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INTERACTION WITH NEARLY ENVIRONMENT AND OLD STRUCTURE FOR A DEEP EXCAVATION. CASE HISTORY IN BUCHAREST

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ABSTRACT

The paper presents the influence of a deep excavation performed in Bucharest on the adjacent ground and on some old buildings around it; the damages and effects appeared during the excavation and the remedial measures are presented in detail, too. The excavation was designed to be 16.15 meters deep, sustained by a slurry wall enclosure of 60 cm thickness and pre-stressed anchors, and steel struts. Due to an accident that occured to the trench walls, a thorough monitoring by instrumentation started. The results of this monitoring are shown.

INTRODUCTION

The site location (Fig. 1) were will be the Millenium Bussiness Center (MBC) is situated in the proximity of old buildings (Armenian Church, Armenian School, Armenian Library, Arcului 4 block of flats) and heavy traffic streets (Carol I Blvd, Armand Calinescu Street.) as is shown in the Fig. 2.

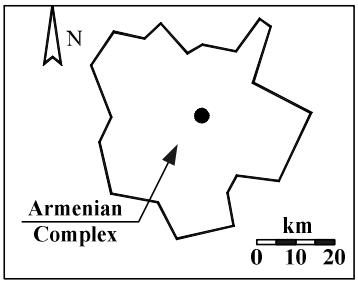

Fig. 1. Bucharest simplified map and site location

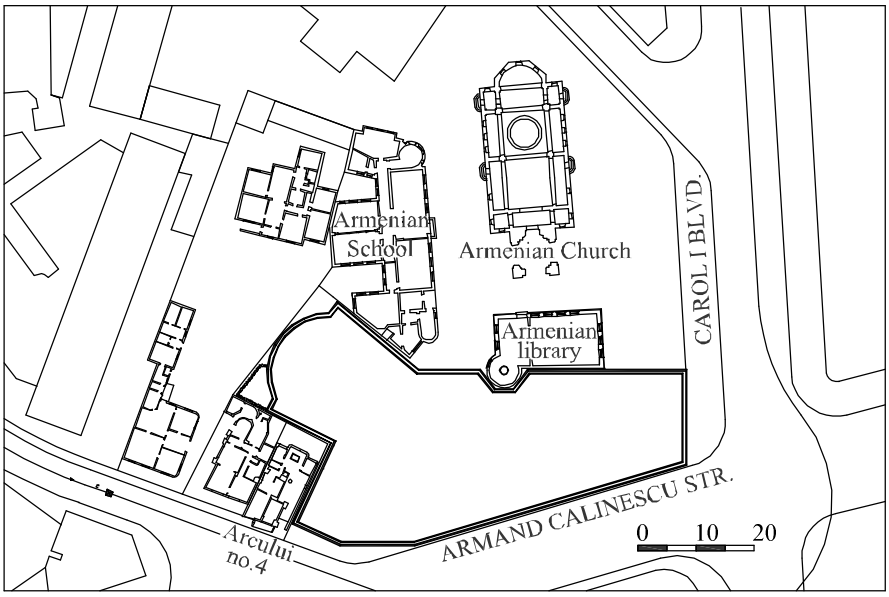

Fig. 2.Deep excavation contour and neighbourhood

The MBC structure will have 4 basements (for parking purposes), a ground floor and 18 stories for offices. The excavation for the execution of the 4 basements was designed to be 16.15 m deep, sustained by a slurry walls enclosure of 60 cm thickness, pre-stressed anchors, and steel struts. The slurry walls and the distribution of the anchors and struts are shown in the Fig. 3.

The digging of the slurry walls started in November, 2000; the excavation started in February, 2001 and was ended in November, 2001.

