



PHD THESIS

PERMANENT STRAIN DEVELOPMENT DYNAMICS
FOR ASPHALT PAVEMENT MATERIALS

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Abstract. This article gives the summary of the author's PhD thesis supervised by Prof Dr Sc Ing Juris Rihards Naudžuns and defended on 10 November 2010 at the Riga Technical University. Introduction provides characteristics of the object of the research – asphalt concrete – from chemical, physical and mechanical aspects. The current situation on the roads and in Latvian transport industry has been described, and urgency of the problem, the necessity to eliminate deficiencies and the economic effect has been substantiated. The aim and tasks of the thesis have been formulated. Chapter 1 is devoted to survey of the literature which provides new and the already known (classical) modelling methods of stress and strain of road pavement layers, as well as description of advantages and deficiencies of these methods. Chapter 2 contains description of test methods used in the Promotion thesis. Properties of experimental specimens and their raw materials have been compared. Methods of designing asphalt mixtures are described. Chapter 3 provides analysis of external factors causing asphalt concrete permanent strain – temperature and transport load. In Chapter 4, test specimens have been experimentally tested with the help of the performance testing methods (wheel tracking test, uniaxial cyclic compression test and triaxial cyclic compression test). Plastic deformations have been determined and deformation rates have been calculated. In Chapter 5, the asphalt pavement quality provision system has been developed on the basis of the analysis of the obtained results and recommendations have been provided for minimising rutting. This thesis is written in Latvian and is available on <http://ortus.rtu.lv/> web page and from the author upon request.

Keywords: asphalt concrete, modified bitumen, rutting, wheel tracking test, equivalent single-axle load, prediction of permanent strain.

1. State of the problem

Significant changes took place on the roads and in Latvian transport industry during the last nineteen years. Due to transition from the earlier used *ГОСТ (государственный стандарт СССР)* [GOST (State Standard of USSR)] standards to the *FAS (Finnish Asphalt Specification)* methods and, starting from 2004, to the European Norms (EN), the quality provision requirements have changed. Alongside with changes of the technical documentation, compositions of asphalt mixtures changed as well. In place of the A [A], Б [B], В [V], Г [G] and Д [D] asphalt mixtures, designed in accordance with the *ГОСТ 9128-84 "Смеси асфальтобетонные дорожные, аэродромные и асфальтобетон. Технические условия"* [Mixtures of Asphalt Road, Airport and Asphalt Concrete. Specifications] methods, the stone mastic asphalt (SMA) and asphalt concrete (AC) mixtures, designed in accordance with the *Ceļš 94. Vispārējie ceļu būves tehniskie noteikumi. 6. daļa. Bituminētās segu konstrukciju kārtas* [Road 94] requirements until 2004 and in accordance with the *Autoceļu*

specifikācijas 2005 [Road Specifications 2005] requirements from 2004, started to be used for the asphalt pavement wear course. These mixtures, being new for Latvian conditions, have been the object of investigation of the world's leading researchers for more than 40 years. These new types of asphalt mixtures, in contrast to simple or conventional compositions, have specific requirements. They need a new approach to design and manufacturing of the mixtures. By using technologies, raw materials and experience currently available with the manufacturers, the SMA and AC asphalt mixtures made and laid in Latvia show unsatisfactory strain properties, and, furthermore, the traffic volume is increasing with every year.

Research object. AC is a typical composite material which is formed by two main components with a completely different origin – bitumen (organic binder) and stone material (mineral aggregate). Bitumen, being a binder of AC, contains, at least, 4 main components, which are of organic origin and have a large range of molecular mass, volatility, structure and other properties. Aggregates are

also formed of various chemical compounds, but of inorganic origin.

Aim and tasks of the research – to develop asphalt mixes by using conventional and unconventional raw materials and to determine their strain development dynamics by using for this purpose the developed methods of predicting the road pavement permanent strain on the basis of comprehensive evaluation of external factors.

