Extended Abstract

Peripheral Earth Retaining Solutions and Bored Piles Foundations

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Abstract

As a result of the growth of urban underground sometimes occurred problems on buildings and nearby infrastructures. That can result in loss of functionality and therefore economic and security risks.

The objectives of this dissertation are the analysis of the site main issues, including the exhaustive monitoring of all types of works and implementation processes related to geotechnical works.

The work presented is the new headquarters of ZON Multimedia in Campo Grande, Lisbon.

Further, the aim of this dissertation was also the construction management, pointing out the functions performed by the engineer on site, and its complementarities with commissioners and subcontractors.

Also important was the analysis of the performance of the various works carried out and focused on various components of manpower, equipment and materials.

The main works carried out were peripheral earth retaining solution with resource to diaphragm wall and the indirect foundation of the building with bored piles. The excavation works were performed using the technology of ‘top down’, though there is a zone of work with resource to temporary anchors. There were also work regarding instrumentation and micro piles for foundation of a crane.

Keywords: project budget, construction management, diaphragm wall, bored piles, temporary ground anchors, instrumentation
1. INTRODUCTION AND BACKGROUND

This dissertation, called Peripheral Earth Retaining Solutions and Bored Piles Foundations - Building Metropolis - Campo Grande, Lisbon, was conducted under an internship of about four months on Mota-Engil Foundations, between July and October of last year, where the author was associated in almost all the execution of the geotechnics' works.

The great problem of these types of geotechnical works, peripheral retaining solutions in urban areas, has to do largely with the limited space available for site implementation. In this situation, the condition factor was related to the large number of adjacent infrastructures, which influenced at all, the building process adopted.

Due to the presence of an infrastructure such as the Metropolitan, the use of anchors in the large part of the work were forbidden, so the solution was using 'top down' technology.

The works carried out were diaphragm walls, bored concrete piles, temporary ground anchors, micro piles and instrumentation. This dissertation will be divided in the opening chapter with considerations of the direction of work, explaining all work processes in a bureaucratic level, the next chapter, the author present the general considerations of the work under study, with a second part with the study of the present work carried out, the details of the geological scenario, the constraints in terms of space and the solution adopted. In the subsequent chapter, we present theoretical concepts about displacements associated with excavations supported by diaphragm walls. The following chapters, all processes of implementation of geotechnical works such as the diaphragm wall, bored concrete piles, and temporary ground anchors, among others were detailed. The most part of these chapters are focused on these processes and construction techniques, the manpower, equipment and materials employed, their income, the budgeting of the work and the many details that have appeared in work. Among the objectives of this work, points to an integration into the work environment, and therefore, a more practical and intelligible knowledge.

Figure 1 – Peripheral containment plant
2. WORK MANAGEMENT
The tasks performed by the director of foundation work consisted of a large number of works:

- Check delivery notes for materials that will serve as a basis billing
- Run up balance sheets, consisting of a summary of monthly expenses sorted by material, manpower and equipment
- Control of the executed quantities, that consisted in measurements of work performed monthly, for billing purposes of the work
- Perform quality control through monitoring works on site, ensure that the materials used were tested or had their certificates on time, check that the equipment was calibrated
- Perform rebudgetisation of work, taking into account the delays / deviations occurred and planning changes in consultation with the Director of the main work, and control also the working time
- It was also responsible for monitoring the safety, make sure all collective protection equipment were available

3. ASSOCIATED DISPLACEMENTS CONCERNING DIAPHRAGM WALLS
The major objectives during the execution of the peripheral earth retaining are to ensure the stability of the support structure and the surrounding mass, preventing displacements associated with the excavation to cause damage in structures and infrastructures nearby.

The displacements of the soils are partly associated with the removal of soil and water into the shear geometry. Can also be caused by changes in ground-water table level, to the construction of the wall, in the case of diaphragm walls, numerous details should be monitored such as the density of the thixotropic mud, the difference between the level of mud and the ground-water table level, the ratio between length and thickness of the wall and the ratio between the thickness and depth of the wall.

The influence the characteristics of the ground mass cannot be ignored, such as their strength, deformability (stress-strain relations) and initial stress.

There are two components of movement associated with the excavation: below the excavation which depend on the soil properties and to a lesser extent, buried depth, stiffness and conditions of support at the foot of the wall. The displacements of above excavation rely heavily on the techniques employed and support system, and the elapsed time during critical phases of the construction process, such as the anchors put into service in a certain level of excavation.

