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Study Achievement of Deep Excavations from the Point of View of Their Effects on Surrounding Existing Buildings

Cosmin Fantaziu*, Răzvan Chirilă

* *Engineer, Department Of Transportation Infrastructure and Foundations,"Gheorghe Asachi" Technical University Iasi, Faculty of Civil Engineering and Building Services, Iasi, 700050, Romania.*

**Corresponding author: fantaziucosmin@yahoo.com*

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Starting from concrete situations encountered in the city of Iasi,Romania, are presented the methods used by the authors to assess the influence siting of new construction in urban areas, densely built. The results are compared with measurements made to support deep excavation and settlements for new buildings and those are in the "zone of influence" them. Proposals are to regulate the obligations of owners to ensure a minimum strength and stability of existing buildings and acceptable limits must fall within which influence design a new structure.

Keywords: *deep excavations, influence, settlements, source of risk, surrounding existing buildings.*

1. Introduction

Density urban growth leads to the need to build tall buildings with deep foundations, positioning the car parks and other facilities in their basements. With the increasing trend of the depth of the foundation of these buildings is highlighted and the need to work to support the earth, larger and more rigid. This trend is reinforced by the need for founding the less compressible soil layers and the desire to create spaces to facilitate positioning of underground utilities and underground parking.

There are numerous sources of risk (hazards) associated with performing deep excavations in urban areas, sources which must be considered in the design and execution of these works for any additional costs to a minimum.

By "sources of risk" means the risk factors that generate and which can lead to poor design of enclosures, thus affecting neighboring buildings.

The assessment of risk sources for disposal may occur additional measures and expenditure in the design and implementation enclosure excavated, that investor is forced to bear.

The beneficiary is required to submit the approval to obtain building permits, at least two alternatives, one of which present minimal technical risk.

The shape and dimensions in plan and excavation depth can be sources of risk. A large irregular outline and plan of excavation increases the complexity of support. The higher the trench depth, increase the difficulties of achieving not only work but also risks for themselves or for construction work in the neighborhood, to their stability, to be taken into account.

Analysis of deep excavation is required, usually before the start of the design process. This is a typical problem of soil-structure interaction. Earth is a nonlinear material, inelastic and anisotropic behavior is strongly influenced by the presence of pore water. Some types of soils presents properties of consolidation and creep. Theoretical analysis of deep excavations involving simulations of elasto-plastic behavior of the earth, behavior interface between land and retaining walls as well as the process of excavation.

Some theories test are not fully developed and some are too complicated to be used in the practice of the design. Thus, the current state is not practical analysis solely to contemporary theories and reasonable analysis of excavation would have to resort to means of classical mechanics of soils.

2. Area of influence of deep excavations

Influence area of a building is defined in "Norms on the principles, requirements and methods of research geotechnical soil" (NP 074/2002) as "the amount of land that is felt the influence of those construction or phenomena that may occur to influence the construction".

Deep trench designer will determine the area of influence of excavation, given the choice to all stages of execution of the works and shall specify measures to be taken for the safety of construction in the area of influence, whose stability and deformations should not be affected.

This area will be detailed design, taking into account the chosen solution and all stages of completion, while ensuring that stability is assured everywhere and admissible deformations.

3. Purpose and objectives

This article aims to analyze the influence of parameters that control the performance of deep excavations in terms of their effects on adjacent existing buildings. For this purpose, analyzes the influence of existing buildings on the answer excavations new surrounding them. As relationship-building adjacent excavation is considered biunivocal, taking into account the effects on the behavior of deep excavations achieve neighboring buildings.

It is noted that, due to lack of experience, combined with in situ measurements from photographs containing deep excavations made in the vicinity of the existing structure (mostly civil) technical regulations mentioned period shall not include requirements or methods for evaluating the effect of the execution and loads transmitted by the new construction on adjacent buildings.

Defining the existence of a zone of influence of any building in the ground in conjunction with European Norm Eurocode 7 Geotechnical design – Part 1 recently adopted as a romanian standard, draws attention to the need to take account of all phenomena that can occur foundation soil and influence on neighboring buildings are in this area.

For deep excavations for construction factors that can significantly influence the existing buildings in the neighborhood are related both execution (excavation works to support, dewatering, etc.) and the load transmitted by the new structure.

In the following we present some possibilities of treating this complex problems based on the methods soils mechanics and recommendations contained in technical regulations and reference works in the country and abroad.

