Implementation of EN 12697-49 standard into practice

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ABSTRACT

European standard EN 12697-49 "Bituminous mixtures – Test methods for hot mix asphalt – Part 49: Determination of friction after polishing" describes the laboratory measurement of surface skid resistance. Measurements can be performed directly on cores taken from asphalt or concrete roads, or on test specimens prepared in a laboratory. Laboratory test specimens can be asphalt slabs made in compactors or samples made from splits of various fractions.
Nowadays the results of friction measurement on various types of cores taken from roads are compared with the results of friction coefficient measured by the TRT dynamic test device. The goal was to verify the accuracy of laboratory measurement of skid resistance and determine the relationship between the values of road surface skid resistance and the intensity of traffic load.
So far, the results of friction after polishing were measured using the Wehner/Schulze test device at the Vienna University of Technology. A new test device complying to EN 12697-49 was installed in the laboratory of the Faculty of Civil Engineering at the Brno University of Technology. The results measured using this new device are compared with those measured in Vienna to harmonize these two devices.

Keywords: Design of pavement, Skid Resistance, Standardisation

1. INTRODUCTION

It is widely known that road skid resistance largely affects safety on roads. It is usually measured by dynamic test devices directly on roads. However, the degree of road skid resistance decreases over time as a result of traffic load and it would therefore be desirable to be able to predict skid resistance progress for different types of asphalt mixtures in advance. The European standard EN 12697-49 “Bituminous mixtures – Test methods for hot mix asphalt – Part 49: Determination of friction after polishing” [1] describes a test method for measuring the friction coefficient of a polished sample that has so-far been referred to as the “Wehner/Schulze method”. This method allows simulating the effect of traffic load on skid resistance on asphalt pavements in laboratory. In a matter of just a few hours it allows predicting the road pavement skid resistance that would normally be observed after many years of being exposed to traffic load. The standard however, does not provide any relationship between the duration of polishing in a laboratory and the real traffic load. For predicting skid resistance in practice however, it is necessary to know this relationship between the real traffic load and laboratory polishing duration. The values measured in a laboratory must be convertible into the longitudinal or side friction coefficient that is usually used to express road skid resistance.
This paper compares results of laboratory and in situ measurements of skid resistance. The aim is to determine the relationship between the values determined in a laboratory and values, which were measured directly on roads. It is also important to confirm that the decrease in friction coefficient measured by the laboratory device corresponds to the friction coefficient progress resulting from traffic load and thus whether it is possible to use such device to determine lifespan of skid resistance properties of road surfaces.

2. LABORATORY TEST DEVICE FOR DETERMINATION OF FRICTION AFTER POLISHING

2.1 Wehner/Schulze machine

The Wehner/Schulze device (Figure 1) is used for laboratory polishing tests. It is composed of two rotary heads, one for polishing and one for measuring the friction on the testing specimen surface. Cores taken from slabs prepared in a laboratory according to [2] or cores extracted from asphalt pavement (Figure 2) can be used as test specimens. Specimens have 225 mm in diameter and thickness varying between 15 mm and 50 mm. Asphalt specimens prepared in a laboratory and cores from new roads can be sand blasted by a blast system before polishing, so that remaining bitumen is removed from the surface. It is also possible to test specimens that haven’t had the remaining asphalt bitumen removed, and therefore determine the time necessary for it to be removed by traffic.
Polishing head is composed of three rubber cones and a device which supplies water and quartz powder mixture. Rubber cones are rolling over the specimen surface during the polishing process with rotation frequency 500 RPM and with a load of 392 N. The water and quartz powder mixture is supplied through the center of the polishing head to the pavement surface by a pump with a capacity of 5 l/min. The device for water and quartz powder supply comprises a container with a stirrer to ensure mixture homogeneity. Polishing models accelerate the effect of traffic load on the surface of pavement wearing courses.
Measuring head is composed of three sliding blocks and a system for measuring the momentum with an accuracy of ± 1 Nm during breaking. During the test the rotating head must reach a speed of 100 km/h in the measuring track of the sliding blocks. It is then clutched to the specimen surface with a static force of 253 N. The rotation of the measuring head is stopped by the friction between sliding blocks and the specimen surface. The speed of the rotating head is gradually decreased to a complete stop. The rotating head is also equipped with a system that measures the rotation speed during breaking with an accuracy of ± 2 rotations/s. During the breaking phase the test specimen surface is supplied with pure water. Sliding blocks, which are responsible for measuring the friction coefficient, are composed of a circular metal segment covered with 5 mm thick rubber.
Clamping system allows fixation of the test specimen and the glass-control plate with textured surface, which is used as a reference surface [1].

