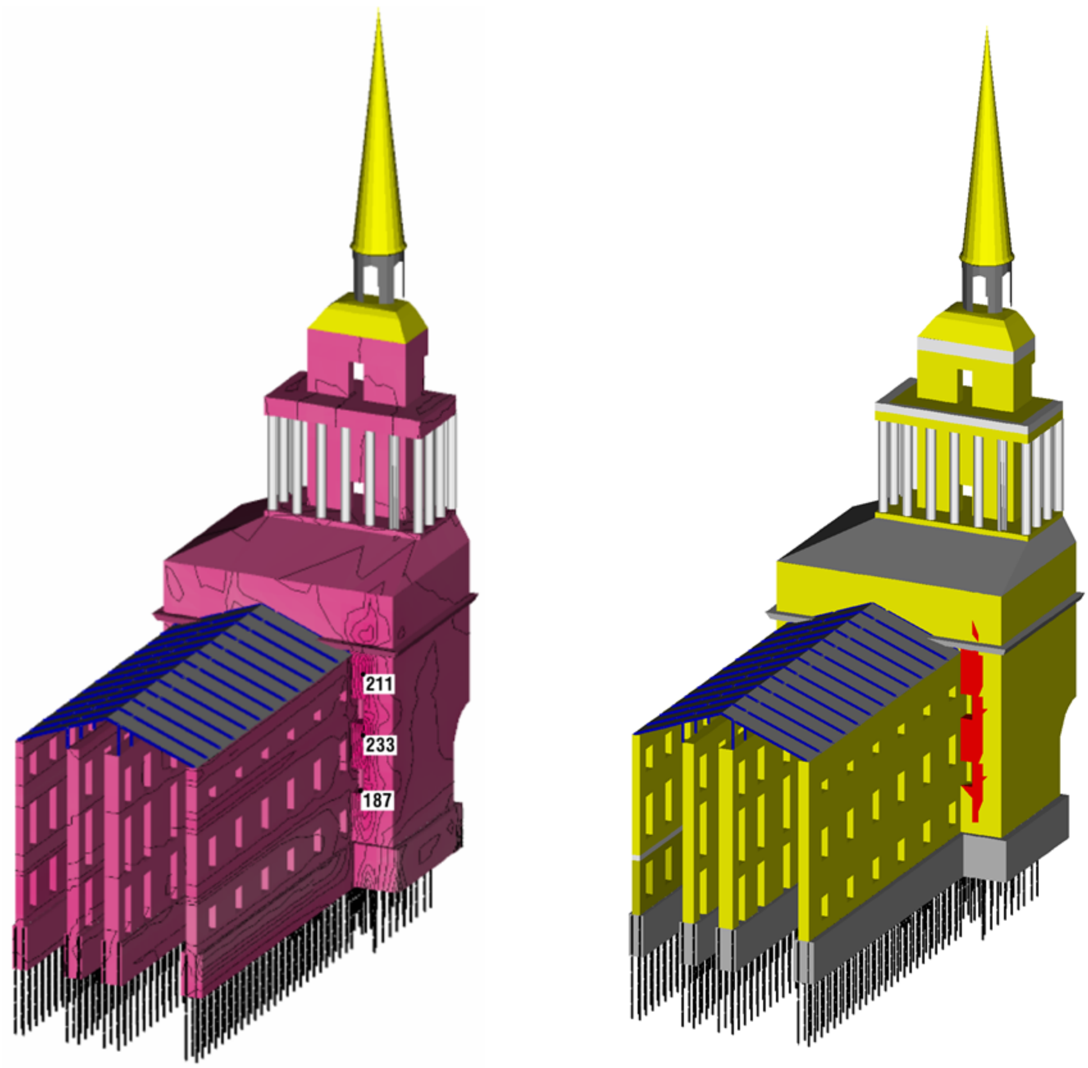
PROCEEDINGS OF TWO SEMINARS OF TC207 ISSMGE in 2015

SOIL-STRUCTURE INTERACTION AND RETAINING WALLS



PILOTES TERRATEST

2016

SEMINARS ON SOIL-STRUCTURE INTERACTION AND RETAINING WALLS

13 September 2015, Edinburgh – Scotland

16 December 2015, Pune – India

Edited by:

Michael Lisyuk
Vladimir Ulitsky
Deepankar Choudhury

2016

Proceedings of two Seminars of TC207 ISSMGE in Edinburgh and Pune in 2015.

The responsibility for content and editing is placed upon the authors of the papers of this volume.

