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Automated systems as a part of geotechnical monitoring in construction and operation of transport tunnels

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Abstract

The safety of mining and tunneling operations considerably depends on availability of the most reliable and timely information on the stress-strain behavior of the "tunnel lining – containing rock massif" system and ground surface. Such information may be received by means of geotechnical monitoring using automated systems. The tasks to be solved as a part of the geotechnical monitoring are related to the assessment of the state of structural units to be built, containing rock massif, ground surface and buildings that fall within the construction-affected area. The need for preserving the buildings and facilities on ground surface gives the priority for the use of automated systems when determining the deformation of soil body starting from the outline of underground facilities and up to the ground surface. The obtained monitoring results allow, in the process of construction, making adjustments to the technological parameters of the mining and tunneling operations, to the parameters of the support setting and the tunnel lining construction technology, developing recommendations how to mitigate adverse effect on the environment. An example of the successful integration of the operational monitoring in an automated process control system is the tunnels of the Adler – Alpica Service section. There are 3 motor-road tunnels and 6 railroad tunnels in this section. During the construction, the lining of all tunnels was provided with control and measurement instrumentation to determine the stress-strain behavior of the "tunnel lining – containing rock massif" system and the seismic monitoring. The primary processing of the controlled parameters is done directly in the tunnels, then they are sent via a fiber-optic network to the geotechnical monitoring server located in the Operations Control Center. After the final processing, the data bank is updated. When the controlled parameters exceed the acceptable levels, an operator has the possibility to see, in the on-line mode, a specific location on the route, from where a signal is generated.

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1. Introduction

The construction of the underground facilities based on accepted practice is related to a change in the stress condition of the containing rock massif, which has effect on the safety of mining and tunneling operations, the stability of the "tunnel lining – containing rock massif" system, and, as the final result, on deformations of ground surface and current buildings. It is specifically of high priority to have the information on the qualitative and quantitative effect on the environment in constructing the subway transport tunnels in major cities, for example, as in Saint Petersburg where the historical center accommodates a large amount of the buildings and structures of the cultural value that are monuments of architecture.

In accordance with the laws of the Russian Federation, an integral part of the construction technological process is the geotechnical monitoring, which allows receiving, in the on-line mode, the information on the conditions of the "tunnel lining – containing rock massif" system, on the force distribution in the three-dimensional structures to be constructed, assessing the adverse effect of mining operations on the safety during the construction and timely preventing emergency situations.

The monitoring tasks [1] are assigned separately for every underground facility depending on the environmental effect assessment of its construction. The geotechnical tasks are solved by means of geophysical, geomechanical and geodetic methods. The direct and indirect methods of determining the controlled parameters make it possible to forecast, to the sufficient accuracy, the engineering and geological conditions ahead of the tunnel faces, to determine the qualitative and quantitative parameters of the stress-strain behavior of the "tunnel lining – massif" system, to determine the actual deformation-and-strength properties of the containing rock massif from the tunnel outline up to the ground surface, etc. The problems to be solved allow receiving the information on every kind of the effect on the environment individually and they complement each other to eliminate a possibility of the incorrect interpretation of the monitoring results.

The following problems are being solved by the automated systems as a part of the geotechnical monitoring during the construction of the transport tunnels:

- control of the stress-strain behavior (SSB) of the tunnel lining;
- control of pore pressure in the containing rock massif;
- control of deep deformations in the containing rock massif from the tunnel outlines to the ground surface;
- control of deformations of the ground surface and current building using robot-aided tacheometers;
- instrumental monitoring of buildings and facilities.

To control the stress-strain behavior of the tunnel supports and lining, the control and measurement instrumentation is used that is factory-installed at the manufacturers' for pre-fabricated structures or during the installation to the design position on site for framed or cast-in-place structures.

The accepted deformations on the tunnel outline move towards the ground surface. As early as at this stage, it is possible to make the quantitative estimate for the future deformations on the surface. At the design stage, a geotechnical forecast is made together with the determination of a subsidence trough. Based on the results of the geotechnical calculations, the deformation values can be compared from the tunnel outline to the ground surface. If the actual deformations of the containing rock massif are determined at the tunnel outline, then an estimate can be made regarding the ground surface deformations.

Extensometers are used to determine the rock massif deformations. The use of the deep extensometers made it possible to solve two important problems in the construction of the escalator tunnels by means of TBM (tunnel-boring machine) in the historical center of Saint Petersburg in the conditions of the compact urban development [2,3]. The first problem is technical. It is an estimate of the need and time for the beginning of compensation grouting into the bedding of the buildings to prevent hazardous deformations from occurring. The second problem is scientific. It is the obtaining of the regular pattern of the deep deformation development with time in accordance with the specific features of the tunnel boring technology. Based on the regular patterns obtained, the major factors were determined that contribute to the formation of the rock massif displacements in the near-outline zone and the recommendations were worked out regarding the adjustments of the construction technology parameters. With