Application of digital technologies at road monitoring

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Abstract. Largely, the condition of the road network determines the economic and social development of any country. Annual monitoring of roads and analysis of their condition allow identifying in advance the sections where repairs are needed. In order to develop a correct and effective repair strategy, it is necessary to be able to analyze large volumes of road monitoring data. Therefore, the development and introduction of specialized software into practice are required for gathering, storing, processing and analyzing a great amount of data. The paper examines current specialized software developed by the specialists of the Department “Construction and Maintenance of Roads” of MADI (software products: ProfORG and Vsteets2) to process road monitoring data. This software makes it possible to record, store, process and analyze information using the DVS-3 road mobile laboratory. The article presents the research results of changes in the longitudinal and transverse roughness of the pavement surfaces performed using the ProfORG and Vsteets2 software.

1. Introduction

The economic and social progress of any country is considerably determined by the condition of roads. The sections of roads requiring rehabilitation may be revealed ahead of time by annual monitoring, that makes it feasible to conduct necessary works for maintaining roads in optimal conditions of use. Obtaining reliable information on the condition of the road pavement surface and its correct processing and analysis are prerequisites for developing an effective repair strategy [1].

Recently, road mobile laboratories, which are equipped with devices for digitizing measurement information, have been used to monitor the condition of roads. Within the annual monitoring, the databases on the transport and operational condition of highways are created. Therefore, there is a need to develop and introduce specialized software into practice with the aim to record, store, process as well as to analyze a large volume of the data obtained.

Such technologies allow identifying regularities of changes in the major transport and operational characteristics, developing forecasting models, and determining the strategy of repair works as well.

2. Problem statement

Many European countries use the monitoring of road pavement surface. In 2010, Denmark, Iceland, Norway and Sweden implemented a joint project NordFoU - Pavement Performance Models (PPM)
Within the framework of the project, various technical and operational characteristics of flexible road pavements were investigated. Researches resulted in

- developing a pavement performance model describing changing in the condition of flexible pavement structures;
- defining calibration coefficients of the model with regard to natural and climatic conditions in research areas;
- developing software application for prognostication of pavement performance at a network level.

Particular attention is paid to road monitoring in the United States. In this country, the instruction on the design of road pavements based on the surveys of the condition of road pavements for many years was developed. The instruction includes the calculations on predicting the major damages to road pavements and changes in transport and operational characteristics [3].

In Russia, roads are also monitored annually. For 10 years, the specialists of MADI have been performing the annual monitoring on sections of the R-22 “Kaspiy” federal road going through the Moscow, Ryazan, Tambov, Voronezh and Volgograd regions. The total length of the monitoring sections was about 775 km. The survey sections had different pavement surface design. Traffic density, depending on the location of the sections, ranged from 3,500 to 18,000 car/day. During monitoring, measurements of longitudinal and transverse roughness of road pavement surface were conducted for each lane, and local damages were recorded using video filming. Works were performed by means of the DVS-4-IK road mobile laboratory.

The survey during several years gave the possibility to develop the system for the control of the road pavement condition aiming at practical application on the R-22 “Kaspiy” road. Also the recommendations on improving the complex evaluation method of the highway maintenance quality in terms of the International Roughness Index 4] were given. Moreover, a remote method for forecasting damages of the cement-concrete pavement was offered [5]. At present, research works continue.

3. Methods and materials
The DVS-4-IK mobile laboratory of the MADI department “Construction and Maintenance of Roads” was used for monitoring of road pavement surface. The laboratory in question is a car equipped with a set of measuring equipment for obtaining, storing and processing data concerning the condition of the road pavement surface and facilities on the road. Figure 1 shows a general view of the DVS-4-IK mobile laboratory.

![Figure 1. General view of the DVS-4-IK mobile laboratory.](image-url)
To obtain and collect data the laboratory is equipped with the following systems:

- video filming;
- georeferencing;
- measuring the microprofile of the carriageway in the longitudinal direction;
- measuring the microprofile of the carriageway in the transverse direction.

To record, store and process the obtained data the laboratory is equipped with the following set of equipment:

- computer;
- monitor;
- data entry means;
- electronic unit for data collection;
- software.

Special ProfORG and Vsteets2 software for researches was developed by the engineers Osipov I.A. and Vaschenko A.V. (MADI).

The obtained data of the longitudinal and transverse roughness of the pavement surface and the continuous video recording of the road condition were processed and systematized in the office. The results of measurements of longitudinal and lateral roughness of road pavement surface of selected road sections of each year inspection could be displayed on the monitor using the ProfORG software. This program made it possible to view video at any point of the road. Thus, a visual identification of the reasons of inadequate values of the longitudinal and transverse roughness of the pavement surface was possible. Figure 2 and 3 show the fragments of the ProfORG program.

