Proceedings of the XVII ECSMGE-2019
Geotechnical Engineering foundation of the future
ISBN 978-9935-9436-1-3
© The authors and IGS: All rights reserved, 2019
doi: 10.32075/17ECSMGE-2019-453

XVII European Conference
ECSMGE 2019
Reykjavik
on Soil Mechanics
and Geotechnical Engineering

Deep excavation and slope stabilization in Tirana, Albania

Excavation profonde et stabilisation de la pente à Tirana, en Albanie

A. Malaj

ALTEA & Geostudio 2000, Tirana, Albania

S.Allkja, L.Harizaj, B.Xhagolli
ALTEA & Geostudio 2000, Tirana, Albania

A. Kosho

Statcraft, Tirana, Albania

ABSTRACT: This study aims to give a summary of geological and geotechnical hazards during deep excavation in Tirana, the methods of realization and elimination of risks for facilities that are adjacent to the new construction. The main issues of the paper are: Geotechnical study for characterization of the construction site, combining the field tests and laboratory testing; Determination of shear strength parameters (φ & C) and water pressure; Prediction of effective and economic engineering measures; Protection of the slopes of deep excavations; Monitoring the stability of the slopes of deep excavation; The correction of calculation errors and engineering measures and their improvement during construction.
This study also provides new techniques that are used for geotechnical studies in Tirana, modern monitoring equipment that are used in several buildings during deep excavation.
The optimal solutions require not only time and know-how but also a faithful partnership between all parties and specialists.

RÉSUMÉ: Cette étude vise à résumer les risques géologiques et géotechniques lors des fouilles profondes à Tirana, les méthodes de réalisation et d'élimination des risques pour les installations adjacentes à la nouvelle construction. Les principaux thèmes abordés dans cet article sont les suivants: Étude géotechnique pour la caractérisation du site de construction, combinant les essais sur le terrain et les essais en laboratoire; Détermination des paramètres de résistance au cisaillement (φ & C) et de la pression de l'eau; Prévision de mesures d'ingénierie efficaces et économiques; Protection des pentes des excavations profondes; Surveiller la stabilité des pentes d'excavation profonde; La correction des erreurs de calcul et des mesures d'ingénierie et leur amélioration pendant la construction.
Cette étude fournit également de nouvelles techniques utilisées pour les études géotechniques à Tirana, des équipements de surveillance modernes utilisés dans plusieurs bâtiments lors de fouilles profondes.
Les solutions optimales nécessitent non seulement du temps et du connaissance, mais également un partenariat fidèle entre toutes les parties et les spécialistes.

Keywords: Geotechnical investigation; deep excavation; slopes stability calculation; monitoring and back analysis.

1 INTRODUCTION

Deep excavation technology is a growing area used in construction of underground tunnels, under passes & crossings and other infrastructure development. It enables real estate developers to effectively utilize the land area by building multi-level basement buildings, parkings, commercial centers etc...

There has been a significant increase in the infrastructure development in general in Albania and particularly in Tirana. This has led to a widespread concern on risks associated with these types of construction.

The construction development in Albania according to the excavation surface and their slopes protection, can be divided in 3 main periods:

The construction period before World War II, where objects of 1-2 storeys high with 1-underground floor have been constructed. The protection of the excavated slope did not require sophisticated engineering means, however these constructions resisted the time.

The construction period from 1945-1990. In this period most of the built objects were 5-6 storeys high with 1-floor underground. These type of constructions did not require significal engineering measures for the protection of the foundation hole, mostly wooden or steel sheet piles were used during this period.

The period after the 1990s until nowadays. This is the period when we talk about a significant urban development. A lot of high rise buildings with many floors underground were built.

Due to lack of the experience in these kind of constructions, during their realization throughout the years, many landslides, slope failures, pile destructions have accured. In many cases the adjacent facilities to the new construction site have been in danger.