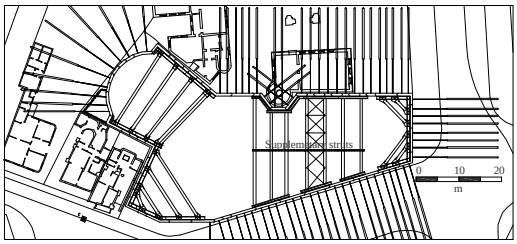

Fig. 3. Slurry walls enclosure, sustaining system, anchors and struts

GEOTECHNICAL ASSESSMENTS

The site location, in Bucharest, is characterized by the following geological formations (according to Fig. 4)

The design took into consideration the possible loads due to the seismic conditions of the site location.

The physical and mechanical characteristics for the geotechnical formations are shown in Table 1.

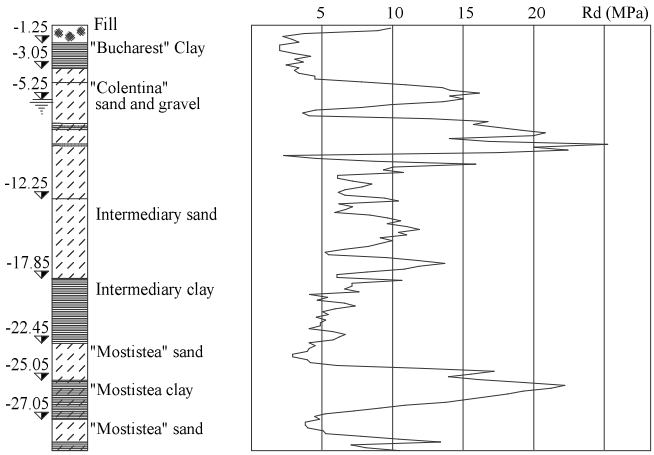

Fig. 4. Lithological column and SPT results

Table 1 Geotechnical characteristics

Soil type	Physical characteristics					Mechanical characteristics		
	γ	n	I_C	I_P	I_D	M_{2-3}	4	c
	(kN/mc)	(%)	(-)	(%)	(-)	kPa	(°)	(kPa)
Bucharest Clay	19	40	0.60	32	-	12500	18	30
"Colentina" sand and gravel	22	33	-	-	0.7	-	36	-
Intermediary sand	19.5	30	-	-	0.5	16600	25	15
Intermediary clay	20	35	0.70	35	-	16600	14	70
"Mostistea" Sand	21	32	-	-	0.7	11100	30	20

The slurry walls have been designed with a length of 21.00m, with 5.00m under the excavation bottom. Analyzing the lithological column it results that the excavation is protected against boiling, by the length of the slurry walls and by the presence of the intermediate clay of 5.00m in thickness.

Considering the irregular form and the dimensions in cross section of the excavation (starting from 15.00m up to 28.00m) it was designed a retaining system using two solutions: five levels of pre stressed anchors 20.00 to 28.00m long, with bulbs of 8.00 and 12.00m and four levels of steel struts made of pipes 600 mm in diameter. The calculated force in the anchors was 540kN.

Analyzing the existing structure of the buildings in the close proximity of the site, it was decided to increase the safety of the old multi-storey building in Arcului 4 Street (Fig. 3), by a screen of tangent micropiles of 180mm diameter drilled 8.00m deep.

The screen was made before the excavation for the slurry walls in that area, in order to protect the basement of the building (see Fig. 5).

THE INFLUENCE OF THE EXECUTION ON THE NEIGHBOURHOOD AREA

Taking into account the density of the buildings in the vicinity, their bad technical shape and the heavy traffic on the two main streets, a system made by settlement and cracks marks was installed in order to evaluate step by step the effects of the execution on these buildings.

The Fig. 5 shows the location of the principal settlement marks, installed on the most sensitive buildings.

