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# DEFORMATIONS OF EXISTING BUILDINGS, CAUSED BY CONSTRUCTION ACTIVITIES

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## ABSTRACT

Construction of a new building (NB) affects existing adjacent old buildings (OB) during pit excavation, piling, footing and NB erection. Two relevant history cases are described. In the first one, the graphs of OB settlements versus distance from the pit are given for the period of pit excavation and the total settlements for the period of NB erection. The second case gives the family of OB settlement time-related graphs versus distance from the pit, in which these settlements were caused by piling operations.

## INTRODUCTION

The city of Moscow is living through an unprecedented building boom in spite of space deficit, heavy traffic and congested urban environment that necessitate erection of tall and slim buildings on top of multi-level underground parking lots. The buildings are getting heavier, the footings are getting deeper and OBs are to be preserved. This is a major challenge to geotechnical engineers. Therefore, lessons learnt from available history cases are very important.

## HISTORY CASE 1

The site is located in Western Administrative Area of Moscow. A 18-storey residential NB, having an Γ-shaped footprint ~20x20 and 8.0 m deep 2-level underground parking, was constructed 1.5..2.5 m off existing OBs. The excavated pit banks were supported by 0.75 m dia 18 m long cast piles, spanned at 0.80 m. The building has a stiff framed structure and sits on 1.2 m thick concrete raft.

The raft is underlain by 0.7..2.8 m thick fill (sand loams, sands and construction debris). 6.2-8.8 m below it, there occur thick medium density and dense sands of various grain size, underlain by sand and clay loams to ~18 m depth. Ground water table depth is at 10.6 11.8 m i.e., the soil base is dry.

Two brickwork 5-storey and one 8-storey OBs are adjacent to the site. Prior to all construction operations the OBs were surveyed to register their initial condition, geodetic benchmarks were installed on them, and the soil under their footings was strengthened by grouting.

After pit excavation the OBs settled 12..18, and 2.0-3.5 mm wide cracks appeared in the walls, therefore, the soil under their footings was regrouted.

Monitoring of settlements continued for 2 years, construction period inclusive. Maximum OB settlements are 24..34 mm now and are still growing. The cracks in the walls are 2..8 mm wide. By the of NB construction period the settlements increased 50%, the settlements propagated as far as 24..30 m under OB i.e., 3...4 times the pit height.

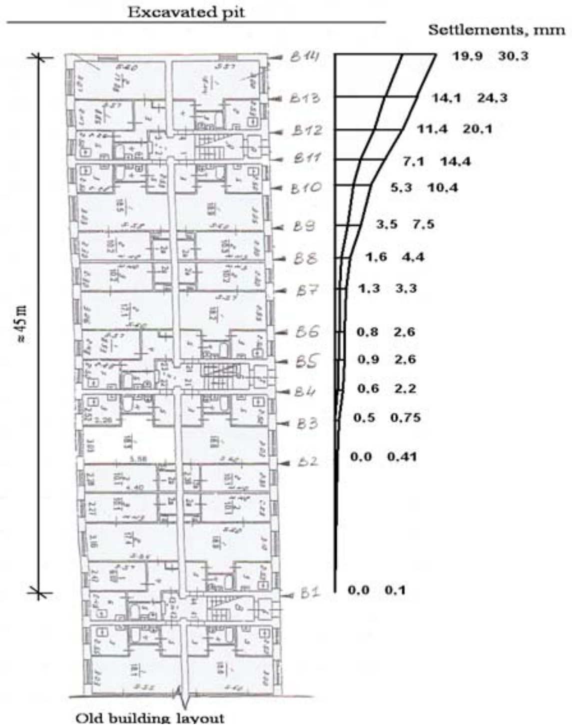

*Fig. 1. Location of benchmarks on OB wall and settlements vs distance: settlements after pit excavation and total settlements after NB erection.*

Fig. 1 shows settlement vs time curves at different points.

Total OB settlement near the pit is 30.3 mm, of which 19.9 mm share is due to excavation influence (PE), the rest 10.4 mm result from NB influence i.e. the ratio of these settlements

$S_{PE}/S_{NB}$~2 near the pit. At greater distances from the pit this ratio changes: $S_{PE}/S_{NB}$ ~ ½ at 20 m from the pit. It means that the influence of NB extends farther than the pit excavation influence.

In order to numerically simulate the extension of the zone a simplified 2D model of $b$=20 m wide NB on Pasternak base ($C_1$ and $C_2$) was developed. Under NB a Winkler layer ($C_3$) was introduced on top of the Pasternak model to simulate soil disrupture zones at the footing edges. The solution was programmed in MathCad. Back analysis showed that the assumption $C_1 \sim E/[H(1-\nu^2)]$ and $C_2 \sim EH/(1-\nu^2)$ gave the best fit. The results are shown on Fig. 2.

