The complex method of estimation of highway maintenance quality taking into account the International Roughness Index

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Abstract. The work deals with improving the method of a complex estimation of highway maintenance quality. The methods of estimation of highway maintenance quality were analyzed. The most complete and reasonable estimation is reached using a complex method. This method takes into account the influence of different transport and operating characteristics on providing secured speed of cars. The car speed impacts on the efficiency of motor traffic. One of the indices influencing the car speed is a road roughness. Today, in the Russian Federation the road roughness is estimated using the International Roughness Index (IRI). But the complex method doesn’t take into account the state-of-art measuring means as well as the International Roughness Index (IRI). The theoretical and experimental studies were carried out to establish the dependence between the IRI index and a partial coefficient of providing the design speed of cars. The model to define the partial coefficient of providing a design speed based on the International Roughness Index (IRI) was offered. The table for calculation of the partial coefficient of providing a design speed was offered as well.

1. Introduction
The problem of rational use of financial resources granted to the programs of development of the road/traffic complex of the Russian Federation is of great importance under modern economic conditions. One of these programs is the National project “Safe and high quality of highways” developed by the Ministry of Transport of Russia in order to implement the provisions of the President Order. The National project involves almost all the country – 83 regions of Russia (except Moscow and St. Petersburg) and 104 urban agglomerations.

To realize such large-scale national projects and to define the priority of works it is necessary to estimate highway maintenance quality (TES AD).

2. Statement of problem
The complex method of estimation of highway maintenance quality developed by Prof. Vasilyev A.P. [1] allows evaluating in full measure and reasonably the road maintenance, taking into account the influence of different operating characteristics on their consumer properties.

The advantages of the complex method of TES AD estimation are as follows:

• using a common criterion (secured design speed) for estimation of highway functionality;
• using a relative index (coefficient of securing design speed) showing the influence of road different transport and operating characteristics on the secured speed that allows comparing the degree of influence of such characteristics on the estimation criterion chosen;
possibility to define the preferable type of repairing works taking into account a profitability of works offered.

It should be noted that some organizations involved in road activity act according to the regulations developed on the basis of the complex method of TES AD estimation.

The complex method of TES AD estimation assumes the calculation of a partial coefficient of design speed securing \( (K_{ds}) \) that is the ratio of the real maximal speed of a single autocar \( (V_{max}) \), secured by road safety, to the basic design speed \( (V_b) \) [1]:

\[
K_{ds} = \frac{V_{max}}{V_b}
\]  

(1)

The reference speed of 120 km/h is accepted as a basic design one [1].

According to the complex method of TES AD estimation ten partial coefficients are defined, each of them shows the influence of a concrete road operating characteristic on the secured speed of movement.

One of the important characteristics is a pavement longitudinal roughness. The pavement longitudinal roughness impacts on speed, traffic safety, fuel rate, comfort, ecology, tear and wear of car suspension. Partial coefficient number six \( (K_{ds6}) \) takes into account the influence of the longitudinal roughness on the speed.

The standard documents acting in the Russian Federation [2, 3] specify the measurement of the longitudinal roughness using profilometric devices, in this case the IRI international index is a result of measurement.

According to the complex method of TES AD estimation \( K_{ds6} \) coefficient is calculated using the data of the actual longitudinal roughness measured by PKRS devices (control device of the roughness and the pavement adhesion of the wheel) and THK (bumpometer) (Table 1). The method doesn’t consider the measurement of the longitudinal roughness using profilometric devices. Therefore, the necessity came to a head to update the method of complex estimation.

| Roughness according to THK, cm/km | \( K_{ds6} \) | Roughness according to PKRS, cm/km | \( K_{ds6} \) |
|----------------------------------|-------------|----------------------------------|-------------|
| less 60                          | 1.25        | до 300                           | 1.25        |
| 70                               | 1.15        | 350                              | 1.20        |
| 80                               | 1.07        | 400                              | 1.12        |
| 90                               | 0.96        | 500                              | 0.98        |
| 100                              | 0.92        | 600                              | 0.84        |
| 120                              | 0.75        | 700                              | 0.72        |
| 140                              | 0.67        | 800                              | 0.65        |
| 160                              | 0.63        | 900                              | 0.59        |
| 200                              | 0.57        | 1000                             | 0.55        |
| 250                              | 0.50        | 1100                             | 0.51        |
| 300                              | 0.43        | 1200                             | 0.43        |
| 350                              | 0.37        | 1400                             | 0.33        |
| 400                              | 0.31        | 1600                             | 0.28        |
| 450                              | 0.25        | 1800                             | 0.24        |
| more 500                         | 0.20        | 2000                             | 0.20        |

