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Road and Rail Infrastructure III

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ALTERNATIVE REHABILITATION METHODS FOR LOW-VOLUME ROADS

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Abstract

This paper aims to illustrate the behaviour of two technologies – soft asphalt pavement and Otta seal in Lithuania. Measurements of roughness and condition of soft asphalt pavement and Otta seal were carried out in spring after the first winter and after one year of exploitation. Based on the results of this research the conclusions and recommendations were made for further soft asphalt and Otta seal application in Lithuania.

Keywords: low-volume roads, gravel pavement, soft asphalt, soft bitumen, Otta seal, visual assessment

1 Introduction

In Lithuania more than third (34.2 %) of the state roads are gravel roads [1]. Average annual daily traffic (AADT) varies from 40 vehicles per day (vpd) to 1000 vpd on these roads, so often they are called low-volume roads [2]. The main function of low-volume roads is to ensure access to objects i.e., join small towns, farmsteads and other objects with higher-significance roads. Though, the maintenance of these roads needs large budget and operation of them awake social discomfort.

The main problem of maintenance of roads with gravel pavement is dustiness. Dust generation from gravel roads decrease visibility, which leads to reduction of traffic safety and speed. Thus, maintenance costs of vehicles, medical costs of accident victims and costs deaths increases [3].

Chemical dust suppressants are used to prevent the loss of fines, e.g. calcium or magnesium chloride, calcium lignosulphonate and etc. The dustiness can be reduced up to 80 % using these suppressants [4]. However, the efficiency of dust suppressants depends on climatic conditions and rainy days [5]. The use of such dust suppressants is not enough efficient due to wet and rainy climate in Lithuania, i.e., the costs for reduction of dustiness are inadequate for desired performance [6].

In Lithuania it has always been an issue in finding durable and economical solutions for paving low-volume roads, which AADT is up to 500 vpd. Recent 20 years conventional asphalt concrete pavement structures were constructed using paving grade bitumen with a penetration 70/100 or 100/150. The performance of these pavements was satisfactory. After recent winters in Lithuania, when the total freezing index (FI) was high, it was observed that in spring on the low-volume roads with asphalt pavement the extent of frost heaves has increased and more pavement defects have occurred. In order to avoid frost heaves a special attention should be paid to the 30 cm thick upper subgrade which should be laid from less frost-sensitive soils or it is necessary to carry out the soil improvement or strengthening. Those additional works would significantly increase road construction costs (up to 25 %). Over the last decade

on the low-volume roads of Nordic countries the soft asphalt has been used which is less sensitive to frost heaves and fatigue, more flexible and has the ability of self-healing.
As for all roads, the pavement strength must be adequate to carry the anticipated traffic load. One type of surfacing that can provide an economic and practical alternative to traditional surfacing is the Otta seal [7]. The Otta seal design solution does not add strength to the existing gravel surface, but this type of the surface dressing improves the gravel road operational characteristics.

2 Experience of the use of soft asphalt and Otta seal

The largest experience of using soft asphalt has been represented by Finland, Sweden and Germany. Soft asphalt is commonly made of mineral material mixture, filler aggregate and binder – soft bitumen. The soft asphalt mixture uses bitumen of high penetration from 250/330 to 650/900 or soft bitumen from V1500 to V12000. The Swedish General Technical Construction Specification for Roads Road 94 indicates that on roads with AADT ≤ 500 vpd the wearing course can be laid on gravel pavement. However, this type of pavement structure shall meet the requirements to layer thicknesses.
Safwat determined that after 7 years of road service life the extent of pavement distresses was inconsiderable and cold-mix asphalt (mix of 83 % of used asphalt granules, 14 % of new mineral materials and 3 % of new bitumen emulsion produced on a basis of soft bitumen) mixtures can be an alternative to hot-mix asphalt mixtures [8]. Jacobson with the co-authors determined that mechanical properties of soft asphalt may vary depending on its service life, composition and production process [9]. Viscosity of the regenerated bitumen binder may vary from 12000 mm^2/s (just after laying asphalt mixture) to 33000 mm^2/s (after three service years). Jacobson with the co-authors states that when defining mechanical properties of soft asphalt it is very important to select properly the testing temperatures depending on a climatic zone where the test soft asphalt mixture is laid [10].
Having studied the technical documents of various European countries the following advantages of soft asphalt are distinguished: elastic, durable, self-healing, low temperature mixing, well workable, and recyclable [11–13]. Also, soft asphalt has some disadvantages: not stable enough, it could form water film on new constructed asphalt pavement, low light reflection, flux used for binder is environmentally unfriendly, limited resistance to abrasion.
The European standard EN 13108-3 specifies requirements for soft asphalt used on the roads and other trafficked areas. According to the standard EN 13108-3 there are several types of soft asphalt (type A; type B; type C; type S). As the aim of further research was to use as softer and reasonable bitumen as possible, it was selected soft asphalt of the types C and S.
The Otta seal is a particular type of bituminous surface treatment which was originally developed by the Norwegian Road Research Laboratory (NRRL) in the early 1960s. The design of the Otta seal is relatively simple. It relies on an empirical approach that is based on experience in the selection of both an appropriate type of binder and an aggregate application rate [7, 14]. According Overby and Pinard the choice of a particular type of Otta seal in relation to traffic level is broadly [7, 14]. It is recommended to use the single Otta seal with sand cover seal when the AADT ‹ 500 vpd and the double Otta seal when the AADT › 500 vpd.
One of the main advantages of an Otta seal is the flexibility it offers in terms of the variety of materials that can be used for producing the graded aggregate [15]. Both crushed or uncrushed material and a mixture of both can be used for producing graded aggregate for Otta seals [7, 16].
The type of binder used in an Otta seal significantly affects its constructability, durability and ultimate performance. It is therefore critically important that a correct choice of binder is made to ensure that the critical function of a complete coating of the mineral aggregate particles, even the fines, is achieved during construction [14].

