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Assessing the influence of jet-grouting underpinning on the nearby buildings

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ABSTRACT

This paper focuses on the underpinning-induced ground movement due to jet-grouting. Jet-grouting technique can cause distortions as a result of an inaccurate processing sequence and/or errors made at different stages of work execution. The aim of this paper is to determine the minimum value of such movement on the basis of the findings obtained at two similar construction sites located in the Historical Center of Moscow, considering that the maximum value is usually unpredictable. Numerical simulation of the process of soil eroding agrees well with the observational data at the current stage. It was found that the minimum value of deformations (only settlement was considered in this study) due to jet-grouting is no less than 2–3 mm. By contrast, the negative scenario of deformation due to foundation underpinning is clearly demonstrated. Also, this paper provides some general solutions for excavation supporting system as well as for underpinning design.

1. Introduction

Before launching a project, a comprehensive geotechnical analysis needs to be conducted in order to find an appropriate design approach and to minimize the potential impact on the adjacent buildings and utilities. Usually, geotechnical engineers use analytical method and numerical simulation in association with their practical knowledge and skills to define the admissible deformations (Burland, 1995). The latest boom in construction has enabled engineers to gain considerable experience in analyzing the geotechnical situations and provided possibilities of comparison between predicted deformations and actual ones. Some analyses have also revealed negative occurrences which need further investigation so that they could be taken into account in the future projects, especially in the complex projects that require great accuracy. This may be achieved by conducting comparative analyses of the field observations with the predicted results obtained by advanced constitutive models (Boone, 2001; Finno et al., 2005). In particular, this kind of analysis allows further higher quality soil investigations and consideration of case histories in similar conditions. However, the main challenge is that there are still some aspects that we, as engineers, are unable to anticipate.

The issue of the geotechnical analysis precision is extremely important, and some research activities are being undertaken in Russia in general (Resin et al., 1996; Ilyichev et al., 2001; Yurkevich, 2004) and at NIIOSP particularly in this regard (Mozgacheva et al., 2007; Razvodovsky et al., 2008; Razvodovsky, 2011; Chepurnova, 2013). A summary of the most significant causes of failure versus their predicted values (Kolybin, 2008; Shishkin et al., 2010; Razvodovsky, 2011) is given in bar chart in Fig. 1. The 'error' bar in Fig. 1 is explained below in Section 3.

The construction of new buildings with deep underground infrastructure in urban environment often involves excavating retaining structures in the vicinity of the already existing structures. On the other hand, as the increasing population pressure drives the need for more infrastructures while simultaneously leading to occupation of larger surface space for residential and other types of developments being customary for major metropolises, the underground constructions will continue to flourish as the preferred solution for infrastructure provision especially for the parking spaces.

Jet-grouting is a well-elaborated technique employed in underpinning projects to minimize settlements and to provide both excavation support and load perception over the world (Burke, 2010; Pinto and Pita, 2010; Cihakova, 2013). The jet-grouting technique brought new sense to the conventional injection technology which seemed to be losing its popularity, and has become the greatest invention in the last two decades in the field of geotechnical engineering. This is especially the case for a new asset with several underground levels constructed in the Historical Center of Moscow.

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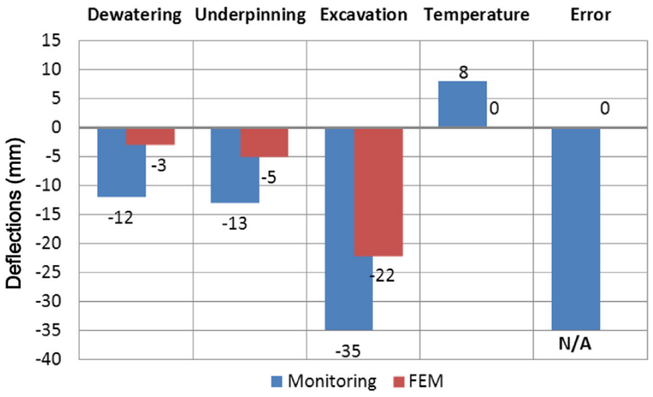

Fig. 1. Causes of failure at a construction site versus their calculated values, where '0' means that the value was not taken into account.

In this paper, some overview of the jet-grouting practical applications is presented. Emphasis is put on the perspective of two recent construction sites located in Moscow, and the analysis of the corresponding geotechnical aspects.

2. Technological settlements

While producing jet-grouting elements for underpinning the existing foundations, an unpredictable damage can inevitably occur. The knowledge of this damage is essential for the choice of jet-grouting technique for underpinning. Practically, a preserved building is affected by additional displacements (settlement or heave); in some cases, their values are two times higher than the admissible level. For this reason, the total settlement value can be assumed to be the sum of the predicted settlements by numerical modeling (S^i_{FEM}) and some unknown values related to general execution accuracy, technology, etc. This total settlement value is difficult to be estimated, and this feature of displacements can significantly violate the entire mode of deformation. However, for the majority of geotechnical projects, this situation tends to be quite common, especially when studying older urban environments (Shishkin et al., 2010; Razvodovsky, 2011).

