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

Solutions de excavation profonde pour la construction d'un parc logistique à Loures (Lisbonne)

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ABSTRACT: This paper aims to describe the deep excavation solutions adopted for the construction of a logistics park with an implantation area of approximately 107 000 m^2, located in the municipality of Loures in Lisbon. The use of this site for the construction of a large-scale building with demanding future performance criteria proved to be extremely challenging, particularly because the original place had previously been used as a limestone quarry and subsequently as a landfill for various materials associated with the construction of the nearest main road network. Given the existing constraints, particularly the desired implantation area, the geological-geotechnical study and the neighboring conditions, a deep excavation solution was defined for a maximum height of 20 m, consisting of a bored pile wall with 800 mm diameter and with shotcrete between the piles, braced by permanent anchors and complemented with a concrete Berlin-type wall solution in areas where the limestone rock, with low degrees of alteration and fracturing, emerged above the excavation bottom. In addition to the adopted design criteria, the proposed instrumentation and monitoring plan for the retaining solution and neighboring infrastructure are also presented.

RÉSUMÉ: Cet article vise à décrire les solutions de excavation profonde adoptées pour la construction d'un parc logistique d'une superficie d'environ 107 000 m^2, situé dans la municipalité de Loures à Lisbonne. L'utilisation de ce site pour la construction d'un bâtiment à grande échelle répondant à des critères de performance futurs exigeants s'est avérée extrêmement difficile, en particulier parce que l'endroit d'origine avait été précédemment utilisé comme carrière de calcaire, puis comme décharge pour divers matériaux associés à la construction du réseau routier principal le plus proche. Compte tenu des contraintes existantes, en particulier de la superficie d'implantation souhaitée, de l'étude géologique-géotechnique et des conditions environnantes, une solution de excavation profonde a été définie pour une hauteur maximale de 20 m, comprenant un mur de pieux forés de 600 mm de diamètre avec du béton projeté entre les pieux, renforcé par des ancres permanentes et complété par des solutions de mur "Berlin" dans les zones où la roche calcaire, avec des degrés d'altération et de fracturation faibles, émergeait au-dessus du fond de excavation. En plus des critères de conception adoptés, le plan d'instrumentation et de surveillance proposé pour la solution de soutènement et les infrastructures avoisinantes sont également présentés.

Keywords: Deep excavation; bored pile wall; concrete Berlin-type wall.

1 INTRODUCTION

The deep excavation solutions presented in the present article are located in the municipality of Loures (Figure 1) and were developed and designed to enable the construction of a logistic park with an approximately 55,000 m^2 footprint.

Figure 1. Site identification (Google Earth image).

The use of this site for the implementation of a large-scale building with demanding future performance criteria proved to be extremely challenging due to the fact that the original land had previously been used as a limestone quarry and subsequently as a dumping for various materials. These two situations determined, during excavation, the occurrence of very abrupt geological transitions and completely distinct geotechnical behaviors over very short distances.

After an extensive geological-geotechnical characterization, substantiated by various prospecting campaigns, the best deep excavation and earth support solutions were adapted for both excavation and embankment areas; the latter, however, are not covered in the present article.

For the excavation areas located in the southern elevation, adjacent to the national road EN250, a bored pile wall was adopted, with a maximum height of 20 m, permanently anchored and complemented with a concrete Berlin-type wall in areas where the limestone mass, with low degrees of alteration and fracturing, emerged above the excavation bottom.

On the other side, for the embankment areas, on the western, northern and eastern elevations, considering the existing levels, available space, and the need to ensure the maximum possible storage capacity for surplus soils from the embankment platform, a gabion wall and a reinforced earth wall with facing panels of precast reinforced concrete were constructed.

2 MAIN EXISTING CONDITIONS

2.1 Geological-geotechnical conditions

Four prospecting campaigns were conducted in the area of the logistics park from 2019 to 2021, that involved the execution of around fifty hollow stem auger borings, accompanied by dynamic penetration tests of the SPT type at every 1.5 m, reaching depths of 34 m, twenty-four exploratory pits, using an excavator, with depths ranging from 0.70 to 4.90 m and ten seismic refraction profiles.

The borings from the second and fourth phases were considered particularly representative for the design of the bored pile wall solution due to their location, almost coinciding with the boundary perimeter of the existing quarry. The analysis of these campaigns confirmed the variability of encountered terrains and abrupt geological variations (Figure 2).

During the excavation process, it was also observed that within a few meters, there was a transition from a rocky mass near the surface to a rocky mass below the excavation bottom (Figure 3).