Our company has studied the geological and geotechnical conditions of many objects built during this period of time, but at this article we are going to analyze only the conditions of a 24-floor high rise building with 6 underground floors, in Tirana.

In the pictures below is presented a typical case of slope failure during construction history and another case of effective use of secant pile walls.



Figure 1. A case of slope failure



Figure 2. The use of secant pile walls

2 GEOLOGICAL AND GEOMORPHOLOGICAL SITE CHARACTERIZATION

The construction study site is located in the center of Tirana city. It has a flat relief and represents the terrace of the streams of Tirana and Lana.

In the field of Tirana there are present alluvial unconsolidated up to consolidated deposits, which contain organic matter. Underneath these deposits there are met the Neogene‘s rocks represented by mudstone and sandstone deposits. (ALTEA & Geostudio 2000)

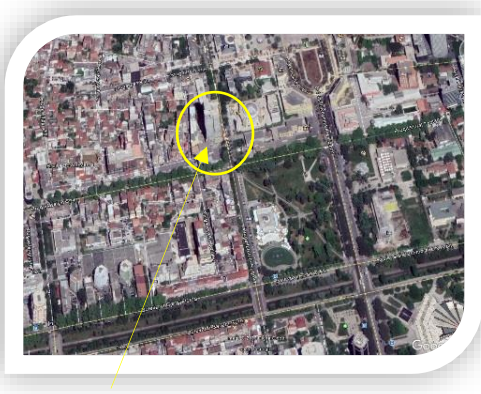


Figure 3. Location of the site under study

2.1 Physical, geological and geodynamic features

To identify the geological and geomorphological features of the construction site many existing studies for Tirana city were analyzed and taken into consideration. (ALTEA & Geostudio 2000)

The most remarkable geological and geodynamic features identified in the area were erosion, weathering and the phenomen of consolidation of the alluvium deposits.

2.2 Geotechnical site characterisation

The aim of field and laboratory works was to determine the geotechnical characteristics of the layers encountered at the construction site. On this purpose, 4-boreholes with 30m depth were executed, 65-SPT testings, 12-permeability testings and laboratory testings. The water table measured from piezometers showed a stabilised depth of (-7.5)*m* below ground surface.

This means high hydrostatic pressure to the excavation depth.

Below it‘s presented the typical lithological profile of the encountered deposits in the study site. (ALTEA & Geostudio 2000, 2008)

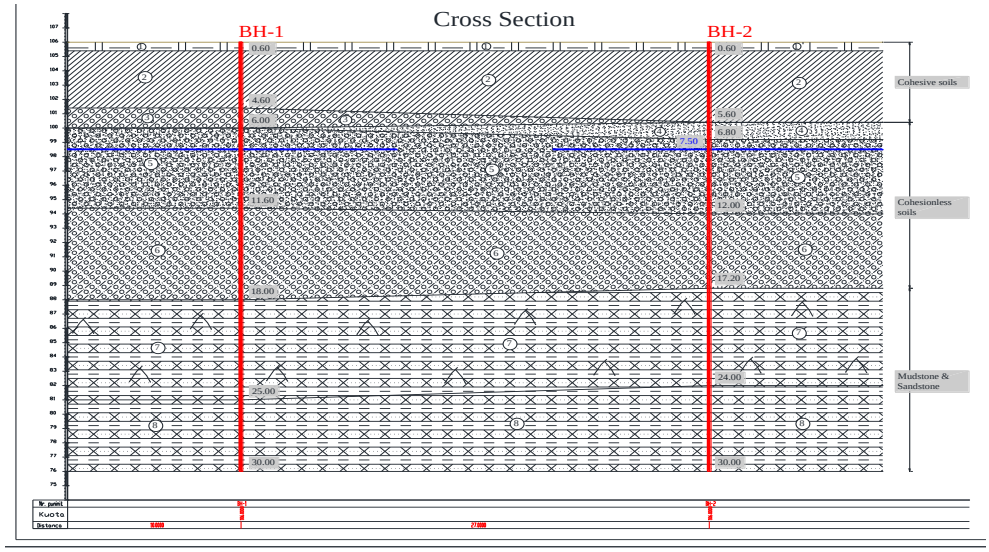


Figure 4. Cross section at study

2.2.1 Results of in-situ and laboratory study

Evaluated layer properties (ALTEA & Geostudio 2000, 2008)