Deformations, particularly settlements, have occurred owing to inaccurate process sequences, and have been appropriately termed as *technological deformations (settlements)*, S^i_{tech}, by the Russian specialists (Ilyichev, 2008). The definition appears to be widely accepted and correspondingly illustrated in Fig. 2.

The numerically predicted settlement, S^i_{FEM} (mm), of an adjacent foundation due to deep excavation and underpinning can be assumed to be

$$S^i_{\mathrm{FEM}} = S^i_{\mathrm{un}} + S^i_{\mathrm{exc}} + S^i_{\mathrm{load}} \tag{1}$$

where S^i_{un}, S^i_{exc}, S^i_{load} are the settlements due to the underpinning, excavation and the construction work, respectively (units are all in mm).

Whereas the total settlement at a site of the adjacent building we consider can be written as

$$\sum S^i = S^i_{\mathrm{FEM}} + S^i_{\mathrm{tech}} \tag{2}$$

According to example of a masonry building on three rows of strip foundation ($i = 1, 2, 3$) in Fig. 2, it is generally considered that

$$S^1_{\mathrm{FEM}} > S^2_{\mathrm{FEM}} > S^3_{\mathrm{FEM}} \tag{3}$$

but

$$S^{\min}_{\mathrm{tech}} < S^i_{\mathrm{tech}} < S^{\max}_{\mathrm{tech}} \tag{4}$$

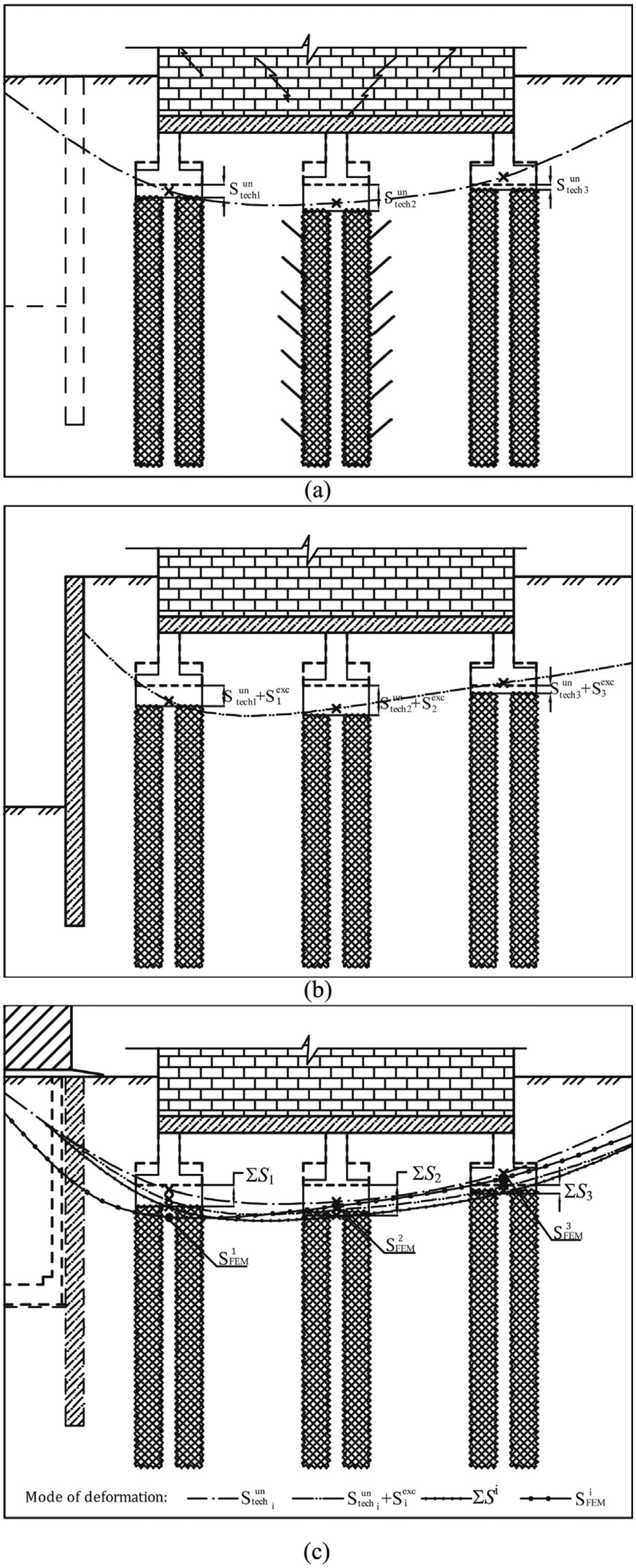

Fig. 2. Definition of the ground and foundation displacements due to the construction of a new building in vicinity of an existing one: (a) underpinning of the existing building foundations and the initial deformation mode ($S^{\mathrm{un}}_{\mathrm{tech}i}$, $i = 1, 2, 3$ – technological settlement of single strip foundation row); (b) progressive deformation due to the deep excavation activities; (c) construction completion.