FACULTY CIVIL ENGINEERING

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Ph.D. THESIS

-ABSTRACT-

CONTRIBUTIONS REGARDING THE DESIGN OF EARTH RETAINING STRUCTURES USED IN DEEP EXCAVATIONS

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1. GENERAL

Rising demand for commercial, residential and industrial needs has driven the architect to consider underground structures in their design. Diaphragm walls have been widely used as primary structural elements for supporting deep excavations in urban area due to their structural advantages. The design of retaining walls and support systems for deep basement construction requires careful analysis, design and monitoring of performance.

This is especially critical for deep basement construction in urban areas where the need for space and high land prices justify the deep basement construction. The walls should be designed to have high stiffness to comply with strict specifications on the limitation of ground movement induced by excavations in congested urban areas.

In this first chapter is presented the history of retaining walls, first diaphragm walls executed and the application in practice of them in worldwide and in Romania too. There are presented few example of underground parkings or buildings with 2, 3, 4 underground levels realized until now.

2 EXECUTION TECHNOLOGIES OF DEEP EXCAVATIONS

In the second chapter there are summarized first, the risk sources of a deep excavation project: location of the project, the geometrical form of the underground structure, different soil conditions with a real problem for the designers ground water level, influence area of the deep excavation to the adjacent buildings.

There are presented the methods of excavation for deep excavations projects: full open-cut, bottom up, island, top-down method, semi top-down method, zone excavation method.

The types retaining walls and their technology of execution with advantages and disadvantages are present in the second chapter too: soldier pile walls, sheet pile walls, diaphragm walls, bored pile walls, secant pile walls, tangent pile walls, CFA pile walls, jet-grouting pile walls.

3 DESIGN OF RETAINING WALLS FOR DEEP EXCAVATIONS

In this chapter, one the most important chapter of the thesis are presented the general principles which the design of earth retaining systems used in deep excavations are based on. The principles of designing retaining walls according to Eurocode 7 (SR EN 1997-1 National Annex) are described herein. The ideal distribution of earth pressure (active and passive) which act on the walls is presented and the concept of partial safety factors, very important in design.

After that there are presented limit states of the retaining walls: ultimate limit state (ULS) here is presented limit equilibrium method (LEM) with partial safety factors which are used in design calculations, serviciability limit state (SLS).

A very important problem which has to be take into account in any design of a deep excavation project is deflection of the walls of excavation, lateral deflection and vertical deflection. In this chapter there is made a large description of these issues which can appear in a deep excavation project both in design but very important during of execution works. There are presented few situations in which the deflection of retaining walls can occur: uplift, bottom heave, safety factors of the excavations, width of the excavation, the depth of the excavation, embedment depth of the wall, wall stiffness, strut stiffness, distance between struts, all of these were presented based on the worldwide researchers, the most important in these problems.

Another part of this chapter is called problems regarding soil-structure interaction in which is presented the concept of earth pressure from the beginning in ancient period where people were built walls for their safety and until now when there are built walls as retaining systems used in deep excavations and slope stability, tunneling. There are summarized the three concepts of earth pressure: earth pressure at the rest, active earth pressure and passive earth pressure in the most important two theories Coulomb and Rankine theories.

Earth pressure can be affected by factors like: ground water level, external surcharges of the ground, influence of the earthquake.
4 CALCULATION METHODS FOR RETAINING WALLS USED IN DEEP EXCAVATIONS

In this chapter there is made an extended characterization of the calculation methods for retaining walls used in deep excavations, limit equilibrium method (LEM): self-supporting walls (cohesion soils and cohesionless soils). Herein is presented the simplified method after Blum 1931. The are presented anchor walls, walls supported at the bottom of the excavation and without retaining systems in upper part, multi propped retaining walls.

A new method is presented in this chapter the EAB (2007) method after Committee of Excavations from Germany. According to this method, the earth pressure has linearly distribution on the entire height of the wall. Based on this method there are presented the most common situations in deep excavation projects/different supported walls, simple or multi propped walls, anchor walls.

