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# Study of Pavement Anomalies Using GPR of OKO-2 series

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**Abstract**. This paper reflects the main aspects of the methodology for studying road pavement structures using non-invasive research methods. The technology for diagnosing highways using OKO-2 georadar complexes has been studied. Non-invasive methods are based on the principle of radar with the generation of electromagnetic high-frequency wave pulses through pavement structures. The scientific work was carried out within the framework of grant funding for a scientific and technical project on the topic: AP19680361 - "Development of computing technologies for diagnosing road pavement of highways." Based on the analysis of radargrams and instrumental examination of highway anomalies using mathematical methods, it is planned to determine numerical algorithms using the theory of ill-posed problems, mathematical apparatus: equations of mathematical physics, optimization methods and the theory of difference schemes. This work is of scientific and practical interest for improving the methodology for georadar inspection of highways.

**Key words.** Mechatronics of georadar research, Ground penetrating radar, OKO-2 device, road pavement, diagnostics, anomaly, algorithm, transport and operational state, interpretation of radargrams, images of road pavement structures, radar principle

Introduction. Timely diagnosis of road pavement structure is the main stage in the inspection of highways. RSE on the PCV "National Center for the Quality of Road Assets" in its activities on road asset management carries out diagnostics and instrumental examination of many thousands of kilometers of roads.

The methodology for diagnosing highways using Oko-2 georadar equipment is described in [1-8]. Analysis of georadargrams allows for high-quality diagnostics and visual assessment of the condition of roads during operation, without opening the structural layers of the road pavement. The result of non-invasive diagnostics is the identification of abnormal sections of roads that do not meet regulatory requirements for their transport and operational condition. Based on georadar data and the results of a highway survey, the types and composition of the main works and activities for maintenance, repair and reconstruction are determined in order to improve their transport and operational condition to the required level.

Research methods. The operation of the OKO-2 georadar is based on the principle of radar - electromagnetic high-frequency wave pulses passing through road pavement structures from several centimeters to several meters, depending on the parameters of the antenna unit, make it possible to create detailed images of road pavement structures displaying anomalies. By road pavement anomalies we mean surface defects in the form of holes, potholes, cracks, subsidence, cavities and voids formed during operation.

Table 1 shows the main technical characteristics of the antenna units of the OKO-2 georadar complexes with antenna units (AB-400R, AB-1000R).

**Table 1.** General technical characteristics of OKO-2 antenna units

| Antenna unit AB-400R | Antenna unit АБ-1000P |
|---|---|
| Work with a gap of up to 30 cm | Work with a separation of 30 cm |
| Center frequency 400 MHz | Center frequency 1000 MHz |
| Sounding depth 3 m | Maximum probing depth up to 1.5 m |

The principle of operation is based on the phenomenon of reflection of electromagnetic waves from surfaces on which electrical properties change. The main parameter of the medium is its dielectric constant (□). During GPR sounding, the GPR moves along the surface being surveyed or with a slight separation (depending on the type of antenna unit). An electromagnetic wave in soil (or other research medium) is reflected from the boundaries of layers that have excellent dielectric properties. The GPR consists of a transmitting (source) and receiving (receiver) antenna. The source emits an electromagnetic wave of a given frequency, and at each point of the distance a trace is recorded - the dependence of the signal amplitude on the time of arrival of the reflection. A set of traces along the entire distance makes up a radargram. The first reflection on the radargram is called a direct wave (forward signal). The direct wave is in most cases the same for all profile traces (Figure 1). It is determined by the design of the antenna and the surface of the profile. Other waves on the radargram are waves reflected from any boundaries of layers or local objects in the soil (or other research environment).