3. Solution

For setting dependence \( K_{ds6} = f( IRI ) \) one can use the known functional dependences between the results of measurements of the longitudinal roughness obtained using different measurement instrumentation (Table 2). According to these data graphic dependencies were plotted (Figure 1).
Table 2. Dependences between the indices of estimation of longitudinal roughness obtained by different measurement instrumentation and the international index IRI

| Author, source | Dependence formula | Equation № |
|----------------|--------------------|------------|
| Prof. V.P. Zhigarev, on the basis of theoretical modeling of the process of vehicle oscillating movement [4] | \( \frac{PKRS}{IRI} = 128 \) | E1 |
| Empirical dependence [5] | \( IRI = 0.0073 \cdot PKRS - 0.33 \) | E2 |
| Empirical dependence [5] | \( IRI = 0.032 \cdot THK + 0.4 \) | E3 |
| Dependence obtained by Prof. O.A. Krasikov [6] | \( IRI = 0.0241 \cdot THK + 0.8253 \) | E4 |

Figure 1. \( K_{ds6} \) dependence on IRI: figures on curves designate the type of the initial dependence in Table 2

The analysis of data showed that the type power function is most suitable for describing the dependence:

\[ K_{ds6} = A \cdot IRI^{-B} , \]

\( A \) and \( B \) are the coefficients needed more precise.

The coefficients of equation (2) were defined and the next formula was obtained:

\[ K_{ds6} = 2.469 \cdot IRI^{-0.8} \] \( (3) \)

with correlation coefficient \( R=0.976 \).

To prove analytical dependence (3) the experimental studies were carried out. The autocar speeds and the IRI longitudinal roughness were measured on experimental objects that were sectors of highways. The first object was “Odintsovo northern roundabout way”, the second one –“R-22 Kaspy”. Four sectors of each object were examined. A total volume of measurements of speed was 47.894 and 51.211 respectively.

The roughness measurements of the traffic area of these sectors were carried out by the DVS-4-IK mobile laboratory (MADI). The laboratory made a video film and measurements of the microprofile. The registration of height marks was carried out at pitch of 125 mm along the movement direction.
To define and fix the speed of the car movement the KRIS-P mobile photoradars were used. A maximal speed of the autocar movement was defined by cumulative curves at 85% providing on every experimental sectors. \( K_{ds6} \) was obtained by formula (1).

The functional dependence was defined using the data of speed and pavement roughness:

\[
K_{ds6} = 0.972 \cdot IRI^{0.483}.
\]  

(4)

The value of the correlation coefficient \( R=0.969 \) shows a high degree of the statistic interdependence between the indices studied.

Figure 2 presents analytical and empirical dependences. It is evident that these dependences are similar.

![Figure 2. Comparison of analytical and empirical dependences \( K_{ds6} = f(IRI) \): 1 – line corresponding to formula (4), 2 – line corresponding to formula (3), 3 – experimental points](image)

The values for \( K_{ds6} \) designation at longitudinal roughness measurement by profilometric devices were tabled on the basis of studies carried out (Table 3).

| Roughness by profilometer (IRI), m/km | \( K_{ds6} \) |
|--------------------------------------|--------------|
| less 0.6                             | 1.23         |
| 0.8                                  | 1.08         |
| 1.0                                  | 0.97         |
| 1.2                                  | 0.89         |
| 1.5                                  | 0.81         |
| 2.0                                  | 0.71         |
| 3.0                                  | 0.59         |
| 5.0                                  | 0.47         |
| 7.0                                  | 0.40         |
| 10.0                                 | 0.34         |
| 14.0                                 | 0.29         |
| more 20.0                            | 0.25         |
4. Conclusions
The studies resulted in the following conclusions:

- It is proved that the power function suits for describing dependence $K_{d6} = f(\text{IRI})$ and is written as $K_{d6} = 0.972 \cdot \text{IRI}^{-0.453}$.
- To get $K_{d6}$ when carrying out the complex method of estimation TES AD the use of Table 3 can be recommended.

Nomenclature

- $TES\ AD$: highway maintenance quality
- $V_b$: basic design speed
- $K_{ds}$: partial coefficient of design speed securing
- $PKRS$: control device of the roughness and the pavement adhesion of the wheel
- $THK$: bumpometer

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