Figure 1: Wehner/Schulze test device at the Vienna University of Technology (left), polishing head (upper right), measuring head (lower right)

Figure 2: Test specimens - cores from laboratory-made slab (left) and asphalt pavements (centre and right)

2.2 Testing procedure

The polishing process is divided into cycles (1 cycle = usually 90 000 passes of rubber cones). After each polishing cycle the sample is washed with water and friction coefficient is measured.
Prior to measuring the friction coefficient of the polished sample, it is necessary to verify the correct functioning of the test device by measuring the friction coefficient of a glass-control plate which is then compared with the reference friction value of this same plate. If the measured values are more than 10 % off from the reference value, the sliding blocks must be replaced.
After verification of the correct functioning of the device the friction coefficient of the test sample is measured. During the entire breaking process the momentum and speed are measured. As soon as the measuring process of the polished sample is finished, another control measurement is performed with the glass plate. The results of the control measurement must be within 10 % deviation from the friction coefficient reference value of the glass plate. This process is repeated after each polishing cycle.
The determined value of momentum M is then used to calculate the friction coefficient μ by using Eq. 1 [1].

(1) $$\mu = \frac{M}{253 \times 0{,}09}$$

where M is the measured momentum in Nm and μ is the friction coefficient.
The calculated friction coefficient value after polishing (Friction After Polishing, FAP) is an average of the two or more separate measurements expressed by the friction coefficient μ_{FAP} calculated using Eq.2 at a defined speed of 60 km/h. If the difference between the two individual measurements (repeatability) is larger than 0.03, the measurement is considered as invalid and a different test sample is used.

(2) $$\mu_{FAP} = \mu_m - \mu_{km} + \mu_{ref}$$

where μ_{FAP} is the single friction measurement, μ_m is friction coefficient at 60 km/h, μ_{km} is the mean value of the control plate before and after the friction measurement and μ_{ref} is a known friction value of the control plate [1].

A speed of 60 km/h was chosen because it is the usual speed for measuring the longitudinal friction coefficient of road surface by dynamic test devices [1].

3. RELATIONSHIP BETWEEN μ_{FAP} AND LONGITUDINAL FRICITON COEFFICIENT

In order to be able to use the Wehner/Schulze device in practice, it is necessary to determine the relationship between the friction coefficient μ_{FAP} determined in a laboratory and the values of friction coefficient measured by dynamic measuring devices. The problem is that there is now approximately 15 different types of dynamic measuring devices being used in Europe. The values of friction coefficient measured using different types of devices on the same surface vary. Several international comparison measurements were already performed with the aim to come up with one standardized parameter that would describe the skid resistance properties of roads and all the dynamic devices would then convert their measurements to this parameter. These comparison measurements resulted in coming up with the so-called SRI (Skid Resistance Index) [3]. The necessary coefficients needed for converting the measured values to SRI were determined for all the devices that were included in the comparison measurements in Vienna in 2008 [4]. Unfortunately, only very limited number of devices were included and in addition, it was shown that different values of friction coefficient are measured on the same surface even by two devices from the same manufacturer, which should have the exact same design construction and measuring conditions. Another comparison measurement was performed in 2015 in Nantes. Results of these measurements have not yet been published and so the SRI parameter is not yet used in practice. Each country has its own method for comparing the dynamic devices used for skid resistance measurements on road surfaces. Therefore also comparison with the Wehner/Schulze laboratory device must be performed separately for each measuring device or group of measuring devices, which are being compared and a unified parameter determined.