4. Practic determination area influence of a building and interaction with existing structures

4.1. The main components of settlements induced in soil by achieve a building

For strength and stability of existing buildings in the area of influence of the new structure are significant size and time evolution of subsidence (vertical displacements, Fig. 1) induced in the ground for the new building.

Plastic deformations from active and pasive zones afferent on a support action also induce local travel, reported by Bransby and Milligan (1975) as due to deformation in undrained conditions in the area defined by line basis of 45 ° inclination support. In this area, any point is considered to have an equal component displacement vertically and horizontally, resulting in deformation of the land surface.

In most cases, additional settlements s were caused by construction and loading the new structure, in the adjacent land, consists of the following components:

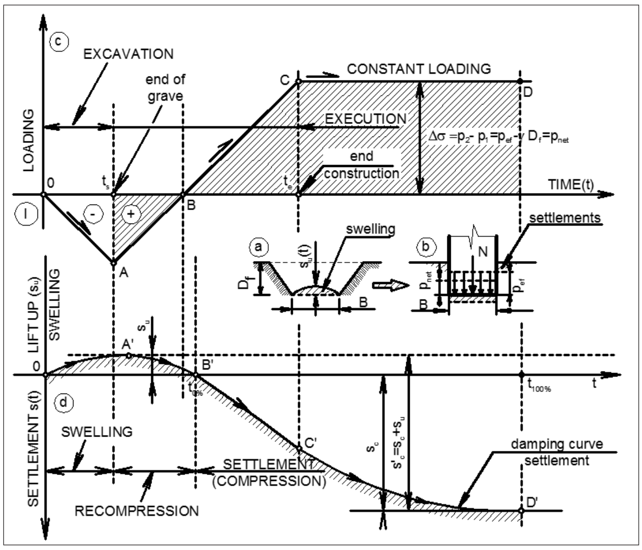
$$s = s_1 + s_H + s_2 \qquad (1)$$

where:

s_1 – settlements caused by excavation execution;

s_H – settlements caused by groundwater regime change (dewatering, etc.);

s_2 – settlements caused due to loading transmitted to the new building.



a) decompression bottom of the pit and its swelling;
b) the emergence recompression and compression land settlements;
c) time variation of the foundation soil loading or pressure to consolidate;
d) strain curve of the ground foundation during and after its execution.

Fig. 1. *Evolution of foundation settlements in connection with the execution of the construction stages*

Of course, in the particular circumstances in connection with the foundation soil or construction of the new module can occur and other influencing factors (wetting layers sensitive dampening effect on the overall stability of the terrain, dynamic effects, etc.).

The following describes some simplified methods for assessing settlements components of Eq. (1).

4.2. Simplified methods for evaluating the area of influence and settlements therein

4.2.1. Subsidence due to deformation work support – component s_1

Support embedded in the excavation.

This system of support is justified, in our country geotechnical conditions for construction with 1...2 basements, when excavation (depth D_f < 5...6 m) does not fall below the groundwater level (Fig. 2). Support can be made of rows of piles (cvasitangents, with interspaces) or of „Berlin” (Fig. 2).

Prisma land that produces active pressure P_a defines the support and influence of the excavation area (distance L_i).

To ensure fitting in the base of excavation must be carried out under P_p mobilize passive resistance (or a fraction thereof – to limit deformations).

It is known that the movement toward massive wall to fully mobilize P_p value is relatively high, even for compact soil: between 0,05 D_p and 0,10 D_p (as recommended by the European standard Eurocode 7). In exchange for the mobilization of resistance equal to 0,5 P_p required much smaller displacements δ_f = (0,01 ... 0,02) D_p.

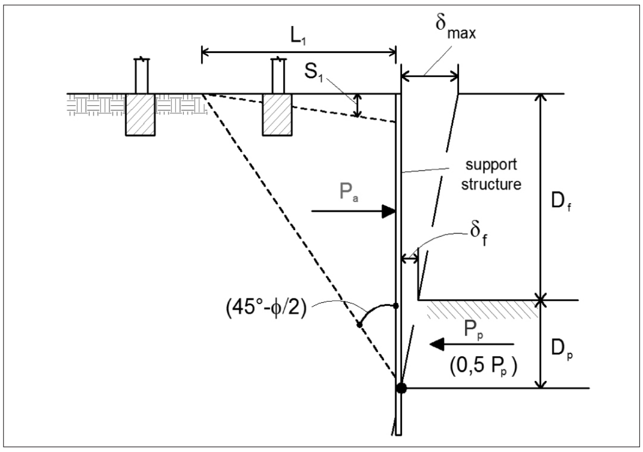


Fig. 2. *The area of influence of a support built in the base excavation*

Since the settlement "s" trench adjacent land surface depends on the maximum horizontal displacement δ_{max} wall appears reasonable to restrict the situation δ_f corresponding partial mobilization of passive pressure (most commonly from 0.5 P_p).