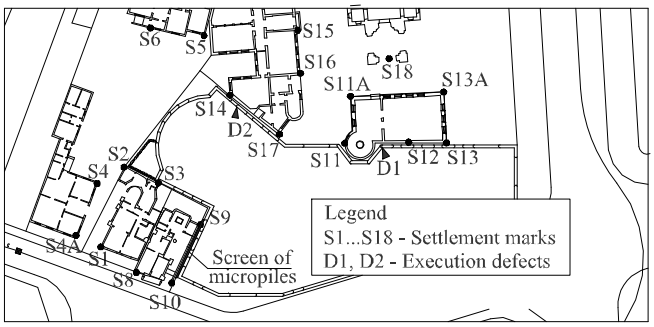

Fig. 5. Surveying marks and technological events location

The most important technological incidents were:

- the execution of the anchors (5 levels A1-A5) below the underground water level was done with important loss of water and granular material (fine sand) during the drilling; it was approximated that volumes between 0.50 to 1.00mc of lost material remained uncompensated for each anchor;

- defects in the slurry walls, located between 13.50m and 16.15m deep, consisting in openings (holes) 0.30m to 0.50m wide (D1, D2); because of the high hydraulic gradient and of the corresponding pressures of the saturated ground (about 100kPa), important volumes of water and solid material flooded into the excavation area.

Analyzing the two types of technological incidents it results that the excavation influenced the surrounding area, especially the foundation ground of the old buildings, with very sensitive structures.

In the Figures 6, 7 and 8 is represented the evolution of the settlements related to the mentioned technological incidents, leading to the following conclusions:

- for the Armenian Library, the drilling of the 3rd level of anchors (-10.55m) and the excavation, lead to an increment of settlements from 2.50 to 3.00cm; it is important to notice the strong influence of the defect in the slurry wall (D1), leading to an increasing of the settlement from 3.00 to 3.50cm (see Fig. 6);

- for the Armenian School, starting with the execution of the 3`d (-10.55m) and 4`h (-11.95m) level of anchors some increase of settlements have been recorded, from 1.00 to 1.50cm; the defect (D2) in the slurry wall had a strong influence, the settlement increased with 6 cm (see Fig. 7);

- for the Armenian Church, situated at about 20.00m distance from the excavation, the major defect D1 in the slurry wall had an important effect, with an increment in settlement of 2.50cm (see Fig. 8); the drilled anchors had less effect (settlement recorded were about 0.50cm).

