USE OF PAVEMENT SURFACE TEXTURE CHARACTERISTICS MEASUREMENT RESULTS IN ESTONIA

Andrus Aavik[1], Tiit Kaal[2], Maret Jentson[3]

[1]Tallinn University of Technology, Tallinn, Estonia
[2]ERC Consulting Ltd., Tallinn, Estonia
[3]Technical Center of Estonian Roads, Tallinn, Estonia
[1]Ehitajate tee 5, 19086 Tallinn, Estonia, andrus.aavik@ttu.ee
[2]Väike-Ameerika 15-9, 10129 Tallinn, Estonia, tiit.kaal@erc-consulting.ee
[3]Väike-Männiku 26, 11216 Tallinn, Estonia, maret.jentson@tehnokeskus.ee

Abstract. Pavement texture has not been systematically evaluated on the level of Estonian national road network. The appropriate knowledge and experience of using parameters, describing the pavement textural condition, for planning of pavement maintenance and repair work is currently insufficient. In other countries pavement texture is evaluated and results are used for planning already for many years. Consequently the current research is describing basic concepts of different pavement texture characteristics: micro-, macro- and megatexture. Experience of measuring and using those characteristics in 13 different countries is analyzed based on the information collected by e-mail survey. Macrotexture is usually characterized using Mean Profile Depth (MPD) or Root Mean Square (RMS) values and megatexture using Root Mean Square (RMS) value. It's established based on the analysis of actual measurement results that MPD and RMS for macrotexture evaluation are well correlated (R^2=0,993) and as result of that only one characteristic (preferably MPD) is sufficient for macrotexture evaluation. Based on the conducted survey the limit values for macro- (MPD_macro) and megatexture (RMS_mega) are suggested for Estonian conditions. Based on the macro- (MPD_macro, RMS_macro) and megatexture (RMS_mega) measurements on Estonian national roads (about 4000 km or 38% of total road network) analysis of their dependence from road class, surface dressing material type, fraction and age, asphalt mix type and age were performed. Analysis did not show any remarkable correlation between abovementioned characteristics and pavement condition. That means it's not possible to determine, based on measured MPD_macro, RMS_macro and RMS_mega values, what type of asphalt concrete mix is used or what fraction of stone is used for surface dressing or what is the age of pavement or surface dressing. During the research also pavement texture characteristics were compared with locations of traffic accidents and there was determined a good relationship which means that pavement texture characteristics are more related to traffic safety measures than for pavement repair and maintenance planning. Also suggestions for use of macro- and megatexture measurement results in Estonian conditions are presented.

Keywords: pavement surface characteristics, macrotexture, megatexture, Mean Profile Depth (MPD), Root Mean Square (RMS)

INTRODUCTION

For determination of the repair and maintenance technology the condition of road pavements has to be known. Pavement condition can be characterized by different parameters and each one of them is indicating certain problem in pavement itself or in road structure. Pavement roughness, defects, rut depth and bearing capacity have been most commonly used parameters for pavement condition evaluation up till now. Starting from 2011 Estonian Road Administration has decided to take into use a new parameter to describe pavement condition – pavement texture. Pavement texture is characterizing the condition of pavement surface and it has direct relationship with traffic safety (frictional properties), driving comfort (noise, unevenness), road user costs (fuel consumption) and also with construction quality (segregation, bleeding). During the routine pavement roughness (IRI) measurements also pavement texture was evaluated on about 4000 km of Estonian national roads in 2011. By the end of 2013 texture measurement data will be available for all paved national road network. For measurements the laser based equipment (Laser Texture Meter LTM-1) is used (Fig. 1).

Pavement texture has not been systematically evaluated on the level of Estonian national road network and the appropriate knowledge and experience of using parameters, describing the pavement textural condition, for planning of pavement maintenance and repair work is currently insufficient. In several other countries pavement texture is evaluated and results are used for planning already for many years. Consequently, as the texture measurements have already started, the question of limit values establishment for certain decision making processes, concerning traffic safety and repair or maintenance works, arises. Current research is describing basic concepts of different pavement texture characteristics (micro-, macro- and megatexture) and analyzing first Estonian measurement results of 2011.

