THE SKID RESISTANCE EVALUATION ON THE LONG-TERM MONITORED ROAD SECTIONS

Peter KOTEK^{1,*}, Matúš KOVÁČ¹, Martin DECKÝ¹

¹ Department of Highway Engineering, Faculty of Civil Engineering, University of Žilina, Univerzitná 8215/1, 010 26 Žilina.

* corresponding author: peter.kotek@fstav.uniza.sk, +421-4-1513 5930.

Abstract

The article deals with the analysis of the skid resistance results measured at the long-term monitored road sections in Slovakia in perspective of the possibility of the deterioration functions determination for the purposes of the pavement management system. There were 11 road sections evaluated, on which have been surface characteristics measured since 1998. The focus was on the evaluation of the longitudinal friction coefficient μ measured by device Skiddometer BV11, which is the property of the Slovak Road Administration. Beside the μ parameter, the test conditions were observed and evaluated, as well (measured speed, air and surface temperature, type of asphalts of the wearing course, traffic load, and the season (spring, autumn, respectively) in which the skid resistance measurements were performed. In conclusion, there was reviewed a presumption of the possibility to determine a deterioration functions for skid resistance in point of view the quality of the data, which have been collected on the Slovak long-term monitored road sections.

Keywords:

Roughness;
Pavement surface;
Friction coefficient;
Asphalt mixture;
Deterioration functions.

1. Introduction

To keep traffic safe, especially during bad weather conditions, the adequate skid resistance is necessary. It ensures interaction of a vehicle wheel and pavement surface. Insufficient skid resistance or its absence makes the roads slippery and risk of car accidents increases. We can say, that it contributes to safety on roads. Therefore it is very important to measure the friction coefficient regularly and make it one of the most important parameters for the decision procedures and for the selection of appropriate and timely repair action. Early discovering of insufficient pavement serviceability is important for both, the safety reasons and the cost effective maintenance of road network. Not to mention that for the correct determination of the optimal time for a repair action is highly needful to have precisely established the deterioration functions. That means that the accurate diagnostics of the pavement surface is the first step for the correct operation of the pavement management system. For the purpose of determination a deterioration functions it is necessary to observe a surface characteristics development as a function of time (pavement age) or traffic (standard axle load applications). This means, that it needs to be done a huge data collection over the years, with strict abiding of the same measurement conditions. The skid resistance of the pavement surface is often described by the coefficient of the sliding friction, which is defined as a relation of tangential friction power and normal power between a rubber tyre tread and pavement surface. This resistant force is showed in Fig. 1.

Fig. 1: Scheme of forces acting on rotating wheel.

The coefficient of sliding friction is defined as a relation of tangential friction force F_T and normal force F_W between rubbers tread and pavement surface according to equation (1) [1]:

$$f = \frac{F_T}{F_W}. \quad (1)$$

There are many conditions that influence the friction coefficient value. The skid resistance depends in the first place on the type of wearing course, the trafficking and climatic conditions. The other conditions which can influence the friction coefficient value are connected to its measurement process and it is very important to try to eliminate them, or at least set them on the same level for every measurement taken to comparison and evaluation process [5].

It is general knowledge that a skid resistance of a pavement vary in time. After an initial period of the life of a pavement the aggregate at first covered by a binder material are gradually exposed and begins a polishing process of aggregate particles, which gradually reduces skid resistance to an equilibrium level. Once equilibrium level has been reached, the skid resistance may vary as a result of seasonal variation, whereas the level of equilibrium highly depends on type of asphalt and traffic load. The process of the skid resistance degradation is illustrated in the Fig. 2.

Fig. 2: Friction coefficient versus number of passes and associated with physical mechanisms [2].

In order to find out, if it is possible to determine skid resistance deterioration functions based on long-term monitoring data, we analysed all Mu friction coefficient measurements performed on selected road sections in Slovakia since 1998.