3 Experimental research of behaviour of soft asphalt and Otta seal in Lithuania

In 2012 the trial sections were built to clarify the effectiveness and functionality of soft asphalt and Otta seal technologies under current traffic and climate conditions. 26 trial sections with double Otta seal and 5 with soft asphalt were built in 5 regions of Lithuania (Table 1). The trial road sections were selected taking into account according to different influencing factors: estimated design load, AADT (Average Annual Daily Traffic), climatic conditions (freezing index, frost depth), raw materials and contractors.

Table 1 List of trial road sections

Region	Road No.	Road section milestones [km]	AADT [v/d]	AADT (Heavy vehicles) [%]
Trial road section with double otta seal				
Klaipėda-Tauragė	1708	9.70–10.35	76	13.16
	1717	9.19–9.30	231	9.09
	3702	8.92–9.40	76	6.58
	4215	6.40–7.20	157	10.83
	4516 (1)	9.95–10.90	120	8.33
	4516 (2)	10.90–11.53	54	7.41
Šiauliai-Telšiai	1018	5.30–5.83	105	0.95
	2707	0.00–0.60	148	3.38
	2735	2.00–2.62	137	9.49
	3208	17.75–19.48	453	44.15
	4118	9.30–10.00	183	4.92
Panevėžys-Utena	1235	0.80–2.12	138	10.87
	1401	25.40–26.15	134	10.45
	2427	1.70–3.10	100	10.00
	2816 (1)	0.00–0.40	173	2.89
	2816 (2)	2.20–4.24	173	2.89
	3610	2.97–3.63	133	9.02
Vilnius-Alytus	3918	3.43–4.03	190	6.84
	4404	15.64–16.17	231	2.60
	4726	0.00–1.05	278	9.71
	5017	7.52–8.38	205	20.49
Kaunas-Marijampolė	2623	2.60–3.58	114	21.05
	2635	2.20–3.40	194	5.15
	2642	0.00–0.95	95	5.26
	3539	0.00–1.40	137	8.96
	5123	2.50–3.50	85	14.12
Trial road section with soft asphalt pavement				
Kaunas-Marijampolė	1716	3.80–5.20	67	10.45
Panevėžys-Utena	2430	0.65–1.75	179	4.47
Šiauliai-Telšiai	4028	1.11–2.12	652	10.12
Vilnius-Alytus	2518	0.75–3.30	153	3.27
	5235	4.23–5.56	133	11.28

When designing soft asphalt pavement structure, the reference was made to "the General Technical Specifications for Roads – Chapter 3 – Pavement Design", issued by the Swedish

National Road Administration. The pavement structure was adapted to the regional climatic conditions, frost index, soil type and traffic loads. Finally, in a combination with Lithuanian "Technical Specifications for the Standardized Road Pavement Structures", the soft asphalt pavement structure, given in Fig. 1, was derived.
The contractors were free to select soft asphalt mix type and to perform type testing. All contractors selected soft asphalt SA 16-d-V6000 Type C. The mechanical and physical properties of soft asphalt SA 16-d-V6000 Type C laid on trial sections are presented in the Table 2.
The double Otta seal was applied on the new 7–10 cm base course from crushed rock. The existing gravel pavement (≥ 30 cm) was matched up to the frost blanket course if an existing material of gravel pavement met the requirements of frost blanket course (Fig. 1).
Bitumen emulsion used for double Otta seal was produced from the soft bitumen V3000 or V6000 and was applied 60 % of the nominal content of binder. The amount of the spread binder was 1.8 kg/m^2 using soft bitumen V3000 and 2.0 kg/m^2 – V6000, respectively.