Fig. 1. Equipment for pavement texture and roughness measurement Laser Texture Meter LTM-1

1 PAVEMENT TEXTURE CHARACTERISTICS

Pavement texture is defined as the vertical unevenness of the absolutely even pavement surface. World Road Association (PIARC) as determined standard categories for pavement texture based on wave length (Fig. 2).

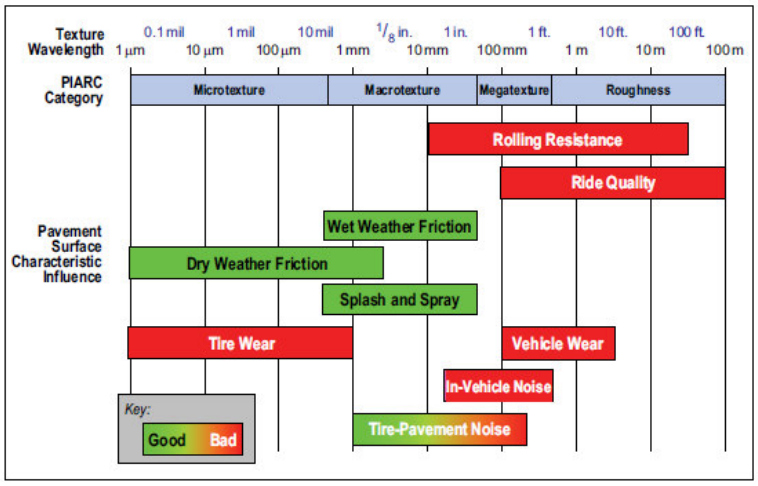

Fig. 2. Pavement texture categories determined by World Road Association and their influence *(Rasmussen et al, 2011)*

According to PIARC there are four wave length standard categories describing the pavement texture *(Rasmussen et al, 2011)*:

- microtexture: wave length 1 µm - 0,5 mm;
- macrotexture: wave length 0,5 – 50 mm;
- megatexture: wave length 50 – 500 mm;
- unevenness: wave length > 500 mm - 100 m (EVS-EN ISO until 50 m).

ISO 13473-1 is determining microtexture starting from wave length 5 µm *(Nitsche Philippe, Spielhofer, 2009)*.

Microtexture is the roughness of the surface of mineral aggregate grain. Macrotexture is the texture of the pavement surface in the scale of the mineral aggregate grain protruding from the pavement surface. Megatexture is the unevenness in the scale of the contact surface between the vehicle tyre and pavement surface. All texture characteristics are influencing to the contact surface area of the road and tyre. *(Liikennevirasto, 2010)*. (Fig. 3)

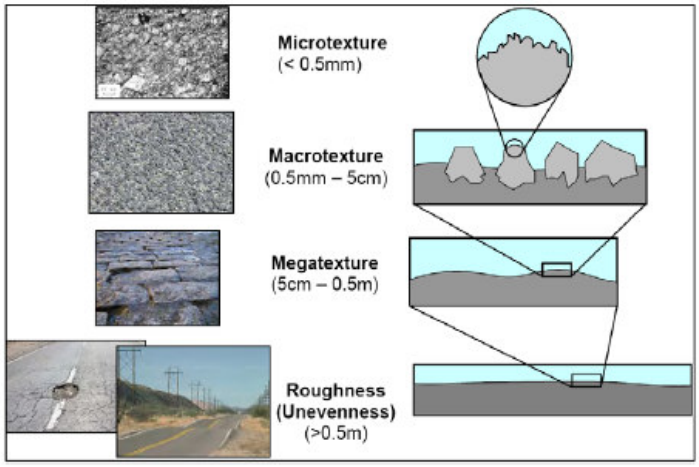

Fig. 3. Comparable scales of different texture categories *(McGhee, Flintsch, 2003)*

For road network level current technology allows conducting measurements for two texture parameters – macro- and megatexture.. To describe those parameters different measures are used:

- MPD – Mean Profile Depth;
- MTD – Mean Texture Depth;
- SMTD – Sensor Measured Texture Depth;
- SH – Surface Height;
- TL – Texture Level;
- PSD – Power Spectral Density;
- RMS – Root Mean Square.

