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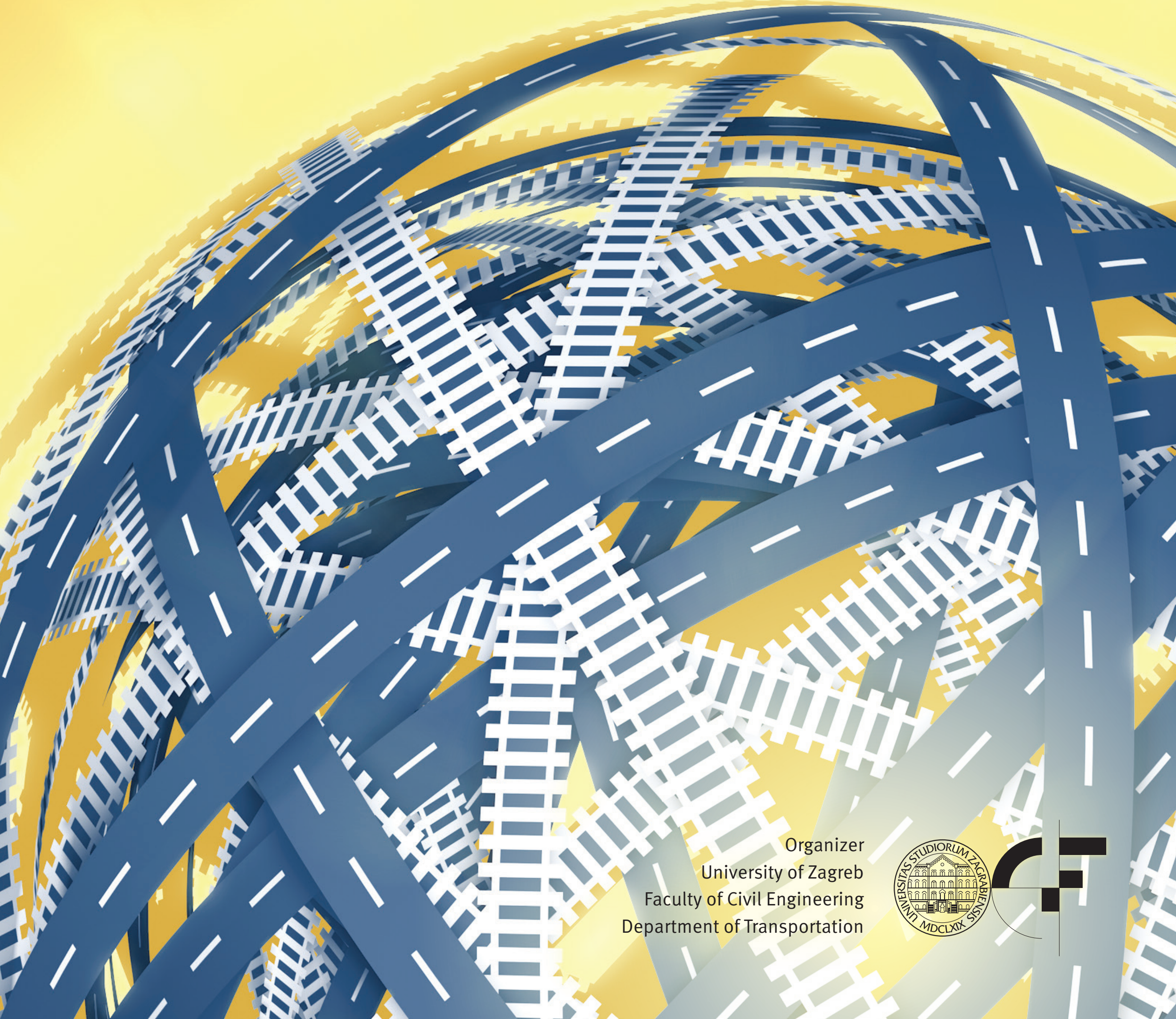
4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



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Road and Rail Infrastructure IV

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EFFECTIVENESS OF THE STEEL MESH TRACK IN STRENGTHENING CRACKED ASPHALT PAVEMENTS