4.2.2. Lowering effect of hydrostatic level – component s_H

Epuisment works, inherent to the excavations which falls below the hydrostatic groundwater production rate decreases outside contour trench, an enclosure is sealed and does not penetrate to the base in a waterproof layer.

Lowering the level of hydrostatic pressure has the effect of increasing geological layers below the initial share of groundwater, because the weight of the earth in the volume variation of water level increase for example the values γ '≈ 10kN/m^3 (in submerged state) in γ = 18 ... 20 kN/m^3.

This increase vertical efforts lead to further subsidence layers to a depth appreciable, if clay layers, these settlements while building evolves over many months (depending on the thickness of the clay layer and the duration of maintenance work epuisment).

It has two common situations for our country:

- when entering excavations 1...3 m below the hydrostatic appears rational development of small walled enclosure depth (or set in impermeable clay layer) and the first epuisment aquifer.
- in the case of deep excavations (building basements with 4...6 levels), the trench penetrates into the clay layer, but due to the negative pressure exerted on the bottom thereof in a confined stream of the second layer is necessary to perform some pumping depth .

4.2.3. The effect of loading the new building – component s_2

Load transmitted foundation of the new building system produces deformations in the ground that extend outside its footprint. In Fig. 3 presents, indicative volume of soil in which vertical compression efforts lead to significant subsidence current cases. Of course the size of the "bulb effect" varies according to the pressure "p" transmitted by the new foundation and the parameters of the deformation of the coating.

Current methods for calculating permit evaluation with acceptable accuracy, the subsidence caused by the new structure, taking into account the influence of the depth of the foundation, the presence of piles (in case of mixed foundation systems) etc..

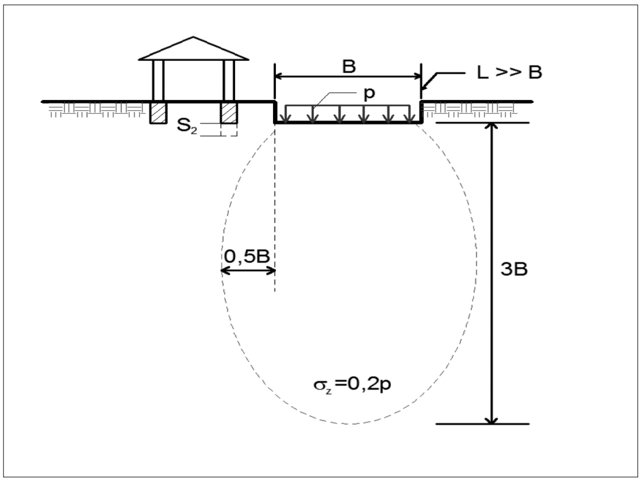


Fig. 3. *Vertical line equal effort (σ_z) under a continuous foundation*

4.3. Improved methods for calculating the deformation field in the phases of excavation and loading

Deformations that occur in the ground after sustaining cooperation with the massive wall of earth in various stages of implementation of excavation and lining of supporting and following discharge caused by excavation and loading provided by the new construction can be assessed using accepted computational models in mechanics lands.

Calculation methods that shape the successive stages of excavation, installation of ground support and load of the soil with new building load allows both evaluation efforts and strains in the supporting structure and the adjacent field trips (settlements caused in the surrounding areas). This enables the designer to "correct" any excessive subsidence on the wall supporting interventions (changing stiffness of the points of support, prestressing bars, and so on).

5. Example

To highlight the above will illustrate a practical case it is necessary to support the walls of the excavation in urban areas of Jassy (Iasi).

The site is bordered on two sides by construction P +1E and the other two sides are bounded by streets serving public traffic.

It wants to make an enclosure to support infrastructure construction of buildings for deployed underground parking on two levels.