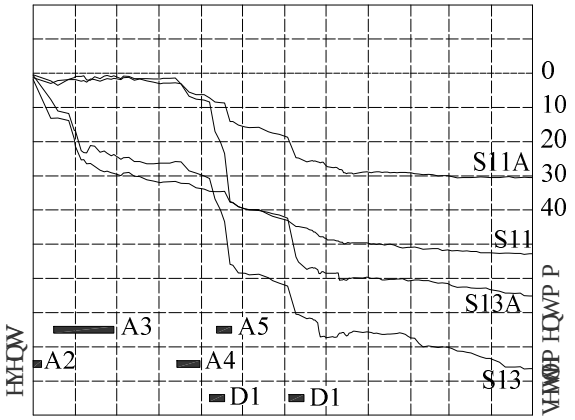

Fig. 6. Settlements evolution Armenian Library

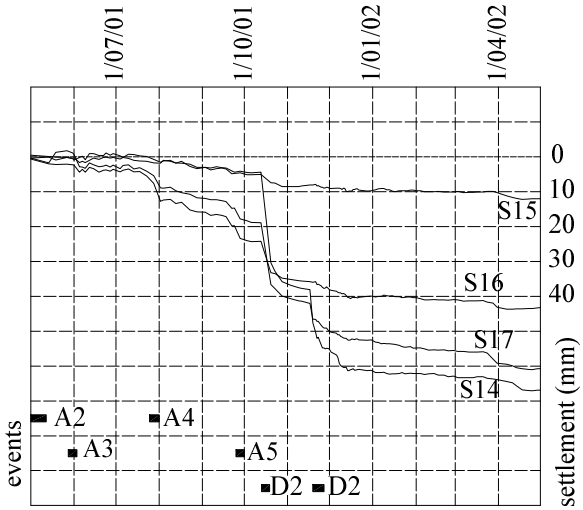

Fig. 7. Settlements evolution Armenian School

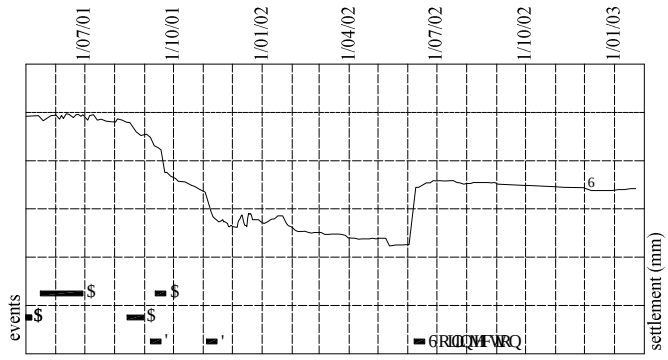

Fig. 8. Settlements evolution, Armenian Church

REMEDIAL MEASURES

Based on the settlements measurements and cracks opening evolution records, two categories of remedy and safety measures have been taken:

-The sustaining system of the slurry walls was supplemented in the Dl defect area with steel struts (at -10.00m level), using piles as intermediary supports (Figure3); in the defect area (with high hydraulic gradient) the 5th level of anchors (at -13.55m) was replaced by local supports - inclined steel struts;
- In order to restore the ground characteristics in the excavation surrounding area, a soil grouting program has been established, using a grid of vertical injectors from 6.00m to 8.00m deep; this program was based on the results of repeated dynamic penetration tests made on site, showing the most affected areas after the technical incidents (Fig. 9).

After the remedy measures, the slurry wall enclosure remained stable, and the settlements of the affected buildings recorded a stabilization trend during December, 2001 (see Figures 6, 7, 8).

The program for the soil consolidation continued by grouting with cement-silicate stable suspensions, until a trend of lifting has been recorded (Fig. 8).

CONCLUSIONS

The facts presented show the importance of using adequate technologies for digging deep excavations in urban areas, with existing buildings in the close proximity of the site.

In the presented case, the major defects in the slurry walls, positioned unfortunately in the most sensitive area, lead to important loss of material and implicitly to settlements and damaging of the adjacent buildings; the influenced area was up to 20-25m from the excavation (Fig. 9).

Important and expensive works were necessary to restore the soil in the surrounding area of the excavation site to the initial state; it is also in progress a program for the consolidation and repair of the affected old buildings.
The experience of this work also shows the importance of the management in coordinating the
building works with an adequate quality control of the hidden works and with the continuous monitoring of the deformations.

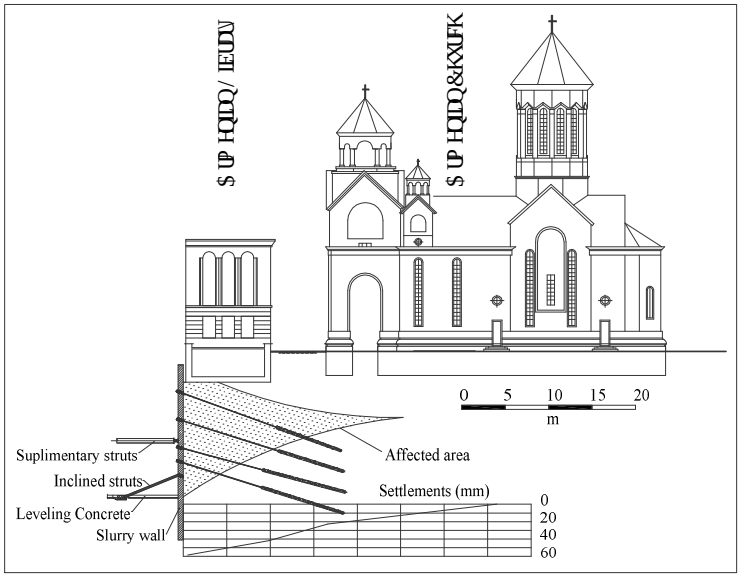

Fig. 9. Average settlements, influence of the defect D1, affected soil area

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