The Vista tower Buenos Aires. Case of deep and complex excavation in urban area

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Abstract. The Vista Tower is a building project under construction in the Palermo neighborhood of Buenos Aires, Argentina. It is a 36-storey tower for offices and residences, built on a structure formed by 5 underground and 2 above-ground basements, reaching a depth of 18.50m at the foundation mat. This excavation is one of the deepest and most challenging in recent years in Buenos Aires due to the few precedents of similar excavation and the many different type of limitation that it presents along its perimeter. In this paper we describe the support methods and the construction procedures employed in the excavation, along with their evolution and adjustment after field observation.

Keywords. Ground anchors, cemented loess, deep excavation, retaining wall.

1. Introduction

The Vista Tower is a building project under construction in the Palermo neighborhood of Buenos Aires, Argentina. It is a 36-storery tower for offices and residences, built on a structure composed of 5 underground and 2 above-ground levels, reaching depths of 18.50 meters at the excavation works. The project presents many different constraints all over its perimeter: the excavation is surrounded by buildings with heights ranging from 4 up to 14 storeys. The excavation is located at ten meters from the metro tunnels and the Scalabrini Ortiz metro station of the Line D of the Buenos Aires metro network. The stratigraphic geotechnical profile shows soils from the Pampeano formation which contains silts and clays with variable levels of cementation, very common all around the city. All these factors make this excavation one of the deepest and most challenging in recent years in Buenos Aires. This project is a landmark in the construction of large excavations in Buenos Aires, because it is a leading case for the enforcement of the updated code for excavations of the City (Code of building of the city of Buenos Aires; Buenos Aires Parliament. (2013), Law 4580). After approval of this law, the use of temporary anchors crossing the boundaries of the property is allowed, provided the neighbours are informed and that all safety provisions are taken. In this paper we describe the support methods and the construction procedures employed in the excavation, along with their evolution and adjustmene after field observation are presented.

2. Soils from the Pampeano formation

The building is located on top of soils of the “Pampeano” formation, that is modified Loess, overconsolidated by dessication and cemented with calcium carbonate in nodule and matrix impregnation forms, composed by multiple clay and lime alternating layers (Bolognesi A, 1975; Fidalgo F, De Francesco F and Pascual R, 1975; Núñez, E. and Micucci, C. 1986b). This type of soil is considered an excellent material for fills and slope constructions (Núñez E, 1986a).
The Pampeano characteristics are directly related to the characteristics of the constituent particles, of the transportation mechanisms, the deposition and climate changes during and after its formation. The sediment of the Pampeano plain includes eolic and pluvial depositions of limes, with important puzzolanic components involving volcanic ashes and amorphous minerals weakly crystallized and scattered by southwest winds during the end of the Tertiary and the beginning of the Quaternary geological periods. Three different strata were identified. The mechanical parameters are listed in Table 1 (Sfriso A, Sagüés P, Quaglia G, Quintela M and Ledesma O, 2008; Codevilla M y Sfriso A, 2011). Figure 1 shows two soil profiles.

Table 1. Soils parameters.

Parameters		**Upper Pampeano**	**Medium Pampeano**	**Deep Pampeano**
Unitary weight	γ [kN/m^3]	19	19	19
Cohesion	c [kPa]	20	30	40
Friction	ϕ [deg]	30	32	32
Stiffness	E [MPa]	80	150	150
Poisson ratio	ν [-]	0.20	0.20	0.20