Tasks of the Thesis:

1. to analyse the mechanism of asphalt pavement permanent strain formation, the existing prediction methods and main (internal and external) factors influencing the strain;
2. to determine properties of the steel manufacturing by-product – Martin steel slag (MSS), as an aggregate, and to compare them with properties of conventional granite, diabase and dolomite aggregates;
3. to mutually compare properties of the unmodified bitumen binder B70/100 and the styrene-butadiene-styrene SBS polymermodified binder;
4. to develop and manufacture the AC and SMA mixtures by using conventional and unconventional aggregates, as well as modified and unmodified bitumen binders and to compare the results and to evaluate their conformity to requirements of the technical regulations;
5. to determine strain properties of the developed asphalt mixtures by means of the cyclic loading and wheel tracking tests and to evaluate the results obtained by different methods;
6. to statistically process the observation data – the traffic load and external air temperatures characteristic for Latvian circumstances - and to analyse the asphalt pavement high performance temperature dynamics;
7. to adapt the methods of the equivalent single-axle load (*ESAL*) estimation for the intensively loaded Latvian streets and roads and to develop the *ESAL* estimation equation (Eq) for the period with the max high performance temperatures;
8. by using strain properties of the asphalt mixtures obtained in the laboratory, the *VESYS* model, the load of heavy transport vehicles expressed in *ESAL* units, as

well as, by considering the specific features of local climatic circumstances, to investigate permanent strain accumulation of the developed asphalt mixtures;

9. to develop a concept of the asphalt pavement quality provision system for the intensively loaded Latvian streets and roads to allow performing systematic evaluation.

2. Scientific novelty

To investigate road pavement strain properties at large traffic loads, unconventional asphalt mixtures – dense graded asphalt AC 11 with Martin steel slag aggregate and SMA 16 with modified bitumen – have been developed.

For the first time among the papers devoted to asphalt pavement permanent strain modelling, the Promotion Thesis provides the equivalent single-axle load *ESAL* estimation Eq for the period with max high road pavement performance temperatures. The Eq is made on the basis of the comprehensive evaluation of the traffic load, air temperature and asphalt pavement high performance temperature which are characteristic for local circumstances.

The offered methods of permanent strain prediction are based on the viscous-elastic system *VESYS* estimation model with *ESAL* values specified for the hot period (spring-summer). It allows predicting permanent strain by considering traffic load expressed in *ESAL* units and local climatic conditions. Rutting prediction is done to timely select the asphalt pavement which is durable and appropriate for the specific weather conditions and traffic load.

The concept of the asphalt pavement quality provision system, which summarises all processes and their quality provision measures, has been developed to determine the existing deficiencies in the quality provision system and to eliminate them in practice.

3. Design of asphalt mixtures, their physical and mechanical properties

The Promotion Thesis problem solution includes usage of unconventional aggregates and modified binders, which

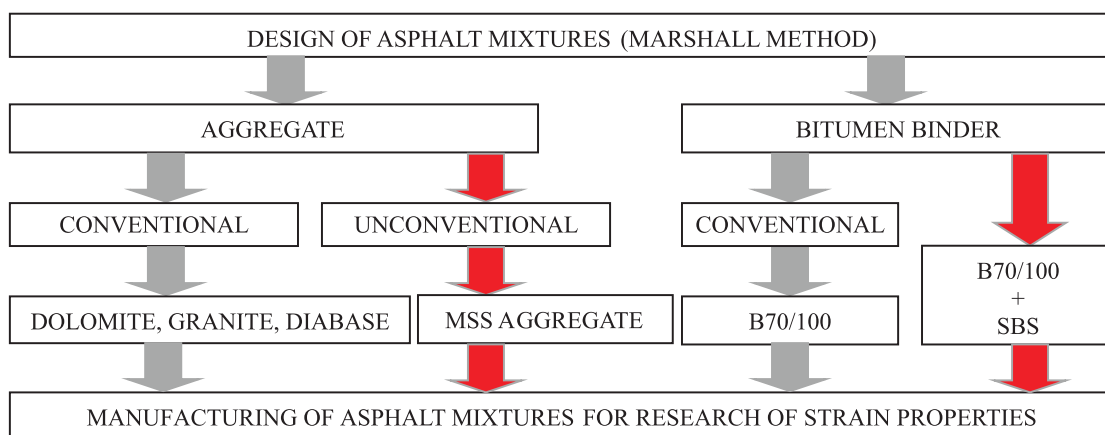


Fig. 1. Selection of raw materials: ➡ – conventional raw material; ➡ – unconventional raw material

are resistant to plastic or permanent deformations, to develop asphalt mixtures (Fig. 1).

