrete Projection Over the Soil Sliding Surface

Temporary Building Shoring

- INTRODUCTION
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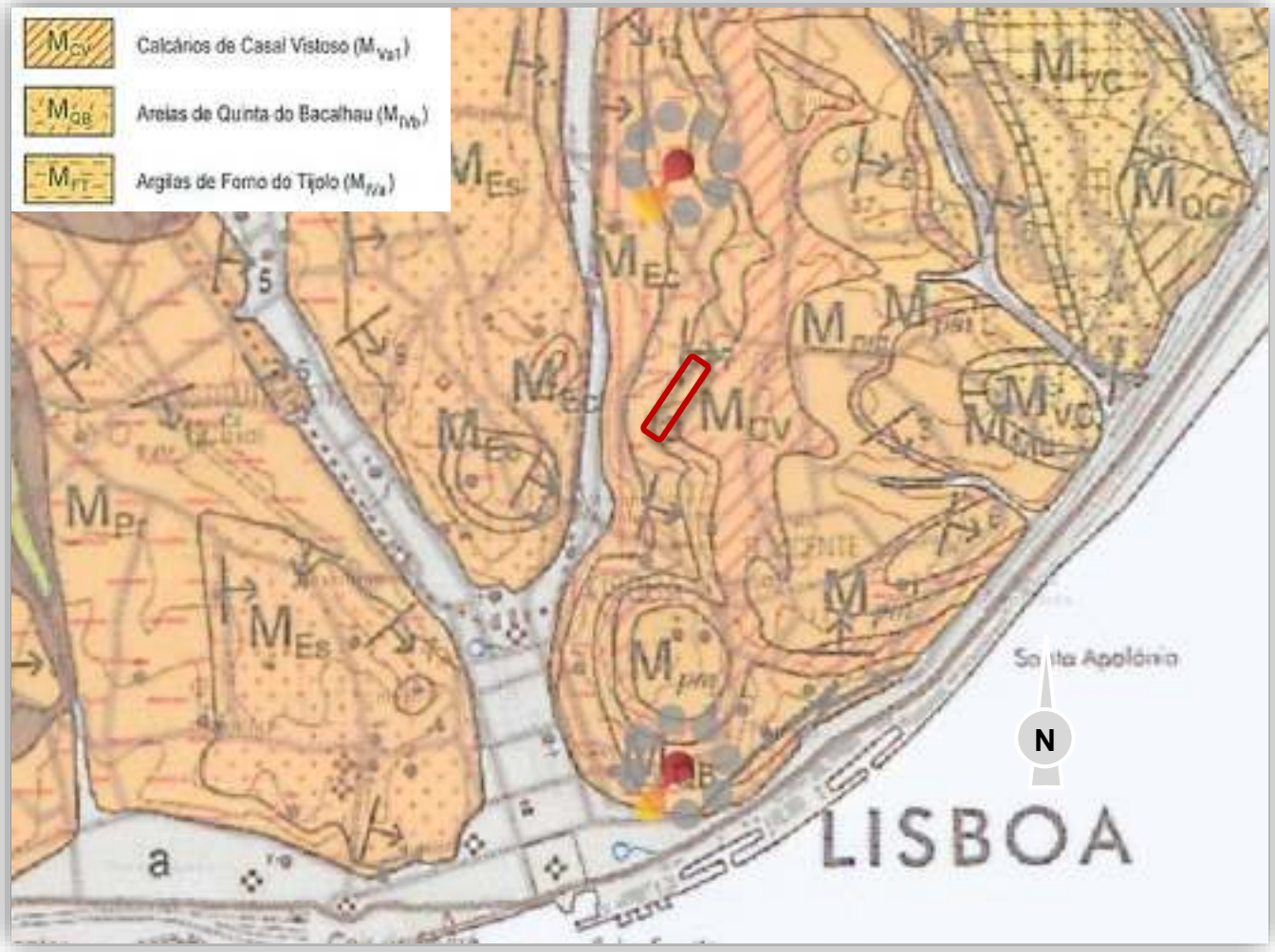
GEOLOGIC AND GEOTECHNICAL SCENARIO



Geologic Map of Portugal

Geologic Strata

Miocene

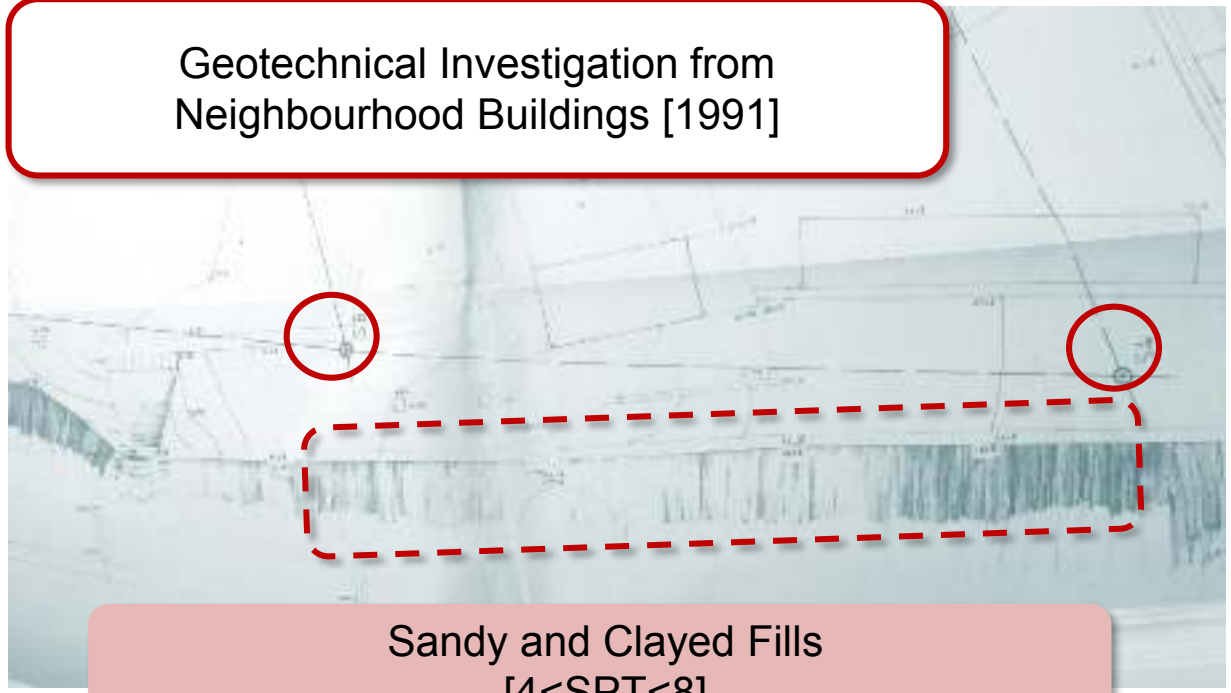
"M_{QB} - Quinta do Bacalhau Sands"

Predominant occurrence of sands with micaceous clay lenticules

source: geoportal.lneg.pt
Geologic Map of Portugal scale 1:50.000

GEOLOGICAL AND GEOTECHNICAL SCENARIO

Geotechnical Investigation from Neighbourhood Buildings [1991]

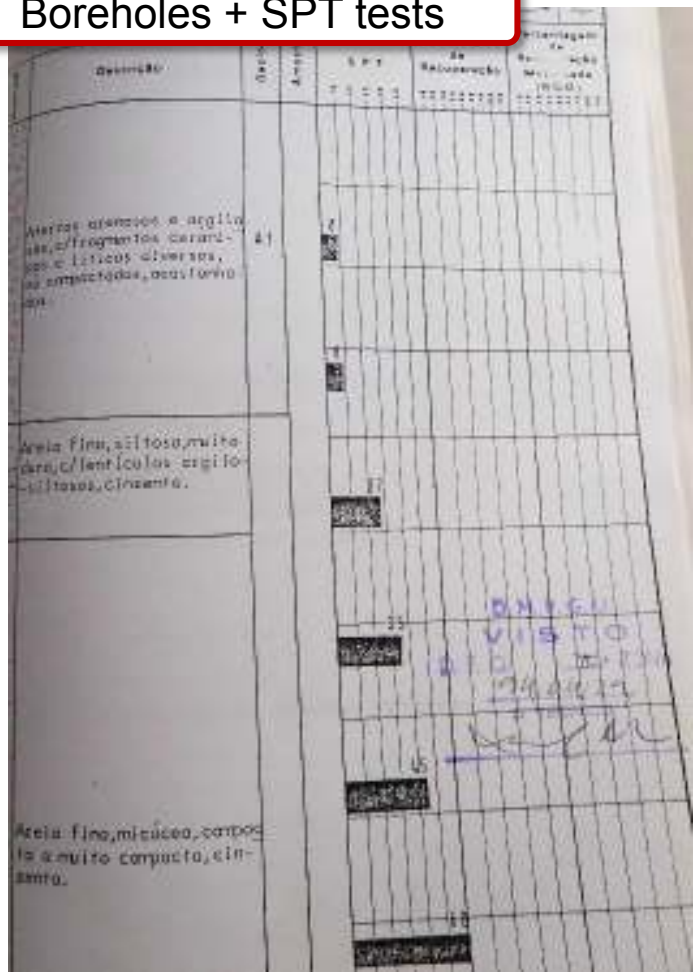


Sandy and Clayed Fills
[4<SPT<8]

Sands with a Limestone Fragments
[26<SPT<38]

Sands with Silty-Clay Lenticules
[SPT>60]

Boreholes + SPT tests



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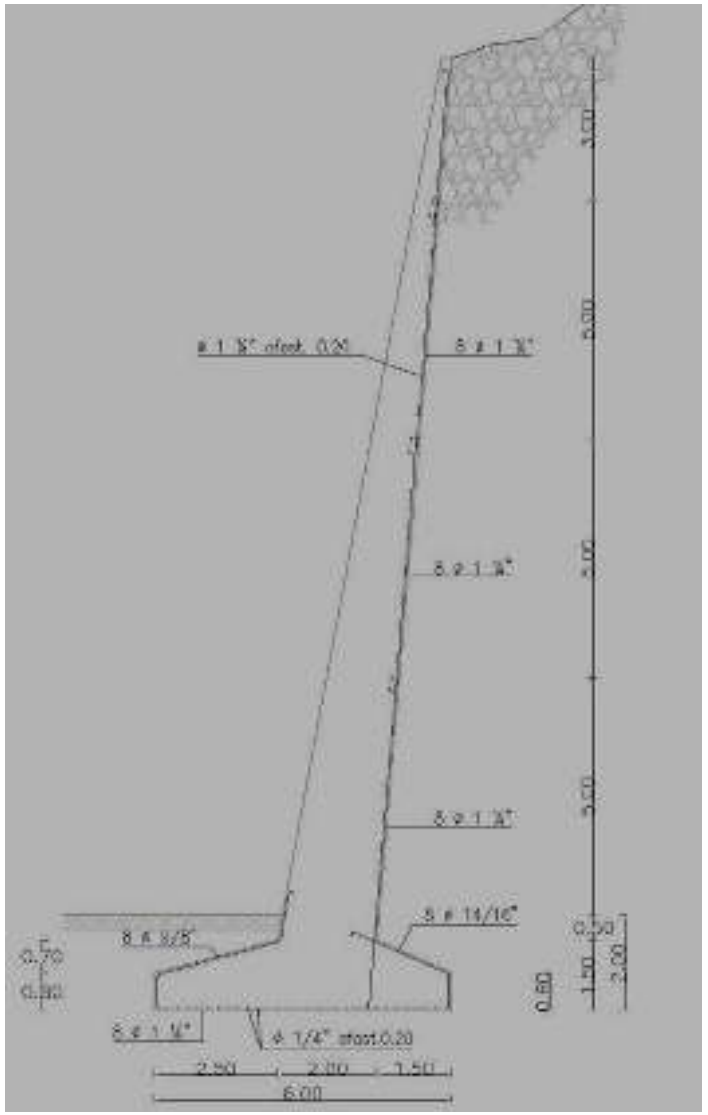


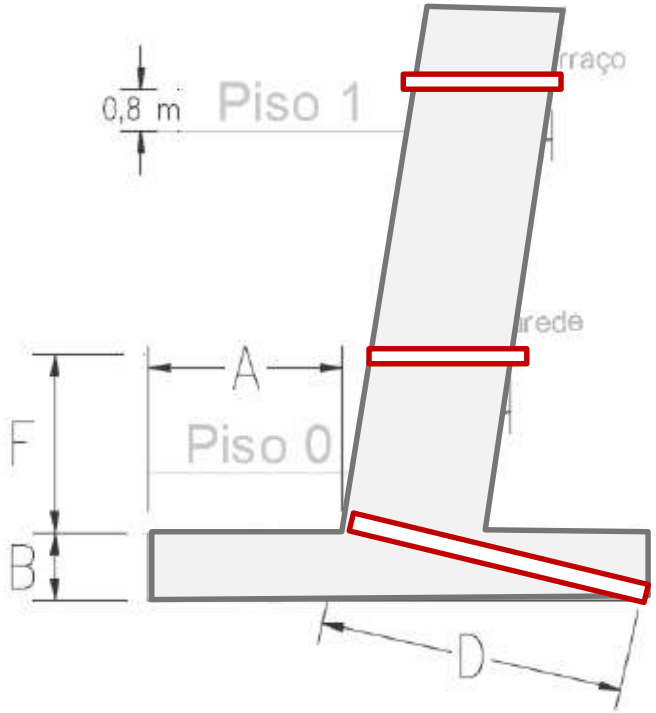
RETAINING WALL INVESTIGATION

Retaining Wall Design Plans [1955]

- Cantilever Retaining Walls
- Height ≈ 19m
- Wall thickness increasing with depth
  - top thickness = 0,20m
  - base thickness = 2,00m
- Strip Footing
  - weight = 6,00m
- Low steel ratio

RETAINING WALL INVESTIGATION

Retaing Wall Core Drilling [2017]



Retaining Wall Geometry Acessment
- Thickness a two different levels -
- Footing Width -

Laboratory Tests
Unconfined Compression Test
- Rupture Tension -
- Elastic Modulus -

σ=11,25 MPa [s=3,4 MPa]

E=17,2 GPa

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STABILIZATION, RECONSTRUCTION AND REINFORCEMENT SOLUTIONS

Goals

- Collapsed Retaining Walls Reconstruction
- Retaining Walls Re-confinement
- Safety Global and Local Increase regarding Static Hydrostatic and Dynamic Loads
- Reinforcement of Drainage Systems

Conditions

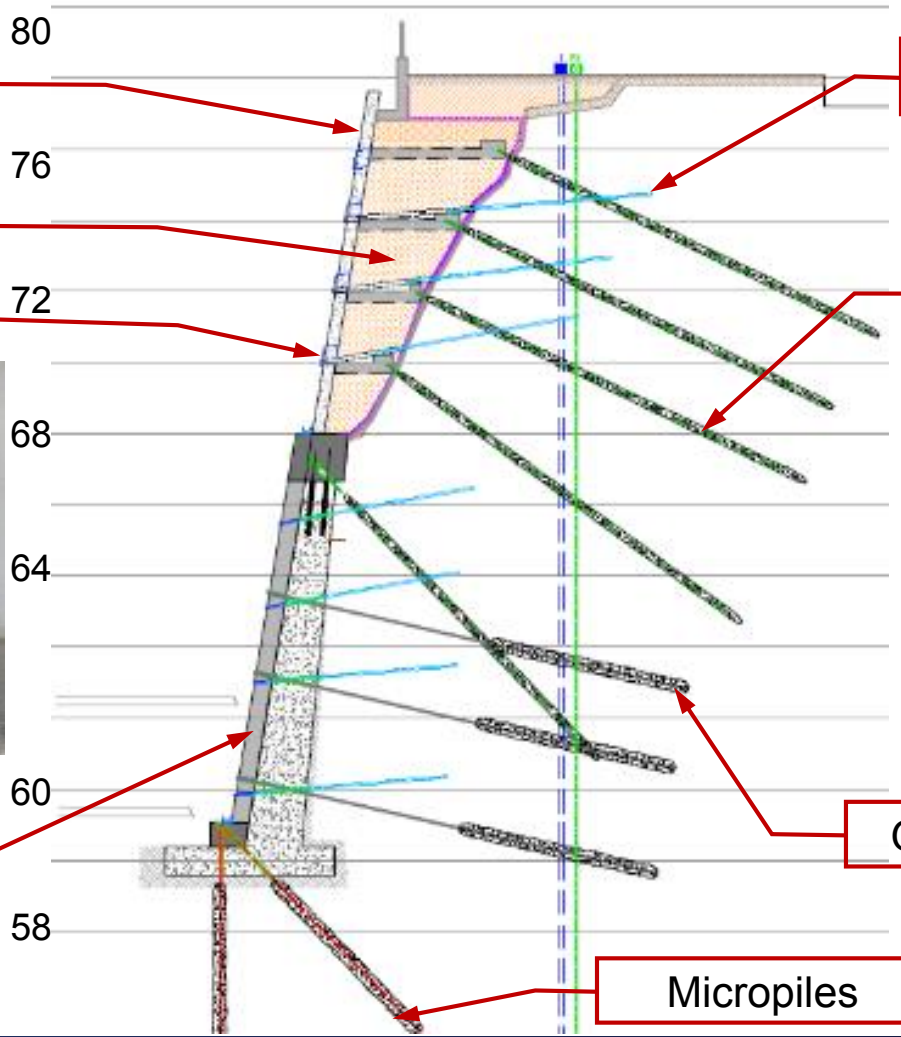
- Urgent Intervention
- Difficult Equipment Accessibility

STABILIZATION, RECONSTRUCTION AND REINFORCEMENT SOLUTIONS

Reinforced Concrete Wall and Slabs

Light Weight Coarse Aggregates Fill

Drainage Windows



Geodrains

Soil Nails connected to the Slabs

Ground Anchors

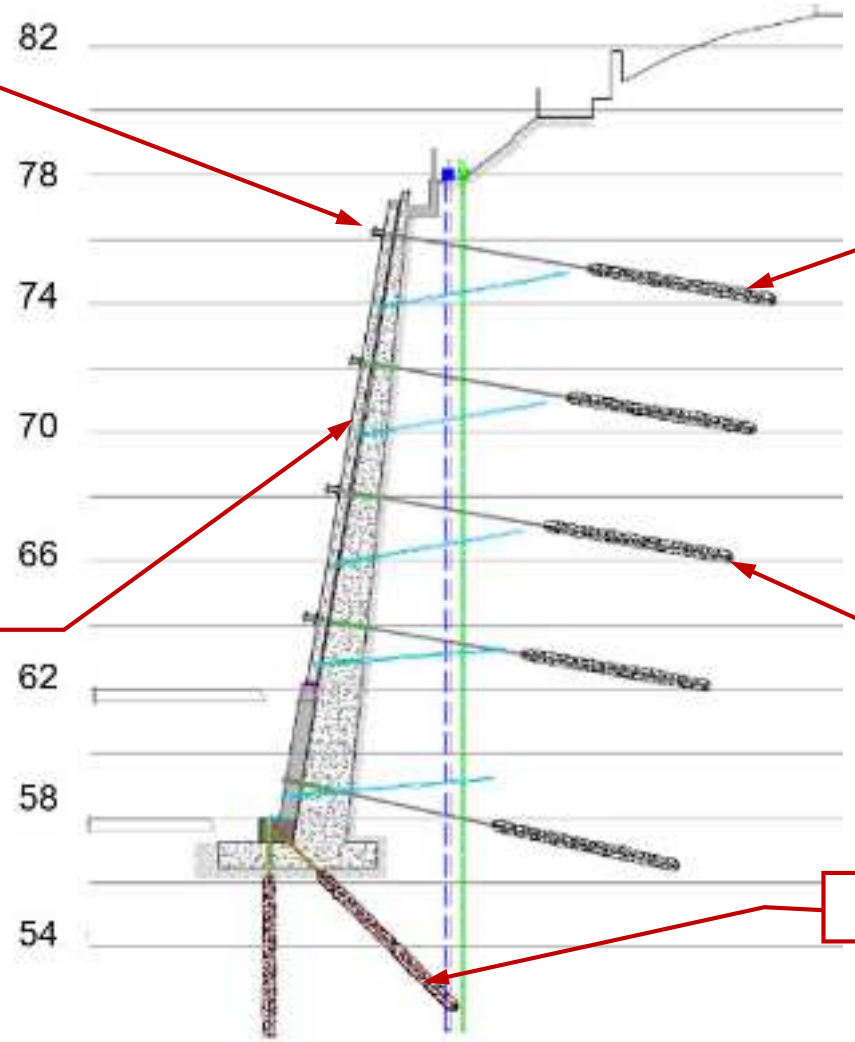
Reinforced Concrete Coating Wall

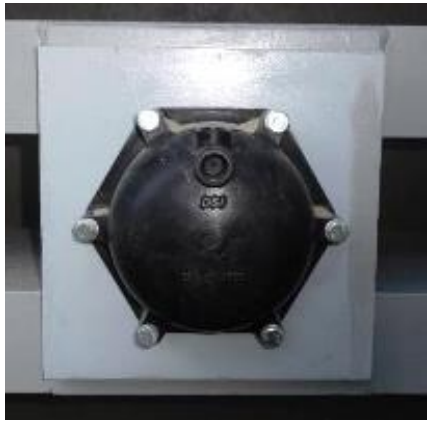
Micropiles

STABILIZATION, RECONSTRUCTION AND REINFORCEMENT SOLUTIONS

Steel Grid installed against the Retaining Wall

Projection of a high resistance mortar with a carbon fibre mesh

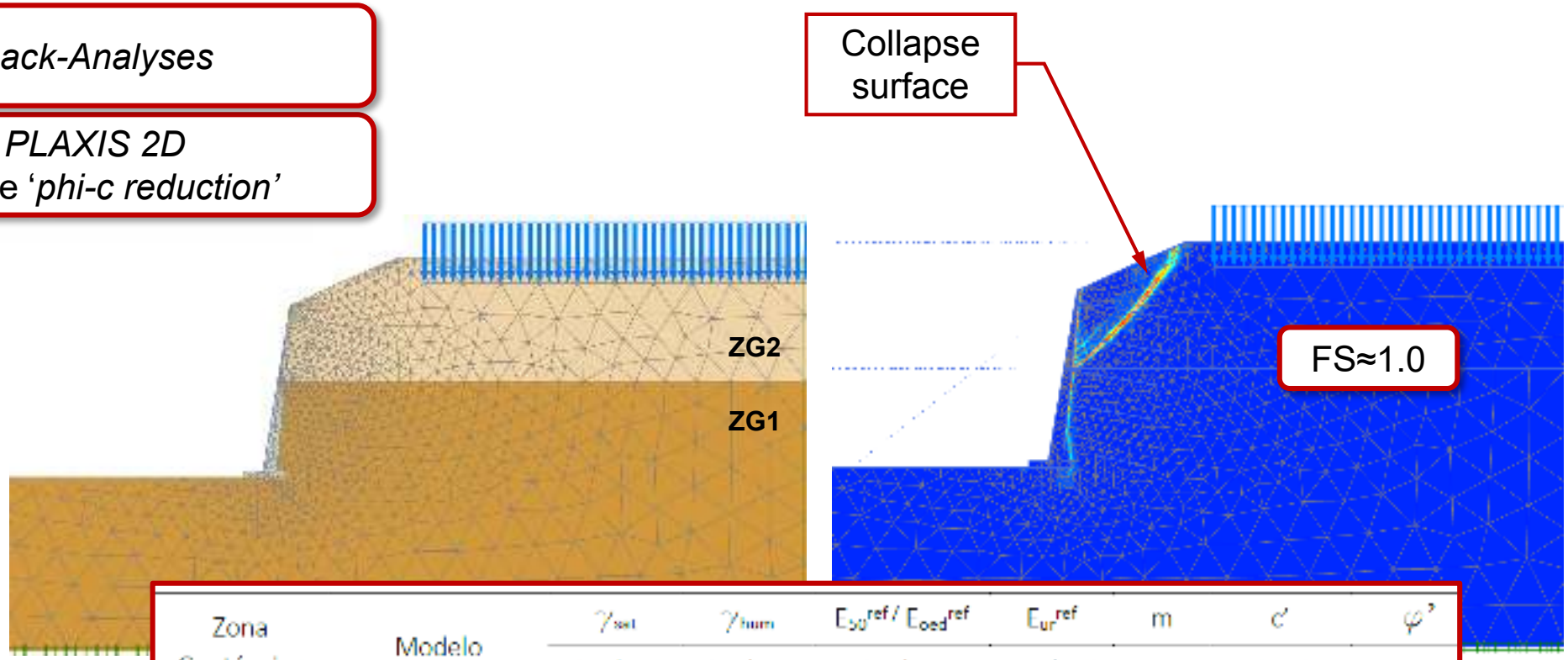




STABILIZATION, RECONSTRUCTION AND REINFORCEMENT SOLUTIONS

Back-Analyses

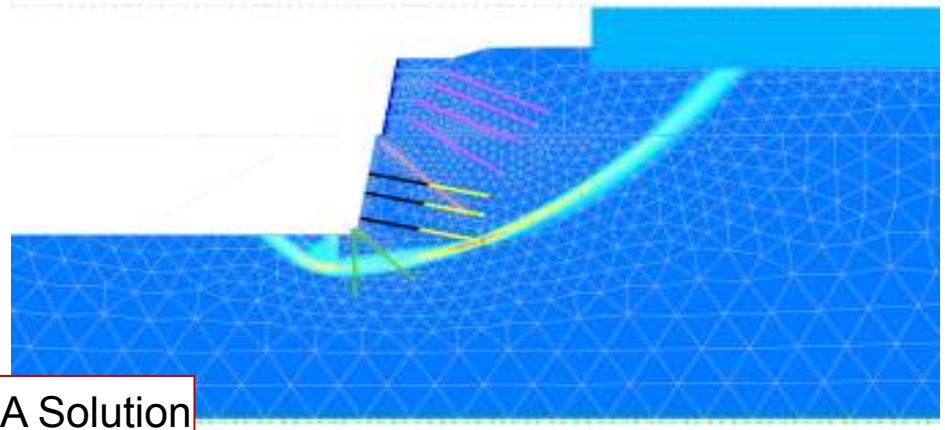
PLAXIS 2D
Análise '*phi-c reduction*'



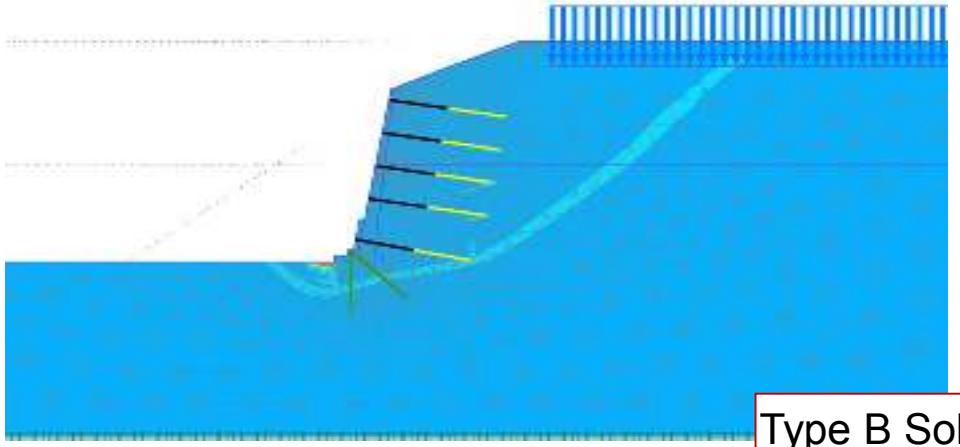
Zona Geotécnica	Modelo	γ_{sat}	γ_{hum}	E_{50}^{ref} / E_{oed}^{ref}	E_{ur}^{ref}	m	c'	φ'
		[kN/m³]	[kN/m³]	[kN/m²]	[kN/m²]	[-]	[kPa]	[°]
ZG2	Hardening-Soil	19,5	18,5	50	150	0,5	10	35
ZG1	Hardening-Soil	20,0	19,5	70	210	0,5	60	40

STABILIZATION, RECONSTRUCTION AND REINFORCEMENT SOLUTIONS

PLAXIS 2D Safety '*phi-c reduction*' Analyses



Type A Solution



Type B Solution

Global Stability Analyses – Global Safety Factors

	Static Load Case	Accidental Load Case	Seismic Load Case
Type A Solution	1.7 > 1.5	1.5 > 1.2	1.3 > 1.2
Type B Solution	2.1 > 1.5	1.9 > 1.2	1.6 > 1.2

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- **CONSTRUCTION CONDITIONS**
- MONITORING PLAN
- FINAL REMARKS

CONSTRUCTION CONDITIONS

Collapsed walls debris and soil extraction inside the basement

Micropile execution inside the building basements

CONSTRUCTION CONDITIONS

Tower crane installation on the adjacent street

Extraction of collapsed walls fragments of large dimension

CONSTRUCTION CONDITIONS

Collapsed wall debris and soil extraction

Scaffold suspended structure

CONSTRUCTION CONDITIONS

Reinforcement concrete beam execution and connection to the existing collapsed wall

CONSTRUCTION CONDITIONS

Filling with light weight coarse aggregates (expanded clay)

CONSTRUCTION CONDITIONS

Steel grid installation

CONSTRUCTION CONDITIONS

Ground anchors execution

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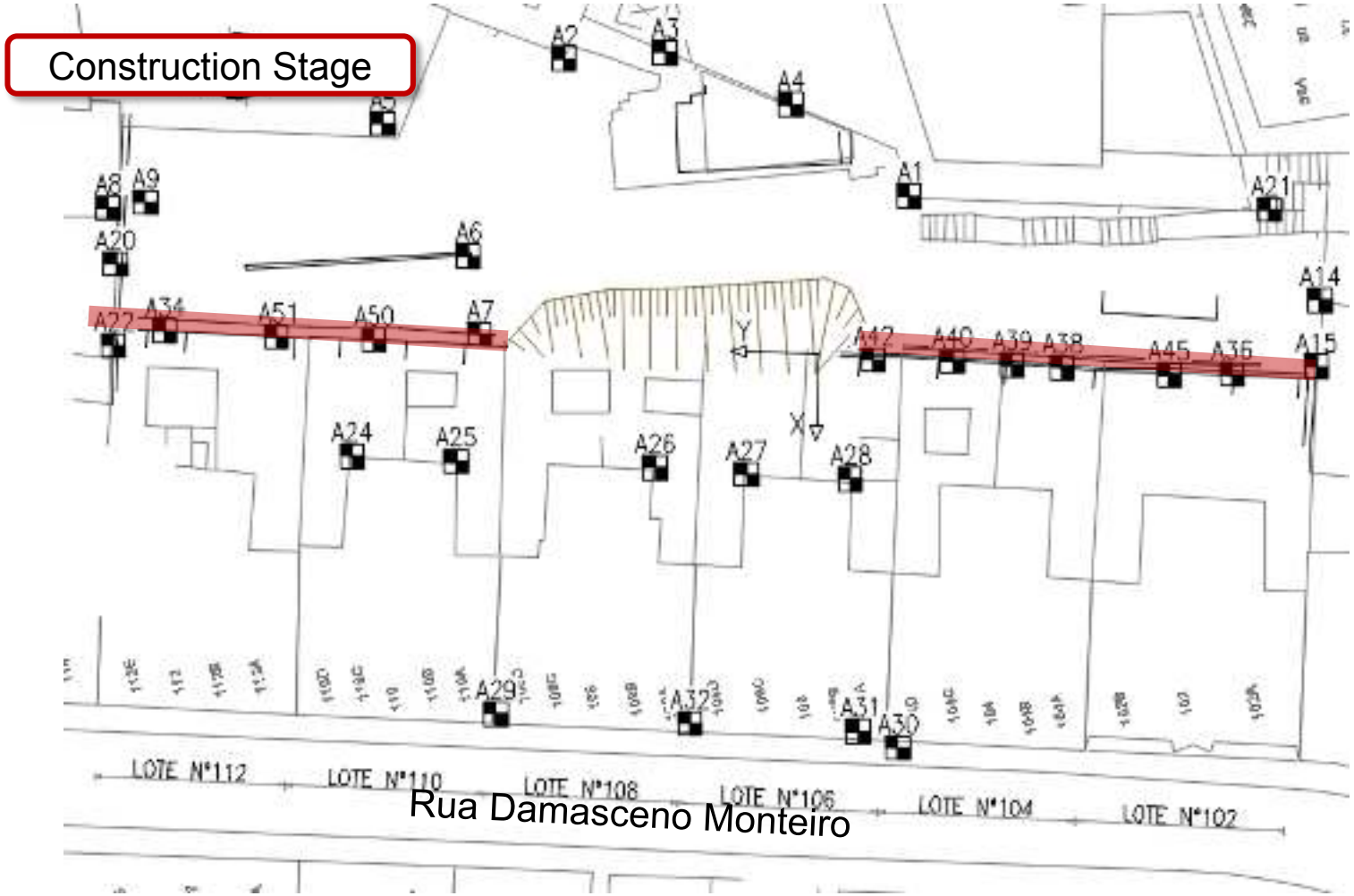
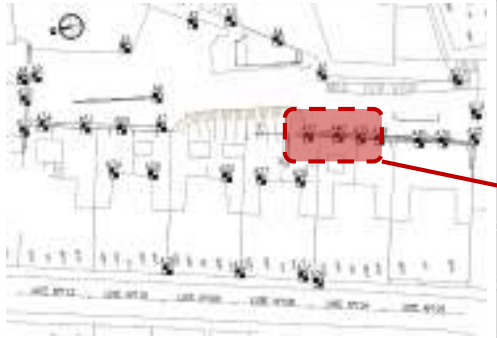
MONITORING PLAN

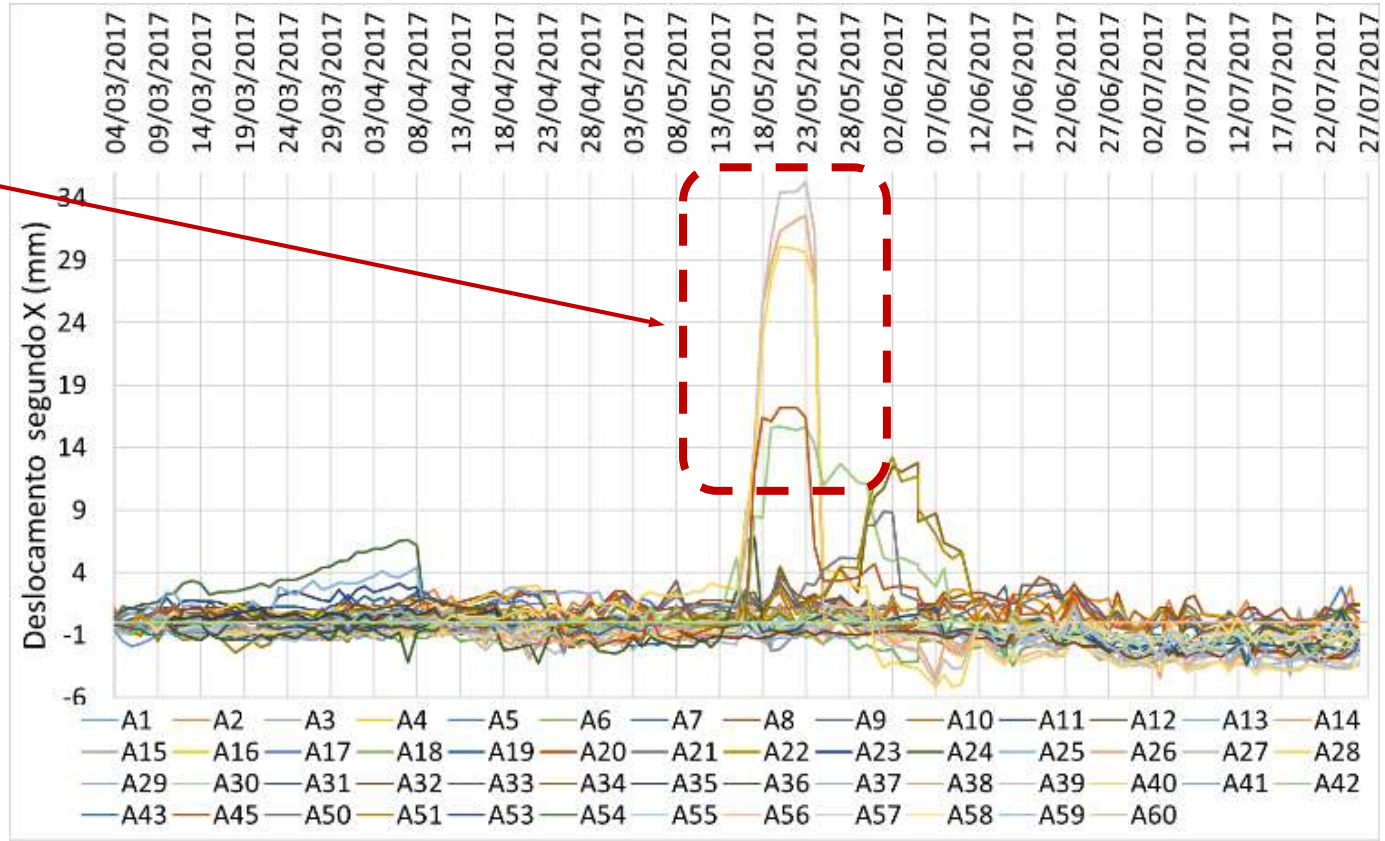


Topographic targets (x37)

MONITORING PLAN

Construction Stage

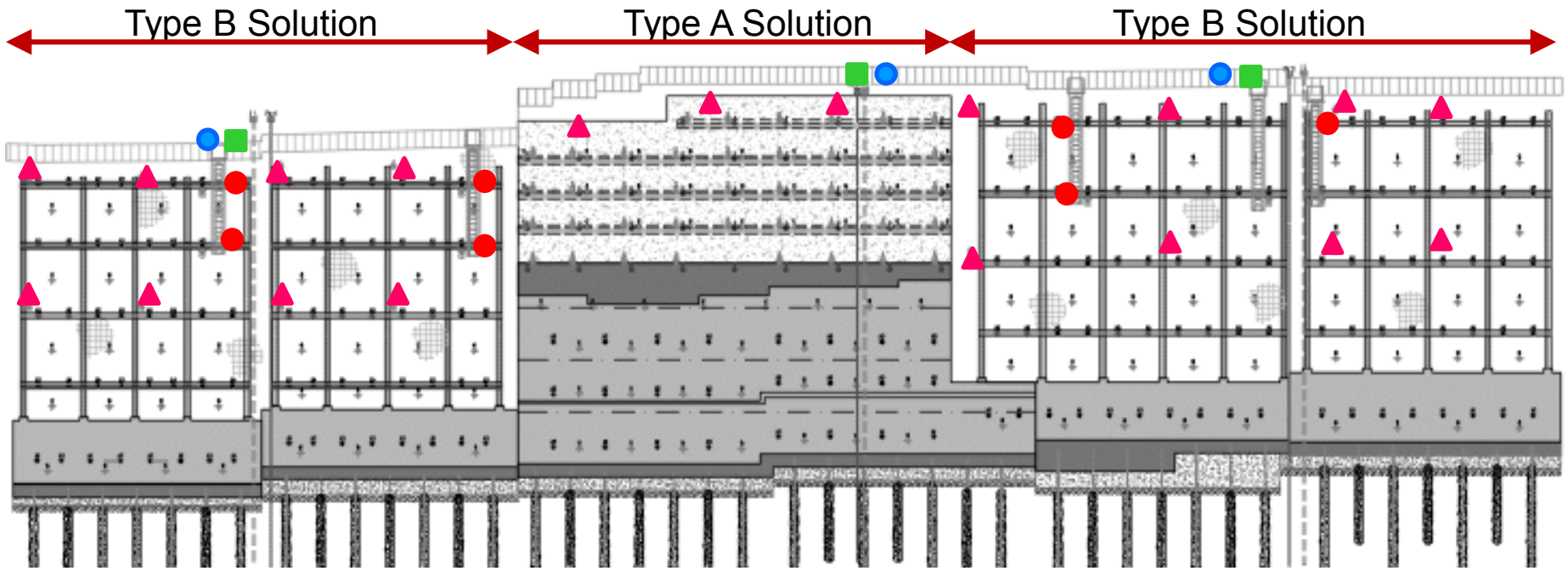




Risk management during the construction works

MONITORING PLAN

Lifetime



- Topographic targets (x19)
- Load cells at ground anchors (x8)
- Inclinometers (x3)
- Piezometers (x3)