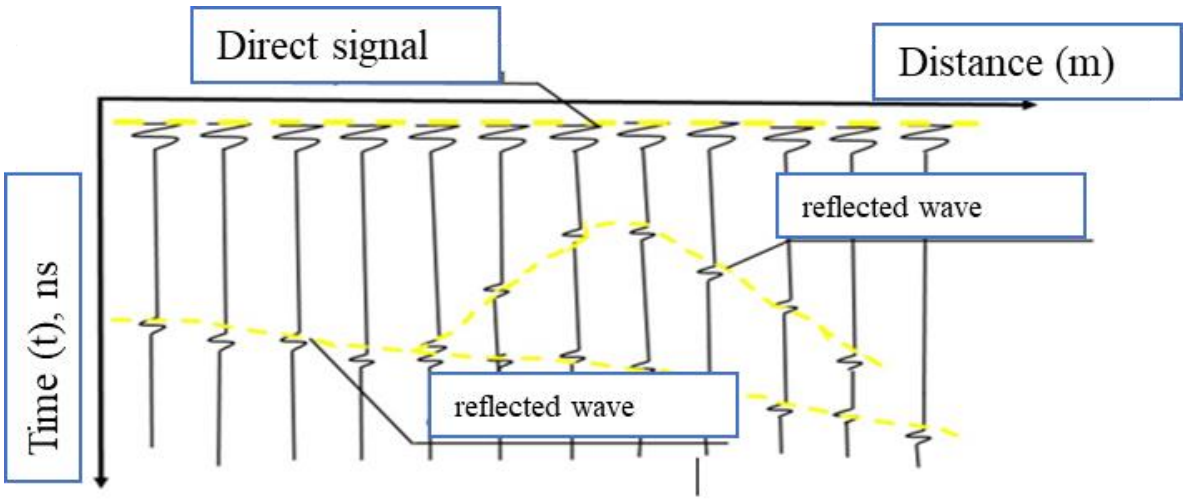


**Fig. 1.** - Schematic representation of the principle of the ground penetrating radar method

Reflected signals from local objects on the radargram are displayed in the form of a characteristic hyperbola (Figure 2). The object from which the reflected wave originated is located at the point corresponding to the vertex of the hyperbola. Application of the georadar method to highlight the boundaries of soil layers, detect local objects, etc. perhaps due to differences in electrical properties. The main properties are electrical resistivity ρ and dielectric constant ε.

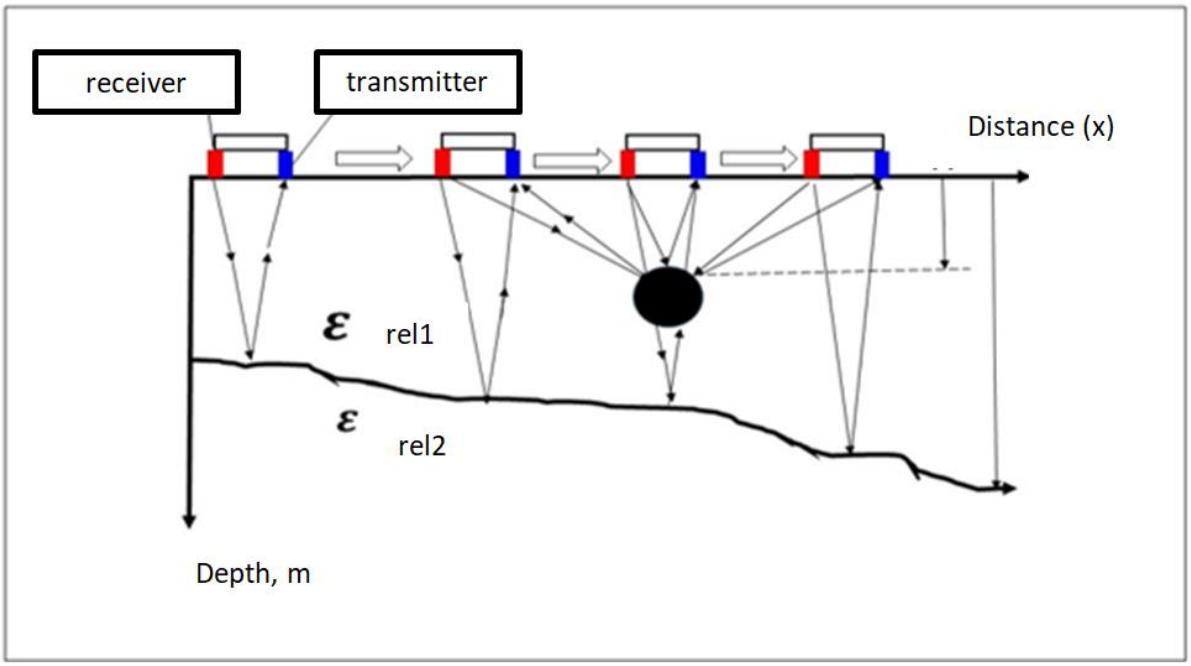


**Fig. 2.** - The principle of the formation of reflected waves from the boundary of two media and a local object

Specific electrical resistance determines the attenuation of the electromagnetic field in the medium, and, consequently, the depth of the study. The lower the attenuation, the greater the depth the field will penetrate, that is, we will receive a response from rocks at greater depths. Almost all substances, except pure metal, can be classified as dielectrics with finite conductivity. In this regard, the concept of relative dielectric constant of a substance was introduced.