Given the great height of the excavation was adopted solution with diaphragm walls support beam 40 cm in section.

Given the desire of the beneficiary to perform an excavation at a depth of 7.40 m above ground level in order to implement the project and to meet the design requirements of regulations encompassing special geotechnical works by active and passive thrusts that develop behind, or in front of the wall, was measured by a predimensioning, the minimum depth of the recess of the wall in the ground equal to 9.00 m

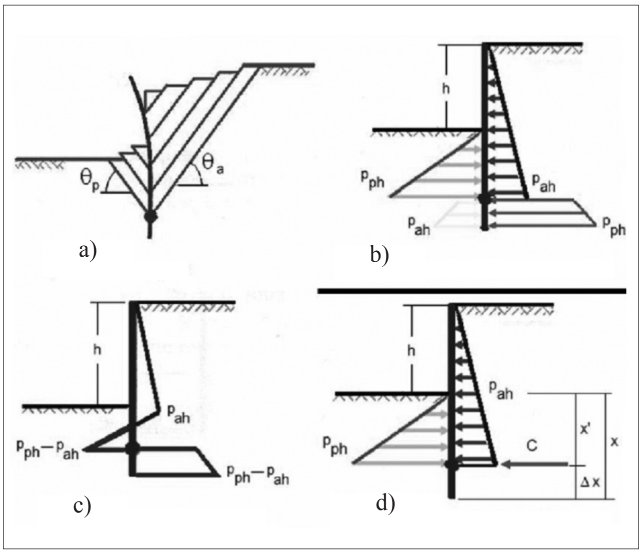


Fig. 4. Pressure diagrams, moments and movements in land case recessed wall

It follows a long trench wall support at least 16.40 m

Given the neighborhood at distances close to the site, special attention is required regarding maximum allowable movements acceptable to not induce further work in the existing building foundations.

Due to the complexity of the problem for a more accurate approach to the calculation adopted by numerical solutions based on Finite Element Method (FEM) using computer programs (in this case Plaxis 25) that can provide a consistent manner, because of the possibilities of modeling a design all the necessary data rigorous.

5.1. Geotechnical characteristics of the soil: Plaxis 25

Table 1. *Geotechnical characteristics of the soil*

Layer	Layer thick.	γ [kN/m³]	c [kPa]	Φ [°]	Sr [%]	E [kPa]
Topsoil	1.00	18.00	10	15	0.81	6000
Black silty clay	2.00	18.83	37	10	0.85	18700
Clay powder	2.00	17.95	14	16	0.88	18500
Brown silty clay	2.00	18.34	20	15	0.87	19600
Brown clay powder	13.00	18.44	5	15	0.9	18500

The groundwater was intercepted at a depth of -11.00 m from ground level.

5.2. Characteristics of materials

Tabel 2. *Characteristics of materials*

Name of the object	EA [kN/m]	γ [kN/m³]	EI [kNm²/m]	ν
Wall moldings	$1.2*10^7$	25.00	$1.6*10^6$	0.2
Existing foundation	$1.0*10^{10}$	22.00	$1.0*10^9$	0.2