3.1 Comparison results

To determine the relationship between μ_{FAP} and longitudinal friction coefficient measured directly on road pavement, cores were taken from trafficked lane of 37 different asphalt roads. Longitudinal friction coefficient F_p of road pavement in trafficked lanes was measured by TRT dynamic test device (Figure 3) [5]. This is a device used for monitoring road skid resistance in the Czech Republic. It has 25 % slip ratio and ASTM blank tire. This device was also included in the comparison measurements in Vienna and Nantes. Friction coefficient μ_{FAP} of cores surface was measured by Wehner/Schulze machine at the Vienna University of Technology and the extracted cores were not polished. Cores were taken from already used as well as from new asphalt wearing courses.
μ_{FAP} values measured on cores taken from roads were compared with the values of longitudinal friction coefficient F_p. The correlation between these values is shown in figure 4 and led to the following relationship:

(3) $$F_p(60\,km/h) = 0{,}9786\mu_{FAP} + 0{,}1728$$

The relationship differs from formulas determined by other laboratories [6, 7]. Their laboratory measurements were correlated with another dynamic devices (ADHERA).

Figure 3: Dynamic measuring device TRT

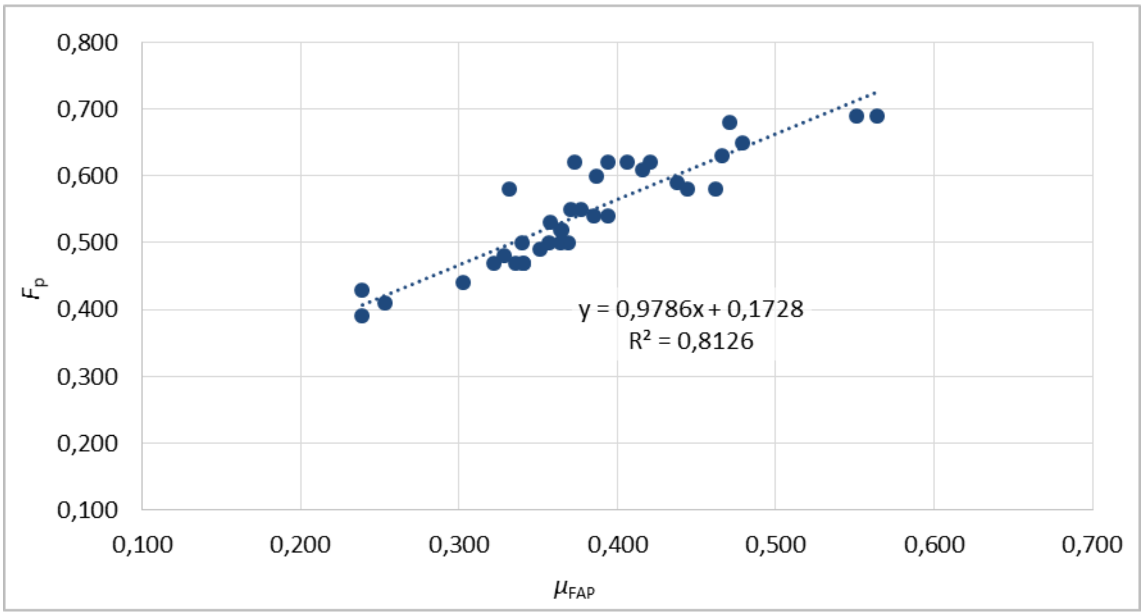

Figure 4: Correlation between friction coefficient measured in laboratory and longitudinal friction coefficient determined directly on road

4. LABORATORY POLISHING AND TRAFFIC LOAD

In order to be able to utilize laboratory polishing results in practice, it is necessary to know the relationship between the polishing duration and the real traffic load. This is problematic because different methods are used to calculate traffic load in different countries. The difference is especially in the way heavy vehicles are counted and categorized (for example with or without a trailer etc.) and it is these vehicles that actually affect the progress of skid resistance properties of roads the most. Passenger cars are usually converted to heavy vehicle equivalents using some equation, which however again differs in different countries. It is therefore necessary to determine the relationship between traffic load and laboratory polishing for each methodology of calculating traffic load separately.