In Estonia macrotexture is characterized using Mean Profile Depth (MPD, Fig. 4) and megatexture using Root Mean Square (RMS).

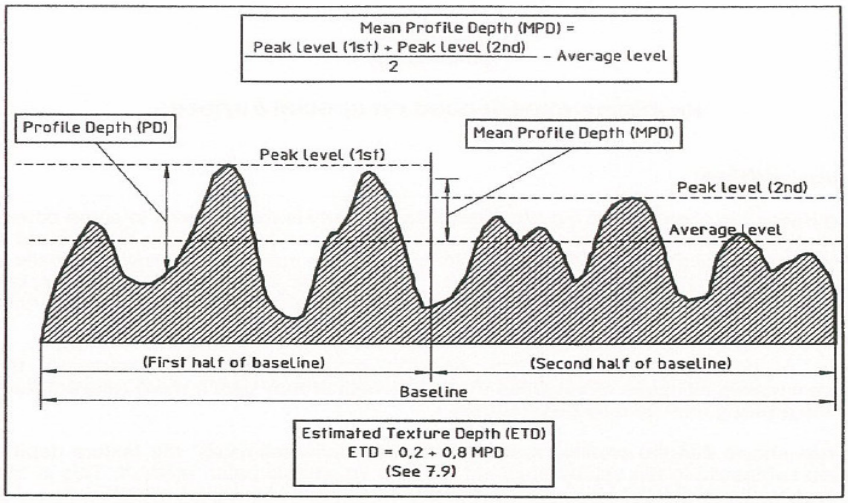

Fig. 4. Determination of the Mean Profile Depth *(EVS-EN ISO 13473-1:2004)*

Value of MPD characterizing macrotexture is dependant of the maximum mineral aggregate grain size used in pavement. Macrotexture facilitates to water removal between tyre and pavement and preventing aquaplaning. From the other hand – growth of the value of MPD is in direct relation with the growth of tyre noise.

Megatexture is undesirable property of the pavement and its value is influenced by the different pavement defects as potholes, ravelling, bridge joints, pavement marking, etc.

2 EXPERIENCE OF OTHER COUNTRIES USING PAVEMENT TEXTURE MEASUREMENT DATA

One aim of the current research was to analyze the situation of pavement texture measurement and measured data usage in other countries. As it appears in the summary table (Table 1), all involved countries are performing texture measurements and 50 % of them are using measurement data in decision making process, but only 30 % of them have established limit values for texture parameters.

Table 1. Summary of experience of measurement and usage of pavement texture parameters in other counties

Nr.	Country	Texture measurements / Use of data in decision making	Texture parameters used in data analyses	Existence of limit values for texture parameters
1	Belgium	yes / in the stadium of research	MPD	under development
2	Lithuania	yes / no	MPD?	no
3	Slovenia	yes / yes	SMTD	yes
4	Norway	yes / in the stadium of research	-	under development
5	France	yes / yes	MPD	yes
6	Great Brittan	yes / yes	SMTD	yes
7	Italy	yes / yes	MPD and SH (also TL, PSD)	partly yes, partly under development
8	Latvia	yes / no	MPD	no
9	Finland	yes / in the stadium of research	RMS	under development
10	Denmark	yes / yes	MPD	yes
11	Sweden	yes / in the stadium of research	MPD (earlier RMS)	partly yes, partly under development
12	Australia	yes / yes	MPD (depending from district)	partly yes, partly under development
13	Estonia	yes / in the stadium of research	MPD and RMS	under development

3 RECOMMENDATIONS FOR PAVEMENT TEXTURE LIMIT VALUES

As the pavement texture measurement experience in Estonia is limited and also there is not enough measurement data for corresponding analyses and scientific decision making therefore recommendations for use of pavement texture values and establishment of their limit values in Estonia is based mainly on the foreign experience and technical capabilities of the used measuring equipment (LMT-1).