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- **FINAL REMARKS**

FINAL REMARKS

Collapse event
27th February 2017

Works beginning
2nd march 2017

Works Completion
1st September 2017

Design and execution completed in a period of 6 months

FINAL REMARKS

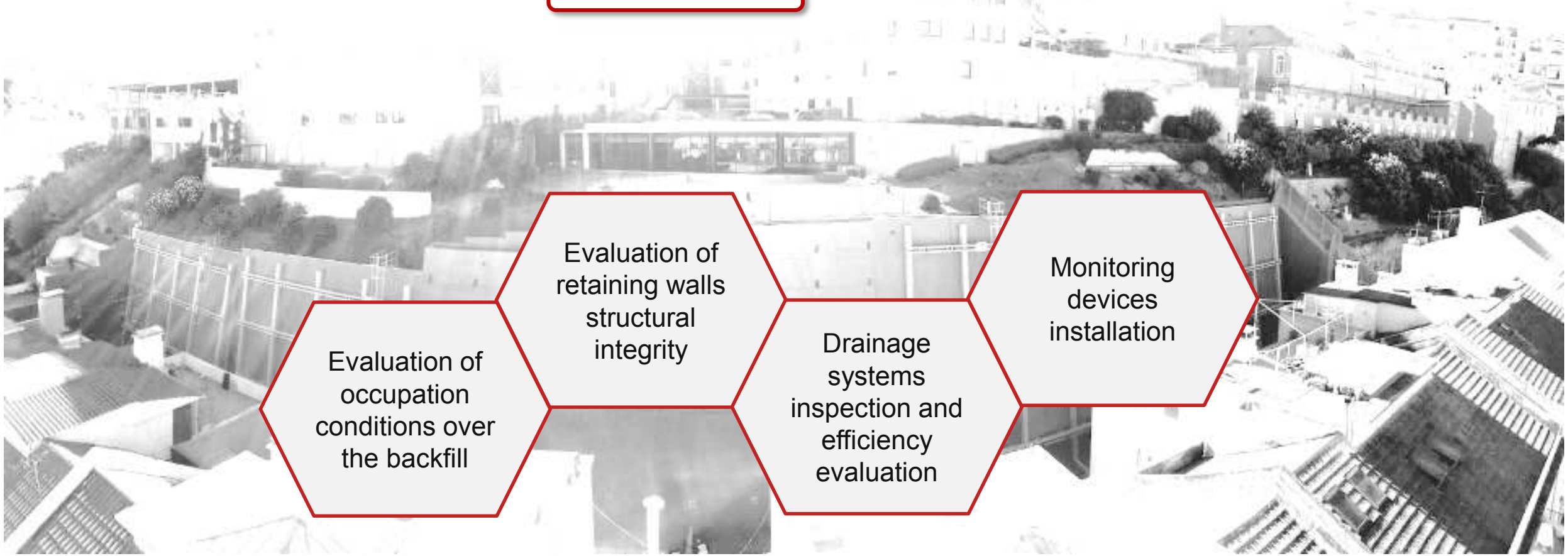
FINAL REMARKS

FINAL REMARKS

FINAL REMARKS

EARTH RETAINING WALLS IN URBAN AREAS

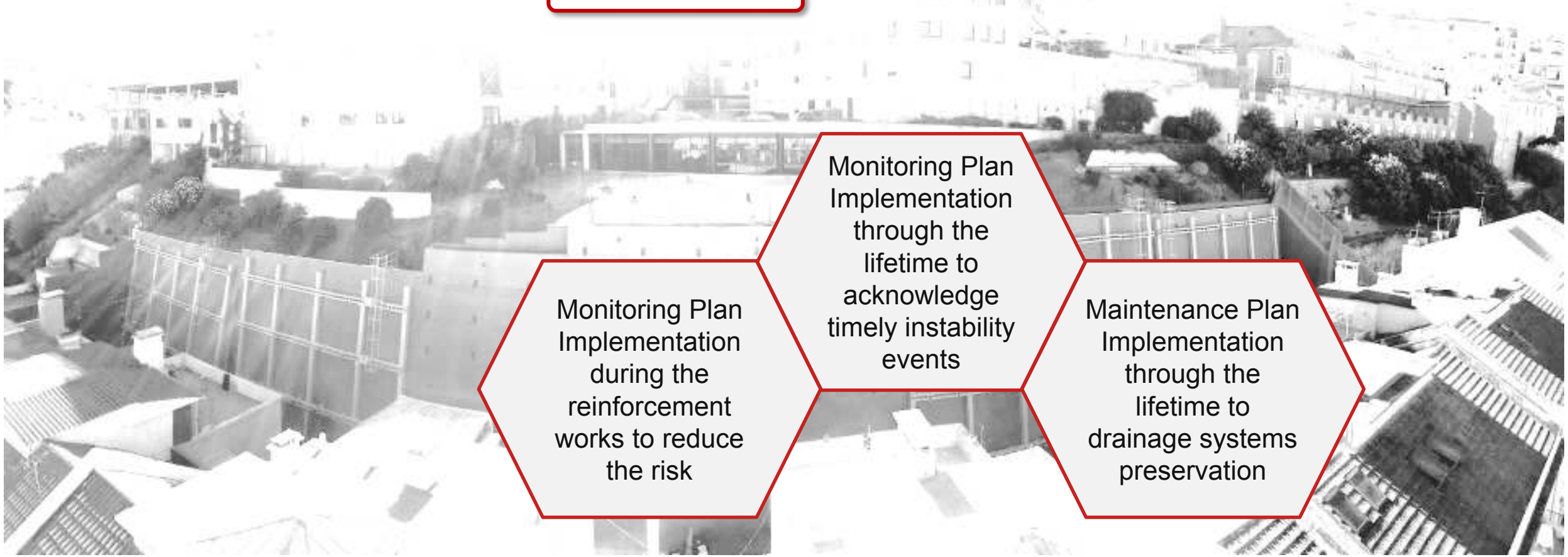
EVALUATION



FINAL REMARKS

EARTH RETAINING WALLS IN URBAN AREAS

INTERVENTION



- Monitoring Plan Implementation during the reinforcement works to reduce the risk
- Monitoring Plan Implementation through the lifetime to acknowledge timely instability events
- Maintenance Plan Implementation through the lifetime to drainage systems preservation

FINAL REMARKS

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4 SEPTEMBER - SESSION TC207 – SOIL-STRUCTURE

RETAINING WALL SOLUTIONS FOR UNDERGROUND EXTENSION OF "HOSPITAL DA LUZ" IN LISBON - PORTUGAL

Rui Tomásio, JETsj, rtomasio@jetsj.com
Alexandre Pinto, JETsj, apinto@jetsj.com

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- INTRODUCTION
- LOCAL CONDITIONS
- ADOPTED SOLUTIONS
- DESIGN
- MONITORING AND SURVEY PLAN
- CONSTRUCTION
- FINAL REMARKS

- **INTRODUCTION**
- LOCAL CONDITIONS
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- Increase of Hospital da Luz capacity, in Carnide, Lisbon
- Construction of 4 underground floors;
- Building footprint of 10.000m ^{2}

- INTRODUCTION
- **LOCAL CONDITIONS**
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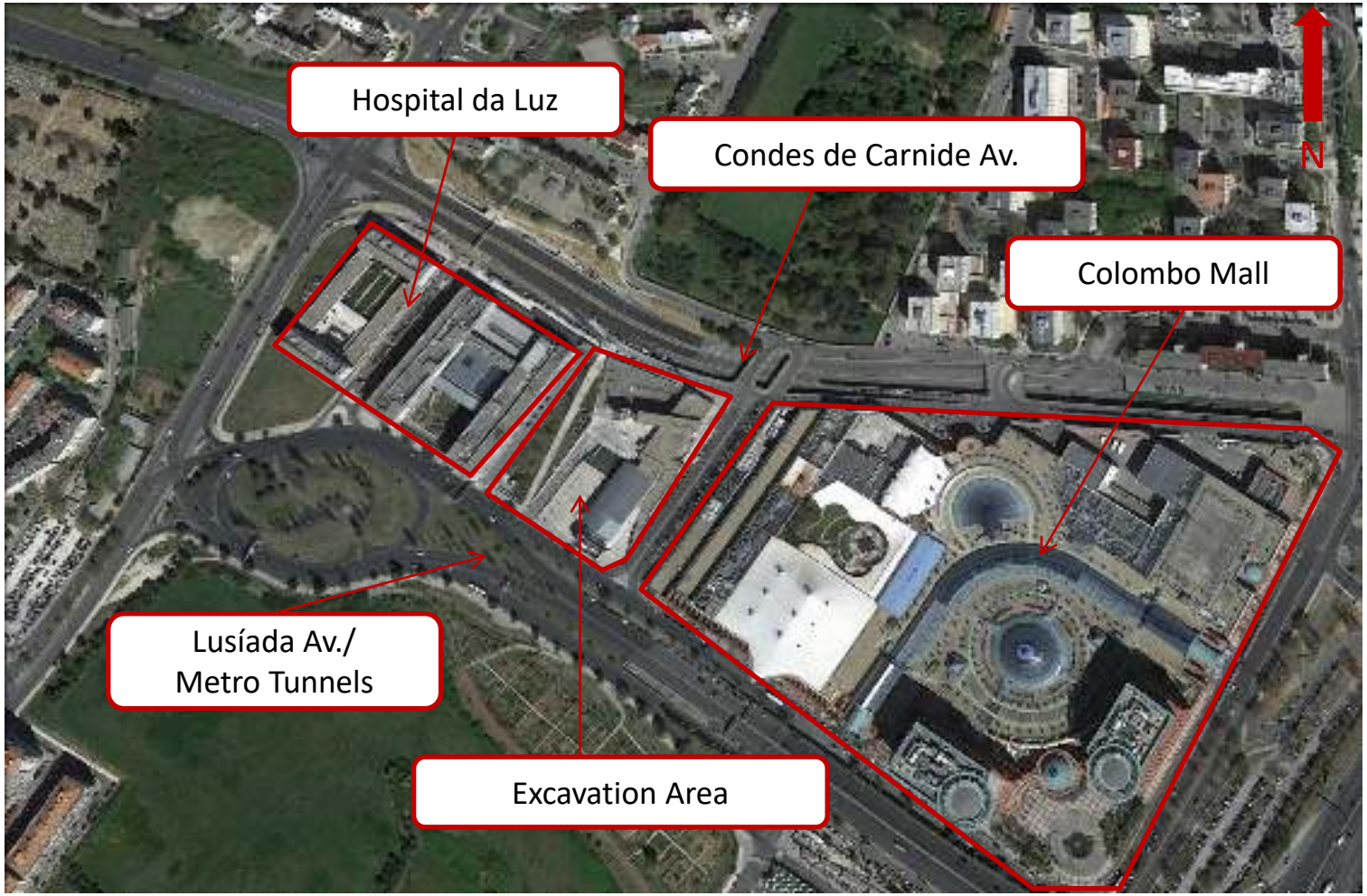
NEIGHBOURHOOD CONDITIONS



PLOT ANCIENT OCCUPATION

GEOLOGICAL AND GEOTECHNICAL SCENARIO

- 11 Geotechnical boreholes
- 3 Piezometers
- Lab Tests
    - Granulometry
    - Moisture Content
    - Atterberg Limits
    - Chemical Aggressiveness
    - Direct Shear Tests

GEOLOGICAL AND GEOTECHNICAL SCENARIO

Based on the information collected with the tests described previously, the following formations were identified, which are in agreement with the information available in the Lisbon Geological Chart:

- Landfills – soils of a diverse nature, but with predominance of silt-clayey soils and sand-silty soils;
- Prazeres clays and limestones – soils dating from the Miocene, constituted by the monotonic alternation of sedimentary layers of fine granulometry soils, constituted by more or less silty clays

- INTRODUCTION
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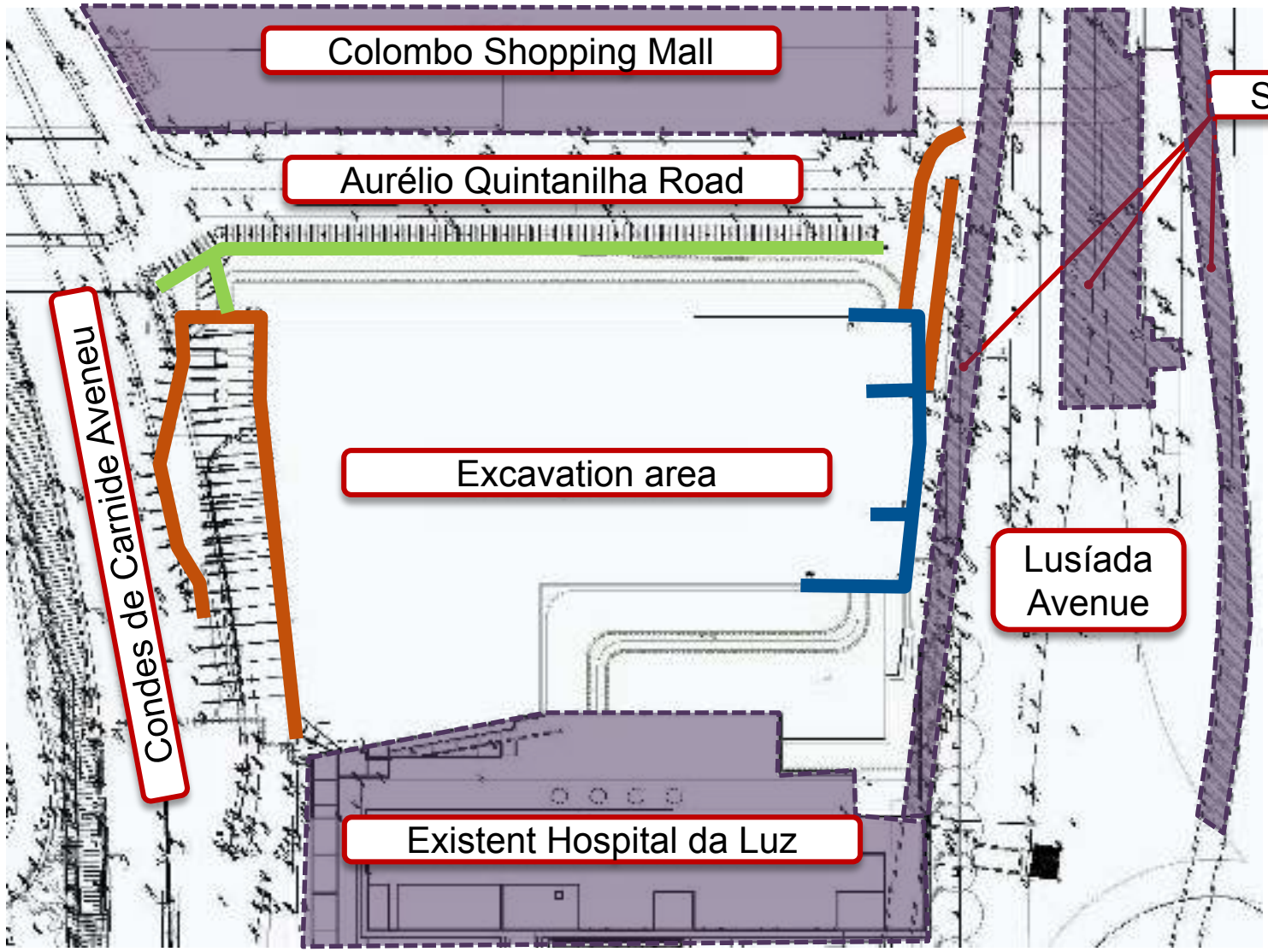
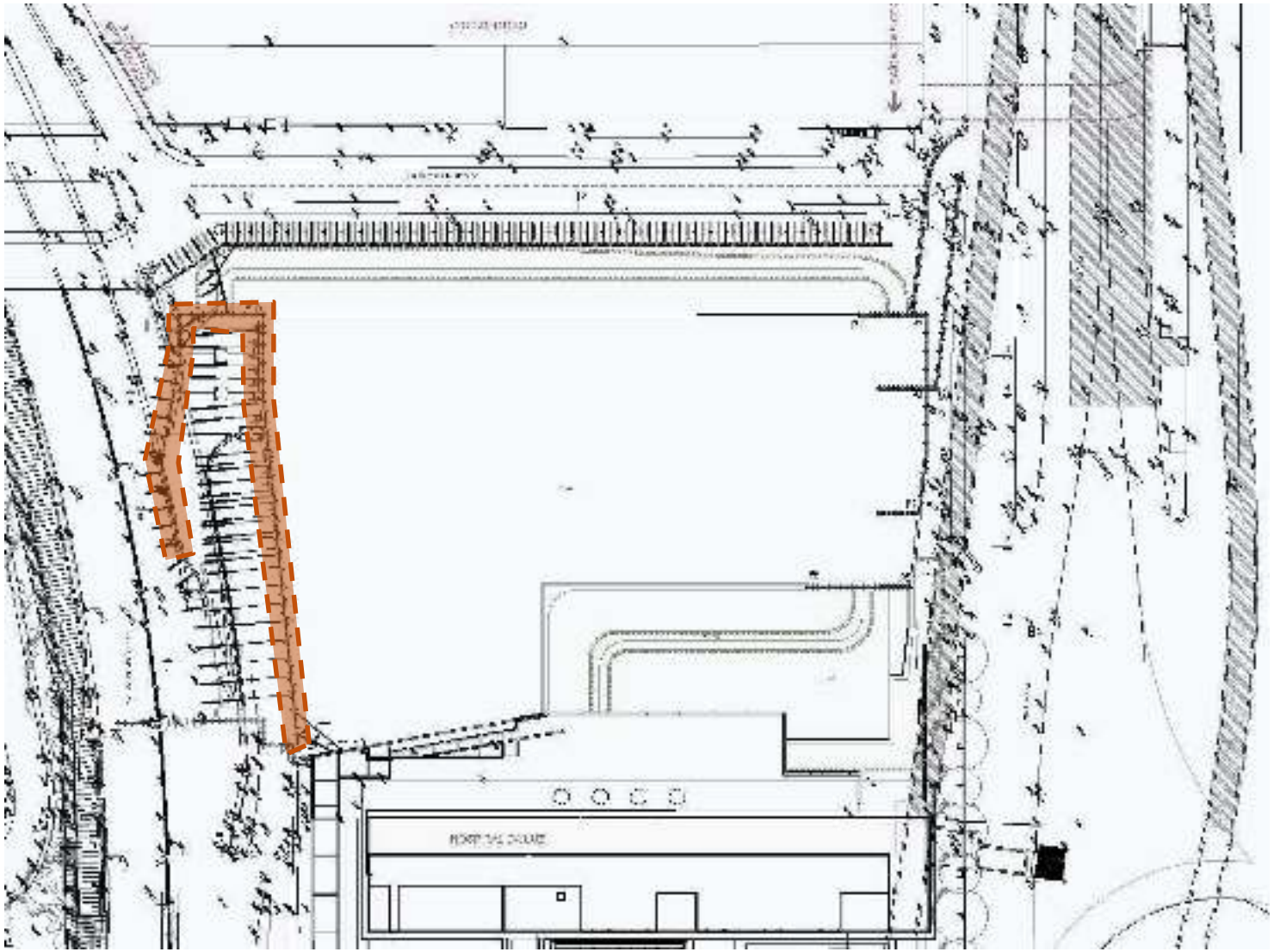

Colombo Shopping Mall
Subway Tunels
Aurélio Quintanilha Road
Condes de Carnide Aveneu
Excavation area
Lusíada Avenue
Existent Hospital da Luz

East

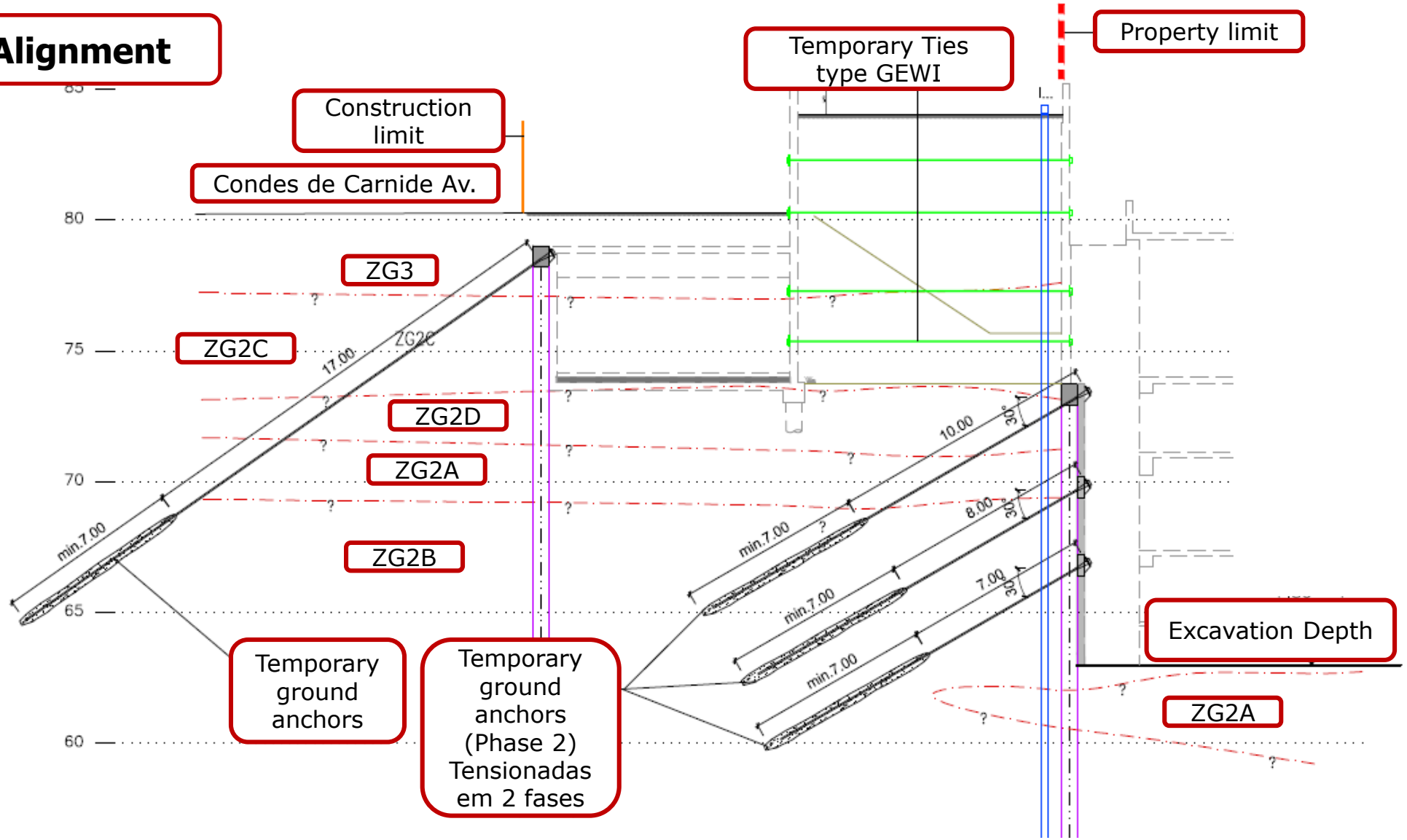
West

East

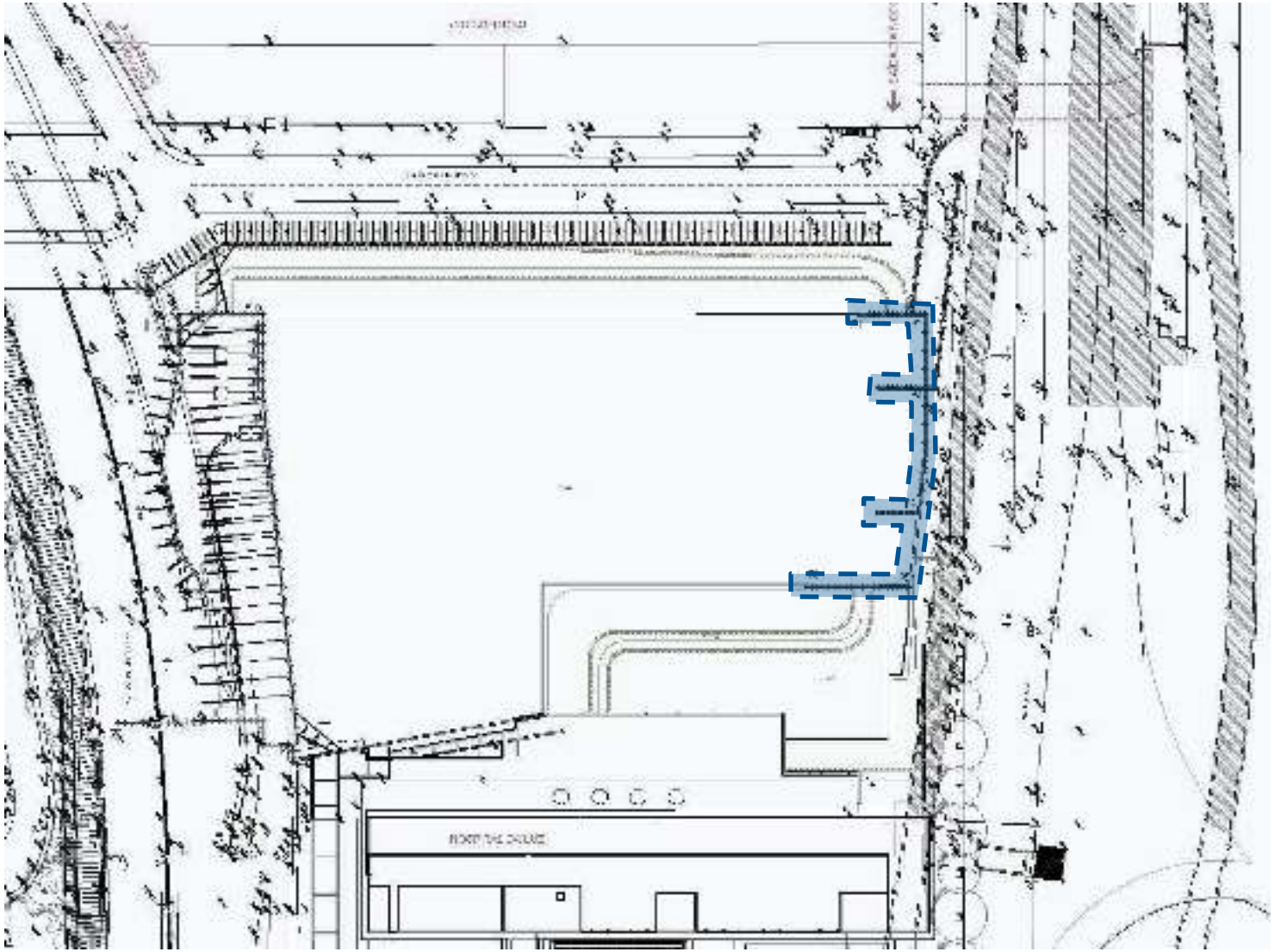


West

East Alignment

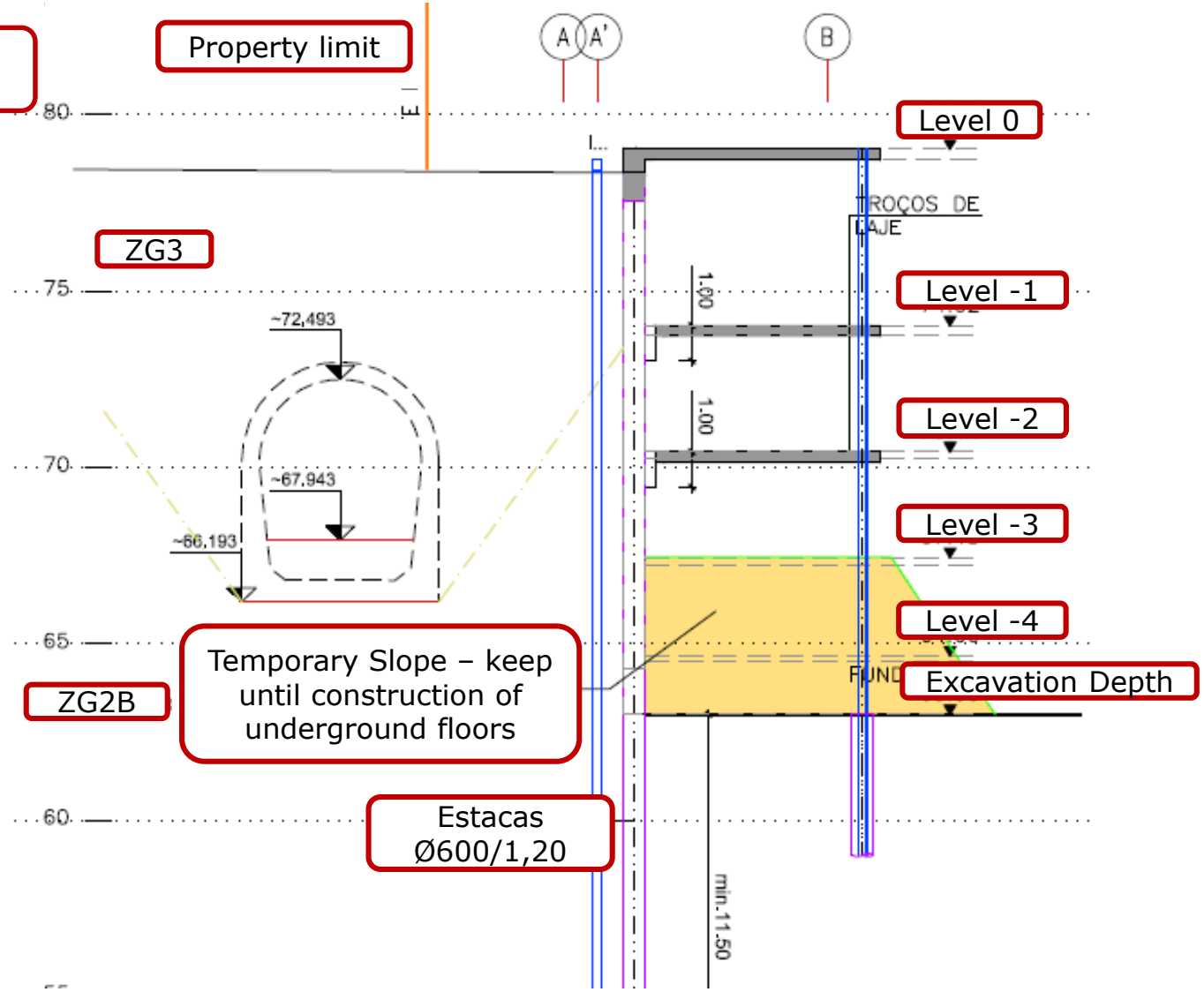


East

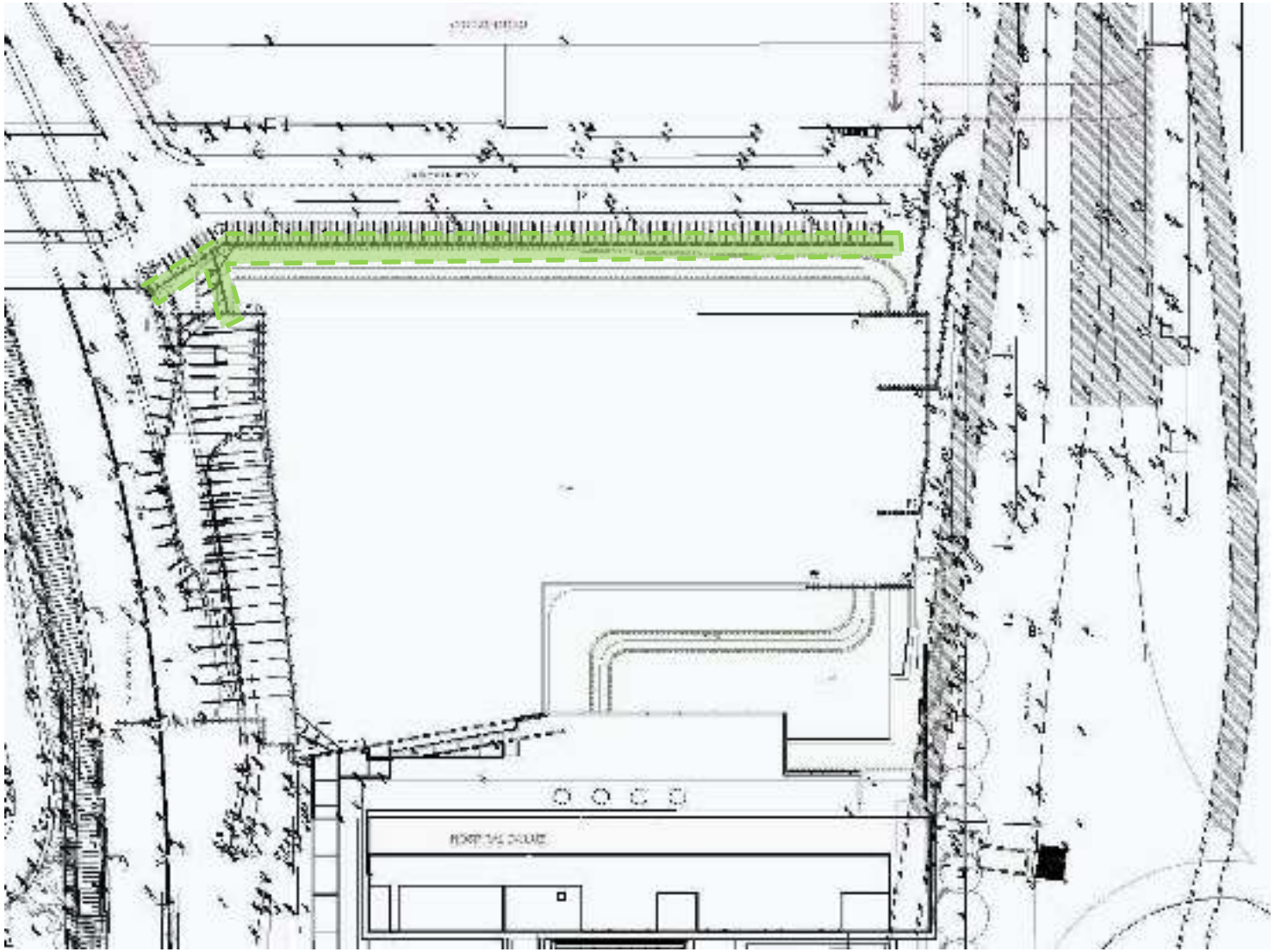


West

West Alignment

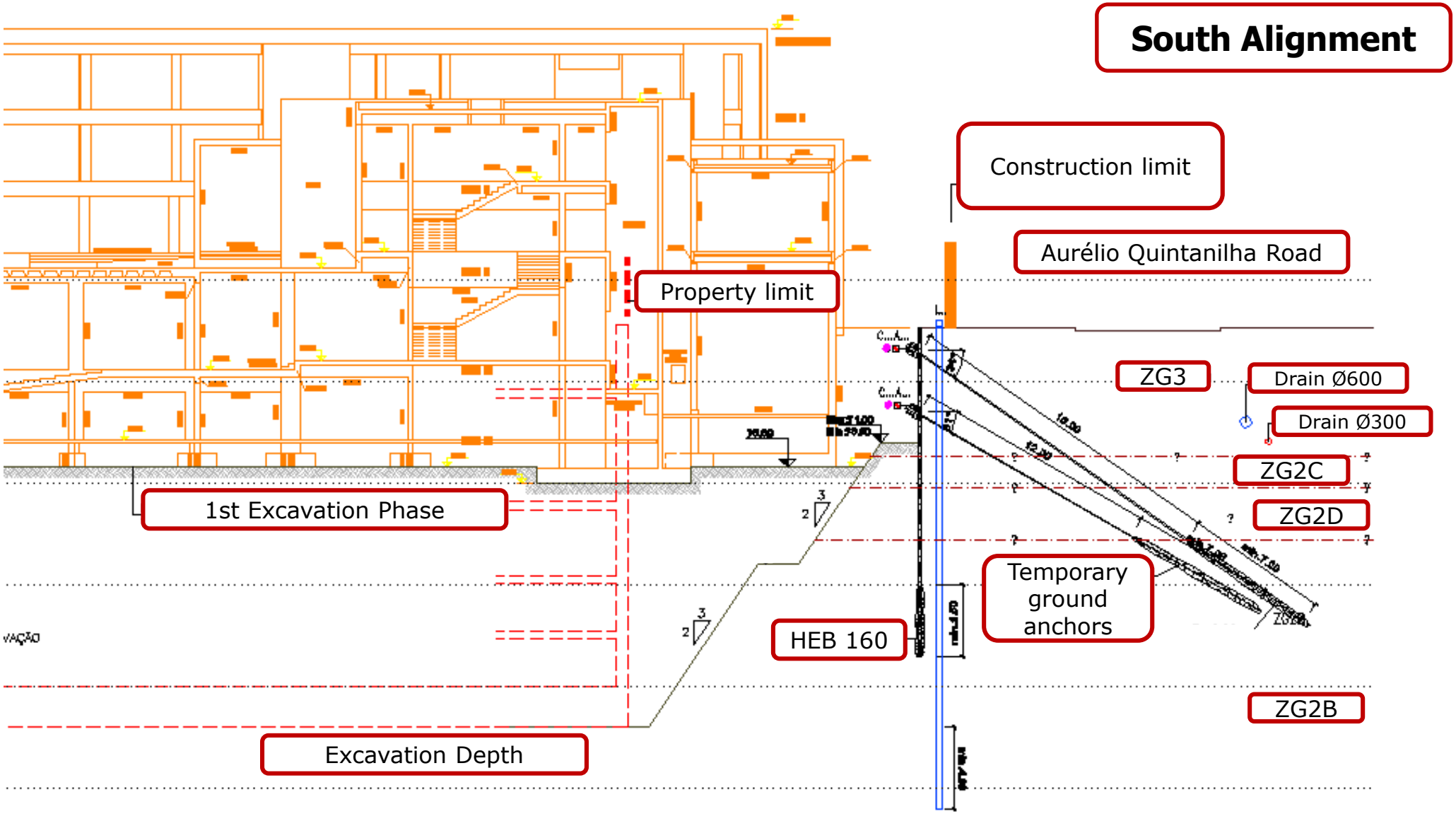


East



West

South Alignment



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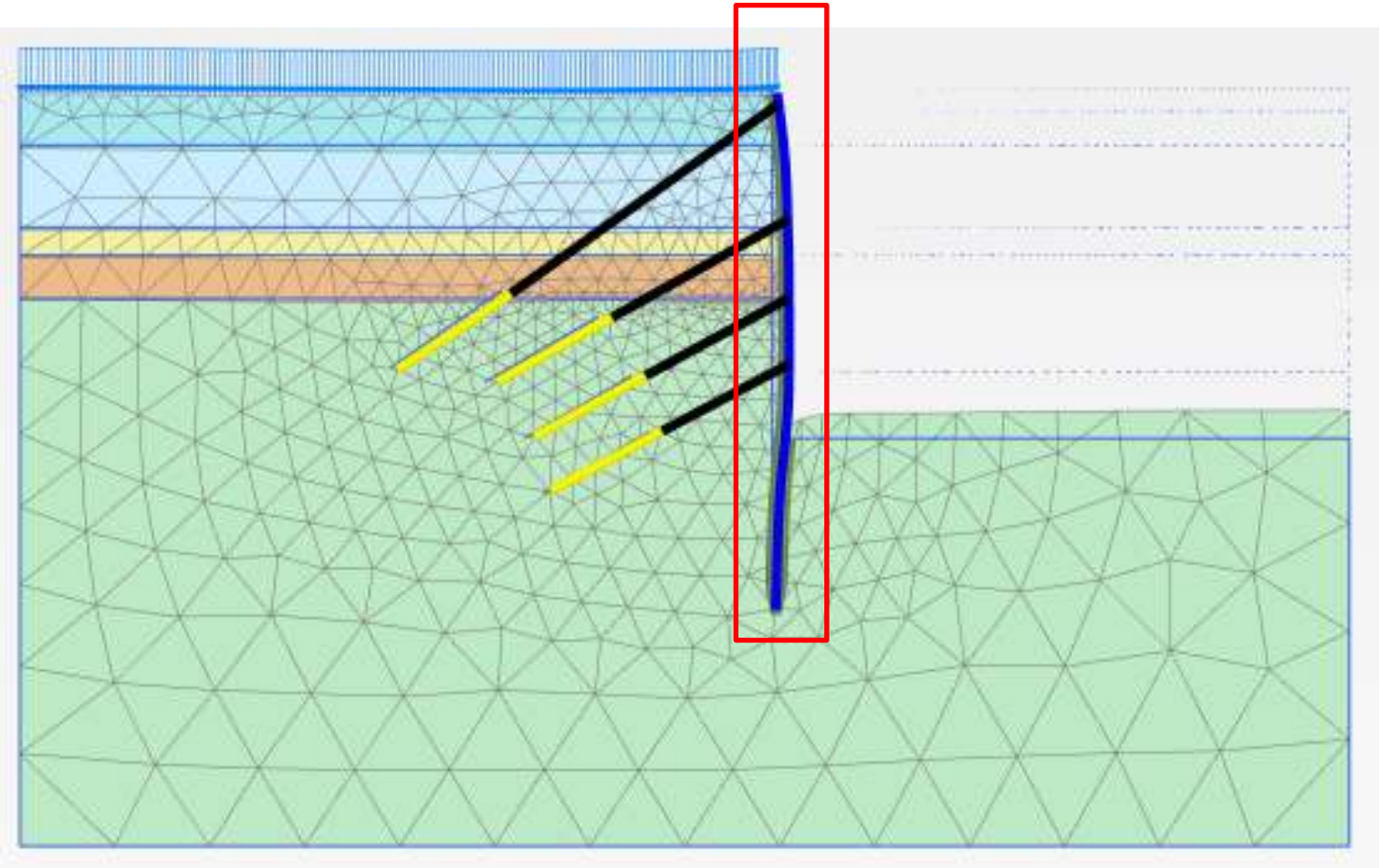
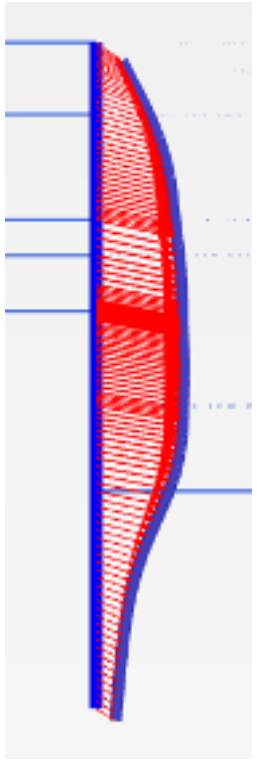
East Elevation – Bored Piles Curtain and Ground Anchors