Asphalt mixtures are manufactured by using conventional bitumen binder (B70/100) and unconventional SBS polymermodified bitumen (PMB) binders. For this purpose, properties of B70/100 and PMB have been investigated. By comparing the obtained results, it has been established that PMB binder has lower penetration (at the temperature of +25 °C), the higher softening point temperature and the higher Frasse breaking point temperature (Fig. 2).

AC aggregates have been selected to contain the main natural stone materials which are used for AC manufacturing – dolomite, granite and diabase (conventional aggregates). Properties of conventional aggregates and MSS aggregates have been investigated and their conformity to the CS 2010 requirements has been evaluated. When comparing the obtained results, it has been established that the MSS aggregate has lower resistance to fragmentation (Los Angeles value LA = 10 and Nordic test value NT = 4), better form (Flakiness Index) (FI = 3) and less filler (< 0.063 mm = 0.1%). The obtained results allow putting forward a hypothesis that, by using MSS aggregates in manufacturing AC, a material resistant to large loads will be obtained, having a large internal friction angle of its mineral skeleton, as well as excellent adherence of car tyres with road pavement will be provided.

SMA and AC mixtures have been designed in accordance with the Marshall method, by using conventional and unconventional raw materials. In total, 7 asphalt mixtures have been made, 2 of them having unconventional raw materials – AC 11/Ref asphalt mixtures with MSS aggregate and bitumen B70/100 and SMA 16/Mod with granite aggregate and PMB binder (Table 1).

4. Methods of investigating strain properties

Methods for investigating strain properties of asphalt specimens have been selected in such a way as to achieve and solve the aims and tasks set in the Thesis, i.e. to determine and compare strain properties of the manufactured asphalt mixtures with the help of the methods, which ensure manufacturing of specimens, testing environment

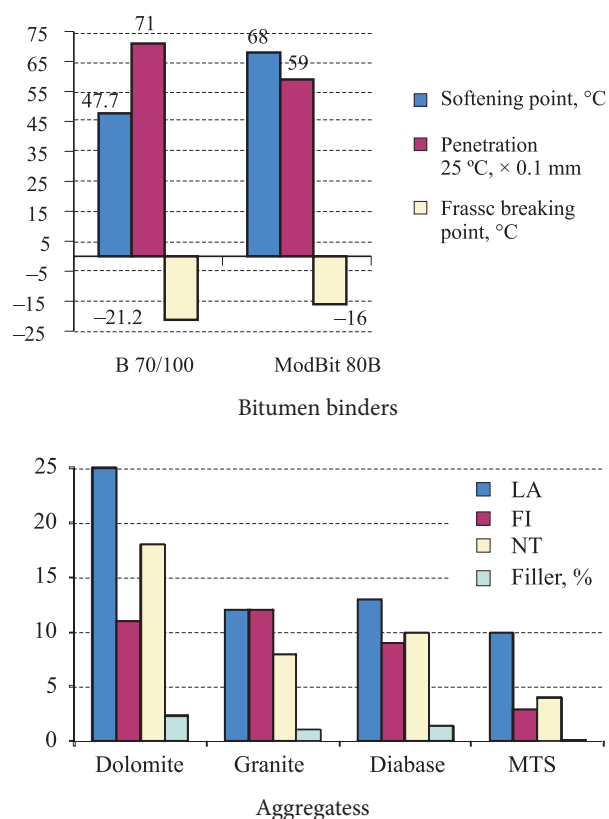


Fig. 2. Comparison of properties

and loading, max close to the real road pavement performance circumstances (performance testing methods) (Fig. 3).

The following performance test methods have been used during the experiments: the wheel tracking test (WTT), (Fig. 5b: the uniaxial cyclic compression test (UCCT) and the triaxial cyclic compression test (TCCT) (Fig. 5a) (Petkevičius, Sivilevičius 2008). The WTT method determines the wheel pressing depth and the permanent strain rate under the 700 N large load of the rotating wheel with the speed of 26.5 cycles/min. The test was performed in a heat-chamber at the temperature of 60 °C. AC