5.3. Modelling by Finite Element Method

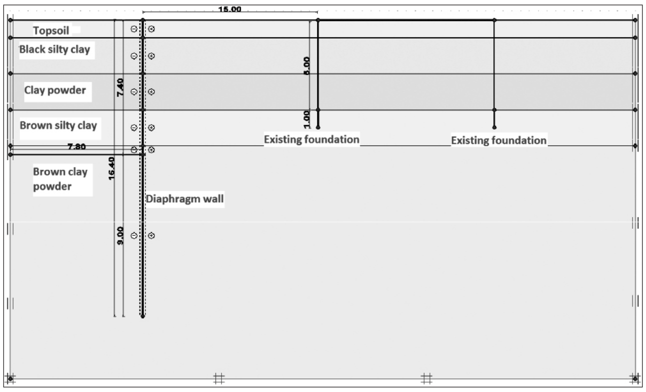


Fig. 5. *Geometry model*

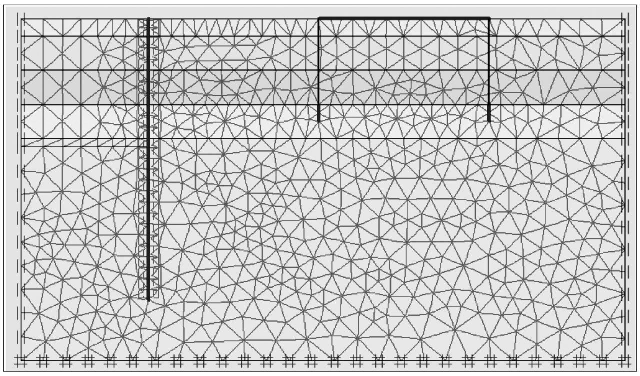


Fig. 6. *Meshing in finite element model created*

5.4. Results and their interpretation

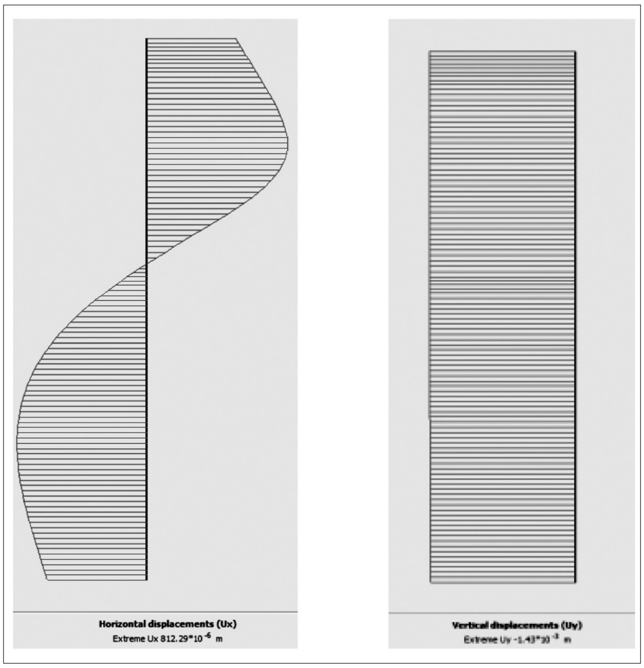
5.4.1. Running calculations pursuing technological phases of execution of the work

Were considered three stages of construction:

a) Execution of diaphragm walls and consideration of existing construction loads – determining the initial efforts of the ground massif;
b) Implementation of the excavation until the rate provided in the project;
c) Determination of safety factor by the criterion of shear strength parameters are reduced to overcome resistance to shear.

5.4.1.1. Stage 1

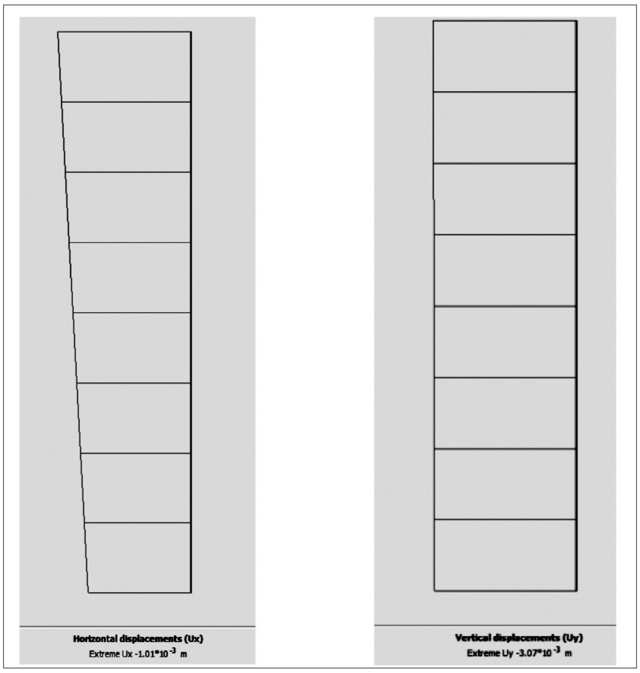
- Horizontal and vertical displacements of diaphragm wall



a) b)

Fig. 7. *Displacements: a) horizontals and b) verticals of diaphragm wall*

- Horizontal and vertical displacements of existing foundation



a) b)