DATA		Physical characteristics										Mechanical Characteristics						
								Grading By Hydrometer				Oedometer		Direct shear		Triaxial	SPT	UCS
Layer number	Layer description	Moisture content	Liquid Limit	Plastic Limit	Plastic Index	Specific gravity	Bulk density	Clay	Silt	Sand	Gravel	Void ratio	Oedometer Modulus	Friction Angle	Cohesion	Cohesion UU	No. of SPT	Uncont.Comp. pressure str.of Rock
		Wo	L.L	P.L	I.P	Gs	γ_n	<0.005	0.005 - 0.075	<4.75	>4.75	$e_{0.}$ init	Eo	ø'	C'	UU	no.	UCS
		%				gr/cm^3	gr/cm^3	%	%	%	%	-	MPa	(°)	kPa	kPa	blows no.	Mpa
Layer no.2 & 3	Firm, clayey SILT, containing fine Gravel and beds of silty Sand	26.85	43.03	26.10	16.91	2.610	1.970	28.30	32.00	21.80	16.70	0.720	8.00	19.00	22.00	34.00	22-24	
Layer no.4, 5 & 6	Medium dense to dense, sandy GRAVEL	11.54	27.57	18.44	9.14	2.630	2.090	8.00	10.00	28.00	54.00	0.580	36.00	38.00	8.00	_	34-36	
Layer no.7 & 8	Weak, weathered Sandstone & Mudstone	17.23	_	_	_	2.670	2.170	_	_	_	_	0.280	118	29.00	56.00	_	>50	3.00

Figure 5. Physical and mechanical properties of the layers present in the construction

3 RISK EVALUATION

Based on the geological situation and the collected geotechnical data, we concluded that at the construction site were present cohesive soils from ground surface to the depth of 7-8*m*.

While from 8*m* until 18*m*, were encountered cohesionless layers, represented by sand and gravel deposits. (ALTEA & Geostudio 2000, 2008)

Considering these conditions; the depth of the excavation hole that went up to 20*m* and the level of underground water too near with the ground surface; we might say that the risk of having a slope failure was very high.

The objects near to the excavated hole were aslo in danger, so the design team had to be very cautious not to neglet a single factor affecting the overall stability.

To prevent slope failure and the adjacent buildings two methods of protection were discussed.

The first was to use diaphragm walls, but this was not applied because that would cause substantial deformations to the adjacent buildings, due to the presence of cohesionless layers. The other way was a new construction technique, never tried before in Albania, the use of secant pile walls.

It was decided to go with the second method. The length of the piles was 30*m*.

3.1 Secant pile wall construction

Secant pile wall was made by the sequenced drilling and concreting of overlapping vertical elements. Primary piles were spaced at slightly less than their nominal diameter. Intermediate secondary piles were then realized, such way that they cut into and interlock with adjacent piles, forming a continuous cut-off structure.

The cut-off wall also provided ground support. The secondary piles were reinforced piles with reinforcing cages.

During wall construction, concrete and steel samples were constantly sent in the laboratory premises to test and evaluate thier quality.

The protection of the faces of the excavated slope from inside was ensured using steel struts.

During this construction phase were also installed inclinometers.

To keep records on the strains of the struts inside the excavated slope, there were installed extensiometers strain gauges.

There were also placed tiltmeters, to control the vertical deviation of the adjacent buildings.

The design team was provided with real time digital data.

There were also foreseen outlets to take the accumulated water away from the excavated space.

The measurements continued until the building reached the ground level.

During this phase a monitoring program has been ellaborated and executed.

