



INVESTIGATION OF ASPHALT CONCRETE PAVEMENT QUALITY OF LITHUANIAN HIGHWAYS

Evaldas Petkevičius¹, Rolandas Petkevičius², Rimantas Babickas¹

¹Dept of Roads, Vilnius Gediminas Technical University, Saulėtekio al.11, LT-10223 Vilnius, Lithuania,
E-mail: kk@ap.vtu.lt

²UAB „Lemminkainen Lietuva“, Granito g. 4, LT-02241 Vilnius, Lithuania
E-mail: vilnius@lemminkainen.lt

Abstract. Planning of road building and repair sectors requires evaluation of the actual state of the road pavement. The available methods of evaluation of the condition and construction of pavement have serious shortcomings: some of them are lacking precision and reliability, others are too sophisticated. For this reason they are not very helpful in practice. Based on analysis of previous works and on the experimental results, a sufficiently accurate and simple method for evaluation of the state of asphalt concrete pavement is suggested. The present status of the asphalt concrete pavement and its construction as well as the main causes of their disintegration are discussed. Important principles of road maintenance, ensuring a longer lifetime of asphalt concrete pavement are presented. Factors indicating the state of the pavement are established. Indices of the state of asphalt concrete pavement roads were analysed and standard values of these indices suggested. Correlation between the pavement smoothness results according to the international index IRI Y_{IRI} and measured with a 4 m long bar is defined. Conclusions and recommendations are given.

Keywords: asphalt concrete pavement, condition of the pavement, smoothness of the pavement, abundance of ruts on the pavement, strength of the pavement, degradation of the pavement, lifetime of the pavement, transport expenses.

1. Introduction

The length of the Lithuanian state roads (the data for 01 01 2005 [1, 2]) is 21 345 km including 1 749 km of trunk roads, 4873 km of country roads and 14 723 km of district roads. The greater part of the state roads (58,97 %) has asphalt concrete or other kinds of asphalt pavement.

The service and maintenance experience shows that the lifetime of the asphalt concrete or other kinds of asphalt pavement of Lithuanian roads is rather short. Cracks, nicks, potholes and other warps appear in winter, autumn and spring. Ruts, corrugations, displacements and other shear deformations occur when air temperature is high (in summer). As time passes, these deformations intensify and the area of disintegrating road sectors increases reducing the traffic flow speed, travelling comfort and security.

The problems of maintenance and repair are mainly related to the increasing number of heavyweight multi-axial vehicles on Lithuanian roads. The smoothness of pavement and strength of construction of Lithuanian roads are unequipped for large heavyweight vehicles.

The state and quality indices of asphalt concrete pave-

ment of roads have been investigated by many scientists [3–12], yet few of them attempted to evaluate the pavement evenness by the international index IRI YIRI versus evenness measured by the aid of measuring bar [3, 12] (this interdependence has not yet been established in Lithuania). Few scientists [3, 5, 6] have undertaken standardisation of the indices of the pavement condition. However, due to an increasing flow of heavy multi-axial vehicles in Lithuania [13], whose contribution to pavement disintegration is greater than that of other vehicles, it is necessary to continue the already assumed investigations of road pavement.

In order to economise financial means the repair of the pavement should be rationally planned, i.e. the rational time frames between repairs should be established. For this purpose it is necessary to analyse the quality indices of asphalt concrete pavement.

2. Methods of research

The asphalt concrete pavement was examined in different wear sectors of highways Vilnius–Kaunas–Klaipėda (A 1) and Vilnius–Ukmergė–Panevėžys (A 2). The follow-

ing indices were measured: flatness of asphalt concrete by using 3 or 4 m long bar (Figs 1 and 2), smoothness of pavement according to the international standard IRI Y_{IRI} by the device DYNATEST 5051 RSP and ruts in the pavement by a 2 m long bar. The obtained results were compared with the limit values of the pavement quality [14].

The experimental data were processed by mathematical statistical methods. Statistical characteristics were quantified by the formula [15]:

$$\bar{x} = \frac{1}{n}(x_1 + x_2 + \dots + x_n) = \frac{1}{n} \sum_{i=1}^n x_i, \quad (1)$$

where: \bar{x} – arithmetic mean of the studied parameter; x_1, x_2, \dots, x_n – the 1st, 2d, ..., i, ..., n (last) values; n – number of values of the studied measurements;

$$\sigma = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2}, \quad (2)$$

where: σ – standard deviation of studied parameter.

$$V = \frac{\sigma}{\bar{x}} \cdot 100, \% \quad (3)$$

where: V – coefficient variation of the studied parameter.