Fig. 8. *Displacements: a) horizontals and b) verticals of existing foundation*

5.4.1.2. Stage 2

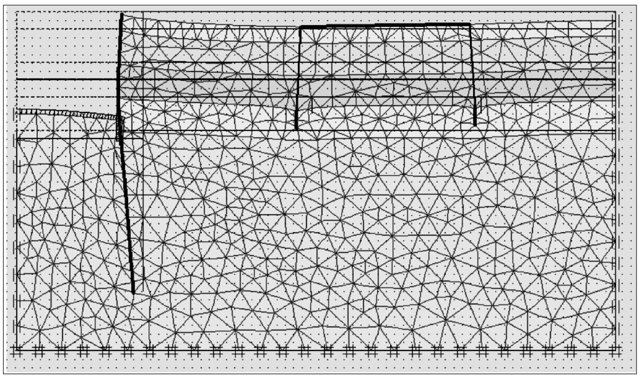
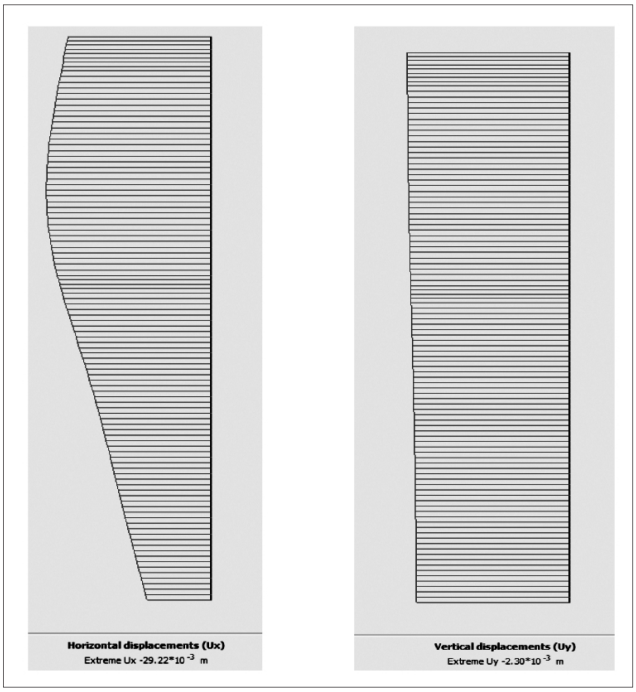


Fig. 9. *Deformed structure*

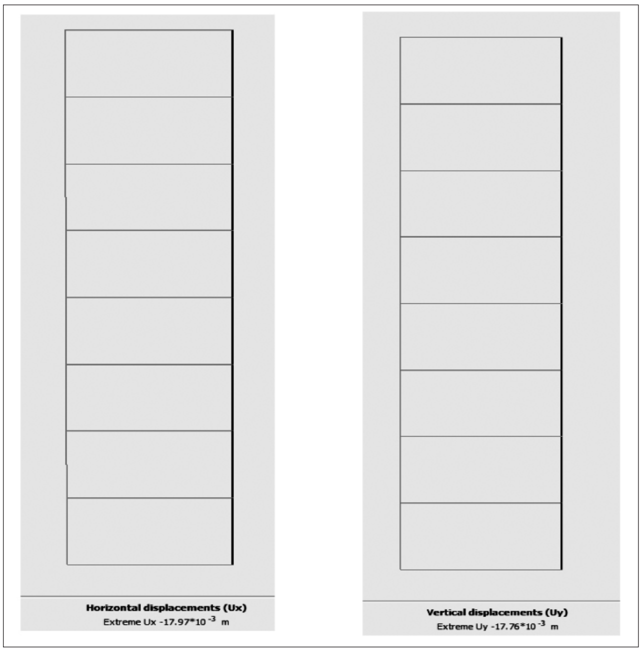
- Horizontal and vertical displacements of diaphragm wall



a) b)

Fig. 10. *Displacements: a) horizontals and b) verticals of diaphragm wall*

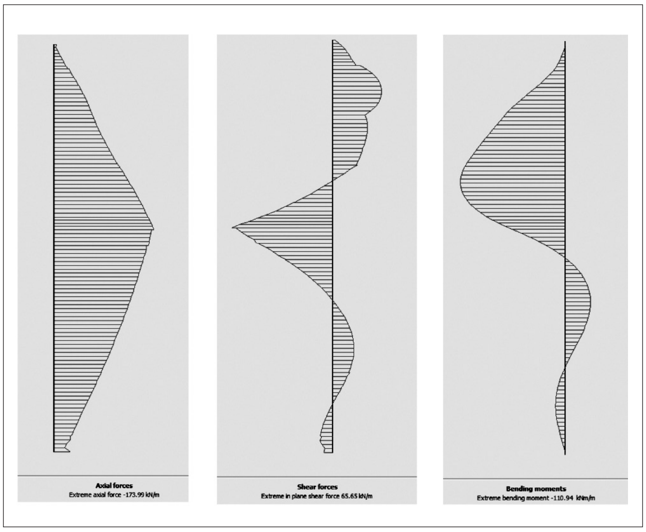
- Horizontal and vertical displacements of existing foundation



a) b)