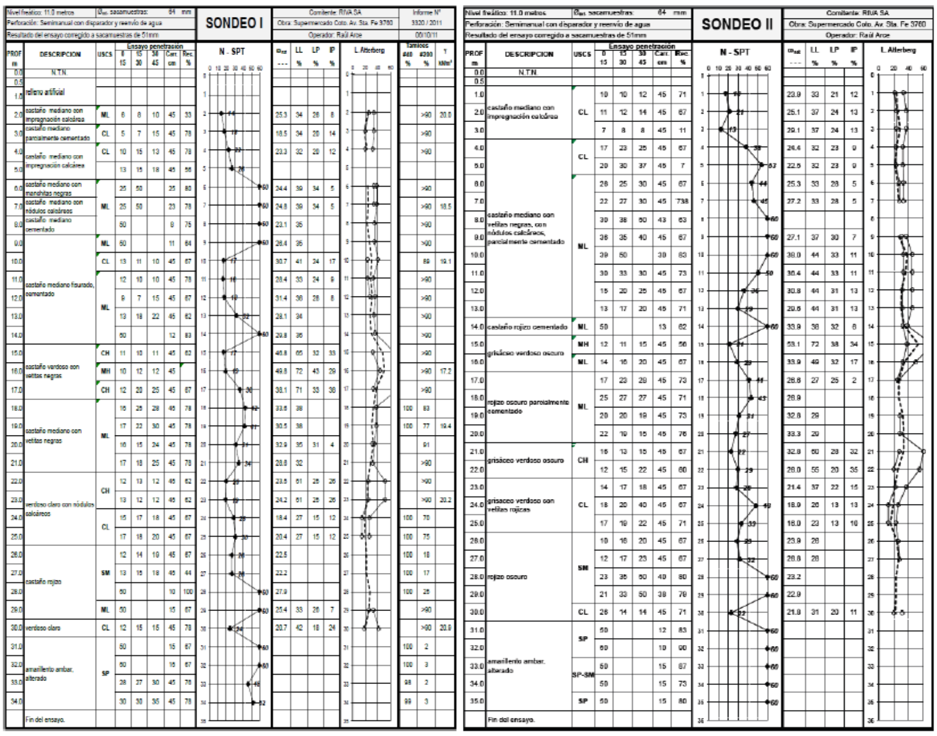


Figure 1. Two SPT tests from the building location. Typical Bs As geological profile.

3. Selection of excavation methodology

Several different excavation procedures were considered: i) bench-berm supported slopes with road-ramps; ii) anchored slopes; iii) vertical excavation with anchors (Fig. 3-1). The implementation of stabilization slopes with ramps delayed the execution of the building foundations and was discarded. Stabilized slopes with passive anchors were also discarded since they lead to unacceptable differential settlements in neighboring building foundations, reaching values of the order of 40mm.
Finally, staged vertical excavations stabilized by passive and active anchors were adopted for the interior boundaries, due to it's higher safety, smaller displacements induced in neighbor constructions and cleaner excavation sequence. Due to external interferences (subway lines, piping, etc.) on the front property line, a different methodology involving a pile-wall with active anchors was adopted. These methodologies are briefly described in the following sections.

4. Excavation methodology for street property line

The D-line subway tunnel lies parallel, 10 meters away from the excavation edge. This promotes a strong constraint for the design of the retaining structure, of the order of 18.5m high.

The adopted solution involved a pile-wall with piles 0.6m dia, 20m – 23m long, connected at their heads by a cap-beam. The pile-wall was supported by three lines of temporary active anchors with 5, 4, and 4 Grade 270 15.2mm strands, 0.15m dia borings and IRS injected bulbs. Between each group of two piles, a 10 cm thick reinforced shortcrete wall with drain holes was specified; a cast-in-place slab was used instead. Figure 2 shows a sketch of the wall.

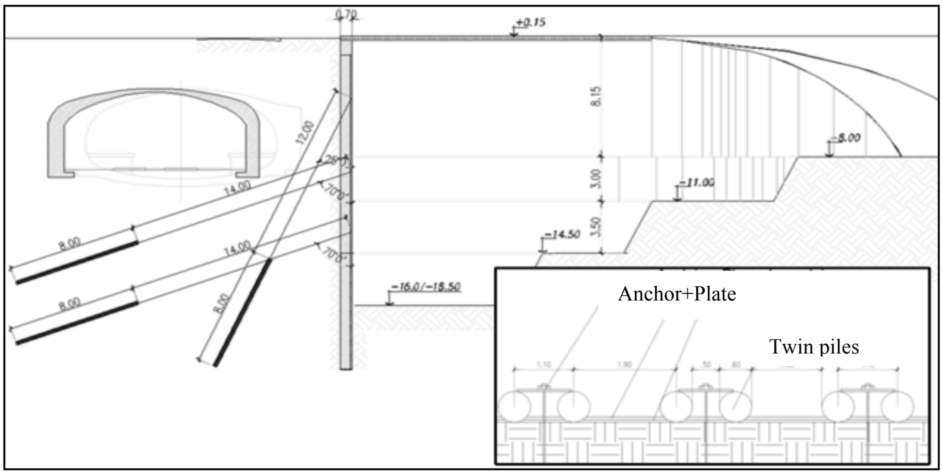


Figure 2. Solution adopted for front property line excavation.

The head of the first anchor line is located at a -4.0 m depth with a 65º inclination to avoid impacting the nearby underground cavern. The rest of the anchor lines have inclinations of 20°, heads located at -9.0m and -13.0m. The tensioning load was 750kN for the first row and 600kN for the second and third rows.

The pile wall plays two different roles: i) it balances the vertical components of the anchor loads; and ii) being a pre-installed vertical support, it effectively reduces the horizontal displacements of the excavation wall with respect to a similar design not using piles. Lateral displacement was a matter of concern for this side of the excavation due to the vicinity of the underground cavern.

