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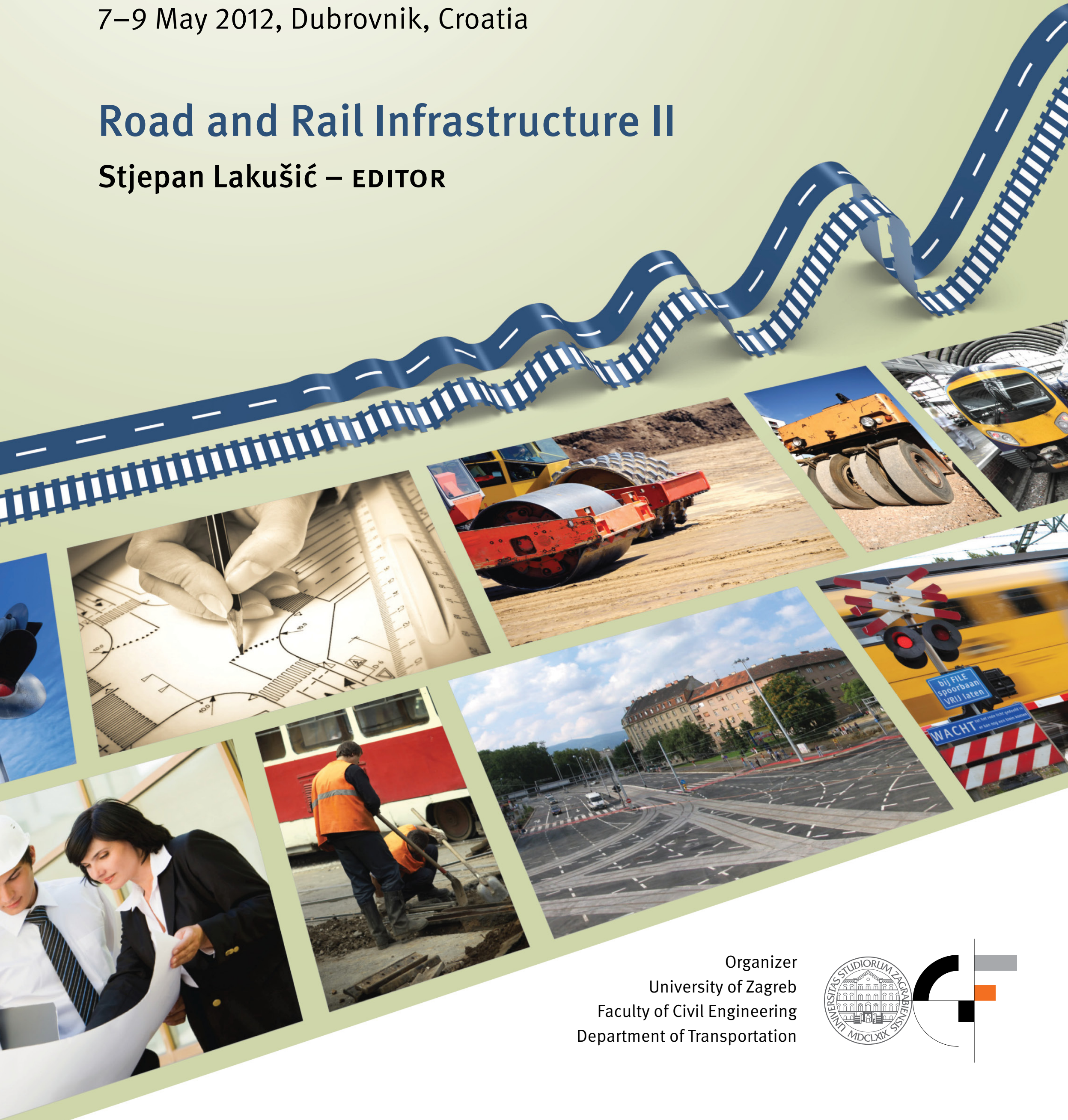
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR



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EVALUATION OF THE EFFECT OF AGGREGATES ANGULARITY ON THE SURFACE PROPERTIES OF HOT MIX ASPHALT

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Abstract

One of the most important properties of flexible pavements is the surface texture. The texture of the pavement surface and is ability to resist the polishing effect of traffic is of prime importance in providing skidding resistance. Pavement surface macrotexture greatly contributes to tire–pavement skid resistance which has a direct effect on traffic operation and safety particularly at high speeds. Doubtless, there exists a close relationship between the surface texture and the angularity characteristics of the aggregates whitin the pavement system.

