Nondestructive quality testing of concrete and asphalt concrete pavements

A I Potapov, A I Shikhov and E N Dunaeva
St. Petersburg Mining University, 2, 21 line of Vasyievsky Island, St. Petersburg, 199106, Russia
E-mail: shihov-gol@mail.ru

Abstract. The technical level of the applied methods and controls has an impact on the result of construction and installation works. One of the main tasks of contractors in the process of paving is to quickly determine the parameters of asphalt pavement. The quality of the asphalt pavement device allows you to increase the service life and reduce the cost of repairing road surfaces. A number of methods and means of nondestructive quality testing of concrete and asphalt concrete pavements are considered. Some characteristics of defects of concrete and asphalt concrete pavements are given. The main attention is paid to ground-penetrating radar methods, eddy-current, radiation and acoustic, also the devices implementing these methods are considered.

1. Introduction
Nondestructive physical methods and means of testing are widely used in the practice of quality testing of materials and products with the greatest use of them in testing products and structures made of metals [1-5].

However, it is not possible to use these methods for nondestructive testing of defects in concrete and asphalt concrete pavements due to the specific properties of concrete and asphalt concrete, mainly due to the high heterogeneity of the structure of these materials.

Despite the recent appearance of a large number of materials used in the construction of highly loaded surfaces, concrete (asphalt concrete) pavements still remain basic. But like every material, they have a number of shortcomings that are associated with the characteristics of production, composition, physical properties and dysfunctions of production technique.

The main defects arising in the operation and production technique of concrete (asphalt) pavements are given in Table 1.

All these and other defects should be detected and then eliminated.

Existant diagnostic methods allow one with greater or lesser accuracy to control the characteristics of concrete (asphalt concrete) pavement and the development of various defects in them, as well as to realize their certification in real time.

Next, several methods and instruments for nondestructive quality testing of concrete (asphalt concrete) pavements will be considered, also some of their advantages and disadvantages will be shown.
| Defect type                              | Short description                                                                 |
|-----------------------------------------|-----------------------------------------------------------------------------------|
| Dusting and raveling of the coating surface | With insufficient strength of the concrete (asphalt concrete) pavement, silica dust forms on the surface, which is deposited on all surfaces during operation |
| Delamination                            | With significant fluctuations in temperature and humidity, delamination can occur to a depth of 3 mm |
| Steam blow                              | With premature compaction at a depth of 1 mm to 3 mm, large pores, filled with air or water, may form |
| Popouts                                 | When alkaline extenders are not properly used, popouts with a size of up to 50 mm appear, besides the process of origination is quite long |
| Cracks                                  | In case of dysfunction of the technology of laying concrete (asphalt concrete) pavement or under the influence of external adverse factors, cracks may form in which water, salts and other corrosion enhancing substances collect |

2. Ground-penetrating radar method

This method is based on the reflection of electromagnetic waves from the boundaries of inhomogeneities in the medium under study, at which the electrical properties — electrical conductivity and dielectric permittivity — change skippingly.

The ground-penetrating radar emits electromagnetic ultra-broadband pulse signals that propagate in the studied medium, then, they are being reflected from objects and layers and received by the antenna, amplified and converted into a digital code for further analysis of the data obtained on the computer.

Ground-penetrating radar tasks are divided into two groups.

The first group is structural tasks (determination of the geological structure of the soil environment) in which a layered medium with constant electro physical parameters inside each layer is chosen as a model.

The second group is searching tasks (search for local inhomogeneities, communications, mines) in which a layered medium with local inhomogeneities in the form of a cylinder, sphere or ellipse is chosen as a model.

There are two main technologies of the GPR surveying: the GPR profiling and the GPR sounding.

During the GPR profiling, a profile is planned, which is then passed by an operator with a ground-penetrating radar, while the antennas of the receiver and radiator (transmitter of the ground-penetrating radar) are being at a fixed (as a rule, by length of antennas) distance from each other.

During the GPR sounding, the distance between the antennas gradually increases. At the same time, either the position of the GPR axis with simultaneous separation of both antennas in different directions, or the position of the transmitting antenna can remain unchanged.

There is the concept of resolution capability. It is the minimal size of inhomogeneity that can be detected on the layer (in depth or horizontally), which is determined according to the wavelength of the sounding signal (practically, to the center frequency of the GPR antenna) and the average velocity of signal propagation in the medium.

The processing of the results of the GPR surveying is reduced to the generation on the radargram of useful waves reflected from the boundaries and from local inhomogeneities.

Depending on the characteristics of the concrete (asphalt) pavement, the type of antenna assembly is selected as part of the GRP “OKO-2” of scientific-productional centre GEOTECH, which can be mounted on the vehicle (Figure 1, Figure 2). It is easy to notice that this method allows monitoring in real-time sufficiently large surface areas, which can be multilayered. The advantages of this method include the noncontact method of control, in contrast to the ultrasonic control, for example. However, one of the main disadvantages of this method is the incorrect presentation of the results, which
complicates their interpretation, for example, measuring the depth of the test object (Figure 3), and also high dependence of results from electromagnetic interference.

