4TH INTERNATIONAL SYMPOSIUM
PRESERVATION OF MONUMENTS & HISTORIC SITES
ATHENS 2026 TC301

EXAMPLES OF PRESERVING HISTORIC BUILDINGS FROM THE IMPACT OF TUNNELLING

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CONFLICT:

Interaction between tunnelling and historic buildings

(Bezrodny et al., 2016; Broere, 2016; Viggiani, 2024; Moormann, 2026; …)

Geotechnical Engineering plays an important role looking for solutions to reduce that impact

Historic buildings classification (country dependent)

- **Grade 1**. Highest significance (world heritage…)
- **Grade 2**. Regional heritage
- **Grade 3**. Local heritage

Introduction

Impact of tunneling:

Severe impact
Moderate impact
Mild impact

Type of protection vs impact of tunnel (allowed):

	Severe impact	Mod. impact	Mild impact
Grade 1	No	No	No
Grade 2	No	No/Possible	Possible
Grade 3	Possible	Possible	Possible

Strict full protection

Keep façade and some inner parts. Internal renovations allowed

Keep façade…

Follow ICOMOS and local…recommendations

Introduction

- → 3 examples of historic buildings affected by tunnels.
- → Context: Railway high speed line Barcelona – French border
- → Crossing the cities of Barcelona and Girona was challenging



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Introduction

CROSSING BARCELONA







Introduction

CROSSING GIRONA





Introduction



Case 1: “Torre del Fang” building
(Grade 3)



Case 2: The “Farinera” building
(Grade 2)



Case 3: The “Sagrada Familia” basilica
(Grade 1)

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The “Torre del Fang” building





Medieval masonry farmhouse from 12th – 15th century (“Torre del Fang” = house of mud)

Municipal building with limited use by neighbourhood

Poor conservation. Plans for future renovation

Located directly in the pathway of the tunnel (pathway defined to cross the city below streets, not below buildings, except this one)

The “Torre del Fang” building

Layout of tunnel in the Sagrera station (cut and cover)

“Torre del Fang”

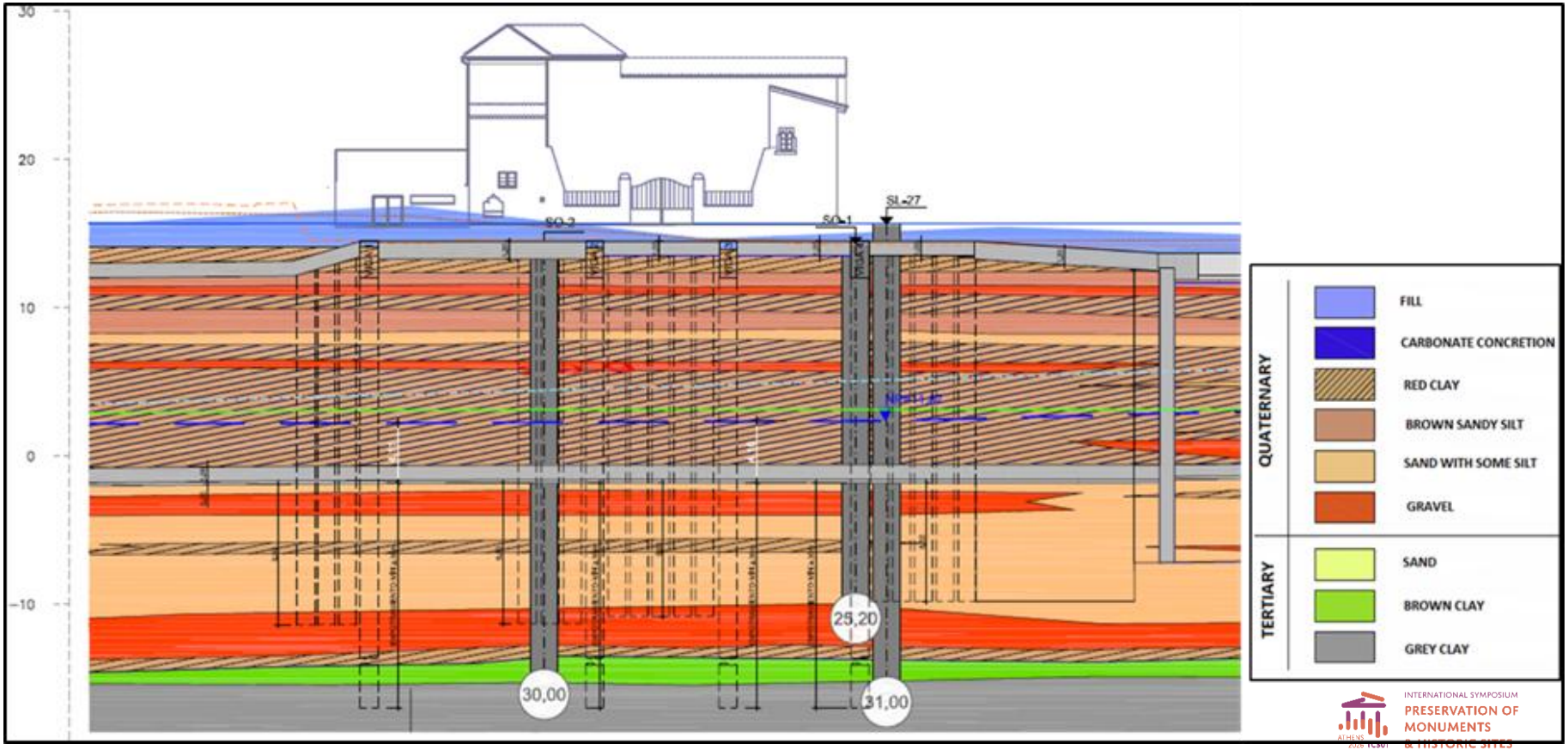


The “Torre del Fang” building

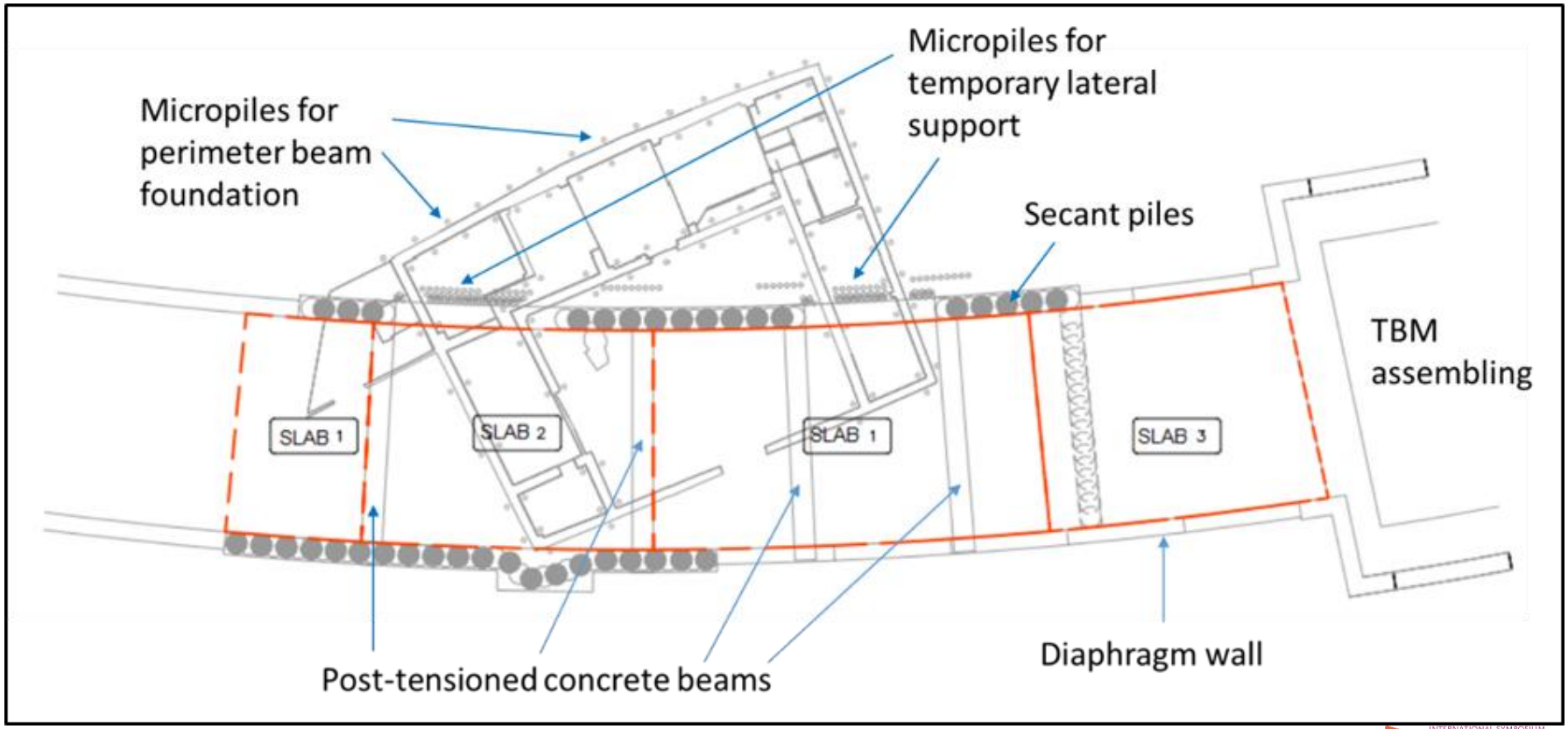


Severe impact

The “Torre del Fang” building



The “Torre del Fang” building



The “Torre del Fang” building



The “Torre del Fang” building

Geotechnical Design:

Plaxis 2D software, Hardening Soil Model

Slightly overconsolidated clay
E_{oed} = 60 – 80 MPa
Water table at about 13 m depth. Temporary lowering of WT

Monitoring: intense task

The “Torre del Fang” building



Monitoring:

measuring displacements on buildings

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The “Torre del Fang” building

The construction + excavation was successful
The “Torre del Fang” did not have significant displacements (< 5 mm)

But…

The impact on the building was severe,
(total change of foundation, dismantling of lateral walls and prestressing bars…)

… a plan for restoration should be developed when the works are finished

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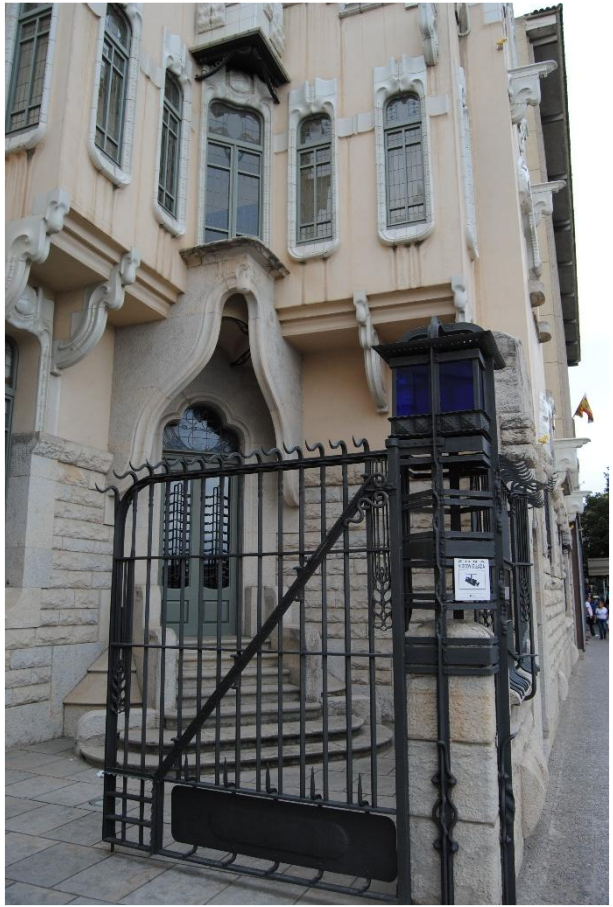
Concluding remarks

The “Farinera” building



1910 architect Rafael Masó Valentí in central part of Girona city
“Noucentisme” style
Masonry building , flour factory + private house