Another important method presented in this chapter is the Subgrade reaction modulus method, where are used elastic supports in the ground, springs.

5 FINITE ELEMENT METHOD

Finite element method, a new trend in design of the all technology prove itself to be very important in the designing of earth retaining systems used in deep excavations. In a few words is presented the history of this method and its principle. The main idea of this method is solving equation systems which include stiffness matrix, nodal forces matrix and nodal deflection matrix.

In this chapter is presented the GFAS package software (Geotechnical and F.E.M. Analysis System) developed by Eng. Cosmin G. Chiorean, Professor PhD at Technical University of Cluj Napoca, Faculty of Civil Engineering, with all components and the principle of calculation.

In the second part of this chapter are presented constitutive soil models which are very important in the design of retaining walls, especially using FEM analysis: Mohr-Coulomb Model (MC), Hardening Soil Model (HSM), Hardening Soil Model with small strain stiffness (HSs).

6 PARAMETRIC STUDY REGARDING THE DESIGN OF EARTH RETAINING SYSTEMS USED IN DEEP EXCAVATIONS

In this chapter there are presented the results of the calculations of retaining walls used in this parametric study. There had been used walls with different free heights (3, 4, 5, 6, 7, 8, 9) meters with different supporting systems placed at different depths and different wall stiffness, strut stiffness, different section of the walls. From all calculations the results were compared: bending moments, lateral deflection of the walls, embedment depth of the wall.

All the calculations were made based on some influence factors, as follows: the influence of design approaches DA with all partial safety factors (according to SR EN 1997-1); the influence of cohesion where it were used soils with different values of cohesion and angle of friction; the influence of calculation method limit equilibrium method (LEM), subgrade reaction modulus (MCR), finite element method (FEM); influence of the wall stiffness where had been taken into account different values of wall stiffness for 3 values of cross section of the wall; the influence of strut stiffness, different values of the strut stiffness had been taken in calculations; the influence of yield criteria, there were calculated walls using different constitutive soil models.

7 CASE STUDIES OF CALCULATION METHODS FOR DESIGNING OF UNDERGROUND STRUCTURES

In this chapter there are presented case studies which were already finished as execution works or in process of execution. There are presented 3 examples of underground structures: 3 underground levels and 10 levels above the ground located in Sibiu, Romania the solution was secant pile walls, another structure is with 2
underground levels an anchored wall in Oradea and the last is with 3 underground levels a secant pile wall in Cluj-Napoca.

8 CONCLUSIONS. PERSONAL CONTRIBUTIONS

The development of the high rise buildings in urban zones forced the contractors and the investors to think about at realization of underground stories especialy car parks.

This rise had two most important consequences: the development of the new technologies for execution of excavations with biger and biger depths and the development of the calculation models and methods. The results from limit equilibrium method (LEM) showed that the sectional efforts were based on earth pressure distribution due to soil conditions; in subgrade reaction modulus (MCR) and finite element analysis (FEM) the results were based on choosing of soil parameters more reliable.

Principal personal contributions of this PhD. Thesis are:
- Fully documentary analysis of earth retaining systems used in deep excavations;
- Description of the most important retaining walls for deep excavations and thei execution technology;
- A detailed presentation of the calculation methods and models used in design of retaining walls;
- A large presentation of the SR EN 1997-1 design principles with discussions about design approaches (DA) and some observations about the way of the righ chosing and application of them.
- Presentation of the design of retaining walls through LEM, MCR, FEM, detailing the problems which require an accurate design.
- The presentation of important conclusions regarding the design of retaining walls used in deep excavations regarding: design approaches, the influence of calculation method, the influence of the prop position and the wall and prop stiffness which had an influence of the values of the sectional efforts, embeddment depth, the wall deflection and the ground deflection.

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