Cores were taken from ten newly constructed roads with the aim to compare laboratory prediction of skid resistance with in situ measurements. Test specimens were taken from road side and polished in laboratory using the Wehner/Schulze machine. Some test specimens were subjected to up to 10 polishing cycles because they were extracted from roads that were highly trafficked. Skid resistance on test sites was monitored in long-term by TRT test device. Obtained values of μ_{FAP} were converted to F_p using formula 3 and compared with F_p values measured by TRT dynamic test device TRT. Examples of these comparisons are shown graphically in Figures 5, 6 and 7. Additional information regarding the test sites is given in Table 1. Important characteristics include the aggregate used, because it has a major effect on the skid resistance properties and their lifespan. Quality of the aggregate is expressed by the Polished Stone Value (PSV). The table also includes the value of traffic load for the particular stretch, expressed as the number of heavy vehicles per 24 hours.

Polishing curves were compared with the traffic load expressed as the number of heavy vehicles (HV). A simple relationship between traffic load and polishing was determined:

(4) $$N = k \cdot HV$$

where N is the number of passes of polishing cones and HV is the number of heavy vehicles. Coefficient k was determined by comparing the laboratory polishing measurement with the actual progress observed in situ on roads. Its value for experimental sites was determined to be 0.056. This same coefficient was determined by other laboratories to be 0.024 [7], 0.1 and 0.05 [8]. Its value varies because of the different approaches for expressing the traffic load. It is necessary to determine the coefficient for each country and method of traffic load measurement separately.

Table 1: Test sites

Site	Aggregate type	PSV	Heavy vehicles per 24 h
1	Greywacke	61	18 291
2	Granite + limestone	-	12 128
3	Granite	51	2 375

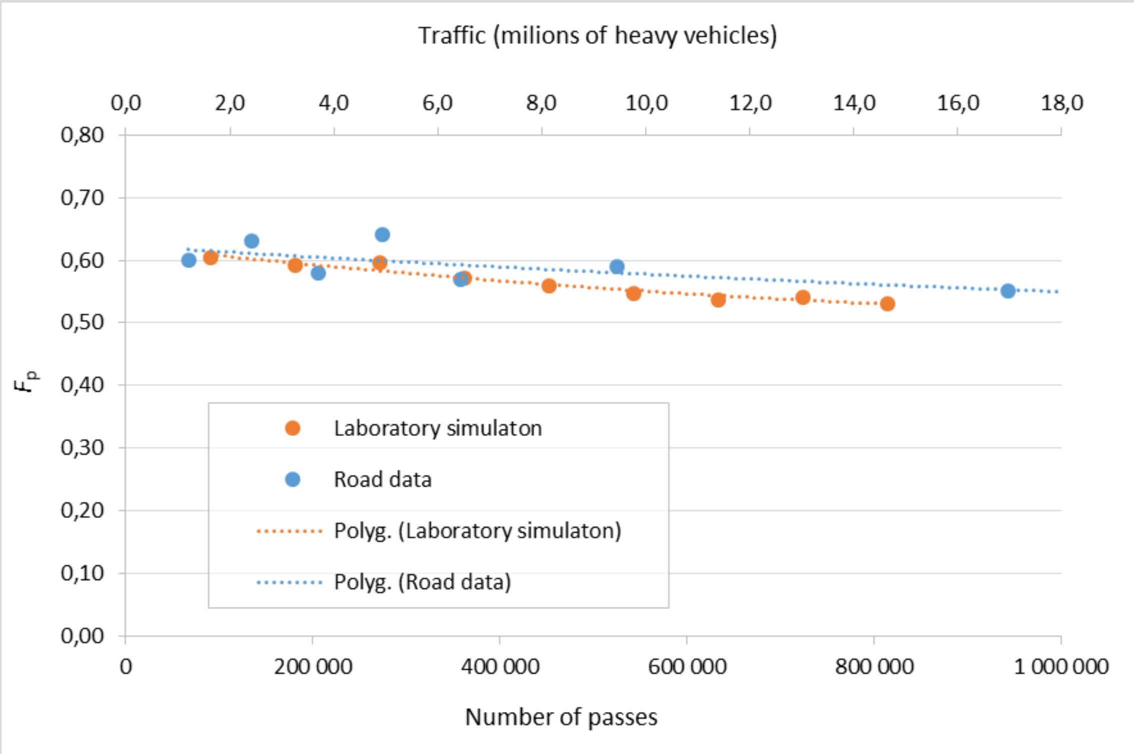

Figure 5: Skid resistance progress – comparison between laboratory simulation and road data (site 1)