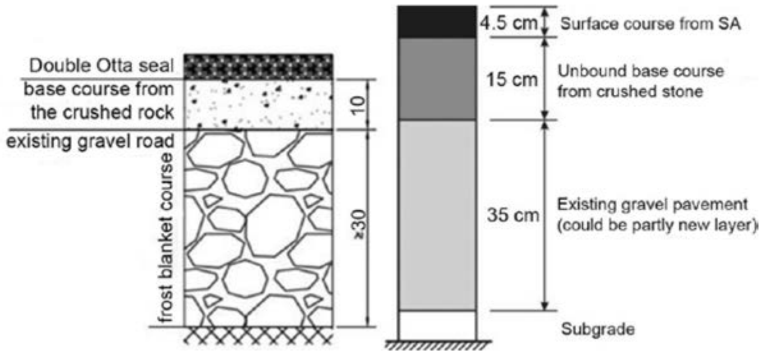

Figure 1 The structure of double Otta seal (on the left) and soft asphalt pavement (on the right)

For double Otta seal 0/16 fraction aggregate was used, which grain size distribution is shown in Fig. 2. The amount (14 l/m^2) of the spread aggregate could be adjusted according to the spread test results. Adhesive additives were not used.

Table 2 The mechanical and physical properties of soft asphalt SA 16-d-V6000 Type C

	Requirements	Road trial section				
		Road No. 1716	Road No. 2430	Road No. 2518	Road No. 4028	Road No. 5235
Bitumen content [%]	$B_{min\ 4.5}$	4.7	5.0	4.7	4.8	4.6
Air voids content V [%]	$V_{min\ 4.0}\ V_{max\ 9.0}$	5.5	6.5	5.5	6.9	6.3
Indirect tensile strength ratio [%]	$ITSR_{60}$	60.0	99.8	66.0	68.0	71.0

Research of functionality of trial sections included evaluation of performance characteristics during different seasons. Performance characteristics were evaluated measuring roughness (International Roughness Index (IRI)) and doing the visual assessment of defects. The measurements of roughness of trial sections with double Otta seal and soft asphalt were made at the beginning of service of trial sections and after 1 year. The visual assessment of defects of trial sections with double Otta seal were performed in autumn, in spring and in autumn (after 1 year), and on the sections with soft asphalt – in spring and in summer.
During spring thaw and summer, after the first winter of the service of trial sections with soft asphalt, a visual assessment of their condition was carried out. The following defects were assessed: longitudinal cracking, potholes, ravelling, seals and bleeding.

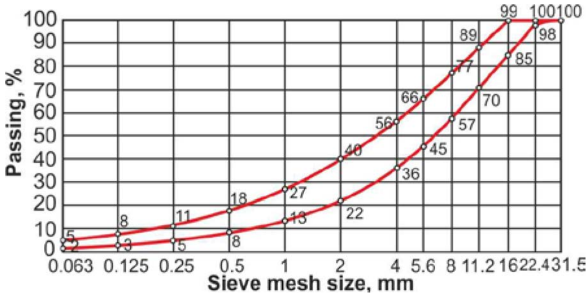

Figure 2 Gradation curves for the double Otta seal aggregate

All defects of trial sections with double Otta seal were grouped into: P_1 – fatting up, bleeding and tracking, %; P_2 – scabbing, tearing and longitudinal joint crack, %; P_3 – corrugation and blister, %; P_4 – streaking, m.

4 Results of experimental research and their analysis

The results of roughness of soft asphalt pavement at the beginning (in November of 2012) of service of trial sections varied from 1.28 m/km to 1.64 m/km and after 1 year (in August of 2013) – from 1.33 m/km to 2.10 m/km (Fig. 3), i.e., roughness increased in average 3 %. The requirement to the IRI of low-volume roads is 3.5 m/km. Also, the results show, that the roughness of pavement is close to the requirements applied to the main heavy duty roads, which is 1.5 m/km.

Figure 3 Roughness of trial sections with double Otta seal

The roughness of trial sections with double Otta seal was measured twice as with soft asphalt pavement. The results of roughness are presented in Fig. 3. The roughness increased on most test road sections compering measurements made in November 2012 and in August of 2013. Except several test road sections where the roughness decreased, i.e., IRI decreased from 2.41 m/km to 2.28 m/km on the road Nr. 4516(1) and from 2.45 m/km to 2.31 m/km on the road Nr. 4516(2) in Klaipėda–Tauragė region, and from 2.53 m/km to 2.43 m/km on the road Nr. 4118 in Šiauliai–Telšiai region (Fig. 3).

