INTERNATIONAL SOCIETY FOR
SOIL MECHANICS AND
GEOTECHNICAL ENGINEERING

SIMSG ISSMGE

This paper was downloaded from the Online Library of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE). The library is available here:

https://www.issmge.org/publications/online-library

This is an open-access database that archives thousands of papers published under the Auspices of the ISSMGE and maintained by the Innovation and Development Committee of ISSMGE.

Geotechnical monitoring of urban building reconstruction during the underground construction

Geotechnique monitoring de reconstruction de la terrain bati a l'occasion de assimilation d'espace souterrain

V.A.Ilyichev, P.A.Konovalov & N.S.Nikiforova – *NIIOSP, Moscow, Russia*

ABSTRACT: The reconstruction of the historical center involving underground space utilization has been taking place in Moscow during last years. In this connection some problems of historical monuments safety appeared. Geomonitoring at the construction of underground structures and reconstruction of historical buildings can solve these problems. The effective results of geomonitoring performance in Moscow have been reported in the paper and illustrated by the examples of the trading and recreational complex «Okhotny Ryad» on Manezhny Square, the Old Gostiny Dvor, the trading center «Berlinsky Dom», administrative buildings with underground parking lots located at 6/8, Maroseika Street.

RÉSUMÉ: La reconstruction du center historique et l'utilisation avec sela l'espace souterrain on été realizes a Moscow pendant l'annees derniers. Dans ces conditions la problem de la sécurité des monuments historiques ont apparu. Cette probleme etait resolú par le monitoring à construction les bâtiments souterrain et reconstruction les edifices historiques. Dans cette article des preaves de success du monitoring a Moscow sont donnees. Ils sont illustrées par exemples des complexes divers.

1 INTRODUCTION

1.1 *Relevance of the Problem*

Reconstruction of whole architectural ensembles of the city and separate buildings is being performed in Moscow. This involves underground development: construction of underground parking lots and stores or deepening of existing basements. Reconstruction is being carried out in tight urban housing environment. The problem of existing buildings preservation emerges. Many of these buildings are historical monuments. Geotechnical monitoring is a tool to be used for solving this problem.

1.2 *Geotechnical Monitoring*

Geotechnical monitoring performed during construction or reconstruction of buildings involving underground construction in tight urban housing environment is a complex system of monitoring of the condition of a constructed or reconstructed building along with bases and foundations of neighboring buildings and soil mass, evaluation of monitoring results and forecast of post-construction changes in their condition for one-year term and the following period of operation. Geotechnical monitoring includes the following units: calculation, measurement, research and development, analytical, ecological and control units.

We carry out geotechnical monitoring at Moscow construction sites: the trading and recreational complex (TRC) «Okhotny Ryad» on Manezhnaya Square, the Old Gostiny Dvor, the trading center «Berlin House», «Romanov Dvor», administrative buildings with an underground parking lot located at 6/8, Maroseika Street, etc.

2 INFORMATION ABOUT THE OBJECTS OF RESEARCH

2.1 *Trading and Recreational Complex (TRC) «Okhotny Ryad»*

A deepened building having 122.0 m level of a deep part, 130.0 m level of a shallow part and 138.0...140.0 m level of the surface has been constructed on Manezhnaya Square in Moscow. 37 m deep «diaphragm wall» serves as an enclosing structure. Open-type construction brought the problem of preservation of neighboring historical buildings: the Central Exhibition Hall (constructed in 1817), the Church of St. Tatyana the Martyr (1833 - 1836), the old building of Moscow State University (1786 - 1793), All-Russian JSC VAO Intourist (1934), the National Hotel (1901 - 1903г.г.), the State Duma building (1932 - 1936), the Moscow Hotel (1935 - 1936), the former V.I. Lenin Museum (1892), the State Historical Museum (SHM) (1874 - 1884г.г.), the Corner Arsenal Tower (1492), the Kremlin Wall (its section up to the Troitsky Tower) (1485 - 1495), Arsenal building (1701 - 1736). Most of these buildings were in unsatisfactory condition and had considerable settlement values due to a long period of operation. Some buildings were reconstructed during deepened facility construction (the National Hotel, the Historical Museum, the Church of St. Tatyana the Martyr, All-Russian JSC VAO Intourist). Almost all buildings have load-bearing brick walls, 2.2...7.4 m deep strip or isolated foundations. The Moscow Hotel is an exception. It was constructed on 16.4 m deep crossing-slabs foundations, slab foundations, columnar foundations and 10.4 drop shafts. Ground water was found at 2-13 m depth from the surface. The ground is formed (from top to bottom) by 2...7 m thick layer of fill-up soil, sands of different sizes, loams, clays and lower – limestones. Foundations of many buildings are overloaded. The pressure under foundations is more than twice higher than the design soil resistance value.