The “Farinera” building



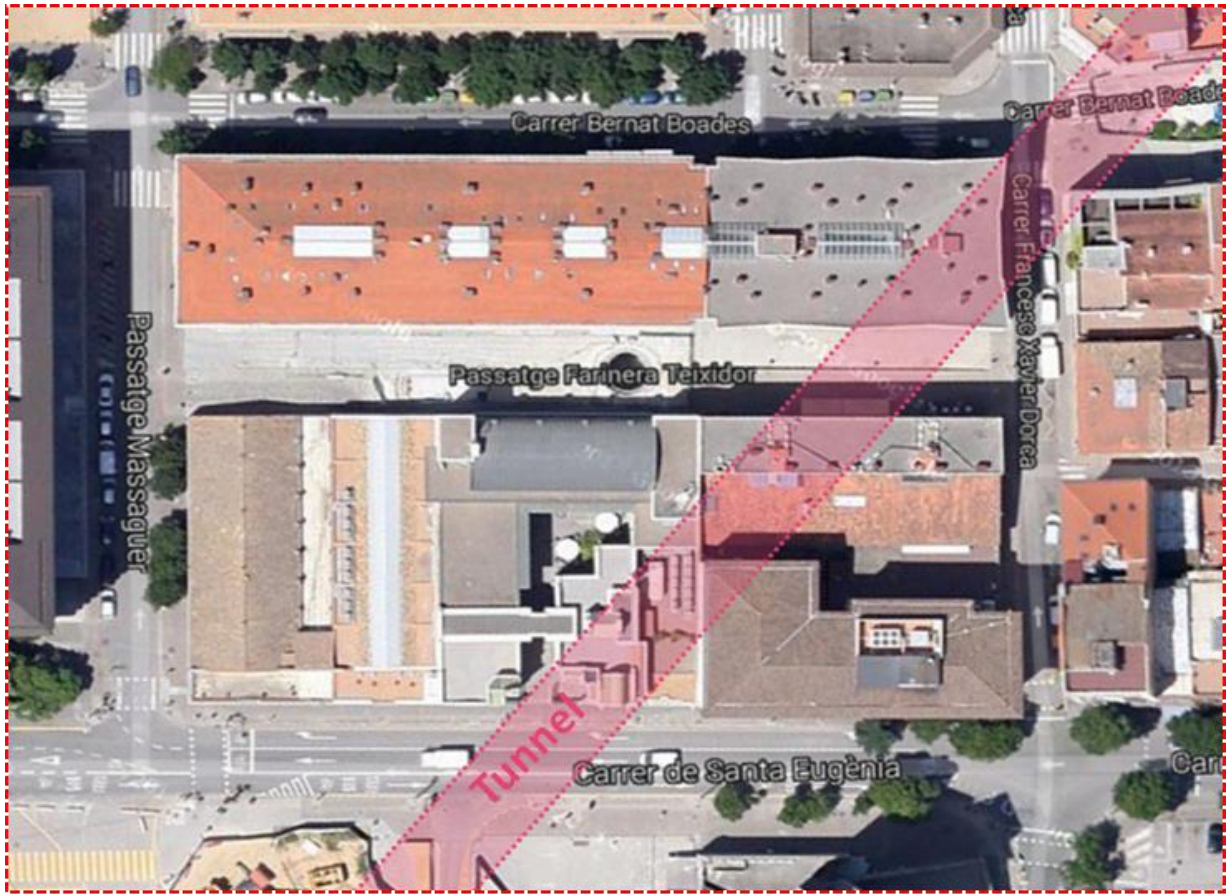


The “Farinera” building





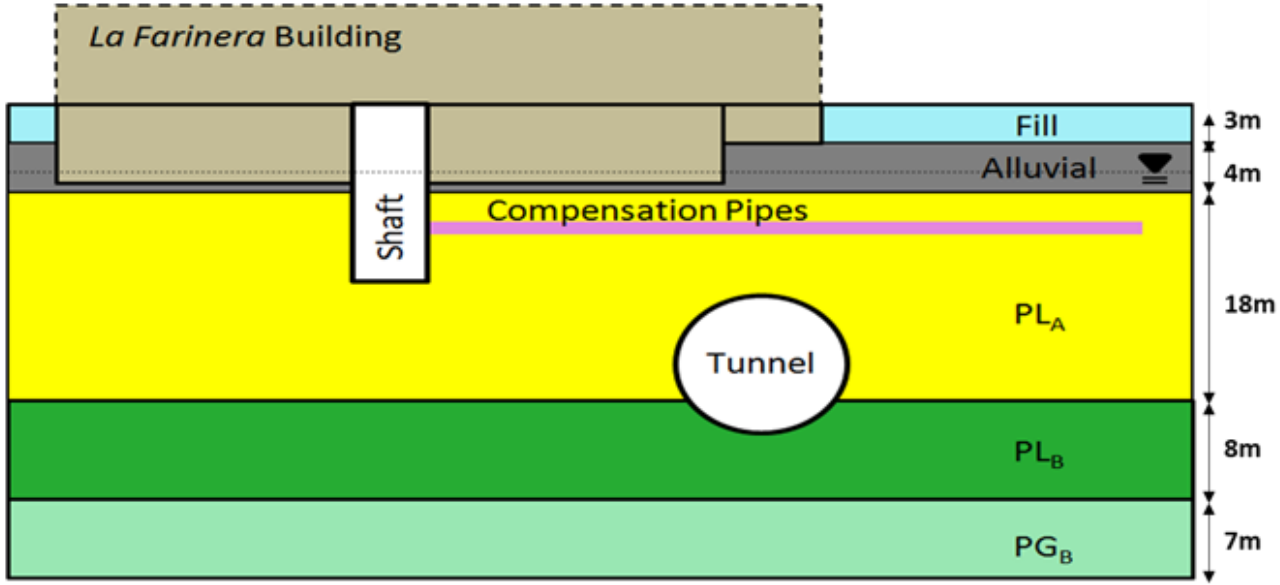
The “Farinera” building



Mild or negligible impact

The “Farinera” building

A compensation grouting technique was planned

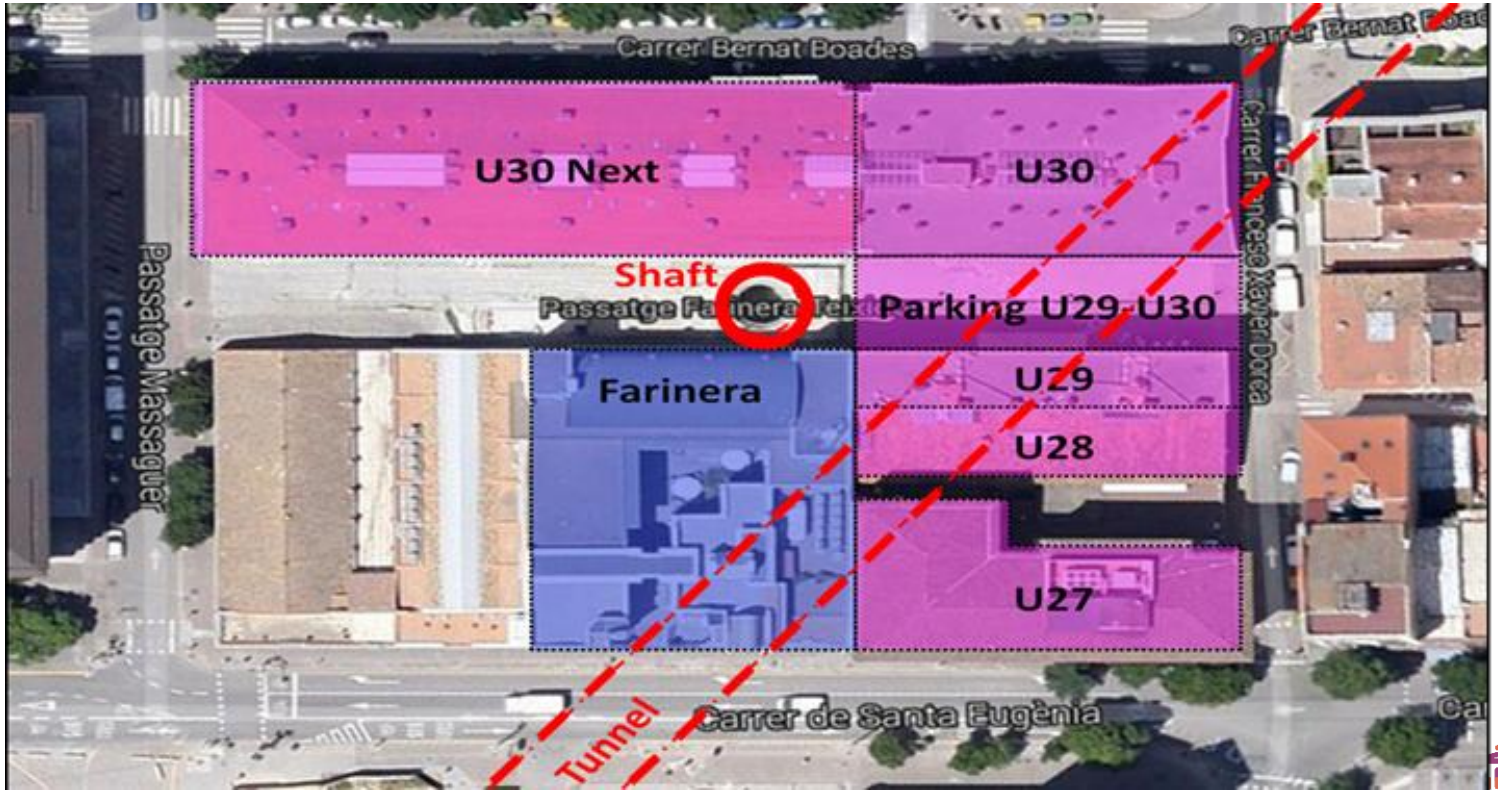


PL: Cohesive Pliocene Material (slightly overconsolidated clay)
(A: shallow , B: deep)

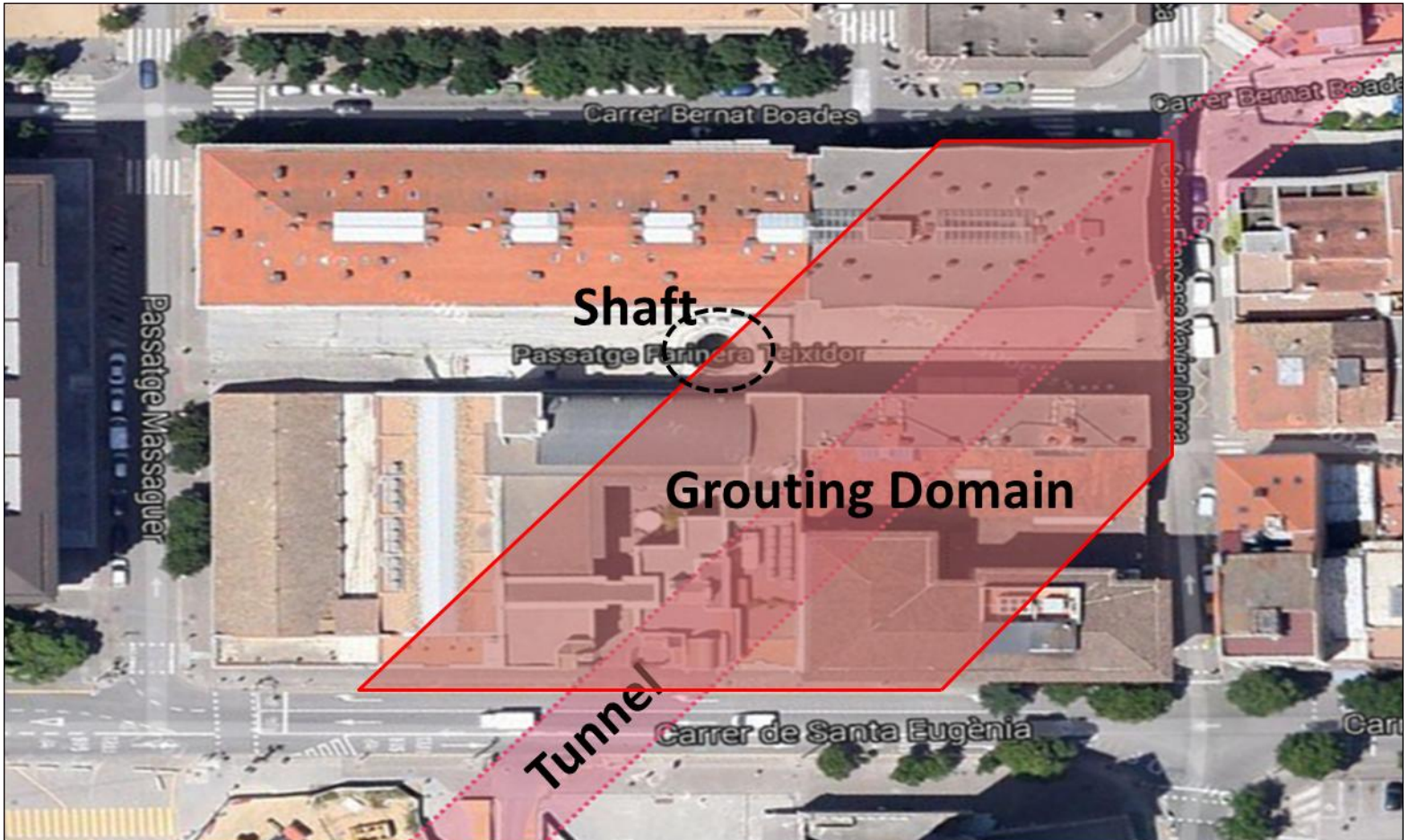
PG: Granular Pliocene Material
(A: shallow , B: deep)

