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28–30 April 2014, Split, Croatia

Road and Rail Infrastructure III

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NEW SOLUTIONS FOR DISTRESSED PAVEMENT REHABILITATION OF VILNIUS CITY STREETS

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Abstract

Permanent deformation in asphalt pavement structures is one of the main pavement distress problems. The common asphalt pavement surface deformations are shoving and rutting at intersections, bus stops and bays, in heavy vehicle loaded urban streets due to acceleration, deceleration, slow moving or standing. It was determined that in many cases the failure was caused by asphalt layers fatigue and low resistance to shear flow. The laboratory research of high modulus asphalt concrete mixtures with different aggregate and binder types showed good results for city streets pavements performance improvement.

Keywords: asphalt pavement, rutting, flow rutting, surface corrugation, plastic (permanent) deformation, high modulus asphalt concrete (HMAC)

1 Introduction

Driving conditions and traffic safety depend on pavement roughness, which generally is a function of all distresses, and its severity level increases with pavement age. Asphalt pavement distresses may be classified into: surface defects (raveling, bleeding and polishing), deformations (rutting, shoving and corrugation), cracks (fatigue, thermal, longitudinal and slippage) and potholes. Although, the most common distresses are fatigue cracking, thermal cracking and rutting [1]. Recently, an increase in severity and extent of rutting in asphalt pavement structures in high traffic flow streets of Vilnius, bus lines and stops has been observed. Permanent deformations in city streets asphalt pavements cause the following concerns [2]: traffic safety, driving comfort, society reaction, and expenditures. For vehicles, there are reduced frictional characteristics (e.g., wheel path flushing), changing lanes becomes hazardous, and there is the risk of loss of control. Ruts influent steering accuracy and comfort can lead to accidents. Rut rehabilitation incurs costs, including user costs due to traffic flow interruptions and increased vehicle maintenance as well as rehabilitation costs. Permanent deformation in one or several pavement layers displays after sufficiently high amount of load repetition. Due to different structure materials properties pavement performs variously at particular loading and climatic conditions. Consequently, different rutting type may occur in asphalt concrete (AC) pavement rutting 2]–[5]: surface wear, initial densification, structural and flow rutting. The surface wear rutting forms only in the top layer of the asphalt, due to progressive loss of coated aggregate particles from the pavement surface, which is caused by combined environmental and tire influence [2], [3], [6]. This problem is not significant when usage of studded tires is controlled [2], [7]. The initial densification rutting forms during the first years of exploitation, due to insufficient compaction of AC layers or all structure layers [3]. The structural rutting affects all structure layers and is related with an appropriate pavement design (evaluation of load, weak subgrade, poor drainage, frost action, etc.), materials specification, and construction quality [2], [3]. Usually, structural rutting is a reflection of permanent deformation within granular base layers and subgrade. The flow rutting forms only in asphalt layers and is related with asphalt mixture mechanical properties, air voids content and mixture resistance to share flow. Flow rutting is the most common rutting type in EU [8]. The aim of this article is to analyze the practice and recommendations of other countries regarding pavement distresses (rutting) rehabilitation, to determine pavement conditions of the most distressed city streets of Vilnius and to suggest reliable solutions for pavement rehabilitation.

2 Permanent rutting rehabilitation solutions

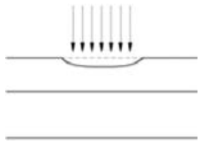
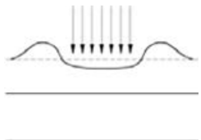
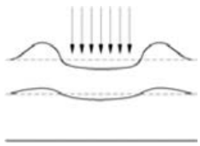
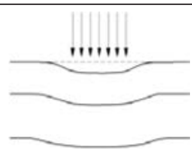
Permanent deformation (rutting) is very important because of its influence on vehicle movement (affecting vehicle tracking), safety (hydroplaning after rain) and dynamic loading (through surface profile variations) [3]. Rutted pavement rehabilitation demand is defined according to monitoring data through rut depth and severity level. The maximum rut depth in subgrade surface of national significance roads in Lithuania is 100-200 mm depending on maintenance level. The maximum rut depth in pavement surface is 40 mm [9]. However, rut depth and roughness is not restricted and there are no confirmed technical documentations for streets maintenance in city streets of Lithuania. Different agencies present different rutting severity levels (Table 1.).