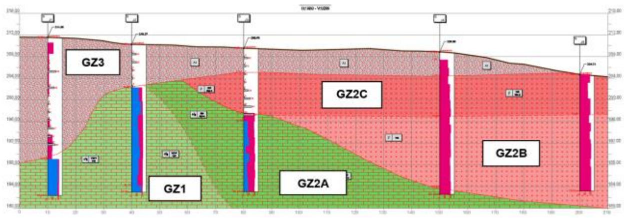

Figure 2. Geotechnical interpretative profile along the alignment of the bored pile wall.

Figure 3. View of abrupt transitions between landfill zones and vertical faces of the limestone quarry.

The analysis of the geological-geotechnical campaign allowed the individualization of the 5 geotechnical zones identified below:

GZ3 - Corresponds to landfill deposits;

GZ2C – Soils corresponding to volcanic breccias and decomposed volcano-sedimentary formations from the Lisbon Volcanic Complex;

GZ2B – Soils corresponding to volcanic breccias and decomposed volcano-sedimentary formations from the Lisbon Volcanic Complex;

GZ2A - Massif corresponding to basalts, volcanic breccias, and decomposed volcano-sedimentary formations or rock ranging from highly altered to moderately altered from the Lisbon Volcanic Complex;

GZ1 - Massif corresponding to whitish crystalline limestones to grayish marly limestones ranging from little to moderately altered.

2.2 Pre-existing conditions

The intervention area is located, in part, over former limestone quarries that were subsequently used as a landfill. In this context, there was a high level of uncertainty about the composition of the fill materials but also about the configuration/inclination of the cut slopes, which were created during the quarrying activities.

2.3 Topographic constrains

The land used for the construction of the logistics park had a slope towards the north, with the area adjacent to national road EN250 being the highest and the area adjacent to a watercourse on the opposite elevation having lower elevations. To achieve a level platform, as previously mentioned, it was necessary to develop a retaining structure through excavation along the northern elevation and part of the western elevation (Figure 4). Additionally, gabion retaining walls and reinforced earth walls were designed on the southern elevation, part of the western elevation, and part of the eastern elevation. As mentioned above, this article will exclusively address the deep excavation solutions in the northern and western elevations.

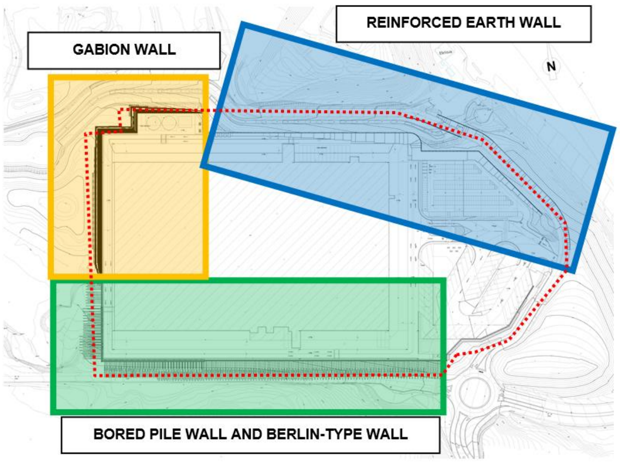

Figure 4. Identification of the retaining and embankment solutions and lot boundary (highlighted in red).

3 PROPOSED SOLUTIONS

3.1 Bored pile wall

Based on the existing constraints, particularly topographical, geological-geotechnical, neighboring occupancy, and the need for rapid execution, it was adopted a bored pile wall, with a 800 mm diameter and spaced at a center-to-center distance of 1.5 m (Figure 5). This arrangement enabled an excavation of about 20 m in maximum height.

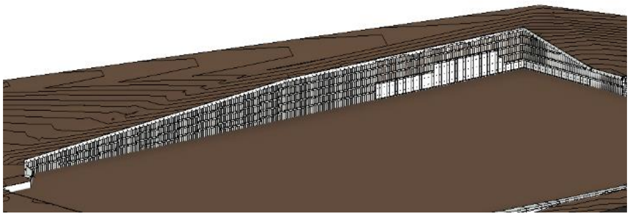

Figure 5. 3D perspective oof the bored pile wall solution.

Given the geological conditions of the site and the length of the piles, they were entirely executed using a telescopic Kelly bar, occasionally with temporary casing at the borehole entrance. When encountering larger blocks or to ensure anchoring in the rock mass, a tricone bit, rock auger, and coring tool were used.