Fig. 11. Displacements: a) horizontals and b) verticals of existing foundation

- Efforts in curved wall



a) b) c)

Fig. 12. Efforts in curved wall: a) Axial force, b) Shear force, c) Bending moment

5.4.1.3. Stage 3

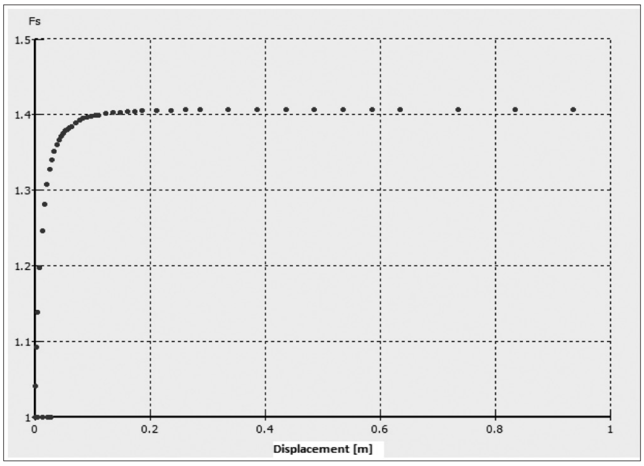


Fig. 13. Safety factor Fs offered by the resistance structure (diaphragm wall)

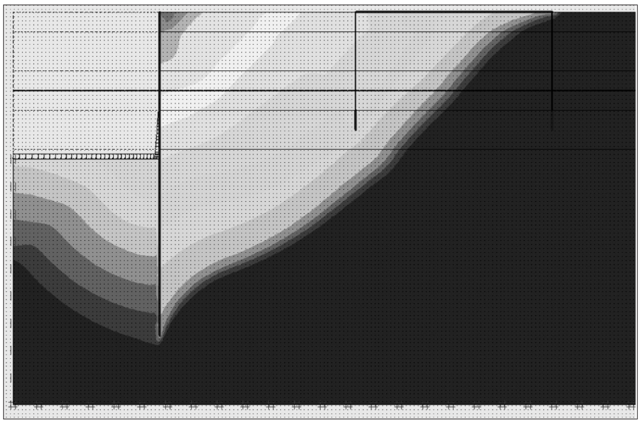


Fig. 14. The area of influence of the excavation

6. Conclusions

To reduce the risk of failure (ultimate limit state) of deep excavations and damage to adjacent buildings (serviceability limit state) support design work should be done through detailed analysis of deformation and verification by several methods (semi-)empirical and simple analytical. Thus, it is required a detailed understanding of how deformation and the mechanism for the transfer of land adjacent to the massive efforts in the construction works.

This paper addresses the issue of estimating the earth movements around deep excavations. First, it analyzes the influence of adjacent excavation construction features through a parametric study on a characteristic pattern. Its dimensions are set about statistics, the analysis of a comprehensive database on retaining walls of excavations and movements induced by them. On the other hand, this is analyzed based on real case studies posed by deep excavations densely built. The main objective of the article is the observation of deformation mechanisms based on the analysis of deformation-induced lateral displacements of the supporting walls of excavations.

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Cosmin FANTAZIU – Department Of Transportation Infrastructure and Foundations,”Gheorghe Asachi” Technical University Iasi, Faculty of Civil Engineering and Building Services, Iasi, 700050, Romania.
Main research area: Geotechnical Engineering.
Address: Iasi, Romania.
Tel.: +40 765652876
E-mail: fantaziucosmin@yahoo.com

Razvan CHIRILA – Department Of Transportation Infrastructure and Foundations,”Gheorghe Asachi” Technical University Iasi, Faculty of Civil Engineering and Building Services, Iasi, 700050, Romania.
Main research area: Geotechnic Engineering.
Address: Iasi, Romania.
Tel.: +40 742085262
E-mail: razvan_fcs@yahoo.com