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Road and Rail Infrastructure V

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PAVEMENT SURFACE MACROTEXTURE ANALYSIS

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Abstract

Asphalt pavement surface macrotexture has an important role in traffic safety. It contributes to skid resistance especially on roads where higher speeds are developed and under wet surface condition, due to its influence on water drainage and reduction of hydroplanning effect. Consequently, sufficient level of surface macrotexture reduces the traffic accidents risk. In order to determine macrotexture values, different measurement procedures are applied. Measurement results are mostly interpreted as mean texture depth (MTD) or mean profile depth (MPD) values and afterwards compared to limit values, describing the quality of macrotexture on examined road section. This paper gives a brief analysis of pavement surface macrotexture characteristics important for skid resistance realization. An overview of methods for macrotexture determination and the comparison of limit values used for characterization of macrotexture performance is shown. In addition part of the research of macrotexture properties of highway pavements done at the Faculty of Civil Engineering University of Rijeka are presented, where macrotexture was determined using vehicle – installed laser profilometer, producing mean profile depth (MPD) values.

Keywords: pavement surface macrotexture, influencing factors, field investigation

1 Introduction

Traffic safety is one of the major concerns for road authorities since it directly affects human lives, and consequently plays a significant role in road management planning and distribution of available budget to necessary road maintenance activities. Due to this, it is highly important to be able to determine road characteristics that influence the level of traffic safety. One of the most influencing road features directly connected to safety level is the pavement surface ability to provide sufficient level of skid resistance. Skid resistance represents friction coefficient realized between pavement surface and vehicle tire, which is a result of interaction between two components of frictional force, adhesion and hysteresis [1]. They contribute to skid resistance realization on different levels, depending of surface texture scale. Skid resistance at low speeds is mostly affected by microtexture characteristics while skid resistance at high speeds is usually governed by macrotexture values. Skid resistance value also depends on other contributing factors, such as vehicle speed and driving maneuver, tire properties and environmental conditions [1]. The general conclusion given in most of traffic accidents studies is that greater number of accidents occurs under wet conditions, when skid resistance ability of pavement surface is reduced due to water film covering surface texture. For roads with higher traffic speeds where pavement surface macrotexture level is one of governing factors in skid resistance realization, it is necessary to ensure proper level of macrotexture and consequently provide sufficient level of traffic safety for road users.
The aim of this paper is to briefly present surface macrotexture properties that influence macrotexture performance in terms of skid resistance realization and its effect on traffic safety level. The conventional methods for macrotexture determination will also be presented,

together with the limit values for macrotexture classification according to existing Croatian regulation [2] and recommended performance indices derived from COST 354 project [3]. Finally, the results of small-scale case study of macrotexture properties performed by Faculty of Civil Engineering Rijeka will be shown in order to establish potential relation between surface macrotexture properties and skid resistance on examined road section.

2 Pavement surface macrotexture properties

Asphalt pavement surface texture is defined as the deviation of a pavement surface from a true planar surface [4] and it can be divided in four scales according to different wavelength range: microtexture (‹ 0,5 mm), macrotexture (0,5-50 mm), megatexture (50 mm-500 mm) and unevenness (› 500 mm) [5]. Micro and macro levels of texture contribute to skid resistance of pavement surface in dry or wet conditions. Microtexture is a result of interaction between pavement surface and vehicle tyre on molecular level, resulting in adhesion component of frictional force [1]. Macrotexture contributes to skid resistance through hysteretic component of frictional force caused by energy loss due to deformation of vehicle tyre rubber in contact with the pavement surface and its magnitude has a particular effect when the pavement surface is wet, since it affects water drainage and consequently reduces the hydroplaning phenomenon [6]. Pavement surface macrotexture mostly depends on asphalt mix properties such as aggregate type, aggregate mix gradation, maximum aggregate size, percentage of air voids, binder type and binder content in the mixture [1]. The researches performed in order to establish the relation between mixture properties and surface macrotexture show that coarser aggregate type (such as granite etc.) with higher amount of angular-shaped aggregate particles produce higher macrotexture values [7, 8]. Also larger nominal maximum aggregate size (NMAS) results in higher macrotexture values [9, 10]. Aggregate mix gradation which is closer to maximum density line results in lower macrotexture values [10, 11]. Besides the aggregate characteristics, binder content and air voids level also influence macrotexture values in a way that higher asphalt binder content results in lower macrotexture values [7, 12] and increase in air voids level results in higher macrotexture values [10, 12]. The relation between pavement surface condition (dry or wet) and macrotexture values and the amount of traffic accidents has been investigated in order to establish threshold values of macrotexture necessary for adequate level of skid resistance on roads where higher traffic speeds are developed. According to several performed researches, the number of traffic accidents increases when pavement surface is wet, especially when macrotexture on inspected location reaches lower wavelength range values [1, 13, 14]. Thus, the importance of surface macrotexture values monitoring is non negligible in terms of assuring proper safety level for road users.