The analysis revealed that the degree of degradation

of the road pavement can be a way determined using the equation [3]:

$$D = \left(S_d + S_{pl} + S_p + \sum_{i=1}^n l_i b_i \right) \cdot 100 / S, \quad (4)$$

where: D – relative width of pavement with defects (degree of degradation), %; S – width of the studied road sector, m^2 ; it is expedient to examine side lane (with heaviest traffic) road sector sectors ($L_r = 30 - 50$ m long); when the roadway width $b = 3,25$ m and $L = 40$ m the value $S = 130$ m^2 , when the roadway width $b = 3,50$ m and $L = 40$ m the value $S = 140$ m^2 and when the roadway width $b = 3,75$ m and $L = 40$ m the value $S = 150$ m^2 ; S_d – width of pavement with cracks, nicks and flaws, m^2 ; S_{pl} – width of pavement with a network of cracks, m^2 ; S_p – width of pavement with waves, ruts and other shear and plastic defects, m^2 ; l_i – length of individual i crack, m; b_i – width of lane which has lost strength and width of the both sides of i crack, depending on the crack width, determined by [16] method, m.

The degree of asphalt concrete pavement degradation D was determined by Eq 4. Experimental data processing revealed interdependences between the value D and smoothness of the pavement Y , between the lifetime of the pavement T and index D , between indices T and Y , between the indices of the abundance of ruts H_a, H_{max}, S and index D etc.

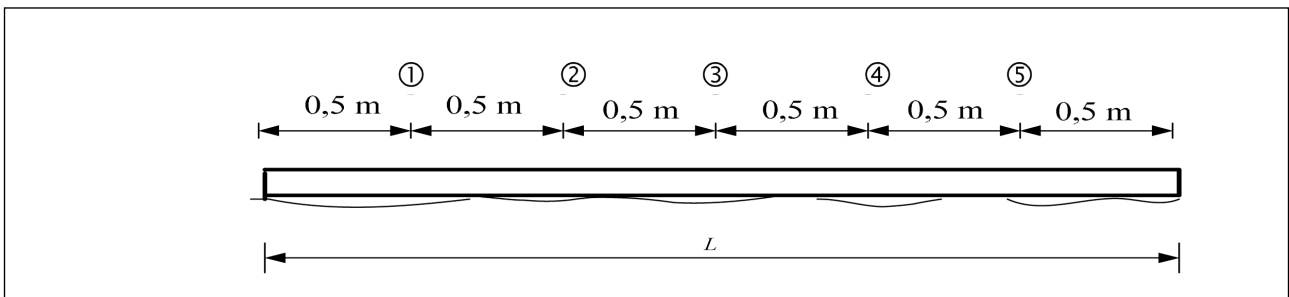


Fig 1. Scheme of measuring sites by 3(4) m long bars (1... 5 – measuring points, L – length of measuring bar, $L = 3$ m or $L = 4$ m)