Water Table: 6 m depth

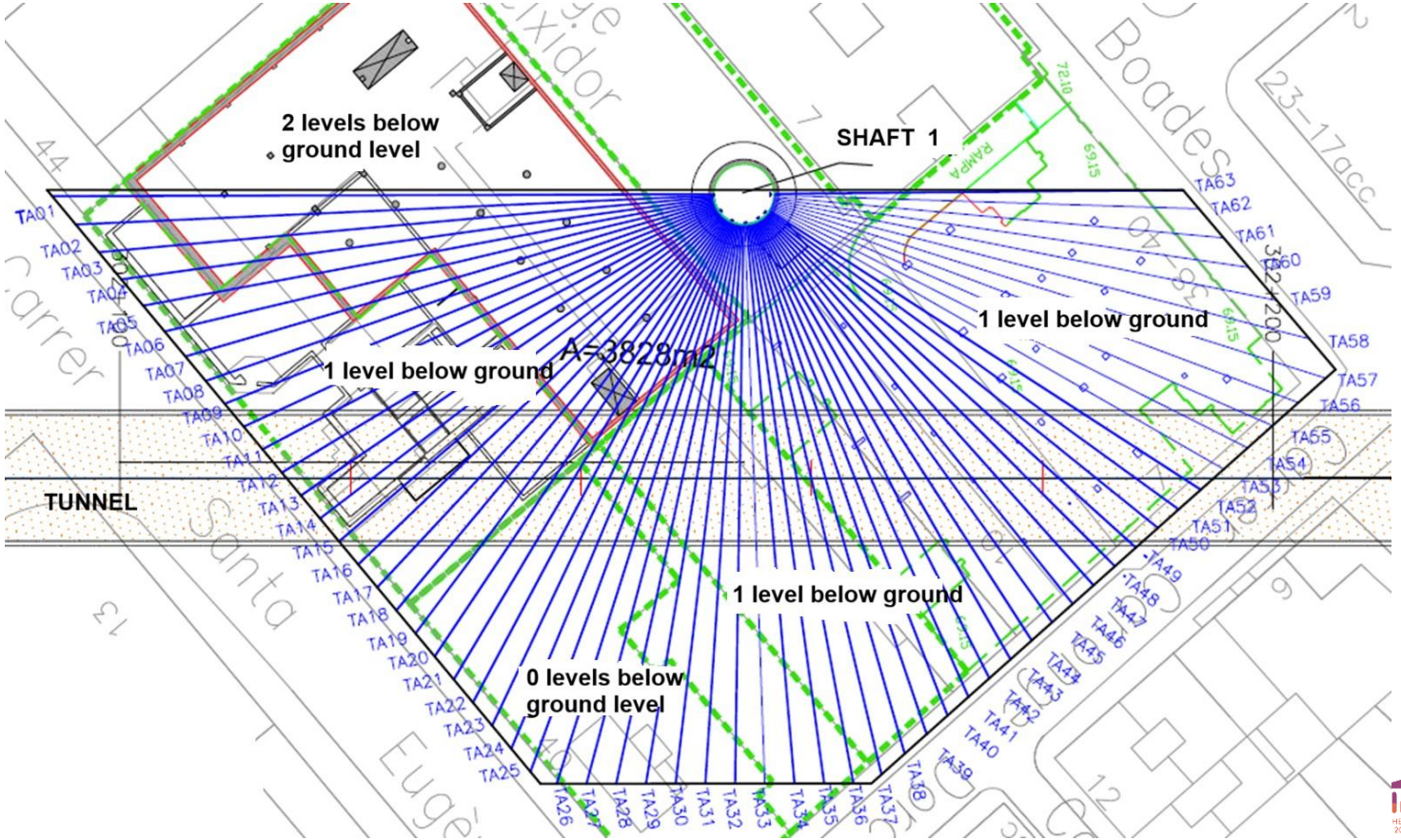
The “Farinera” building



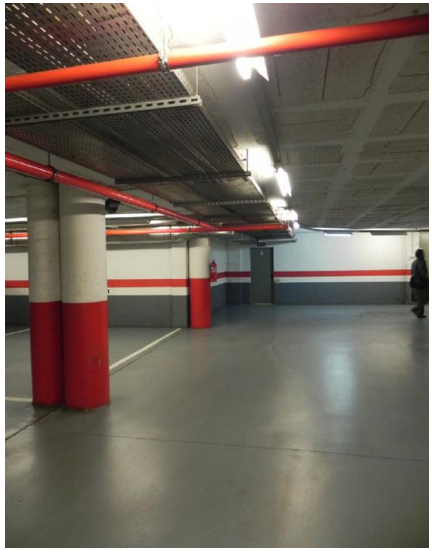
The “Farinera” building

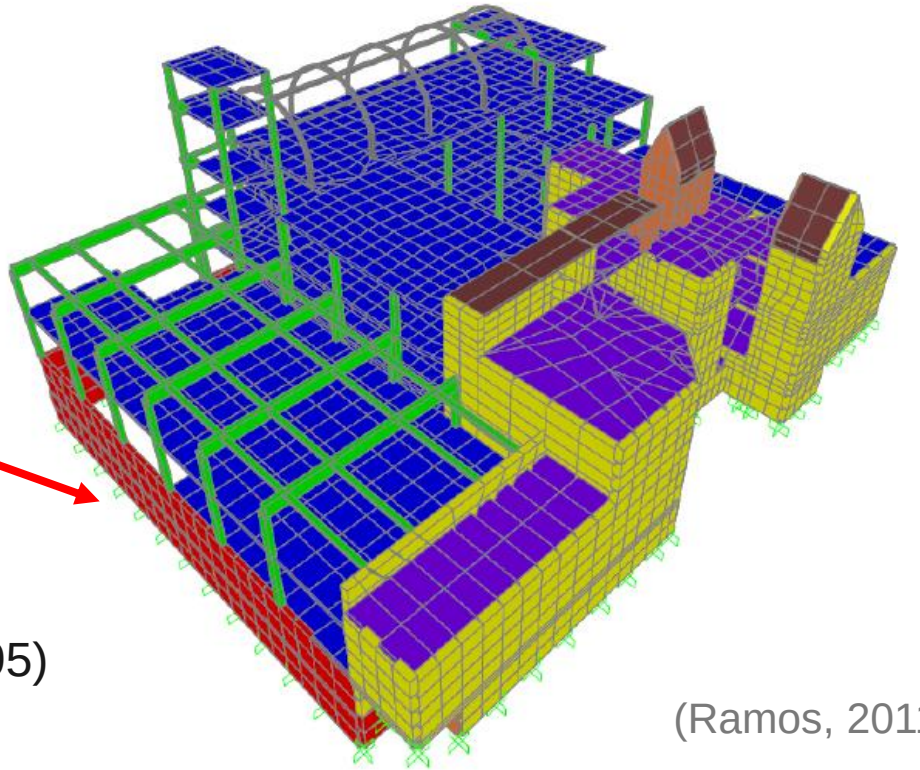


The “Farinera” building



The “Farinera” building





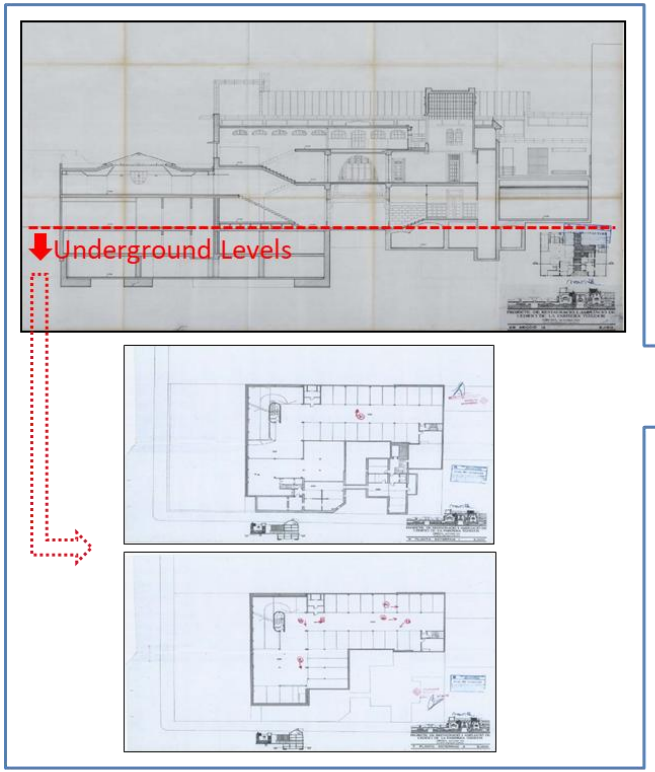
Modern expansion of the building including underground basement (1995)

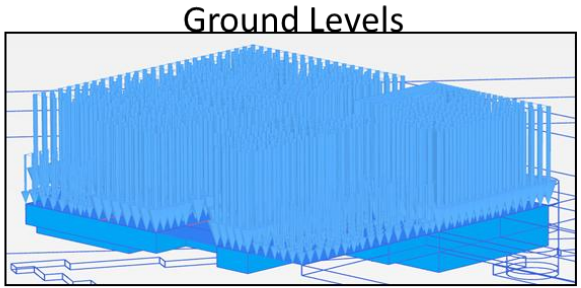
(Ramos, 2011)

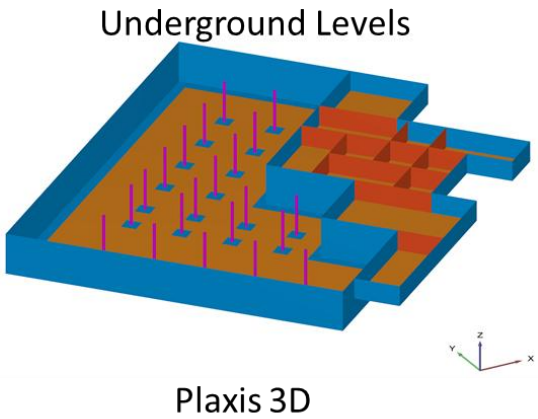
Structural analysis using SAP2000
Limit value of 7 mm of settlement