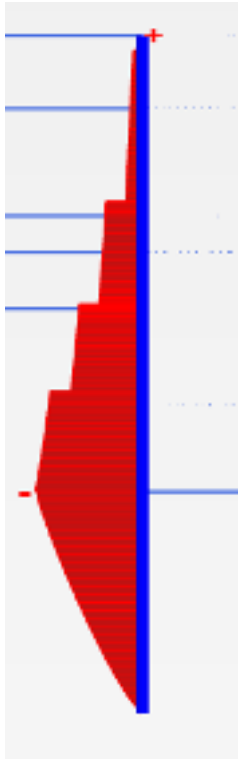


Deformation

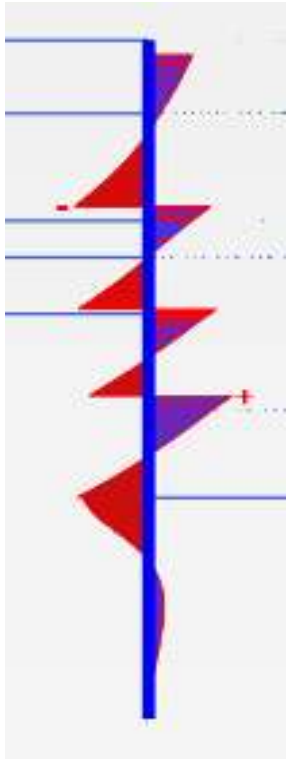


15,6mm

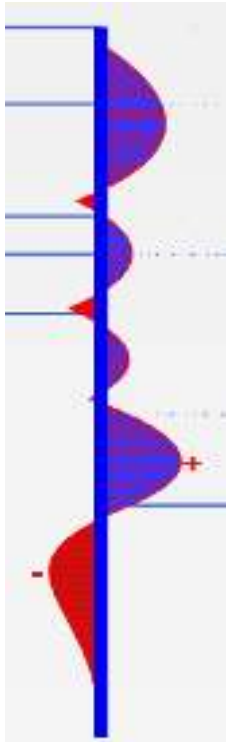
Stresses



737kN/m

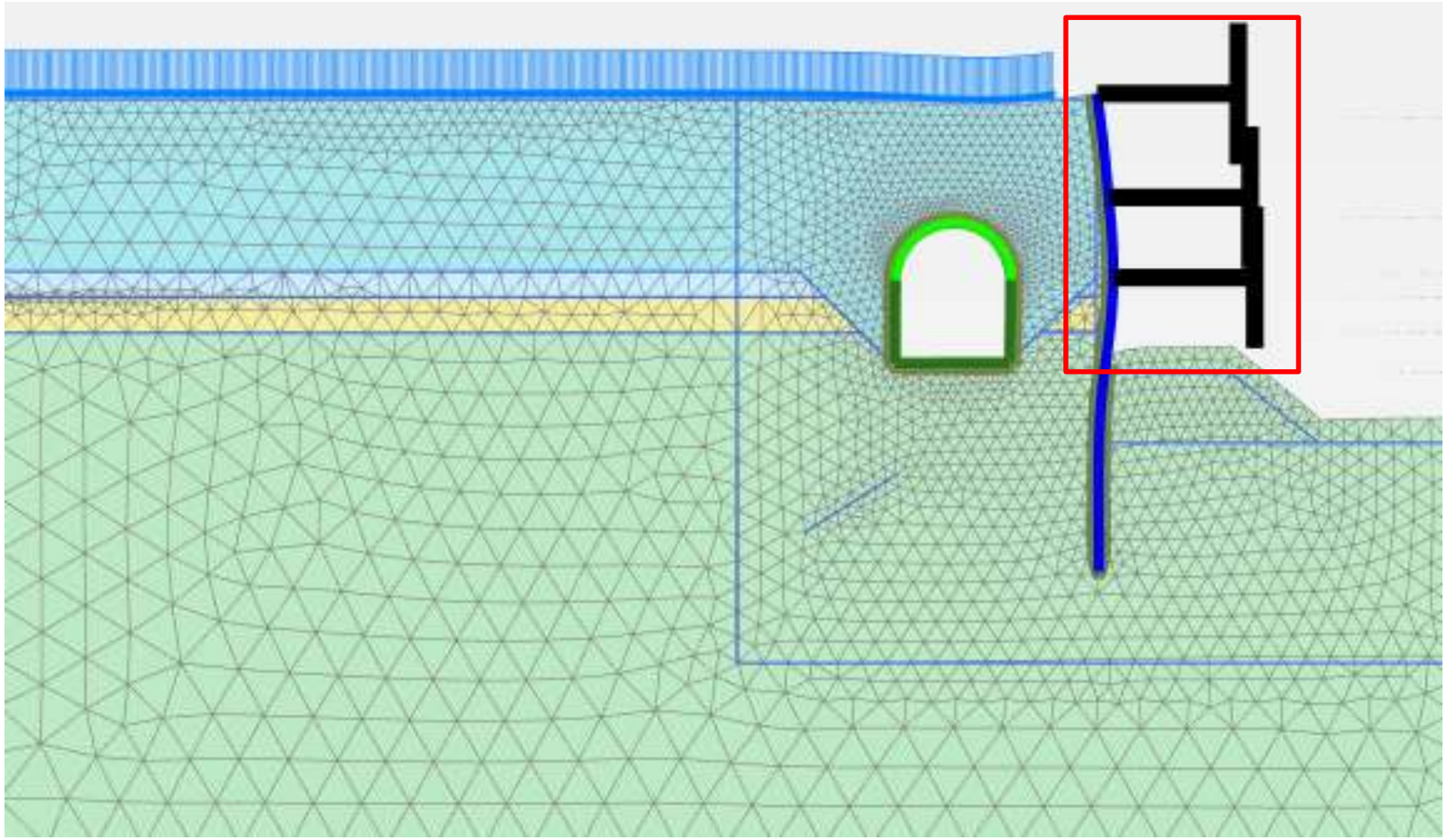


144,2kN/m
-126,9kN/m

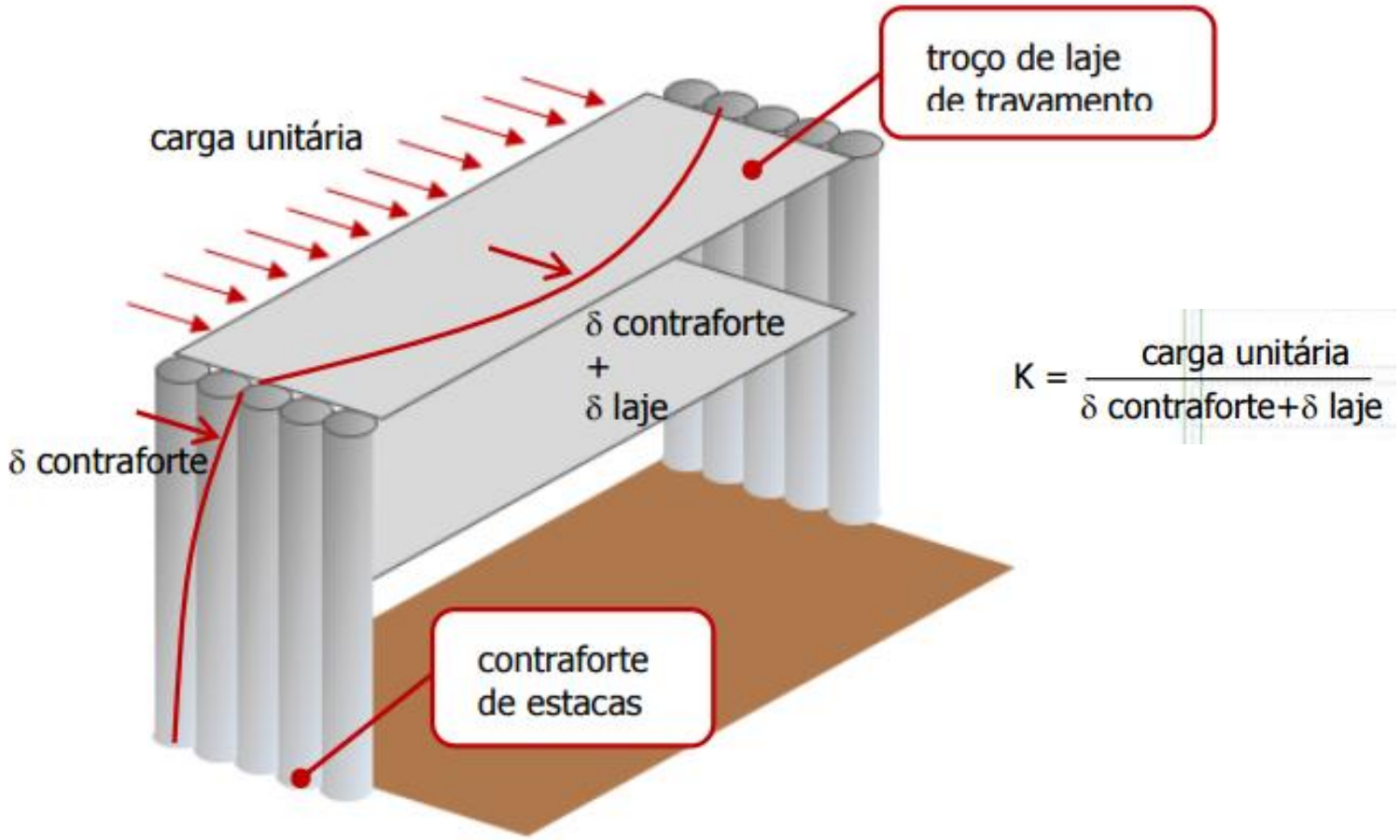


131,7kNm/m
-84,1kNm/m

West Elevation – Bored Piles Curtain and Partial Slabs



West Elevation – Bored Piles Curtain and Partial Slabs



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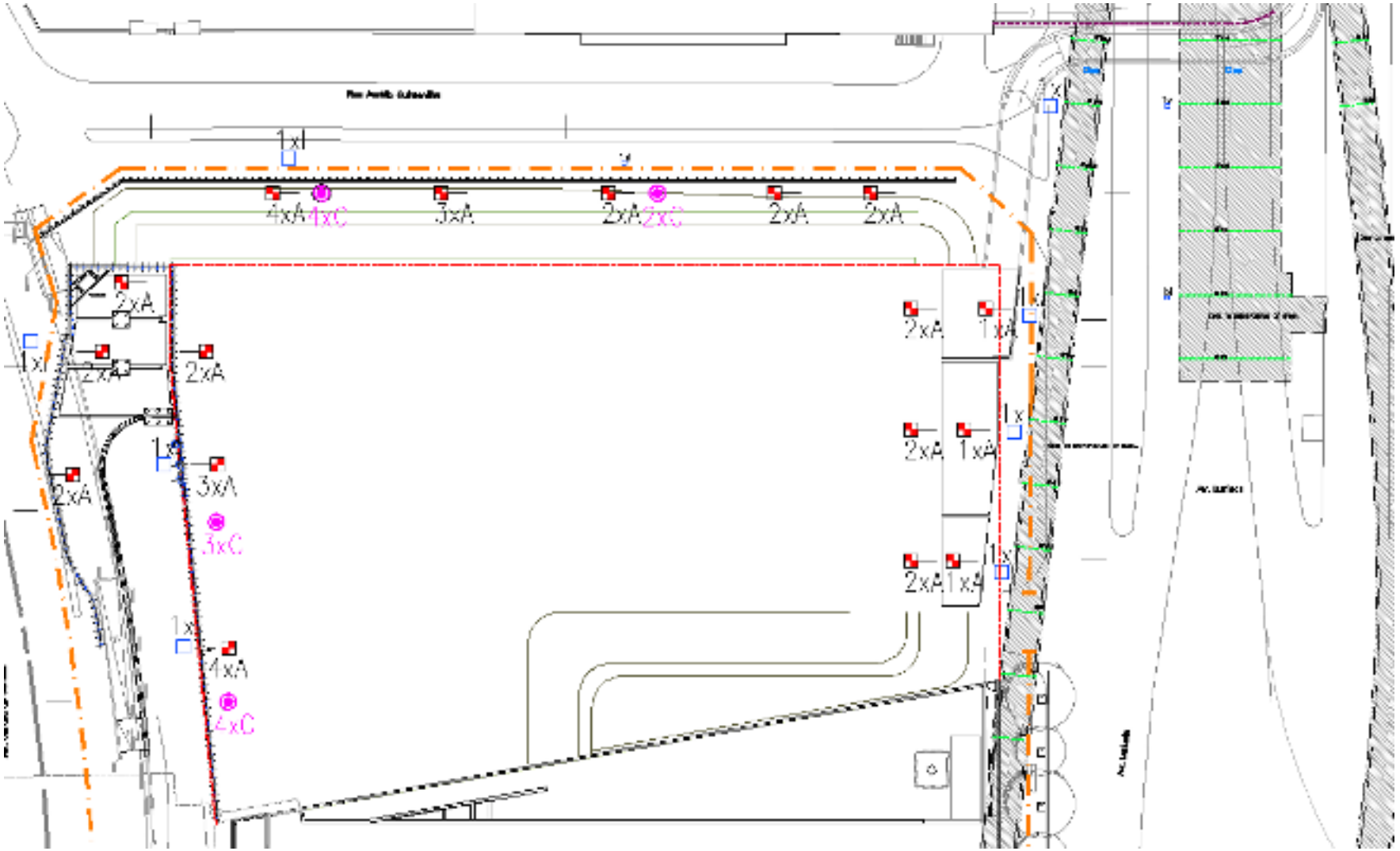
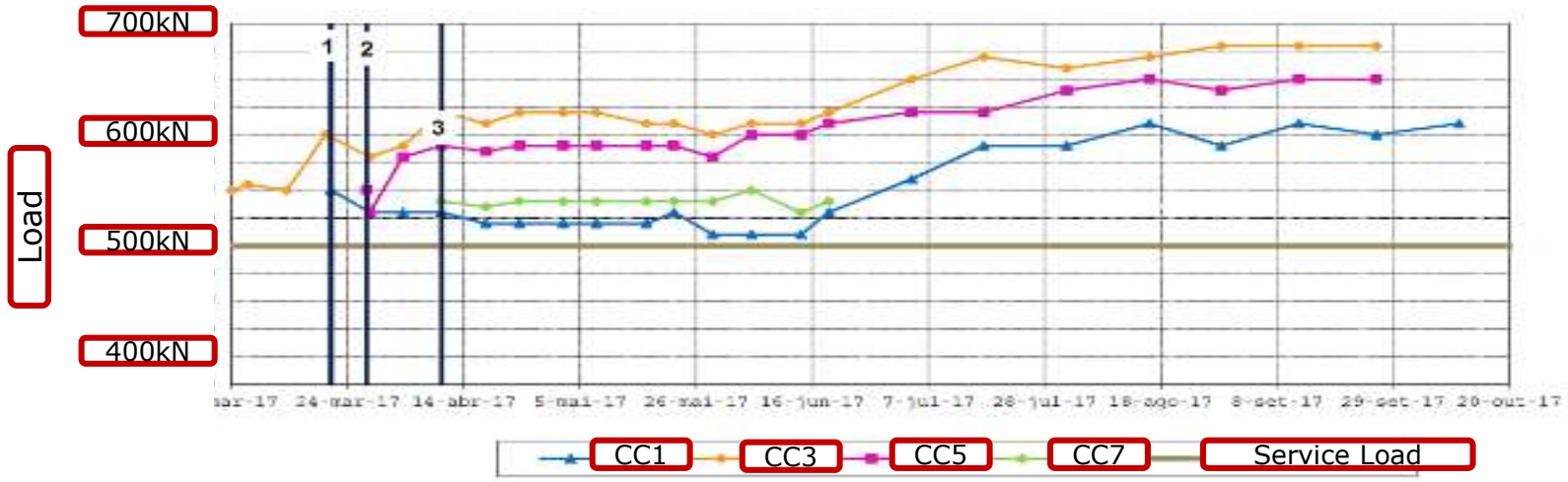
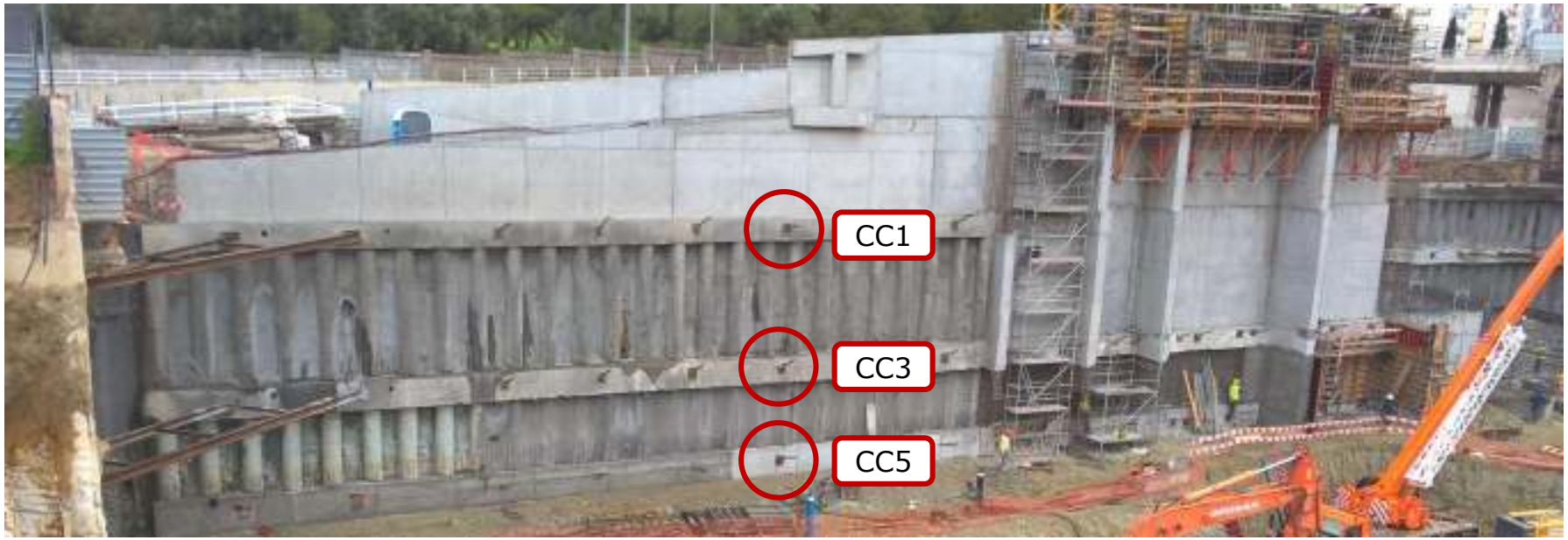
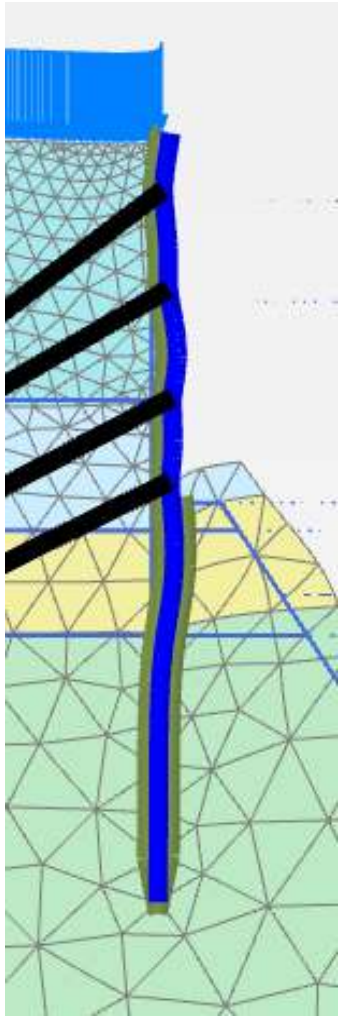
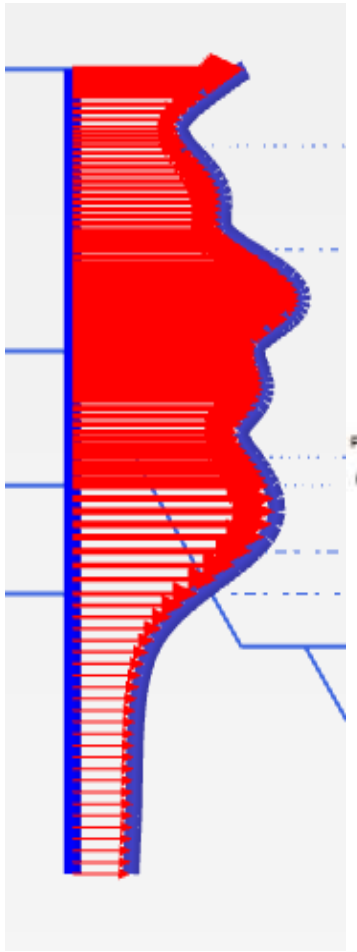
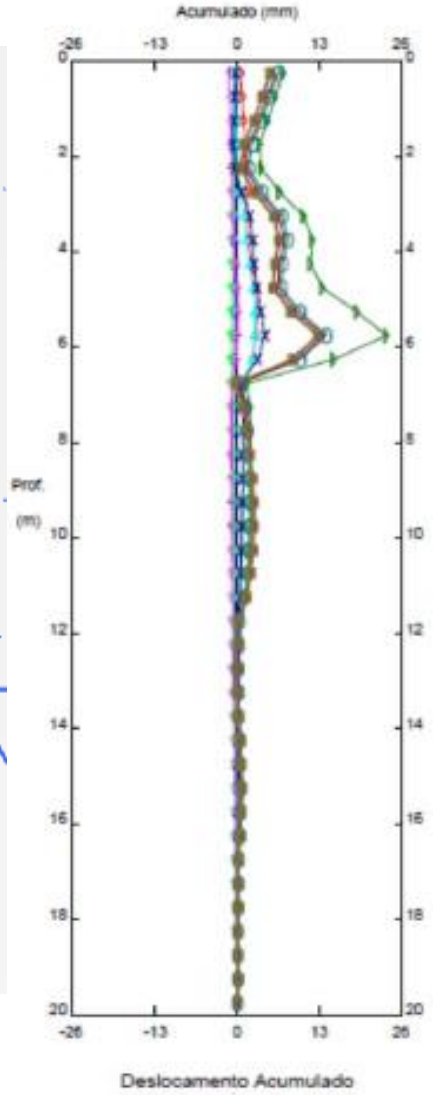

1xI
4xA 1xC
3xA
2xA 2xC
2xA
2xA
2xA
1xI
2xA
2xA
2xA
1xI
3xA
3xC
1xI
1xA
4xC
2xA
1xA
2xA
1xA
1xI
2xA
1xA

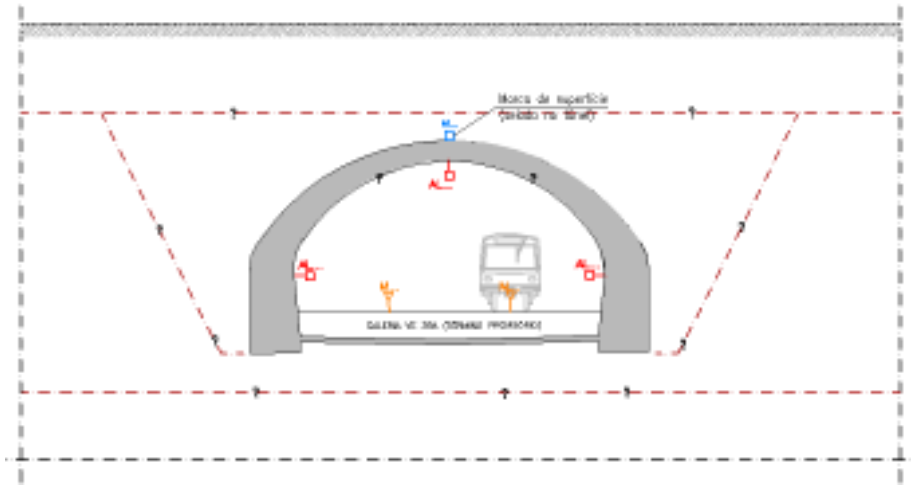

700kN
600kN
500kN
400kN
Load
1
2
3
CC1
CC3
CC5
CC7
Service Load


CC1
CC3
CC5






Acumulado (mm)
-26
-13
0
13
26
Prof. (m)
0
2
4
6
8
10
12
14
16
18
20
Deslocamento Acumulado



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Set / 2016


Dez / 2016


South Alignment
Jan / 2017


East Alignment
South Alignment

West Alignment

Fev / 2017


South Alignment
Fev / 2017


East Alignment
South Alignment
Mar / 2017


West Alignment
Abril / 2017

East Alignment

West Alignment

West Elevation

- INTRODUCTION
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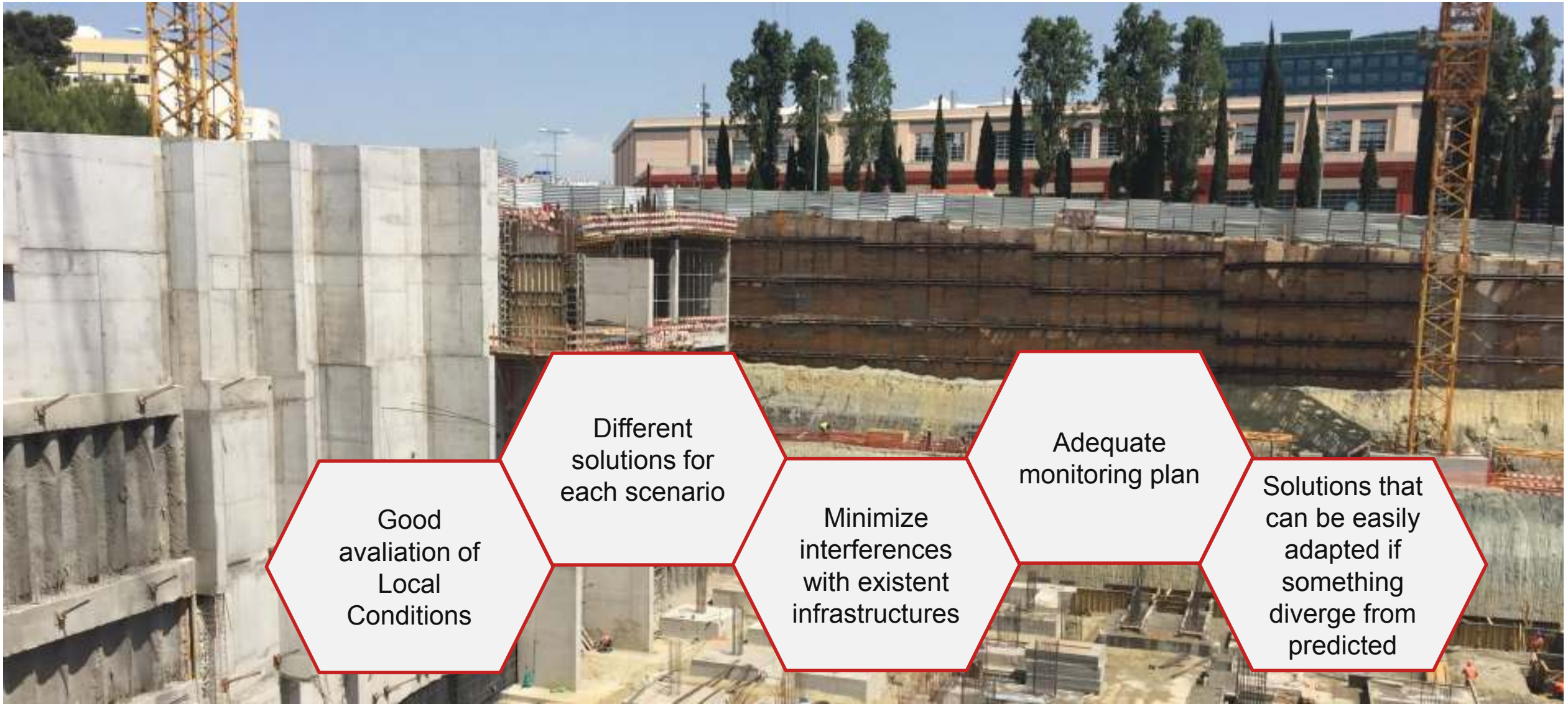
Good avaliation of Local Conditions
Different solutions for each scenario
Minimize interferences with existent infrastructures
Adequate monitoring plan
Solutions that can be easily adapted if something diverge from predicted

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REYKJAVIK, ICELAND
1 - 6 SEPTEMBER 2019

XVII EUROPEAN CONFERENCE ON SOIL MECHANICS AND GEOTECHNICAL ENGINEERING

4 SEPTEMBER - SESSION TC207 – SOIL-STRUCTURE

ESTABILIZAÇÃO, RECONSTRUÇÃO E REFORÇO URGENTE DE MUROS DE SUPORTE DE GRANDE ALTURA EM LISBOA

THANK YOU FOR YOUR KIND ATTENTION

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ACKNOWLEDGMENTS

LUZ SAÚDE · TEIXEIRA TRIGO, LDA · DimStrut. Engenharia de Estruturas · MOTA-ENGIL · CONSTRUÇÕES

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XVII EUROPEAN CONFERENCE ON SOIL MECHANICS AND GEOTECHNICAL ENGINEERING

03 SEPTEMBER – SESSION D3 - 6, TC301, HALL RÍMA B

PRESERVATION OF HISTORIC SITES

LANDSLIDE RISK MITIGATION OF "SÃO PEDRO DE ALCÂNTARA VIEWPOINT SLOPE" IN LISBON HISTORICAL CENTER

Alexandre Pinto, JETsj, apinto@jetsj.com
Catarina Fartaria, JETsj, cfartaria@jetsj.com
António Cristovão, Keller
Miguel Rocha, Teixeira Duarte

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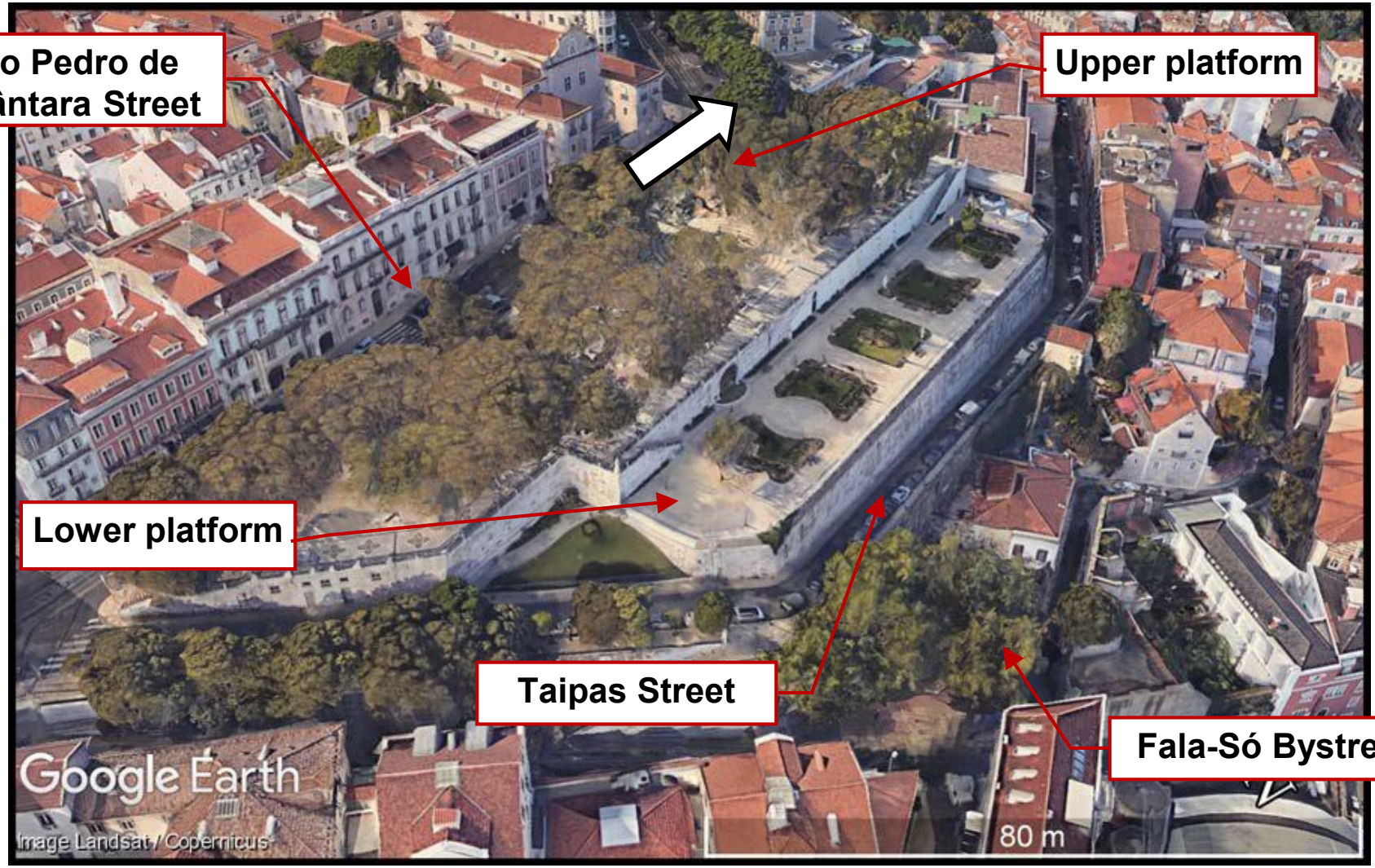
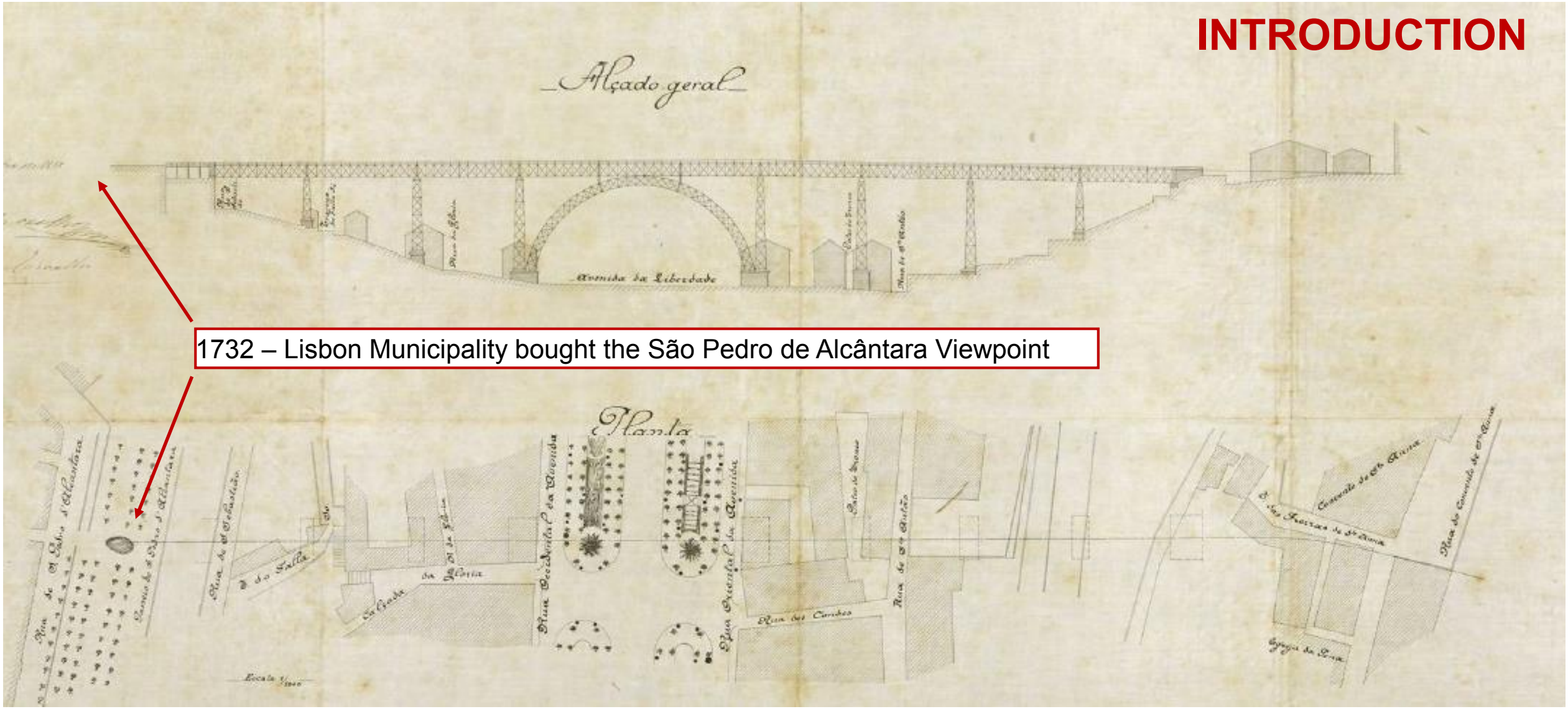
INTRODUCTION