To determine the number of local damages on the road pavement as well as to evaluate them, the Vsteets2 program was used, which allowed defining the geometric dimensions of damages in terms of the extent (length of cracks on the pavement surface) or the area (in the case of a pothole). Figure 4 demonstrates a fragment of Vsteets2 program.

![Figure 2](image-url)

**Figure 2.** Data on longitudinal roughness of the pavement surface in the ProfORG software: green columns are the values of the IRI along the traffic lane in the forward (at the bottom) and reverse (at the top) directions during survey periods - May, October, July; red scale is a distance in kilometers; blue rectangles indicate kilometers.
**Figure 3.** Data on the transverse roughness of the road pavement surface and video image of the measurement section in the ProfORG software: blue columns are the values of the rut depth along the traffic lanes in the forward (at the bottom) and reverse (at the top) directions during the survey periods - May, October, July; red scale is a distance in kilometers; blue rectangles indicate kilometers.

**Figure 4.** Determination of the area of a local damage of road pavement surface in Vsteets2 software: damage area is highlighted in red.
4. Results and discussions
Based on the annual monitoring of the condition of the pavement surface of the R-22 “Kaspiy” federal road the intense increase in the values of indicators (dynamics of change) of the longitudinal and transverse roughness at different density of traffic was established. Figure 5 shows the results of measurement of the longitudinal roughness after 6 years of inspection, and Figure 6 indicates the results of measurement of transverse roughness after 5 years of inspection.

An annual increase in the International Roughness Index $\Delta \text{IRI}$ depending on the initial value of $\text{IRI}_0$ and traffic density is given in Table 1. The values of the annual increase in the rut depth for asphalt-concrete and cement-concrete pavements, depending on the traffic density, are presented in Tables 2 and 3.

![Figure 5](image1)

**Figure 5.** Values of the IRI on the section 198+500 – 202+350 km of the R22 “Kaspiy” federal road.

![Figure 6](image2)

**Figure 6.** Values of a rut depth on the section 250+000 – 260+000 km of the R22 “Kaspiy” federal road.
Table 1. Annual increase in the International Roughness Index

| Traffic density in one lane, car/day | Annual increase in the International Roughness Index | at IRI₀ value, m/km |
|-------------------------------------|------------------------------------------------------|---------------------|
|                                     | ≤ 1.5  | 1.5 – 2.2 | ≥ 2.2  |
| < 2 500                            | 0.10   | 0.10      | 0.15   |
| 2 500 – 5 000                      | 0.10   | 0.15      | 0.20   |
| 5 000 – 10 000                     | 0.10   | 0.20      | 0.20   |
| 10 000 – 20 000                    | 0.15   | 0.20      | 0.25   |
| > 20 000                           | 0.15   | 0.25      | 0.25   |

Table 2. Annual increase in a rut depth for asphalt-concrete pavement

| Traffic density in one lane, car/day | Annual increase in a rut depth ∆Κ, mm |
|-------------------------------------|--------------------------------------|
|                                     | ≤ 1 000                              |
|                                     | 1 000 – 2 500                        |
|                                     | 2 500 – 5 000                        |
|                                     | 5 000 – 10 000                       |
|                                     | 10 000 – 20 000                      |
|                                     | > 20 000                             |
|                                     | 1.00                                 |
|                                     | 1.25                                 |
|                                     | 2.00                                 |
|                                     | 2.50                                 |
|                                     | 3.00                                 |
|                                     | 6.00                                 |

Table 3. Annual increase in a rut depth for cement-concrete pavement (data for the first two years of operation)

| Traffic density in one lane, car/day | Annual increase in a rut depth ∆Κ, mm |
|-------------------------------------|--------------------------------------|
|                                     | ≤ 2 500                              |
|                                     | 2 500 – 5 000                        |
|                                     | 5 000 – 10 000                       |
|                                     | 10 000 – 20 000                      |
|                                     | > 20 000                             |
|                                     | 0.50                                 |
|                                     | 1.00                                 |
|                                     | 1.25                                 |
|                                     | 1.50                                 |
|                                     | 2.50                                 |

5. Conclusion

The use of digital technologies when monitoring roads enables quickly obtaining and processing a large amount of data on the transport and operational condition of roads, systematizing and storing this information as well.

The database, resulted from the annual monitoring of the road condition, permits to resolve various scientific and practical problems:

- to establish dependencies between individual technical and operational characteristics of roads;
- to simulate mathematically the change in the technical and operational characteristics of roads over time;
- to specify the methods of calculating and evaluating the condition of road pavement surface;
- to schedule repair works efficiently and in proper time [6].

The results of survey show that an intensive increase in the value of the IRI depends to a greater extent on the initial value of IRI₀ than on the traffic density.

It has been established that the transverse roughness decrease occurred more intensively than longitudinal one, and depended mainly on the traffic density.

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