Table 1. Asphalt mixtures

Asphalt mixture type	Aggregate fraction d–D, mm						Bitumen		
	11–16	5–11	8–11	5–8	2–5	0–5	Dolomite powder	B70/100	ModBit
	mass %								
AC 11/Lim ³⁾	–	37.7	–	–	11.3	37.7 ¹⁾	7.6	5.7	–
AC 11/D ⁵⁾	–	–	21.9	7.6	1.9	60.2	3.8	4.6	–
AC 11/Ref ⁶⁾	14.0	29.8	–	–	–	42.9	6.5	6.8	–
AC 16/Lim	20.9	29.5	–	–	1.0	37.1 ²⁾	6.6	4.9	–
AC 8/Lim	–	–	–	27.2	15.0	42.2 ¹⁾	9.4	6.1	–
SMA 16/Mod	39.9	–	28.3	9.5	–	14.1	7.3	–	5.9
SMA 11/D	–	–	51.7	17.9	0.9	15.1	8.5	5.5	–

Note: ¹⁾ natural washed sand; ²⁾ crushed sand; ³⁾ Lim – dolomite; ⁴⁾ Gr – granite; ⁵⁾ D – diabase; ⁶⁾ MSS.

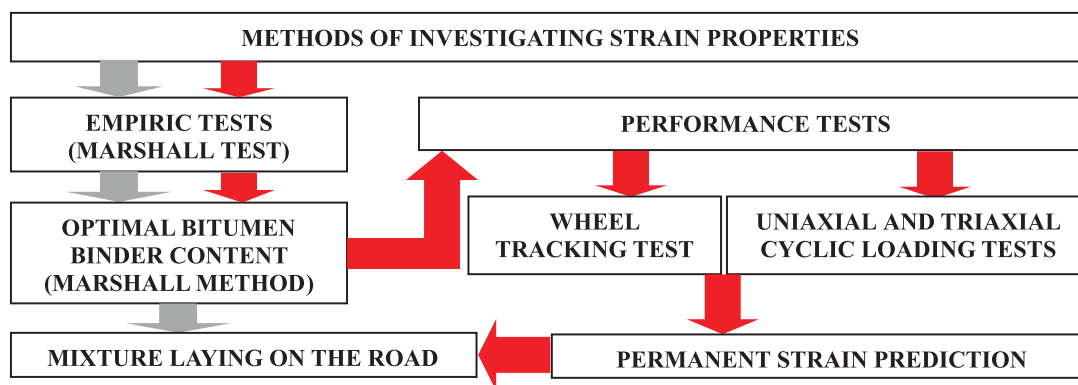


Fig. 3. Permanent strain research methods used in the thesis: – without evaluation of performance properties; – with evaluation of performance properties

strain properties have been determined for the rectangular shape specimens with the base area of 305×305 mm. Thickness of the tested specimens conforms to that of the pavement surface layer – 40 mm (Fig. 5). The UCCT and TCCT tests determine permanent strain of asphalt cylindrical specimens and the strain speed at cyclic loading by applying several thousand loading cycles to the specimens. In the 3-axial loading case, horizontal confining stress has been applied to the specimens. It limits lateral deformation of specimens and, in comparison with the uni-axial loading, the 3-axial one is much closer to the real road pavement performance circumstances. The stiffness modulus has been determined for the cylindrical specimens ($h = 40$ mm, $\varnothing \approx 100$ mm) cored from AC slabs by using the indirect tension loading system (Fig. 4).

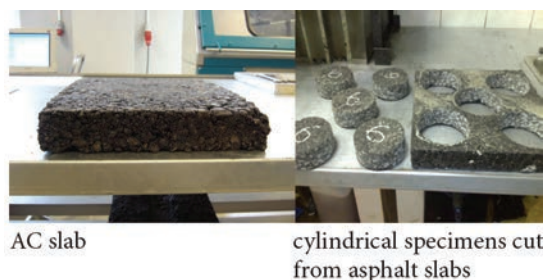
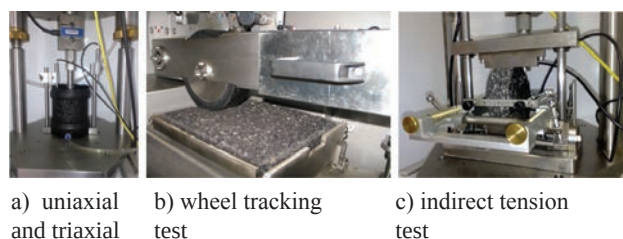


Fig. 4. AC specimens



a) uniaxial and triaxial cyclic loading tests

b) wheel tracking test

c) indirect tension test

Fig. 5. Performance tests

5. Permanent strain reasons and methods of their evaluation

A certain concurrence of external factors – transport load and pavement temperature – leads to the accelerated permanent strain formation in asphalt pavement (Kapski *et al.* 2008). The actual temperature of asphalt pavement changes depending on the air temperature, which, in its turn, depends on the season, time of the day and specifics of local climatic circumstances. The Promotion Thesis provides statistical processing of the observation data – transport load and external air temperatures which are characteristic for Latvian circumstances (Haritonovs *et al.* 2010).

