

INTERNATIONAL SOCIETY FOR SOIL MECHANICS AND GEOTECHNICAL ENGINEERING



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.

Use of soil-structure interaction analysis for historical monuments preservation

L'emploi de l'analyse d'interaction sol-structures en conservation des monuments historiques

V.M. Ulitsky, A.G. Shashkin, M.B. Lisyuk
Institute of Geotechnical Engineering, Saint Petersburg, Russia

Abstract

Numerical analysis of historical monuments has been conducted using *FEM models* software which features various models of ground behaviour and of superstructure's response. The possibilities of solving physical and geometrical non-linear problems in 3D with several million of freedom degrees make the software an effective tool in preservation of the historical buildings, palaces, and monuments.

Keywords — *Soil-structure interaction, preservation of monuments, numerical analysis*

DISCUSSION

Numerical assessment of different risk factors and their combinations, as well as of their influence on 'structure-foundation-subsoil' system is an essential part of evaluation of historical monuments condition and design of the preservation methods.

Geotechnical engineers in Saint Petersburg developed the *FEM models* software which can accommodate modelling of 'structure-foundation-subsoil' system in 3-D setting utilizing various physical and geometrical non-linear models of ground and superstructure [1].

The *FEM models* software makes it possible to analyse building, foundations and subsoil as one system with the account of their interaction. The number of degrees of freedom for such calculations can be up to several millions. The software allows to model a building-foundation-subsoil system with all important structural elements on a usual PC over the timeframe acceptable to the designer.

The software features a 'problem solver' which creates the finite elements system solution matrix from matrices of individual finite elements and follows that by building up the solution procedure for sets of linear algebraic equations with several million of unknowns.

More than 20 historical monuments were analyzed with the help of *FEM models* software. Two very important monuments are discussed.

Stock Exchange on Vasilievsky Island spit. This is one of the most beautiful buildings in St. Petersburg. It was constructed in 1805. To identify the reason of the deformations and cracks of the building available historical data was explored, site conditions were investigated, the superstructure and foundation were carefully studied, dynamic background created by traffic was measured. On the basis of this data Soil-structure interaction (SSI) analysis has been conducted.

The analysis has made it possible to reveal the main reason of the building's deformations – non-uniform layer of soft clay in subsoil. The calculations results are in good

agreement with the monitoring data. It was found that there is no need in underpinning of the building.

Constantinovsky Palace in the suburb of Strelina. This palace is almost 300 years old. By 2000 the palace and its retaining structures were almost completely dilapidated.

SSI analysis helped to establish the main causative factor of the palace dilapidation – influence of frost heave and decay of timber piles. The design of retaining structures underpinning was based on the results of SSI analysis. The palace was successfully underpinned and reconstructed in 2003 by the Tercentenary of Saint Petersburg.

CONCLUSIONS

Soil-structure interaction analysis provides the following possibilities in preservation of historical monuments.

SSI analysis helps to establish causative factors responsible for the monument's deformations and deterioration. It provides a detailed information on 'structure-foundation-subsoil' system behaviour with account of different factors. These factors are: types and condition of historical foundations, soil properties and their variation in time, ground water level, type of historical structural elements and degree of their deterioration.

SSI analysis describes behaviour not only of foundations and subsoil, but also of the superstructure. It effectively describes the failure and deterioration mechanism of subsoil, foundations, and structural elements of the monument. SSI analysis is very essential for monuments preservation design in congested urban areas.

REFERENCES

- [1] V.M. Ulitsky, A.G. Shashkin, A.G. Shashkin, M.B. Lisyuk. *Soil-Structure Interaction: Methodology of Analysis and Application in Design*. St. Petersburg, ASV Publishers, 2003.