

Peripheral earth retaining walls solutions at the EDEN Hotel Estoril, Portugal

Ricardo Justiniano

JETSj Geotecnia, Lisboa, Portugal, rjustiniano@jetsj.com

Alexandre Pinto

JETSj Geotecnia, Lisboa, Portugal, apinto@jetsj.com

ABSTRACT: This paper describes the main design and execution criteria adopted for the peripheral earth retaining walls solution, required for the construction of four to six underground floors for the new EDEN Hotel building, at Estoril, Portugal. The excavation has 24m maximum depth, intersecting mainly sandstones and limestones layers with different weathering levels. The excavation site faces a 2m diameter important water drainage pipeline located at 10m depth, as well as existing buildings. Bottom excavation is 15m below Atlantic Ocean level. To minimize the ground deformations and waterflow into the excavation pit, reinforced concrete bored piles walls with 600mm or 800mm diameter lined by shotcrete layer with 0.15m thickness was designed. The piles walls were braced by the following solutions: i) reinforced concrete basements slabs strips, temporarily supported by vertical micropiles, ii) ring beams at the circular area, connected to the bored piles walls at the underground slab levels, iii) temporary ground anchors. The main results of the monitoring and survey plan are presented, crucial to managing the excavation geotechnical risk.

KEYWORDS: Deep excavation, retaining walls, bored piles, slab strips, ring beams.

1 INTRODUCTION

The aim of this paper is to describe the excavation and earth retaining solutions implemented for the construction of the hotel and residential development named EDEN Hotel Estoril underground floors. The building is located near the Atlantic Ocean, requiring the excavation of four underground floors on South side and six underground floors on the North side (see Figure 1 and Figure 2).

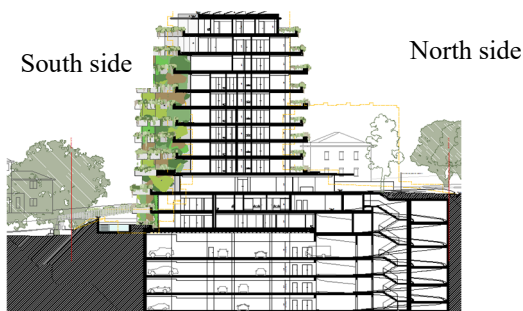


Figure 1. New building cross section.

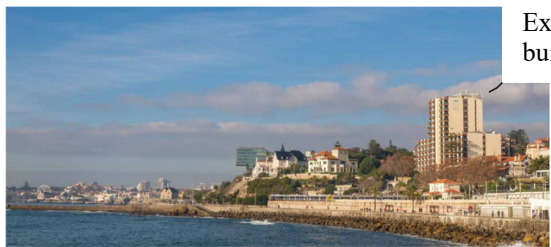


Figure 2. Existing building, before demolition.

2 MAIN CONSTRAINTS

The EDEN Hotel Estoril main challenge was the execution of four to six underground floors in very heterogeneous rock mass, below ground water table, and 14 upper floors above ground level. To meet this challenge, adopted solution had to take into consideration site constraints, especially during excavation phase.

In Portuguese market, excavation and retaining solutions that use pre-stressed ground anchors have, in general, a

temporary nature, with the horizontal equilibrium of earth pressures ensured by the basement's slabs. In this project, this solution was not possible at the North side and East side due to the presence of existing large drainage pipe and lack of legal support from East side neighbors.

To address this challenge, a slab strips solution was designed for North and East side. Due to the excavation of large volumes of rock mass, an access ramp was a critical element for the excavation works in due time. This restriction led to a more singular solution, combining temporary anchors with the slab's strips solution.

In the Northeast side of the development, a spiral ramp (24m diameter) was located for the building operation. In this side, neither temporary ground anchor or slab's strips were viable solutions due the drainage pipe location and the risks and difficulties of execution a spiral ramp using a partial top-down method. Therefore, a ring beam solution at each underground slab level was considered, with the beams end reacting against the basement slab's strip.

For the design of the retaining walls drainage solution, it was critical to control the water inflow. A hydrogeologic study was performed using 4 piezometers, and a set of pumping tests were executed to estimate the permeability coefficients (k).