5.1. Temperature influence evaluation

Pursuant to the research of strain properties of asphalt specimens, the temperature has been determined at which asphalt pavement plastic deformation rapidly increases (the resilient modulus decreases). For this purpose, elastic and plastic deformations of the test specimens have been determined at different temperatures – from +20 °C to +60 °C. As the obtained results show, rapid reduction of the resilient modulus and increase of plastic deformation is observed at the temperature exceeding +40 °C (Fig. 6).

In accordance with the analysis of the air temperature data appropriate for Latvian climatic circumstances and the asphalt pavement high performance temperature, it has been established that asphalt pavement permanent strain can develop during the period of April to September from 7.00 to 21.00 (Fig. 7). The annual average daily traffic (AADT) during this period is max.

5.2. Traffic load

Traffic axle load, volume and driving speed are the second most important external factor influencing permanent strain (Laurinavičius *et al.* 2007). To predict the rate of permanent strain formation, comprehensive evaluation of the traffic load and volume has been made. To estimate the road pavement load carrying capacity, the equivalent single-axle load (ESAL) concept has been developed, when road pavement damages can be expressed with the help of the ESAL value depending on the axle load according

Technical Circular TC01-04 Pavement Structure Design Guidelines. It is offered to express the traffic load characteristic for Latvian circumstances in *ESAL* units of measurement by using the following correlation:

$$ESAL = f_i \times G \times AADT \times 365 \times N_i \times EALF_i, \quad (1)$$

where *ESAL* – equivalent single-axle load (unit of measurement: the number of vehicle axle (equivalent to the 11.5 t axle) loading cycles during the road pavement service period); f_i – design lane factor; *G* – traffic volume growth factor; *AADT* – annual average daily traffic volume during the first year of asphalt pavement performance; N_i – number of axles on each vehicle in axle category *i*; $EALF_i$ – load equivalency factor for axle category *i*.

The traffic volume and load data have been obtained from the traffic statistics station, which is located at the Riga detour road A4 (Baltezers–Saulkalne). As, due to the Latvian variable weather circumstances and unpredictable economic situation, external factors causing permanent strain can significantly differ from the ones observed during previous years, several assumptions based on these observations have been introduced:

- average annual traffic growth – 2%;
- asphalt pavement service life in accordance with the project – 20 years;
- number of days a year with asphalt pavement high performance temperature – 2%;
- rutting takes place during the period of April to September from 7.00 till 21.00, when asphalt pavement temperature may reach and exceed the critical performance temperature – (+40 °C);
- during the period of April to September the *ESAL* value is 55% of the annual value, and from 7.00 till 21.00 it is 85% of the daily value.

By assuming the annual traffic growth value (2%) and the designed pavement service life (20 years), the traffic growth factor (during 20 years) has been calculated:

$$G = \frac{(1+r)^n - 1}{r} = 24.30, \quad (2)$$

where *G* – traffic growth factor; $r = \frac{i}{100}$ – traffic average annual growth rate; *i* – traffic growth rate a year – 2%; *n* – designed pavement service life in years.

For *ESAL* calculation, vehicles on the Riga detour road A4 have been divided with an hour interval, based on the vehicle weight category and number of axles. The analysis of the vehicle division data on the detour road A4 shows that 74% are 2-axle cars, 4% – 2-axle trucks, 1% 6-axle and 3-axle trucks, 4% – 4-axle trucks and 16% 5-axle freight trucks.

By using the determined parameters – *AADT*, *EALF*, *G* and the two-way lane number coefficient $f_i = 0.5$, the total *ESAL* for each vehicle weight category has been calculated (Table 2).