São Pedro de Alcântara VP

INTRODUCTION



INTRODUCTION



1732 – Lisbon Municipality bought the São Pedro de Alcântara Viewpoint

INTRODUCTION

1835 – …
Public Garden

High heritage value

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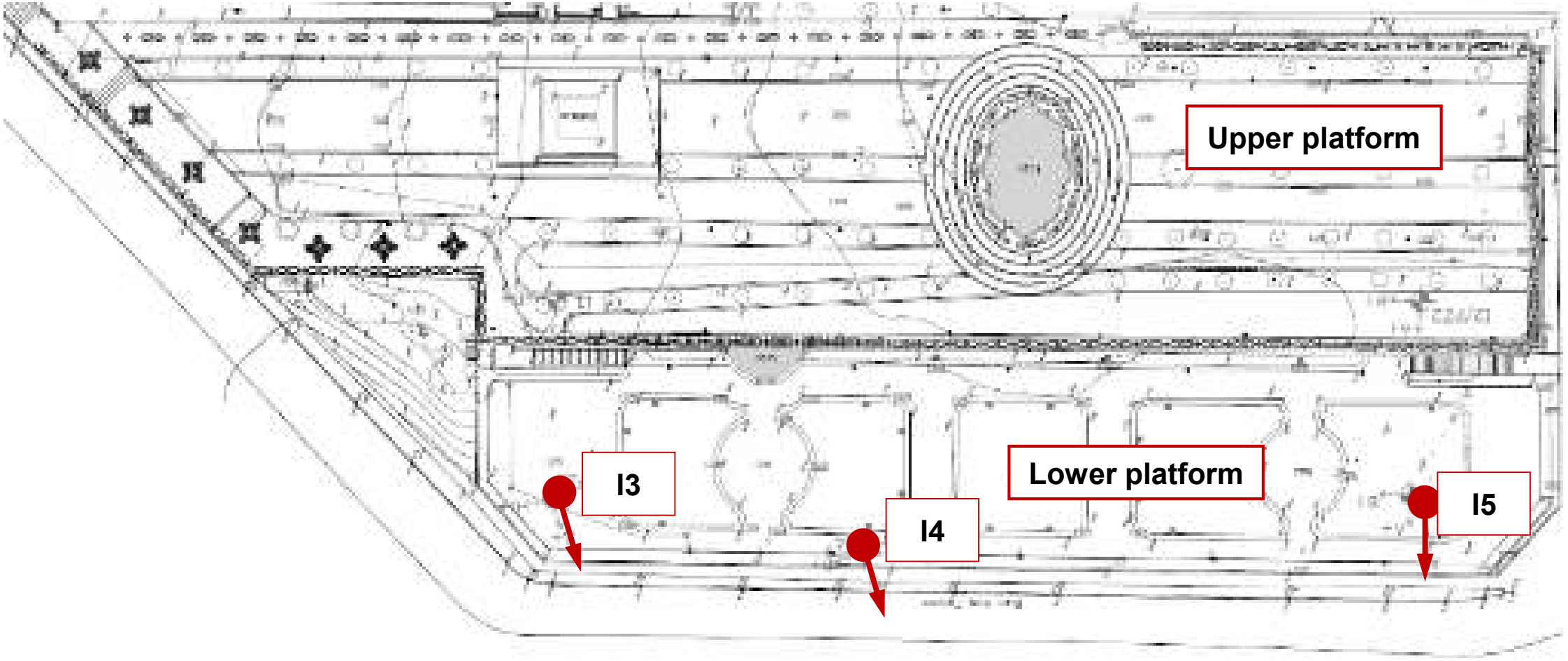
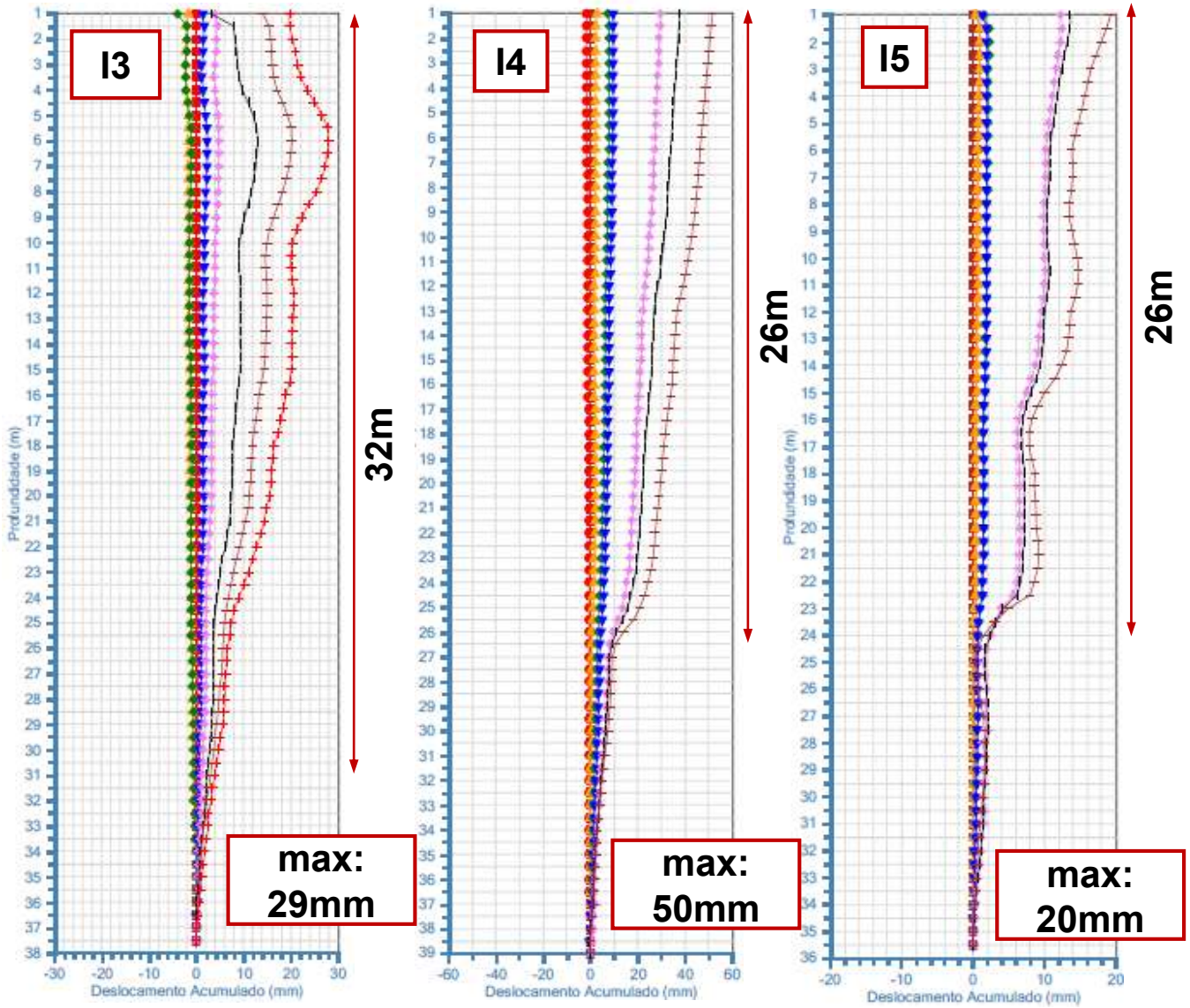
Inclinometers installed in 2011

INSTABILITY INDICATORS



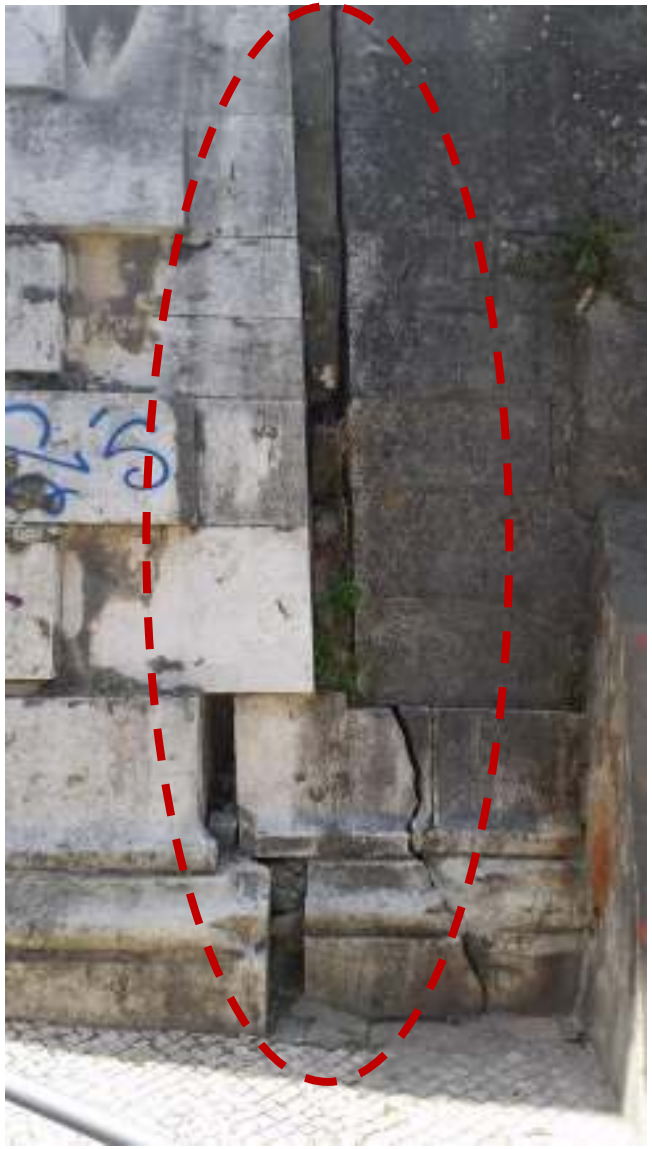


INSTABILITY INDICATORS

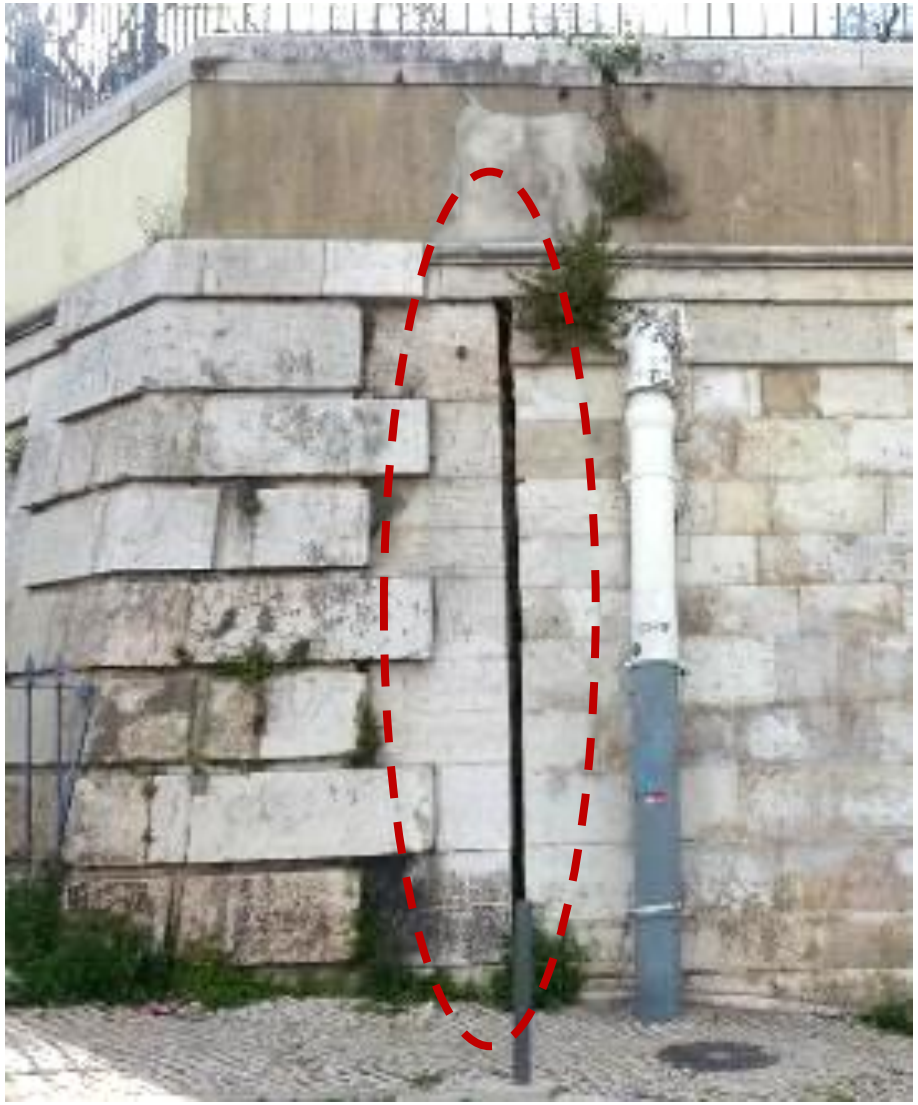
Accumulated horizontal displacments – May 2016

Movements indicating a potencial global instability surface

INSTABILITY INDICATORS



INSTABILITY INDICATORS



NEIGHBOR CONDITIONS

- Walls instability
- Access to the site area
- Historical and heritage issues, including garden and public furniture
- Heavy traffic, noise and vibrations

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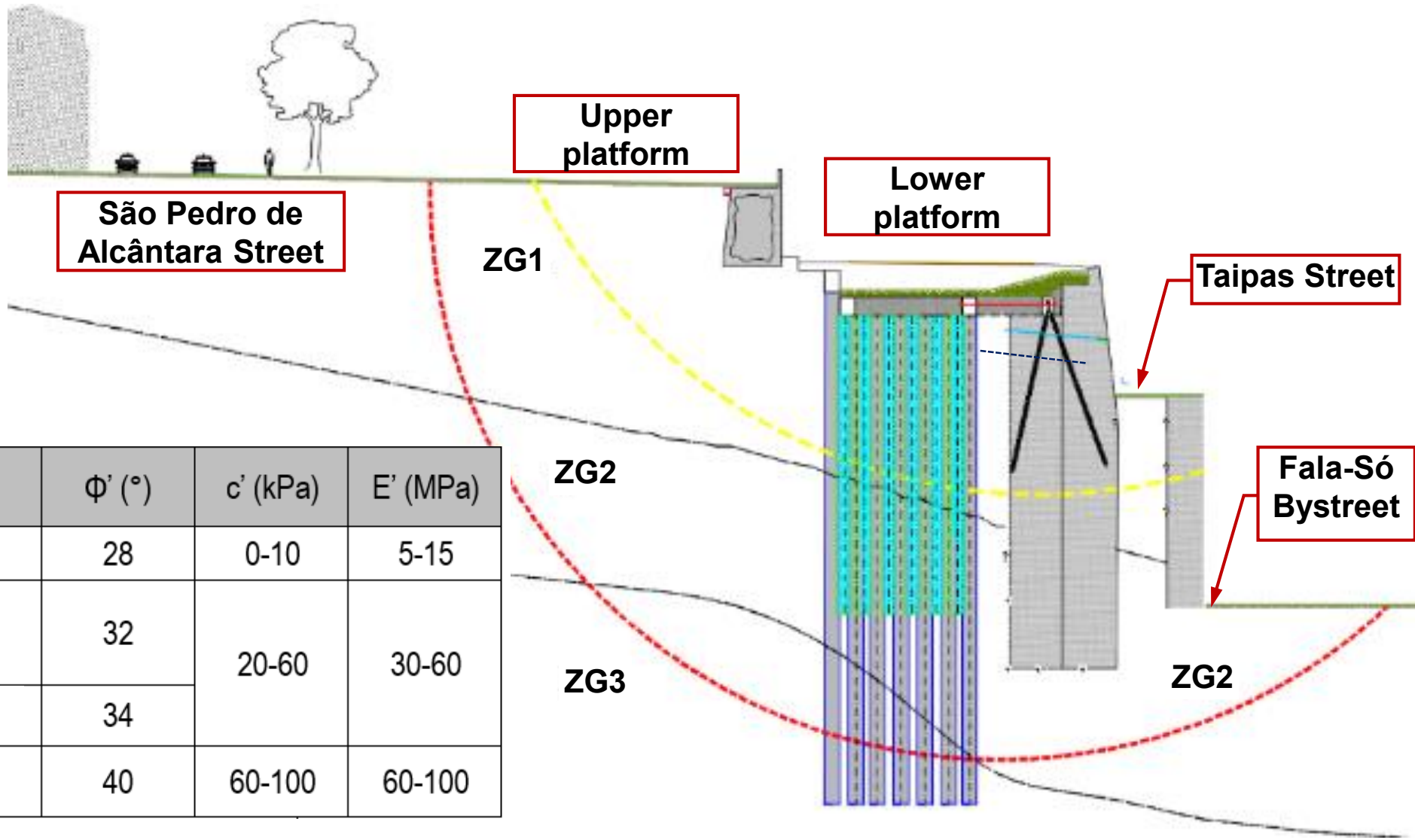
GEOLOGICAL AND GEOTECHNICAL SCENARIO



Zona	Constituição	Φ' (°)	c' (kPa)	E' (MPa)
ZG1	**Sandy silts**	28	0-10	5-15
ZG2-1	**Clays, sands and limestones**	32	20-60	30-60
ZG2-2	**Silty clays**	34		
ZG3	**Silty clays and limestones**	40	60-100	60-100

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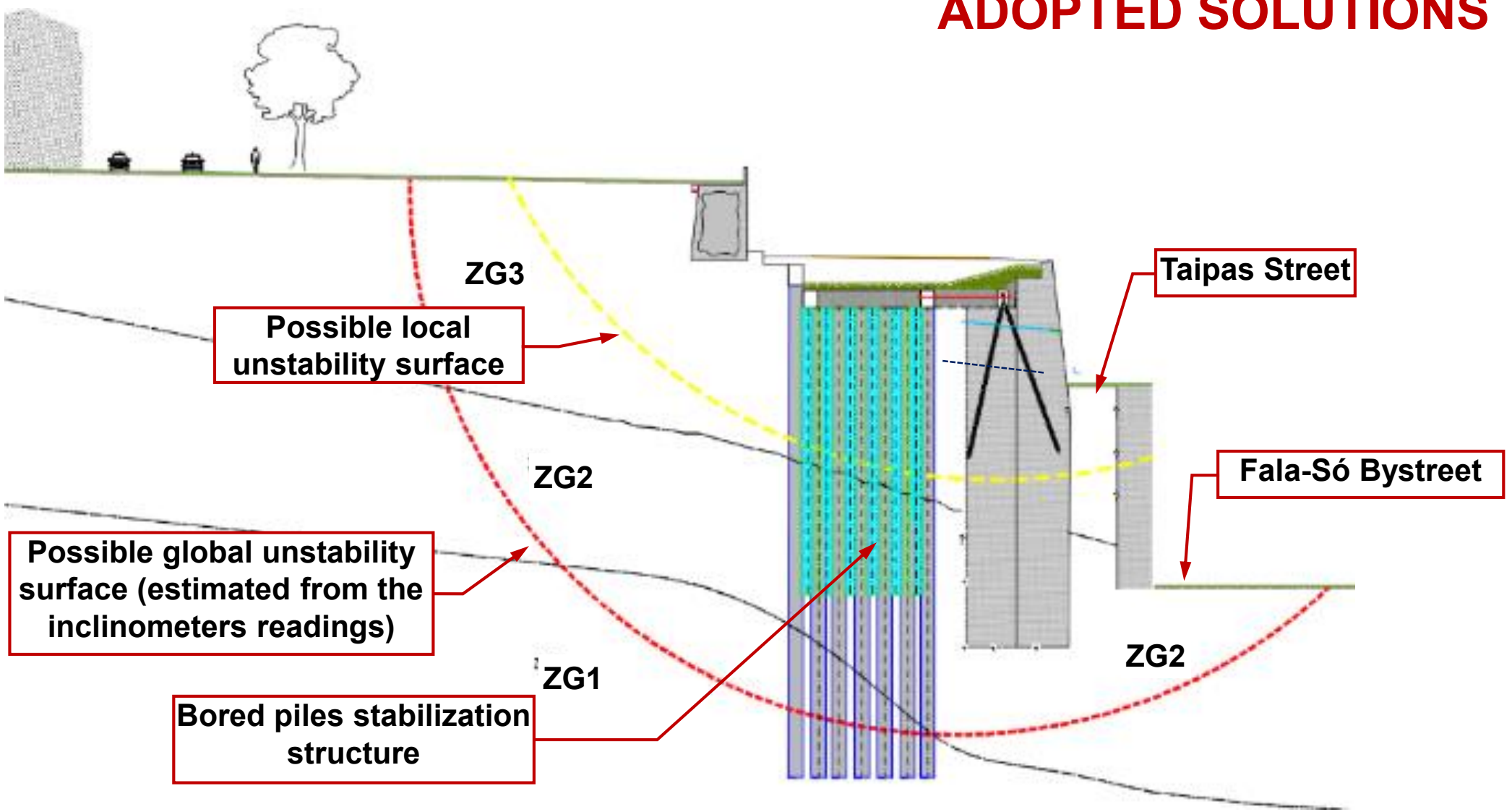
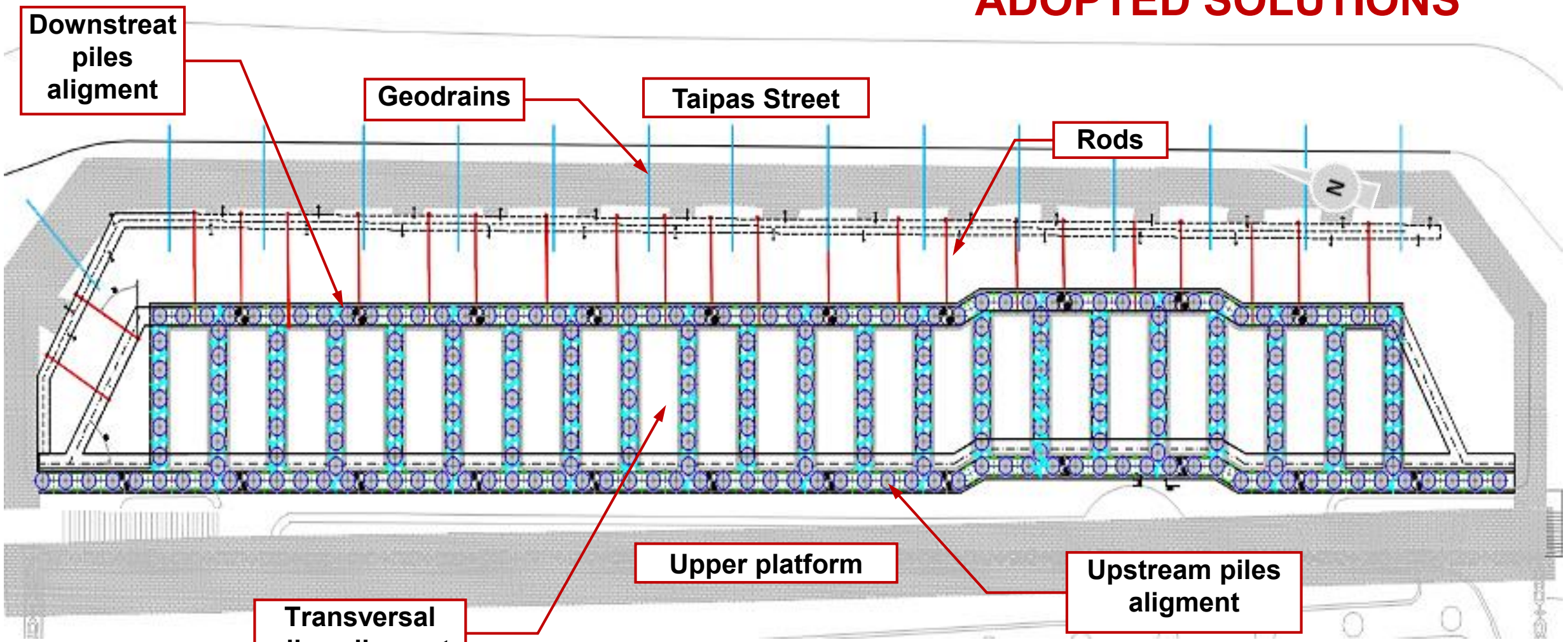
ADOPTED SOLUTIONS

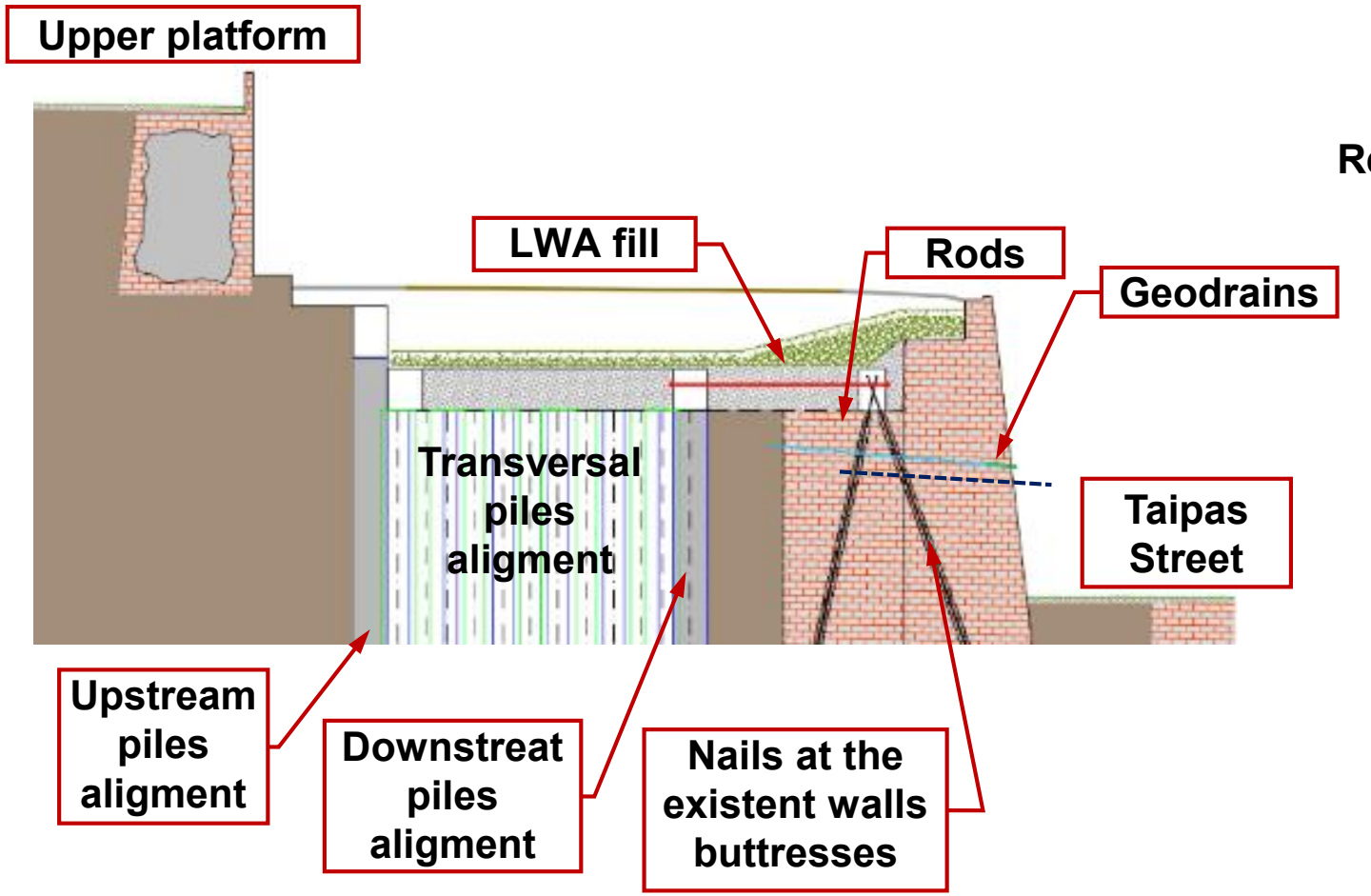


ADOPTED SOLUTIONS



Plan

ADOPTED SOLUTIONS



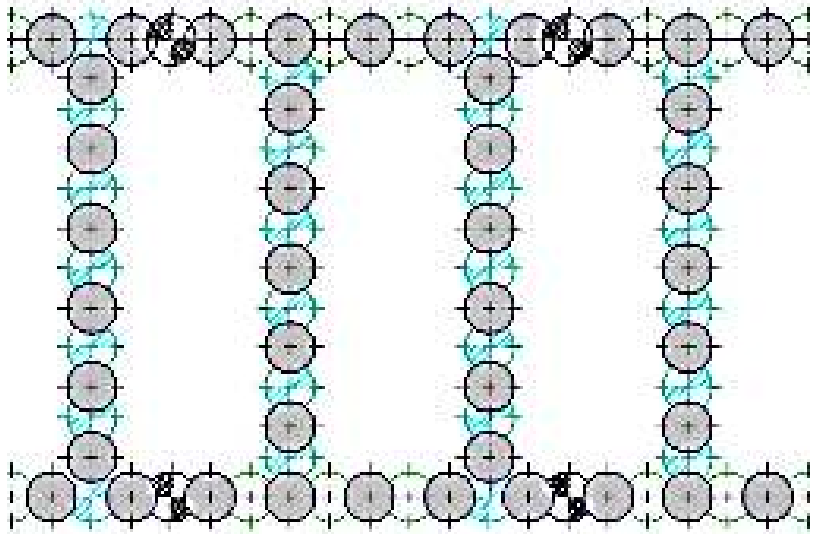
Cross Section

Piles Ø1000mm
Reinforced concrete
L=34.5m

Piles Ø1000mm
Reinforced concrete
L=12.0n

L=16.3n

L=21.5n



Plan

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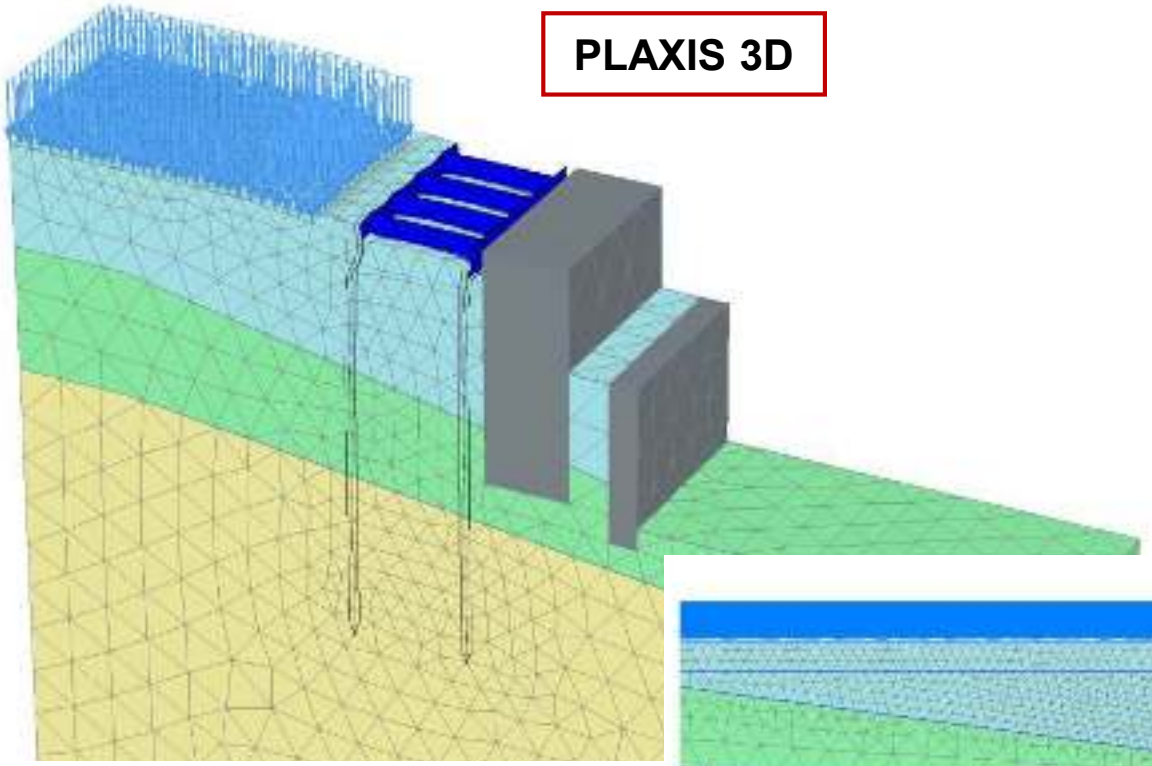
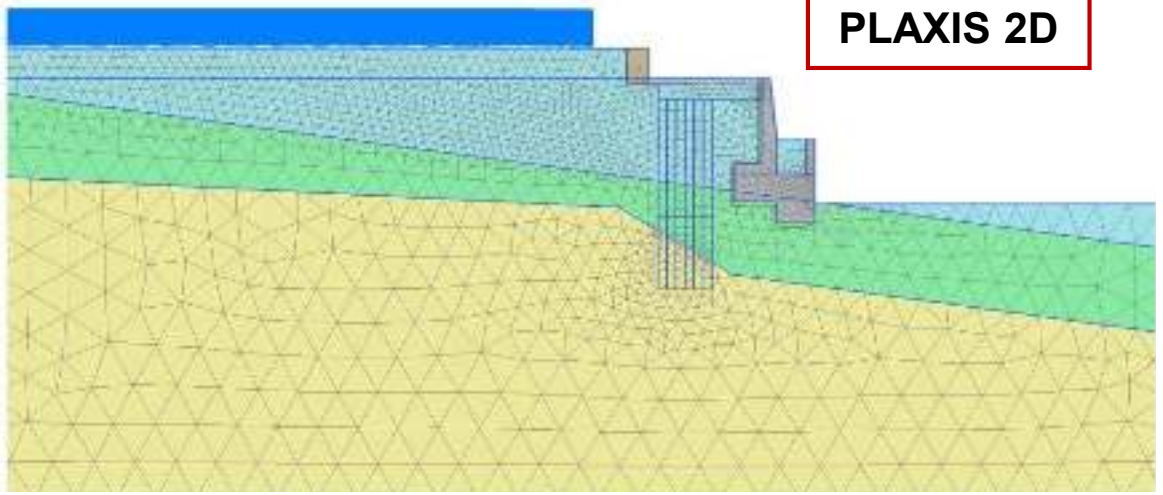
ANALYTICAL MODELS