Proposed pavement macrotexture MPD limit values are dependant from the maximum allowed traffic speed and traffic volume (Table 2). Higher traffic speed is requiring higher friction properties of the pavement to ensure necessary vehicle stopping distances which are dependent from the macrotexture. High traffic volumes are causing tens traffic situations which are also requiring for proper action higher friction properties of the pavement.

Table 2. Proposed pavement macrotexture MPD limit values in Estonia, mm

ADT, vehicles/24h	Maximum allowed traffic speed, km/h			
	110	90	70	50
< 500	≥0.40	≥0.35	≥0.30	≥0.25
500 – 1000				
1000 – 5000				
> 5000				

Alternative to multiple MPD limit values (Table 2) is to use only one MPD limit value on the whole road network which is ≥0.4 mm (that means MPD values less than 0.4 mm are not recommendable). Limit value for megatexture RMS is determined by Finland and its maximum value is 0.9 mm. Any argumentation for determination of that limit value is not available. As currently other information concerning the RMS limit value determination is not available it's suggested to establish megatexture RMS limit value ≤0.9 mm in Estonia (that means RMS values over 0.9 mm are not recommendable).

4 ANALYSES OF TEXTURE MEASUREMENT RESULTS

During the roughness measurements also following pavement texture characteristics were recorded:

- macrotexture Root Mean Square (RMS);
- macrotexture Mean Profile Depth (MPD);
- megatexture Root Mean Square (RMS).

As it was established, there exists very good relationship between macrotexture's Root Mean Square and Mean Profile Depth values (R^2=0,99), consequently in further analyses only Mean Profile Depth values are used.

Relationship between macrotexture's Root Mean Square and Mean Profile Depth values:

$$MPDmacro = 1.729 * RMSmacro + 0.019 \quad (1)$$

where: *RMSmacro* – measured Root Mean Square of macrotexture, mm;
MPDmacro – calculated Mean Profile depth of macrotexture, mm.

Measured texture data is analysed based on the following indicators:

- road type: main, basic and secondary roads;
- pavement type: without surface dressing, with surface dressing;
- surface dressing material type: granite, limestone, graded crushed gravel.

4.1 Pavement texture of different road types

Values of pavement macrotexture are distributed on main, basic and secondary roads differently depending from the road type (Fig. 5).

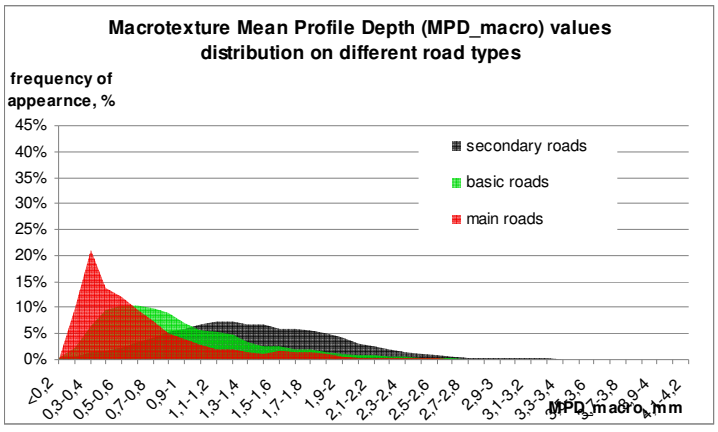

Fig. 5. Distribution of macrotexture Mean Profile Depth values on different road types