3 GEOLOGICAL GEOTECHNICAL AND HYDROGEOLOGIC SCENARIO

According to the Geological Map of Portugal at 1:50,000 scale, at the site area with was expected to intersect sandstone and limestones, dated from Cretaceous period. Depending on the location, sandstone and limestones present a W5 F5 to W2 F3 classification. Figure 3 shows the approximate location of the study area on an excerpt from the Portugal Geological Map at a 1:50,000 scale.

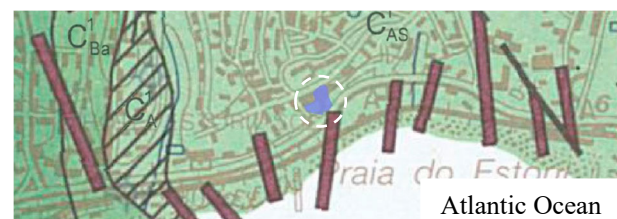


Figure 3. Excerpt from the Portugal Mainland Geological Map at 1:50,000 Scale.

Two site investigation campaigns were performed, one campaign (ENGCEO 2024) focused on the soil and rock mass behavior and included boreholes with SPT and laboratory tests and the other campaign (GEOCONTOLE 2024) focused on the ground water table, rock permeability and aquifer regime.

The results of those campaigns allowed the characterization of materials in terms of their resistance, deformability and permeability and supported geological and geotechnical zoning used at the project stage. The following geotechnical zoning, from top to bottom was considered:

- ZG3 – Landfills deposits, mostly sandy, and silty-sandy fill, with SPT values between 5 and 10 blows and a thickness of about 1 to 2m.
- ZG2 – Sandstone or limestone W4/W5 (SPT bigger than 60 blows), and thickness varying between 3.0 and 8.0m.
- ZG1 – Limestone W3/W2 (SPT bigger than 60 blows).

Table 1 shows the main geotechnical parameters considered at the numerical models.

Table 1 – Main geotechnical parameters.

Layers	γ (kN/m ³)	c' (kPa)	ϕ' (°)	E (MPa)	ν
Fill	18	2	26	5	0.3
ZG2	23	50	32	100	0.3
ZG1	24	100	35	200	0.3

Hydrogeologic information conclude that site intersected a non productive aquifer. In a conservative approach, the water inflow could reach 150m³/day for the whole excavation, or 0,05m height /m² site plant / day. This value was considered acceptable at the design stage. As precaution measures, several pumping devices were mobilized on site.

4 EXCAVATION AND RETAINING WALLS SOLUTIONS

The excavation and retaining walls solutions included the construction of reinforced concrete bored piles walls: i) 600 mm diameter spaced between axes 1,0m or 1,2m; ii) 800 mm diameter piles spaced between 1,4m or 1,6m. As shown in Figure 4, three types of solution were executed to brace the piles walls.

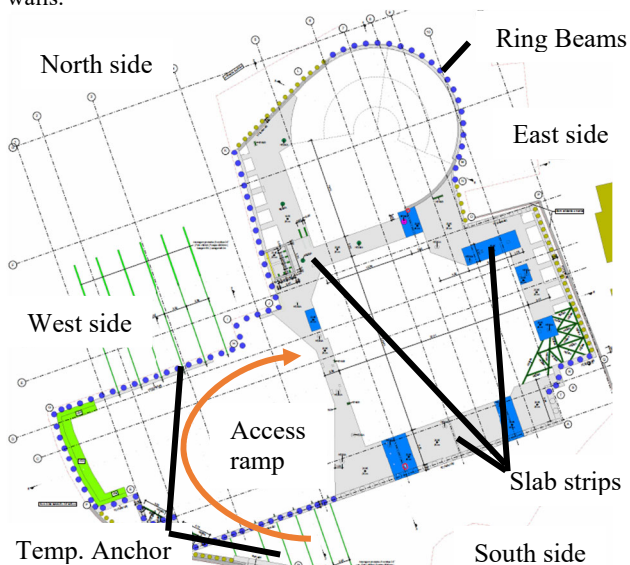


Figure 4. Plan view of earth retaining bracing solutions.

For the main ramp access (Southwest side), temporary prestressed ground anchors of 6 Ø0.60” strands (Grade 270k), with Pnet=600kN, spaced 3,2m apart were considered at three to four levels. (see Figure 5 and Figure 6).