Published by: Georeconstruction Engineering Co.
190005 Russia, Izmaylovsky prospect 4
georeconstruction.com

ISBN 978-5-9906877-0-7

PREFACE

This proceeding volume contains technical papers submitted to two Workshops of ISSMGE Technical Committee TC 207 on Soil-Structure Interaction and Retaining Walls, which were held in 2015:

– Seminar on Soil-Structure Interaction and Retaining Walls at Edinburgh, Scotland, in collaboration with TC305 on Megacities, 13 September 2015, and

– Seminar on Soil-Structure Interaction and Retaining Walls at Pune, India, 16 December 2015, in collaboration with TC212 on Deep foundations.

Both Seminars dealt with the different aspects of interaction of structures with the ground.

Numerical calculations of buildings and structures in the framework of soil-structure interaction do not pertain only to the domain of design of unique and technically sophisticated or hazardous buildings and structures any more. They become actively involved in everyday design practice which, as a rule, includes geotechnical investigations. For example recently adopted Russian Federal Law No 384-93 regarding safety of buildings and structures has complicated the tasks associated with numerical modeling, as it requires account of "plastic and rheological properties of soils and construction materials".

The existing modern software complexes making numerical calculations do not always consider these particularities. Moreover, commercial software largely used in the global practice of construction design not always can confirm data obtained at real sites concerning actual strain-stress behaviour of buildings and structures. In a number of cases, software becomes a "black box", whereas a geotechnical engineer involved in calculations is not able to be an active participant of simulation. Application of soil models which are not tested and adapted to geotechnical conditions of a certain area is a factor of excessive risk for high-level responsibility of structures.

As regards new projects and preservation of the unique objects where there are actual data on differential settlements of their parts, good software for numerical simulation should at least predict these deformations. As for damaged buildings requiring reconstruction, such software should take into account actual strain-stress state at the moment of planned reconstruction.

In order to overcome these considerable shortcomings, authors from different countries have been developing and applying models of soil behavior which allows describing nonlinear soil deformation in time.

These models must be scrupulously verified in dozens of sites subjected to instrumented monitoring.

The proceedings of the two workshops include contributions of 36 authors from 11 countries. We hope that the proceedings will be useful for experts in the field soil-structure interaction and retaining structures.

Michael Lisyuk	Vladimir Ulitsky	Deepankar Choudhury
Chair of TC207	Past Chair of TC207	Secretary of TC207

St. Petersburg – Mumbai
27 April, 2016

MEMBERS OF TECHNICAL COMMITTEE 207
"SOIL-STRUCTURE INTERACTION AND RETAINING WALLS"
ISSMGE

Michael Lisyuk, Chairman, *Russia*
Vladimir Ulitsky, Past Chairman, *Russia*

Deepankar Choudhury, Secretary, *India*

William Van Impe, *Belgium*
Konstantin Shashkin, *Russia*
Chris Haberfield, *Australia*
Yasser El-Mossallamy, *Egypt*
Rolf Katzenbach, *Germany*
Hugh St. John, *UK*
Rich Finno, *USA*
Fang Liu, *China*
J. Kos, *Czech & Slovak Republics*
Kari Avellan, *Finland*
Catherine Jacquard, *France*
Olivier PAL, *France*
James Sze, *Hong Kong*
Venkataram Balakumar, *India*
G. Madhavi Latha, *India*
N.K. Samadhiya, *India*
Omar al-Farouk Salem al-Damluji, *Iraq*
H. Hazarika, *Japan*
Ohsumi Tsuneo, *Japan*
Mandy Korff, *Netherlands*
G. Horodecki, *Poland*
Florian Roman, *Romania*
Z.G. Ter-Martirosyan, *Russia*
Victor CW Ong, *Singapore*
A.R. Walker, *Singapore*
Paul Morrison, *UK*
Igor Sokolić, *Croatia*
Juan Manuel Fernández Vincent, *Argentina*
Omer Bilgin, *USA*
Jan Couck, *Belgium*
Claudio di Prisco, *Italy*
Guido Gottardi, *Italy*
Amir M. Kaynia, *Norway*
Balazs Moczar, *Hungary*
Javier Moreno, *Spain*
Pantelis Pantelidis, *Greece*
Lars Vollmert, *Germany*
Werner Bilfinger, *Brazil*
Arnoldas Norkus, *Lithuania*
Gökhan Baykal, *Turkey*
Talal Awwad, *Syria*

Askar Zhussupbekov, *Kazakhstan*
Doda Enver, *Albania*
Yuan Huina, *China*
Horatiu Popa, *Romania*
Castorina Silva Vieira, *Portugal*
Mehmet Berilgen, *Turkey*
Deniz Ulgen, *Turkey*
Alexandra Ene, *Romania*
Nuno Guerra, *Portugal*