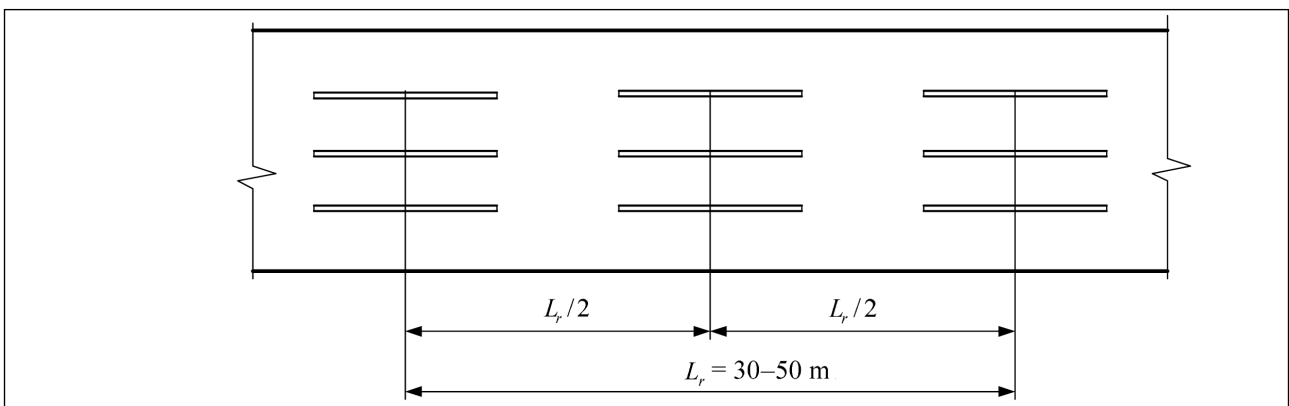


Fig 2. Scheme of placing sites of measuring bars 3(4) m in the roadway (in $L_r = 30 - 50$ m)

3. Investigation of some quality indicators of asphalt concrete pavement

A special experiment was carried out for an analysis of quality indices of asphalt concrete pavement. The following indices were examined in 103 elementary 30–50 m long and 3,75 m wide side lane sectors of highways A 1 and A 2: smoothness of the pavement measured by a 3,0 m long bar – indices \bar{Y}_{\max} and \bar{Y} , mm; \bar{Y} , cm/km; smoothness of the pavement measured by a 4,0 m long bar – indices \bar{Y}_{\max} and \bar{Y} , mm; \bar{Y} , m/km; degree of degradation of the pavement – indices D, D_n, D_e, D_t , %; abundance of ruts – indices H_a, H_{\max}, S .

Denotations and characteristics of studied indices: \bar{Y}_{\max} – arithmetic mean of the highest values of smoothness of pavement measured by 3 or 4 m long bars when the number of measuring sectors was $n = 9$; \bar{Y} – arithmetic mean \bar{x} of all values of smoothness of pavement measured by 3 or 4 m long bars when the number of measuring sectors was $n = 45$ (3 m long bar) and $n = 63$ (4 m long bar); D – degree of degradation – total D , wear degradation D_n , erosion degradation D_e , cracks entailed by temperature D_t , %; H_a, H_{\max} – average and greatest depth of a rut, mm; S – area of cross-section of a rut, mm².

The following statistical characteristics were determined in sectors of highways Vilnius–Kaunas (A 1), Kaunas–Klaipėda (A 1) and Vilnius–Ukmergė–Panevėžys (A 2): arithmetic mean \bar{x} , standard deviation σ and coefficient variation of V (Table 1).

The obtained results show that the differences of asphalt concrete pavement in the highway sectors Vilnius–Kaunas, Kaunas–Klaipėda and Vilnius–Ukmergė–Panevėžys were negligible (Table 1). The degradation degree D in the sector Vilnius–Kaunas ranged from 0 to

14,01 %. The proportion of wear degradation and wear due to insufficient strength of pavement was 14,77 %, erosion degradation – 3,75 % and cracks due to temperature fluctuations – 81,48 %. The degree of degradation D in the sector Kaunas–Klaipėda varied from 0 to 39,78 %. The proportions of wear degradation and wear due to insufficient strength of pavement was 39,89 %, erosion degradation – 40,46 %, cracks due to temperature fluctuations – 19,65 %. The degree of degradation D in the sector Vilnius–Ukmergė–Panevėžys ranged from 0 to 61,27 %. The proportions of wear degradation and wear due to insufficient strength of pavement was 56,49 %, erosion degradation – 22,10 %, cracks due to temperature fluctuations – 21,41 %. The following defects of pavement were dominant in the Lithuanian roads: degradation due to temperature-entailed cracks and wear and degradation due to insufficient strength of the pavement. The obtained results showed that the smoothness of pavement usually satisfy the normal (Gauss') law (Table 1).

The correlation of pavement smoothness measured with 3 and 4 m long bars in the highways A 1 and A 2 is given in Fig 3.

The results reveal a close correlation between the studied parameters (correlation coefficient $r = 0,93$) (Fig 3).

Investigation results obtained in 1999–2001 served as a basis for determining correlation between the smoothness indices Y and Y_{\max} , between the indices of the smoothness σ_y and $\sigma_{y_{\max}}$, between the smoothness indices Y and Y_{IRI} , between the smoothness indices Y_{\max} and Y_{IRI} , between the lifetime T and smoothness index Y_{IRI} , between the degree of degradation D and smoothness Y_{IRI} (Fig 4–9). The values of correlation coefficients in the determined interdependences ranged from $r = 0,73$ to $r = 0,96$.