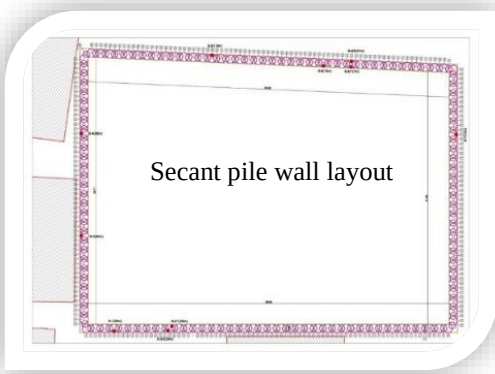


Figure 6. General layout of the secant pile wall

4 CONSTRUCTION OF THE UNDERGROUND FLOORS

The excavation of the underground floor was made using an excavator, JCB type.

Primarily, it was excavated the first floor, steel struts were monted so they could brace opposite sides of the excavation against each other, and propping each other up.

At the same manner it was proceeded for the other 5-floors, as shown at the figure below.

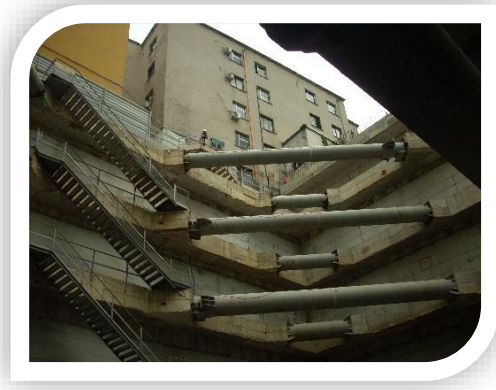


Figure 7. During construction of the underground floors

During the piling construction phase, inclinometers have been installed.

Inclinometer reading was done manually, but from all the other equipments digital measurements data were provided. (ALTEA & Geostudio 2000, 2008)