CORRESPONDING Members

Lei Lou, *USA*
Kiyota Takashi, *Japan*
Atsuko Sato, *Japan*
Khoa Van Nguyen, *France*
Hamza Gullu, *Turkey*
Onder Akcakal, *Turkey*
Müge İnanir, *Turkey*
Ozgur Bezgin, *Turkey*
Mete Erdemgil, *Turkey*

Webmaster

Eugene Dubinin, *Russia*

FRIENDS of TC207

Regina Dashko, *Russia*
Anna Shidlovskaya, *Russia*

TABLE OF CONTENTS

Monitored deep excavation in the Ripio de Santiago de Chile

Juan Manuel Fernandez Vincent
Regional Technical Manager, Pilotes Terratest S.A., Chile

Freddy Lopez Loayza
Project Engineer, Pilotes Terratest S.A., Chile

Sergio Diaz Casado
Project Engineer, Pilotes Terratest S.A., Chile

Abstract: The typical retaining wall system used to execute the excavations carried out in Santiago corresponds to a discontinuous wall consisting on reinforced concrete piles, laterally braced with ground anchors.This paper presents a traditional contiguous wall system designed for a 21m deep excavation in the "Ripio de Santiago", and presents the results of the geotechnical monitoring carried out in the construction site for a typical section, consisting on inclinometer and anchor load measurements.

Keywords. Deep excavations, Ripio deSantiago, ground anchors, monitoring

1. INTRODUCTION

The city of Santiago de Chile, the country's capital with more than six million inhabitants, has been developing its buildings and underground spaces, changing the standard excavation in the year 2000 from 10-15m up to 20-30meters nowadays. Ground anchors took a big part as a technological tool to aid in that task, being introduced in the building industry in 1996 by this company. The accumulated expertise gained over the years and improved knowledge of the performance of the deep excavations of the time, was also fundamental.

The typical retaining wall system used to execute the excavations carried out in Santiago corresponds to a discontinuous wall consisting on reinforced concrete piles, laterally braced with ground anchors. The piles can be dug manually (usually in a rectangular shape), or drilled by a rig. The square piles initially were of one meter side and its separation was about 2,0-2,2m. Then the section turned rectangular and more efficient and with separations of 3,0-3,5m with up to 5,0m recorded.

2. GEOLOGICAL CONDITIONS

Santiago lies in the central part of an 80-km-long and 30-km-wide basin, a large bowl-shaped valley at the northern end of the central depression of Chile, which was caused by tectonic movements in the Tertiary of an area between two major faults parallel to two mountain chains running north-south. Volcanic activity dated between the upper Oligocene and lower Miocene is believed to have formed the basement of the Santiago basin. The basin itself is covered by sediments, most of which have been transported from the Andes mountains by a branched river system (Valenzuela 1978). The thickness of the sedimentary cover varies over short scales and can exceed more than 550 m. The sediments are mainly composed of gravel, sand and clay. Some deposits are believed to result from volcanic mud flows or glaciers.

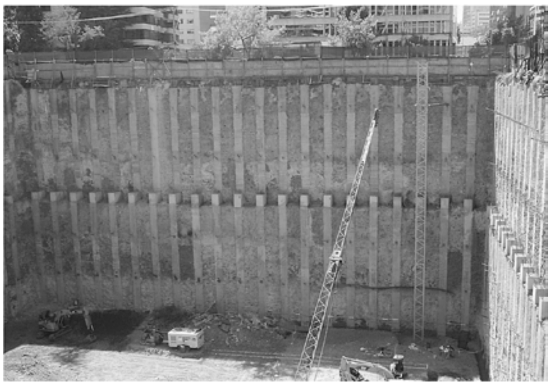


Figure 1. Deep excavation of 33 meters

3. GEOTECHNICAL CONDITIONS

The Santiago gravel is a Quaternary fluvial-glacial deposit, associated to the main drainage systems existing in the area: the Mapocho and the Maipo Rivers. The so called "Ripio de Santiago" presents excellent geomechanical characteristics.

From the surface down to a depth of 5–7 m, the gravel contains low-plasticity silty fines, with a cohesion of about 20kPa, and an angle of internal friction as high as 45º. This upper gravelly layer is known as the Second Deposition of the Mapocho River. This stratum is underlaid by the First Deposition of the Mapocho River. The first deposition is denser than the second one, but it has a similar granulometry. The following parameters for this deposition are commonly accepted: γ = 22,5kN/m3; c´= 20 – 37kPa; φ´=45°; E´=200-250 MPa.