The maximum displacements of the wall were 7.0 mm at the top, 1.0mm – 5.0mm along the first anchor line and down to the bottom of the excavation.

The following construction sequence was employed:

i) execution of the pile wall and cap beam

ii) excavation down to the first anchor line;

iii) installation of the first anchor line;

iv) filling of the space between piles with reinforced concrete, converting twin piles into a thick rectangular column;

v) post-tensioning of the first anchor line;

vi) process repeated in the second and third lines; and final excavation.

Figure 3 shows a pictures of the construction of the front line wall. Figure 4 shows the finished wall and starting of the construction of the foundation mat of the building.

Figure 3. Construction stages of the front property line wall.

Figure 4. Front property line wall finished and starting of construction of the building's foundation mat.

5. Excavation methodology for internal property lines

For the rest of the boundaries of the excavation, a conventional staged construction was employed using active and passive anchors and cast-in-place concrete. Shotcrete was considered for a primary support but discarded due to architectural restrictions on the total thickness of the support wall. The boundary was divided into four typical sections. For each of these sections, the number of anchor rows and type was specified according to Table 2.

Table 2. Anchors length for each sector.

Depth	17.0m	15.5m	17.5m	19.60m
	Anchor length [m] Free / fixed	Anchor length [m] Free / fixed	Anchor length [m] Free / fixed	Anchor length [m] Free / fixed
Line 1	10.0 / 9.0	10.0 / 9.0	10.0 / 9.0	12.0 / 9.0
Line 2	8.0 / 9.0	9.0 / 9.0	8.0 / 9.0	11.0 / 9.0
Line 3	7.0 / 9.0	7.0 / 9.0	7.0 / 9.0	10.0 / 9.0
Line 4	7.0 / 9.0	- / 10.0(1)	- / 5.0(1)	8.0 / 9.0
Line 5	- / 7.0(1)	-	-	- / 10.0(1)
Line 6	-	-	-	- / 10.0(1)
Line 7	-	-	-	- / 8.0(1)

References: (1) passive anchors

Adopting active anchors for the upper lines proved very efficient in reducing the lateral displacements of the neighboring structures. The separation between the anchors was between 1.5m and 2.0m, with a vertical separation of the order of 3.0m to 4.0m. Additional anchors were installed where required to improve the support of existing neighbor footings.

Anchors installed in the interior boundaries had a 15° inclination, 5 Grade 270 15.2mm strands, and a post-tensioning load of 700 kN. Passive anchors were 0.15m dia, 9.0m long and reinforced with standard construction rebars dia 25mm.

The design and construction of the anchor plates faced many challenges. It was considered against the code to install the plates beyond the property line; the perimeter wall had no thickness allowance for including the plate, and there was no time for casting prefabricated removable plates. Also, building the permanent wall and using it to support the anchor load would have required extra reinforcement of the wall. Due to all these circumstances, the anchor plates were cast-in-situ as portions of the final wall, meaning that the plates included the final reinforcement of the wall. After post-tensioning and initial settlement of the plates, a 30cm thick final supporting wall was constructed. The following construction sequence was employed:

i) excavation in limited spans down to the first anchor line;
ii) installing of the anchors;
iii) casting of the anchor plates;
iv) post-tensioning of the first row of anchors;
v) casting of the final wall;
vi) procedure repeated for the remaining spans in the same level;
vii) procedure repeated for the next levels.

Figure 5 shows the construction sequence for the anchor plate. Figure 6 shows the finished excavation of the back end of the building. On the right of Figure 6, the warehouse of the construction site is shown – wood structure, supported on long piles.

The analysis of the final design was performed using Plaxis software and conventional limit state analyses (Nuñez, E. 1972; Nuñez, E. 2000). All the construction steps were simulated for different geotechnical scenarios, load and drainage conditions. The models allowed to estimate the settlements of the neighboring structures and provided a reliable tool to demonstrate to the client and to the inspection authorities that the procedure would not involve damage to the neighbor constructions. Figure 7 shows two outputs of the numerical models of the excavations. Figure 8 shows the displacement record some selected points of two sector of the excavation. These points were located at ground level all along the property lines. This control allowed having an idea of the excavation behavior, and also permits to compare the real displacement of the structure with the model´s ones, what was useful to know the rehabilitee of the numerical models made. A global study of the displacement data recorded is necessary to achieve a displacement tendency, because the accuracy of the measurements it’s not enough to know a the exact position of the control points due to different errors that are inherent of the measurements (thermal behavior of the structure with control points and/or measurement error that has the Instrument). That is why some checkpoints seem to diminish their movements, without this being associated with any construction stage.

Figure 5. Construction sequence of the anchor plates and permanent wall.

Figure 6. Finished excavation.