Table 1. Statistical characteristics of the pavement state of main Lithuanian highways

Index of the pavement state		Roads					
		Highway Vilnius–Ukmergė–Panevėžys (A2), number of measuring sectors $n = 43$			Highways (A1) and (A2), number of measuring sectors $n = 103$		
Denomination of the index and measuring unit	Specific features of measuring	\bar{X}	σ	$V, \%$	\bar{X}	σ	$V, \%$
Y_{\max} , mm Y , mm Y , cm/km	By a 3 m long bar	1,29 0,53 346	0,55 0,24 73	42,75 44,90 21,19	1,62 0,83 388	0,57 0,25 68	35,38 30,34 17,44
Y_{\max} , mm Y , mm Y , m/km	By a 4 m long bar	1,50 0,61 3,61	0,68 0,26 0,86	45,48 43,11 23,83	1,88 0,90 4,12	0,86 0,36 0,82	45,48 40,00 19,88
H_{\max} , mm H_a , mm S , mm ²	Side rut of the roadway	4,23 1,96 2 237	2,57 1,08 1 371	60,76 54,80 61,26	7,17 3,46 4 590	5,14 2,55 3 857	71,75 73,78 84,03
H_{\max} , mm H_a , mm S , mm ²	Inner rut of the roadway	2,58 1,92 1 962	1,40 1,40 1 773	54,26 73,09 90,40	6,59 3,23 4 023	4,79 2,30 3 680	72,63 71,28 91,48
D , % D_n , % D_e , % D_t , %	Degradation of the whole side lane	11,68 8,51 2,14 1,03	15,27 14,37 5,91 1,39	130,74 168,84 275,71 135,12	9,06 5,29 2,52 1,25	11,56 9,89 5,50 1,48	127,58 186,98 218,45 118,76

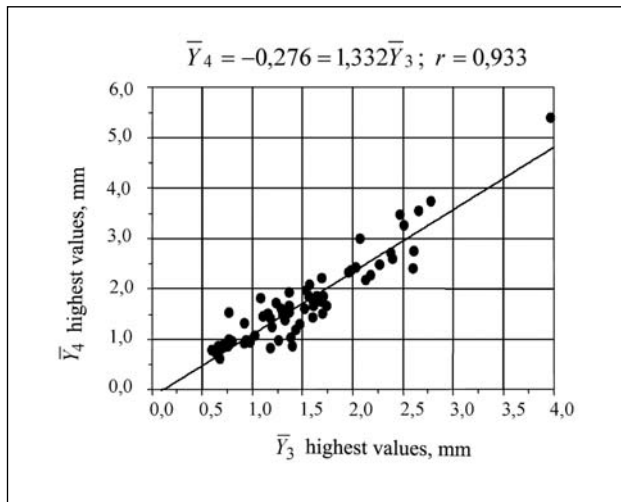


Fig 3. Interrelation of the highest values of the smoothness of pavement: \bar{Y}_3 measured with a 3 m long bar and \bar{Y}_4 with a 4 m long bar

Investigations carried out by the staff of the Roads Department of Vilnius Gediminas Technical University including individual investigations of the authors [3] show that when the strength coefficient K_{st} reaches its critical value $K_{st} = 1,0$ the degree of degradation also reaches its critical value $D = 16\%$. When the degradation value reaches its critical value, the lifetime of pavement of Lithuanian roads T also becomes critical $T = 8$ years. The data provided by the Institute of Transport and Road Research [17] show that the increase of Y_{IRI} from 2,0 m/km to 2,5 m/km entail an increase of transport expenses (I_t spent on 1000 cars to pavement 1 km of the road) by 1,7 % and from 2,0 m/km to 2,75 m/km – by 2,5 %. We suggest to use the smoothness value of asphalt concrete pavement according to IRI $Y_{IRI} = 2,5$ m/km as a criterion for determining the lifetime of the pavement till the minor repair T_v and the smoothness value $Y_{IRI} = 2,75$ m/km as a criterion for determining the lifetime of pavement till the major repair T_k . The suggested is 5 years and – 8 years.