PLAXIS 3D



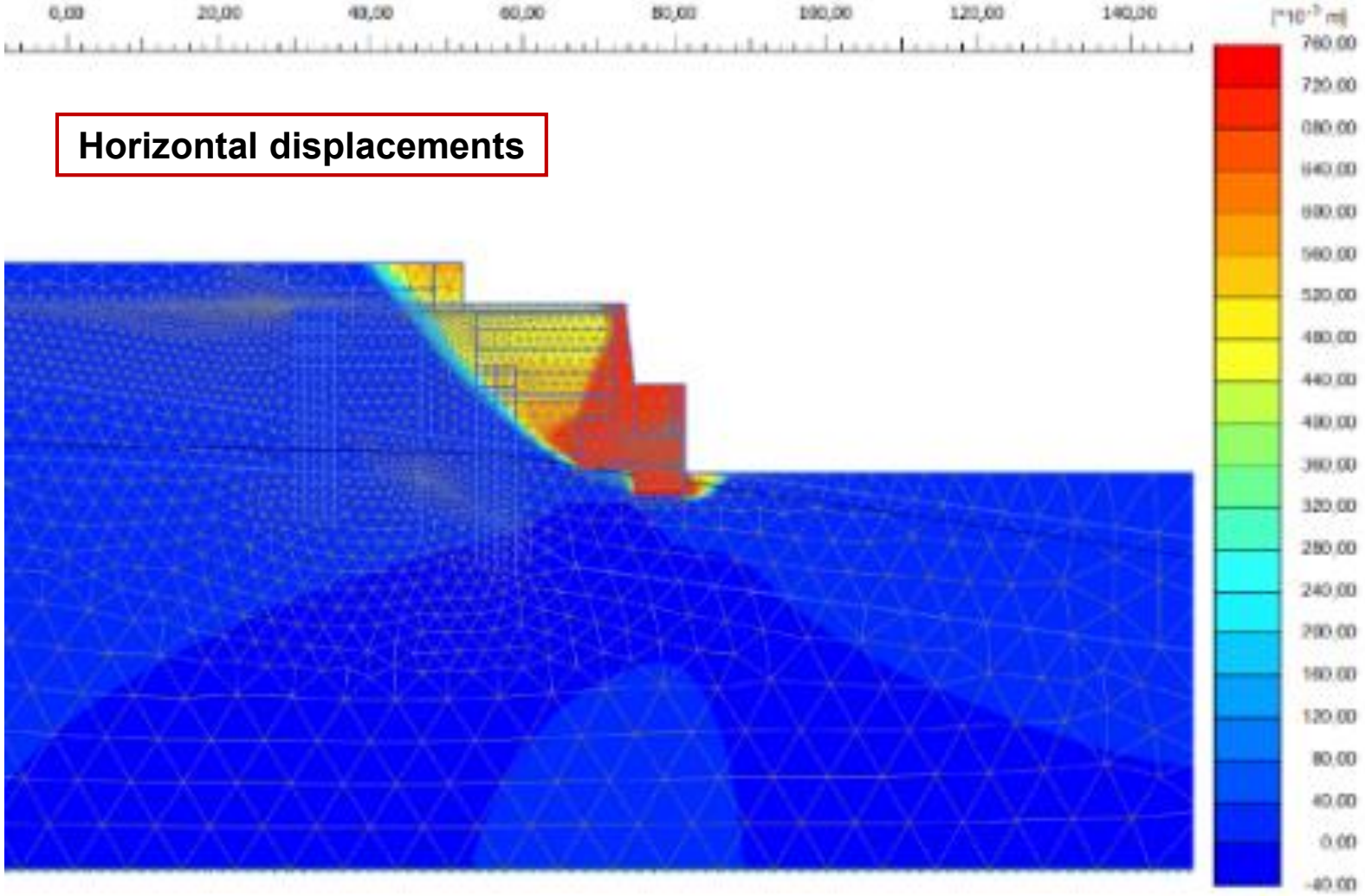
PLAXIS 2D



Comparative analysis: before and after the stabilization and drainage works

ANALYTICAL MODELS

Horizontal displacements



Stuation	Static	Dinamic
Before	1,12	< 1,00
After	1,70	1,25

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SITE WORKS

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SITE WORKS

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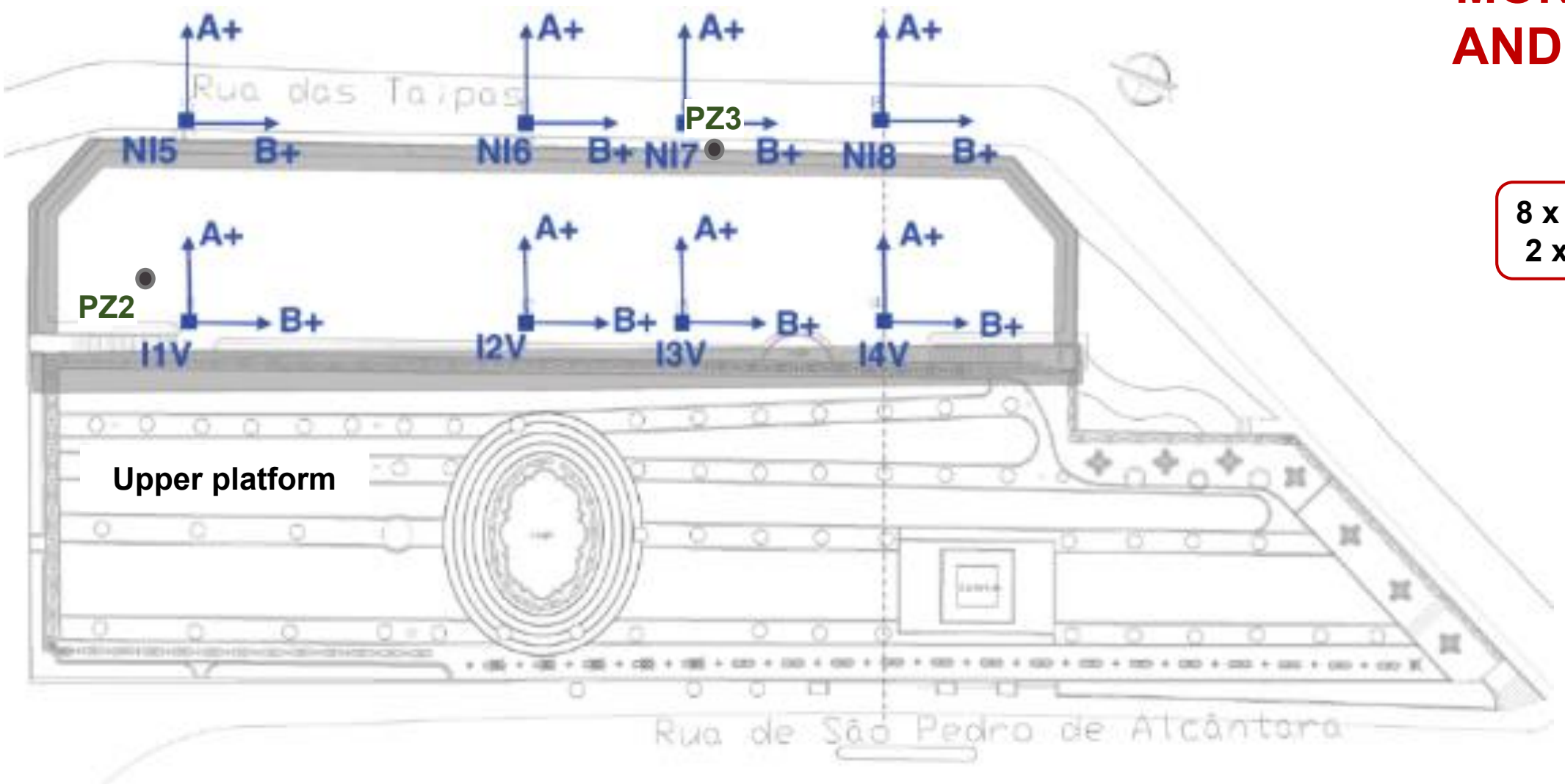
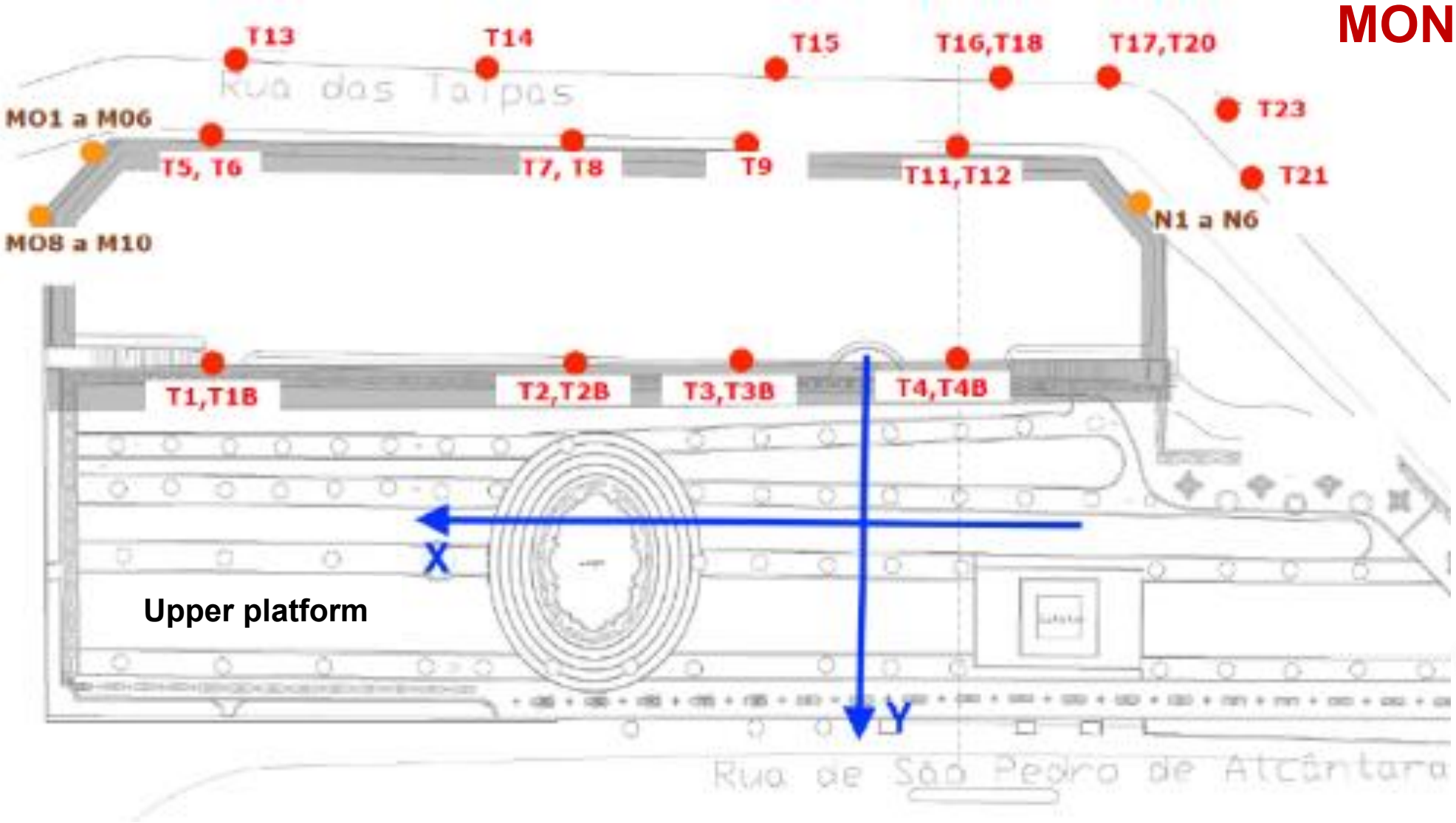
MONITORING AND SURVEY



8 x Inclinometers
2 x Piezometers

MONITORING AND SURVEY



39 x Topographic prisms

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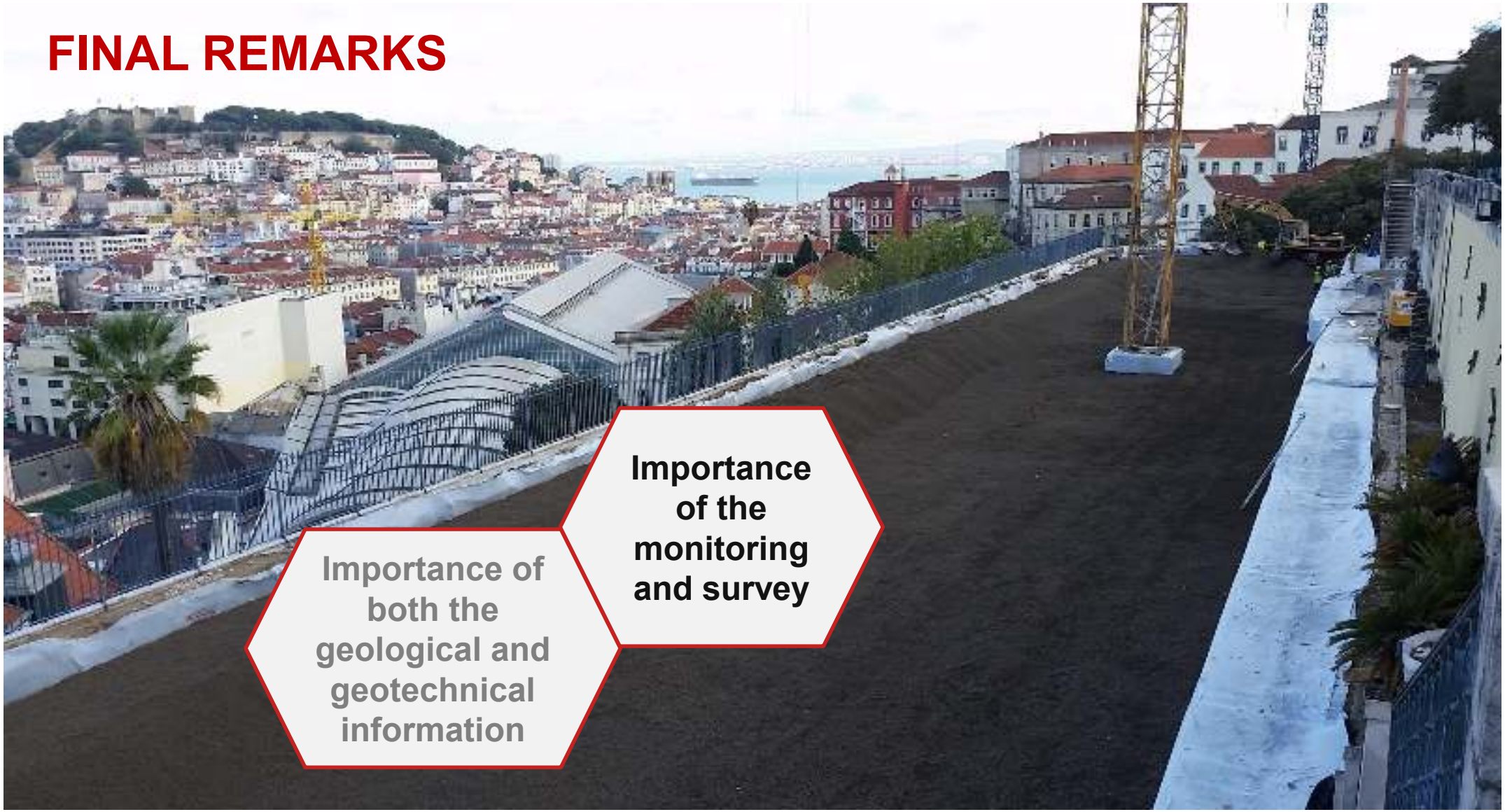
FINAL REMARKS

Importance of both the geological and geotechnical information

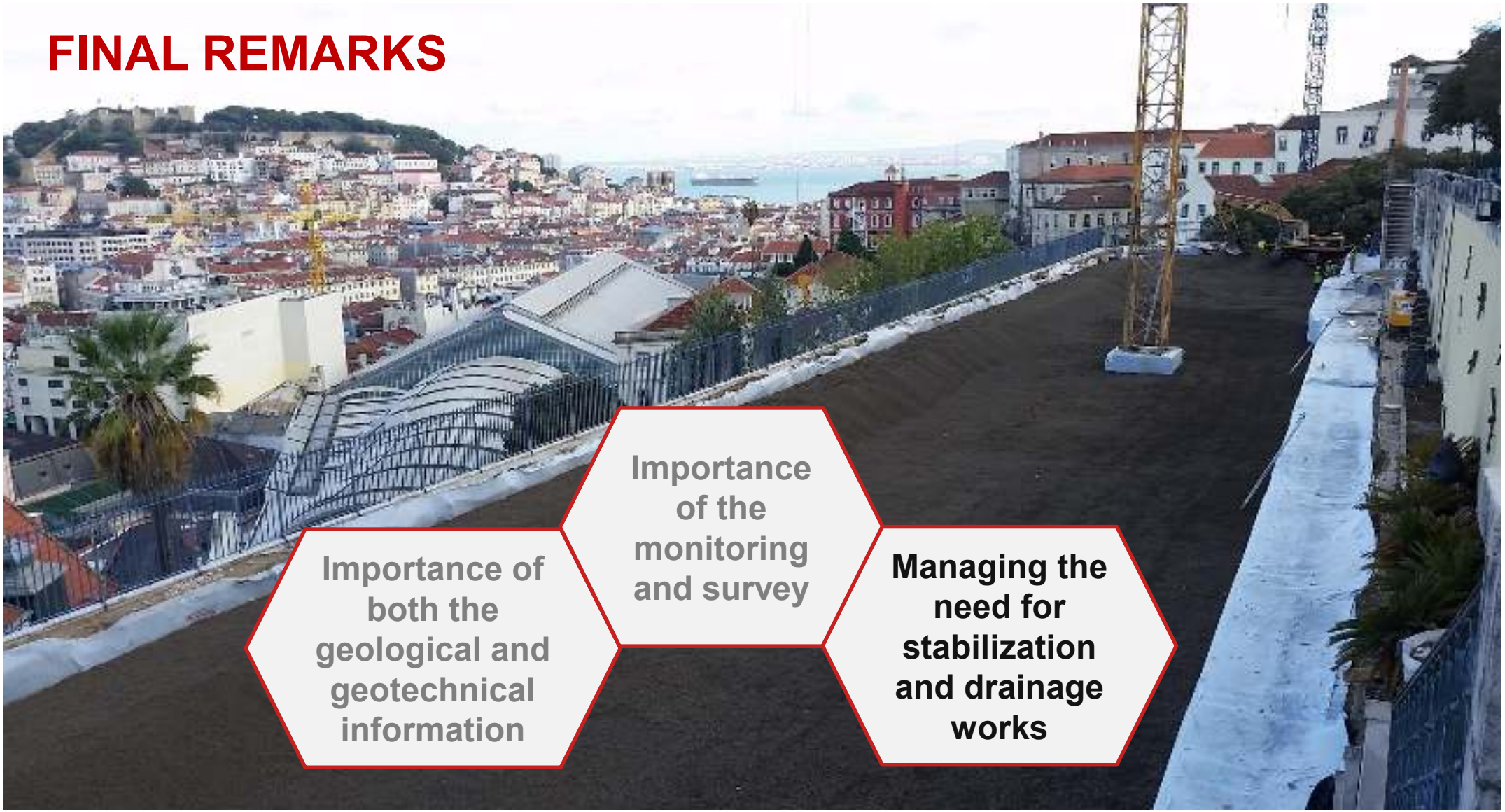
FINAL REMARKS



Importance of the monitoring and survey

Importance of both the geological and geotechnical information

FINAL REMARKS



Importance of the monitoring and survey

Importance of both the geological and geotechnical information

Managing the need for stabilization and drainage works

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04 SEPTEMBER – SESSION D6 – 7, TC DISCUSSION II,

HALL BJORTULOFT

SOIL STRUCTURE AND GROUND IMPROVEMENT

INFINITY TOWER, HIGH RISE BUILDING IN LISBON: INNOVATIVE SOLUTIONS FOR A DEEP AND COMPLEX EXCAVATION

Catarina Fartaria, JETsj, cfartaria@jetsj.com
Alexandre Pinto, JETsj, apinto@jetsj.com
Guilherme Pisco, JETsj, gpisco@jetsj.com
João Gondar, JETsj

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- PROPOSED SOLUTIONS
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- FINAL REMARKS

- **INTRODUCTION**
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LOCATION

Site

ARCHITECTURAL FEATURES

- The future tallest modern building of Lisbon will feature 26 floors and 4 basements.
- An iconic building in Lisbon's skyline with an impressive contemporary architecture.

https://www.infinity-tower.com/

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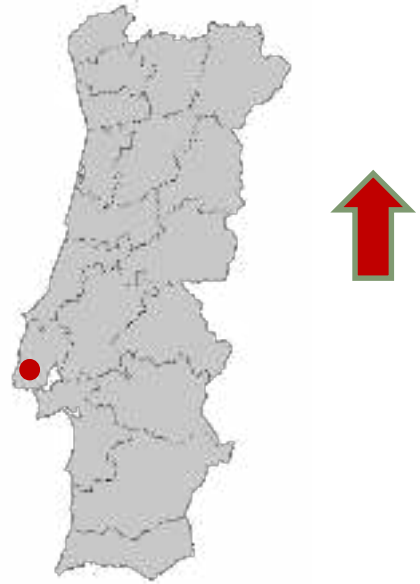
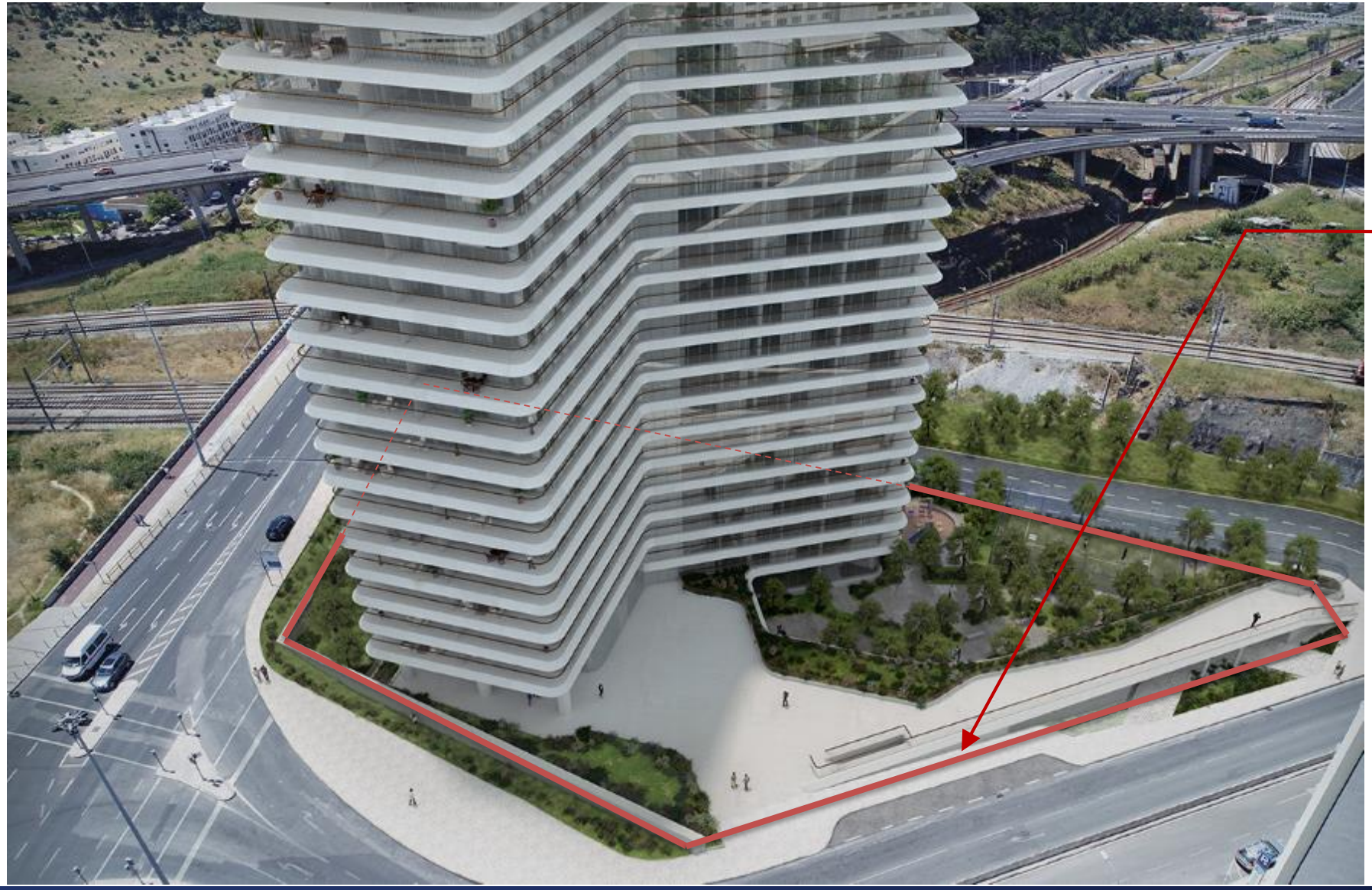
NEIGHBOR CONDITIONS

WW Drainage tunnel



Site

NEIGHBOR CONDITIONS



Excavation area: 4.600m²

NEIGHBOR CONDITIONS

MAIN CONDITIONS

- Geotechnical and Geological: Landfills + Lisbon Volcanic Complex.
- Topographic: small hill.
- Surrounding Infrastructures: Alcantara WW Drainage Tunnel.
- Surrounding Infrastructures: Roads + Roadway Viaduct.
- Surrounding Infrastructures: Railway Line.

TOPOGRAPHY

- **The existing topography, with the building location laying over a small hill, leads to an excavation depth ranging from 18m to 7m at the opposite alignments**

VIADUCT

Viaduct

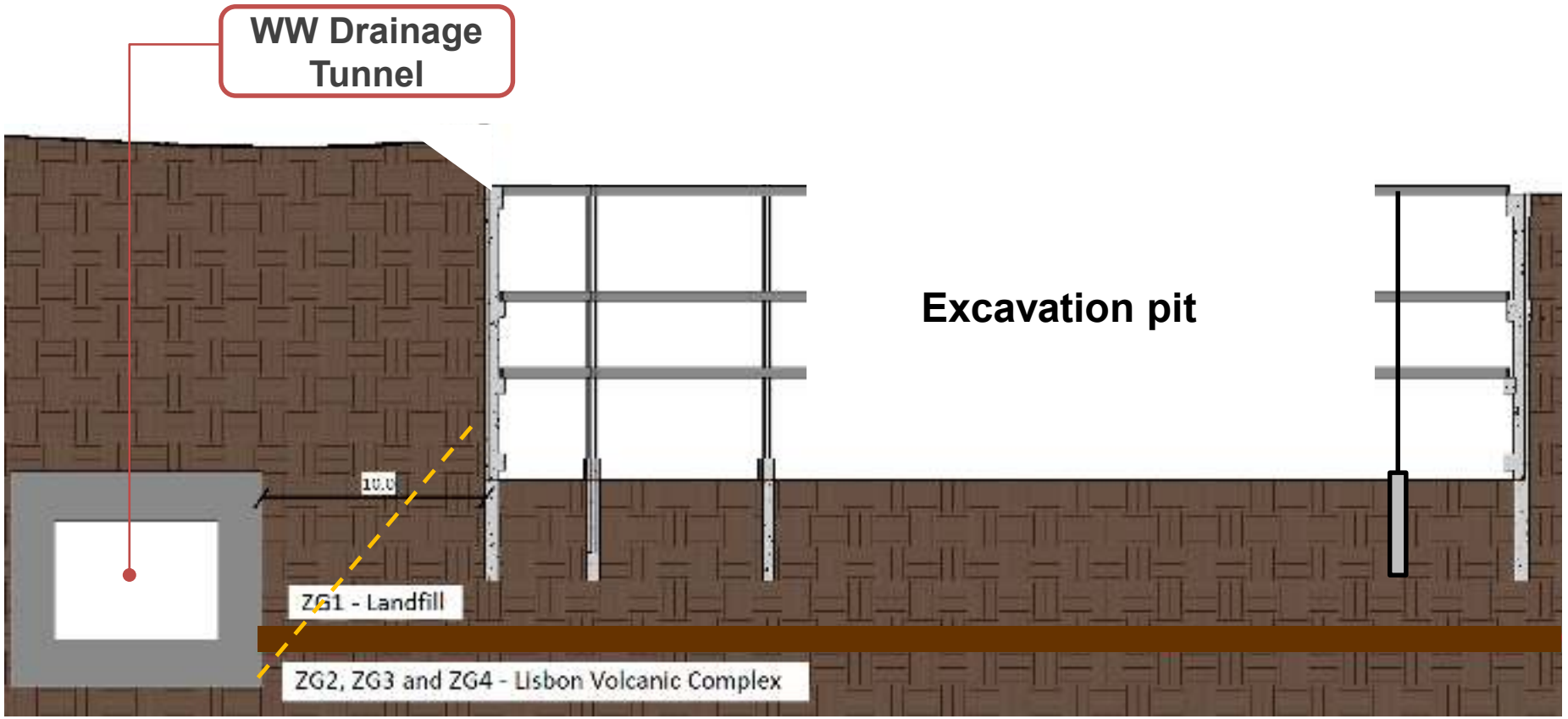
ALCANTARA STREAM

Alcantara Stream, 1912

ALCANTARA WW DRAINAGE TUNNEL

Alcantara Waste Water Drainage Tunnel, 1945

ALCANTARA WW DRAINAGE TUNNEL



- INTRODUCTION
- MAIN CONDITIONS
- **GEOLOGICAL AND GEOTECHNICAL SCENARIO**
- PROPOSED SOLUTIONS
- DESIGN
- FINAL REMARKS

GEOTECHNICAL FEATURES

- Heterogeneous Urban Fills.
- About 20m excavation depth intersecting Urban Fills and the Lisbon Volcanic Complex: mainly basalts and clay tuffs
- Lisbon Volcanic Complex: formed 72 million years ago by several important volcanic episodes, showing mainly basaltic sheets, volcanic tuffs, pyroclasts, volcanic breccias, etc,

GEOTECHNICAL SITE INVESTIGATION

9 boreholes location

GEOTECHNICAL FEATURES

Basalts

Tuffs

Fills

GEOTECHNICAL ZONES

Geotechnical Zone	Description	γ (kN/m³)	Ø' (º)	c' (kPa)	Es (MPa)
ZG1	Landfill (5≤NSPT≤17)	18	30	0	15
ZG2	Pyroclastic tuffs and low-quality basalts W4 to W3-4; F5 to F4-5 with recovery ranging from 60% e 100% e RQD=0%	22	33	50	65
ZG3	Basalts W3 to W3-2, F4 to F4-5, with 90% recovery ranging and 20% ≤RQD≤75%, interbedded with basalts W3-2, F4-5 with 100% recover and 47%≤RQD≤74%	22	37	80	120
ZG4	Basalts W3-2 to F4-3, with 100% recovery and 56%≤RQD≤76%	22	45	100	150

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PROPOSED SOLUTIONS

The retaining walls solutions were proposed considering the existing restraints, with the following purposes

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- **Control the ground deformation;**
- **To minimize the interferences with the surrounding infrastructures and services;**
- **Improve Safety + Reduce Schedule + Decrease Costs.**

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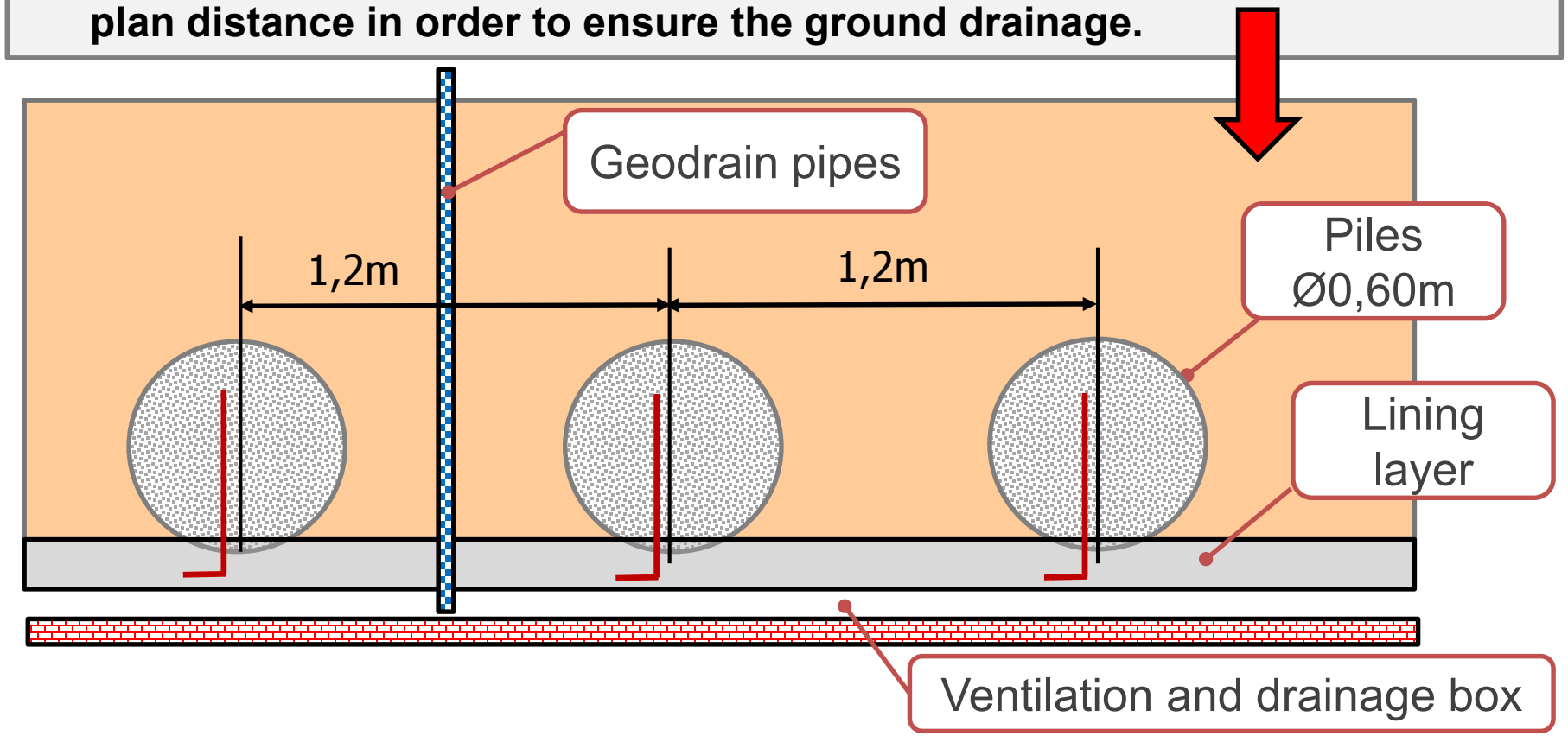
- **Control the ground deformation;**
- **To minimize the interferences with the surrounding infrastructures and services;**
- **Improve Safety + Reduce Schedule + Decrease Costs.**

- **Bored Pilled Wall solutions with 600mm diameter pile and a plan space ranging between 0.80m and 1.20m.**
- **The total pile's depth ranges from 21.60m to 10.30m, all with a minimum embedment length of 4.00m.**

PROPOSED SOLUTIONS

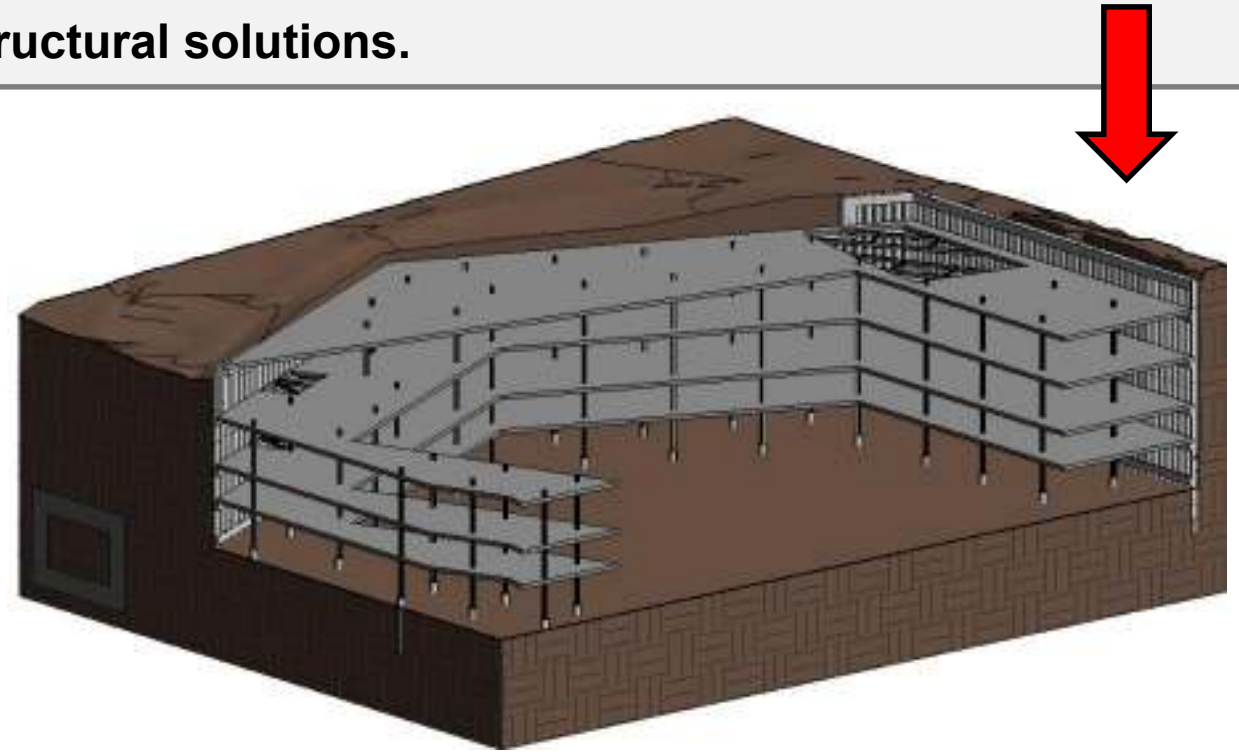
- **The ground between the piles will be lined by a shotcrete layer of 150mm minimum thickness**
- **Geodrain pipes with 3m length will be installed with a minimum of 3.60m plan distance in order to ensure the ground drainage.**



Solution plan

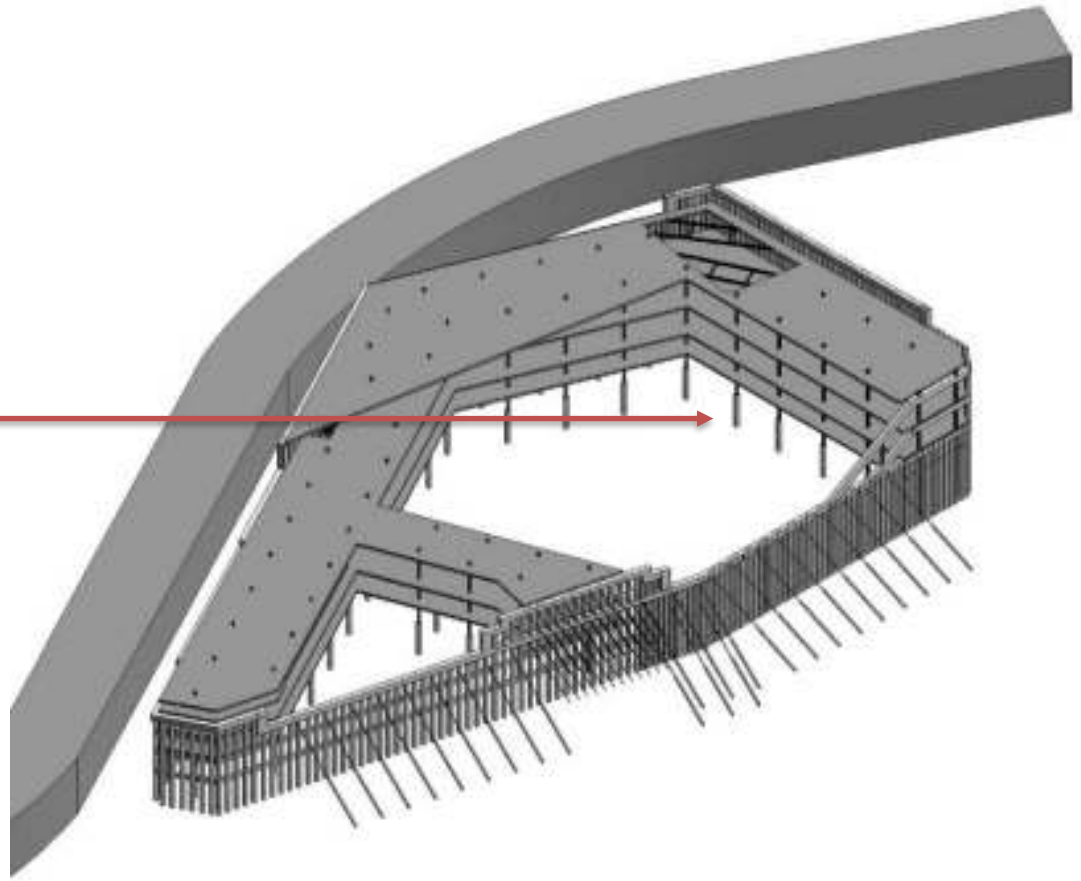
PROPOSED SOLUTIONS

- In the west view, the wall will be braced by one level of <u>temporary ground anchors</u> to be installed at level -2 with 3.60m plan space.
- The remaining excavation alignments will be stabilized with <u>slab bands of 12m width and 0.35m minimum thickness</u>, compatible with both the architecture and structural solutions.