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Abstract

In recent years many works have been done in Poland on application of geotextiles and related products to strengthen existing, cracked asphalt pavement structures. Relatively frequently, besides glass, glass-coal and polyester nets, the pavement reinforcing with steel mesh track (to simplify called later as the steel net) is also met, specially on national roads, trafficked with heavy vehicles. The purpose of the paper is to present the selected experiences gained while renewing and strengthening the national roads in the South of Poland. To these works, the steel mesh track of tensile strength 40/50 kN/m was applied. In the paper some design data were given, among others the subgrade analyses, existing layers system, as well as results of the elastic deflections and modulus, measured with FWD apparatus, on the pavement before and after its strengthening. The concept of the reconstruction works comprised the milling of the upper bituminous layer of 4 cm in thickness, laying the profiling course, installing the steel mesh track and bonding it with slurry seal course to the lower surface. As the overlay, two bituminous layers: 4 cm SMA + 8 ÷ 10 cm AC in thickness were placed. After 3 ÷ 5 years of the service, the measuring of pavement deflection bowl with the FWD was conducted and on the base of it, the estimation of its bearing capacity was carried out. Finally, due to the back analyses using the mechanical-empirical calculations, the profit of applying the steel mesh as the reinforcing interlayer in the system of asphalt layers was proved.

Keywords: Bearing capacity of pavement, Reinforcement with geotextiles, Steel mesh track, FWD deflections, interlayer system

1 Introduction

Problem of strengthening the asphalt layers with using steel grid (mesh track) as well as using the synthetic or glass geogrid interlayer has been recognized from early 90-ties, at the beginning mainly from the practical point of view; lately, the theoretical approach to designing of the pavement structure with geosynthetics has been developed. At first, those interlayers were considered as the stress relieving, i.e. anticracking material, laid over the cracked semi-rigid asphalt pavement, to repair the reflective cracking on the pavement surface. This method regarded as very encouraging, became popular in Poland.
The first comparative tests carried out in the Belgian Road Research Centre in Brussels [1] in early 90-ties on the efficiency of geosynthetics (for nonsynthethic raw material it is also called geotextile) have brought promising results (Figure 1). Those tests revealed, that the steel mesh placed in the asphalt layers submitted to the tensile stress, has got the most advantageous influence on reducing the propagation of crack, reflected from the discontinuity in lower layer. Testing of the above interlayers on real road sections [2] confirmed the best performance in delaying reflective cracking by glass fibre grid and steel mesh track, other types of intermediate layers have proved less effective. Similar results were achieved in Por-

tuguese research [3], where steel mesh with slurry seal had the best performance, and the bitumen impregnated geotextile sections were second best.

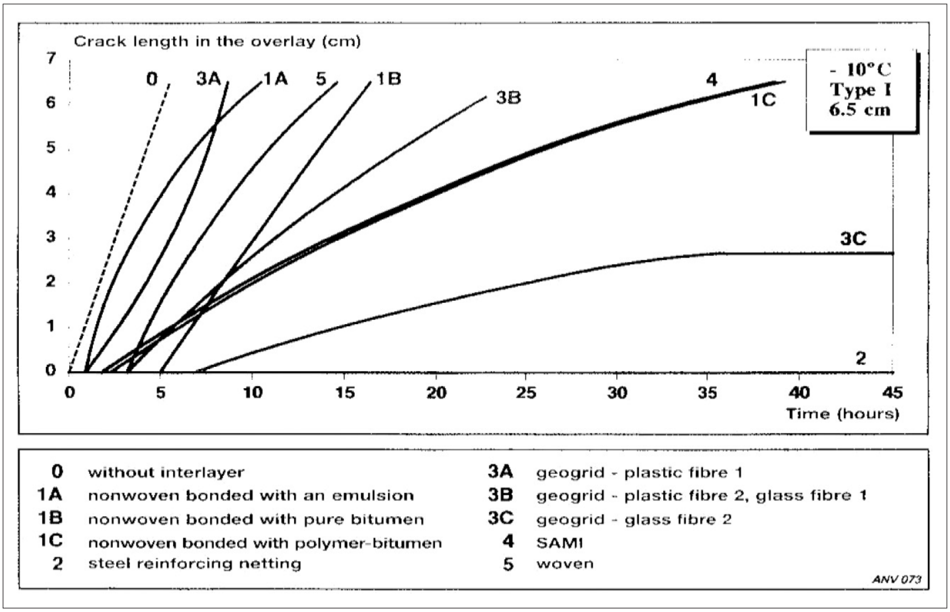

Figure 1 The early comparative tests on the efficiency of the stress relieving interlayer, delaying the reflective cracking propagation in the semirigid asphalt pavements [1]Styles dialogue in Microsoft Word 97-2003.