It was also determined that IRI met the requirement (IRI ‹ 3.5 m/km) on almost all the test sections except road Nr. 2816(1) where measurements were made in August of 2013 and road Nr. 2816(2), where measurements were made in November of 2012 and in August of 2013, i.e., IRI › 3.5 m/km (did not meet the requirement). These two test road sections are in the Panevėžys–Utena region.
The results of visual assessment of trial sections with soft asphalt made in summer shows that longitudinal cracks has decreased due to self-healing ability under high asphalt pavement temperature (Fig. 4). Longitudinal cracks decreased by 62.98 % in road No. 2430, and in road No. 1716 – healed. These results confirm the advantage of soft asphalt, but longitudinal cracks not always heal completely.

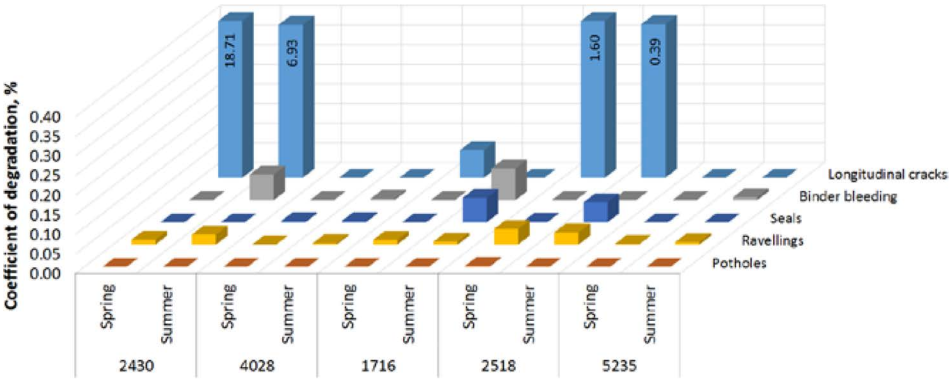

Figure 4 Results of the visual assessment of the trial sections with soft asphalt

During the visual assessment in summer the bleeding of soft asphalt pavement was observed, but the amount of it was small. It doesn't have impact to maintenance of pavement. But, the bled bitumen sticks to tyres of vehicles, and this process could increase ravellings. In roads No. 1716 and No. 2518 the decrease of ravellings was observed, i.e., respectively by 21.18 % and 34.00 %, which could form due to bleeding of bitumen. Though, in roads No. 2430 and No. 5235 it was observed significant increase of ravellings, i.e., respectively by 112.50 % and 400.00 %.
The amount of seals increased 2500 % or 25 times in road No. 2518. The analysis of results showed that main reason is an inadequate composition of soft asphalt mix and/or physic and mechanical properties.
The visual assessment of trial sections with double Otta seal was made in autumn of 2012 (at the beginning of service of trial sections), in spring and in autumn of 2013 according to qualitative visual assessment methodology prepared by authors. Results of the visual assessment of trial sections with double Otta seal are shown in Fig. 5 and Fig. 6.
During the visual assessments it was found that the most significant defects were of P1 group (fatting up, bleeding and tracking). Defects of group P2 (scabbing, tearing and longitudinal joint crack) were found less in autumn of 2013 comparing with results found in spring of 2013 and in autumn of 2012. Defects of group P3 (corrugation and blister) were found less than other groups (P1, P2 and P4). The streaking (defect of group P4) was found in 4 of the 26 road sections, i.e., 145.00 m – in road No. 4726 and 20.00 m – in road No. 4404 in Vilnius–Alytus region, 5.00 m – in road No. 3208 and 156.00 m – in road No. 2735 in Šiauliai–Telšiai region.