Higher pavement macrotexture values are characteristic for secondary roads, medium values for basic roads and smaller values for main roads. As the value of pavement macrotexture is influenced by the grains of mineral material, sticking out from the pavement surface, there exists justification for above mentioned distribution of macrotexture values – as most of Estonian secondary roads are surface dressed and the percentage of surface dressed basic roads in comparison with main roads is

bigger then also their macrotexture values are accordingly higher. New pavements of main roads are usually not surface dressed and therefore their macrotexture values are smaller.
Distribution of megatexture values on different road types (Fig. 6) is similar to the distribution of macrotexture values. Megatexture RMS measurement results are spread in a narrower area (0-1.5 mm) in comparison with macrotexture MPD measurement results (0-2.8 mm).

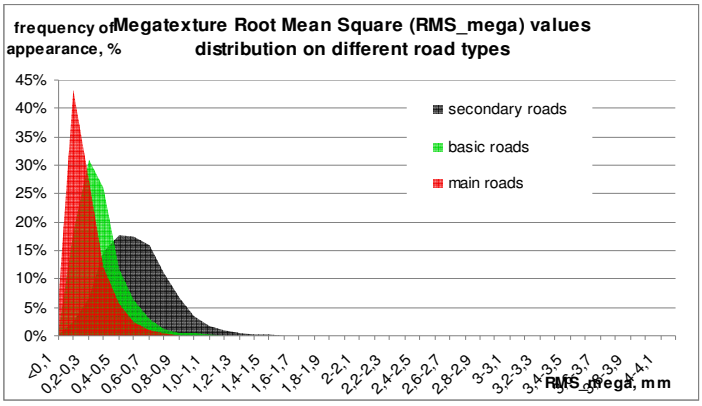

Fig. 6. Distribution of megatexture Root Mean Square values on different road types

4.2 Texture of different pavement types

Separately is analysed the influence of surface dressing to the values of pavement macro- and megatexture. According to the measurement results macrotexture MPD values and megatexture RMS values are higher on surface dressed pavements (Fig. 7 and 8).

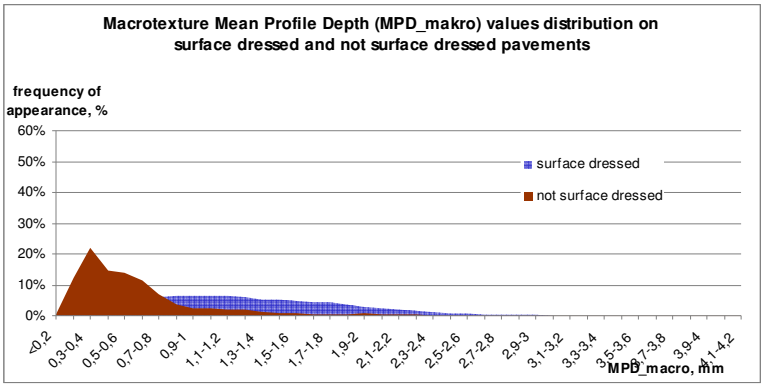

Fig. 7. Distribution of macrotexture Mean Profile Depth values on different pavement types

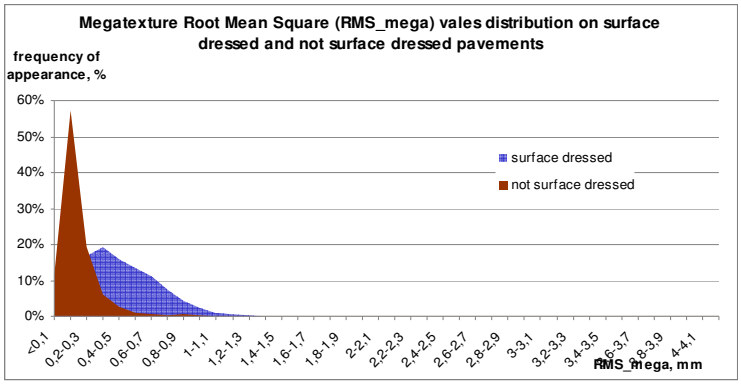

Fig. 8. Distribution of megatexture Root Mean Square values on different pavement types

Measurement results are partly overlapping on surface dressed and not surface dressed pavement types, which means their texture characteristics can be similar. That can be related to various different factors – materials used for surface dressing, surface dressing age etc. Therefore, based on the texture measurement results, can not be decided whether the pavement is surface dressed or not. It can only be supposed that smaller measurement results are probably from not surface dressed pavement.

