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

Renforcement des murs de soutènement et des chaussées d'un entrepôt industriel à Quinta do Adarse, Alverca, Portugal

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ABSTRACT: The aim of this article is to present the solutions for the main retaining walls and pavement strengthening, adopted in an industrial warehouse at Quinta do Adarse, in the proximities of the Tagus River right bank, at Alverca, Portugal. The existent cantilever reinforced concrete wall with 300m of length and 6m of maximum height, was strengthened with a cap distribution beam due to excessive deformation. The cap distribution beam was supported by inclined steel struts and founded on micropiles. At the warehouse pavements, some differential settlements were detected around the stiffer structural foundations, mainly due to the water inflow at the pavement earth fill foundation, which required a strengthening solution. Therefore, injections were used to avoid the replacement of the pavement and minimize the impacts on the warehouse's normal operation.

RÉSUMÉ: Le but du présent article est de présenter les solutions pour les principaux murs de soutènement et le renforcement de la chaussée, adoptées dans un entrepôt industriel à Quinta do Adarse, à proximité de la rive droite du Tage, à Alverca, Portugal. Le béton armé en porte-à-faux existant, qui est un mur de 300 m de longueur et 6 m de hauteur maximale, a été renforcé avec une poutre de répartition de couverture en raison d'une déformation excessive. La poutre de distribution du chapeau était soutenue par des entretoises en acier inclinées et fondée sur des micropieux. Au niveau des revêtements de l'entrepôt, certains tassements différentiels ont été mobilisés autour des fondations structurelles plus rigides, principalement en raison de l'afflux d'eau au niveau des fondations en terre de la chaussée, ce qui a nécessité une solution de renforcement. Par conséquent, des injections ont été utilisées pour éviter le remplacement du revêtement et minimiser les impacts sur le fonctionnement normal de l'entrepôt.

Keywords: Strengthening; wall; micropiles; pavement; injection.

1 INTRODUCTION

The aim of the present work is to present the adapted solutions for strengthening the retaining walls and pavements of an operating industrial warehouse, by using micropiles, cap distribution beams, and ground consolidation with polyurethane resin injection.

The reinforcement and strengthening of retaining walls and pavements at operating industrial warehouses require solutions with minimum impact on the normal operation.

Strengthening solutions with micropiles have advantages due to their diversity and execution possibilities for small spaces with difficult access, or sensitive to noise and vibrations, as well as soils with the presence of boulders, rock, concrete, and voids. The micropiles are also distinguished by the fact that they can be carried out on slopes (Barbosa, 2019).

To strengthen the pavements, a non-invasive technique may be required, with the physical-mechanical characteristics of the injected material remaining unchanged over time, so the solution of injecting expansive resin to treat the pavement foundation ground allows for a safe and practical intervention (Favaretti et al., 2014).

2 THE INDUSTRIAL WAREHOUSE

The site is a warehouse with an area of 20,250 m^2 (270 m x 75 m), built in the 1990's at Quinta do Adarse, Alverca, Portugal (Figure 1). The retaining wall is a reinforced concrete cantilever structure with 6 m of height extending over 320 m of length. The wall was designed to support the difference of approximately 4 m, existing between the lot where the warehouse is located and the adjacent areas.

The pavements with 5.0 m x 5.0 m panels were built with 0.10 m concrete industrial ground floor reinforced with steel mesh AR 30. The pavements were founded on a 0.20 m thick layer of crushed stone or aggregates fill, separated from the underlying ground, most likely pre-existing landfills by a geotextile blanket. As it was an operating industrial warehouse under operation (Figure 2a), the stresses on the pavement are related to the weight of the materials stored on shelves (Figure 2b) as well as to the traffic of loading and transport equipment (forklifts).

Figure 1. Aerial view of the site (Google Earth).

Figure 2. a) External view of the warehouse and b) Internal view of the materials stored on shelves.

3 GEOLOGICAL AND GEOTHECNICAL PROFILE

The site under study is located, from a geological point of view, over an alluvium (a) and river terrace deposits (Qf), from the Quaternary, associated with the Tagus River basin, according to Sheet 34 B - Loures of the Geological Chart of Portugal at scale 1/50.000. It is constituted of clays, silty clays, sands, and silty sands with pebbles and sometimes conglomerates with limestone elements. These formations are based on Miocene layers of sands, sandstones, mudstones, and limestones from the Tortonian (MT).

The solutions proposed are based on the results of the tests carried out in the geological-geotechnical study, and in the values presented in the reference bibliography for alluvial soft silty-clay in Portugal (Esteves, 2014).

4 PATHOLOGIES

4.1 Retaining wall pathologies

There are occasional and localized phenomena of instability in the walls leading to cracks and excessive deformation (Figure 3).