The diaphragm walls, with about 8 meters fitting in bedrock, can in general keep the displacement below the acceptable, due to their high rigidity, good support at the foot, and with the shoring slabs carried out to ensure horizontal support, that were 2.80 meters spaced height.
4. GEOLOGY–GEOTECHNICAL SCENARIO

Based in the outcome of prospection works was carried out a geotechnical scenario of the site.

We thus defined four main geotechnical areas:

- Geotechnical Zone 4 - superficial zone, made up of landfills and alluvium, whether sandy, silty and clayey, with pebbles up to 10 cm.

- Geotechnical Zone 3 - characterized by Miocene soils in large part by silty sands, sometimes clayey. There were defined two sub-zones, the zone 3B with SPT <30 blows and zone 3A SPT between 30 to 60 blows.

- Geotechnical Zone 2 - characterized by silty clays and clayey silts. There were defined two sub-zones, the zone 2B with SPT with less than 30 blows and zone 2A with a number of SPT blows between 30 to 60 blows.

- Geotechnical Zone 1 - Represented by Miocene formations comprising mainly marly limestones and calcarenites with number of SPT blows higher than 60 blows.

Figure 2 – Execution of excavation

GEOTECHNICAL WORKS: OPERATIONAL PROCEEDINGS

Prior to the beginning of work was presented in the proposal submitted by the subcontractor to the main contractor, the average daily income expected for each type of work.

- Diaphragm wall with 60 cm thick: 80 square meters / day
- Temporary ground anchors: 70 linear meters / day
- Bored piles with 1.2 meters diameter: 35 linear meters / day
- Bored piles with 1.5 meters diameter: 30 linear meters / day
- Micro Piles: 50 linear meters / day
5. **BORED PILES**

The bored concrete piles performed in this work, with $\Phi 1.2$ and $\Phi 1.5 m$ diameter had an average length of approximately 12 meters. Prior to the start of the work the subcontractor had to provide to the inspection, the execution system and equipment proposed, and prove the ability to penetrate the pile in the bedrock stratum.

![Figure 3 - Bored concrete piles plant](image)

The most important parameters to control during the execution of the piles, in terms of materials were concrete and bentonite mud. Concerning concrete, it was required that the maximum size inert was less than 25 mm, and the cone Abrams test cone lowering was between 18 and 22 cm.

The bentonite mud newly produced, fresh, should have the following properties:

- Density between 1.00 and 1.05 g/cm$^3$
- Viscosity between 32 and 50 seconds
- Null sand content

Because the bentonite is an expensive product, the bentonite slurry was recycled, with new acceptance parameters values:

- Density less than 1.20 g/cm$^3$
- Viscosity between 35 and 90 seconds
- The sand content varies according to the strata traversed

The construction process of the piles comprises the following steps:

- Implementation
- Positioning
- Drilling
- Placement of steel reinforcement
- Installation of trémie pipes

Among the construction details stands out: execution of a reinforced concrete slab in order to position the drilling equipment, change the drilling equipment during excavation to replace the auger used in upper strata above the ground-water table level, and replace it by a bucket used
below the ground-water table level. The level of bentonite mud should be at least 2 meters above the ground-water table level, to prevent any rapid lowering of the bentonite mud, with consequences on the stability of the hole. After reaching the ground-water table level, immediately began to pump mud to the hole digging. The drilling was done according to the project in order to penetrate about 3Φ in the area of bedrock. It has great importance to clean the bottom of the hole of the pile with the bucket due to structural working of the pile by base.

In the installation of trémie pipes, during the first concreting, the pipe should be approximately positioned 20-30 cm above the bottom of the hole. It is also necessary that the bottom of the pipe is at least two meters immersed in the concrete during the following operations of concreting.

A total of 83 piles were executed, about 1800 linear meters of piles.

6. DIAPHRAGM WALLS
This technique has enabled new forms and structures - continuous walls, sealing curtains, etc. Having as precursor the industry of oil, the performance of these walls is based on trenching and is able to support the walls of a hole, as it runs at the expense of a given fluid stabilizer, such as bentonite mud previously shown in the piles chapter.

As major advantages, there is a low disturbance of the surrounding ground, its implementation, the proper sealing of the earth mass and the ability to reach great depths. Its disadvantages points to the fact that is an expensive solution, taking into account the use of bentonite mud and high need for space on site.

The walls may be shaped with three functions: foundation in order to transmit the vertical forces, support to absorb horizontal earth pressures, and waterproofing function as water barrier.

The construction process is very similar to the bored piles. The specifications of the bentonite mud are also similar. To dig the trench excavation it is used a crane with bucket jaw (grab).