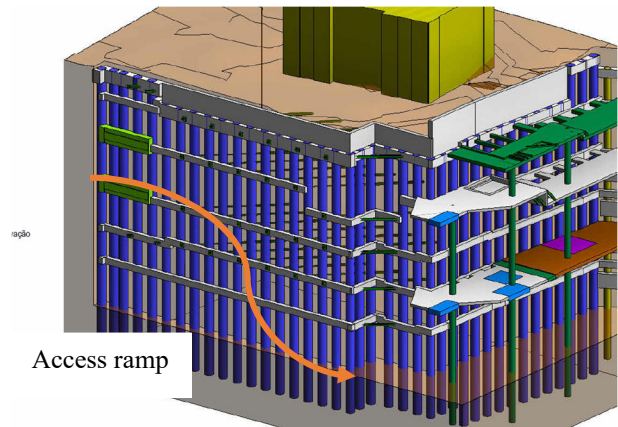


Figure 5. West side temporary anchors and temporary access ramp.

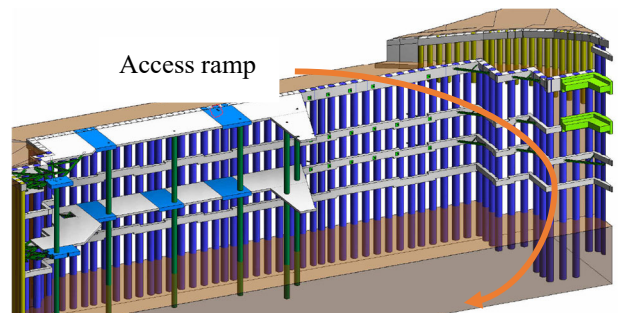


Figure 6. South side temporary anchors and temporary access ramp.

For the North, South and East side, a slab’s strip solution was adopted, with 0,25m thickness, in general, respecting the basements structural solution. This solution considered all openings necessary for the execution of all other projects (Ventilation, Waters etc.). In opening areas, steel sections of HEA120 or HEA200 S275JR were considered to avoid stresses concentration and improve the slabs behavior.

Additional reinforcements of 10Ø25mm to 16Ø32mm, depending on area, were added to the slab’s strips borders (in addition to the reinforcement already present in structural project), to consider the forces during excavation phase.

Slabs capitels (with 0,40m to 0,70m of thickness) were considered at the slab’s strips (blue elements in figure 4) to keep the slab geometry respecting the architectural and structural projects.

Due to the size of the slab’s strip and the need to control the deformations during excavation phases, additional micropiles (HEA200 S275JR or HEA300 S275JR) were considered for temporary vertical support of the slab strips. Micropiles had IPE120 S275JR beams weld at slab levels (embedded at the slabs), to avoid punching.

At the North side, with up to 24m deep, 3 levels of slab strips were built. At the South and East sides, up to 18m deep, 2 levels of slab strips were considered (see figure 7 and 8). This type of solution was also previously adopted with success in other big size developments in Miraflores (Justiniano, R; Pinto, A. 2024), Parque das Nações (Silva, N. et al., 2024) and Benfica (Pinto. A. et al., 2019).

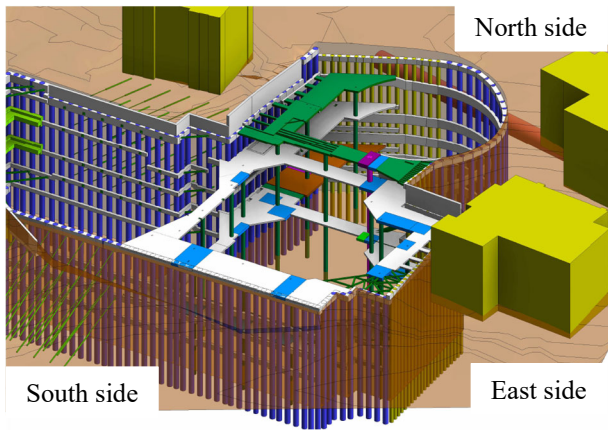


Figure 7. 3D view of slab's strip.