Table 2. Recommended allowed values for parameters of asphalt concrete pavement of Lithuanian highways

Parameter of the state of pavement and its measuring unit	Recommended allowed the state of pavement indices
Smoothness of pavement Y_{IRI} , m/km:	
Till the minor repair	2,50
Till the major repair	2,75
Indices of the abundance of ruts:	
Till the minor repair	
H_{max} , mm	6,0
H_a , mm	3,0
S , mm ²	3 000
Life-time of the pavement T , years:	
Till the minor repair T_v	5
Till the major repair T_k	8

The determined interrelations of abundance of ruts H_{max} , H_a , S , and smoothness according to IRI Y_{IRI} in the highway Vilnius–Panevėžys enabled the authors to recommend the limit values of the abundance of ruts H_{max} , H_a , S (Table 2).

The adoption of the rational values of the state of pavement could contribute to effective use of means for the pavement repair.

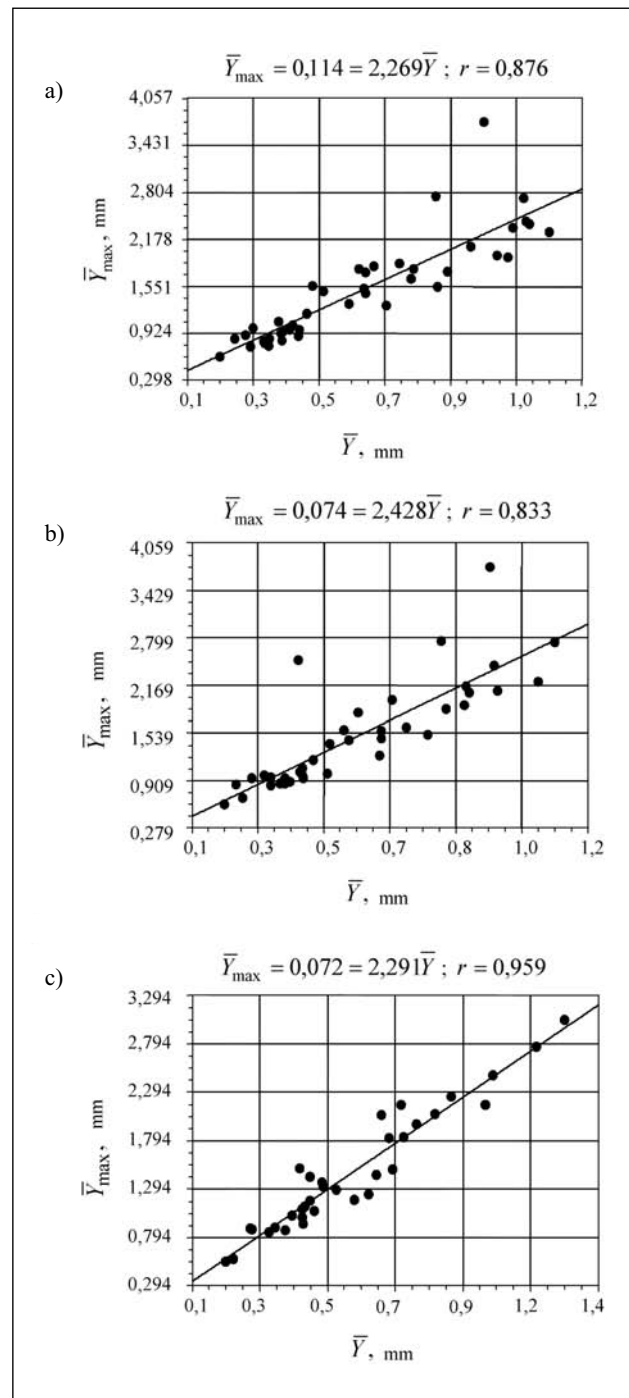


Fig 4. Interrelations of the arithmetic means of the highest and all smoothness values \bar{Y}_{max} and \bar{Y} (Highway Vilnius–Ukmergė–Panevėžys (A2)); (a) data of 1999; b) data of 2000; c) data of 2001