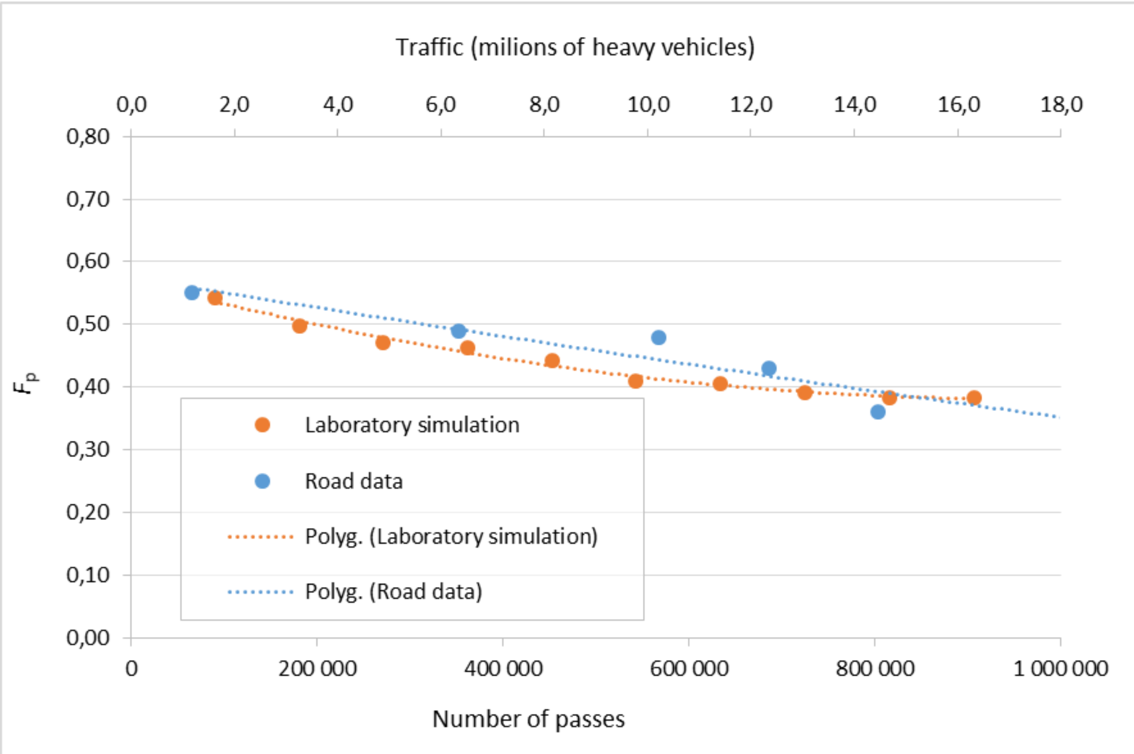

Figure 6: Skid resistance progress – comparison between laboratory simulation and road data (site 2)