3 Pavement surface macrotexture determination

Many researches show that it is quite demanding to predict skid resistance or macrotexture value solely on the results of laboratory investigation, due to the complexity of skid resistance mechanism and involvement of various influencing factors. Determination of pavement surface macrotexture is currently based on laboratory and field investigation of fabricated specimens or existing roads, using measuring methods different for its measuring principles – the volumetric method and electro-optic or laser non-contact method [6, 15]. Volumetric method is based on spreading a known volume of homogenous material on pavement surface and measuring the resulting area, characterized as surface texture depth, MTD (Mean Texture Depth). Laser-based method is a non-contact measurement of pavement surface macrotexture, which is then usually described by macrotexture profile characteristics such as Mean Profile Depth (MPD), calculated from texture measurements as shown on Figure 1. The advantage of laser-based measuring method is the possibility of performing high speed measurements, which is particularly useful for field investigation of pavement macrotexture where data is collected using vehicle installed laser profilometers. Besides the previously described methods, the macrotexture data is recently obtained by new techniques such as image analysis and image processing, microscopy methods, interferometry and structured light techniques for surface topography acquisition [6, 13]. Surface texture measurement methods are thoroughly described in relevant standards; HRN EN 13036-1:2010 (Road and airfield surface characteristics-Test methods-Part 1: Measurement of pavement surface macrotexture depth using a volumetric patch test) and HRN EN ISO 13473-1:2004 (Characterization of pavement texture by use of surface profiles-Part 1: Determination of Mean Profile Depth). The latter gives an optional proposal of transformation equation from MPD value to ETD (Estimated Texture Depth) value, which is an estimation of texture depth measured by profilometer method and can be used for a nominal comparison of texture depth values obtained with volumetric method [4]. The transformation equation is

$$ETD = 0{,}2\ mm + 0{,}8 \times MPD \tag{1}$$

Macrotexture measurement is performed in order to characterize pavement surface performance as an indicator of traffic safety level on examined road section. Measured values are compared to threshold values defined in different regulations, where minimal surface texture depth or surface profile height are defined for different speed limits or road category.

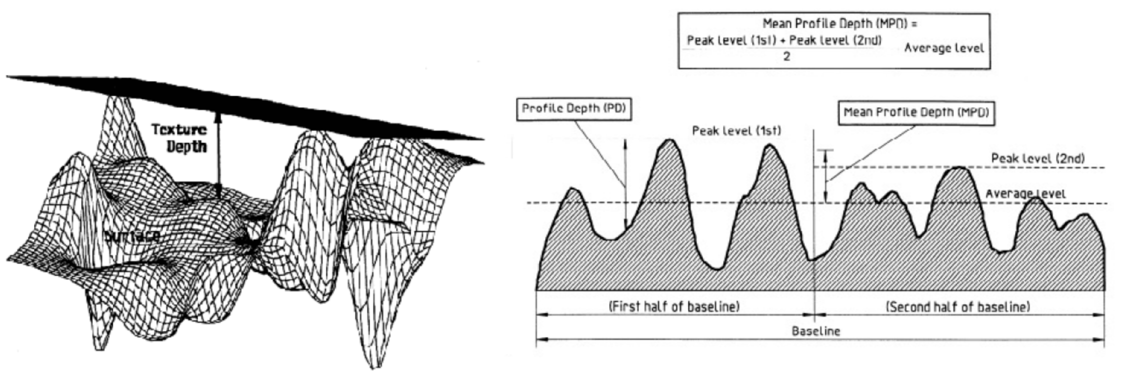

Figure 1 Surface texture depth and MPD calculation, as shown in [4]

In 2008. COST 354 Action – Performance Indicators for Road Pavements defined macrotexture performance indicator as level of macrotexture according to Mean Profile Depth (MPD) height [3]. This research action included several European countries and analysed measuring principles and technical parameters for pavement texture characterization in each country, resulting in uniformly defined performance indicator MPD [3]. In Table 1. performance indicators for macrotexture, together with their ETD equivalents calculated using transformation equation (1) are presented.

Table 1 Macrotexture performance indicators in MPD values [3]

Performance indicator	0–1 (very good)	1–2 (good)	2–3 (satisfactory)	3–4 (unsatisfactory)	4–5 (very bad)
MPD [mm] – motorways and primary roads	1,25–1,06	1,06–0,87	0,87–0,68	0,68–0,49	0,49–0,30
ETD [mm] – motorways and primary roads	1,2–1,048	1,048–0,896	0,896–0,744	0,744–0,592	0,592–0,44
MPD [mm] – secondary and local roads	1,01–0,87	0,87–0,72	0,72–0,58	0,58–0,43	0,43–0,29
ETD [mm] – secondary and local roads	1,008–0,896	0,896–0,776	0,776–0,664	0,664–0,544	0,544–0,432

Croatian national regulation [2] defines limit macrotexture depth values obtained by sand patch method according to speed limit, as shown in Table 2. The transformed ETD values could be nominally compared to limit values of texture depth shown in Table 2. It can be seen that the highest limit value given by [2] is 0,70 mm texture depth, while COST 354 Action classifies this value under lower level of satisfactory performance indicator grade. The limit values of texture depth on roads with lower speed limits are significantly lower than ETD values characterised as satisfactory level of macrotexture.