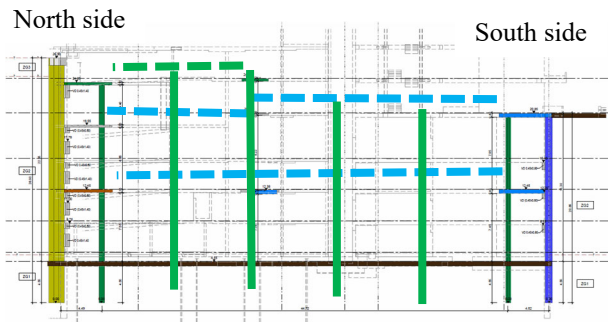


Figure 8. Slabs Strips solution – North South section.

At the Northeast side, at the spiral ramp, ring beams of reinforced concrete 0,45x1,40m were adopted. The main challenge with this solution was the connection with the slab's strips solution, as the ring beams need a reaction end point at each side to accommodate axial reaction compression loads (up to 5000 kN).

On the north side the ring beams were connected to the piles walls at all basement levels. At the east side the ring beams were connected to the underground slab levels 2, 1 and -2. Temporary strut bars were needed with 2x HEB500 S275 JR to assure the ring beam reactions at level -1 and -3 to slab level -2 and excavation bottom level (see figure 9).

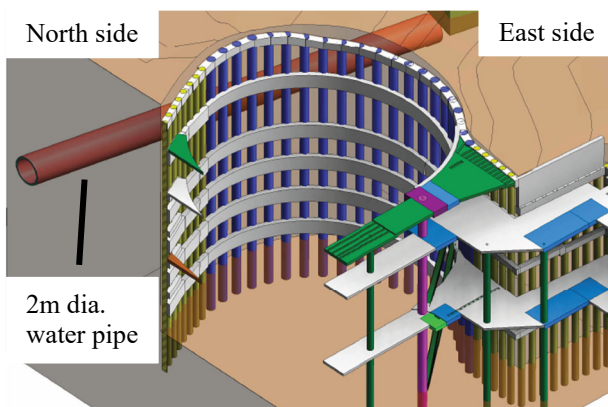


Figure 9. 3D view on the ring beams area where arch effect is mobilized.

5 CONSTRUCTION PHASE / MODELS

The excavation construction phase followed, in general, the following step:

- Execution of the monitoring and survey plan in existing buildings.

- Demolish of existing EDEN building.
- Execution of retaining piles walls.
- Execution of strip slab at level 2.
- Execution of temporary anchors on northwest side.
- Execution of ring beam, level 2.
- Execution of strip slab at level 1.
- Execution of ring beam at level 1 and -1.
- Execution of temporary anchors on south side.
- Execution of strip slab at level -2.
- Execution of ring beam at level -2 and -3.
- Arrive at level -4 (bottom excavation).

Plaxis 2D models were considered (Figure 10 and Figure 11), considering all construction stages, and the geomechanics properties (see Table 1). Axisymmetric models were also considered for the spiral ramp solution.

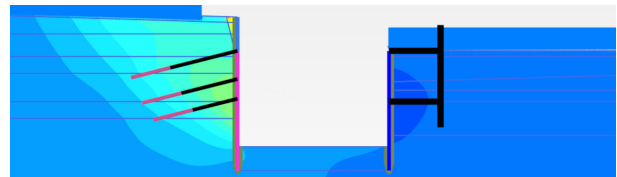


Figure 10. Temporary ground anchor model plus 2 strip slabs.

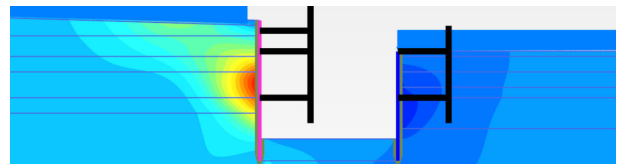


Figure 11. 3 Slab's strips model.

For the Plaxis 2D models, piles were modeled as plate elements, temporary anchors were modeled as node-to-node elements and embedded beam elements, strip slabs were modeled as "fixed end anchor" with a calibrated stiffness. The stiffness of the strip slab was calibrated taking into consideration the Autodesk Robot 3D models. In general, "Hardening soil" soil model was considered.

For the evaluation of strips slabs forces a 3D model (Autodesk Robot) was adopted (figure 12).