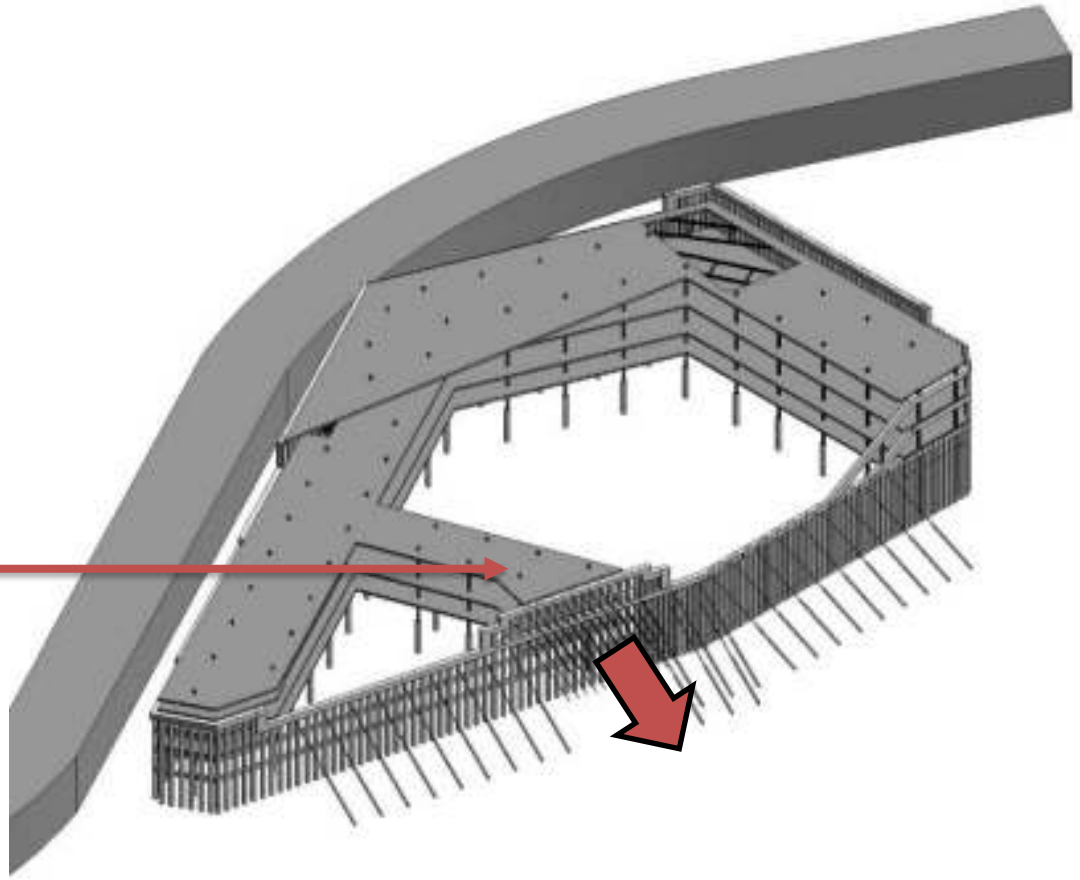
PROPOSED SOLUTIONS

- The slab bands will be supported by vertical steel profiles HEB260 embed in 600mm bored piles, 4m below the excavation final level.



PROPOSED SOLUTIONS

- The slab bands will be supported by vertical steel profiles HEB260 embed in 600mm bored piles, 4.00m below the bottom level of excavation.
- The slab bands above level -2 will be supported by slimmer slab strips of about 7m width that will react against the piles wall at the west view.



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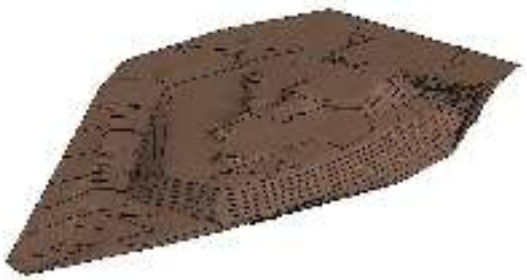
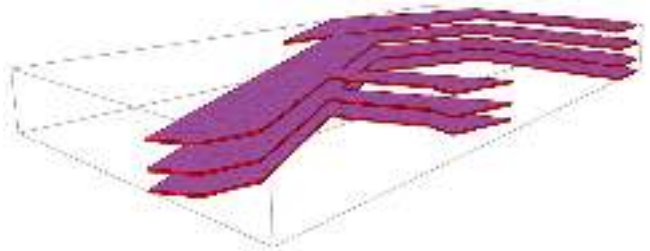
- **DESIGN**
- FINAL REMARKS

DESIGN METHODOLOGY



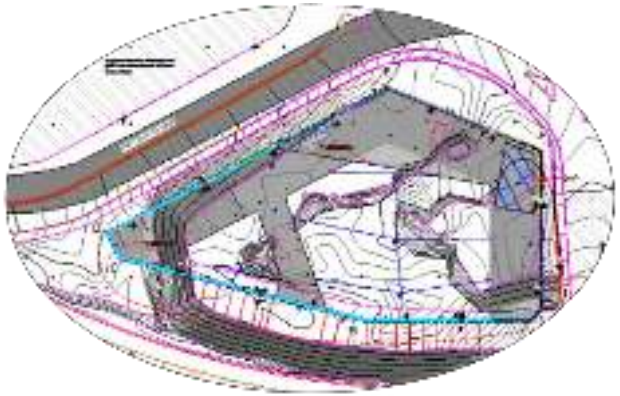


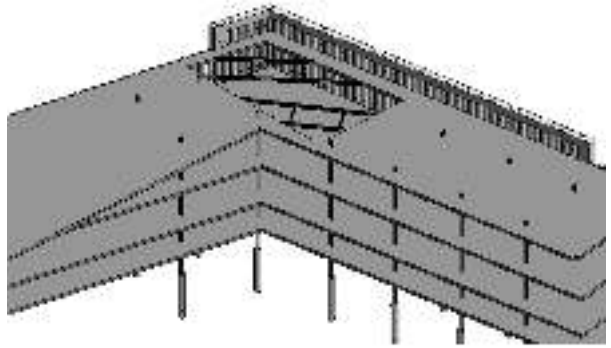
Preparation
- Units
- Levels
- Geolocation

Topography
- Earthworks quantities
- Restraints

Structure
- Bored Piles
- Slab bands
- RC beams
- Steel profiles
- Ground anchors

Analysis
- Plaxis
- SAP2000

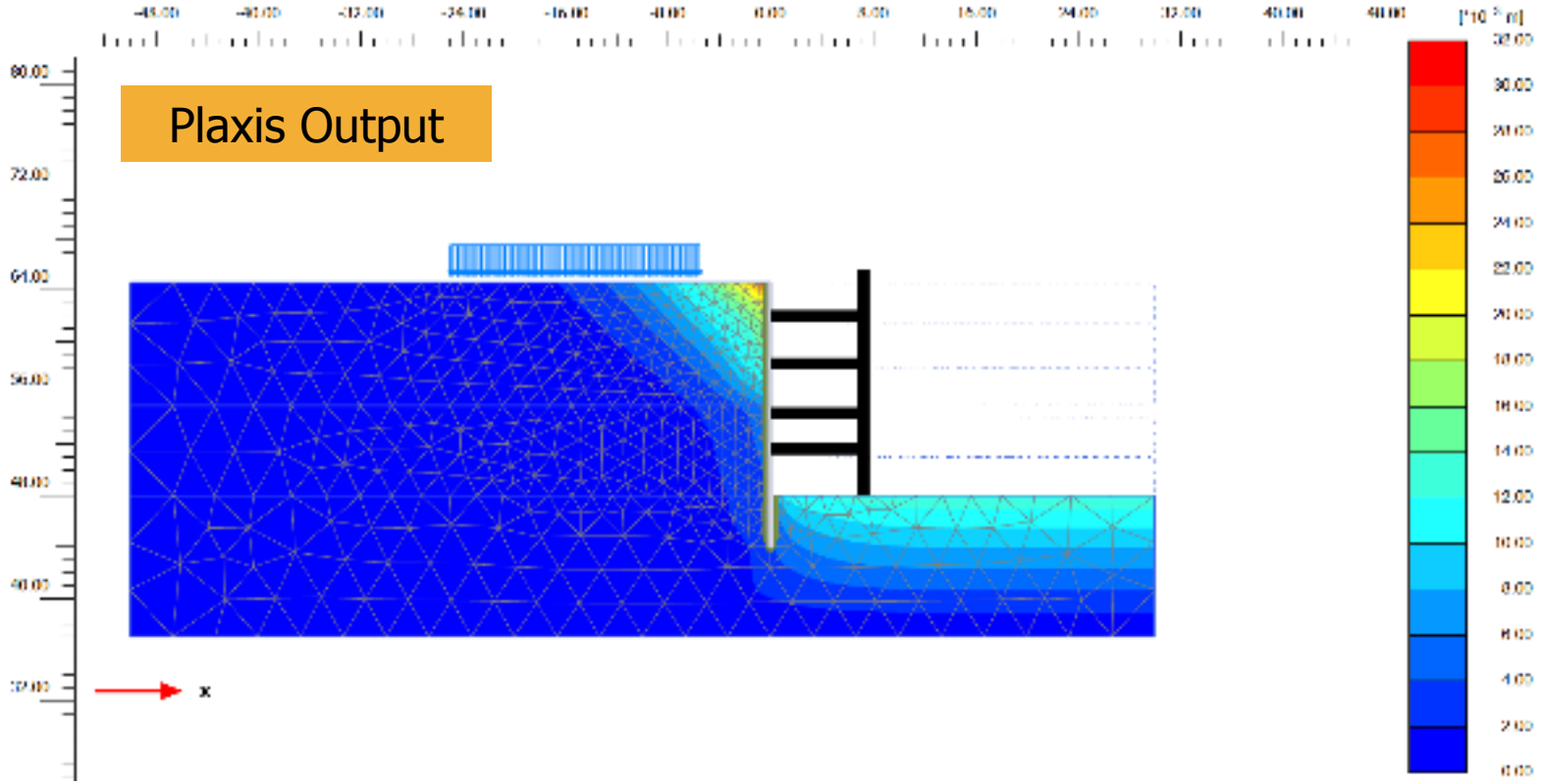




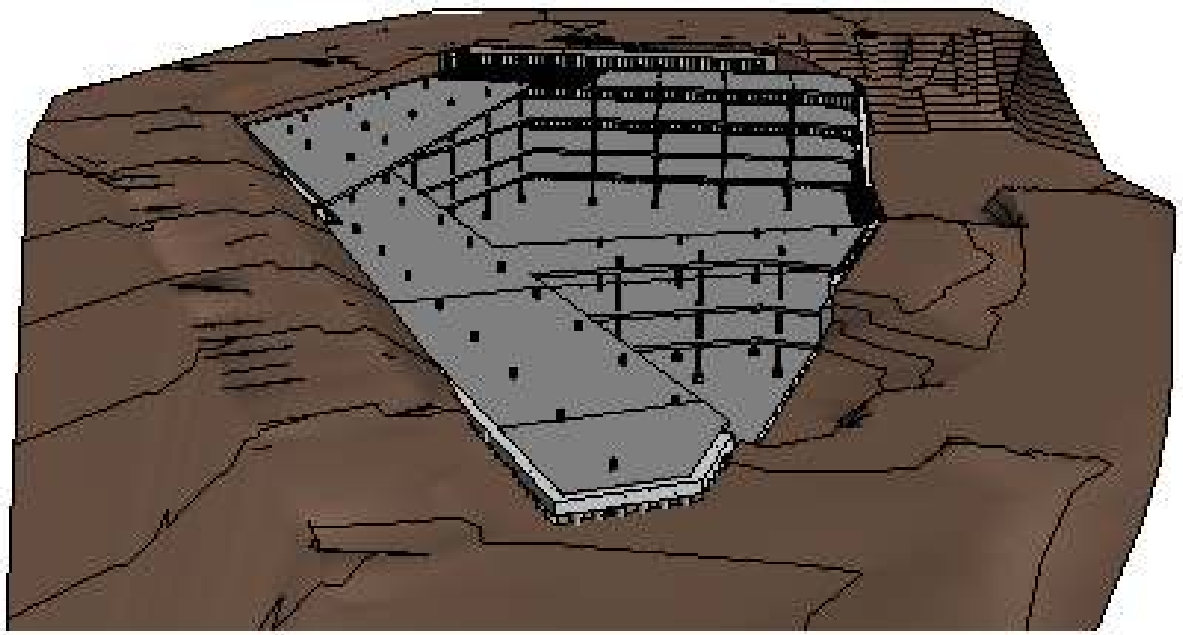
DESIGN METHODOLOGY

- The solution were evaluated using the geotechnical software (PLAXIS2D)

- Displacements were estimated and analyzed considering the geotechnical zones and correspondent parameters.



DESIGN METHODOLOGY



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- DESIGN
- **FINAL REMARKS**

FINAL REMARKS

- **The importance of all the restraints assessment on an urban and complex excavation**

FINAL REMARKS

- The importance of all the restraints assessment on an urban and complex excavation

- **The use of BIM methodology allowed an <u>accurate coordination with the architecture and others engineering projects</u> and promoted efficiency in terms of project documentation, especially when changes were needed.**

FINAL REMARKS

- The importance of all the restraints assessment on an urban and complex excavation

- The use of BIM methodology allowed an accurate coordination with the architecture and others engineering projects and promoted efficiency in terms of project documentation, especially when changes were needed.

- **The BIM model can be a very useful at both the construction and the building maintenance / management under operation phases**

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XVII EUROPEAN CONFERENCE ON SOIL MECHANICS AND GEOTECHNICAL ENGINEERING

04 SEPTEMBER – SESSION D6 – 7, TC DISCUSSION II

SOIL STRUCTURE AND GROUND IMPROVEMENT

INFINITY TOWER, HIGH RISE BUILDING IN LISBON: INNOVATIVE SOLUTIONS FOR A DEEP AND COMPLEX EXCAVATION

THANK YOU FOR YOUR KIND ATTENTION

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2 SEPTEMBER – KEYNOTE SESSION 2 – PLENARY PAPERS

THE USE OF BIM TECHNOLOGY IN GEOTECHNICAL ENGINEERING

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Alexandre Pinto, JETsj, apinto@jetsj.com
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- INTRODUCTION
- STUDY CASE
- 3/D BIM MODELING
- 4/D BIM MODELING
- 5/D BIM MODELING
- FINAL REMARKS

INTRODUCTION

Difficulty ***implementing*** *planning* ***(4D)*** *and budgeting* ***(5D)*** *tools.*

McGraw Hill Construction (2012)

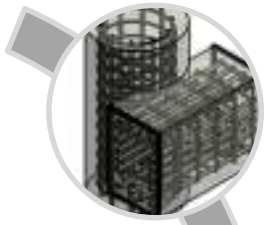
Productivity and construction digitalization

Low national Implementation of BIM

4D+5D capabilities to be seized

Advantages + Low implementation in Geotechnical Engineering

5D/BIM + Geotechnical Engineering



Structure (3D)
- 3D parametric modeling
- Geological and geotechnical layers

Planning (4D)
- Construction Simulation
- Clash detection
- Resource allocation

Budgeting (5D)
- Automatized QTO
- Procurement
- Multi-scenario analysis

"Geotechnical engineering includes not only ***financial risks*** *but also for structural and physical integrity"*

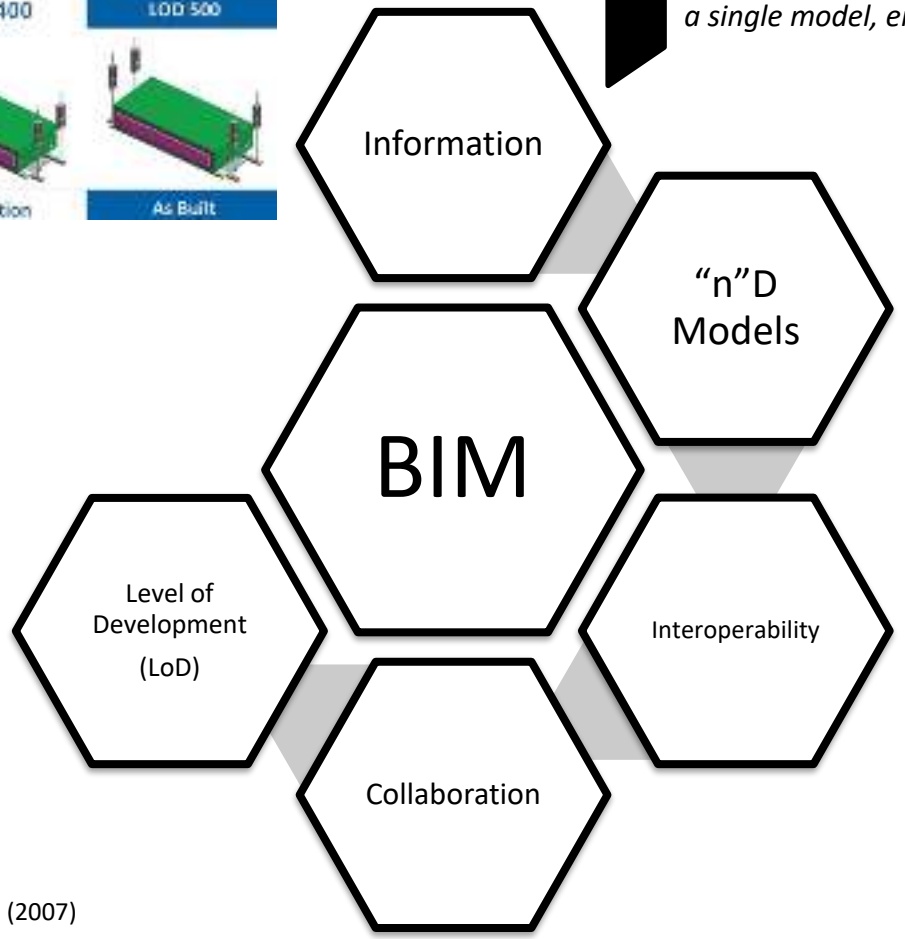
Sterling (2017)

INTRODUCTION

B uilding
I nformation
M odeling

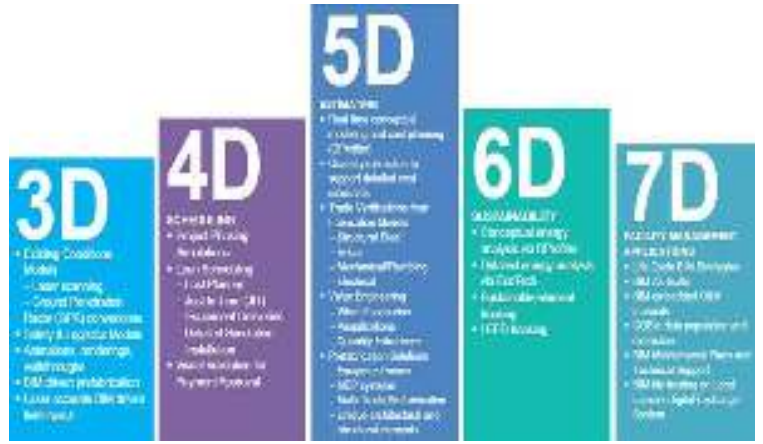
*"The methodology won´t be **linear** but **colaborative**"*

Carmona & Irwin (2007)



*"**Information** coming from different sources is **centralized** in a single model, ensuring its constant share and update"*

Carmona & Irwin (2007)



- INTRODUCTION
- **STUDY CASE**
- 3/D BIM MODELING
- 4/D BIM MODELING
- 5/D BIM MODELING
- FINAL REMARKS

STUDY CASE:
LISBON'S PUBLIC PARKING LOT "ARCO DO CEGO"

Restrains:

- Geological and geotechnical
- Adjacent infrastructures
- Execution deadlines

Constructive Solutions:

- Bored Pile Wall - 600mm //1,2m
- Temporary grout anchors - 2 levels
- King Post Walls - Ramp

- INTRODUCTION
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- 5/D BIM MODELING
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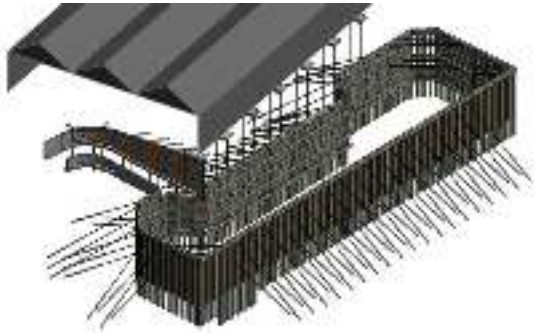
3D/BIM MODELING

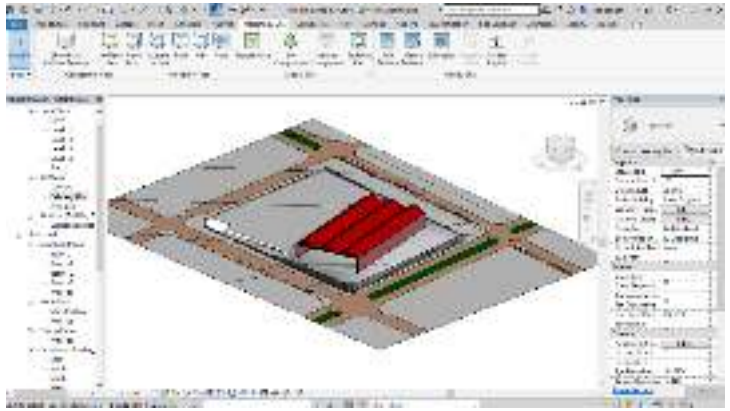


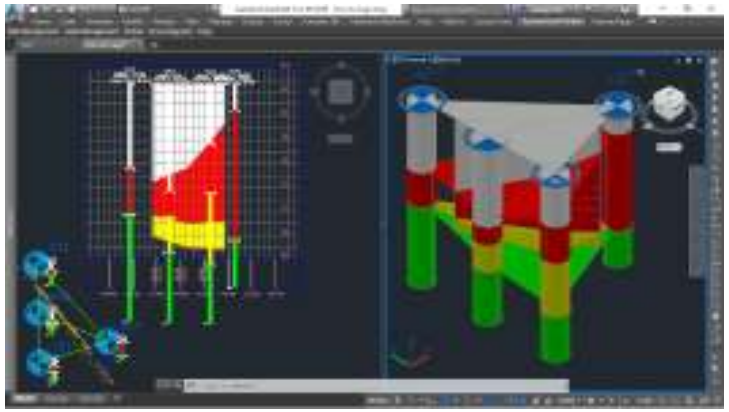
Preparation
- Georeferencing
- Units
- Phasing
- Levels

Topography
- Quantities
- Restrains

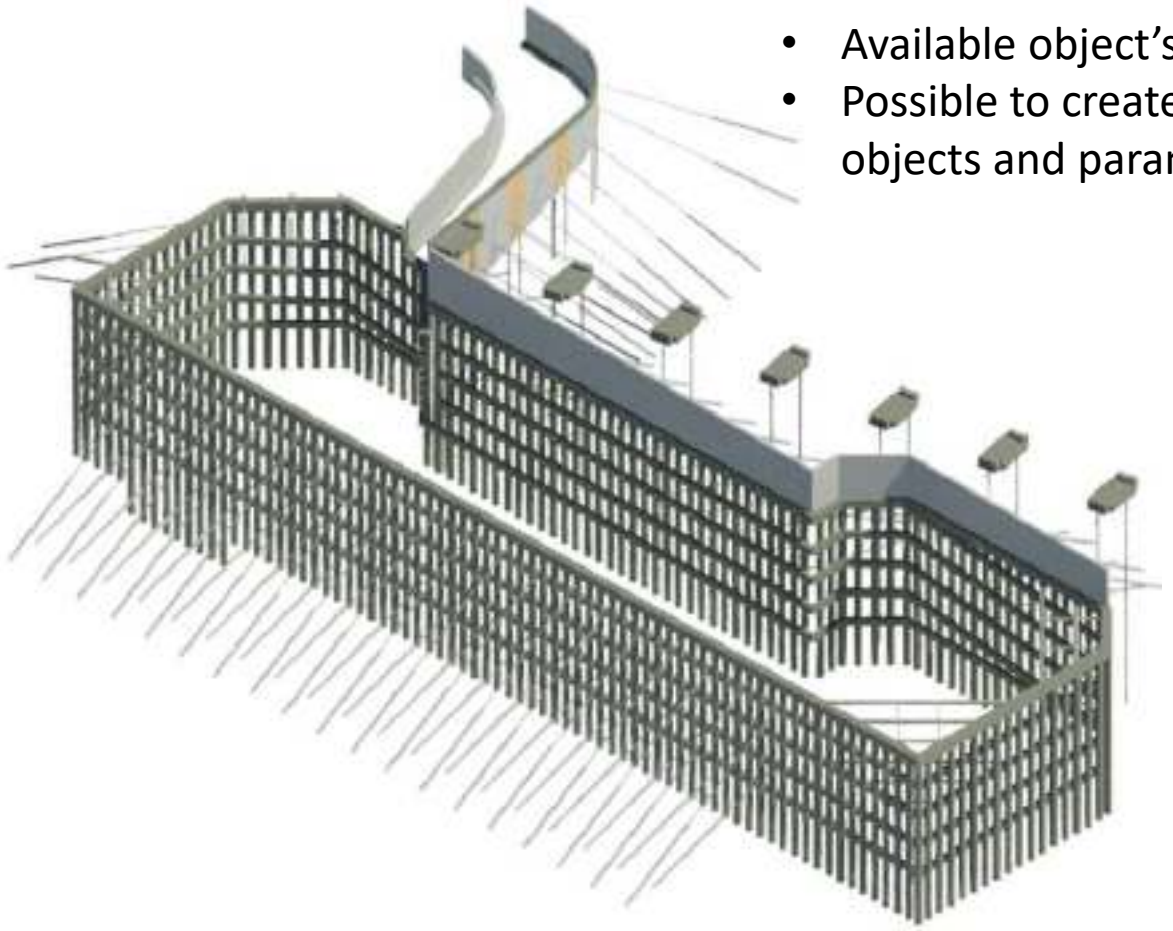
Structure
- Bored Piles
- King Post Walls
- Concrete Beams
- Steel Profiles
- Grout anchors

Geotechnical Layers
- Compatibilization
- Optimization

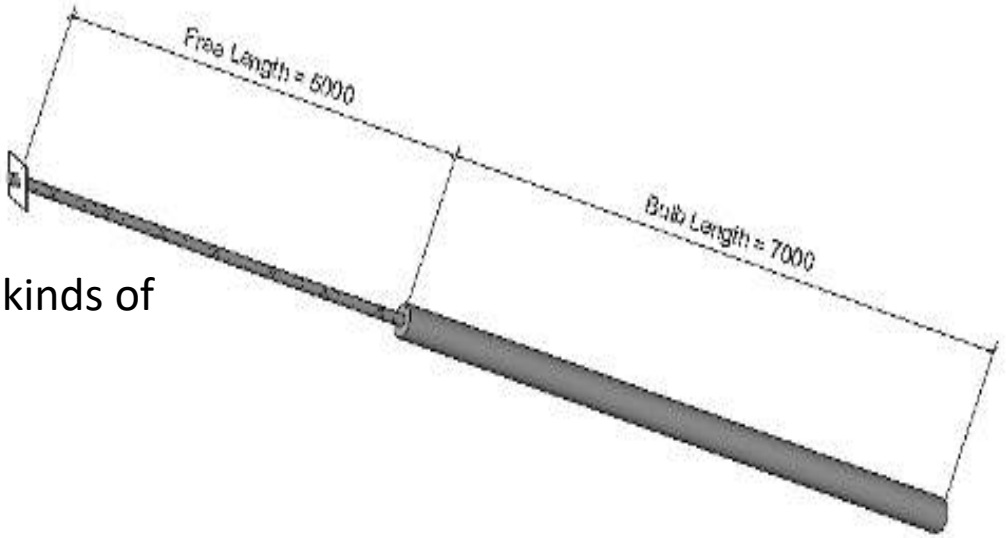


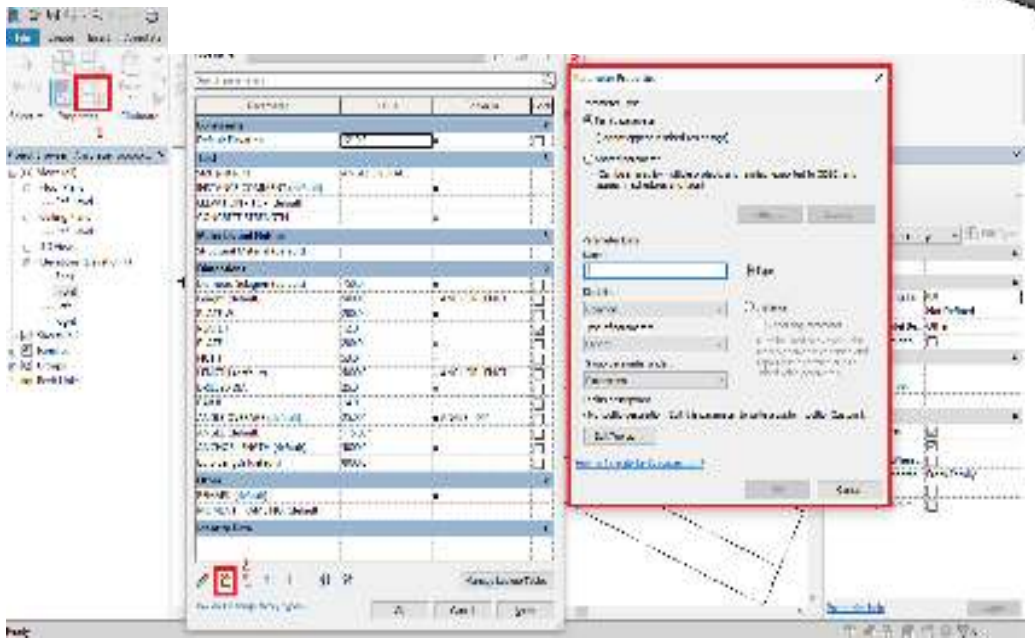


3D/BIM MODELING
PARAMETRIC ELEMENTS

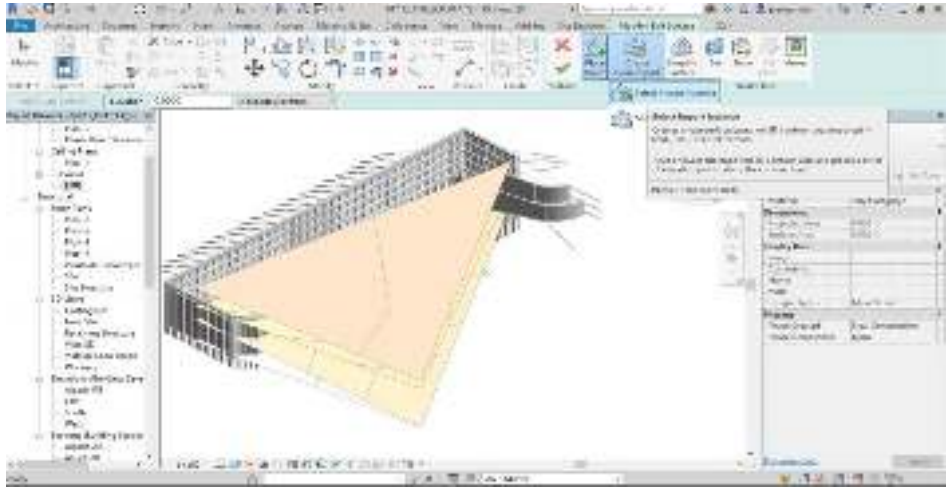


- Available object's library
- Possible to create different kinds of objects and parameters



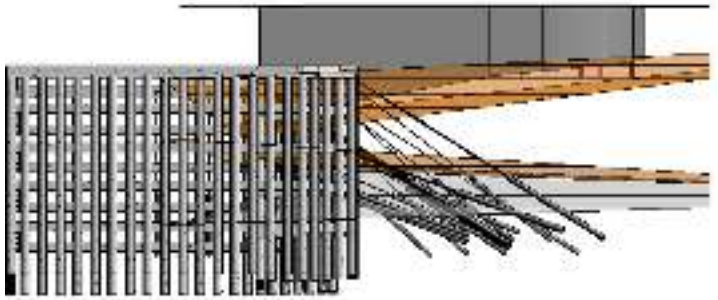


3D/BIM MODELING
GEOTECHNICAL LAYERS



1 – Geological and Geotechnical Study

Layer	Geotechnical Zone	N_{spt}	Weight (kN/m³)	Angle of Friction (°)	Cohesion (kPa)	Young Modulus (MPa)
Landfill	ZG3	0 – 7	18	24	-	3
Miocenic	ZG2A	6 – 26	19	32	5	10
	ZG2B	30 - 45	20	34	10	20
	ZG1	60	20	36	20	50

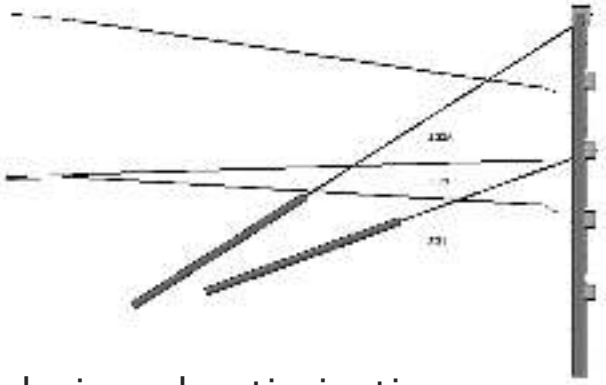


3 – Import to 3D model

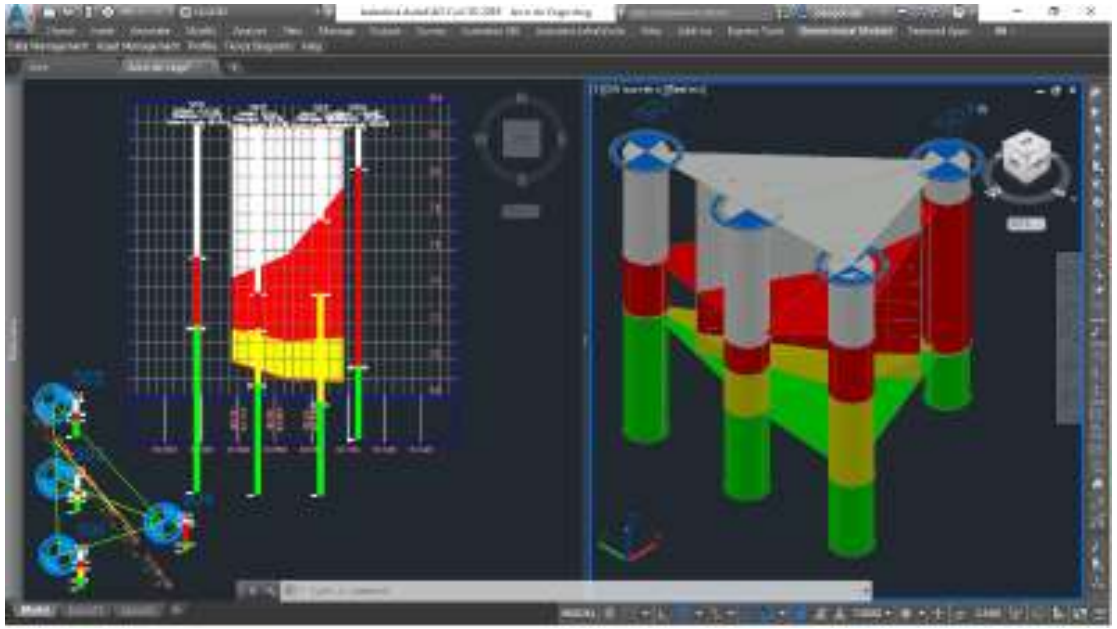
- Revit

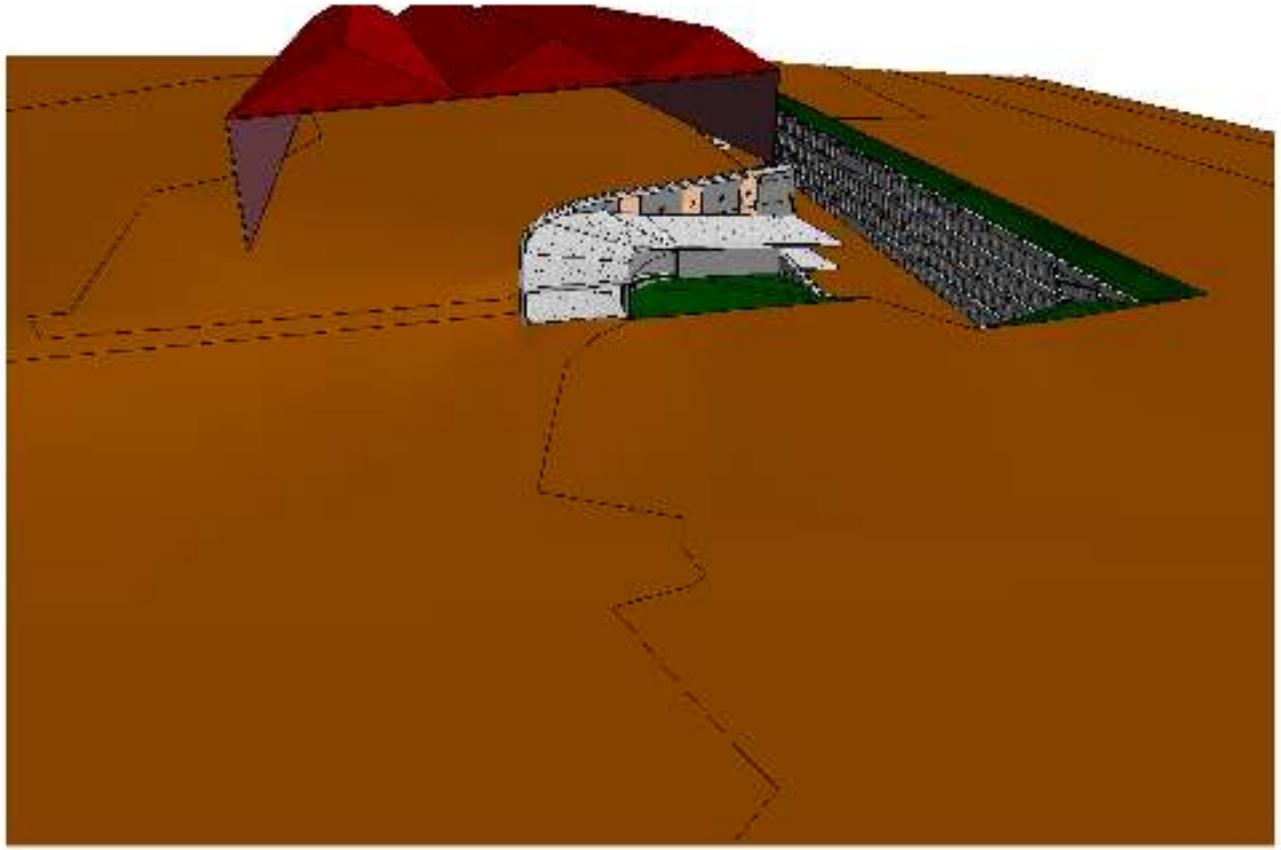
2 - Surfaces

- AutoCAD Civil 3D



4 – Analysis and optimization





+	-
Facilitated design changes	
Immediate quantity take off	
Compatibility and 3D clash check	Topography Modeling