4.3 Change of pavement texture during pavement service life

During the current research also change of pavement texture values during pavement service life was analysed. In other words pavement texture values on pavements of different age were compared.
On pavements without surface dressing change of texture values by time has a good relationship (Fig. 9). It can be stated that during the pavement service life macrotexture values are decreasing faster than megatexture values.

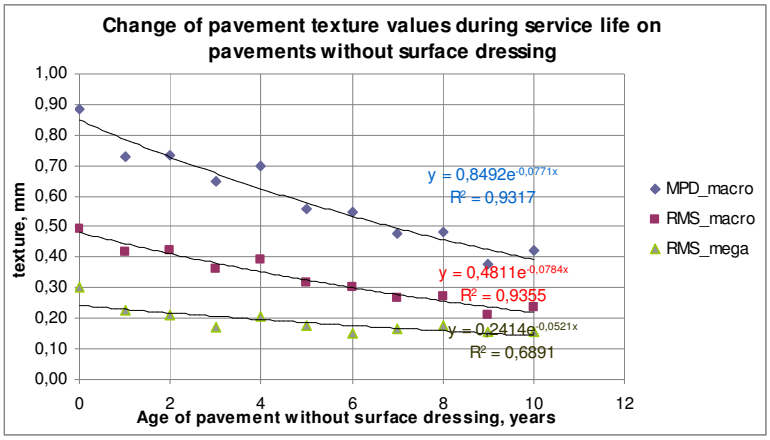

Fig. 9. Change of pavement texture values during service life on pavements without surface dressing

Also changes of texture values on pavements with different asphalt concrete types (SMA 12, SMA 16, AC 12 surf and AC 16 bin) were analysed (Table 3).

Table 3. Analysed asphalt concrete pavement mixture types and their texture values, mm

Mix type	RMS_macro range, mm	MPD_mega range, mm	RMS_mega range, mm
SMA 16	0.3-1.0	0.6-1.8	0.2-0.6
SMA 12	0.1-0.4	0.2-0.8	0.1-0.3
AC 12 surf	0.1-0.4	0.2-0.8	0.1-0.2
AC 16 bin	0.2-0.8	0.4-1.4	0.1-0.5

Different asphalt concrete mixture types have well determined ranges of texture values but ranges of different mixes are overlapping and according to the measured texture value it's not possible to specify what kind of asphalt mix is used on certain road section.
On pavements with surface dressing the change of macrotexture during the first two service years is quite intensive. After that period texture values are stabilizing for some years and at the age 5-6 years surface dressed pavement texture values are increasing. (Fig. 10)
Also change of texture values is analysed on pavements with different surface dressing materials (Fig. 11 and 12). Texture values of pavements, surface dressed with granite and graded crushed gravel, are behaving similarly: during the pavement service life texture values are decreasing.

Texture values of pavements, surface dressed with limestone, are at the same time, inversely to granite and gravel, increasing. What are the reasons of that kind behaviour of pavement texture values with limestone surface dressing have to be determined.