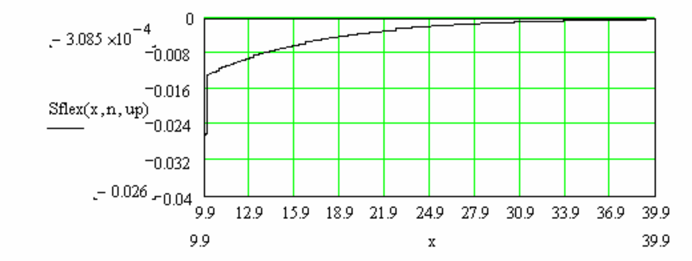

*Fig. 2. OB settlements profile versus distance from NB pit*

According to Russian standards the thickness of the active (compressible layer) was assumed to be $H$= 6+0.1 $b$=*8* m.

## CASE HISTORY 2

Another case history belongs to Moscow historical downtown. A 6-storey NB was to be erected at 15, Malaya Nikitskaya. The historical OB was planned to be pulled down, but the main façade, facing the street, had to be preserved. NB construction site is adjacent to other four OBs, which are historical and architectural landmarks.

8 m deep two-level parking lot was planned to be constructed under NB. Sheet piling enclosure was designed to protect the pit excavation.

In the period from 1979 to 2007 multiple site surveys were performed on the site. It was found that the active zone below the OB footings confined alluvial medium grain size gravely sands, sparse large grain size sands and medium grain size sands, having deformation modulus $E_o$=32 MPa. Ground water table was registered at 6-6.5 m depth from the surface.

The OBs in the influence zone have been surveyed since July 2004 that showed their unsatisfactory or pre-emergency condition. The site survey also showed that no essential changes have occurred in geological and hydro-geological situation on the site during the whole period. Construction operations on the site started in September 2007 by strengthening subsoil and footings of the preserved part of OB. The registered vertical displacements, observed on the monitored buildings, were, by then, within 3.1 to 5.5 mm range. The next operations stage envisaged drilling of 377 mm dia 18 m long pilot holes for cast sheet piles. Auger drilling operations were performed in October of 2007.

The drilling operations caused OB settlements that reached 2.5 to 90.8 mm by the end of October 2007 (Fig. 3). Then the construction operations were suspended, and a decision was made to assess the possible changes of soil physico-mechanical properties within the active zone under OBs footings. This task was carried out with the help of Electro-Dynamic Cone Penetration Tests (EDCT) to measure $q_c$, $f_s$, $R_f$. Also specific electric conductivity $\rho$ was measured that enabled soil type identification vs depth.

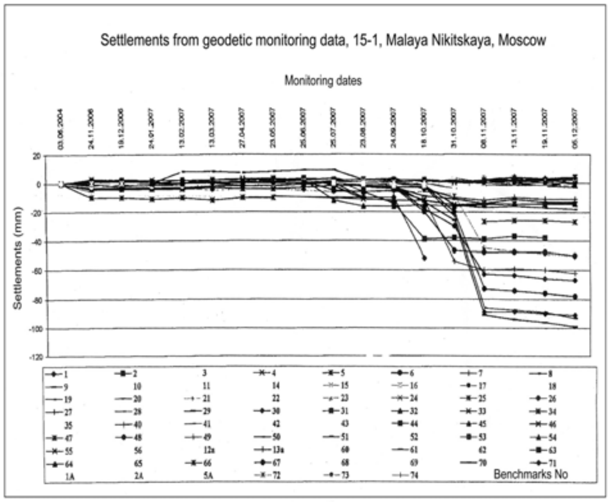

*Fig. 3. OB settlements during construction operations. The drop corresponds to drilling operations period*

The EDCT data analysis showed that sand deformation modulus $E_o$ reduced times 1.8 during pilot bore holes drilling as compared to its initial value. Also it was found that during drilling operations bentonite mud slurry was not adequately supplied to retain borehole walls, and, therefore, some of the pilot bore holes could have collapsed. All of it caused soil softening that resulted in abrupt OB ~ 80 mm settlements (Fig. 3).

## CONCLUSIONS

1. Precision geodetic monitoring showed up to 30 m extent of new building influence zones, affecting adjacent old buildings.

2. The settlements within the influence zone under old buildings are caused both by pit excavation and by new building impact. Near the pit the share of settlements, caused by the new building, is less than that, caused by excavation. It is visa versa at greater distances from the pit. The extent of the influence zone was about 30 m off the pit edge. In both history cases the pit depth was 8 m deep.

3. Simulation of the influence zone settlement with the help of a new building simplified model and modified Pasternak model of soil base showed that the assumption $C_1 \sim E/[H(1-\nu^2)]$ and $C_2 \sim EH/(1-\nu^2)$ gives an acceptable fit for the influence zones approximation.

4. The above evidence shows that underground construction operations could largely affect soil compressibility. It is

especially so, because similar events were registered at other construction sites, located in Moscow historical downtown with similar geological conditions. Therefore, underground development projects designs shall envisage environmentally safe excavation and piling technology in combination with proactive emergency measures for protecting old buildings, located within new construction site influence zones.