In all cases de-bonding has to be avoided, otherwise fatigue cracking may appear after finishing these works very quickly. The problem of the conditions required to ensure the effectiveness of geotextile interlayers in the system of asphalt layers was tested in works [4, 5].
In the last years some new research works were taken up, focussed on using the steel grid or glass-carbon grid in asphalt layers as the real reinforcement, diminishing the pavement deflection values, in this way increasing the pavement bearing capacity. Due to which, the fatigue life of the asphalt pavement can be prolonged, or the thickness of the asphalt layers decreased. As the research examples, it can be referred to the research in Belgian Road Research Centre [6], and in Cracow University of Technology [7, 8].
The present paper is devoted to the practical effects (diminishing of deflections) of applying the steel mesh track (the steel net), measured and estimated for the site condition on the asphalt pavement, constructed in the South region of Poland on national roads sections. FWD test results, before and after the reconstruction, have been provided by General Directorate for National Roads and Motorways (GDDKiA), Branch Krakow.

2 Selection of testing sections

The road sections selected for the reinforcement and tests did not have proper bearing capacity and were seriously damaged: many longitudinal, transversal (reflective crackings), single and alligator cracks were observed, as well as uneven areas, viscoplastic/structural ruts and patches. The example of the previous pavement condition is done at Figure 2.
All selected sections before reinforcement were submitted to the diagnostic tests of their conditions, according to the Polish System of Pavements Condition Evaluation with the measurement of the deflection bowl and using the Falling Weight Deflection apparatus.

Figure 2 View of damaged pavement on national road 44

Besides, test holes were made to identify the existing pavements structure and subgrade conditions as well as some laboratory tests on drilled cores were carried out. Those were as follows: the creep test of asphalt samples, the gradation and sand equivalent of aggregates from the base, and soils plasticity test. The list of the analysed road sections together with layers thicknesses measured on pavement cores and layers modulus determined from the back analysis are given in Table 1.

Table 1 Summary of the analyzed road sections.

Road number	Localization (km)	Asphalt layers	Aggregate subbase	Subgrade
94 – roadway right (Section1)	285+488 ÷ 286+300	H = 28 cm E = 4111 MPa	H = 17 cm E = 165 MPa	H = infinity E = 92 MPa
	286+300 ÷ 287+450	H = 28 cm E = 3855 MPa	H = 31 cm E = 370 MPa	H = infinity E = 71 MPa
	287+450 ÷ 288+320	H = 26 cm E = 3349 MPa	H = 51 cm E = 159 MPa	H = infinity E = 73 MPa
94 – roadway left (Section 2)	285+488 ÷ 286+650	H = 22 cm E = 3580 MPa	H = 40 cm E = 308 MPa	H = infinity E = 84 MPa
	286+650 ÷ 287+870	H = 22 cm E = 2726 MPa	H = 47 cm E = 249 MPa	H = infinity E = 76 MPa
	287+870 ÷ 288+320	H = 25 cm E = 6594 MPa	H = 47 cm E = 240 MPa	H = infinity E = 132 MPa
94 (Section 3)	305+100 ÷ 307+100	H = 21 cm E = 2661 MPa	H = 29 cm E = 281 MPa	H = infinity E = 57 MPa
7 (Section 4)	632+200 ÷ 634+200	H = 19 cm E = 1903 MPa	H = 66 cm E = 295 MPa	H = infinity E = 66 MPa
44 (Section 5)	101+900 ÷ 102+900	H = 17 cm E = 1500 MPa	H =40 cm E = 200 MPa	H = infinity E = 50 MPa

3 Designed reinforcing structures and there field evaluation

Design activities of the reinforcement included the surface milling to profile the existing structure, laying the steel net and fitting it to the lower layer with slurry seal, next placing the new binding and wearing bituminous layers of total thickness 12 ÷ 14 cm. Details of the designed structures on each road sections are given in Table 2.

Table 2 Designed structures of pavement reinforcement for the analysed sections of roads.