This paper describes the evaluation of the angularity characteristics of the aggregates crushed with different types of crushers, and their impact on the surface properties of the pavements such as texture and surface friction. For this purpose, limestone aggregates were prepared using impact, jaw, and roll crushers. Following the determination of the angularity characteristics of the aggregate using ASTM C1252 involving two different test methods (Methods A and B) and the EN 933-6, the asphalt slabs (65x65 cm) have been prepared and compacted at their optimum bitumen contents. Texture properties of the slabs have been studied using sand patch method and laser scanner. The frictional properties have been also determined by means of Dynamic Friction Tester (DFT). Finally, evaluations have been made to determine the relationship of aggregate angularity and the surface properties.

Keywords: aggregate angularity, skid resistance, surface friction,
crushers, dynamic friction tester, laser scanner

1 Introduction

With continuous growth in amount of highway traffic and capacity, traffic crashes increase annually over the whole world. Along this increase, a great demand and focus on the needs for safer roads and highways become prior in road projects. Pavement surface friction is a key factor influencing wet–pavement accidents and, consequently, road safety [1]. Wilson and Dunn (2005) classified the factors that affect pavement skid resistance into four chief groups: road surface and aggregate factors, vehicle factors, load factors and environmental factors [2]. Among these Categories, road authorities can develop material and construction specifications that influence the second category (road surface and aggregate), which influences the microtexture and macrotexture of an asphalt pavement surface [3]. Microtexture is defined as pavement surface deviation from a planar surface in the range of less than 0.5 mm in height and typical peak–peak amplitude less than 0.2 mm and is responsible for maintaining the contact between the pavement surface and the tire [4].

Microtexture is primarily influenced by aggregate particle mineralogy, which affects the initial texture of the aggregate surface and the ability of the aggregate to retain its texture against the polishing action of traffic and environmental factors. Macrotexture is defined as pavement surface deviation from a planar surface in the range of 0.5 to 50 mm in height and typical peak–peak amplitude 0.2–10 mm. Pavement macrotexture is primarily influenced by the size, shape, and gradation of coarse aggregates; the nominal maximum aggregate size (NMAS), and construction techniques. Macrotexture influences skid resistance by controlling the paths available for water to escape so that it does not accumulate between the tire and the pavement surface, and by changing the tire tread rubber deformation. Bond showed how differences on microtexture and macrotexture of pavement surfaces influence peak brake coefficients of a standard test tire [5].

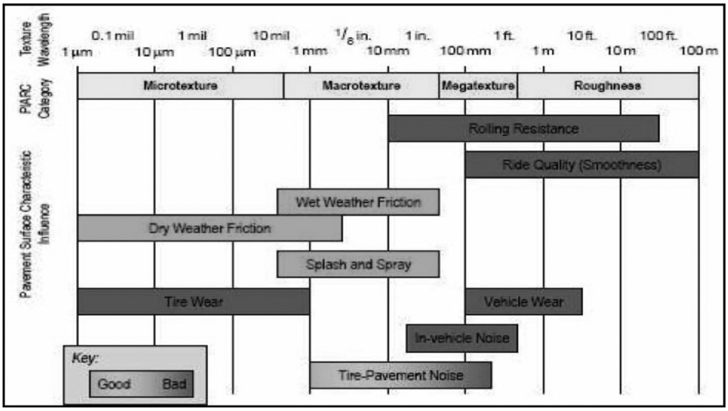

Figure 1 Pavement surface characteristics classification and their impact on pavement performance measurements

The primary indexes used to characterize the texture with the above mentioned techniques are the mean texture depth (MTD) and the mean profile depth (MPD).

2 Experimental

2.1 Materials

2.1.1 Bitumen

The bitumen with a 50/70 penetration grade was procured from Aliaga/Izmir Oil Terminal of the Turkish Petroleum Refinery Corporation. In order to characterize the properties of the base bitumen, conventional test methods such as: penetration test, softening point test, ductility, and test were performed. These tests were conducted in conformity with the relevant test methods that are presented in Table 1.

2.1.2 Aggregate

Natural Limestone ballasts were procured from Dere Beton/Izmir quarry. ballast particles were crushed with different crushers to obtain particle sizes as specified in gradation. Grading of aggregate was chosen in conformity with the Type 2 wearing course of Turkish Specifications. The results of aggregate properties are presented in Table 2.

The ASTM C1252 'Uncompacted Void Content of Fine Aggregate' was used to determine the uncompacted unit weights of the fine aggregates. This method estimates the angularity, sphericity and surface texture of the aggregate having a given grading. There are two methods for running this test: Methods A and B. The mass of the sample for both methods is fixed at 190 g. Method A specifies a standard gradation ranging from 8# (2.36mm) sieve to 100# (0.15mm). Method B specifies that the test be run on the three individual size fractions (B1, B2, B3); 8–16# (2.36–1.18mm), 16–30# (1.18–0.6mm) and 30–50# (0.6–0.3mm).