Hydrological conditions are also favourable and the ground water level is at a depth of 70-80m below ground surface. The occurrence of water infiltration is associated to existing water bearing layers, leaking tubes and surface water percolating through the permeable gravel layers.

Figure 2. Deep excavation of 26,5m.

4. DESIGN ISSUES

The norm NCh3206.Of2010 defines the requirements that an excavation have to deal with. Usually, the key issue for the design of a deep excavation is its deformation. Often this is done by modelling the excavation and its construction phases, defining the most suitable earth pressure redistribution diagrams (i.e. after the EAB 2012 or own experience), and increased earth pressure coefficients, where applicable. Also, as a highly active tectonic region, the seismic verification plays an important role in the design and it is approached with a pseudo-static analysis, such as the proposed by Kuntsche (EAU 1990) or Mononobe-Okabe.

A basic acceleration of Ao=0,30g applies to this site (Zone II, after NCh433.Of2009). For temporary works, it can be reduced in function of the level of expected post-seismic plastic deformation (in function of characteristic of neighbour structure to protect or level of risk to assume). For a very stiff soil as the "Ripio de Santiago", usually a reduction factor of 0,50 applies to streets and 0,60 to neighbour structures.

The ground anchors length is dealt either by the simplified method of the seismic wedge analysis or by the Ranke-Ostermeyer deep seated stability analysis.

5. MONITORING PARQUE ORIENTE

Pilotes Terratest decided to monitor one of its projects in which its own Engineering design was to be executed in the Parque Oriente Building. Bored cased piles were executed in order to guarantee a minimum deviation of the wall due to the big boulders usually present.

Figure 3. Bored cased piles being executed

The typical section was 21,2m depth, and the monitored one was on the vicinity of the avenue Alonso de Cordova. An inclinometer casing was disposed in one pile attached to the reinforcement cage in its full length, and the two rows of ground anchors were instrumented with load cells when the sequence of construction applied. The inclinometer restriction in depth probed, after numerical analysis, not to influence more than 1mm the final stage readings because of the soil great rigidity.

Piles of 880 mm diameter were arranged every 3,20 m. In the monitored section, the first row of ground anchors was placed at 4,50 m depth and the second one at 13,0 m depth. The service loads of each anchor were 880 kN (275 kN/m) and 1245 kN (389kN/m) for the first and second row respectively.

Figure 4. Installation of the pile reinforcement cage with the inclinometer tube attached

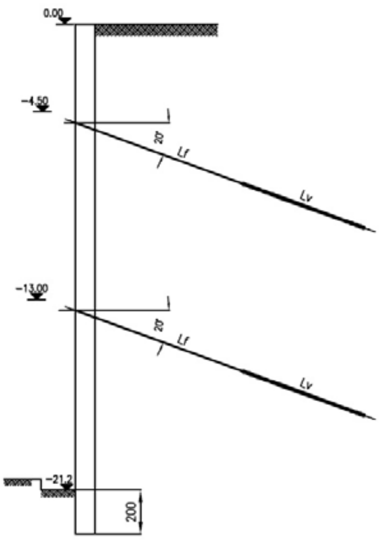


Figure 5. Cross section of the anchored pile wall.

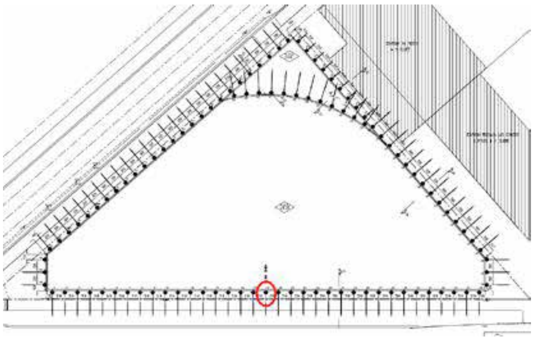


Figure 6. Excavation layout and monitored pile.

5.1. Construction sequence

The first excavation stage was carried to 5,50 m depth where the first row anchors were executed.

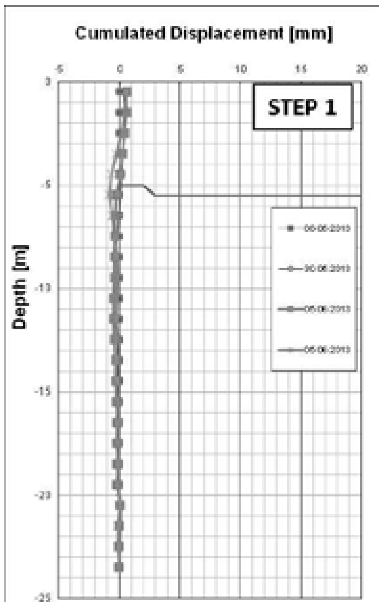


Figure 7. Horizontal deformations of stage 1.