Table 2 Macrotexture depth limit values [2]

Speed limit [km/h]	60	80	100	120
Texture depth [mm]	0,13 – 0,30	0,19 – 0,40	0,27 – 0,53	0,37 – 0,70

4 Case study – pavement surface macrotexture analysis

Faculty of Civil Engineering Rijeka performed pavement surface macrotexture and skid resistance measurements on junction Draga, connecting state road D404 and motorway A7, in December 2016. The location of performed measurements is shown on Figure 2.

Figure 2 Junction Draga connecting state roads A7 and D404 with yellow marked analysed ramp

The goal of the research was to determine the properties of pavement surface and investigate its possible relation to traffic accidents. Detailed measurement and analysis results are shown in report [15]. After the initial surface properties were determined, pavement surface was subjected to renewal treatment using shot blast technology [15, 16] in order to improve pavement surface performance. Surface properties were investigated again after the treatment. The wearing course on given location is Stone mastix asphalt SMA 11. The overall investigated length was 300 m, where first 40 meters is straight and the rest of the measured length is in left curve. The average vertical slope is 3 %.

4.1 Traffic accidents analysis

This research was motivated by increase in reported traffic accidents on investigated location during 2016, as seen in Table 3. and performed in cooperation with Croatian roads and company Signalinea d.o.o. A brief analysis of traffic accidents data from 2012 – 2017 provided by Croatian Ministry of Internal Affairs [17] on investigated location showed that most of the reported accidents happened when pavement surface was wet, which is comparable to traffic accidents analysis results performed in previously mentioned researches. A significant increase of traffic accidents happened after five years of pavement service life, possibly related to increase of surface texture degradation over time. It is also noticeable that there were no recorded accidents during 2017, which could be addressed to macrotexture and skid resistance increase after the renewal treatment.

Table 3 Reported traffic accidents on analysed location [17]

Surface condition/ Nr. of accidents	2012	2013	2014	2015	2016	2017
Dry	0	0	0	1	1	0
Wet	1	1	0	1	5	0

4.2 Analysis of measurement results

Surface macrotexture measurement was performed with Hawkeye 2000 laser profilometer. MPD values were calculated for 5 meter subsection length and compared to limit values according to [3], showing satisfactory level of average surface profile depth before the treatment and very good average profile depth after the treatment. Skid resistance was measured with Micro Grip-Tester under wet conditions, with controlled water film thickness of 0.25 mm. Skid resistance values expressed in GN were transferred to F 60 values using the PIARC model [5] and compared to limit values given by [3], showing average satisfactory level. Figures 3. and 4. show the increase in surface profile depth (MPD) and F60 (determined from GN values) after the surface treatment was applied.