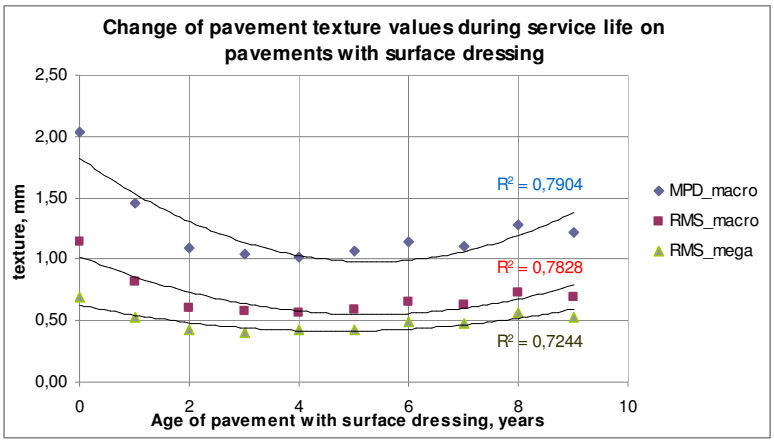

Fig. 10. Change of pavement texture values during service life on pavements with surface dressing

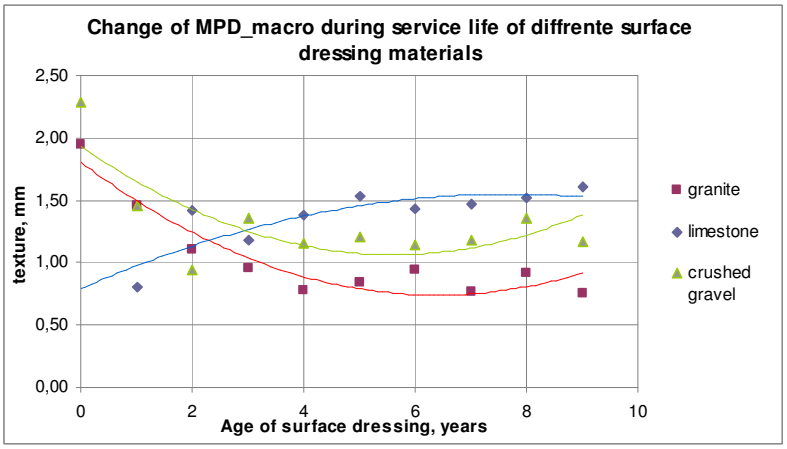

Fig. 11. Change of pavement macrotexture values during service life on pavements with different surface dressing materials

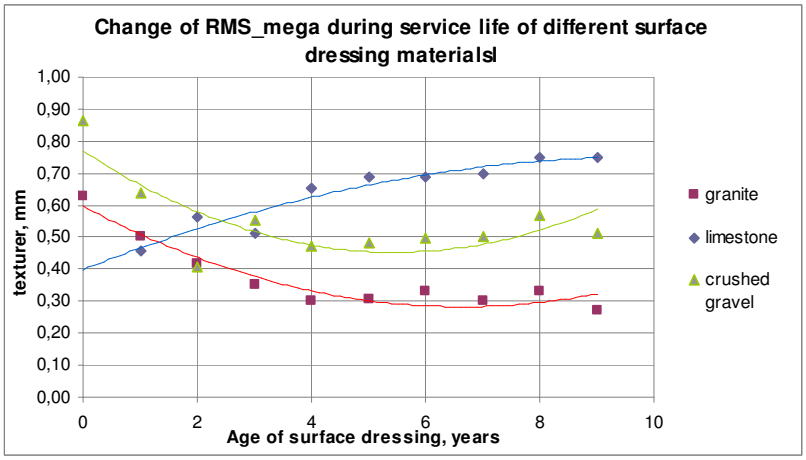

Fig. 12. Change of pavement megatexture values during service life on pavements with different surface dressing materials

4.4 Pavement texture and traffic accidents

As pavement macrotexture has influence to the frictional properties of the pavement, there are analysed pavement macrotexture values measured in 2011 and traffic accidents that took place during past 10 years on those roads (Fig. 13). Traffic accidents are not classified according to accident types and road conditions during the accident. Repair- and construction work performed on those roads during the accident analyses period were not taken into account at this stage of the research.