The “Farinera” building

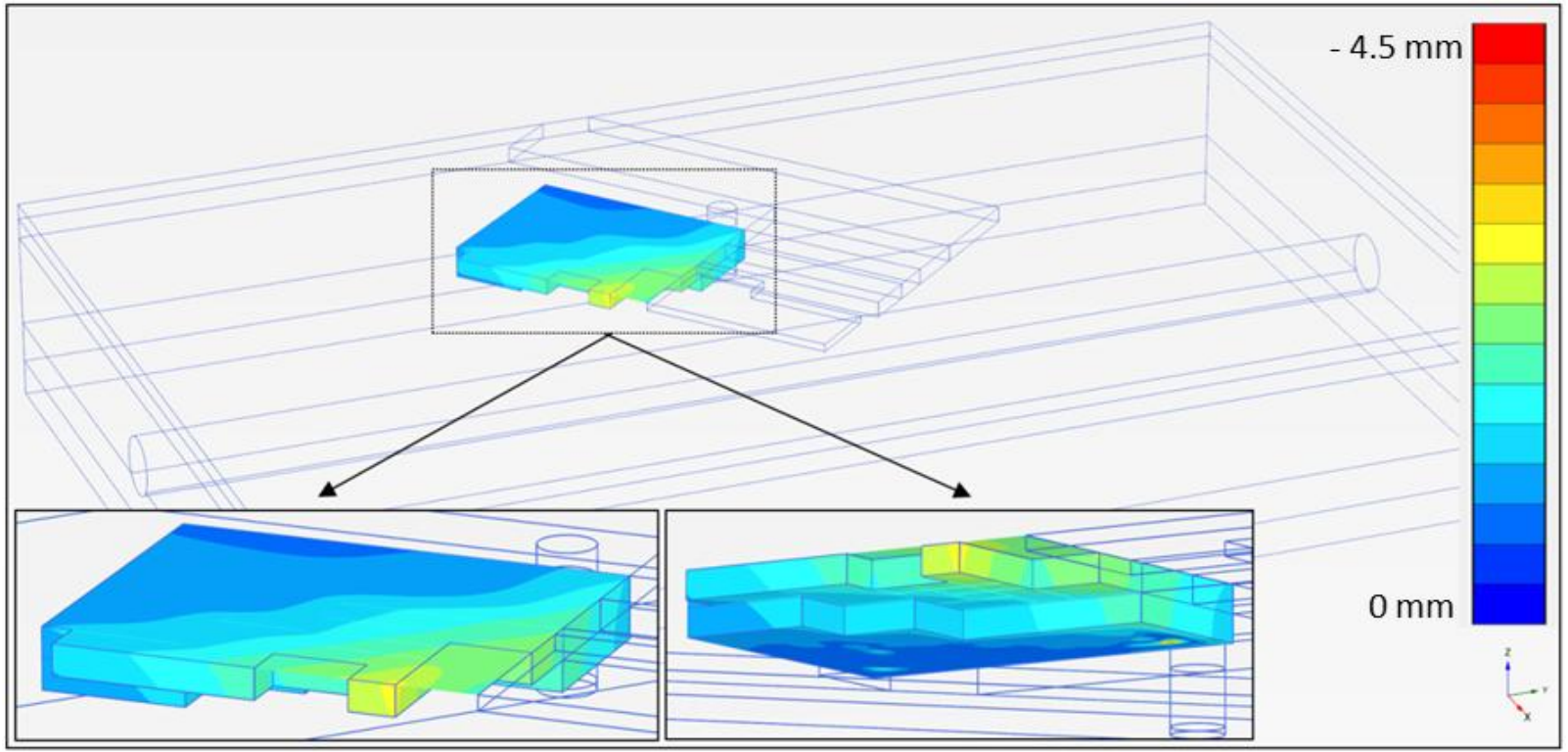
Geotechnical analysis using Plaxis 3D







The “Farinera” building



Plaxis 3D model **without** compensation grouting

The “Farinera” building

Simulation of compensation grouting:

3 Stages

Conditioning stage (1)

- 1st phase: Initial injection, No movements
- 2nd phase: Small uplift

Compensation stage (2)

During tunnel excavation. Grout injection if sett. > 5mm

Post-treatment stage (3)

In case consolidation settlements occur

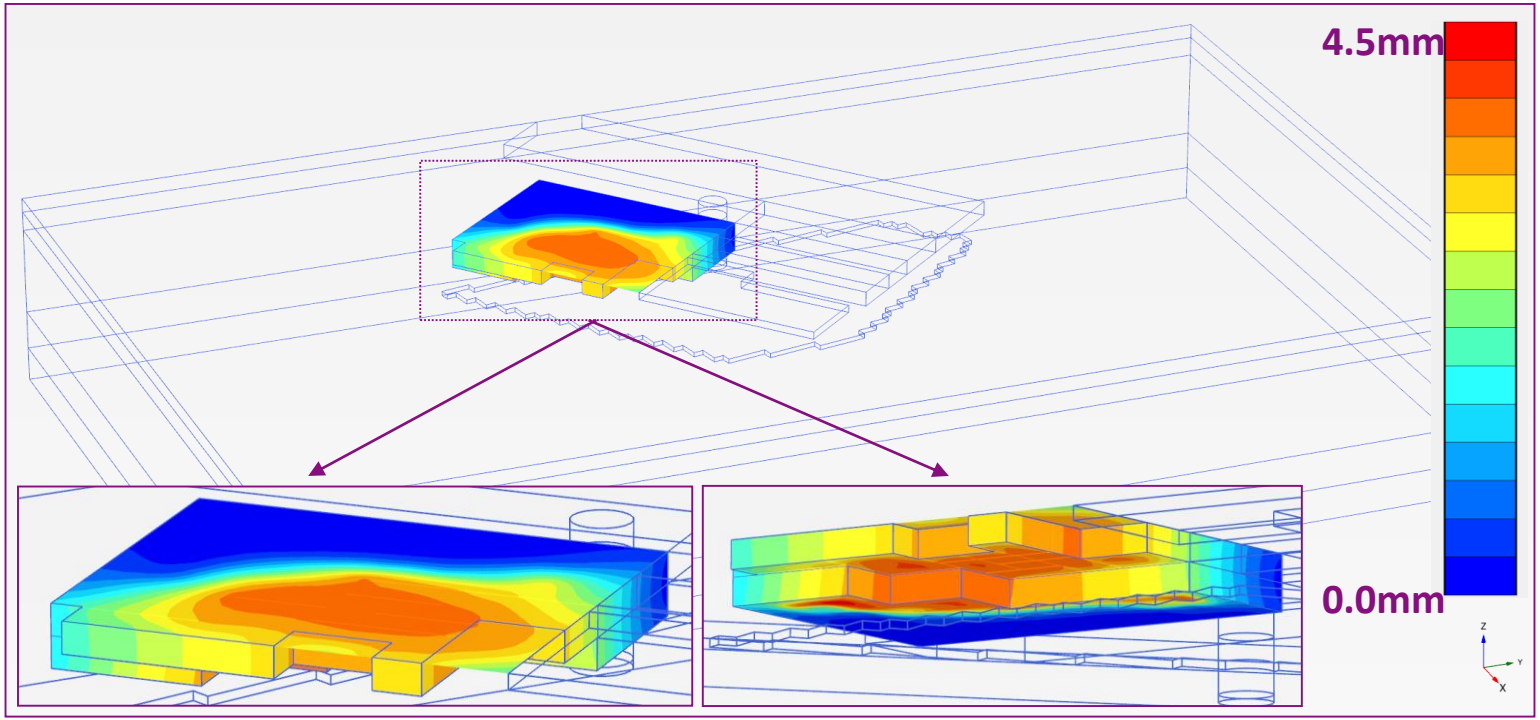
Initial grouted volume included in the FE Mesh

Fixed vol. strain applied (local expansion)