Foundation pit excavation was performed through a «diaphragm wall» installation with the help of special structures made of floor slabs of the shallow part.

2.2 *Old Gostiny Dvor*

This building is a monument of history and architecture dating back to the XIX century. It is a trapezium-shaped 2-3-storied brick building with 600 m long walls. Before reconstruction, settlement of the building amounted to 10...100 m. During reconstruction one story was overbuilt, basements were made 4 m deeper, the courtyard was covered with a translucent cover and an underground storey was built inside the yard. Various soil beddings, including up to 6 m thick fill-up soil layer with organic impurities are available in the construction area. Before reconstruction the Old Gostiny Dvor had 2-3 m strip foundations. Underground water is found at 4-5 m depth. Then 11-15 m long

root piles were constructed. Base loading increase outstripped pile installation works.

2.3 *Administrative building located at 6/8, Maroseika Street*

Five buildings dating back to the XIX century relate to the zone affected by the 3-storied building with a 1-storied underground parking lot. Three of these buildings are monuments of architecture. The site is formed by a 1-6 m thick layer of fill-up soil, under which there is a 1-1.5 m thick layer of sands. Lower there are 2-4 m thick layers of high-plasticity and low-plasticity loams. Underground water may be found at 0.5-2 m depth.

Foundation pit was shored with the help of horizontal struts made of pipes.

2.4 *Trading Center «Berlinsky Dom»*

The building of the trading center «Berlinsky Dom» located at the crossing of Kuznetsky Most Street and Petrovka Street in Moscow is being constructed. The building will have three underground and three overground floors. Its construction was started in October, 1998, and in spring, 1999, the site was conserved after the construction of the first underground floor. After a year and a half the construction of the building was restarted. Five buildings got into the zone affected by the constructed building having an underground part. Among them the Mosproject-3 building and the State Municipal Inspection building were affected most of all. The Mosproject-3 building is located hard by «Berlinsky Dom».

Design level of the bottom underground floor is 9.6 m and the level of the bottom of the «diaphragm wall» – 17.0 m.

Foundation pit was excavated through special windows in floor structures of the top floor.

3. GEOTECHNICAL SITUATION ANALYSIS

3.1. *Surrounding Buildings Location with Respect to the Facility with Underground Structure*

Considering the surrounding buildings location with respect to the constructed facility having an underground part, it is possible to say that the ratio between the distance between them and the foundation pit depth varies from 0 to 3.9 and amounts to:

- 0 – for the Old Gostiny Dvor and «Berlinsky Dom» (near Mosproject-3);
- 1.0-3.0 – for the building located at 6/8, Maroseika Street;
- 2.1-3.0 – for the TRC «Okhotny Ryad».

3.2 *Existing Buildings Condition*

According to [1] the surrounding buildings' structures relate to III-V category, i.e. they are in unsatisfactory or emergency condition. Many buildings have been reconstructed and floors were added to them. Their foundations bases are overloaded, i.e. the pressure on foundation beds is more than twice higher than design resistance of soils.

3.3 *Foundation Pit Excavation Method*

All deepened buildings are erected by the «diaphragm wall» method. But the following three foundation pit excavation ways may be singled out:

- with anchor-fastened «diaphragm wall» (1);
- «diaphragm wall» fastened with the help of struts made of pipes (2);
- soil excavation and removal through the windows in floor structures of the top floor (3).

3.4 *Existing Buildings Deformations*

Specifications of the buildings relating to the zone affected by deepened facilities at various Moscow sites, foundation pit excavation method and buildings' deformations are presented in Table 1.

Table 1. Existing buildings' deformations during deepened facilities construction

Facility	Specifications				
	Condition category	L/H *	Found. pit excavation method**	S, *** mm	ρ****, 1/m
TRC «Okhotny Ryad»:					
The Moscow Hotel	III	2.1	1	5	$\pm 1 \ldots 5 \times 10^{-5}$
The National Hotel	IV	2.4	1	4	$\pm 2 \ldots 3 \times 10^{-4}$
The Historical Museum	IV	3.9	1	6	$\pm 1 \ldots 2 \times 10^{-4}$
The Old Gostiny Dvor	IV	0	1	49	$\pm 1 \ldots 2 \times 10^{-4}$
6/8, Maroseika Street:					
4, Petroverigsky Lane	III	3.0	2	7	$\pm 1 \ldots 3 \times 10^{-4}$
1, Petroverigsky Lane	II	0.9	2	2	$\pm 1 \ldots 3 \times 10^{-5}$
8, Maroseika Street	III	1.0	2	18	$\pm 1 \ldots 6 \times 10^{-3}$
6, Maroseika Street	III	2.0	2	3	$\pm 2 \ldots 3 \times 10^{-4}$
Bath House	IV	1.0	2	42	-
«Berlinsky Dom»					
Mosproject-3	III	0	3	11	-

*L – distance between a building and a deepened facility,
H – depth of a deepened facility
** 1 – anchor fastening of a «diaphragm wall»,
2 – fastening with struts made of pipes,
3 – excavation through windows in floor structures of the top floor,
***S – maximal settlement of the building,
****ρ - foundation curvature in the length dimension.