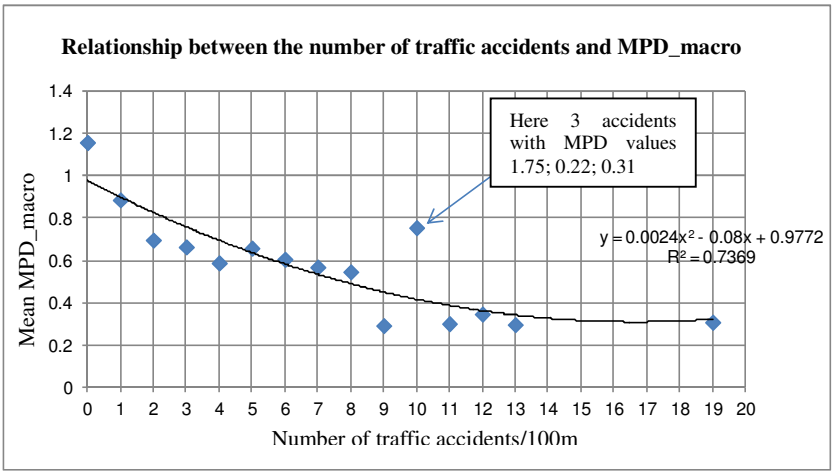

Fig. 13. Relationship between the number of traffic accidents per 100 m road section and pavement macrotexture values on those sections

With the decrease of pavement macrotexture values the probability of traffic accident is increasing. As it was the first attempt of authors to find relationship between pavement texture values and accident rate and the first simplified approach gave a quite interesting result, it's worth to continue with that kind of detailed research after pavement texture measurements have been performed on all national road network in 2013.

CONCLUSIONS

As the result of the current research following can be concluded:

- All texture categories (micro-, macro- and megatexture) are influencing the contact surface of tyre with pavement, but only microtexture is having direct influence to the friction between the tyre and pavement surface and with that to the traffic safety. Macrotexture is assuring waterless contact between tyre and pavement surface and decreasing aquaplaning danger but at the same time increasing tyre noise.
- All 13 countries, involved in pavement texture measurement and result usage survey, are performing texture measurements and 50 % of them are using measurement data in decision making process, but only 30 % of them have established limit values for texture parameters.
- As there existing very good relationship between macrotexture's Root Mean Square and Mean Profile Depth values, it's sufficient to use for analyses only Mean Profile Depth values.
- Pavement macrotexture MPD limit values are proposed for Estonia and they are dependant from the maximum allowed traffic speed and traffic volume (Table 2).
- It's suggested to establish megatexture RMS limit value ≤0.9 mm in Estonia.
- Higher macrotexture values are characteristic for secondary roads, medium values for basic roads and smaller values for main roads.

- Distribution of megatexture values on different road types is similar to the distribution of macrotexture values. Megatexture RMS measurement results are spread in a narrower area in comparison with macrotexture MPD measurement results.
- According to the measurement results macrotexture MPD values and megatexture RMS values are bigger on surface dressed pavements.
- Based on the texture measurement results, it cannot be decided whether the pavement is surface dressed or not. It can only be supposed that smaller texture measurement results are probably from not surface dressed pavement.
- During the pavement service life macrotexture values are decreasing faster than megatexture values.
- Different asphalt concrete mixture types have well determined ranges of texture values but ranges of different mixes are overlapping and according to the measured texture value it's not possible to specify what kind of asphalt mix is used on certain road section.
- With the decrease of pavement macrotexture values the probability of traffic accident is increasing.

Texture measurement data can be used for the following purposes in Estonia:

- Macrotexture for the evaluation of pavement traffic safety and frictional properties;
- Megatexture as the pavement property that has to be avoided, or road sections with high megatexture values over certain limit value have to be added to the repair list;
- Macro- and megatexture values of different surface dressing materials for selection appropriate surface dressing materials;
- Macro- and megatexture values as quality criteria, based on what the quality of the new pavement or surface dressing can be assessed.

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