Thus the construction procedure is as it follows:

- Implementation on site
- Execution of the guide walls
- Preparation and regeneration of mud
- Excavation of trenches
- Placement of the joint pipes
- Placement of reinforcement steel cage
- Concreting
The diaphragm wall had a thickness of 60 centimeters.

The guide walls performed in this work were about 1 meter in height and 0.25 meters thick. The excavation operations were quite lengthy and might take several hours using the bucket jaws, excavating averaged about 0.40 meters in each fall of the grab, performing a total of 17 meters. The considerations presented in the piles chapter within the levels of the mud inside the hole dig and trémie pipes position are the same here in the diaphragm walls.

In diaphragm walls, can be distinguish three types of panels: the startup panel, which counts with the aid of two joint pipe, to seal the concreting. Continuity panel with the aid of a pipe joint, the other adjacent panel acts as border and is already done. Finally, the closure panels without pipe joint, as the borders are the two adjacent panels.

During the execution of bored piles, it is essential to sketch concreting curves to evaluate the consumption of concrete in relation to depth of the trench, allowing in future works, with similar geology, to optimize the processes and take into account security measures.

Duration of the implementation procedures for a continuity panel

- Drilling 3:30 hours
- Placing of the joint pipe 0:10 hours
- Placement of reinforcement 0:15 hours
- Concreting 2:00 hours

There were also carried out walls, with function of foundation, rather than the primary function of support and waterproofing. The main difference, at the level of procedure in this type of wall, was the need to conduct two pre-drill hole for installation of the joint pipes, in each border. Those process took in average about 1:30 hours.

In total was executed about 4000 m$^3$ of retaining wall and approximately 500 m$^3$ of wall with foundation purpose.
7. TEMPORARY GROUND ANCHORS

Although much of the area of work was performed using top-down technology and the shoring of the containment performed with their own structure’s slabs, it was also used ground anchors. Given the absence of constraints in terms of infrastructure and the need for entry and exit zone of trucks for carrying out the excavation, in the west zone, were adopted ground anchors as a solution to provide horizontal shoring of the peripheral containment. There were performed anchors of 400, 450, 500, 550 and 750 KN, with total length variable between 13 and 15 meters. The implementation process of the anchors comprises the following steps:

- Site implementation
- Positioning
- Drilling
- Placement of anchorage
- Injection and reinjection
- Tensioning

Before drilling the anchor hole, as previous step was execute cores in the area of the anchors deployment, instead of negatives in the steel reinforcement cage, in which there could be deviations in height from the exact spot. The inclination of the anchor was obtained by a level placed on the tower of the drilling machine. The drilling was carried out with the extraction of the ground by rotation with the introduction of successive auger sections.

Before placing the ground anchor, it was necessary to wash the hole with cement grout to prevent the collapse of the hole and subsequently start the injection of the hole using cement grout with a water / cement ratio = 0.4, without pressure, filling only the hole of the anchorage.

![Drilling of the ground anchor](image)
After doing the repetitive re-injections, with the cement grout having a water / cement ratio equal to 0.25, until the pump reached 30-35 bar gauge pressure. Note that the amount of cement grout was constant in each re-injection, using about 5 cement bags, about 175 kg. The tensioning of the anchorage was carried out 7 days after the last re-injection, after performing a reception test in all anchors, with a higher load than the service load.

Duration of injection processes

• Wash / pre-sealing 0:10 hours
• Sealing/Injection 00:20 hours
• Re-injection 00:20 hours

In total were made 83 anchors totaling approximately 1200 linear meters.

There were also presented in this work, chapters regarding micro piles for establishment of a crane, and instrumentation that included load cells, inclinometers and piezometers. These chapters do not feature in this abstract.

8. CONCLUSIONS

The main goal of this dissertation was to provide practical knowledge concerning diaphragm walls, bored concrete piles and ground anchors, with special focus on design details, less learned in faculty.

This work covered all types of construction details under this type of works, situations that might arise errors and constructive pathologies, the procedures under the management of work, notions of productivity and duration of these types of geotechnical works, and also obtaining notions of cost and budgeting of these works.

Concluding, the margin for error in peripheral earth retaining solutions on urban works is very slim due to great importance of nearby infra-structures and structures, so the control of quality has to be essential, making the results accomplished of the instrumentation a good sign to certificate the options made by the design engineer. In this case, the horizontal displacements of the peripheral retaining structure and the settlements on the neighboring zones had to be minimized and these objectives were fully achieved.

9. ACKNOWLEDGMENTS

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10. REFERENCES


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