Road number	Localization (km)	Milling depth	Interlayer	New asphalt layers
94 – roadway right (section 1)	285+488 ÷ 288+320	2 ÷ 5 cm	Steel mesh track with 1 cm of slurry seal	8 ÷ 9 cm HM AC + 4 cm SMA
94 – roadway left (section 2)	285+488 ÷ 288+320	3 ÷ 5 cm	Steel mesh track with 1 cm of slurry seal	8 cm HM AC + 4cm SMA
94 (section 3)	305+100 ÷ 307+100	4 cm	Steel mesh track with 1 cm of slurry seal	8 cm HM AC + 4 cm SMA
7 (section 4)	632+200 ÷ 634+200	6 cm	Steel mesh track with 1 cm of slurry seal	10 cm AC + 4 cm SMA
44 (section 5)	101+900 ÷ 102+900	5 cm	Steel mesh track with 1 cm of slurry seal	8 cm HM AC + 4 cm SMA

Designed reinforcing structures were verified with mechanical-empirical method, using the Asphalt Institute USA fatigue criteria [9]. Material parameters were assumed acc. to the Polish recommendations [10], stress and strain states were calculated with the computer program BISAR 3.0, results are given in Table 3. Obtained results have satisfied the requirements for the designed traffic category (that is >14.6 M cycles of standard axle 100 kN during the whole period of pavement exploitation, equal to 20 years).

Table 3 Results of the fatigue durability of pavement for the analyzed sections of roads.

Road number	Localization [km]	Horizontal strain in asphalt layers	Vertical strain on subgrade	Fatigue durability of pavement [M 100 kN/axle]
94 – roadway right (section 1)	285+488 ÷ 286+300	52.8×10^{-6}	-132×10^{-6}	52.8
	286+300 ÷ 287+450	47.8×10^{-6}	-124×10^{-6}	78.8
	287+450 ÷ 288+320	64.3×10^{-6}	-127×10^{-6}	33.5
94 – roadway left (section 2)	285+488 ÷ 286+650	59.4×10^{-6}	-122×10^{-6}	46.0
	286+650 ÷ 287+870	74.3×10^{-6}	-131×10^{-6}	28.1
	287+870 ÷ 288+320	39.2×10^{-6}	-118×10^{-6}	95.8
94 (section 3)	305+100 ÷ 307+100	86.3×10^{-6}	-218×10^{-6}	17.6
7 (section 4)	632+200 ÷ 634+200	79.2×10^{-6}	-117×10^{-6}	18.1
44 (section 5)	101+900 ÷ 102+900	71.7×10^{-6}	-233×10^{-6}	16.5

During 3-5 years after reinforcement, any damage on the renewed pavements evaluated visually was not seen. In the same time, the tests of elastic deflections with FWD apparatus were carried out on all sections, what allowed to compare the bearing capacity of pavements before and after reinforcement (all values were converted to the equivalent temperature 20°C acc. to [11]). Example of obtained results are presented in Figure 3. To evaluate the significance level of the changes, the statistical tests were conducted with using the method of multiple comparisons and LSD procedures in the Statgraphics program (95% confidence level); the results are presented in Table 4. For all analysed road sections, deflection values after reinforcement are substantially lower than before that treatment, the highest differences were observed for the section of previously the lowest bearing capacity and the thinnest thickness of the structure.

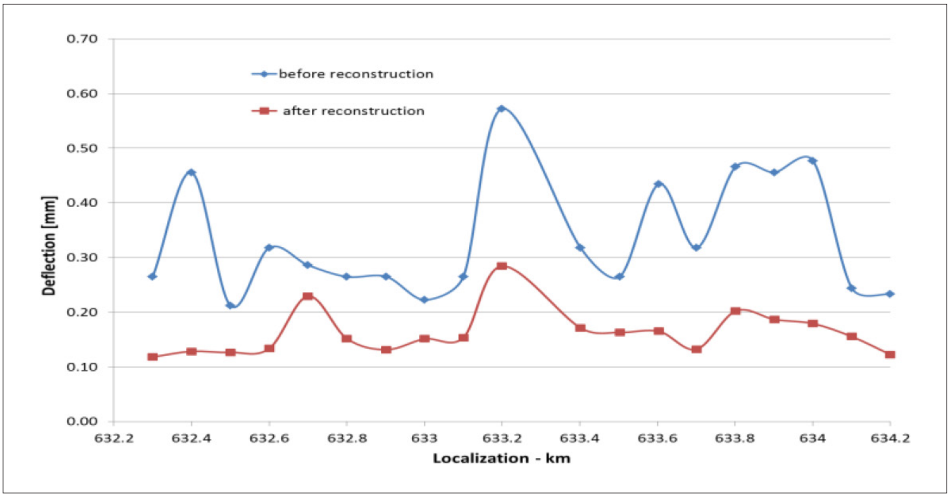

Figure 3 Comparison of the pavement deflections before and after reinforcement for the road section DK 7 – km 632+200 – 634+200.