2. Data analysis

The equipment Skiddometer BV11, owned by Slovak Road Administration, is used to measure skid resistance in Slovakia. The measuring device consists of the single trailer pulled by delivery truck with the opened landscaped tipping body for transporting the equipment and a water tank. The device allows measurement of the longitudinal friction by recording shear resistance using independent measuring wheel with slip ratio of 17 %. The measurements have been regularly performed since 1998 in spring and autumn on long-term monitored road sections. Output of the equipment is the parameter Mu describing longitudinal friction every second meter on the road. Measurement technique and evaluation are described in detail in the technical regulation TP14/2006 [3].

Primary problem of usability of measured data in order to determine a deterioration function is their repeatability and reproducibility [5]. To compare longitudinal friction values measured regularly throughout a long period, it is necessary to select measurements with approximately the same measuring conditions, especially measuring speed with permissible deviation of $\pm 10\%$ [4], because by different measuring speeds there are reached different longitudinal friction values. The longitudinal friction values are decreasing when increasing speed on both, dry and wet pavement surface. There was chosen a comparative speed of $80 \text{ km} \cdot \text{h}^{-1}$, because most of these measurements were performed at this speed almost on all road sections. According to technical regulation TP14/2006 [3], it is also

possible to make a conversion for Mu parameters measured at different measuring speeds, but objective results are not guaranteed. The monitored road sections are about the same length 1000 m. The example of longitudinal friction course measured on the long-term monitored road section Zlatovce D1 – PO in 1998 – 2008 is showed in the Fig. 3. There can be seen fluctuating but stable course of Mu values on the road section.

Fig. 3: The course of longitudinal friction on the long-term monitored road part Zlatovce D1 in 1998-2008.

In the article, there are as an example mentioned four long-term monitored road sections of Slovak road network which were selected from many analyses done at the author's working place. The road parts are two highways and two roads of the first class. The chosen parts distinguish from each other by the location in Slovakia, traffic meaning [6], traffic intensity, age and type of wearing course. Analysed period was selected to avoid interventions to the wearing course as repair or reconstruction of the road. Only local corrections were realized, which do not negatively affect the diagnostic.

- the section Zlatovce is situated on the highway D1 between Trenčín and Dubnica nad Váhom and was opened for traffic in 1996 with wearing course marked as AC I;
- the section Piešťany is situated on the highway D1 between Piešťany and Horná Streda and was opened for traffic in 1988 with wearing course marked as AC II;
- the section Gánovce is situated on the road I/18 between Poprad and Spišský Štvrtok. New wearing course marked as AC modified was laid in 1995;
- the section Žilina STK is situated on the road I/18 between Žilina and Nová Mojšová Lúčka. New wearing course marked as AC was laid in 1992.

Figs. 4, 5 show single road parts according to longitudinal friction during ten years. Distinct fluctuating behaviour of average values of longitudinal friction can be seen. There is shown measured speed on the single graphs, which was not always uniform, and so as the temperature. After partially removing apparently wrong values (in red) we can see it is not possible to clearly determine decrease of Mu values. When a filter which represents 10 % deviation from the average Mu value during 10 years is used, we can see that Mu has sustained process in the interval (± 10 % deviation from the average Mu value in the monitored period).

Fig. 4: Longitudinal friction on road part Zlatovce D1 with wearing course AC I in 1998-2008.

Fig. 5: Longitudinal friction on road part Žilina – STK 1/18 – ZA with wearing course AC in 1998-2008.

By monitoring longitudinal friction on all road sections no relevant dependency of decreasing values in time was shown contrary to traffic intensity which happened to rise every year. We could obtain a specific dependency with the use of extreme and purpose-built filtration of measured data, but credibility of the model would be debatable. Comparison of longitudinal friction and traffic intensity on monitored road parts is shown in Fig. 6 and Table 1.

Fig. 6: Comparison of longitudinal friction and traffic intensity on monitored road parts.