For further calculation, the *ESAL* value must be determined for the period when rutting takes place – hot

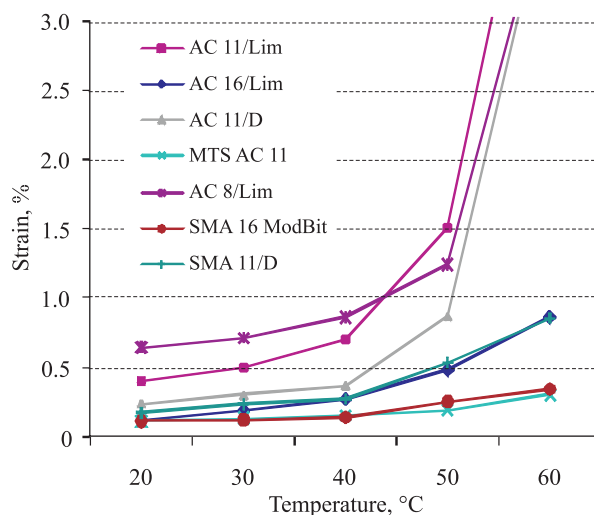


Fig. 6. AC plastic strain at different temperatures

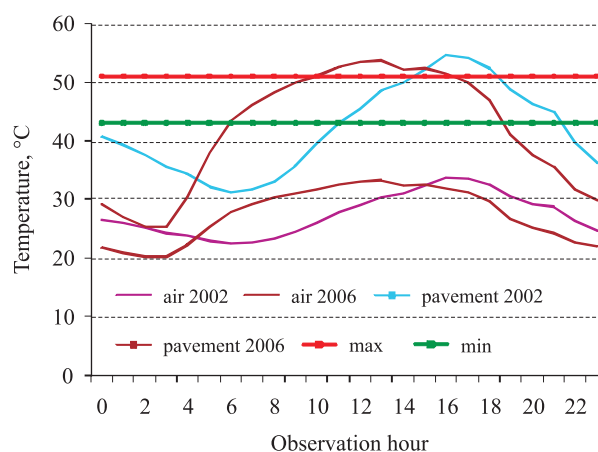


Fig. 7. Dynamics of asphalt pavement temperature change

spring-summer months with asphalt pavement high performance temperature. In accordance with the earlier introduced assumptions, the *ESAL* calculation correlation has been made for the period with asphalt pavement high performance temperature:

$$ESAL_0^{hp} = ESAL_0 a_1 a_2 a_3 = 6452, \quad (3)$$

$$ESAL_0 = \frac{\sum ESAL_i}{G} = 0.69 \times 10^6, \quad (4)$$

where $ESAL_0^{hp}$ – equivalent single-axle load during the period with pavement high performance temperature; $ESAL_0$ – equivalent single-axle load during the first asphalt pavement service year; a_1 , a_2 – parameter which includes the season and the number of days a year with asphalt pavement high performance temperature; a_3 – parameter which includes the number of hours a day with asphalt pavement high performance temperature; *G* – traffic volume growth factor.

Table 2. ESAL and its calculation parameters

Vehicle axle number	Lane number coefficient, f_i	Growth, G	AADT, vpd	EALF, f	Group ESAL $\times 10^{-6}$	Total ESAL $\times 10^{-6}$
2				0.007	0.2	
3				1.05	0.46	
4	0.5	24.3	10.000	1.50	2.7	16.7
5				1.76	12.5	
6				1.82	0.8	

5.3. Permanent strain and its prediction

Rutting of the researched asphalt mixtures has been investigated by using the power functions which is a mathematical model of the permanent strain prediction (Rabbira Gabra 2002; Eisenmann 1987; Blab *et al.* 2004):

$$\varepsilon_p = aN^b, \quad (5)$$

where ε_p – permanent strain, mm; a , b – material constants; N – number of loading cycles.

The a parameter characterises permanent strain increase at $N = 1$, whereas the b parameter – the strain increase rate.

Accumulation of plastic deformation (ε_{pn}) from the number of traffic loading cycles (ESAL units) is expressed by the relation (Kenis 1997):

$$\varepsilon_{pn} = \frac{\partial \varepsilon_p}{\partial N} = \frac{\partial}{\partial N}(aN^b) = abN^{b-1}. \quad (6)$$

By analysing the WTT test results and applying the linear correlation curve methodology, as well as by considering the experimentally determined resilient modulus of asphalt specimens, a mathematical model (7) parameters μ and α have been calculated. The μ parameter characterises the relation of plastic and elastic deformations, whereas the α parameter – the permanent strain increase rate (Sivapatham, Beckedahl 2005):

$$\varepsilon_p(N) = \mu \varepsilon_r N^\alpha, \quad (7)$$

where ε_r – resilient strain, mm.