Table 4 Analysis of significance of FWD deflection [μm] differences before and after reconstruction, with using the steel net.

Time of measuring	average	standard deviation	coefficient of variation [%]	difference	+/– limits (95%)
DK 94, km 285+488 – 288+320, roadway right (section 1)					
Before reconstruction	188	77	40,6		
After reconstruction	118	37	31,6	70	38*
DK 94, km 285+488 – 288+320, roadway left (section 2)					
Before reconstruction	177	52	29,4		
After reconstruction	110	29	26,9	67	38*
DK 94, km 305+100 – 307+100 (section 3)					
Before reconstruction	306	83	27,0		
After reconstruction	084	22	25,7	222	31*
DK 7, km 632+200 – 634+200 (section 4)					
Before reconstruction	306	98	32,1		
After reconstruction	163	41	25,5	144	40*
DK 44, km 101+900 – 102+900 (section 5)					
Before reconstruction	639	165	25,8		
After reconstruction	230	65	28,1	409	45*
**denotes a statistically significant difference*					

The comparison of obtained deflection measurement results with the Polish required values according to the pavement condition evaluation system, i.e. DSN [12], classifies all road tested sections in the class A, what means that the remaining fatigue life is equal to minimum 20 years (the results are given in Figure 4).

To separate and evaluate the influence of the steel net on the rebuilt structure bearing capacity, the next step of analysis was done. It was the comparison of the deflection bowl from FWD test and converted to the static deflection bowl for the structure acc. to [13] with the steel net, with the results for the structure without the steel net, which were calculated using mechanical-empirical calculations in the programme BISAR (the temperature in both cases was brought to 20°C [11]). Next, for both cases, significance tests for differences in the deflection values were carried out.

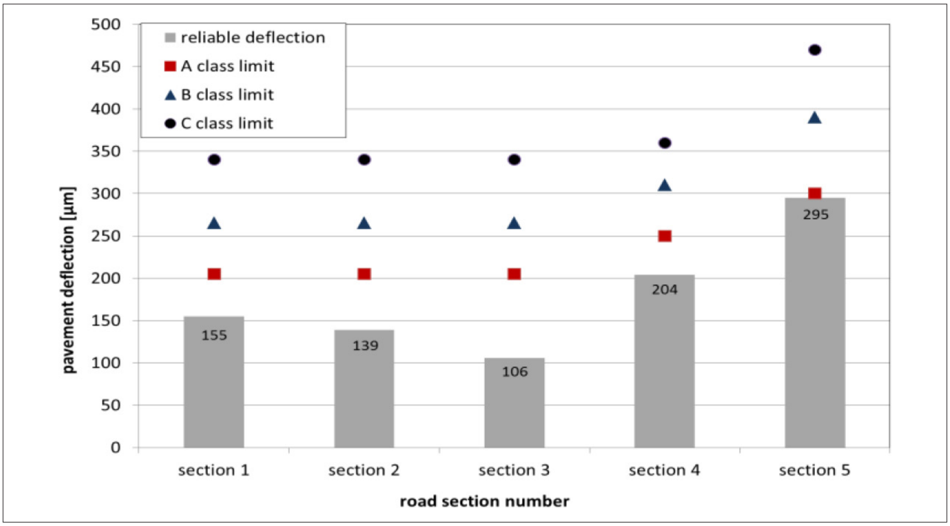

Figure 4 Evaluation of pavement FWD deflection acc. to DSN [12].

Results of the presented analyses given in Table 5 reveal, that the deflection values measured on the sections with the FWD method (steel net reinforced sections), are lower than deflections calculated for reinforcement structures without steel net, what proves the positive effect of the steel net applied to reinforced sections. The most profitable effect was obtained for sections where, before rebuilding, the biggest deflections were obtained, what can explain better mobilization of the steel net in the pavement structure.

Table 5 Significance tests for deflection differences on the sections reinforced with (deflections measured) and without steel net (deflections calculated).