Table 1 Results of the experiments conducted on asphalt cement

Test	Specification	Results	Specification limits
Penetration (250 °C; 0.1 mm)	ASTM D5 EN 1426	55	50–70
Softening point (°C)	ASTM D36 EN 1427	49.1	46–54
Viscosity at (135°C)-Pa.s	ASTM D4402	0.338	-
TFOT (163 °C; 5h)	ASTM D1754 EN 12607-1		
Change of mass (%)		0.04	0.5 (max)
Retained penetration (%)	ASTM D5 EN 1426	51	50 (min)
Ductility (25°C)-cm	ASTM D113	100	-
Specific gravity	ASTM D70	1.030	-
Flash point (°C)	ASTM D92 EN 22592	+260	230 (min)

Also another standard method, which is similar to ASTM C1252, has been existed for coarse aggregates. Modified ASTM C1252 'Determining the Percent of Solids and Voids in Coarse Aggregate' (AASHTO TP 56) was used to determine the angularity, sphericity and surface texture of the coarse aggregate. The mass needed to perform the test is 5000g. Method A specifies a standard gradation ranging from 19mm sieve to 4.75mm. Method B specifies that the test be run on the three individual size fractions (B1, B2, B3); 19mm–12.5mm, 12.5mm–9.5mm and 9.5mm–4.75mm [6]. The EN 933-6 'Geometrical Properties of Aggregates Assessments of Surface Characteristics, Flow Coefficient of Aggregates' test method was used to determine the flow coefficient of aggregates. As seen in table 3, the flow coefficients related to 10–200# yield higher values (which means higher angularity) compared to 5–200# which demonstrates the effect of gradation on the flow coefficients of the samples [7].
Table 3 presents the evaluation of the angularity between aggregates prepared with different crushers.

Table 2 The properties of limestone aggregate

Test	Specification	Result	Specification limits
Specific gravity (coarse aggregate)	ASTM C 127	2.653	-
Specific gravity (fine aggregate)	ASTM C 128	2.663	-
Los Angeles abrasion (%)	ASTM C 131	24.4	Max 30
Sodium sulphate soundness (%)	ASTM C 88	1.47	Max 10-20

Table 3 Uncompacted void content and flow coefficient of aggregates

Aggregate type	Uncompacted void content on standard graded sample,% (ASTM C1252)				Flow coefficient, s (EN 933-6)	
	Fine aggregates		Coarse aggregates			
	Method A	Method B	Method A	Method B	5-200#	10-200#
IA	43	46	42	43	26.71	38.25
JA	41	42	41	43	25.6	37.96
RA	39	41	38	40	20.58	34.18

IA, JA, RA, aggregate samples which were prepared with Impact, Jaw and roll crusher.

2.2 Crushers

Crushing is the process of reducing the dimension of rocks to desired values. Crushing reduces the size of the rock particles to make them suitable for use in mixtures [8]. Crushing also changes the texture and shape of particles.
In this study, aggregates were prepared using 3 different crusher.

- Impact crusher: In this class crusher comminution is by impact rather than compression by sharp blows applied at high speed to free–falling rock.
- Jaw crusher: The distinctive feature of this class of crusher is the two plates which open and shut like animal jaws. The jaws are set at an acute angle to each other, and one jaw is pivoted so that it swings relative to the other fixed jaw.
- Roll crusher: Roll crusher, or crushing rolls, are still used in some mills, although they have been replaced in many installations by cone crushers.

2.3 Preparation of asphalt slabs

A limestone aggregate was used in all the Hot mix asphalt (HMA) mixes for this investigation. Aggregates crushed with different crushers and blended in batches to provide the design gradation. For each of the batches the design optimum asphalt content was found as 4.65%, 4.60% and 4.60% for I1, J1 and R1 respectively. The HMA mix weight was calculated to produce a slab 2 inches thick. Each batch of aggregate was split and placed in two buckets for heating. The asphalt cement was weighed placed in a beakers can for heating. The two steel buckets of aggregate to make up the total batch were placed in a 170°C oven overnight. This temperature and time was chosen to assure a constant temperature throughout the aggregate before mixing. After mixing aggregates with bitumen in mixer, The HMA was immediately placed in the center area of mold. The HMA was then pushed out to the corners and smoothed out using trowel. Specimens were compacted using the walk–behind roller at their compaction temprature. Each sample was 26 inches (650mm) in side and approximately 2 inches (50mm) in thick.

2.4 Test methods

There are many methods developed to measure Macro and skid resistance properties of a pavement so far [9]. Methods and the associated tests used in this study are mostly based on ASTM standards. These methods are accordingly Sand patch method [10] to measure mean texture depth (MTD), a recent and more reliable method of laser Scanner [11] to obtain mean profile depth (MPD) values and Dynamic Friction Tester [12] which is used to measure the friction coefficient of a surface at a regular speed (0 – 90 Km/hr).