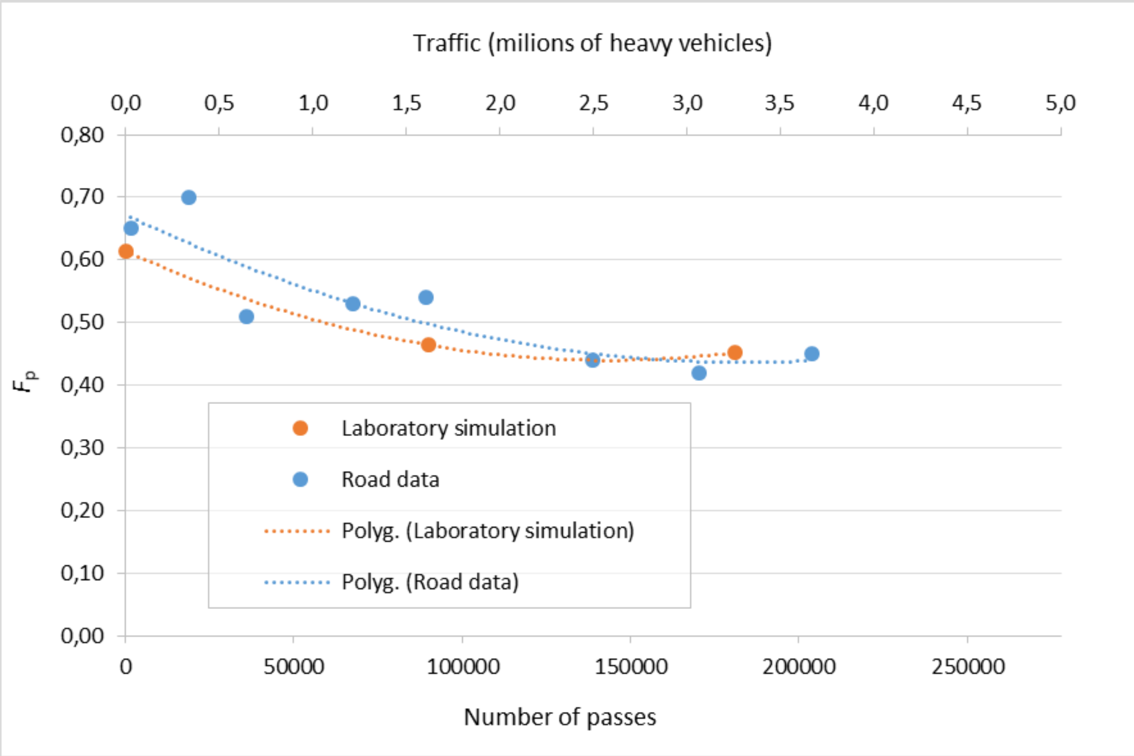

Figure 7: Skid resistance evolution – comparison between laboratory simulation and road data (site 3)

5. CONCLUSIONS

A laboratory test method for simulating polishing induced by traffic was introduced. Laboratory measurements were correlated with longitudinal friction coefficient measured by the TRT dynamic test device to determine the relationship between μ_{FAP} and F_p values.

Relationship between number of passes of polishing cones and traffic load was determined. This calculation gives an opportunity to predict the lifespan of road skid resistance based on traffic load. However, it still needs to be confirmed by further measurements.

Skid resistance was monitored in long-term on test sites using the TRT device. These measurements were compared to laboratory polishing measurements. Polishing curves are quite similar to road data, but they do not match perfectly. This is because the method does not take into account the effect of binder ageing and seasonal variations of skid resistance. However, it provides an overall picture of the lifespan of road skid resistance. Laboratory progress can be made more accurate using some prediction models that have already been developed by other laboratories [7, 9]. These prediction models also take into account binder ageing and the effects of weather conditions, it is however necessary to have other laboratory devices to simulate these effects. Such laboratory test is then more accurate, however also more time-consuming and expensive. The aim of this paper was to verify, if it is possible to use only the Wehner/Schulze device to make an approximate prediction of the progress of skid resistance properties on roads. It was proven that this is possible because even for stretches that have been monitored for more than 10 years already (Figures 5 and 6), the determined longitudinal friction coefficient F_p did not differ substantially from the coefficient determined after polishing in laboratory.

This paper also briefly talks about the issue of comparing the individual dynamic measuring devices and the approaches of calculating the traffic load. It is now necessary to perform comparisons of laboratory devices used for polishing with each dynamic measuring device separately and it is also necessary to determine a new conversion factor for comparing polishing and traffic load for each particular methodology used for traffic load calculation.

A newly installed test device in the laboratory of the Faculty of Civil Engineering at the Brno University of Technology was developed in compliance with the EN 12697-4 [1] (Figure 8). It is fully automatized and improved based on the experiences with Wehner/Schulze machine at the Vienna University of Technology. It has a good repeatability (less than 0.03). Values of the friction coefficient μ_{FAP} determined using this new device are currently being compared to values determined using the Wehner/Schulze device in Vienna. Given the complexity of such comparisons, a question arises whether same values would be determined for the same sample. Even measuring devices from the same manufacturer don´t report comparable values of friction coefficient on the same test stretch. Prior to each measurement, every laboratory device is calibrated using a reference glass, for which a standard specifies a particular value of friction coefficient, however this glass has a very smooth surface and such smooth surface is not in reality found on real road surfaces. Calibration using a surface with a higher friction coefficient is not required by the standard and the devices can therefore measure differently at these more rough surfaces, just like some dynamic measuring devices. In the future, it would be useful to perform comparisons of the laboratory devices in order to determine the friction coefficient after polishing.

Figure 8: New machine according EN 12697-49

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