Table 1: Comparison of friction (μ) and traffic intensity (passes/24 hour) on monitored road parts.

Name of section	2000			2005			2010		
	Heavy trucks	Passenger car	Together	Heavy trucks	Passenger car	Together	Heavy trucks	Passenger car	Together
Zlatovce D1	4125	10254	14874	7045	13151	20213	9541	21253	30794
Piešťany D1	3125	9978	13108	5845	14804	20649	7562	18131	25693
Gánovce I/18	2095	9746	11841	3508	10584	14092	1757	8750	10507
Žilina - STK I/18	4377	12312	16726	7494	16315	23867	7345	21693	29089

We can say that the values of longitudinal friction on the road sections during monitored period vary after filtering off the incorrect measurements and statistical processing as following:

- variability of μ values for AC I in the section Zlatovce from 1998 to 2008 ranged between 64 - 74 points which creates variation interval of 10 points;
- variability of μ values for the mixture AC II in the section Piešťany from 1998 to 2008 ranged between 61 - 73 points which creates variation interval of 12 points;
- variability of μ values for the mixture AC in the section Gánovce from 1998 to 2008 ranged between 57 - 69 points which creates variation interval of 12 points;
- variability of μ values for the mixture AC in the section Žilina STK v from 1998 to 2008 ranged between 46-56 points which creates variation interval of 10 points.

When comparing values of longitudinal friction on the road sections with measured temperature (Fig. 7), no dependency was proven between the values on single surfaces. Approximately the same values of longitudinal friction were reached in time by various temperatures. Although measured temperature does not mirror temperature of the pavement surface because it is measured right above the pavement surface, but is very close to it. It can be figured that the temperature does not have such an effect as it is credited to it when measuring by Skiddometer BV11. The reason is that a water film of one millimetre thick is put before the measuring wheel and the water has some stable temperature during measuring and cools both, the measuring wheel and the pavement surface, so conditions (at least the temperature) by repeated measurements are approximately the same. This fact was also proven by additional measurements performed by authors on selected test road sections. This comparison is not unambiguous because the measurements were done in long-time distances (circa half of the year), and besides the temperature changes the properties of the surface had been changing as well.

Fig. 7: Dependency of longitudinal friction on measured temperature on selected road sections.

When analysing an influence of speed on the average longitudinal friction value, there was confirmed the dependency of decreasing values by increasing speed. By comparing the speeds 60 km/h and 80 km/h at road section Žilina-STK I/18 – ZA (Fig. 8), we can see longitudinal friction

increases by lower speed. The growth was about four units in average what is connected with the relation according to TP14/2006 [3]:

$$\mu_{80} = 0.93 \times \mu_{60}. \quad (2)$$

Differences between recounted values of longitudinal friction measured at 60 km/h to 80 km/h and values actually measured at 80 km/h were about three units in average. On Fig. 8, there can be seen longitudinal friction values by speed of 60 km/h and 80 km/h during 10 year period on the road section Žilina STK.

Fig. 8: Analysis of longitudinal friction values by speed of 60 km.h⁻¹ and 80 km.h⁻¹ during 10 year period on the road section Žilina STK.

When comparing seasons, it is obvious that higher values of longitudinal friction were reached on several road sections of different mixture type in spring than in autumn. The higher value of longitudinal friction in spring can be derived from lower temperature during winter and longer rainy periods. It can also relate to use of various chemical and inert spreading on road parts. Lower value of longitudinal friction in autumn can be connected to higher temperatures during summer. It can also bear on longer dry period when dust and small impurities are put down on the pavement. They create thin film by contact with water and it prevents contact of tyre with aggregate surface on microscopic level, so this could be the main reason why the value of measured longitudinal friction is markedly fallen.