Table 1 Rutting severity due to rut depth

Agency	**Rut depth [mm]**		
	Low severity level	**Medium severity level**	**High severity level**
NRC CNRC, Canada [2]	6 – 13	13 – 25	› 25
Transportation information center [4]	‹ 12,7	‹ 25,4	‹ 50,8
Washington State Department of Transportation	6,3-12,7	12,7-19,1	› 19,1
Ohio Department of Transportation	3,2-9,5	9,5-19,1	› 19,1
Texas Department of Transportation [10]	6,4-12,5	12,7-25,2	25,4-50,6
Illinois Department of Transportation [11]	‹ 4	4 – 9	› 9
DMRB, UK [12]	‹ 6	‹ 11	‹ 20

According to literature review, pavement degradation should be evaluated in further steps [2], [3], [7]: (1) visual inspection of the pavement; (2) transversal profile measurements; (3) pavement bearing capacity determination using falling weight deflectometer; (4) pavement structure materials sampling and testing (especially asphalt pavement layers and subgrade soils); (5) exploitation condition evaluation of pavement structure.
For simplicity, the rutting increment behavior can be observed from transversal profile analysis, which is useful for corrective actions selection [7]. According to Strategic Highway Research Program (SHRP) on Long-Term Pavement Performance program (LTPP) study pavement transverse profiles can provide information needed to select rehabilitation method such as shape and type of rutting, depth, and lateral location of longitudinal pavement deformations [13], [14]. On the basis of literature review and experience, asphalt pavement structure rehabilitation can be selected considering rutting profile type (Table 2.)

Table 2 Asphalt pavement structure rutting profile type [2], [7], [15]

Rutting type	Description	Transversal profile	Rehabilitation solutions
Wear rutting	Rutting is in the wearing layer, without flow deformations		Surface preservation (maintenance) · Surface treatment · Surface milling · Rut filling · Hot in-place recycling of wearing layer; · Wearing layer replacement.
Flow rutting of wearing layer	Rutting is in wearing layer with flow deformations		Surface preservation (maintenance) and improvement (repair) · Surface milling (short-term) · Hot in-place recycling of wearing layer; · Wearing layer replacement with stiffer AC mixture
Flow rutting of wearing and binder layers	Rutting is more than just in wearing layer with flow deformations		Pavement improvement (rehabilitation) · Asphalt pavement strengthening (replacing) with stiffer AC base or/and binder layer · Pavement strengthening (replacing) with PCC
Structural rutting	Deformations in all layers		Pavement structure improvement (reconstruction) · Improvement of pavement structure bearing capacity · Drainage improvement