**Fig.3.** - Mobile road diagnostic laboratory with installed Oko-2 ground penetrating radars, with AB-400R and AB-1000R antenna units

Scientific results. The software supplied with the device uses an engineering method for interpreting radargrams, which consists of comparing the obtained radargrams with a database of known species. Experimentally established or physically based formulas for determining the geoelectric section are also used.

Preparatory work for the Oko-2 georadar for inspecting automotive work includes: 1. installation of the antenna unit using a universal suspension on the vehicle; 2. mounting the displacement sensor on the rear wheel of the car; 3. selection of antenna unit and sounding parameters.

The georadar series: "Oko-2", with the antenna unit AB-400R and AB-1000R, is intended for diagnostics of road surfaces (highway routes). This modification allows you to take real data at a travel speed of 60-80 km/h. The device determines the thickness of the layers of the road surface, during repeated research it determines changes in the boundaries of the layers, and issues recommendations to conduct additional research in the zone of decompaction of the road pavement.

Interpretation of georadar data - obtaining the most complete information about the structure of road pavement, expressed in the form of geological sections: determining changes in the thickness of the layers of road pavement; determination of the soil moisture zone; determining the spatial outline of the bottom of the layers; determination of groundwater infiltration paths; identification of defects made during road works; release of foreign inclusions in the soil.

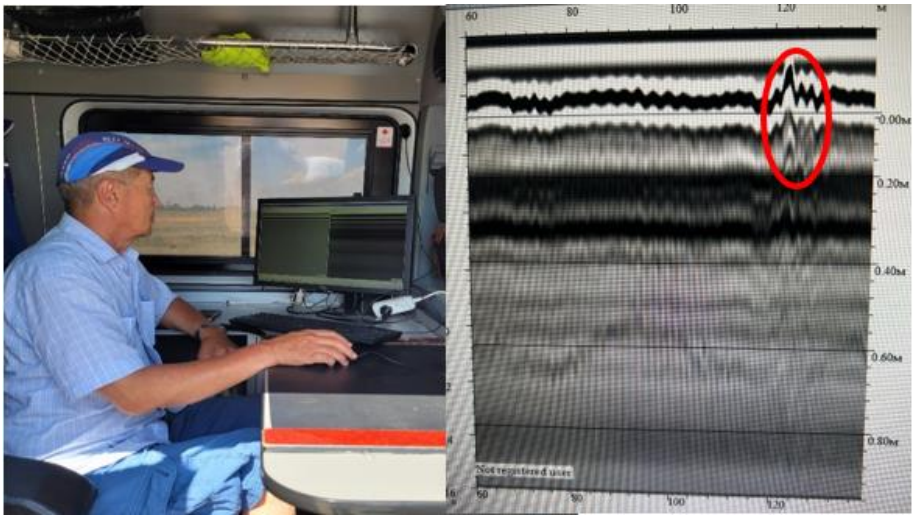

**Fig. 4.** - Radargram with an anomaly of pavement defects

A georadar survey of the subgrade, base and road surfaces was carried out using the Oko-2 series device (AB-400R and AB-1000R) with the following results:

section of the road being repaired under the project “Major repairs of the road “Eastern Bypass of Astana - Art. Saryoba", km 0-23 and km 23-41.

During the departure, a georadar measurement was carried out using the Oko-2 device (AB-400R and AB-1000R) on the laid structural layers of road pavement:

- the bottom layer of the base is made of crushed stone-peved mixture C4;
- the top layer of the base is made of crushed stone-sand mixture C6, treated with Portland cement M-400 in an amount of 7%.
- the bottom layer of coating with hot coarse-grained porous asphalt concrete Grade 2.

Similarly, a section of the R-2 "Astana – Korgalzhyn" highway, km 49-51, was examined.

**Fig 4.** - Surveying with ground penetrating radar anomalies and defects in the road surface of the R-2 "Astana – Korgalzhyn" highway, km 49-51

Georadar measurements using the Oko-2 device (AB-400R and AB-1000R) on the section of the R-2 Astana-Korgalzhyn highway with the entrance to the Korgalzhyn Nature Reserve were carried out in places where there were obvious defects and anomalies - destruction and potholes on the surface and base of the road.

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