Research of Road Pavement Survey Process Using Georadiolocation

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Abstract. The authors of this paper carried out a survey of road pavement and analyzed the need for such survey. The research was conducted using an operating facility as an example. In this paper, the decisions are grounded, the survey stages are described. Mobile methods of non-destructive control for road structures diagnostics are of particular importance at the moment. As a part of this research, the tasks related to determining the thickness of structural layers, the uniformity of materials, and the detection of voids under the auto-road surfacing were solved. The results of diagnostics and quality control of road-building works, as well as georadiolocation (GPR) technologies, are considered in detail. The results of tests of different GPR models and the economic efficiency of their use in road industry are described. The test results are illustrated with radarograms. The result of the GPR study of an auto-road section is presented. The results of the work showed that GPR research methods as a part of the survey allow reasonably planning and carrying out measures to eliminate and prevent various types of subsidence and road surfacing destruction, as well as to assess the nature and extent of the negative processes development. With the timely elimination of these problems, major damage and subsequent costly repairs can be avoided. Having compared the most significant factors, the authors make the conclusion that the method under research has got advantages, which are high efficiency and high capacity.

1. Introduction

Auto-roads experience strong load impact, and that is why destructive processes are typical here [1]. For the correct application of the technology and the amount of effort when doing the diagnostic work, as well as for the efficient use of funds, it is necessary to know exactly all the parameters of each road pavement layer.

Drilling the existing road bed and pavement in the traditional way is a time consuming, costly and inefficient process. It is believed that for an objective assessment of the road pavement it is enough to drill one well per 500 m of the road.

However, as practice shows, this is certainly not enough, as the road pavement structure can be very heterogeneous, so it is obvious that the random sampling of cores cannot possibly characterize the pavement’s condition in an arbitrary section. Therefore, during the survey it is advisable to use the modern express method [2], which allows performing a large amount of work within a short period of time and to obtain reliable results - GPR scanning.
The purpose of this research is to test the hypothesis that on existing roads, using GPR, you can determine the thickness of the road pavement’s structural layers and the location of utility lines, as well as to assess the homogeneity of materials and the degree of their destruction.

The main objectives of this research include the assessment of the researched objects’ structural performance, basing on their internal structure, geometrical dimensions and the information about their physical condition.

The engineering tasks fulfilled using geophysical methods are elementary, because the auto-roads under study, as objects of scientific research [3], are governed by the existing regulatory documents. The results of the research showed that the actual parameters do not always coincide with the design and regulatory data.

Consequently, the use of geophysical methods is of great importance, when conducting the survey of the hidden parts of auto-roads, inaccessible to instrumental examination.

2. Materials and methods
It is common to conduct geophysical research in combination with the drilling of wells - cores. With the right approach to geophysics, using the latter as a method of obtaining exact information about the geological structure between two cores, you can get the results that reflect the actual situation as close as possible. The results obtained using geophysical methods show the true picture only to some extent. The depth of occurrence and the thickness of layers are accessed with a certain accuracy, which depends on the amount of geological information about the object under study, the accuracy of measuring instruments and many other factors.

The set of reflected signals is a radarogram, the analysis of which allows obtaining information about the object’s structure.

The authors used the wave method of geophysics – GPR in their work, and this method’s main aim is to research the environment’s response to the emitted electromagnetic field and to access the thickness of the road pavement’s layers.

Before carrying out the survey of the road pavement using GPR methods, some planning work was done, which included the analysis of the area’s climatic characteristics, the existing design projects and the road sections’ profiles; certain tasks were set, with detailing the necessary prerequisites for the successful implementation of the survey and the timeframe for this work. The methods of work were described - the order, the length of the road, the set of equipment for doing the research was selected, basing on economic and practical considerations. Before conducting the survey on site, a set of GPR equipment was calibrated for the start of the work. GPR setup and data accumulation were carried out in accordance with the passport for this equipment.

3. Results
As a result of surveying the transport and operational status of the road section, the traffic way’s surfacing was found to be in poor condition.

When surveying the current state of the auto-road surfacing, the following defects were identified: transverse cracks, wheel tracking, dimple rupture (each damage has got the cover area over 0.09 m² in and the depth up to 5 cm), see figure 1. In the existing five artificial culverts the survey revealed: the shift of pipe rings in horizontal and vertical planes; the destruction of portal and wing walls on the inlet and outlet culverts; the destruction of stabilizing structures up to the end of the wing walls made of monolithic concrete, or such structures’ absence. With the help of GPR, voids under the road surfacing were detected, which directly influence the thickness test of structural layers and the homogeneity of materials of the road under study.
Figure 1. Existing defects on the section of auto-road under study

The depth of sensing the area under study was 2 meters, which allowed determining the thickness of the road pavement layers with sufficient accuracy, and identifying the internal destruction of the asphalt roadway - revealing the density of its structure.