Rehabilitation solution should be selected carefully considering all pavement design input data (traffic, subgrade type, drainage and environmental conditions, etc.) and life-cycle cost analysis. Medium and high severity non-structural rutting is repaired by improving the surface or pavement layers. If pavement structural bearing capacity during all seasons is sufficient, then surface layer rehabilitation solutions can be classified [2]: (A) surface preservation (maintenance) – surface milling and treatment extend pavement design life from 1 to 3 years; (B) surface improvement (repair) – wearing layer hot-in place recycling, wearing layer replacement (milling < 50 mm AC layer thickness), AC overlay – from 3 to 10 years; (C) pavement improvement with AC (rehabilitation) – asphalt layers (milling > 125 mm thickness) and laying stiffer AC mixtures – from 15 to 20 years; (D) pavement improvement with Portland Cement Concrete (PCC) (rehabilitation) – ultra-thin concrete pavement can extend pavement design life from 5 to 15 years; conventional concrete pavement – from 15 to 30 years.
Rehabilitation using PCC overlay on an existing pavement surface is called white-topping (WT) [16], [17]. There are two types of WT: (1) bonded PCC Overlay – slab performs the same as existing pavement structure; (2) un-bonded PCC Overlay – slab performs as conventional PCC layer of pavement structure. According to Breyer [18], if pavement structure is frequently influenced by a specific loading, concrete pavement may be considered reasonable for low traffic flows. Semi-Flexible Pavement (SFP) is used in bus stops and intersection pavements in Finland, Sweden and Denmark. SFP consists of a porous asphalt pavement (voids between 25 percent and 30 percent) flooded with a high performance, micro-silica and Portland cement-based grout. SFP provides an alternative surfacing material tracked-vehicle roads, hardstands, and aircraft parking aprons [20]. Although, the biggest number of thermal cracking was observed in SFP after 5 years of exploitation in Road of Experimental Pavement Structures [21].
Rehabilitation using AC overlay should be done considering mixture properties and it's resistance to deformations. Choi [23] stated that shear resistance of a binder at high service temperatures was an important property for the flow rut resistance of asphalt and determined that dynamic viscosity can be considered as an indicator or rut resistance at low strains. Rese-

arch showed that rutting resistance of High Modulus Asphalt Concrete (HMAC) is twice higher than that of hot mix asphalt, and the fatigue resistance is 5–10 times higher [24]. Vaitkus and Vorobjovas [25] tested HMAC mixture properties and performance, which was made from lower quality aggregates, but used stiffer binders. Researchers determined that the lowest rut depth from Wheel Tracking Test (WTT) after 10000 cycles was obtained 0,77 mm in HMAC with crushed granite mineral aggregate and PMB 25/55-60, and RD was 3,5 times smaller than AC 16 AS (with PMB 45/80-55) which is often used to lay pavement structure in Lithuania.
Hot in-place recycling may be also applied for preservation and improvement of pavement surface layers. Recycling can be done at traffic line width and at deformed pavement part. The recycling technology adjusted for rut rehabilitation was developed in Lemminkainen, Finland and it is called Rut-Remix®. Rut-Remix technology is an economical solution for rehabilitation because it renews only deformed zone 1 m width. However, this technology can be applied only for wearing (low severity) rut, where rut depth is to 2-3 cm.

3 Experimental research

Research was done in sixteen distressed pavements of the city streets of Vilnius. Pavement transverse surface profile was measured in most damaged section of the street. Measurements were done using 3 m long straightedge. The distance from horizontal line to pavement surface was measured with ±1 mm accuracy. In order to determine deformation in asphalt layers, 150 mm diameter cores of pavement were taken in the measuring line. Each core was drilled with 20-30 mm covering. Drilled cores were tested in Road Research Laboratory of Road Research Institute of Vilnius Gediminas technical university. The thickness of every layer and the type of asphalt mixtures were determined. Summarized information, measured rut depth (RD) and severity level of distressed city streets pavements of Vilnius is shown in Table 3.

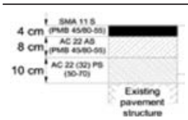
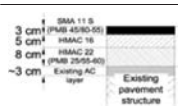
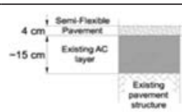
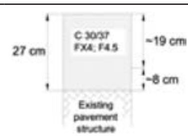
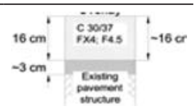
Table 3 Summarized information, measured RD and severity level of distressed city streets pavements of Vilnius