During the roads condition analysis, the GPR method is used in the following ways:
- surveying of subgrade soils of roads and its foundation (quality control of a new subgrade construction, including the control of hidden work; monitoring of the foundation settling; searching for weakened and watering zones; testing the depth of the groundwater level, the permafrost soils, etc.);
- surveying of pavement layers (determination of the boundaries and depth of layers; assessment of the homogeneity of road-building materials, flooded layers of pavement);
- surveying of asphalt pavement (testing layer depth, the presence of cracks, inhomogeneities).

This method of nondestructive testing is considered in more detail in our work [6].

3. Eddy-current testing method
This method is based on the dependence of the amplitude, phase, transient characteristics and frequency spectrum of the exciting currents in the product; its structure and size, physical and mechanical properties and denseness of the material, distance to the detector, frequency and rate of stirring, including vibrations.

For nondestructive depth testing of the concrete (asphalt) pavement, OOO “Introplus” has developed Stratotest 4100 (pavement depth gauge). This apparatus is based on the eddy-current principle of operation. "Measuring reflectors" with a sticky layer attached to the base before road carpets laying. Sheets of aluminum foil, used as "measuring reflectors", have a sticky layer for attachment to the substrate on one side. After laying the pavement, the "reflectors" work as checkpoints for the detector of the apparatus (Figure 4).
4. Radiation testing method

This method is based on the reducing or reflection (backscattering) of ionizing radiation. The radiation that passes through the measured material contains information about the depth, then, it is being registered by a radiation detector. Next, an electrical signal that is proportional to the radiation intensity enters the meter circuit from the detector.

Apparatus Troxler 4640B which is used to control the density of concrete (asphalt) pavement was based on this method (Figure 6).

Figure 5. Eddy-current pavement depth gauge Stratotest

Figure 6. Radioisotope apparatus Troxler 4640-B for monitoring the density of concrete (asphalt) and cement concrete layers 2.5–10 cm in depth.
That eliminates the influence of layers located under the asphalt concrete layer, which is very important because the work is carried out according to the surface measuring scheme: the capsule with the source and the counter register are located on the surface. In order to achieve independence of the measurement result of the density of the thin top layer from the density of the underlayers, the apparatus developers used 2 systems of Geiger-Muller counters, one of which measures the reflection of gamma radiation within the upper part of the medium under the detector, and the other measures the total reflection within the upper and bottom parts. It turns out that it is possible to estimate the average density of the material in the upper thin layer by the difference between them.

The use of radioisotopes during measurements imposes certain restrictions on the use of the apparatus itself. All of them are related to the safety of the flaw detector operator himself.

5. Acoustic method
This method of nondestructive testing is based on the property of acoustic waves to reflect differently from objects of different densities, as well as from the boundaries of different medium. The method is so extensive and multifaceted that it is impossible to describe all possible options and methods of control in a single article, therefore, we give an assessment only to some of the most common appliance.

In most cases, speaking of acoustic control, mean an ultrasonic method. Existing devices use different methods of obtaining information about the object of control, which can be divided by excitation methods, reception and parameters of the ultrasonic wave, as well as methods for interpreting the results obtained.

Ultrasonic low-frequency flaw detector A1220 MONOLIT (Figure 7) is designed for solving problems of thickness gauging and flaw detection of complex materials such as concrete, mountain stone, asphalt.

![Figure 7. Ultrasonic flaw detector A1220 MONOLIT](image)

It allows for testing by the echo method with one-way access to the test object using body waves. Another device is presented in Figure 8.
Ultrasonic tomograph A1040M POLIGON is a multifunctional device that provides solutions for non-destructive testing of concrete using the low-frequency (20-100 kHz) ultrasonic range and tomographic methods of signal processing.

It is designed to visualize the internal structure of products and structures made of reinforced concrete and stone with one-way access to them in order to search for foreign inclusions, voids and cracks inside these materials, as well as to determine the state of the power reinforcement in reinforced concrete.

These and the vast majority of acoustic non-destructive testing devices use ultrasonic body waves, which imposes certain restrictions on their use, for example, the inability to control large areas and surface lengths in real time, therefore using bending waves (Lamb waves) to control concrete (asphalt) pavements seem more promising.

Possessing all the advantages of ultrasonic radiation, Lamb waves have additional characteristics, the use of which will expand the acoustic method. These include a large propagation distance compared to body waves due to the fact that they diverge in two directions and due to this the amplitude of Lamb waves decreases proportionally to 1/√R, and not 1/R (where R is the distance to the radiation source) for body waves, there is also no limitation on the material of the test object.

Many commercially available instruments can easily be adapted to use Lamb waves, which is an additional argument to support their use.

### 6. Conclusion

In this small review article, only the most common methods and devices of non-destructive testing were mentioned, which can be used for defectoscopy of concrete and asphalt concrete pavements. Less common or too expensive ones are very specific and difficult, we have not considered them. These include the infrared thermal method, electrochemical, mechanical, and others, which are discussed in detail in our papers [8].

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