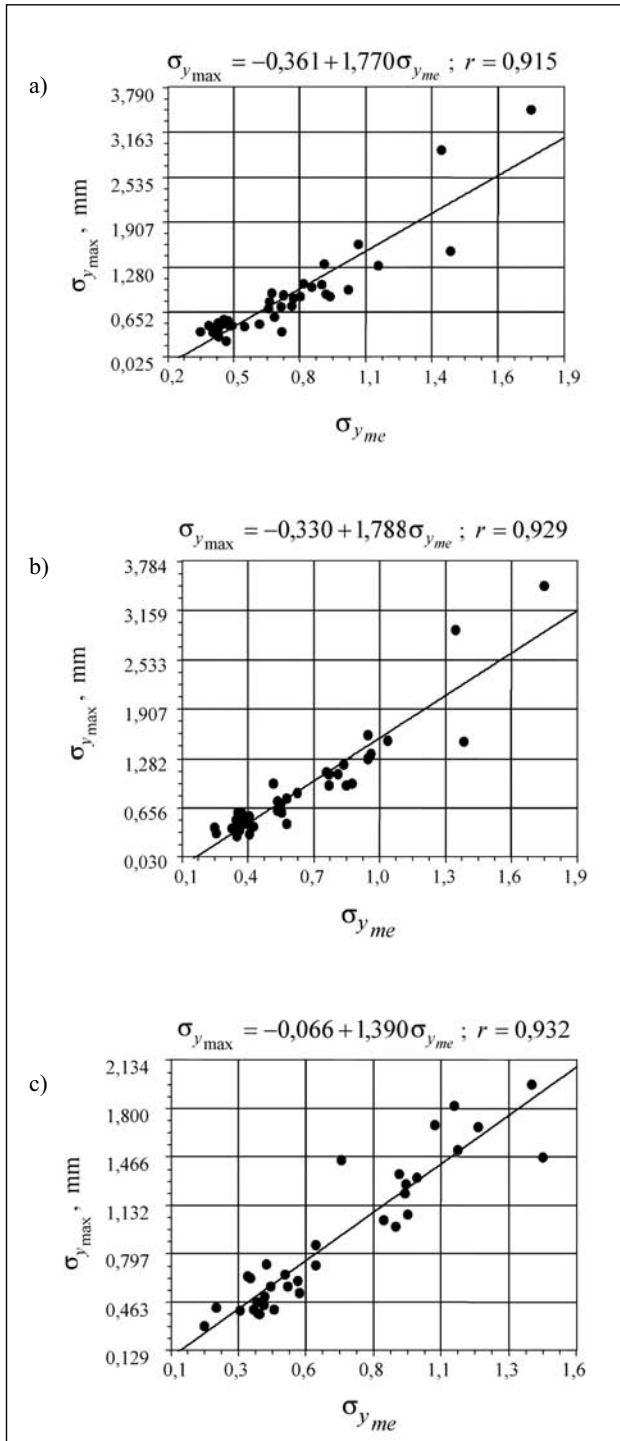


Fig 5. Interrelations of the standard deviations of the highest and all values of smoothness $\sigma_{y_{max}}$ and σ_y (Highway Vilnius–Ukmergė–Panevėžys (A2)); a) data of 1999; b) data of 2000; c) data of 2001

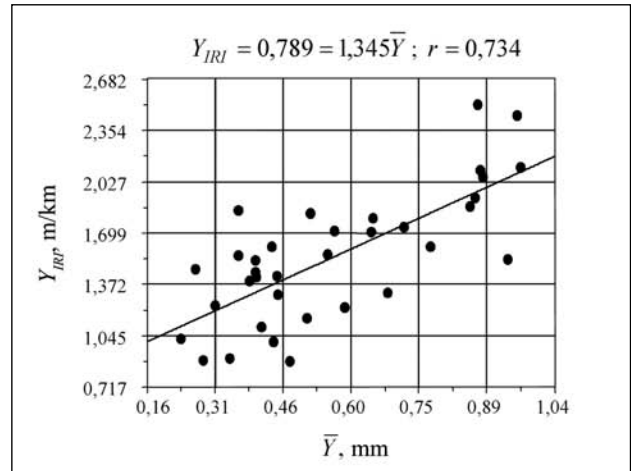


Fig 6. Interrelation of the arithmetic means of smoothness according to IRI Y_{IRI} and all smoothness values \bar{Y} (Highway Vilnius–Ukmergė–Panevėžys (A2), data of 2000)