The radarograms obtained at the analyzed object - in the field, were processed using specialized software, see Figure 2.

Figure 2. Determining the thickness of the road pavement’s structural layers and the internal destruction of the asphalt roadway, using a GPR

The GPR system made it possible not only to find the utility lines, but also to determine the location of faulty sections of the road under study, to detect the voids or areas with high soil moisture.

In the course of this research, latent defects of the roadbed were revealed, see Figure 3. GPR surveys showed that floodwaters get into the lower part of the roadbed, as the integrity of the culvert pipe is broken. Only due to GPR and the use of non-destructive methods gaps between walls (the side walls of the pipe turned out to be located above the level of the tray) were found, with vertical cracks in them. The cause of washing out in the lower part of the roadbed was also determined.

Figure 3. The result of surveying the culvert pipe
In the course of the engineering survey conducted using a GPR, it was found out that the road pavement of improved lightweight type has got the following structural layers: the underlying layer of sand; the base of crushed stone; the asphalt surfacing with a certain thickness.

In this paper, not only the thickness of the road pavement was determined, but also the degree of compaction of the road-building materials that constitute it. Measurements were made in order to analyze the moisture content in the material and the degree of its compaction, and the obtained values were used to estimate the degree of compaction of the layers under study. The complex dielectric constant of the materials constituting the road pavement’s layers was calculated using the formula (1), [4]:

\[ e = e' - je'' \]  

(1)

where \( e' \) is the real part connected with the polarization of the dielectric, as affected by the applied field; \( e'' \) is the imaginary part connected with the finite conductivity of the dielectric \( j \).

The more air, the lower the dielectric constant, and vice versa. E.g., the dielectric constant of air is equal to one, of water – to 81, of stronger materials – within the range from 4 to 10 [5]. In the calculations the real part was used, since, as affected by the applied field, it is directly connected to the polarization of the dielectric.

In the road pavement materials under study, the dielectric constant was influenced by moisture, i.e. taking into account the rising of underground water, the road pavement layers were over wetted. As a result, the dielectric constant increased fivefold and sometimes tenfold. So, an increase in moisture concentration in the weak materials of the road-pavement can lead to their destruction.

Taking into account the identified defects in the surfacing, and their absence in the other layers of the road pavement, as found out using GPR scanning, the decision was taken to remove the top surfacing layer by cold milling, and then - to put over layers of asphalt.

The results of the work showed that the GPR survey process allows reasonably planning and carrying out measures to eliminate and prevent various kinds of road surfacing damage.

4. Discussions

The roadway wears out due to many factors that influence it. Among such factors are: repeated load, natural factors, violations of construction technology, and the impact of moisture on the roadbed and roadway. In the course of analysis, the effect of these factors on the road was evaluated, as a consequence of the occurrence of stresses and deformations, which eventually lead to the destruction of the auto-road as a whole [6, 7].

The accumulation of defects caused by deformations is a permanent and inevitable process. Such accumulation occurs unevenly, and as a result of it, some sections of the auto-road wear out earlier than the standard operation time.

Due to conducting surveys of auto-roads using GPR technologies, it is possible to determine the soil-hydrogeological conditions in the area; to define the underground water level, the location and size of utility lines; to assess the impact of auto-roads on the environment and other parameters.

The scientific approach to the identification and detection of local defects, considered within the frames of this paper, substantiates the efficiency of the use of GPR technologies in road construction, and proves that the obtained research results are of general character. This research proves the need to develop the scientific methods of conducting GPR surveys. The scientific argumentation of latent defects occurrence in road structures will allow going to a new level of efficient repair work in road industry. GPR technologies are highly productive and environment friendly methods of non-destructive control in road construction. The use of such technologies on auto-roads will lead to a reduction in construction and operational costs, and will increase the roads’ reliability.
5. Conclusions
The main conclusions of the work are as follows:
1. The scientific support of projects using GPR methods will allow controlling the density and moisture level of the laid road-pavement materials, as well as identifying their latent defects.
2. The results of the research are a qualitative assessment of the roadbed condition – the internal defects of the roadbed, and a quantitative assessment of the roadbed status - the location of such defects.
3. The analysis of the road pavement materials dielectric constant allows increasing the accuracy of evaluating the thickness of structural layers.
4. The research done in this area has shown that the use of GPR technologies for surveying auto-roads makes it possible to reduce the time required to estimate the thickness of the layers and their moisture level, and as a result - to predict a possible loss of the roadway stability.
5. In road industry the use of GPR is multi-faceted, the possibilities offered by GPR technologies have not been investigated yet.

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