Section No.	Site characteristic	HVTF[1], v./d.	AC thickness, mm	Surface transvers slope direction	Measured RD, mm		Rutting type	Severity Level[2]
					Left	Right		
1.	intersection zone	3317	235	right	35-40	55-60	Structural and flow	High
2.	bus-stop section	580	150	left	35-40	30-35	Structural and flow	High
3.	intersection zone	264	150	right	20-25	30-35	Initial densification	High
4.	intersection zone	522	185	right	60-65	70-75	Structural	High
5.	uphill section	1309	195	right	15-20	15-20	Wear	Medium
6.	intersection zone	482	180	right	50-55	60-65	Flow	High
7.	intersection zone	206	190	right	30-35	30-35	Structural and flow	High
8.	intersection zone	771	110	left	50-55	30-35	Structural and flow	High
9.	bus-stop section	786	210	right	40-45	30-35	Flow	High
10.	intersection zone	657	260	right	60-65	50-55	Structural and flow	High
11.	intersection zone	482	195	right	10-15	10-15	Initial densification	Low
12.	intersection zone	482	160	right	65-70	60-65	Flow	High
13.	acceleration zone	1640	180	right	65-70	30-35	Wear and structural	High
14.	intersection zone	1152	250	left	60-65	20-25	Flow	High
15.	bus-stop section	318	180	left	80-100	80-100	Flow	High
16.	intersection zone	568	125	right	35-40	55-60	Structural and flow	High

[1] HVTF – Heavy vehicle traffic flow
[2] According to NRC CNRC regulations, see Table 1.

All types of permanent deformations were detected in distressed streets pavements: wear rutting (defined in No 5 and 13), initial densification (defined in No 3 and 11); structural rutting (defined in No 7) and flow rutting (defined in No 6, 9, 12, 14 and 15). It was also observed that in high severity flow rutting, deformation affected granular base layer, thus structural and flow rutting type was defined in No. 1, 2, 4, 8, 10 and 16. Structural and flow rutting established in most cases (56 %), flow rutting detected in fourth place (25 %), were noticed from distressed pavement transversal profiles and measurements.
Rehabilitation solutions for distressed pavements were carried out according to experimental research, KPT SDK 07 and RStO 12 pavement design guides, and Vaitkus and Vorobjovas' research [25]. Rut-Remix was proposed for pavement with low and medium rut severity preservation hot-in place recycle. Extra rehabilitation solutions, using rigid and semi-flexible pavements, were carried out for five sections (Table 4). Rehabilitation costs were defined individually in sections No. 4, 6, 9, 15 and 16 considering existing pavement milling, depose of waste, cracks sealing, quantity of materials, joint installations, laying works, compaction, joint sealing, curining. Costs were calculated with SISTELA software taking the prices from 2013. The costs for rehabilitation solutions are shown in Table 5. The comparison of rehabilitation solution costs is shown in Figure 1.

Table 4 Rehabilitation using AC, HMAC SF PCC and WT overlays

AC Overlay	HMAC Overlay	SF Overlay	PCC Overlay	WT Overlay
Section No. 4				
				
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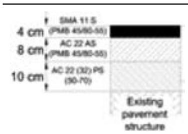
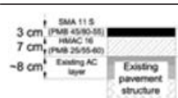
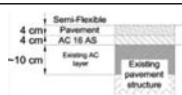
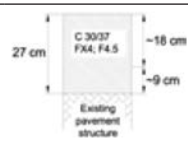
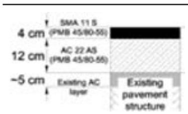
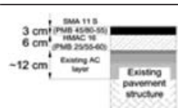
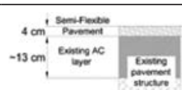
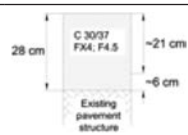
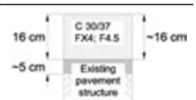
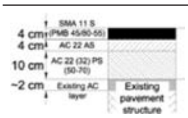
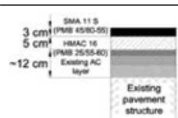
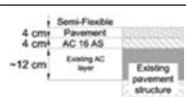
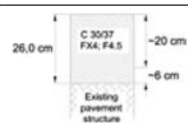
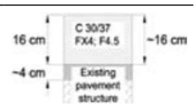
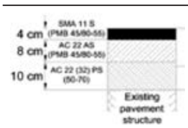
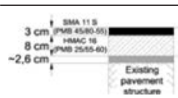
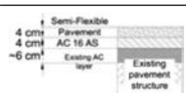
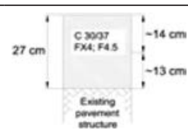
				