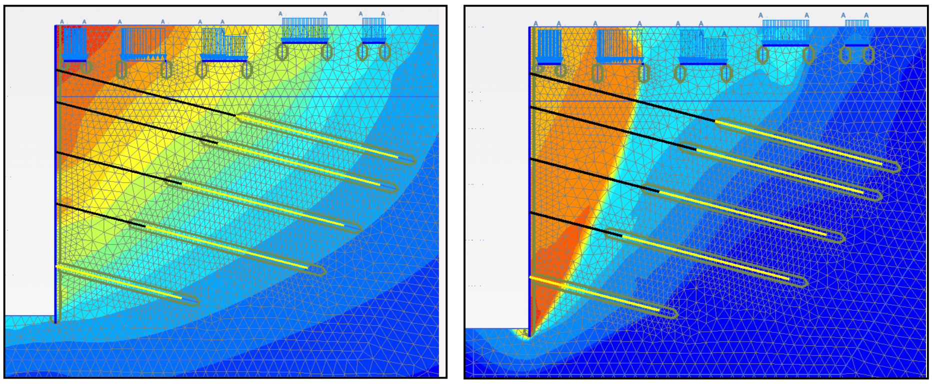
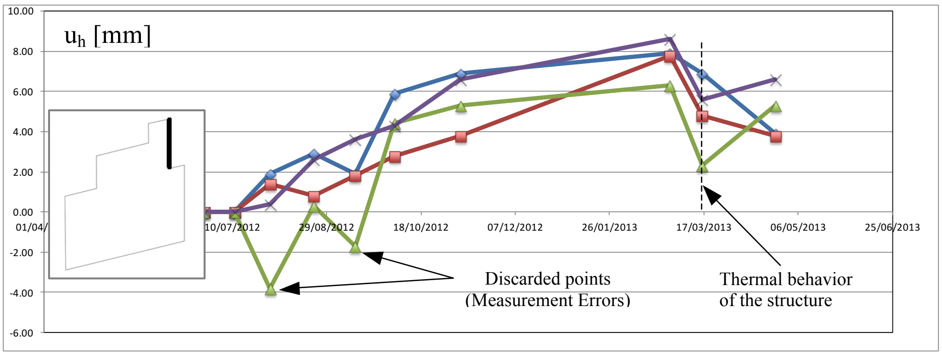


Figure 7. Left: Horizontal displacement map (max: 15mm). Right: calculation of the safety factor.



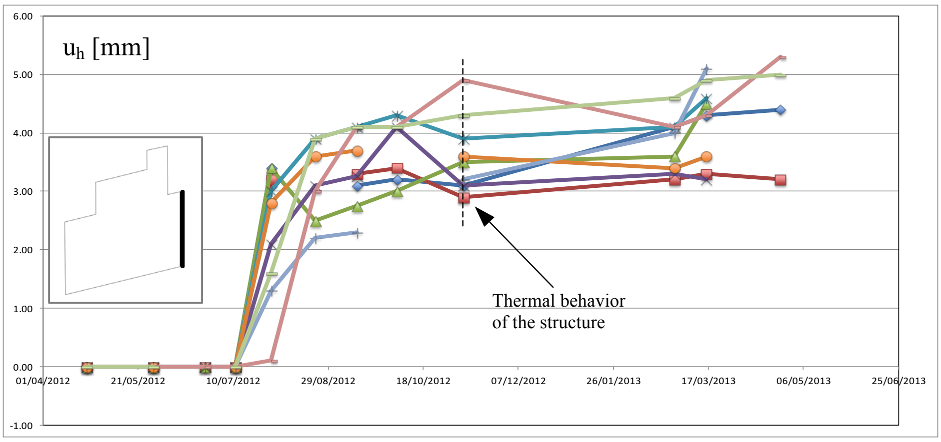


Figure 8. Horizontal displacement report for control points at some walls.

6. Conclusions

The design and construction of the excavation of the Vista Tower is presented. The excavation was 18.50m deep in a dense urban area located in the central part of Buenos Aires. A brief geotechnical setting was given and some details of the retaining wall and their supports were provided.

The tasks of design and excavation carried out in this project were conducted during the enactment of the anchor law of the Buenos Aires City, and was taken as an illustration of the need for the use of actives anchors in urban areas or where limited deformation results in a and limiting factor.

The excavation process effectively accomplished a clean working site in the scheduled time and reduced the displacements of neighbor construction to a minimum, including a large cavern located only 10m away from the front property line.

7. Acknowledgements

The authors wish to acknowledge to RIVA SA for their collaboration and permission to publish the material in this work. Sfriso particularly thanks to Prof. Eduardo Núñez for their continued advice and cooperation on issues such as the one at issue in this work.

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