However, it is remarkable that there is no friction coefficient level decrease over the years, but a chaotic development of skid resistance at the approximately same speed appears instead. This phenomenon was observed on all road sections. By comparison of friction coefficient values shown in the Fig. 6, it seems that the skid resistance level varies with similar pattern on all compared road sections. It may be caused by the device calibration or setting for the current year. But it is also possible that the chaotic behaviour of the skid resistance level is caused by inconsistent compliance with the conditions of measurement, such as measuring in the exact same wheel path and accurate determination of the beginning and the end of the measurement.

3. Conclusions

The article points at the fact that measurement of skid resistance requires high claims on the accuracy of the measurement. There are many test conditions which could influence the measurement results and cannot be always removed, or set at the same level. The friction coefficient value depends especially on the age of wearing course, on the traffic load and on the climate conditions. There are also parameters which influence the measured value of the friction

coefficient, such as measuring speed, tyre (type, normal load, tread depth, pressure), and the season, in which was the measurement performed.

Analysed results point out the fact that although the value of friction coefficient changes in time, it is very difficult to find any relevant dependencies on time / traffic load, which would be evaluated from the results of more than 10 years' monitoring on Slovak roads. There wasn't find any decreasing development of the skid resistance level despite the fact that was proven no influence of temperature on friction coefficient. There was also proven an influence of measuring speed on average skid resistance level, but the results obtained by the measurements at the same speed vary chaotically. It is impossible to determine an influence of asphalt type on skid resistance, because there is lack of information about the wearing course asphalt mixture composition, especially aggregate particle size distribution, maximum nominal aggregate size and content and type of bitumen binder.

On the basis of all evaluated data obtained on all analysed road sections, we can claim that momentarily it is impossible to determinate any relevant and objective deterioration functions for skid resistance in Slovakia.

In order to determine deterioration functions for skid resistance in the future, it will be necessary to keep in mind strict abiding of all measurement conditions. Some of them have to be eliminate by device operator (tyre tread depth, tyre pressure), and some of influences will have to be removed systematically (beginning and end of friction coefficient recording, keeping in the same wheel path, measuring speed, etc.) by using technological equipment. For next monitoring in the future it would also be appropriate to see more to a selection of new road sections where enough information about pavement (wearing course) would be available and also all repair of surface would be recorded. During long-term monitored period it is necessary to consider especially local climatic and geometric conditions of the road part.

Acknowledgement

The research is supported by European regional development fund and Slovak state budget by the project "Research centre of University of Žilina", ITMS 26220220183.

References

- [1] ČELKO J. et al.: Povrchové vlastnosti vozoviek (Prevádzková spôsobilosť vozoviek), EDIS Žilina, 2000. ISBN 80-7100-774-9.
- [2] DO, M. T. - KANE, M: 'Pavement polishing—Development of a dedicated laboratory test and its correlation with road results', 2007, Wear 263, pp. 36–42.
- [3] TP14/2006, Meranie a hodnotenie drsnosti vozoviek pomocou zariadením SKIDDOMETER BV11 a PROFILOGRAPH GE.
- [4] TPA 2009. Modely degradácie a degradačné funkcie drsnosti asfaltových vozoviek: rozborová úloha. Bratislava 2009.
- [5] KOVÁČ, M. et al: Diagnostika parametrov prevádzkovej spôsobilosti vozoviek, EDIS Žilina 2012. ISBN 978-80-554-0568-1.
- [6] LEITNER, B.: Autoregressive models in modelling and simulation of transport means working conditions. In: Transport means 2010 : proceedings of the 14th international conference : October 21-22, 2010, Kaunas University of Technology, Lithuania. - ISSN 1822-296X. - Kaunas : Kaunas University of Technology, 2010. - S. 21-24.
- [7] SLABEJ, M.: Performance of selected pavement serviceability parameters and surface deteriorations, 14-th International scientific conference VSU 2014, 5 – 6. June 2014, Sofia, Bulgaria, ISSN/ISBN: 1314-071X.