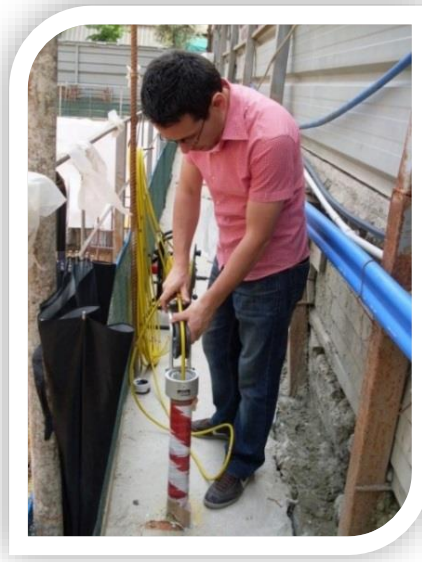


Figure 8. Inclinometer installation around the excavated area

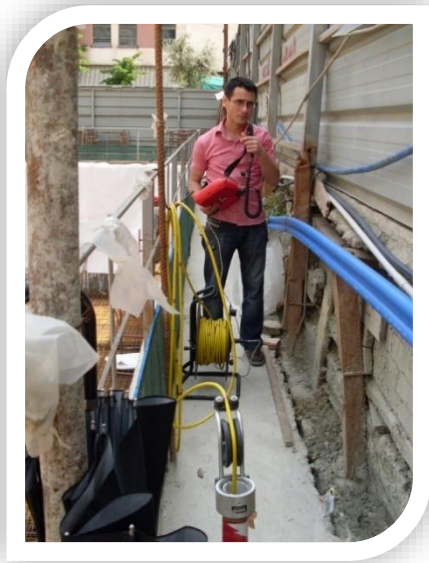


Figure 9. Inclinometer readings

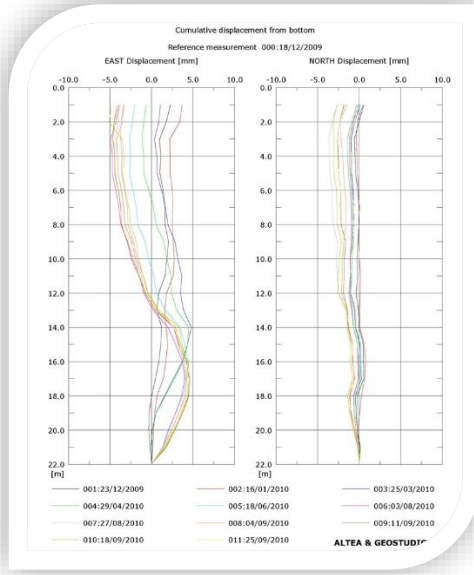


Figure 10. Inclinometer measuring results on different periods during construction

After reaching the bottom level of the excavation and before starting to build the foundation slab, two additional borings with 35m depth were performed.

There were also taken samples to evaluate the properties of the ground after the removal of the soil and rock layers from site. (ALTEA & Geostudio 2000, 2008)

The calculation design of the foundation of this building was made after reflecting these newely collected data.



Figure 11. Extensometers strain gauge

5 MONITORING OF THE EXCAVATION SLOPE AND BACK ANALYSIS

During construction of the underground floors the monitoring process has been continuous.

For each deviation exceeding the allowable calculated values, additional engineering measures were taken and back analysis were made. (SISGEO, 2000)



Figure 12. Drilling process at the bottom level of the excavation

The monitoring process still goes on in nowadays.

The taken engineering measures, resulted effective because it was ensured the slope stability and none of the adjacent objects were damaged.

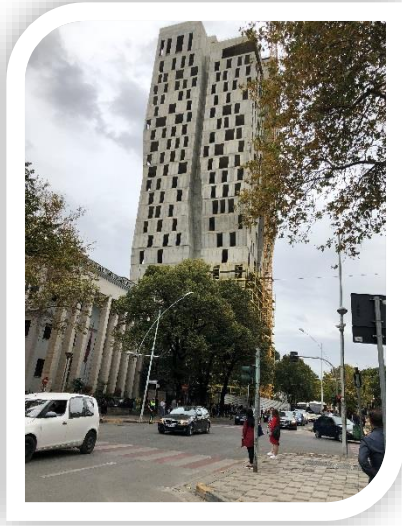


Figure 13. View of the building in nowadays

6 CONCLUSIONS

Underground works in urban areas consist of many dangers, they can be avoided with the cooperation of geologists, designing team and investors.

Geological and geotechnical evaluation in this study is done according to Eurocode 7 or ASTM normatives.

Geological drillings must be done respecting the technical conditions.

Field tests should be performed according to the geological situation.

Laboratory analyzes for soil characterization should be compared with the ones evaluated in field.

Piezometers should be installed to measure and assess the underground water levels and pressure.

The used construction materials also must be tested.

Monitoring of the excavated slope and the surrounding buildings should be made.

Based on the received information proper adjustments on the engineering measures tending to stabilize the excavated surface must be reflected in the calculation model.

The optimal solution requires not only time, money and knowledge but also a faithful partnership between all involved group of specialists.

7 ACKNOWLEDGEMENTS

The work presented here represents a collaborative effort between the authors and numerous colleagues from “A.L.T.E.A & Geostudio 2000” Company and a close collaboration with SISGEO company for the monitoring program realization.

8 REFERENCES

Geology and Geodesy enterprise, 1950-1990. Geological and engineering survey of Tirana city: Albania

A.L.T.E.A & Geostudio 2000, 2008. Geological and Geotechnical study report of a 24-floors building with 6 floors parking underground. Tirana: Albania

ASTM standarts. 2003

AASHTOO standarts. 2006

Chang-Yu, Ou (ed.) 2009. Deep Excavation: Theory and Practice. London: Taylor & Francis Ltd.

Look, B. Handbook of geotechnical investigation and design tables 2006. London: Taylor & Francis Ltd.

Tomlison, M.J. Foundation desing and construction (ed.4). London: E& FN Spon.