- INTRODUCTION
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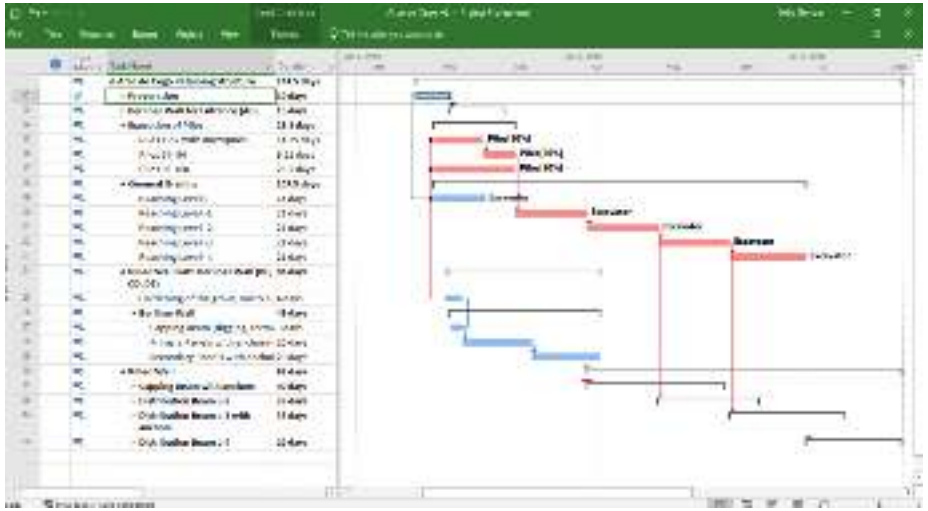
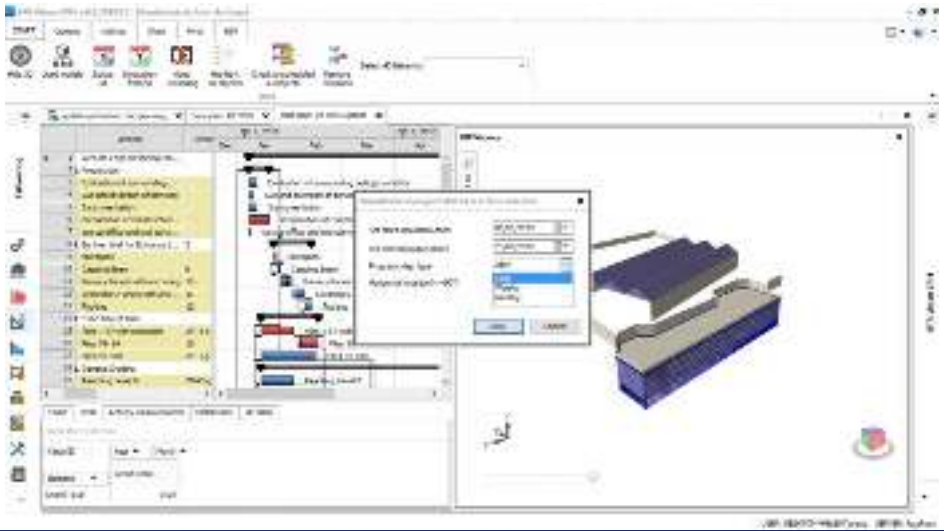
- 3/D BIM MODELING
- **4/D BIM MODELING**
- 5/D BIM MODELING
- FINAL REMARKS

4D/BIM MODEL





Construction Planning

(MS Project)

Import

3D Model (IFC) + Planning (XML);

Link

3D elements with planning

- INTRODUCTION
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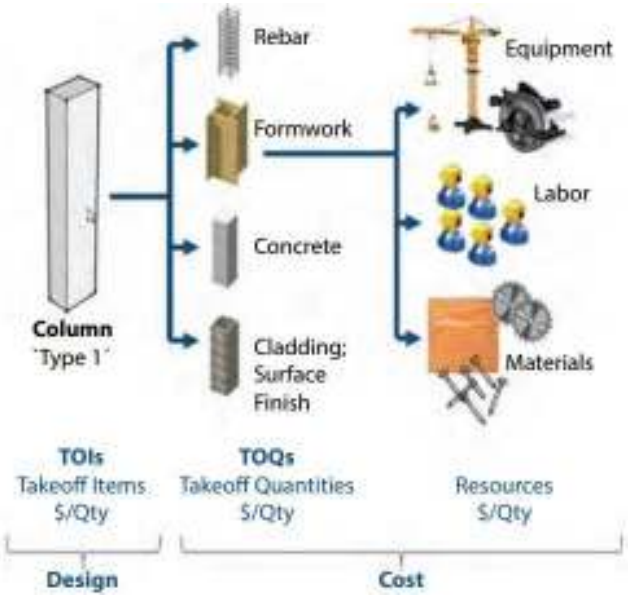
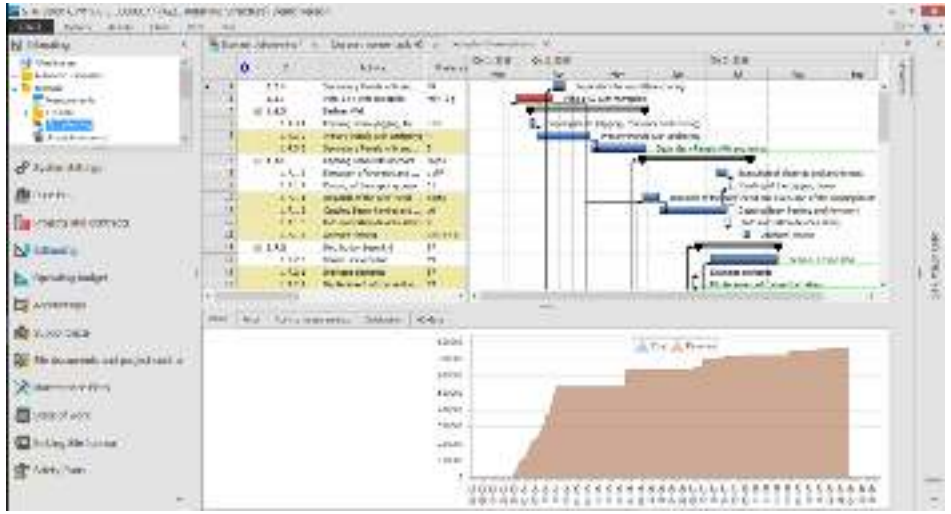
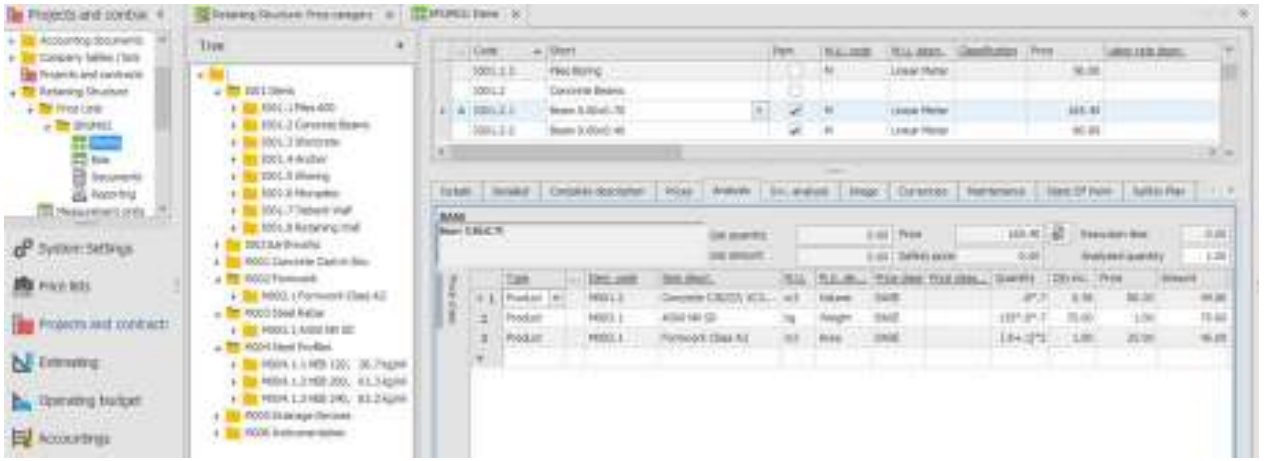
- 3/D BIM MODELING
- 4/D BIM MODELING
- **5/D BIM MODELING**
- FINAL REMARKS

5D/BIM MODEL





- Unit prices; Price categories.
- Cost breakdown
- Work Breakdown Structure
- Measurement Rules

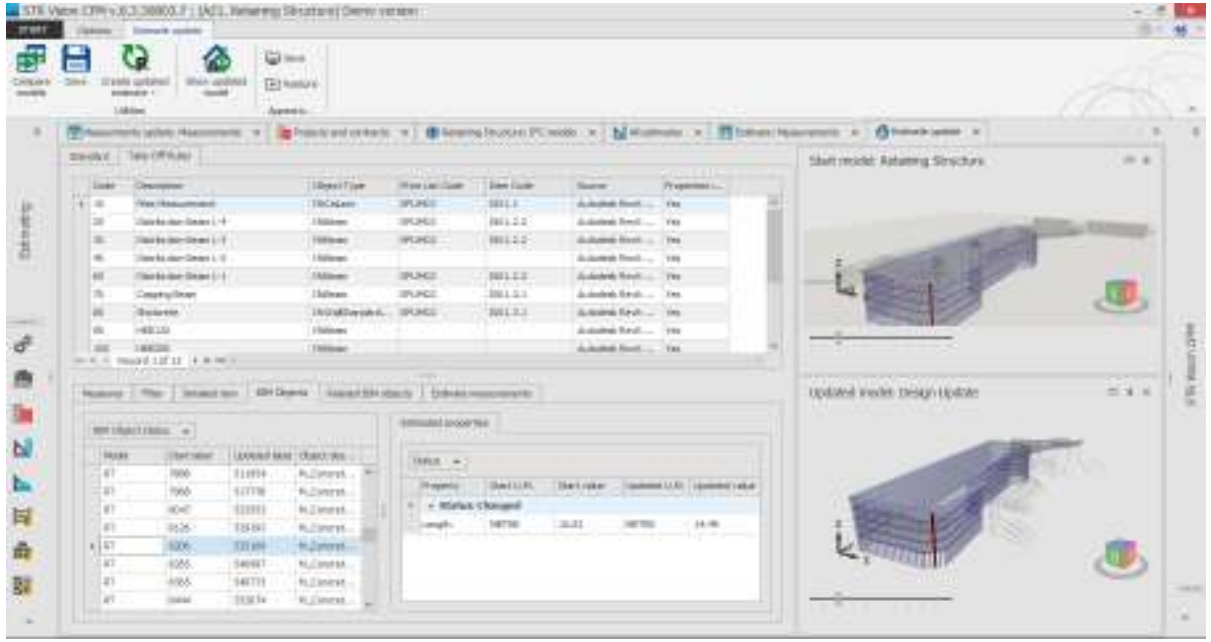


5D/BIM Model

5D/BIM MODEL

Available Tools:

- Price comparison between different design solutions;
- Constructive materials price analysis;
- Analyze different planning options;
- Procurement and bid selection support.

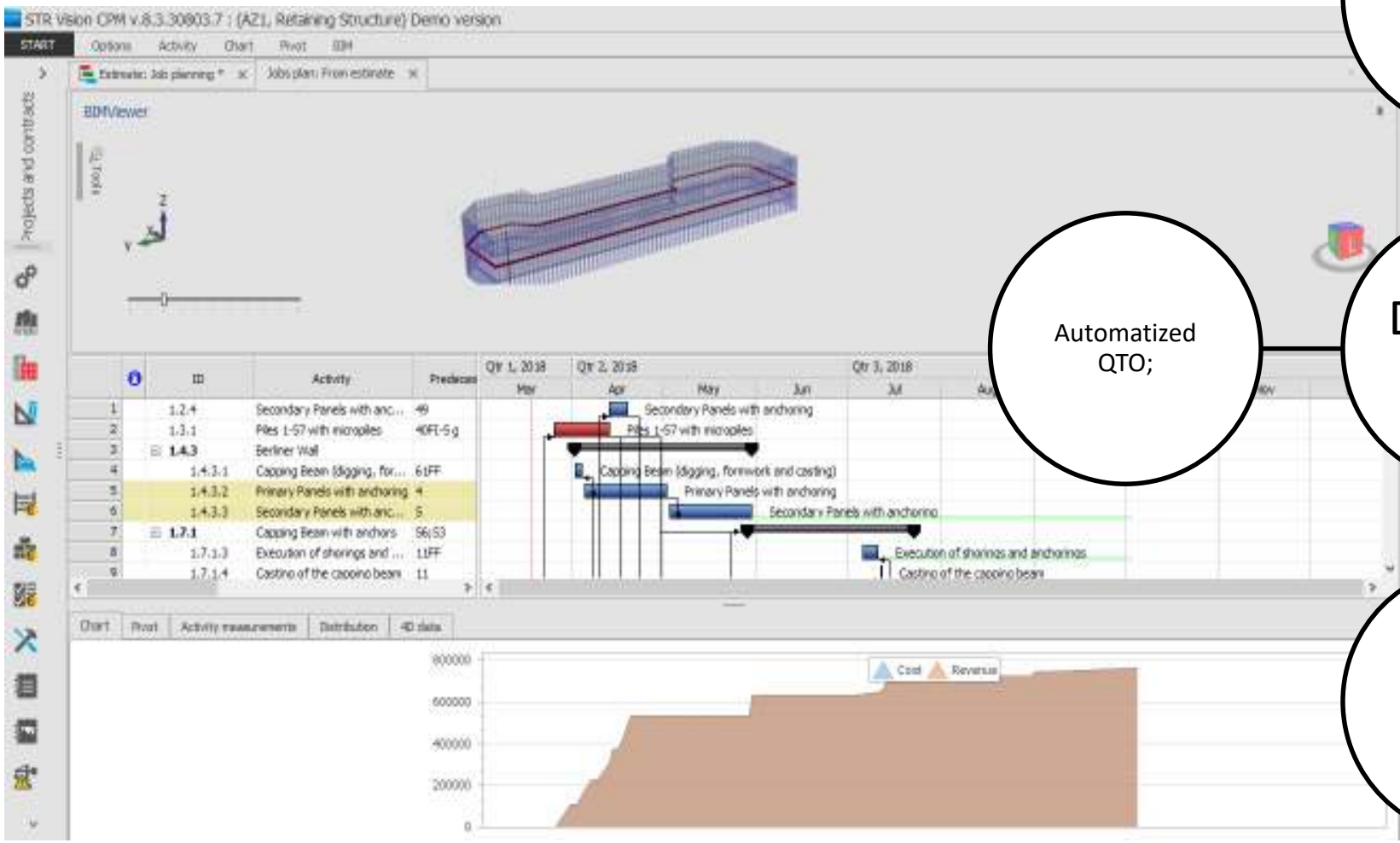


5D/BIM MODEL

Design

Planning

Budget



Operational Control

Automatized QTO;

Decision Making

Design/material price analysis

Design-planning-cost

- INTRODUCTION
- STUDY CASE
- 3/D BIM MODELING
- CONSTRUCTION MANAGEMENT BASED ON BIM
- **FINAL REMARKS**

FINAL REMARKS

Advantages for Geotechnical Engineering:

- 3D analysis;
- Collaboration;
- Optimized solutions;
- Decision-making;
- Reduced risk.

Challenges:

- Improve interoperability;
- Training + experience.

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THE USE OF BIM TECHNOLOGY IN GEOTECHNICAL ENGINEERING

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3 SEPTEMBER - SESSION D3-6 - PRESERVATON OF HISTORIC SITES

AR53 – GROUND IMPROVEMENT AND EARTH RETAINING SOLUTIONS IN LISBON'S DOWNTOWN

AR53 – SOLUTIONS D'AMÉLIORATION ET DE RÉTENTION DES SOLS DANS LE CENTRE-VILLE DE LISBONNE

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- INTRODUCTION
- MAIN CONDITIONS
- ADOPTED SOLUTIONS
- DESIGN
- CONSTRUCTION
- MONITORING AND SURVEY PLAN
- FINAL REMARKS

- ❑ **INTRODUCTION**
- ❑ MAIN CONDITIONS
- ❑ ADOPTED SOLUTIONS
- ❑ DESIGN
- ❑ CONSTRUCTION
- ❑ MONITORING AND SURVEY PLAN
- ❑ FINAL REMARKS

INTRODUCTION

LOCATION

INTRODUCTION

LOCATION

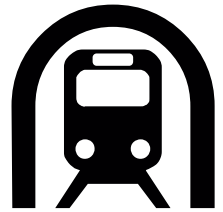
- Earth retaining structure
- Foundations

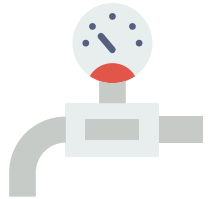
- 4 → 7 floors above the street level
- 0 → 2 basement floors

- ❑ INTRODUCTION
- ❑ **MAIN CONDITIONS**
- ❑ ADOPTED SOLUTIONS
- ❑ DESIGN
- ❑ CONSTRUCTION
- ❑ MONITORING AND SURVEY PLAN
- ❑ FINAL REMARKS

MAIN CONDITIONS

1. Neighbouring conditions
2. Geological and geotechnical conditions
3. Demolition
4. Infrastructures
5. Schedule




MAIN CONDITIONS

NEIGHBOURING CONDITIONS

MAIN CONDITIONS

GEOLOGICAL AND GEOTECHNICAL CONDITIONS

source: geoportal.lneg.pt
Carta Geológica de Portugal scale 1:50000 (Carta 34D)

MAIN CONDITIONS

GEOLOGICAL AND GEOTECHNICAL CONDITIONS

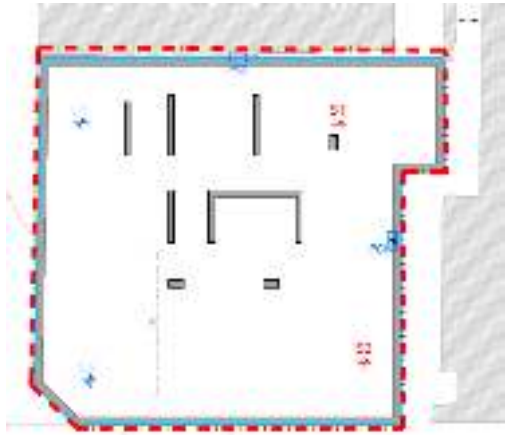
Site investigation campaign:

S... 2 Borehole (SPT)

SP... 2 Boreholes (SPT) + piezometer

PC... 2 Shafts (3m depth)

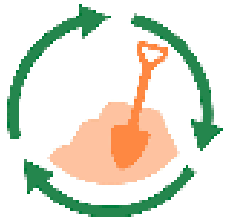
Confirmation of the neighbour building geometry and foundations levels



Zone	Lithology	N_{spt}	Φ′ [º]	γ [kN/m³]	E′ [MPa]
ZG1	Landfills, silt sands	< 5	26	16	6
ZG2A	Silty clay, sometimes sandy	7 – 44	31	18	30
ZG3	Miocene sandstones	≥ 60	38	20	100

MAIN CONDITIONS

DEMOLITION



- ❑ INTRODUCTION
- ❑ MAIN CONDITIONS
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- ❑ FINAL REMARKS

ADOPTED SOLUTIONS

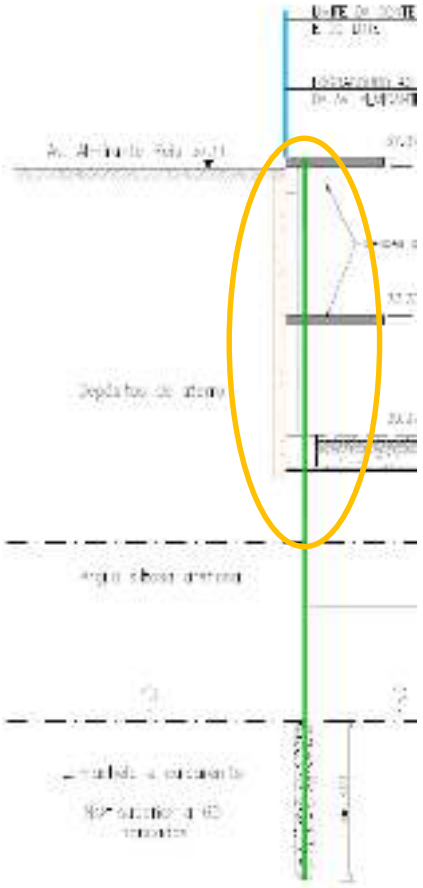
GOALS

- Deformations control
- Ease, speed and safety of execution
- ↓ interference with neighboring infrastructures (Subway)
- ↓ Extra cost and delays

ADOPTED SOLUTIONS

GROUND TREATMENT

- Cement columns ϕ =300mm
- L_{total} =**1850 m**
- ≠ inclinations
  - Street
  - Neighbors buildings

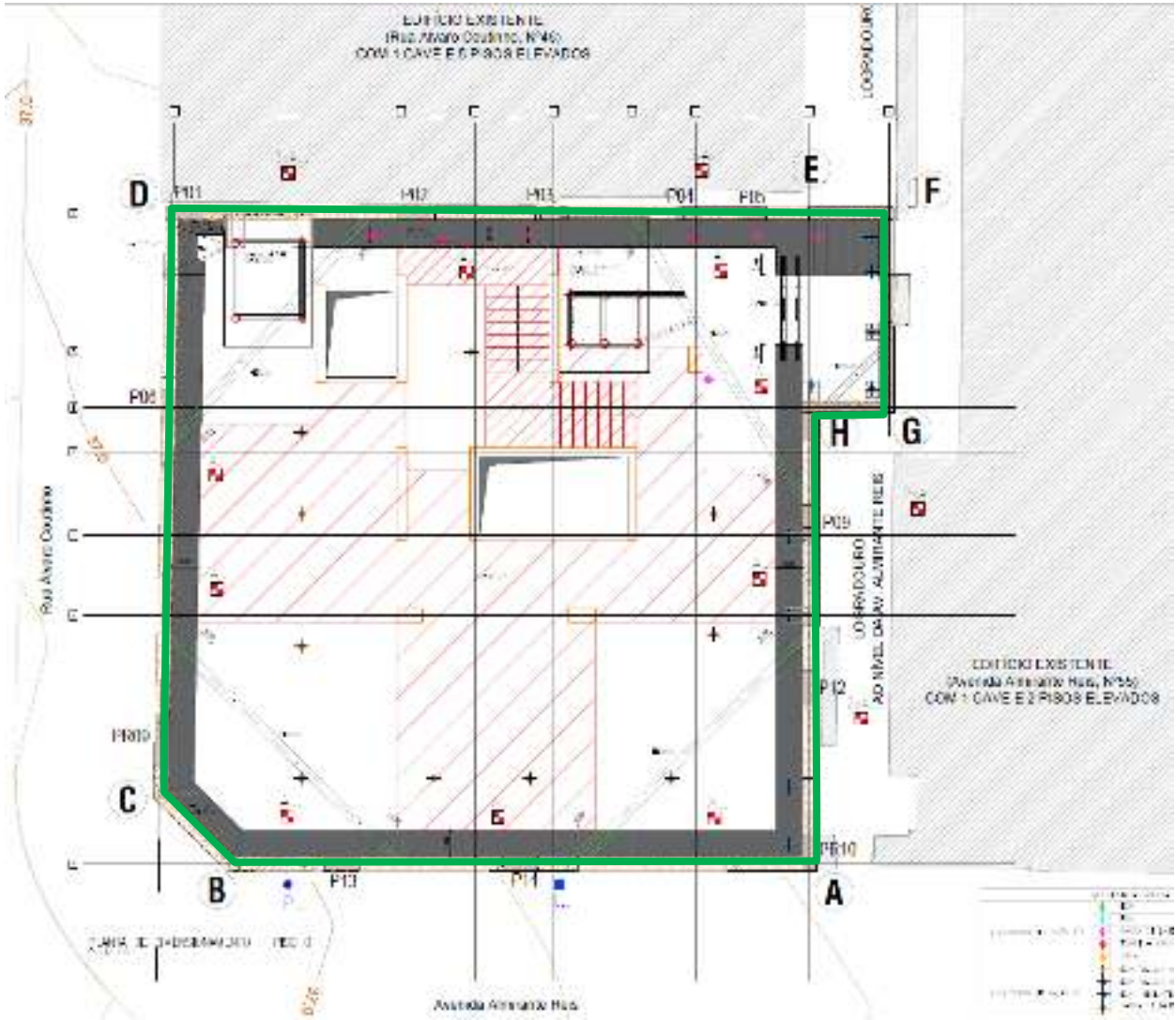


ADOPTED SOLUTIONS

EARTH RETAINIG WALL

- **Berlin Type wall**
  - Phased construction
  - Primary and secondary panels
  - Micropiles

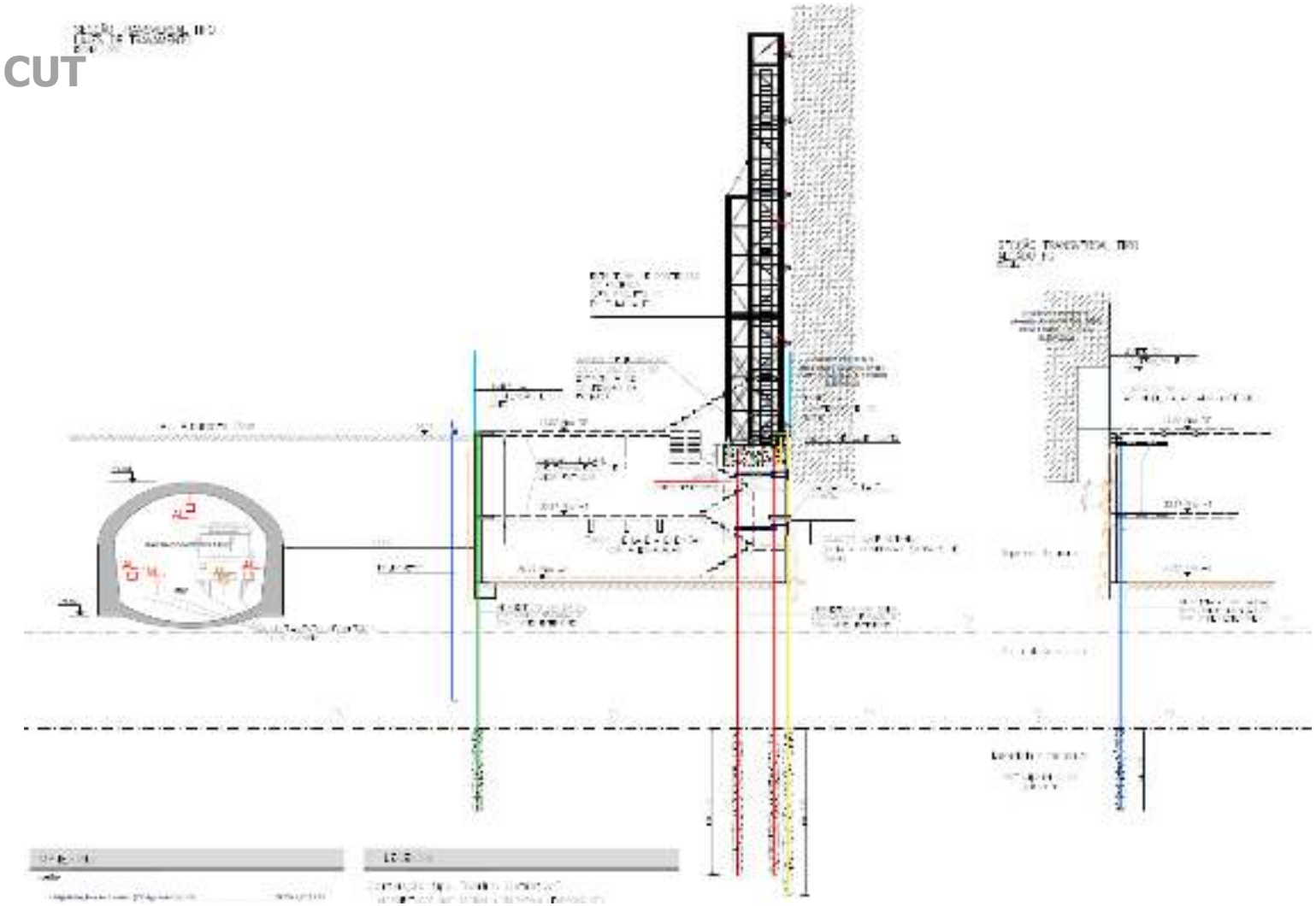
- **Bracing**
  - Temporary phase
    - Slab bands
    - Corner shores
  - Final phase
    - Basement slabs



ADOPTED SOLUTIONS

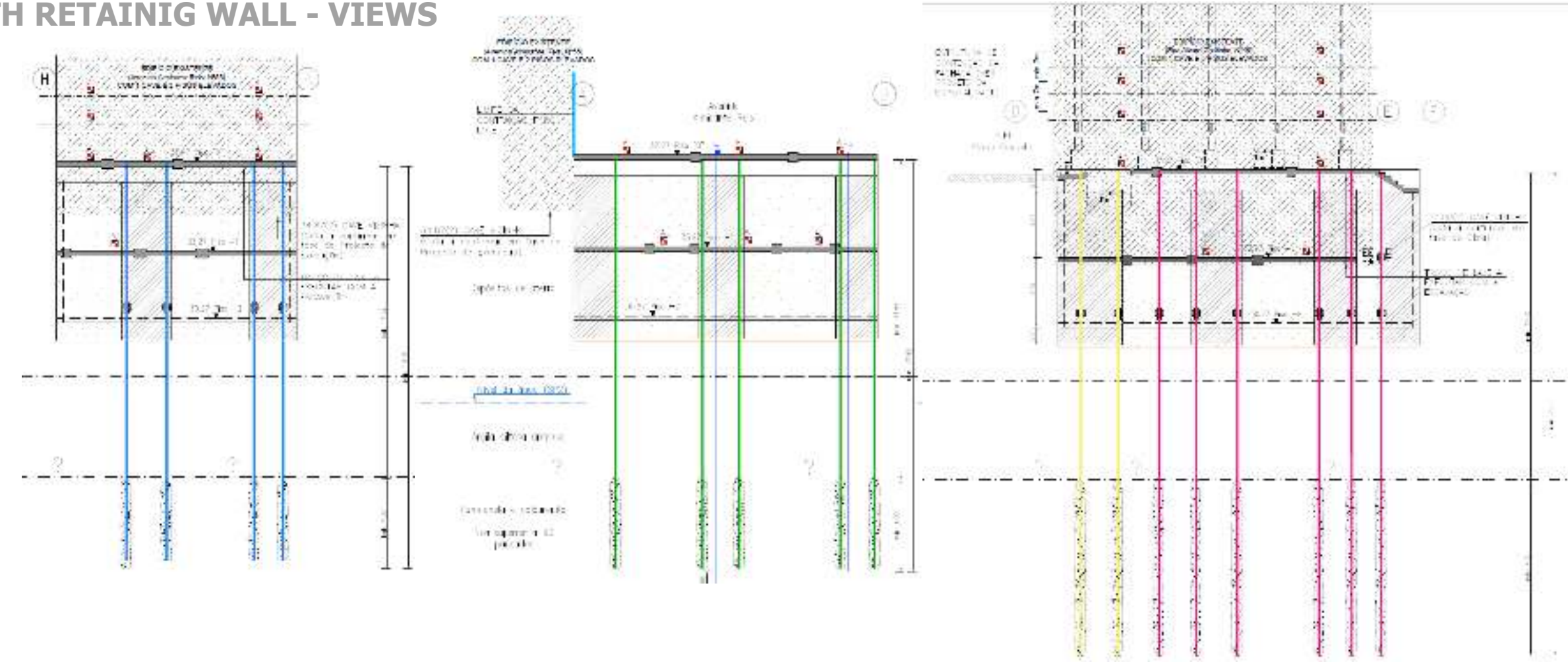
EARTH RETAINIG WALL – SECTION CUT

- **Berlin Type wall**
  - Phased construction
  - Primary and secondary panels
  - Micropiles
- **Bracing**
  - Temporary phase
    - Slab bands
    - Corner shores
  - Final phase
    - Basement slabs



ADOPTED SOLUTIONS

EARTH RETAINIG WALL - VIEWS



ADOPTED SOLUTIONS

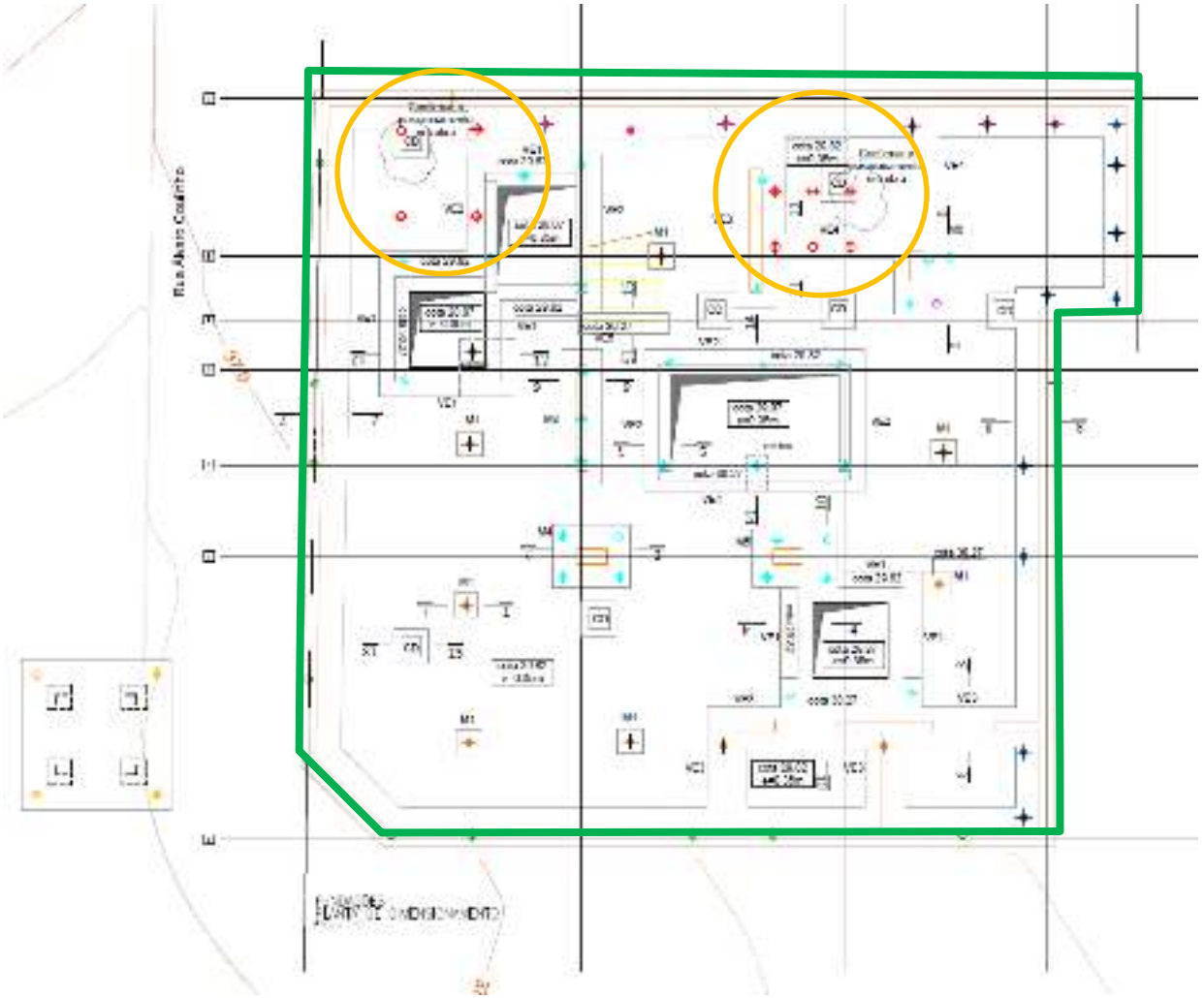
MICROPILES

- Foundations
  - Facade Retaining Structure
  - Building
  - Crane
- Earth Retaining Wall

80 micropiles

1509 m

Double function!