Volume loss 0.3%

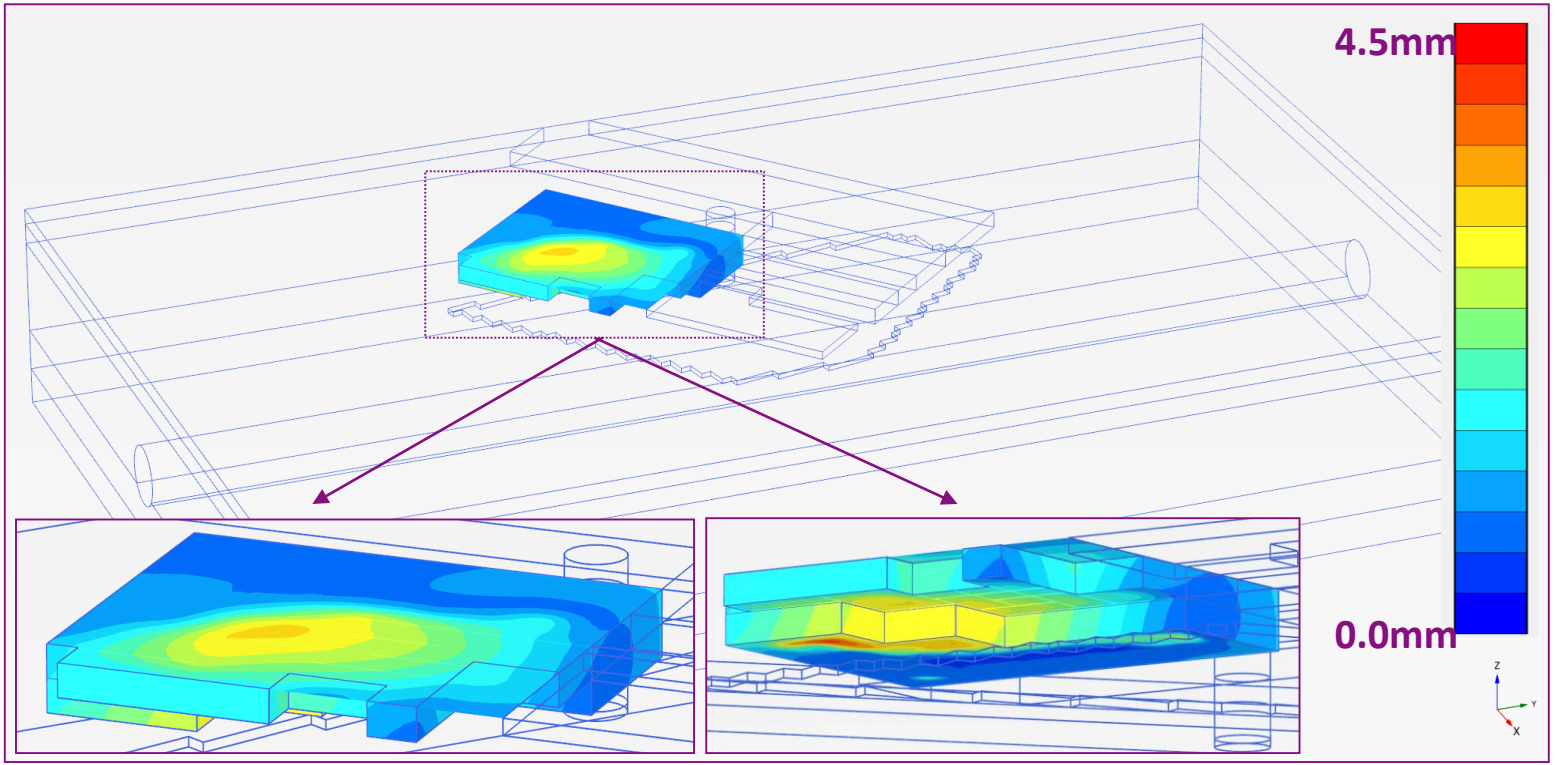
Dissipation of pore water pressure

The “Farinera” building



Computed displacements due to pre-conditioning, **before tunnel excavation** → uplift

The “Farinera” building

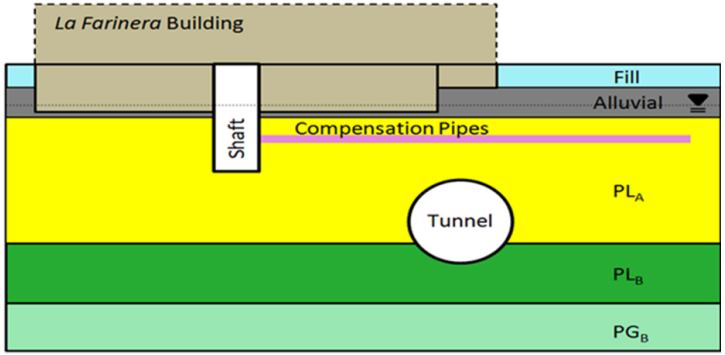


Computed displacements **long term after tunnel excavation**
All displacements upwards

The “Farinera” building

Final impact of the tunnel, thanks to the compensation grouting, was negligible

Generally it is a precise technique, but there are risks… sometimes, drilling the compensation pipes generates settlements on the building already



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The “Sagrada Familia” basilica

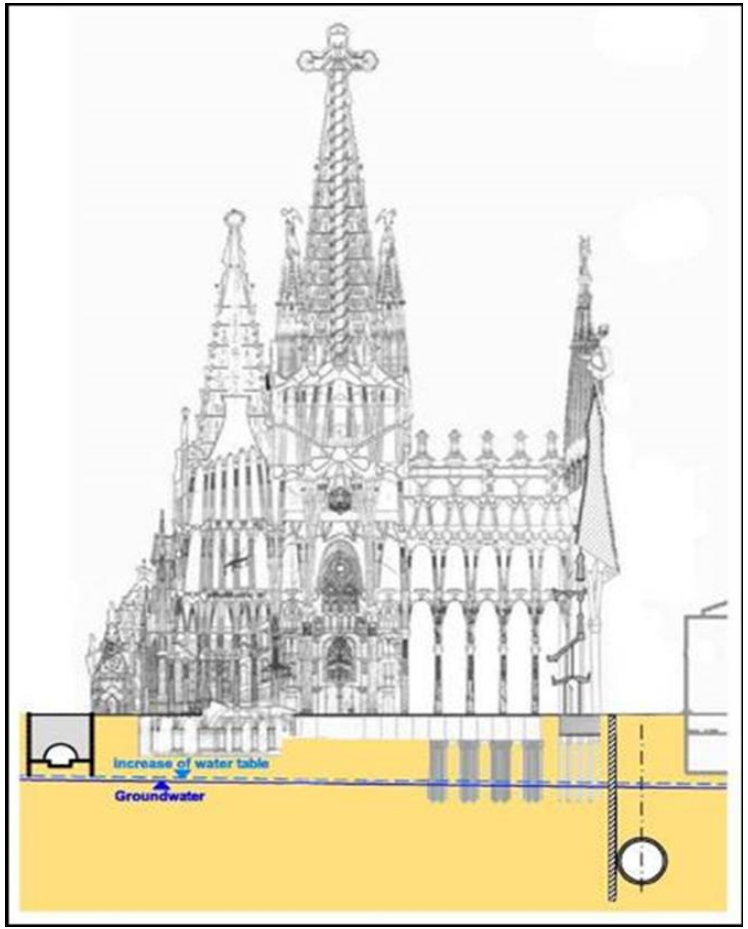




Initiated in 1882 by architect Antoni Gaudí

World Heritage

The “Sagrada Familia” basilica

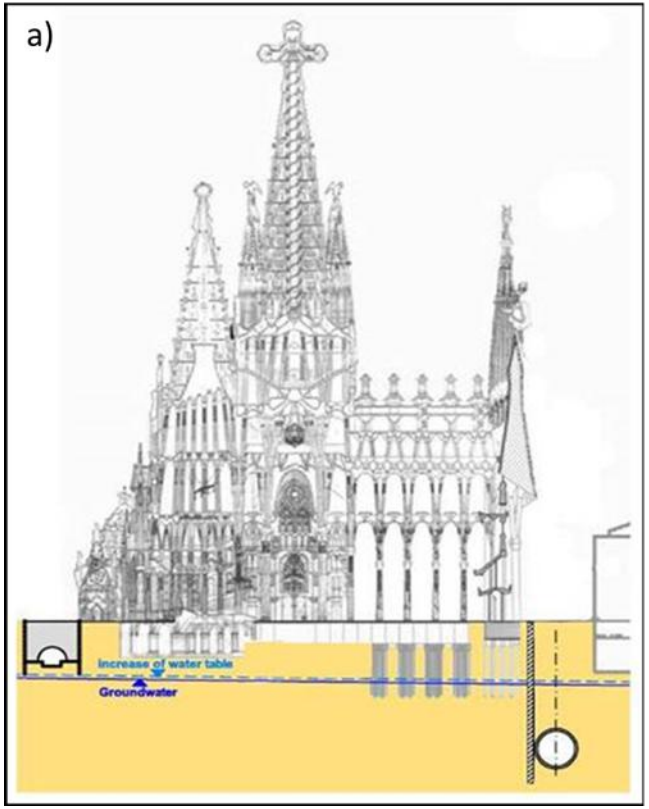


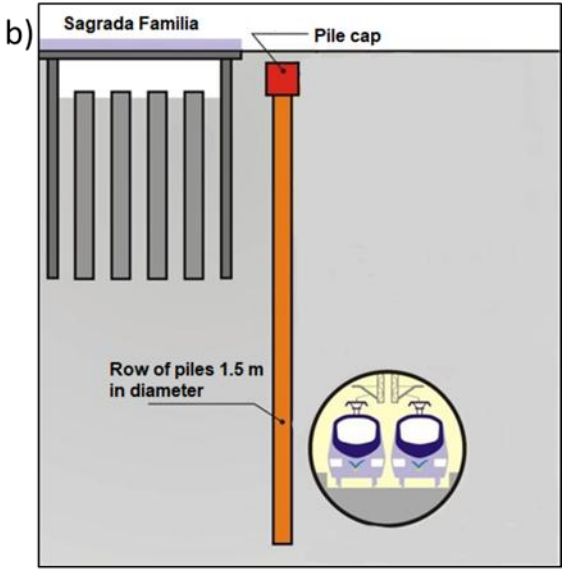
Tunnel next to the basilica, below the street