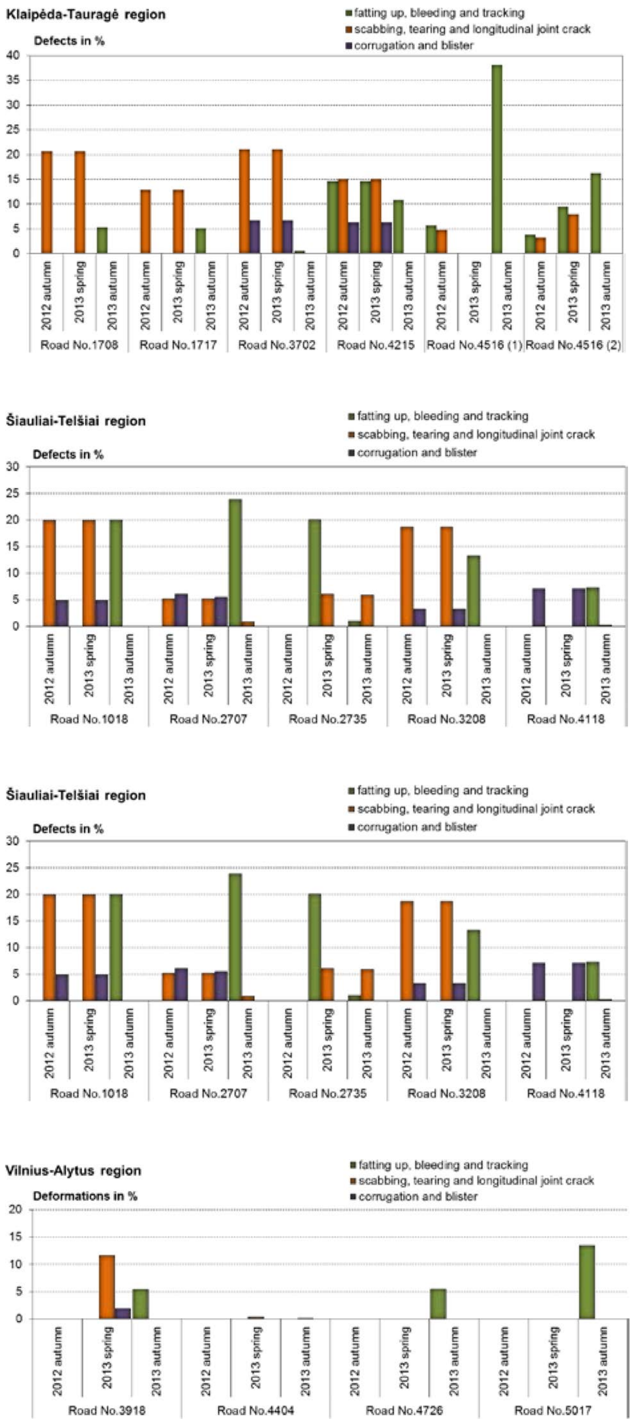

Figure 5 Results of the visual assessment of the trial sections with double Otta seal

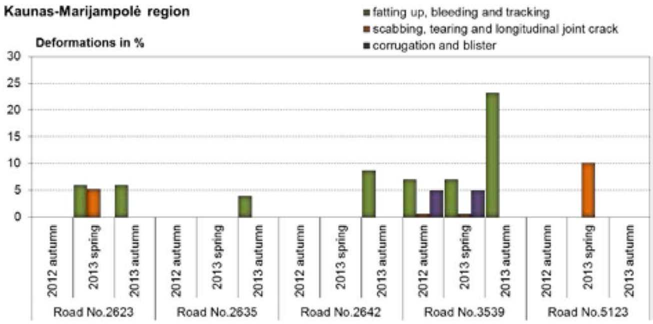

Figure 6 Results of the visual assessment of the trial sections with double Otta seal

5 Conclusions

Based on the experience of foreign countries and short term researches made in Lithuania it was proved that double Otta seal and soft asphalt technologies applied on gravel roads with AADT less than 500 vpd are applicable.
The average roughness of all the trial sections with soft asphalt pavement (from 1.33 m/km to 2.10 m/km) or most of the trial sections with double Otta seal (from 1.84 m/km to 3.76 m/km) complies with the requirements (≤ 3.5 m/km) to the roads of regional significance, and roughness is similar to that of the sections with asphalt base course-pavement.
Trial road sections with soft asphalt pavement are in good condition after 10–12 months of operation (including period of winter and summer). The main defect as longitudinal cracks were observed only in 3 trial sections of 5, and in one of them they healed. Longitudinal cracks decreased by 36 % compering to maximum length of them. Average length of longitudinal cracks varied from 0.7 m to 180 m per 1 kilometre in winter and varied from 0 m to 69 m per kilometre after summer.
Most significant defects (fatting up, bleeding and tracking) were found in the test road sections after one year of operation. The causes were inappropriate aggregate of the double Otta seal and too high binder content and too soft (low viscosity) binder, as well as improperly carried out maintenance of the test road sections in summer. The causes of scabbing, tearing, and longitudinal joint crack, corrugation and blister were unqualified procedure of applying the double Otta seal. The cause of streaking was not enough binder and an uneven binder distribution within the nozzle beam.
The analysis of results showed that there is no correlation between amount of defects and AADT and traffic of heavy vehicle in it.

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