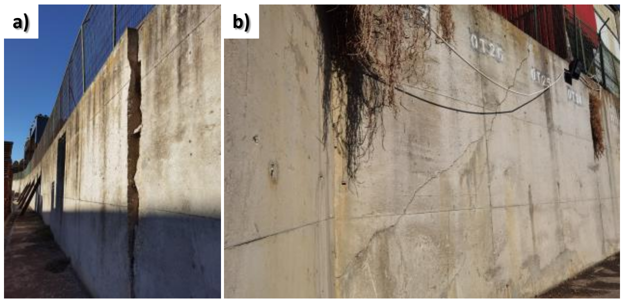

Figure 3. Pathologies at the retaining wall: a) excessive deformations b) cracks.

It should be noted the presence of four silos on the upper level, whose foundation solution was unknown. These structures may have increased ground pressure on the retaining walls. It can also be seen that, in some cases, the walls have already been reinforced in the past, with steel bracing solutions (Figure 4a) and nails or using tie rods (Figure 4b), which failed to stabilize the wall.

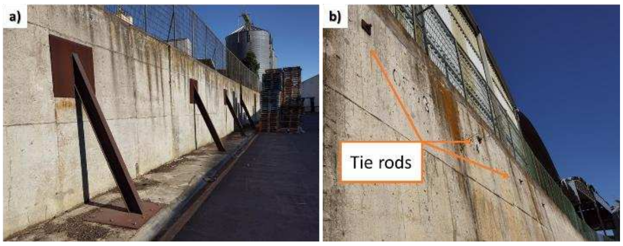

Figure 4. a) Steel bracing b) nailing or tie rods on the retaining wall.

4.2 Pavements pathologies

The loads to which the warehouse pavements are submitted are due to the weight of the materials stored on the shelves as well as the loads associated with the passage of loading and transport equipment (forklifts). It was seen that the pathologies worsened in the southern part of the warehouse indicating an increase in the pavements loads (Figure 5).

The pathologies, which required the adapted strengthening solutions, were identified in the pavements, facades, unloading dock, and stairs.

Close to the facades and columns, the presence of cracks in the concrete pavement was observed, as well as evidence of differential settlements between the pavement and the remaining structural elements (Figure 5a-b). On the walls of the east and west facades, which were built of prefabricated concrete slabs, horizontal cracks were also observed (Figure 5c).

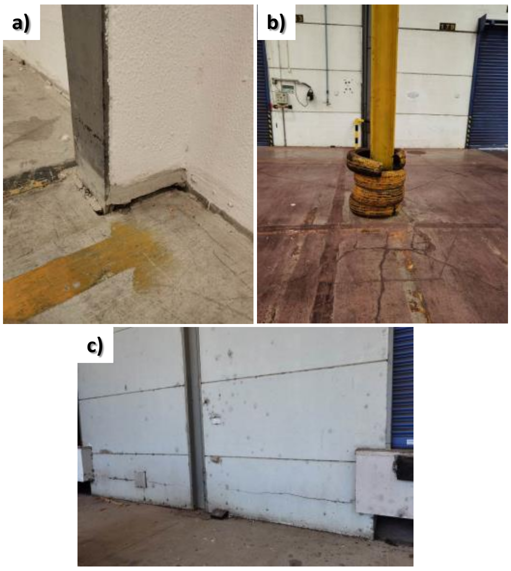

Figure 5. Main pathologies. a) differential settlements between the pavement and the facade, b) degradation of the pavement around a pile cap, c) cracking in the east side of the warehouse.

5 COMPRESSION STRENGTH TESTS ON CONCRETE

To find out the compressive strength of the existing wall concrete, six drillholes were made along the length of the wall, located at a height of 2.0 m perpendicular to the wall face. The collected specimens had a diameter of 82 mm and a length between 37.5 cm and 41.5 cm.

In general, the specimens were homogeneous, with a good distribution of limestone aggregate, but with some voids. These voids may indicate a lack of vibration during pouring.

Figure 6. Uniaxial compression-strength testing – UCS.

Uniaxial compression strength (UCS) tests were carried out on five of the collected specimens (Figure 6) to measure the mechanical resistance of the existing concrete wall. The uniaxial compression strength of the samples ranged between 16.56 MPa and 28.30 MPa.

6 STRENGTHENING SOLUTIONS

6.1 Retaining wall strengthening

The proposed solution includes the construction of a bracing element with the aim of increasing the wall resistance to horizontal pressure. This element consists of a 0.45 x 0.70 m distribution beam at the wall's mid-height, which is designed to transfer the horizontal forces to inclined micropiles, with tubular section of Ø88.9 x 12.0 mm and Ø88.9 x 9.5 mm, spaced 4.50 m, in the direction of the wall's development. The micropiles had a variable length of between 14 m and 15 m, thus guaranteeing minimum sealing lengths of 8 m and 9 m in the ground layer (natural ground with a NSPT of more than 20 blows).

To accommodate the increased vertical load caused by the axial force on the inclined micropiles, capping and distribution beams, were also built. Vertical micropiles were installed, also spaced 4.50 m. The vertical micropiles had an estimated variable length of between 11 m and 13 m, thus guaranteeing minimum sealing lengths of 6 m and 8 m in the stiffer ground layer.