To enable prediction of permanent strain, the following assumptions have been used:

- rutting appears on roads or streets in accordance with the “number of loading cycles – strain” correlation, which is obtained by performing the permanent strain;
- laboratory research with the help of the WTT method;
- rutting appears only in the AC surface layer and is not related to strain properties of the bottom layers, i.e. ruts are not the structural or impress result;
- the surface layer has no temperature gradient, the temperature is constant in the entire material;
- the traffic load expressed in ESAL units is 16.7 mln during twenty years (Table 2);
- rutting appears at the temperature of +40 °C and higher.

By considering the earlier determined resilient modulus of the asphalt specimens, depth of ruts and their rate results, permanent strain parameters and external factors of permanent strain formation – local climatic circumstances and traffic load expressed in ESAL units of measurement for the pavement high performance temperature period, the theoretical dynamics of rut development for the Riga detour road A4 (Fig. 8) has been determined. By comparing the obtained results for seven asphalt mixtures designed during the research, it has been determined that the conventional dense graded AC mixtures have ruts ≥ 13 mm deep, which becomes dangerous and may cause hydroplaning when the driving speed exceeds 80 km/h, and this will be reached already during the first year of the road pavement service. It is important to note that, among three best specimens, there is one conventional SMA 11/D mixture with the diabase aggregate. This confirms that also unmodified bitumen is appropriate for manufacturing SMA mixtures, if, prior to manufacturing it, a thorough calculation of its grading composition is made.

6. Concept of the quality provision system

It has been established that, irrespective of the clearly understandable mechanics, the recommended specifications and general conformity of the asphalt pavement layer formation stages to the quality requirements, at some renovated road pavement sections of the Latvian

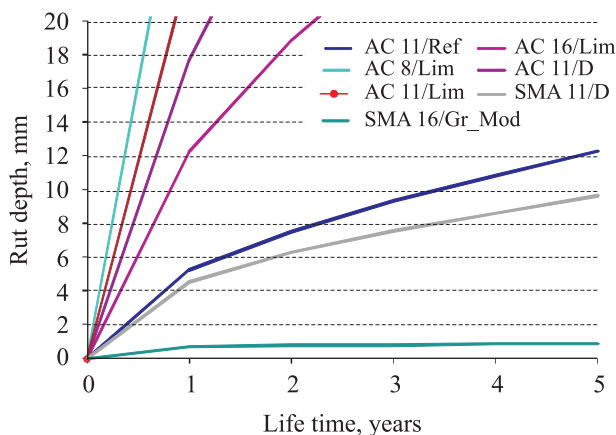


Fig. 8. Permanent strain formation dynamics (loading circumstances of the Riga detour road A4)

roads ruts appear after a short period of payment service. In order to avoid this, a concept of quality provision system of asphalt pavement has been developed in the thesis which is the quality provision algorithm of the entire process and, thus, allows tracing its every procedure (Fig. 9).

The aforesaid certifies that, irrespective of some positive properties of the SMA and AC asphalt mixtures; there is no sufficient experience of their practical usage on the Latvian streets and roads. Their usage on the Latvian roads and streets demonstrate that the result is not satisfactory – the inadmissible ruts appear. The Promotion thesis, by analysing the developed stages of the quality provision system – selection of the AC type, requirements to raw materials, design and the manufactured material quality control, offers some recommendations which implemen-

tation could minimise rutting on the newly built Latvian streets and roads:

- improvement of requirements of the technical regulations *Autoceļu specifikācijas 2010* [Road Specifications 2010] – approbation of new methods for performance testing and their introduction for quality control of asphalt mixtures and cored specimens;
- providing CE marking, which certifies that asphalt conforms to the EU directives, i.e. the manufacturing process control has been elaborated and certified, and main functional properties of the materials are periodically determined at low and high temperatures, in accordance with the AC type testing standard *LVS EN 13108-20*;
- observation of the AASHTO and NAPA recommendations with regards to manufacturing and