The horizontal deformation of the pile in a cantilever behavior was of 1,3mm, and also was measured just before and after the anchor was tensioned and the wall moved 0,75mm backwards, and in the second row it was 0,45mm.

The second excavation stage was carried to 13,50 m depth where the second row anchors where executed. The excavation continued to 15,50 m depth before tensioning the anchor. A berm was left in front of the piles to allow the tensioning works.

The third excavation stage was carried to the maximum excavation depth. A maximum horizontal deformation of 15mm was measured at maximum excavation depth.

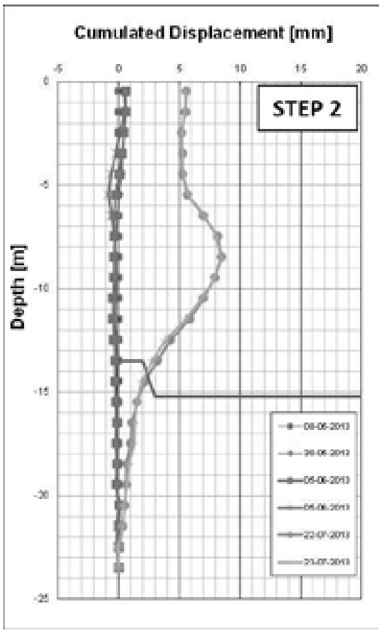


Figure 8. Horizontal deformations of stage 2.

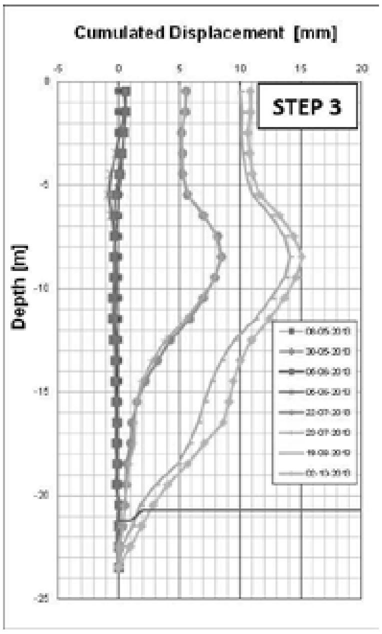


Figure 9. Horizontal deformations of stage 3.

The anchors loads were also measured at the mentioned stages. The anchor load variation behaviour was coherent with the expected very low creep value (ks) of the set soil-grout-steel and the measured deformation of the pile wall, related to its free length (specific deformation)

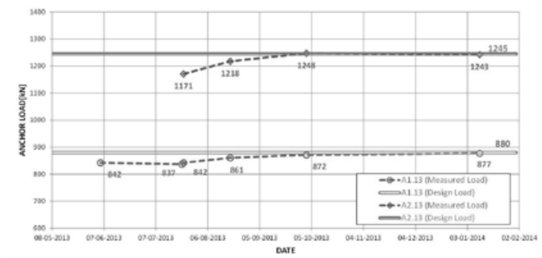


Figure 10. Ground anchor loads measured.

6. CONCLUSIONS

The monitoring of the jobsite verified the expected deformation perfomance of the wall and ground anchors behavior, and it helps the development of a robust expertise to safely approach deeper excavations in the future in order to provide the solutions that society demands from the a specialist geotechnical contractor.

7. REFERENCES

Boldrini, S. & Lopez, F. 2014.Design and Instrumentation of an Excavation with a contiguous pile Wall in the Santiago Gravel. *Proceedings of the VIII Chilean Geotechnical Engineering Congress*.

German Geotechnical Society 2012.Recommendations on Excavations (EAB 2012). 2nd Edition Berlin: Ernst &Sohn

German Geotechnical Society 1990.Recommendations of the Working Committee for Waterfront Structures (EAU1990). 8th Edition Berlin: Ernst &Sohn

INN-Chile 2010. NCh3206.Of2010 Geotecnia – Excavaciones, entibaciones y socalzados – Requisitos. NCh433.Of2009. Diseño Sísmico de Edificios.

Ranke-Ostermeyer. 1968. Bautechnik (Construction Engineering), Issue 10.

Valenzuela, G. 1978. Suelo de fundacion de Santiago. *Instituto de Investigaciones Geologicas,* Boletin No.33.

Figure 11.Deep excavation of 28 meters.

Figure 12. Inclinometer and load cell readings.

Figure 13.Parque Oriente building excavation completed.