2.4.1 Sand patch

The volumetric, or sand patch method (ASTM E 965, 2006), has been historically used as the main technique for measuring pavement macrotexture. The texture depth of the surface on which the sand patch test is performed, is represented by MTD.25 mm3 of fine glass beads (75µm in dimensions) are spread on a circular area over a cleaned surface measuring the average diameter of the resulting circle.MTD values are then calculated using the equation (1).

$$MTD = \frac{40xV}{\pi x D^2} \tag{1}$$

Where V is volume of glass beads in mm^3 and D is average diameter of the circles in mm.

2.4.2 3D LASER Scanning test

3D laser Scanning test is used to scan surface macrotexture profiles of the pavement surfaces. Data collecting system includes a LASER scanner and a built–in USB output to transfer scanned data to the portable computer to execute additional processing by software package which accompanies the device to give out Mean Profile Depth (MPD) values as the conflicts between the peak and mean elevations for sequential sections.The 3D laser scanner with enhanced sensor performance introduced in this study inspected full range of colors and depths on asphalt pavement surfaces. The MPD values are computed from a sample baseline divided into two equal halves as presented in Figure 2 left. The peak level in each half is determined and the average of the two peaks is termed the MPD value.

2.4.3 Dynamic Friction Tester

The pavement surface texture and skid resistance was measured in each polished location at different polishing intervals using the dynamic friction tester (DFT), respectively. The DFT device (Figure 2 right) consists of three rubber sliders attached to a rotating disk driven by a motor that can reach up to 80 km/h tangential speed. While the device drags on the pavement surface, the coefficient of friction of the surface is determined by measuring the traction force in each rubber slider.

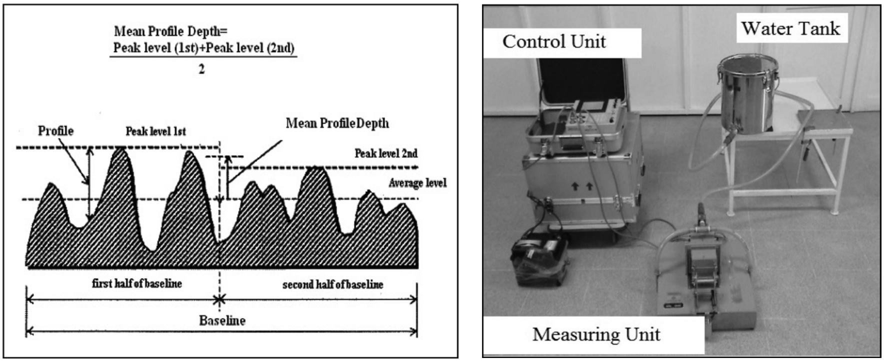

Figure 2 Method for MPD Calculation (left) and DFT Tester Units (right)

3 Results and discussions

3.1 MTD and (MPD)

The variation of MTD and MPD values are presented in table 4. IP, JP, RP pavement samples which were prepared with IA, JA and RA aggregates. As presented in table 4, the MTD and MPD values of sample J1 (which is crushed with jaw crusher) is greater than other specimens.

Table 4 MTD and MPD values

Specimen type	MTD (mm)	MPD (mm)
IP	0.852	0.546
JP	0.872	0.685
RP	0.767	0.494

3.2 DFT(20) values

An additional analysis was done to compare the DFT (20) values. DFT (20) values are used as standard values for friction coefficients recently. Table 5 shown values of this comparison.

Table 5 DFT(20) values

Specimen type	DFT(20)
IP	0.317
JP	0.384
RP	0.281

As given in table 5 specimens which prepared with jaw crusher (J1) have respectively high DFT (20) values.

4 Conclusions

Aggregate particle shape, size and gradation have an impact on the performance of asphaltic mixtures. In asphaltic mixtures, the shape of aggregate particles is related to surface texture and skid resistance of pavements. In summary, the results of the research indicate that it is possible to control and predict frictional properties of the pavement by selecting the crusher type.

Crushers can change the aggregate angularity and shape and it is directly affects the skid resistance of HMA. The influence of the aggregate type on asphalt concrete skid resistance was investigated through preparing and testing laboratory slabs.

R1 sample (the sample which was prepared with roll crusher) has the lowest angularity values between all samples and also has the lowest DF (20), MPD and MTD values. The results of the friction measurements by the DFT device showed that the J1 sample (the sample which was prepared with jaw crusher) had higher DFT (20) values than the other samples. Also it has the greatest MPD and MTD values. Consequently this type of crusher can be preferred as a secure type of crusher in terms of skid resistance. The fact proves the compatibility between MTD and MPD values.

The results of the analysis confirmed the strong relationship between mix frictional properties and aggregate properties.

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