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Lithological Profiling of Rocky Slopes Using GeoReader Software Based on the Results of Ground Penetrating Radar Method

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Abstract

The paper presents the Ground Penetrating Radar (GPR) technique for the survey of deforming rocky slopes of the railway subgrades. The developed software GeoReader allows the delineation of the boundaries in soils, which compose the slope, and definition of the possible slip surface. We have summarized the results of the use of the technique in certain sections of the Far Eastern Railway.

The current level of development in the sphere of geo-survey does not allow for the complete abandonment of costly and labor-intensive conventional survey techniques, such as boring. Nevertheless, in the near future geophysical methods will be able to provide complete information on the object of investigation.

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Keywords: ground penetrating radar, common-offset reflection survey, common-midpoint method, subgrade;

Introduction

Large amounts of work on the reconstruction of operation lines are being conducted in the Eastern polygon of the railways of Russia. Among others, reconstruction resolves the tasks of extending the station tracks, laying second tracks and increasing curve radiuses. These jobs involve widening of the subgrade, displacing the center line

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of the track and determining the design parameters that will ensure the stability of the newly formed slopes. High quality engineering geological survey results are crucial for laying out such jobs.

Unfortunately, the performance of high quality survey jobs on an operating railway track is very complicated. Some sections do not have a developed motor-road network which sometimes makes delivery of the equipment and machinery to the work site impossible and, consequently makes implementation of the work tasks impossible also.

The ground penetrating radar survey offers the possibility of solving some of the problems, emerging in the process of the survey. Portability, high speed and low labor cost are the main advantages of the geophysical methods in comparison with the traditional geological-engineering survey methods. In our view, geophysical methods do not cancel traditional ones, but complement them and allow specialists to provide a higher quality of results.

Ground penetrating radar (GPR) is a geophysical method for the non-destructive detection of ground layers by electromagnetic waves. GPR measures the two-way travel-time of the reflected electromagnetic wave propagating through the ground layers. The thickness of these layers is estimated after the determination of the EM velocity, *V*, propagation which, in turn, is controlled by the relative dielectric permittivity ε_r [1]:

$$V = \frac{c}{\sqrt{\varepsilon_r}} \tag{1}$$

where c is the EM velocity in vacuum, 0.3 m/ns.

GPR has been proved to be an effective non-destructive tool for solving a variety of engineering tasks [1]. The benefits of the method include development of a continuous GPR section, high efficiency and low cost. However, the complexity of the processing of the results is dependent on the experience of the engineer, which may significantly reduce the accuracy.

Materials and methods

There are very few papers dedicated to the use of the ground penetration radar method in the survey of unstable rock slopes. The theoretical basis of the GPR method from the point of view of resolving this task was given in the work of T. Toshioka [2]. Research [3] conducted within the frameworks of the research project "Landslide Hazard Assessment and Cultural Heritage", describes the employment of the GPR method when monitoring landslides in Austria. The paper [4] is devoted to GPR surveying of road failures as they relate to filling slope stability (using in particular a three-dimensional survey method). This paper describes ground penetrating radar method as an efficient, non-destructive and cost effective tool in characterizing the nature of slope stability problems as they relate to road construction. The work of British scientists [5] gives an example of using GPR methods for studying the influence of badger setts on the stability of slopes prone to landslide. The research paper [6] gives a theoretical basis for forecasting landslide deformation based on the interpretation of the amplitude-frequency characteristics of the returned GPR signal.

The practice of employing LOZA GPR units produces good results under very different conditions [7, 8]. Antennae with a carrier signal frequency of 100-150 MHz are used under common conditions. In order to increase the depth of the cross-section, the radar is equipped with antennae with frequencies of 25 and 50 MHz. We used the LOZA-N GPR unit with a 3.0 meter long 50 MHz antennae. The time-base was 1024 ns and the sampling frequency was 1 GHz. The antennae are not cable-connected which allows the performance of GPR measurement to determine the velocity of wave propagation in ground layers.

The research described in the paper is based on the results obtained by the research workers of the Far Eastern State Transport University [9, 10, 11].

Two groups of profiles are assigned and performed on the research object. The cross-sectional profiles are assigned from the base of the slope upwards. They are usually used to determine the possible slip surface on deforming or potentially dangerous slopes. The longitudinal profile is assigned along the slope or along the axis of the existing railroad. These profiles are essential for detecting the delineation of a landslide ground massif and