Deflections [µm] (T=20°C)	average	standard deviation	coefficient of variation [%]	difference	+/– limits	
					95%	90%
DK 94, km 285+488 – 288+320, roadway right (section 1)						
Calculated	207	54	26,1			
Measured	199	64	32,2	8	32	27
DK 94, km 285+488 – 288+320, roadway left (section 2)						
Calculated	183	55	30,1			
Measured	173	46	26,9	10	27	23
DK 94, km 305+100 – 307+100 (section 3)						
Calculated	258	65	25,3			
Measured	112	29	25,7	146	22*	19*
DK 7, km 632+200 – 634+200 (section 4)						
Calculated	226	62	27,5			
Measured	196	52	26,7	30	33	28*
DK 44, km 101+900 – 102+900 (section 5)						
Calculated	372	83	22,3			
Measured	304	85	28,1	68	54*	45*
**denotes a statistically significant difference*						

4 Conclusions

Presented in this paper tests of the road sections and analyses of the results allowed to draw the following conclusions:

1) Condition of pavements of all analysed road sections reinforced with the steel net and 12 ÷ 14 bituminous overlay after several years of exploitation is very good. No damages were observed, what confirms the effectiveness of applied solution. Bearing capacity of the tested sections evaluated according to the pavement condition evaluation system, i.e. DSN [12], classifies all road tested sections in the class A, what means that the remaining fatigue life is equal to minimum 20 years.
2) Increase of the bearing capacity of reinforced pavements evaluated with the FWD method for all sections is very substantial.
3) Deflection values measured on the pavements reinforced with the steel net are lower than deflections calculated with BISAR program for the pavement structure without the steel net. The differences are substantial for 2-3 tested sections, depending on the assumed significance level 95% or 90 %.
4) The best effectiveness of the steel net applied is observed for the sections where the bearing capacity before rebuilding was the lowest, and where the steel net is placed in the tension zone.
5) Analysed road sections require longer periods of time to observe their condition, and in this way to better evaluate the steel net efficiency in reducing the possible reflective crackings as well as in prolonging the fatigue life.

References

[1] Vanelstraete, A., Francken, L.: Laboratory testing and numerical modelling of overlay systems on cement concrete slabs, Proceedings of the 3rd RILEM Conference on Reflective Cracking in Pavements, Maastricht, pp. 170-181, 1996.

[2] Vervaecke, F., Maeck, J., Vanelstraete, A.: On site validation and long term performance of anti-cracking interfaces, Proceedings of the 6th RILEM International conference on cracking in pavements, Chicago, pp. 761-768, 2008.

[3] Antunes, M.l., Fontul, S., Pinelo, A.M.: Anti-reflective cracking solution for asphalt overlays: 8 years performance monitoring, Proceedings of the 6th RILEM International conference on cracking in pavements, Chicago, pp. 791-798, 2008.

[4] Grzybowska, W., Zieliński, P., Górszczyk, J.: Influence of material parameters on durability of asphalt mixtures in different loading conditions, Research Project financed by Polish Research Committee (No 8.T07 E. 043.21), Cracow, 2003 (Edition in Polish).

[5] Zieliński, P.: Chosen problems of asphalt pavement durability with the geotextile interlayer, PhD thesis, Cracow University of Technology, 2004, (Edition in Polish).

[6] Vanelstraete, A., Leonard, D.: The Design of concrete pavements reinforced with glass fibre grid – Comparison between the anticracking systems Bitufor and Trasys, Belgian Road Research Centre, Brussels, June 1999.

[7] Grzybowska, W., Górszczyk, J., Zieliński, P.: Modeling of the asphalt pavement structure behavior in different conditions of interlayer bonding, using geosynthetic reinforcement, Research Project financed by Polish Ministry of Education and Computerization (No 4T07E 01328), 2007 (Edition in Polish).

[8] Górszczyk, J.: The influence of reinforcing geosynthetic interlayer on the fatigue durability of asphalt road pavement, PhD thesis, Cracow University of Technology, 2010 (Edition in Polish).

[9] Research and development of the Asphalt Institute's: Thickness Design Manual (MS-1). Ninth edition, The Asphalt Institute, Research Report No. 82-2, RR-82-2, August 1982

[10] Gdansk University of Technology: Catalogue for flexible and semirigid typical pavement structures, 2012 (Edition in Polish).

[11] IBDiM: Catalogue for designing of flexible and semirigid pavement structures rebuilding and renovation, Warsaw, 2013 (Edition in Polish).

[12] GDDKiA: The pavement condition evaluation system – usage guidelines, Warsaw, 2015 (Edition in Polish).

[13] Krawczyk, B.: Identyfication of parameters for road pavement models derived from dynamic impulse test, PhD thesis, Wrocław University of Technology, 2012, (Edition in Polish).