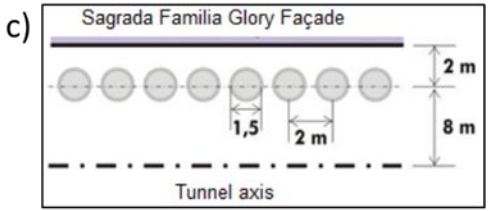
Design of a stiff pile wall separating the basilica from the tunnel

IMPACT should be negligible

The “Sagrada Familia” basilica







Wall of piles:

1.5 m diameter
Length: 41 m

Distance between axis: 2 m

Vertical gap between piles to avoid groundwater barrier effect

The “Sagrada Familia” basilica



The “Sagrada Familia” basilica



The “Sagrada Familia” basilica



The “Sagrada Familia” basilica





The “Sagrada Familia” basilica



The “Sagrada Familia” basilica



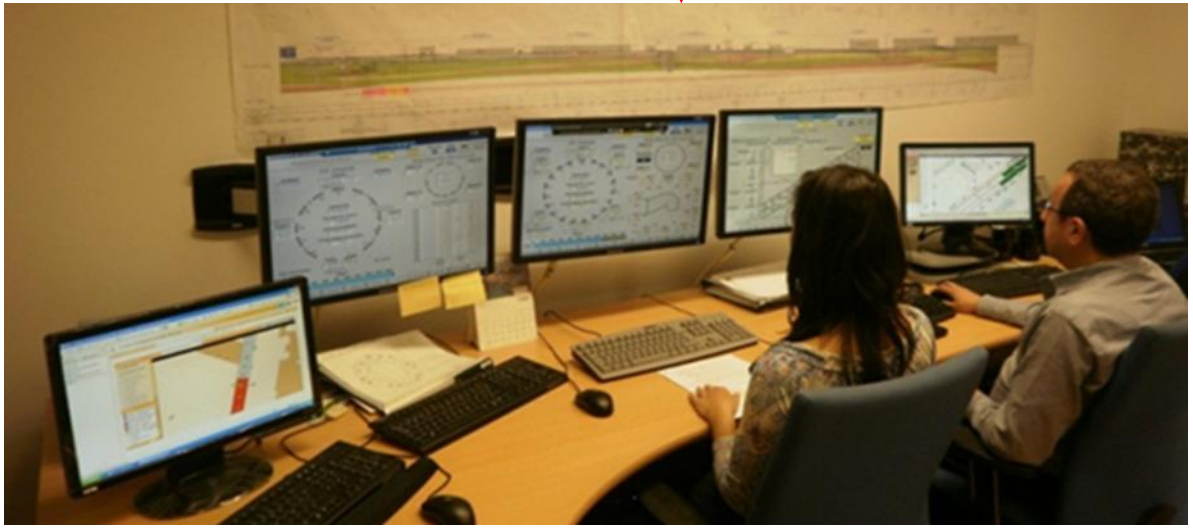
The “Sagrada Familia” basilica



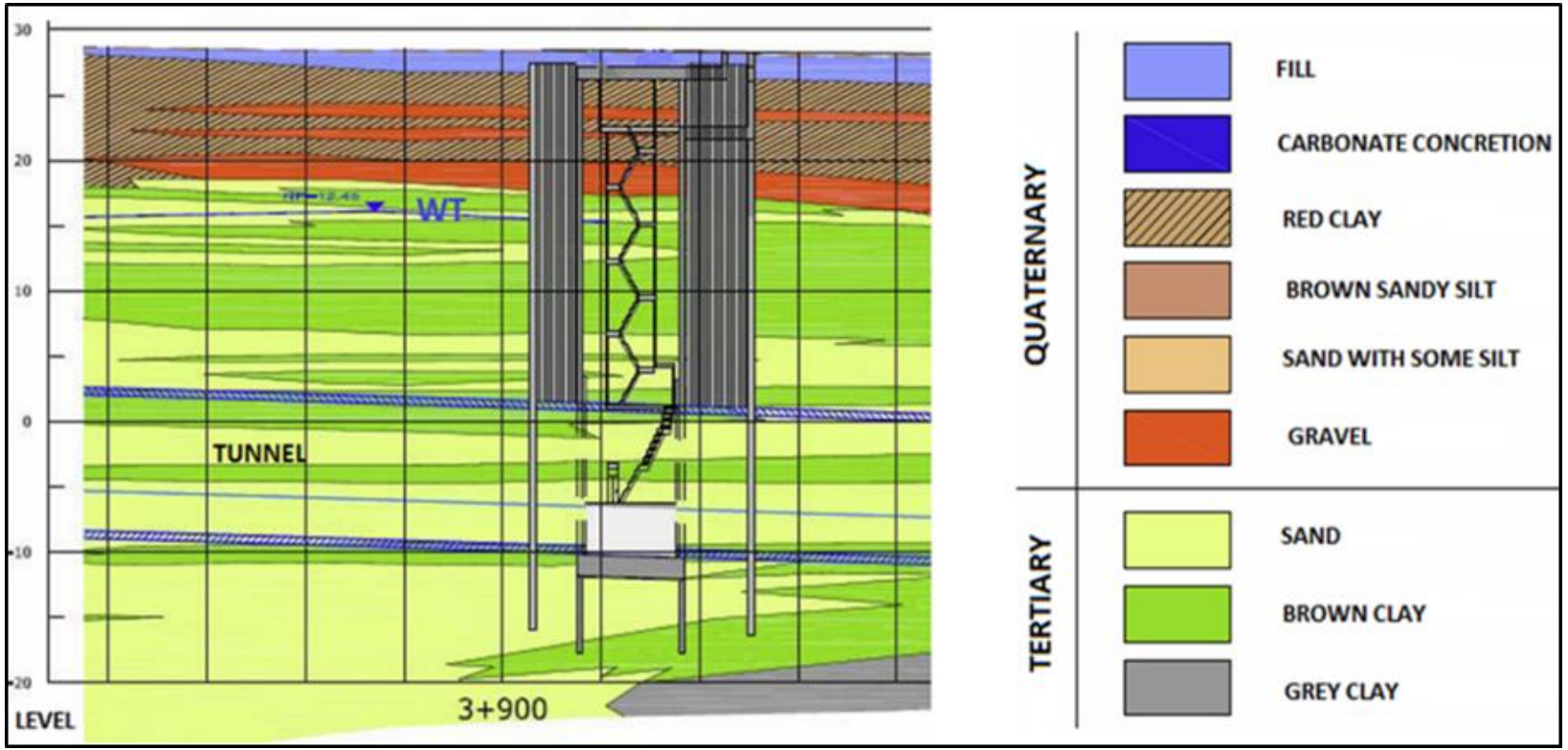
Double check of all Machine Operations

Inside the machine (driver team)

Outside, checking machine parameters and field instrumentation

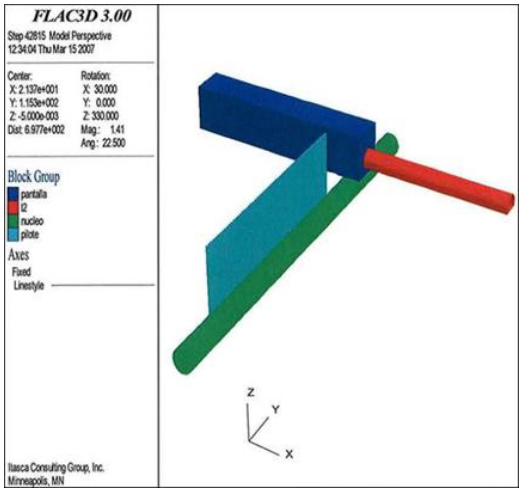


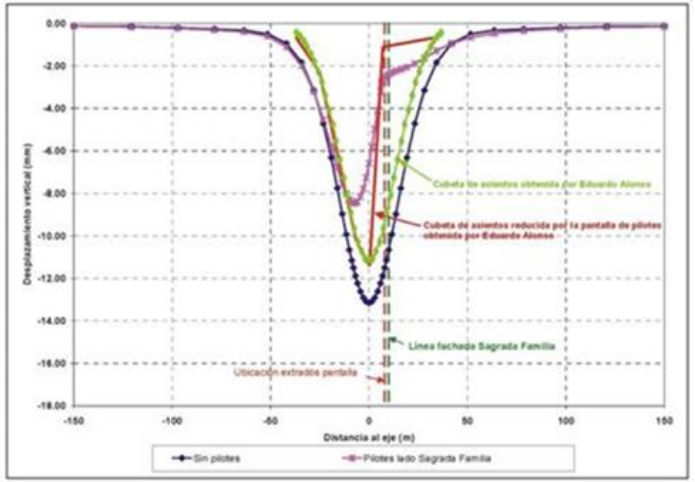
The “Sagrada Familia” basilica



The “Sagrada Familia” basilica

Numerical analysis carried out during the design phase: 2000 - 2007
(several constitutive models used … Elastic Mohr-Coulomb)