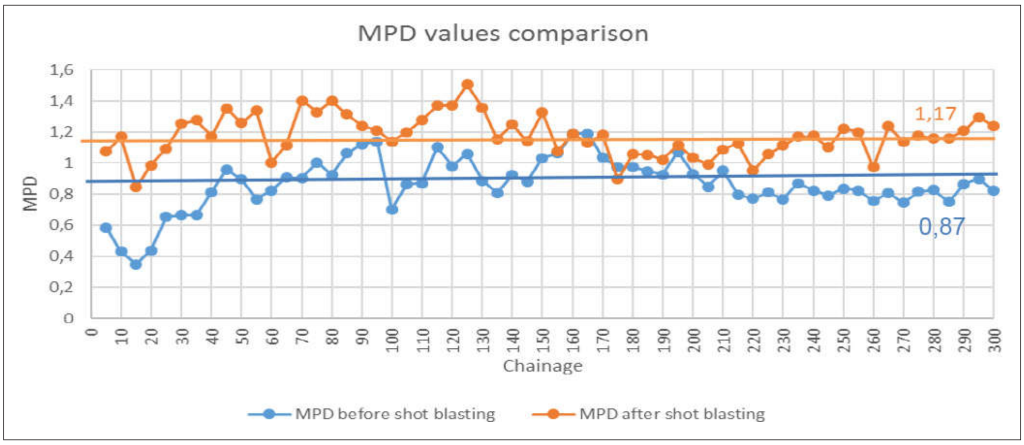

Figure 3 Comparison of MPD values before/after shot blast treatment

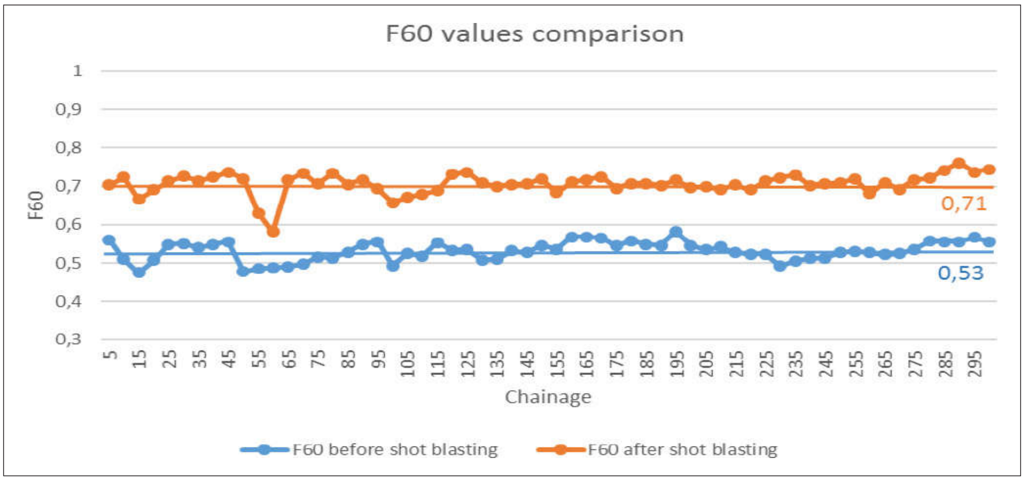

Figure 4 Comparison of F 60 values before/after shot blast treatment

Both measured values increased after the shot blasting treatment, so their relationship was investigated in order to establish possible correlation between MPD and F 60. Due to limited amount of collected data and analyses done without considering other influencing factors (e.g. asphalt mixture properties, traffic amount – AADT or similar, road geometry, environmental factors etc.), given correlation is only a general representation of relationship between the examined values. In order to carry out more detailed correlation analysis, more sections and other influencing factors should be included. Figure 5. shows the correlation between the measured values, where it can be seen that correlation coefficient R has a mediocre strength value: $R^2 = 0,59$, $R = 0,77$).

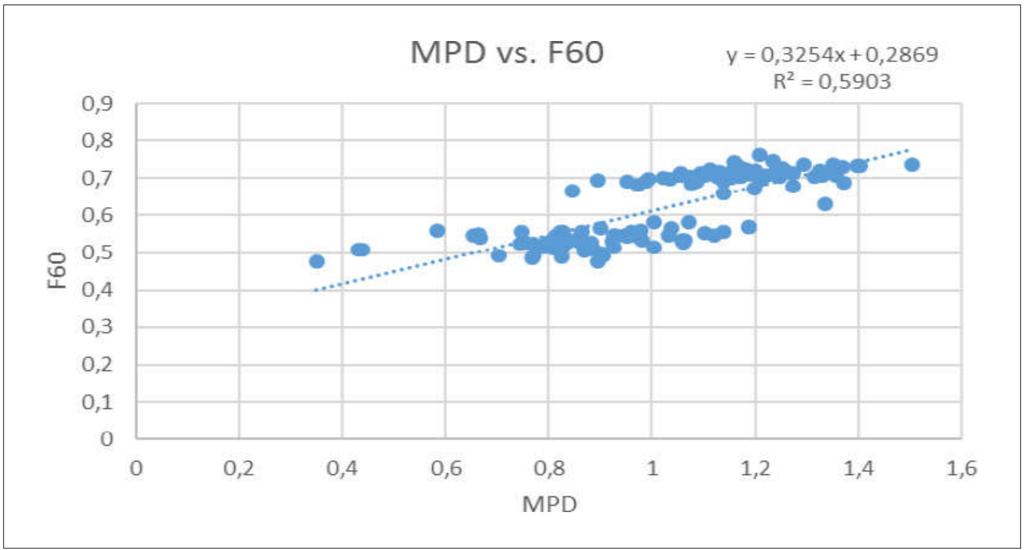

Figure 5 Correlation between MPD and F 60 values

5 Conclusion

Pavement surface macrotexture and its influence on skid resistance was investigated due to increase in reported traffic accidents on given location. Analysis was performed as a small-scale case study, where surface macrotexture and skid resistance were measured before and after applied surface renewal treatment and both investigated properties increased after the shot blasting. In fact, there were no new reported traffic accidents during 2017 at the spot. An attempt to establish correlation between these performance indicators showed moderate linear relationship. For establishing better correlation, it is necessary to perform investigation on larger scale and include other influencing factors governing skid resistance on examined roads.

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