The boreholes for placing the micropiles were at least Ø220 mm, and the tubes were subjected to filling and sealing injection. The injection was carried out using an appropriate system – I.R.S. (Repetitive and Selective Injection), using non-return valves and a double plug, for the length corresponding to the sealing bulb.

As the beam is supported directly on the micropiles, part of the steel tube was exposed permanently. Therefore, the micropiles were properly protected against corrosion, with a sacrificial thickness, compatible with the conditions of the environment and the life of the structure. Figure 7 shows the typical cross-section of the proposed solution.

Sub-horizontal geodrains with a diameter of Ø50 mm, creped and wrapped in 300 gr/m^2 geotextile, with a length of 3 m, were also installed, to relieve hydrostatic pressures. In addition, cracks in the existing wall were filled with non-shrinking mortar. To prevent the reoccurrence of pathologies, AISI316 stainless steel staples were also installed, spaced 0.40 m, whenever the cracks were larger than 10 mm.

Compression tests were performed in the concrete to evaluate the state of degradation of the wall. The structure was initially modelled using the GEO5 software to represent the current situation of the existing reinforced concrete wall, which only resists the static conditions, with a unitary safety factor. Subsequently, a second model was developed also considering the actions correspondent to earth pressures and surcharger to estimate the respective efforts and, therefore, to calculate the reinforcement structure in accordance with current regulations.

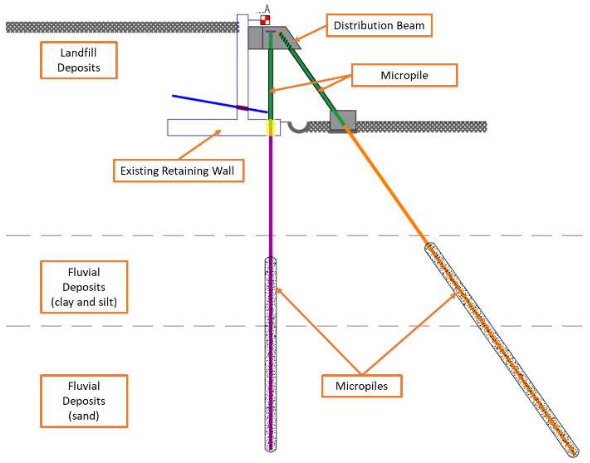

Figure 7. Cross section of the wall reinforcement solution

6.2 Pavement strengthening

The locations where internal erosion of the soil underlying the pavement was suspected a ground consolidation solution using the Uretek - Floor Lift type resin, or equivalent, was chosen. The resin has a density of 45 kg/m^3 (minimum) and expansion capacity up to 30 times its initial volume in free expansion.

This technique makes it possible to increase the compactness of the ground immediately below the pavement, without excavations, vibrations, or mechanical forces, thus minimizing the risk associated with possible damage to existing structures. The injections were made through small diameter holes, thus avoiding the need to build a new pavement structure (Uretek Floor Lift, 2023). In addition, this technology allowed to restore the pavement's planimetry and re-establish its contact with the ground (Figure 8).

In this context, the adapted solution consisted of drilling small diameter holes, arranged in a square grid of 1.20 x 1.20 m. Injection tubes were installed in these holes, approximately 6 and 12 mm in diameter. Through these tubes, a polyurethane resin was injected between the base of the industrial floor and up to approximately 1.0 m depth. In the first injection phase, the polyurethane resin, which is in liquid form, penetrates the voids in the soil and subsequently expands, sealing the surrounding soil, forming a rigid foam that increases the ground compactness. The injection process is monitored by reading equipment based on laser technology, indicating the increase in the soil's load-bearing capacity and the recovery of the differential settlements.

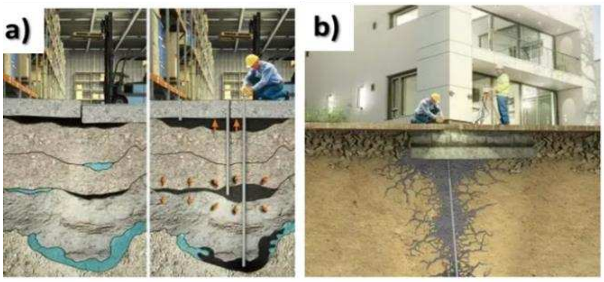

Figure 8. Injection system - Uretek Floor Lift (https://www.uretek.pt).

7 FINAL REMARKS

The aim of the present work was to present the designed solutions for strengthening main retaining walls and warehouse pavements. The strengthening solutions were defined considering the constraints, the severity of the detected pathologies and economic viability, with the aim of improving and guaranteeing the continued safe use of the warehouse area.

In the case of the retaining walls, the solution was associated to the construction of a bracing element for the existing support structure, which is a 0.45x0.70m distribution beam at the wall's mid-height, designed to transfer the horizontal forces to inclined micropiles. For the pavement, a ground consolidation solution of the Uretek - Floor Lift type was used, followed by drilling of holes in a square grid where polyurethane resin was injected.

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