Settlements of existing buildings amounted to 2-49 mm. Maximal settlement values varying from 42 to 49 mm and L/H value varying from 0 to 1.0 were specific for the buildings in emergency condition relating to V category. Settlement of the buildings relating to III condition category with L/H equal to 0-1.0 varied from 11 to 18 mm. Settlement of the buildings relating to II condition category with L/H equal to 0-1.0 made 2 mm. Settlement of the buildings relating to III, IV condition category with L/H equal to 2.0-3.9 varied from 3 to 7 mm. Performed analysis allowed us to indicate approximate values of future settlement of the existing buildings depending upon their structure condition category and their closeness to a deepened facility. This data is presented in Table 2.

Table 2. Maximal settlement of the buildings surrounding a deepened facility constructed, S, mm

L/H *	Building condition category		
	II	III	IV
0...1.0	< 3	10...20	40...50
2.0...3.0		3...7	4
>3.0			6

*L – distance between a building and a deepened facility,
H – depth of a deepened facility

Are these settlement values dangerous for the buildings relating to the zone affected by a deepened facility? Maximum permissible settlement values for newly constructed buildings meet norms [2]. However, these norms cannot be applied to the following kinds of buildings:

- buildings operated for a long time relating to III or IV category of structure condition;
- buildings based on overloaded foundations (p > R, p – pressure under foundation base, R – design resistance of base soils);
- buildings under reconstruction;
- monuments of history and architecture which should not get cracks.

Usually it is multistory brick buildings with load bearing walls. As a rule, this kind of buildings surround the facilities with deepened parts constructed in tight urban construction environment. During foundation pit excavation existing neighboring buildings react to settlements difference variability. Therefore, we have suggested an additional criterion for evaluation of safe condition of such buildings – foundation surface curvature ρ, 1/m, characterizing settlement difference variability (Table 3). According to Construction Rules and Regulations [2], the following condition should be met:

$$S(x) < [S] \qquad (1)$$

here S(x) – maximum settlement of a building, cm; [S] – maximal permissible settlement for this kind of buildings, cm.

We suggest to introduce the value $\rho(x) \sim S''(x)$, 1/m.

$$S''(x) \sim \frac{S(x+2\Delta x)-2S(x+\Delta x)+S(x)}{(\Delta x)^2} \qquad (2)$$

Table 3. Curvature of the foundations of existing buildings during deepened facilities construction, ρ, 1 / m

L/H *	Building's condition category II - III	IV	Cracks emergence
0...4.0	$\pm$ n** x (10^{-1} 10^{-4})	$\pm$ n** x 10^{-4}	Yes
1.0...2.0	$\pm$ n** x 10^{-5}		No

*L – distance between a building a a deepened facility,
H – depth of a deepened facility,
**n = 1-6

Analyzing Table 3, it is possible to note that cracks in the structures of the multistory brick buildings with load bearing walls that have been operated for a long time do not emerge, provided that these buildings' foundations curvature does not exceed n x 10^{-5}, 1/m. The value ρ = n x 10^{-5}, 1/m is recommended as a maximum permissible deformation value for existing buildings in the areas of historical buildings relating to the zones affected by deepened facilities.

4. CONCLUSIONS

1. The results of geotechnical monitoring of Moscow facilities with deepened parts and of neighboring buildings are presented in the article.
2. Based on observations analysis, approximate values of buildings' settlement resulting from a deepened facility construction depending upon the condition of their structures with relation to closeness to a deepened facility and foundation pit excavation method are specified.
3. Foundation surface curvature is suggested as a criterion for existing buildings deformation evaluation during construction or reconstruction involving underground development.

5. LITERATURE

1. Recommendations on Examination and Monitoring of the Technical Condition of the Operated Buildings Located Near New Construction or Reconstruction Sites. The Government of Moscow, Moscow Architectural Committee, Moscow, 1998.
2. Construction Rules and Regulations 2.02.01-83 «Bases of buildings and facilities». Moscow, 1983.