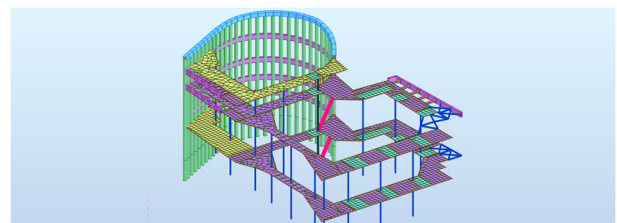


Figure 12. Autodesk Robot 3D model.

This model was also important to evaluate the forces at ring beams, as well as the local impact on adjacent piles and the ring beams. At this model, piles were modeled as plate elements, slabs as finite elements slabs and strut bars as plate elements.

6 MONITORING AND SURVEY PLAN

The Monitoring and Survey Plan, essential for a project with this complexity, was a fundamental tool to validate on time the main design assumptions and managing geotechnical risk. As already stated, several monitoring devices were installed along

the peripheral piles walls and nearby structures (see Figure 13), including:

- Piezometers: to measure the groundwater table level.
- Inclinometers: to measure horizontal displacements with depth.
- Topographic targets: to measure planimetric and altimetric movements.
- Load cells: to measure the loads in both the pre-stressed.

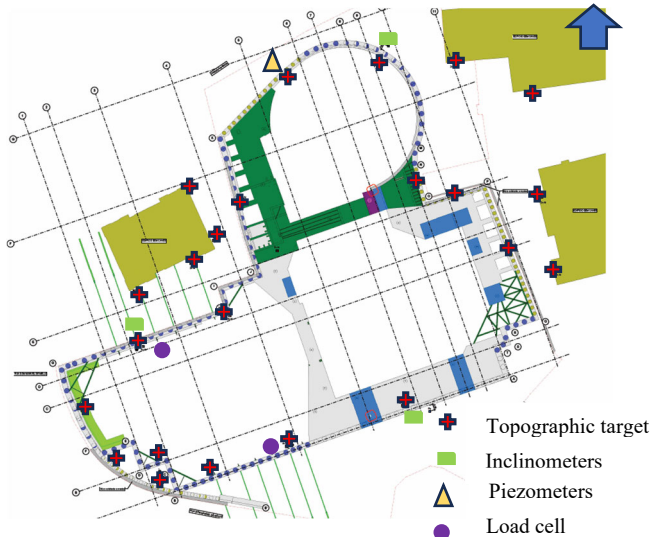


Figure 13. Plan view of the monitoring devices.

The monitoring and survey plan defined weekly readings and established alert and alarm thresholds for each excavation stage and device. Figure 14 shows horizontal deformation at a neighbor building. Figure 15 shows horizontal deformations at the Northwest side retaining piles wall.

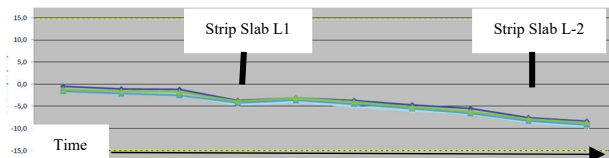


Figure 14. Deformation of a neighbor building (mm).

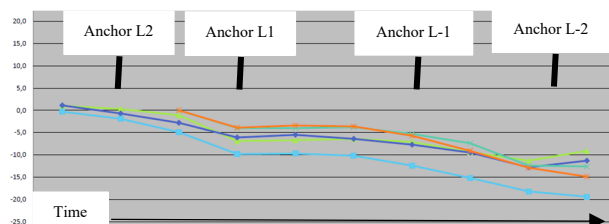


Figure 15. Horizontal deformation at Northwest side piles wall (mm).

The results of the monitoring and survey plan are compatible with the numeric ones.

Regarding the water inflow, until December 2025 (see Figure 16), the ground water table was not intercepted, even though the excavation is already 7m initially estimated value. Nevertheless, the consequences of the ground water table lowering at nearby structures shall be evaluated with the results of the monitoring and survey plan, and, if necessary, additional measures will be adopted.

7 FINAL REMARKS

This paper aims to present the excavation and peripheral retaining solutions adopted for the construction of four to six underground floors for the construction of a large-sized development located near the Atlantic Ocean.

The complexity of this project was only possible to manage with BIM tools, allowing the compatibilization of many projects at the same timeframe, considering also the site constraints. BIM tools also contributed to a faster response to challenges that arose with the execution on site.



Figure 16. View of the excavation works in December 2025.

8 ACKNOWLEDGEMENTS

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