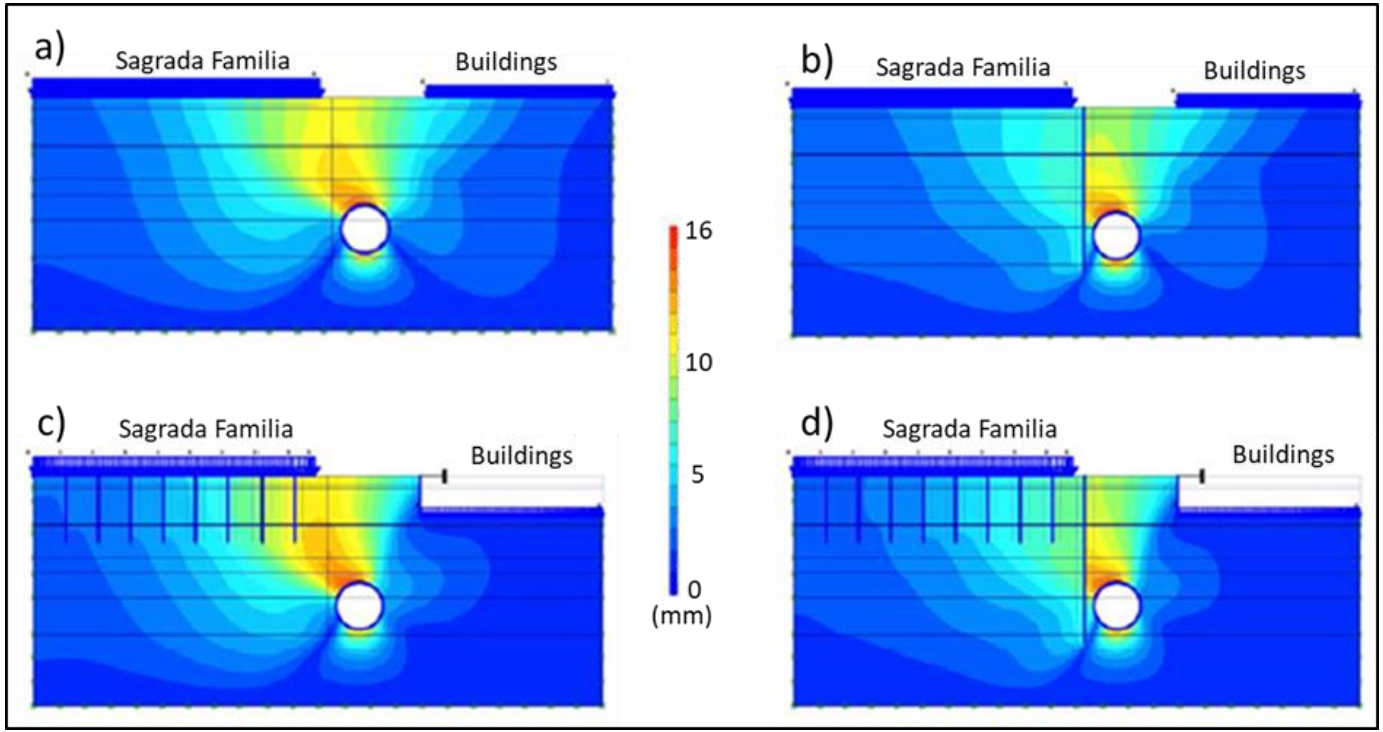
In 2008, Plaxis 2D incorporated Hardening Soil Small Strain model, based on the PhD thesis by Benz (2007).
Far from failure, nonlinear elastic behaviour is crucial

The “Sagrada Familia” basilica

2D analyses carried out after tunnel initiation, using HSS model

With wall, impact on the Sagrada Familia was about 5 to 6 mm in the worst scenario

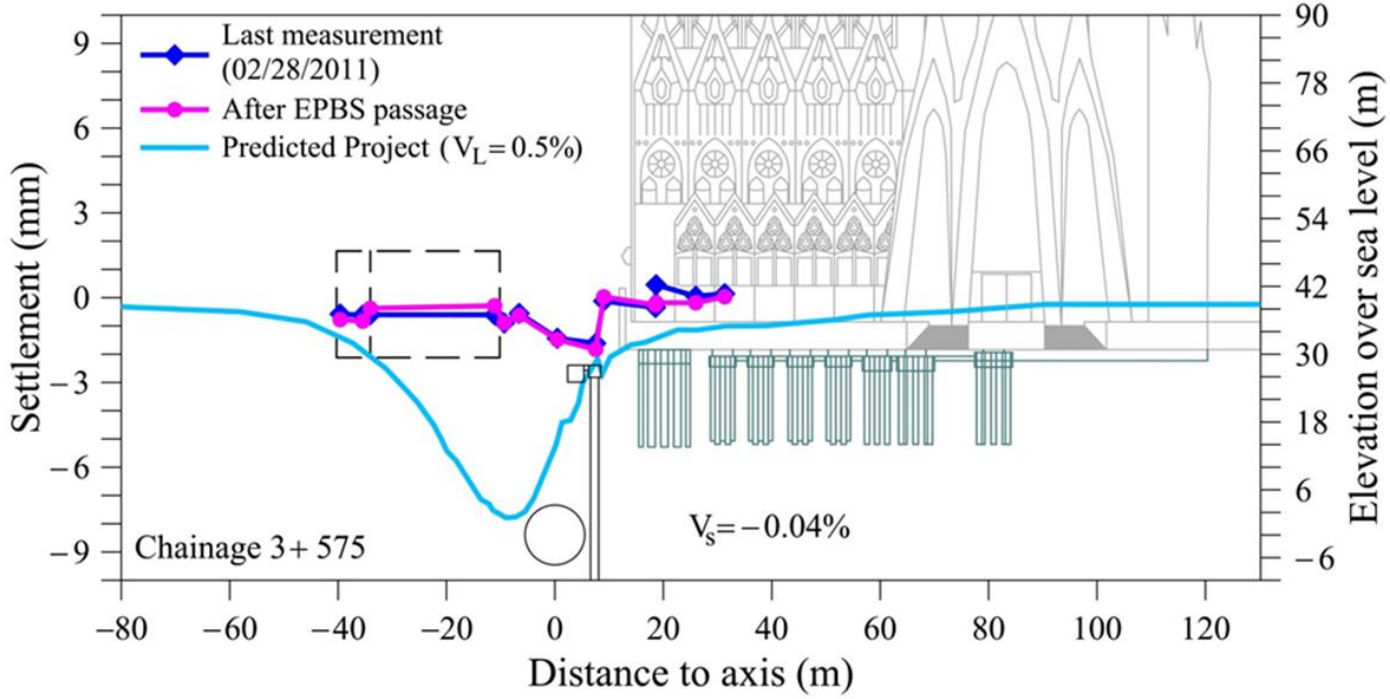
Buildings in front of the basilica were not affected



The “Sagrada Familia” basilica

Settlements measured, due to tunnel excavation

V_{LOSS} was less than 0.05% in that area



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Lessons learned & Future challenges

3 different examples:

	Severe impact	Mod. impact	Mild impact
Grade 1	No	No	No
Grade 2	No	No/Possible	Possible
Grade 3	Possible	Possible	Possible







Different successful solutions

Lessons learned & Future challenges

From the **PREDICTIVE** point of view:

- There are developed computational procedures to predict impact of a tunnel on a historic building
  - Geotech.: FEM, constitutive models including small strain behaviour
  - Structural.: FEM, models simulating masonry, etc.

- Challenges
  - Coupling Structural + Geotechnical Analyses (comput. time)
  - Geometry and parameters difficult to obtain (non-destr. tests)
  - Assessment of the impact (too simple charts…)

Lessons learned & Future challenges

From the **CONSTRUCTION** point of view:

- TBMs have increased the safety of tunnelling works.
  - Volume loss in the examples described below 0.1%
  - Risk limited to a small sinkhole
  - Two teams checking the operations: driving team + controlling team
  - Vertical shafts excavated using hydromills

- Challenges
  - Control of operations and decision protocol
  - Monitoring data is difficult to manage/interpret quickly (development of BIM models… AI …?)

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Concluding remarks

3 Examples of interaction tunnel – historic building
3 different building grades and 3 different approaches

Final displacements generated on the historic buildings by the tunnel were negligible

Lessons learned:
These experiences may be useful for future similar cases

Challenges:
Interaction with historical constructions is always challenging, because of lack of information + risk involved → Future research

Acknowledgements

Profs. E. E. Alonso, G. Ramos, and A. Lloret
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