- ❑ INTRODUCTION
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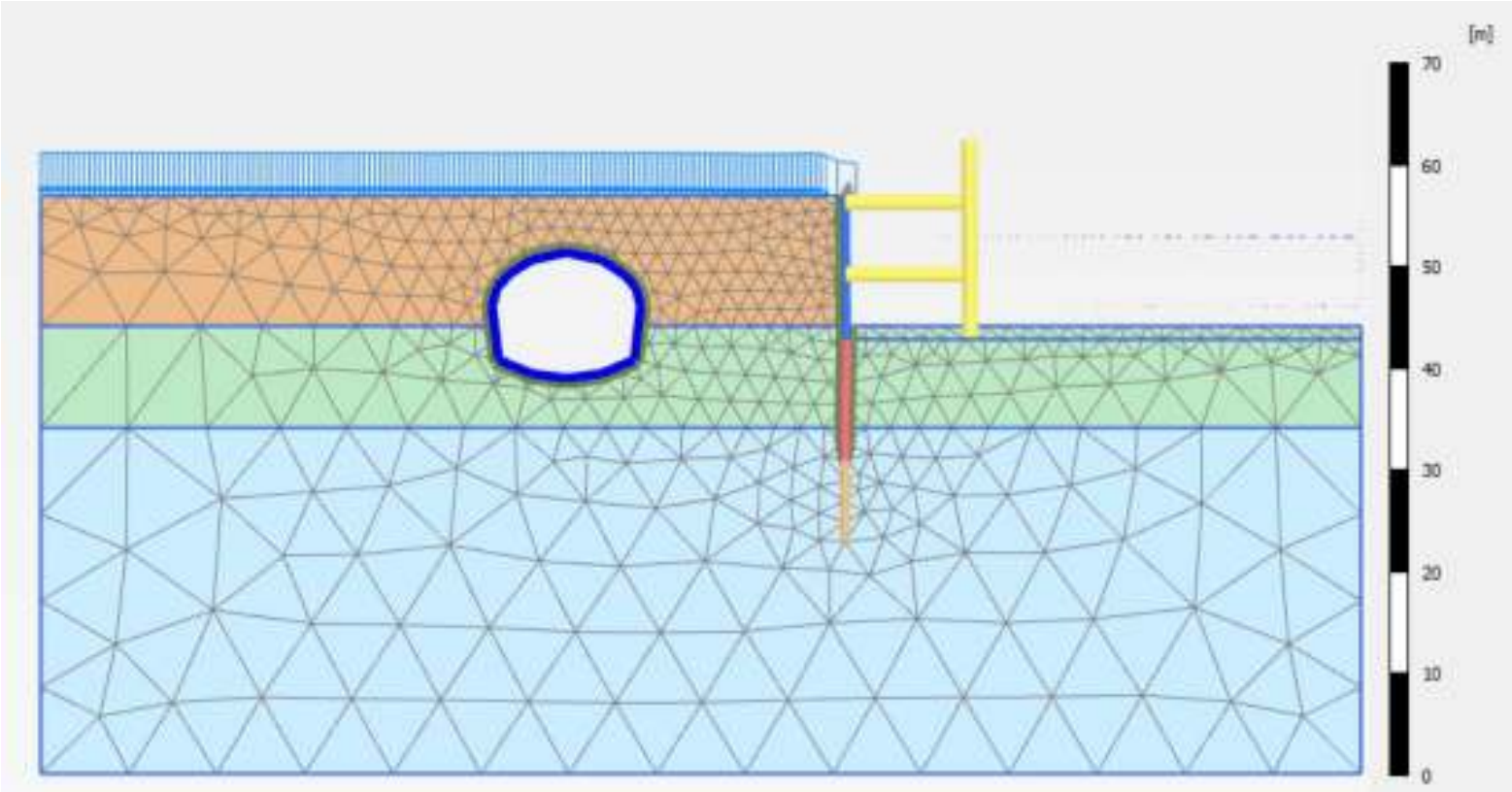
DESIGN

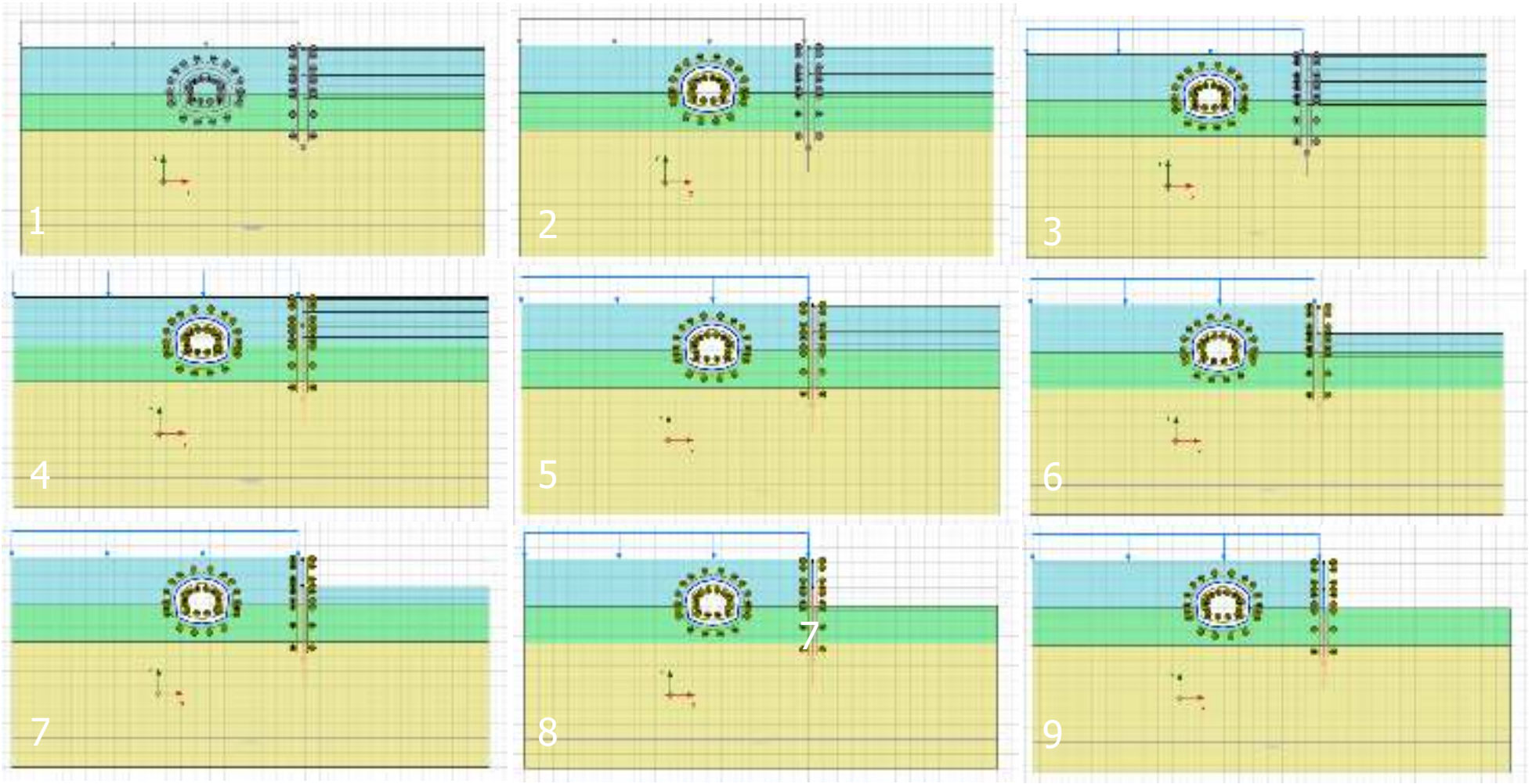
MODEL

Plaxis 2D → Hardening Soil Model → Stage Construtions



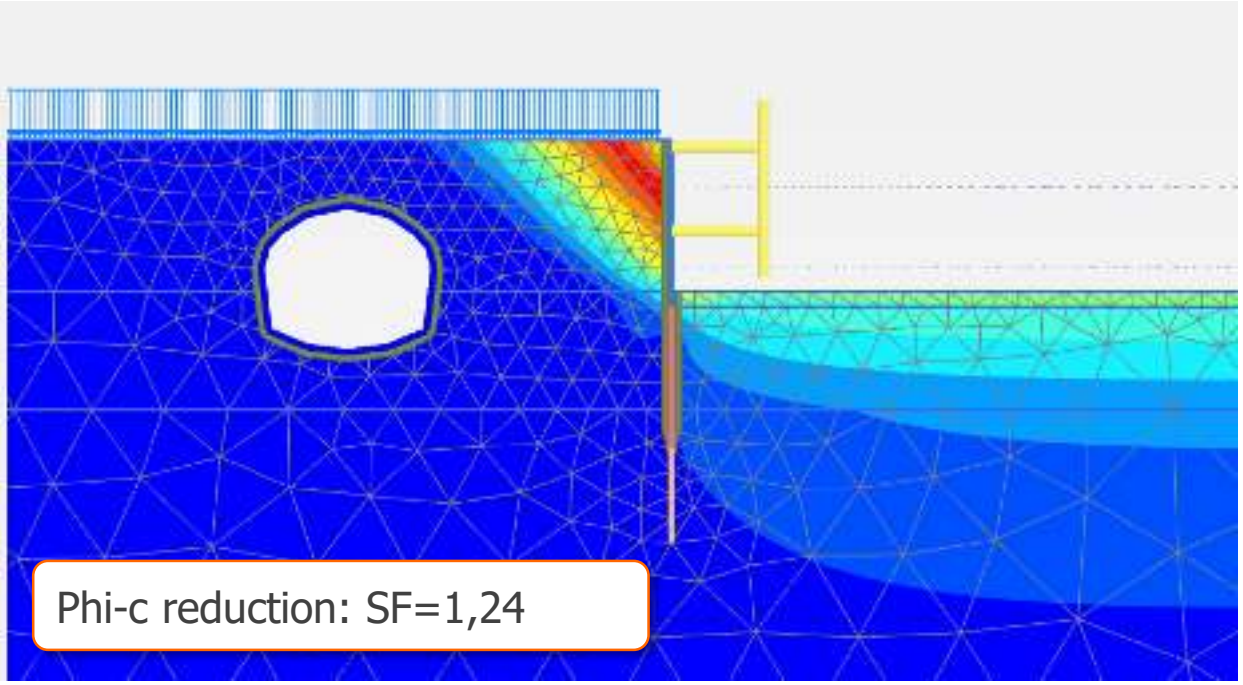
DESIGN

MODEL



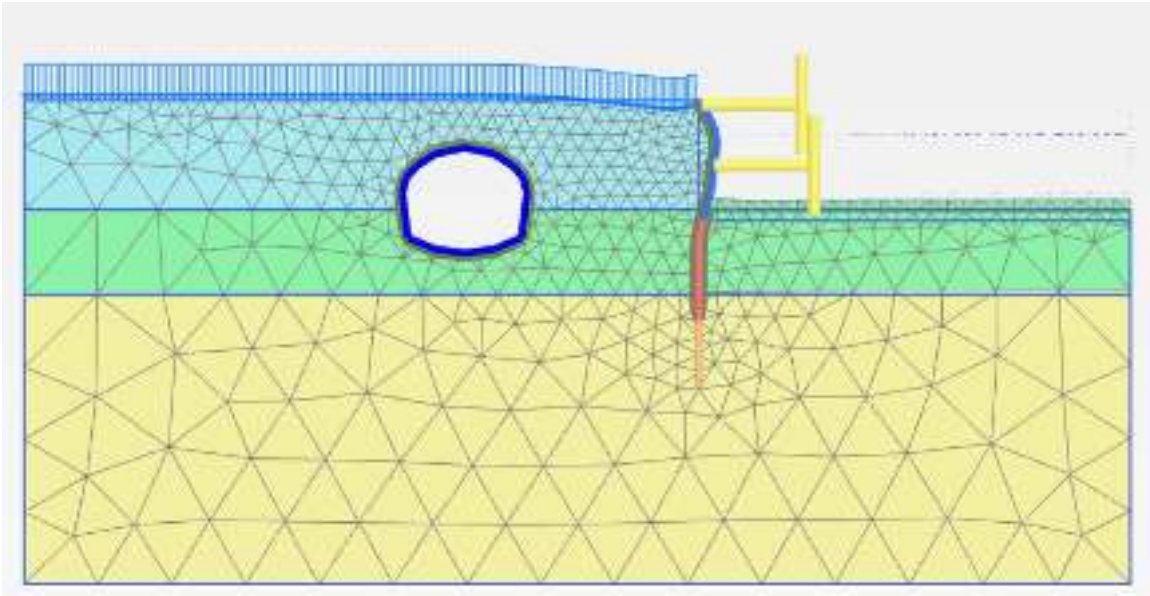
DESIGN

MODEL



Plaxis Output:

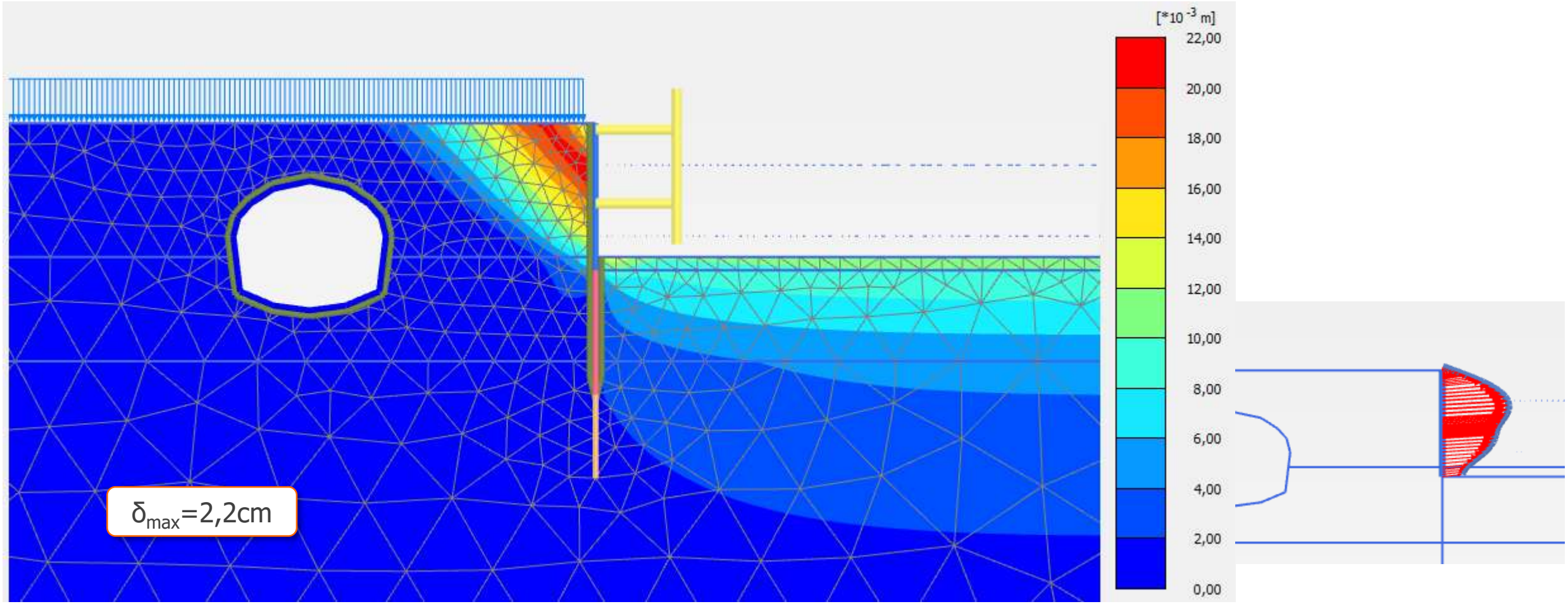
- Global safety factor
- Stresses of structural elements
- Displacements



DESIGN

MODEL

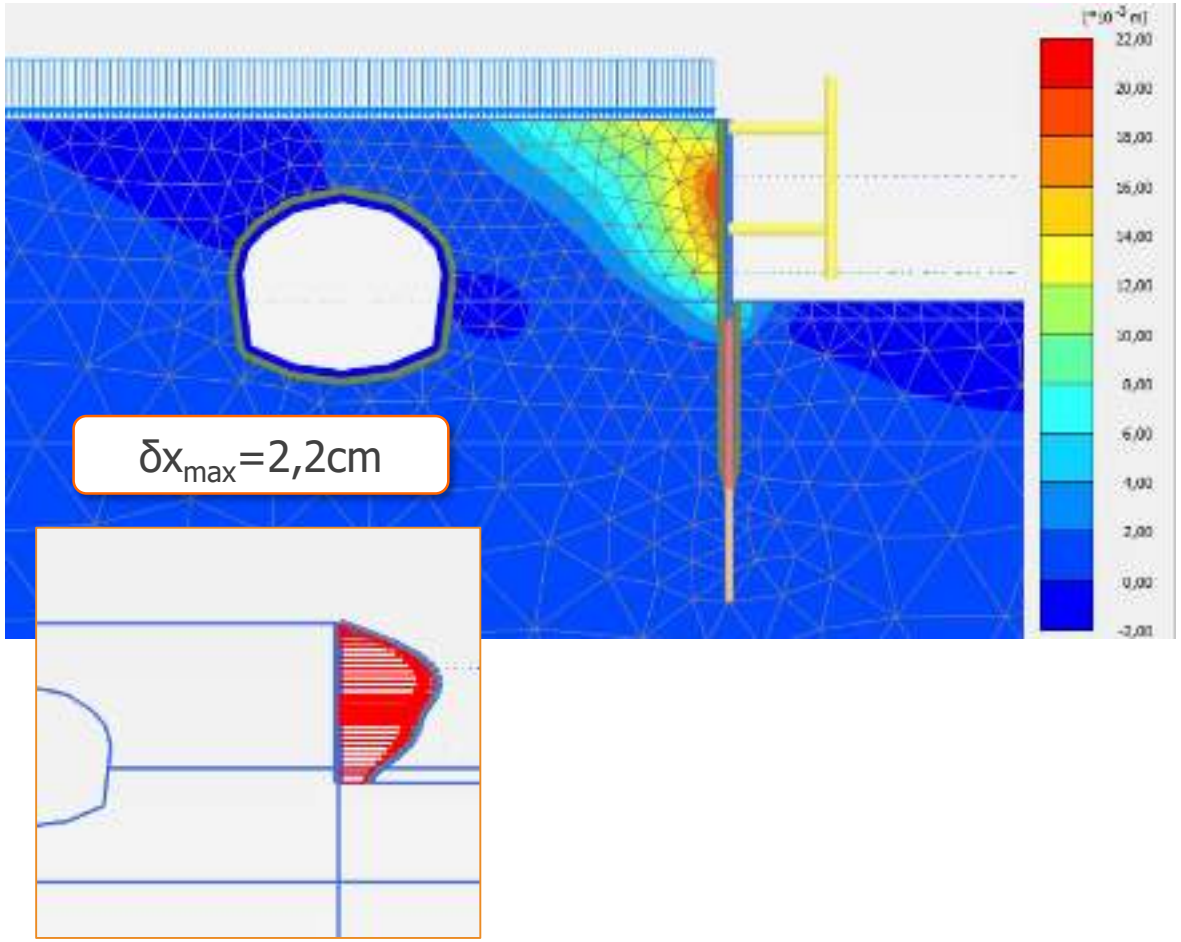
Last excavation phase: Total displacements

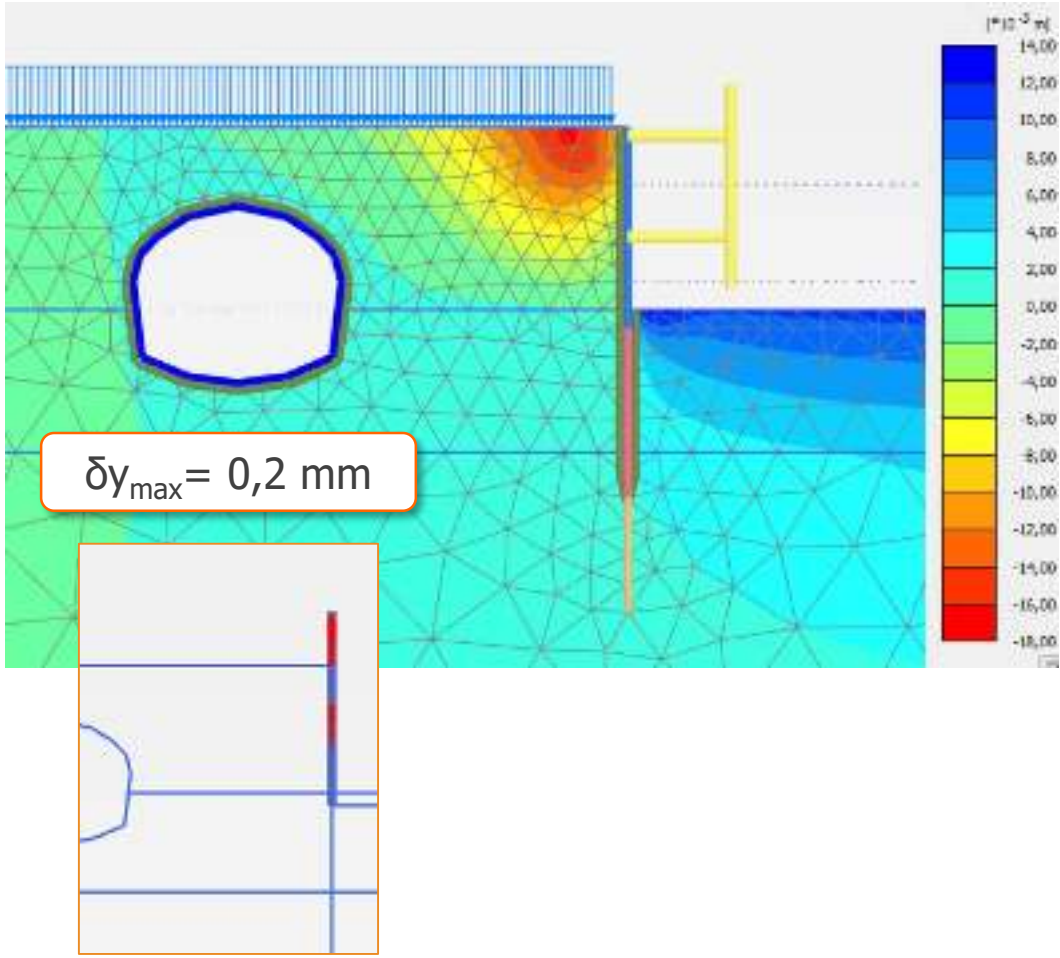


DESIGN

MODEL

Last excavation phase: horizontal and vertical displacements

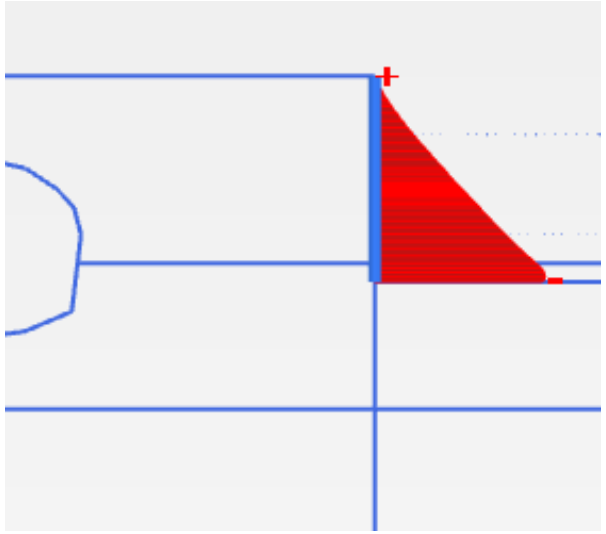




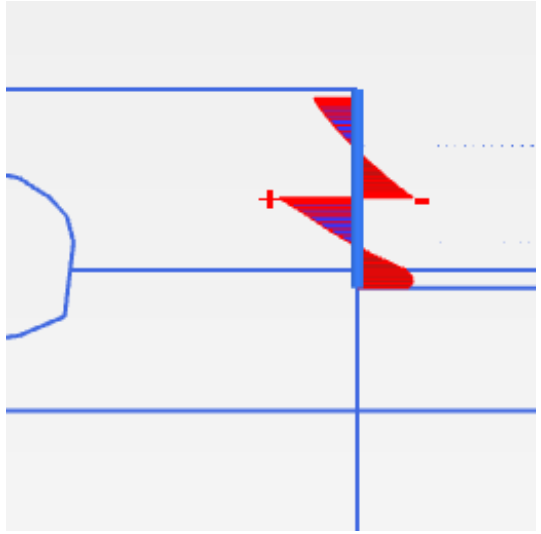
DESIGN

MODEL

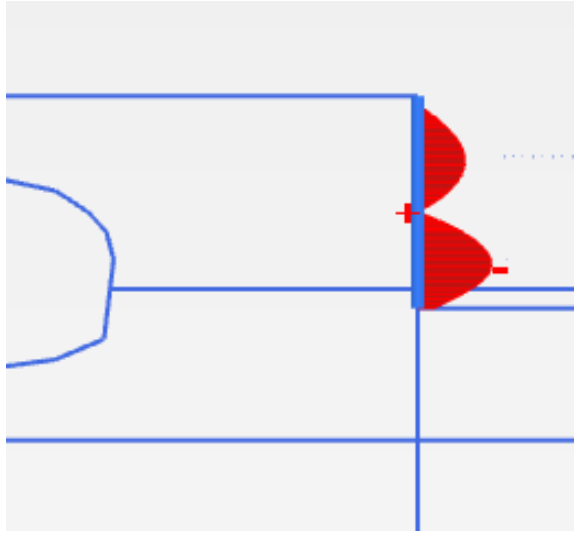
Last excavation phase



Axial stresses (N_{max})



Transverse stresses (Q_{max})



Bending moment (M_{max})

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CONSTRUCTION

SEPTEMBER 2018; DECEMBER 2018 - DEMOLITION

CONSTRUCTION

MARCH 2019 – CAPPING BEAM

CONSTRUCTION

MARCH 2019 - MICROPILES

CONSTRUCTION

APRIL 2019 – 1st LEVEL OF EXCAVATION

CONSTRUCTION

APRIL 2019 - 1st LEVEL OF BERLIN WALL

CONSTRUCTION

JUNE 2019 -1ST LEVEL OF BERLIN WALL
JULY 2019 - 2ND LEVEL OF BERLIN WALL

CONSTRUCTION

JULY 2019 – LAST LEVEL OF BERLIN WALL

CONSTRUCTION

AUGUST 2019 – TEMPORARY BRACES

CONSTRUCTION

AUGUST 2019 – END OF EXCAVATION

CONSTRUCTION

AUGUST 2019 – FACADE RETAINING STRUCTURE

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MONITORING AND SURVEY PLAN

WHAT TO MEASURE

- Vertical and horizontal displacements
  - Retaining wall
  - Neighbouring buildings
  - Lisbon's Metro Tunnel
- Horizontal displacements of the retained ground
- Ground water table depth

MONITORING AND SURVEY PLAN

HOW TO MEASURE

- Vertical and horizontal displacements
  - Retaining wall
  - Neighbouring buildings
  - Lisbon's Metro Tunnel

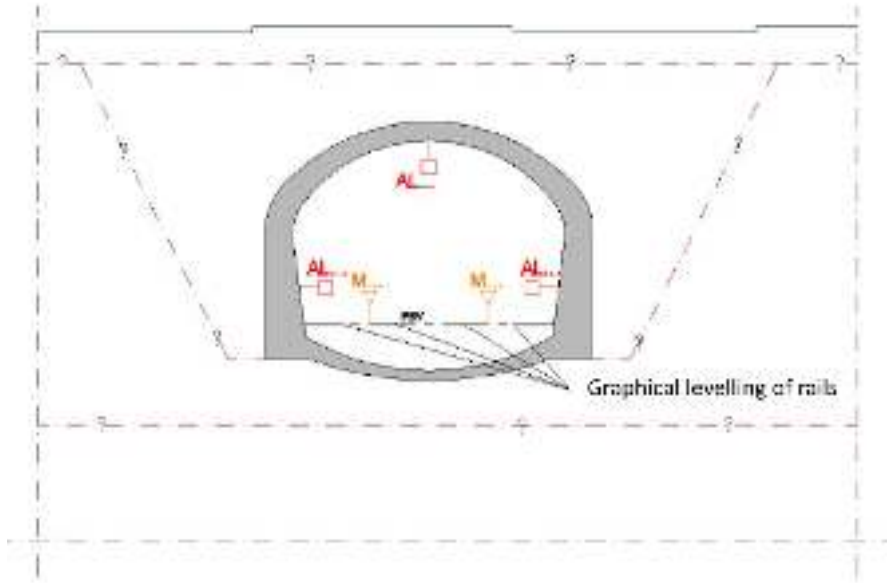
→ Topographic targets

- Horizontal displacements of the retained ground → Inclinometers
- Ground water table depth → Piezometers

MONITORING AND SURVEY PLAN

WHEN TO INTERVENE

	ALERT		ALARM	
	dx [mm]	dy [mm]	dx [mm]	dy [mm]
Bored Pile Wall	20	15	30	22.5
Neighbouring buildings	20	15	40	30
Lisbon Metro crown	7	7	10	10
Lisbon Metro rails	3 (4m)	3 (6m)	5 (4m)	5 (6m)



MONITORING AND SURVEY PLAN

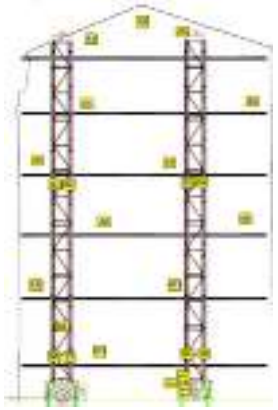
HOW TO ACT

- Ground improvement behind the retaining wall
- Reinforce of the horizontal bracing
  - Extra shoring (pre-stressed)
- Reinforce the drainage condition of the retaining wall

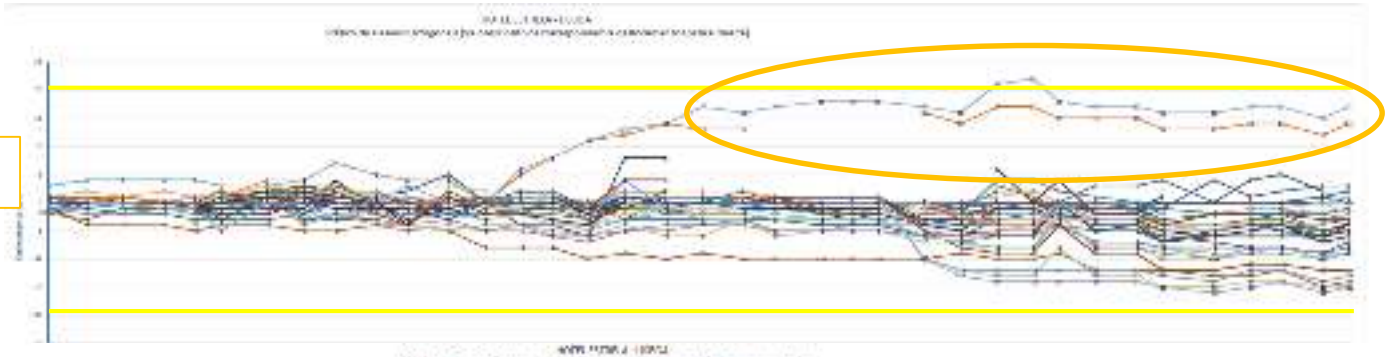
MONITORING AND SURVEY PLAN

TOPOGRAPHIC TARGETS MEASUREMENTS

Alert δx; δy/δz **20 / 15mm**
Alarm δx; δy/δz **30 / 22.5mm**



δx



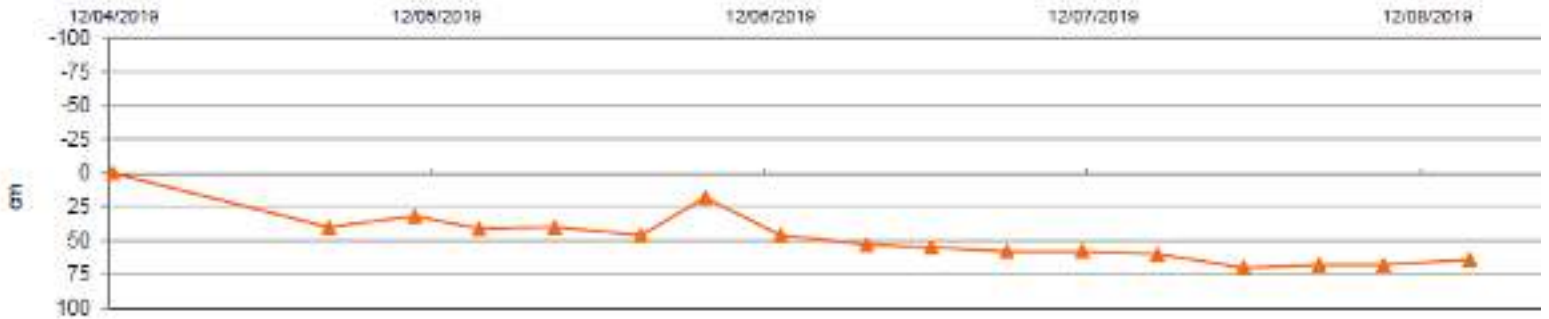
δy

δz

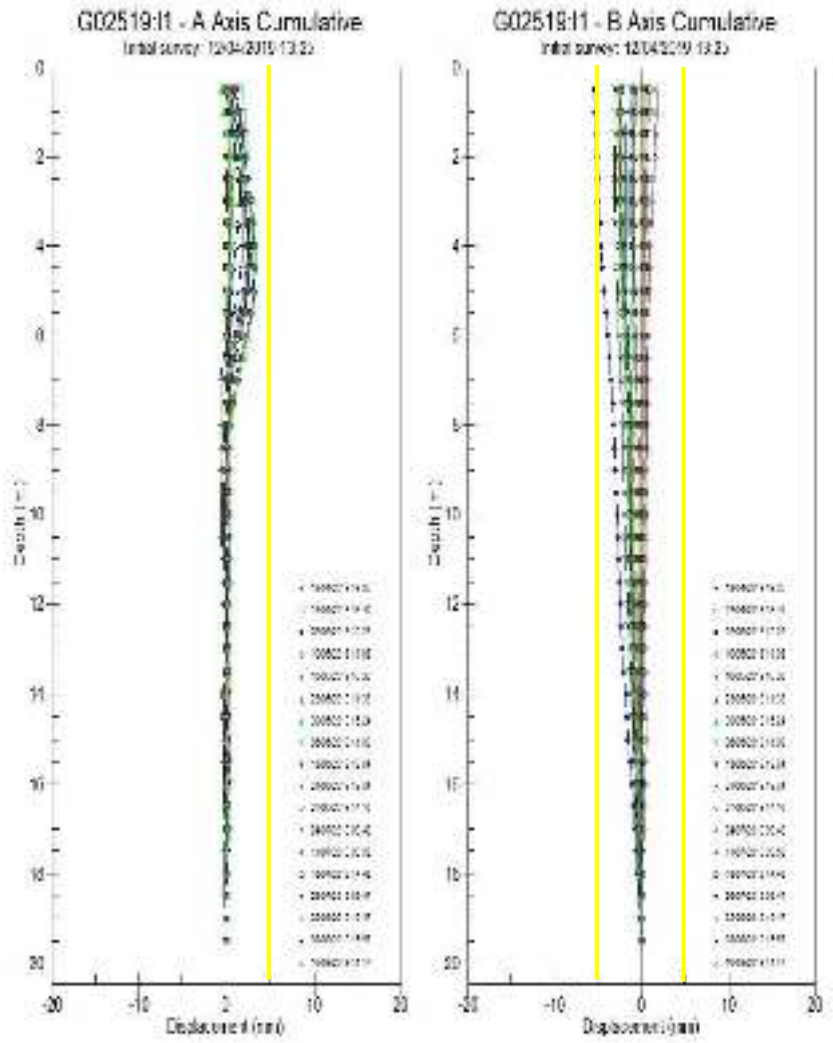
MONITORING AND SURVEY PLAN

INCLINOMETER AND PIEZOMETER MEASUREMENTS

Water level depth(cm) – PZ1



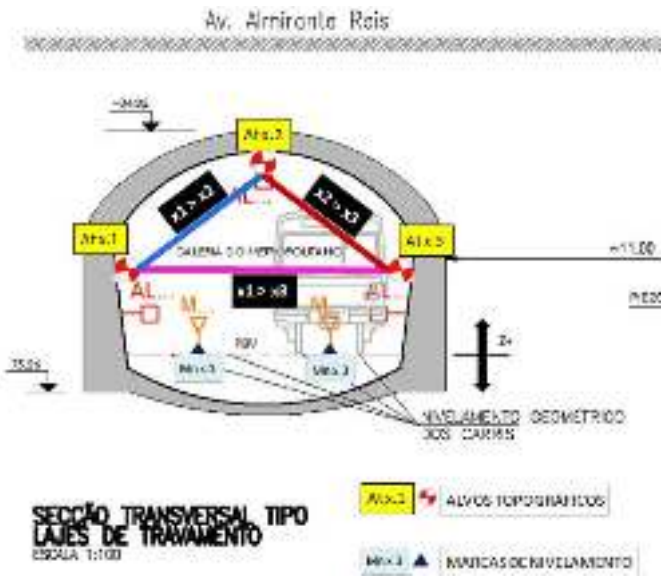
NOTA: variação negativa – subida do nível de água; variação positiva – descida do nível de água

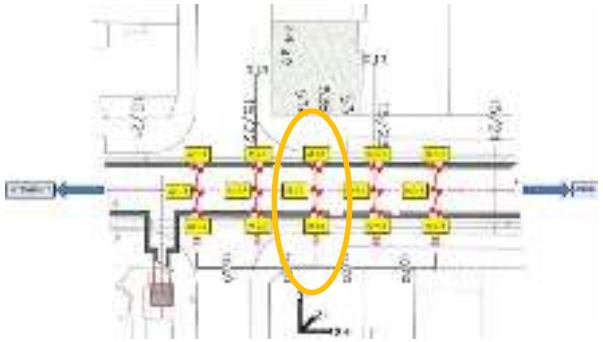


MONITORING AND SURVEY PLAN

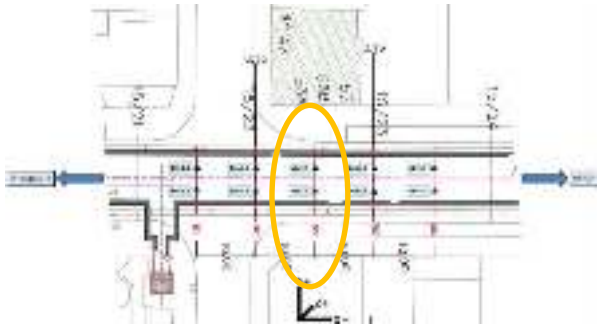
MEASURES – LISBON'S METRO TUNNEL

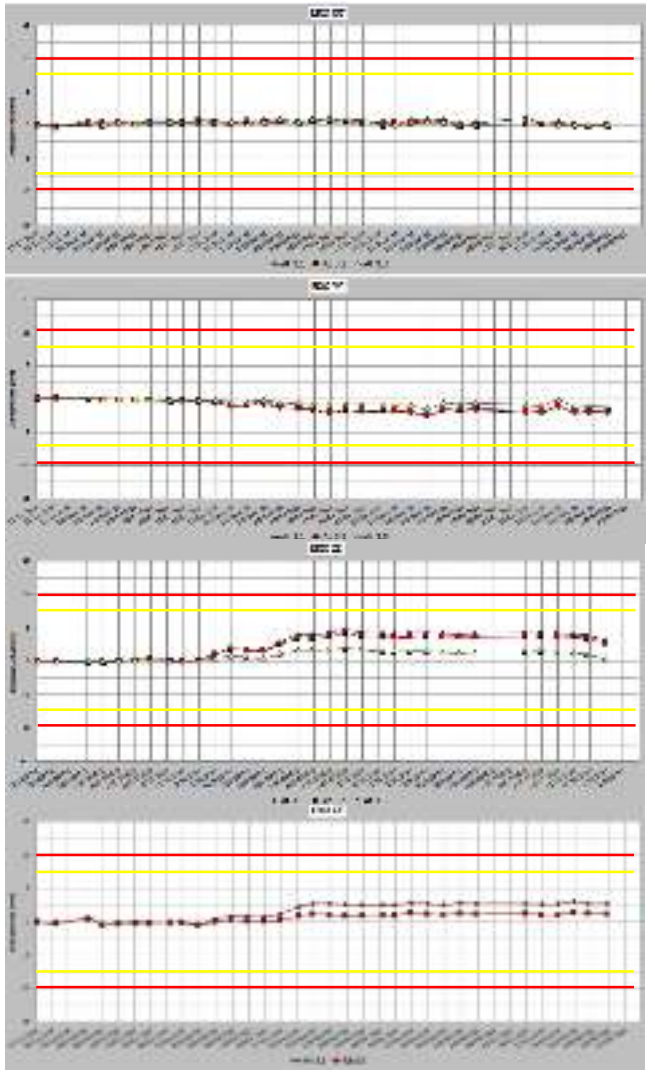
- 5 instrumentation sections
- 15 Topographic targets – δx; δy
- 10 Topographic leveling – δz





Alert **7mm**
Alarm **10mm**





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FINAL REMARKS

Soil surprises…

…constant update of the project !

- ↑ importance
  - Respect the **phased construction** of the Berlin type wall
  - **Efficiency**: design micropiles with double function
  - Execution of the **definite wall** simultaneously with the excavation
  - **Clear communication** between designer and constructor
  - **Monitoring** and survey plan

ECSMGE 2019
Reykjavík

SIMSG ISSMGE

GEOTECHNICAL ENGINEERING,

FOUNDATION OF THE FUTURE

REYKJAVIK, ICELAND
1 - 6 SEPTEMBER 2019

Þakka þér fyrir

Thank you for your kind attention

JET SJ

THE GROUND IS OUR CHALLENGE

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