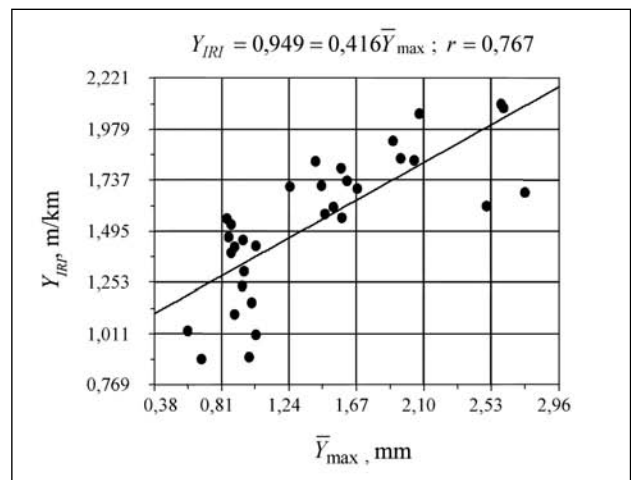


Fig 7. Interrelation of the arithmetic means of smoothness according to IRI Y_{IRI} and highest smoothness values \bar{Y}_{max} (Highway Vilnius–Ukmergė–Panevėžys (A2), data of 2000)

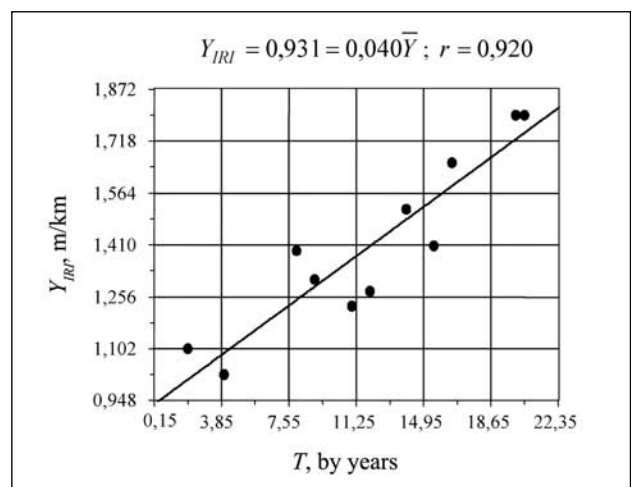


Fig 8. Interrelation of smoothness according IRI Y_{IRI} and lifetime of the pavement T (Highway Vilnius–Ukmergė–Panevėžys (A2), data of 2000)

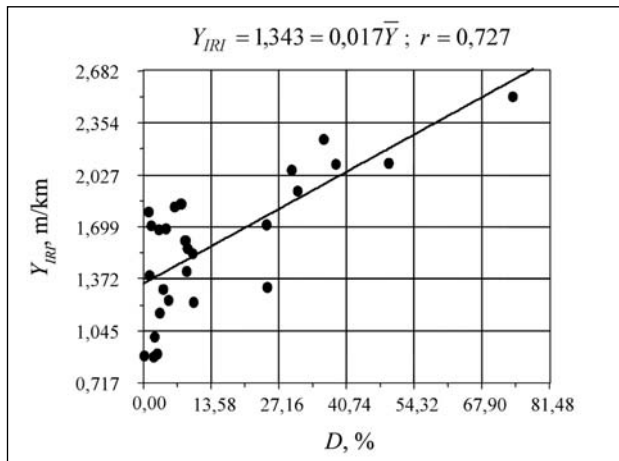


Fig 9. Interrelation of smoothness according to IRI Y_{IRI} and degree of degradation of pavement D values (Highway Vilnius–Ukmergė–Panevėžys (A2), data of 2000)

4. Conclusions

1. The study revealed that there is a close correlation between the degree of disintegration D and smoothness of pavement Y . This correlation served as a basis for an assumption that when the critical degree of degradation is $D = 8 \%$, the pavement requires a minor repair and when it is $D = 16 \%$, the pavement requires a major repair. Index $D = 8 \%$ is recommended as a criterion indicating the necessity for minor repair of the pavement and $D = 16 \%$ as a criteria indicating the necessity for major repair.

2. The differences of the pavement state and its service characteristics in the Lithuanian highways and distribution of their values are negligible. Distribution of obtained results satisfied the normal law.

3. Cracks entailed by temperature fluctuation, wear degradation and degradation due to insufficient strength of the pavement are the dominant defects of Lithuanian highways.

4. Results obtained in 1999–2001 showed that there is a close correlation between the pavement quality indices Y , D , Y and Y_{IRI} and other indices (the values of correlation coefficient r ranged from 0,73 to 0,96). The recommended allowed (standard) values of the state of pavement in the highways were established on the basis of the obtained results.

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