To enhance efficiency in excavation, the wall was braced using 2 to 5 levels of permanent anchors with planar spacings of 3.0 m, aiming to provide temporary and definitive horizontal balance of the containment against ground impulses, both in static and seismic conditions.

To ensure a more even distribution of forces on the wall and prevent excessive load concentration, reinforced concrete distribution beams were implemented and properly anchored to the piles (Figure 6).

The anchors were installed at different inclinations to the horizontal (between 15º and 30º) and with variable free lengths (between 9 m and 17 m), with a minimum sealing length of 8 m (Bustamante and Doix., 1985) and a maximum long-term traction of 900 kN.

Considering the permanent nature of the anchors, the provisions of NP EN 1537 were followed regarding the characteristics of the tendons, injection grout, anchor head protection components, and anti-corrosion protection.

The exposed soil between piles was protected with a sprayed concrete coating applied in two layers and reinforced with metal fibers. The area was properly drained using geodrains between piles.

Figure 6. Excavation works near the bored pile wall.

3.2 Concrete Berlin-type retaining wall

As indicated in the geological-geotechnical study, an intersection of the piles with slightly altered limestone occurred near the corner of the wall. In this area, the pile wall was underpinned using micro-piles. The remaining excavation was carried out with advances under a concrete Berlin-type retaining wall with rock bolts (Figure 7).

In this type of solution, the retaining wall is constructed in levels, from top to bottom. Each level is created by constructing reinforced concrete panels (first the primary panels and then the secondary ones), supported by spaced micro-piles, on average 3 m apart. These micro-piles are installed before the start of excavation work and function to support the vertical loads to which the retaining wall is subjected. The panels, with a theoretical minimum thickness of 30 cm, are cast against the open vertical face of the limestone mass and connected at the top through a reinforced concrete beam with pre-stressed anchors. This beam simultaneously ensures the underpinning of the base of the bored pile wall and the partial transfer of vertical loads to the micro-piles.

Regarding the horizontal bracing of this wall, the execution of high-strength steel tie rods with a diameter of 32 mm was anticipated.

Figure 7. Excavation works near the concrete berlin-type retaining wall.

4 DESIGN METHODS

To analyze the behavior of the retaining wall solutions with respect to forces and deformations, finite element models were employed using the PLAXIS 2D software.

The analyses conducted generally involved studying various cross-sections deemed representative of the diverse geometries along the lengths of each of the construction solutions used.

The geomechanical behavior of soils was simulated using Hardening-Soil constitutive models, while for more rocky materials, their behavior was simulated using elasto-plastic Mohr-Coulomb constitutive models, and thus, without hardening.

Structural elements, such as the bored pile wall, concrete Berlin-type retaining wall, and anchors, were modeled based on their elastic properties. The modeling limited their maximum strength to ultimate limit states, allowing for the assessment of the maximum global safety factor.

5 MONITORING PLAN

The implemented monitoring plan aimed to ensure the safe and cost-effective execution of activities related to excavation process and during the lifespan of the logistics park. Additionally, it involved analyzing the surrounding behavior during this phase of construction, leading to adaptations based on the obtained results.

Installed devices allowed for the measurement of the following parameters on a weekly basis:

- Horizontal and vertical displacements of the retaining structures using topographic targets;
- Horizontal displacements of the soil behind the retaining solutions using inclinometers;
- Measurement of tension load in the anchors using load cells.

As of the current date, no significant deviations from the project estimates have been recorded based on the available readings. The maximum horizontal movements on the targets and inclinometers are approximately 15 mm, associated with a maximum excavation height of about 15 m and anchor load increments of less than 10%.

6 CONCLUSIONS

Considering the positive outcomes of the established instrumentation and observation plan, along with the accomplishments during the excavation works, it is concluded that the alternative solutions developed in the context of the design and construction process carried out in collaboration between the designer (JET_{SJ}) and the contractor (Norton EI), have proven to be extremely versatile and well-suited to local constraints.

ACKNOWLEDGEMENTS

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REFERENCES

Bustamante, M.; Doix, B. (1985). Une méthode pour le calcul de tirants et des micropieux in-jectés. Bulletin de Liaison des Laboratoires des Ponts et Chaussées, Ministère de L'Équipe-ment, du Logement, des Transports et de la Mer, Paris. 140, 75-92.

CT156 LNEC (2016). NP EN 1537 – Execution of special geotechnical works. Groud anchors. In portuguese.