Section No. 9				
				
Section No. 15				
				
Section No. 16				
				

Table 5 The cost for rehabilitation solutions costs

Section No.	Site characteristic		Rehabilitation cost (with VAT 21 %), €				
			AC Overlay	HMAC Overlay	SF Overlay	PCC Overlay	WT Overlay
4	Intersection zone	175 m²	17442,5	13994,6	12389,8	15268,5	12596,5
6	Intersection zone	217 m²	21466,3	12129,4	18446,9	18107,8	-
9	Bus-stop section	189 m²	16323,0	8892,7	13299,9	17222,5	13469,9
15	Bus-stop section	220 m²	18284,6	10224,3	20213,9	18242,3	15916,7
16	Intersection zone	420 m²	40974,0	23199,7	35652,2	35889,4	-

Rehabilitation cost using usual asphalt mixtures (AC) overlay determined higher comparing to other rehabilitation solutions in section No. 4, 6 and 16. Rehabilitation cost using SF overlay was about 8 % lower than PCC overlay cost. Rehabilitation using WT solutions could be used in sections No 6 and 16, because the existing asphalt layer thickness was too low. Although, rehabilitation cost of WT overlay was similar or slightly different from SF rehabilitation cost. HMAC overlay cost was 20-43 % lower than usual AC overlay cost and varies from 8 892.7 to 23 199.7 € depending on individual section condition. To sum up, rehabilitation using HMAC overlay was cheaper in most cases.

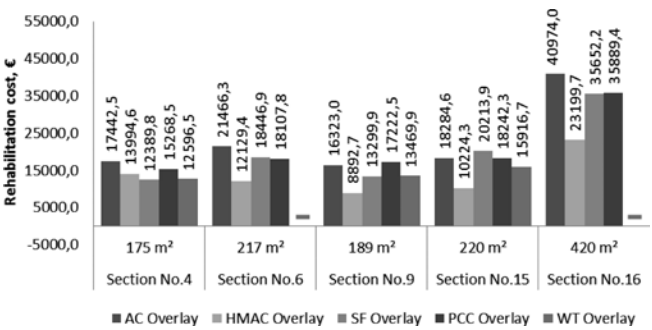


Figure 1 The comparison of rehabilitation solutions costs

4 Conclusions

The analysis of the distressed pavement structures has revealed that, rut depths exceed 60 mm and are deeper in 44 % of researched pavement sections. All types of rutting were detected in distressed streets pavements: wear rutting, initial densification (construction works failure), structural rutting (structure failure) and flow rutting (asphalt mixture failure). However, deformations mostly emerged in asphalt wearing or/and asphalt binder layers due to insufficient asphalt mixture shear flow (flow rutting resistance).

In most cases rehabilitation cost for solutions with high modulus asphalt concrete (HMAC) layers was 20-43 % cheaper than asphalt concrete (AC) overlay rehabilitation cost.

Semi-flexible (SF) pavement overlay cost is less or more similar to concrete withe-topping overlay cost and 8 % lower than Portland cement concrete (PCC) overlay, and could be used when there is need of pavement bearing capacity improvement.

To conclude, the experimental research has shown that, rehabilitation solution should be derived individually, although high modulus asphalt concrete overlay was a reasonable solution for pavements where flow rutting occurs in binder layer. Hot in place recycling is a very relevant solution for less distressed pavements (wearing rutting, surface course rutting) rehabilitation.

References

[1] Huang, Y. H.: Pavement Analysis and Design, Second edition, New Jersey, 2004.

[2] NRC CNRC: Rut Mitigation Techniques at Intersections. Canada, 2003.

[3] Morosiuk, G. & Riley, M.: Volume 6. Modelling Road Deterioration and Works Effects in HDM-4, in Highway development & Management, World Road Association, 2004.

[4] Walker, D. Entine, L. & Kummer, S.: Pavement Surface Evaluation and Rutting. Asphalt Roads, Transportation Information Center University of Wisconsin-Madison, 2002.

[5] NCHRP 1-37A: Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures, Champaign, Illinois, USA, 2004.

[6] Oscarsson, E.: Evaluation of the Mechanistic–Empirical Pavement Design Guide Model for Permanent Deformations in Asphalt Concrete, Road Materials and Pavement Design, Vol. 12, No. 1, pp. 37–56, 2011.

[7] NCHRP Report.468: Contributions of Pavement Structural Layers to Rutting of Hot Mix Asphalt Pavements, Washington, USA, 2002.

[8] COST 333: Development of New Bituminous Pavement Design Method, Brussels, Luxembourg, 1999.

[9] LAKD: Kelių priežiūros vadovas Part I. KPV PN-05., Vilnius, Lithuania, 2005.

[10] Texas Department of Transportation: Pavement Design Guide, USA, 2011.

[11] IDOT: Bureau of Design and Environment Manual. Pavement rehabilitation. Ilinois, USA, 2012.

[12] DMRB: Data for Pavement Assessment HD 29/08, London, UK, 2008.

[13] Fang, H., Haddock, J. E., White, T. D. & Hand, A. J.: On the characterization of flexible pavement rutting using creep model-based finite element analysis, Finite Elements in Analysis and Design, Vol. 41, No. 1, pp. 49–73, 2004.

[14] Gramling, W. L., Hunt, J. E. & Suzuki, G. S.: Rational Approach to Cross-Profile and Rut Depth Analysis, Transportation Research Board, National Research Council, Washington D.C., pp. 173–179, 1991.

[15] Vaitkus, A., Čygas D. & Kleizienė, R.: Research of asphalt pavement rutting in Vilnius city streets, in The 9th International Conference "Environmental Engineering, 2014.

[16] Harrington, D., et al.: Guide to Concrete Overlays. Sustainable Solutions for Resurfacing and Rehabilitating Existing Pavements, Iowa, USA, 2008.

[17] Kleizienė, R., Vaitkus, A. & Čygas, D.: The Analysis Of Concrete Pavement Application Possibilities For Road Pavement Structures, in The XXVIII International Baltic Road Conference, 2012.

[18] Breyer, G.: Entscheidungskriterien für den Bau von Betonfahrbahndecken in Österreich, in BETONOVÉ VOZOVKY 2004 Sborník přednášek 1. mezinárodní konference, 2004.

[19] Gawedzinski, M. J.: Evaluation of semi-flexible (resin-modified) pavement report, Illinois, USA, 2008.

[20] Ahlrich R. C. & Anderton, G. L.: Construction and Evaluation of Resin Modified Pavement, 1991.

[21] Vaitkus, A., et. all.: The Road of Experimental Pavement Structures: Experience of Five Years Operation, The Baltic Journal of Road and Bridge Engineering, Vol. 7, No. 3, pp. 220–227, 2012.

[22] Tarefder, R. A., Zaman, M. & Hobson, K.: A Laboratory and Statistical Evaluation of Factors Affecting Rutting, The International Journal of Pavement Engineering, Vol. 4, No. 1, pp. 59–68, 2003.

[23] Choi, Y. K.: Visco-Elastic Analysis of the Elastomeric Binder Shear Resistance in Relation to Asphalt Rutting, Road Materials and Pavement Design, Vol. 12, No. 4, pp. 767–794, 2011.

[24] Lee, H. J., Lee, J. H. & Park, H. M.: Performance evaluation of high modulus asphalt mixtures for long life asphalt pavements, Construction and Building Materials, Vol. 21, No. 5, pp. 1079–1087, 2007.

[25] Vaitkus A. & Vorobjovas, V.: Use of local aggregates in high modulus asphalt concrete layers, Građevinar, Vol. 65, No. 4, pp. 353–360, 2013.