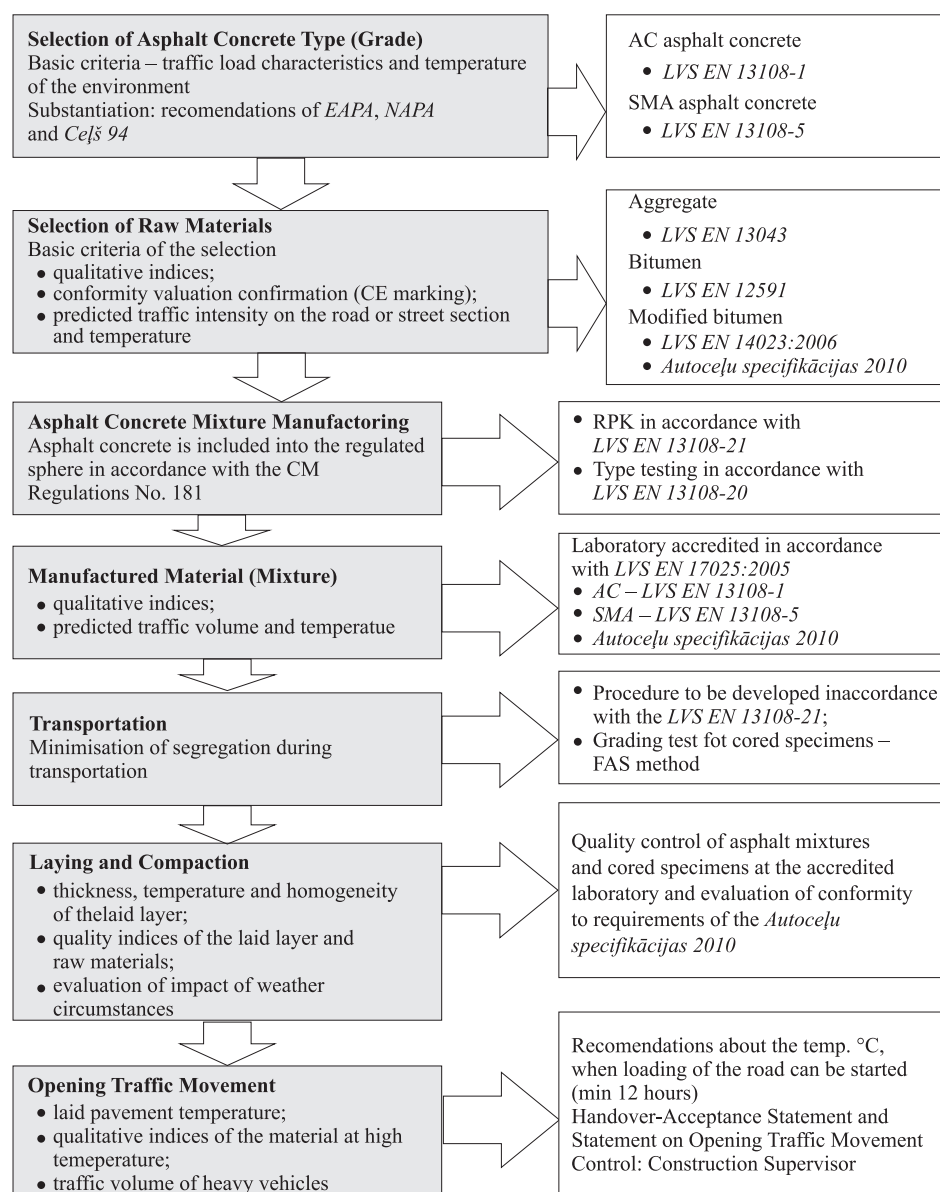


Fig. 9. Concept of the asphalt pavement quality provision system: – processes and procedures; – quality provision measures

laying of the SMA and AC mixtures, i.e., by using qualitative aggregates and modified bitumen, strictly observing the material supply sequence, temperature and duration of mixing at manufacturing, mixing of the mixture at the start and finish of laying, thoroughly following the procedure of rolling (the road-roller type, temperature, rolling speed, etc.);

- development of the procedure of asphalt mixture transportation and laying of each asphalt mixture type;
- introduction of the methods determining progressive compaction for quality control of the entire road pavement layer;
- collection of informative data (thickness of the road pavement structure and its separate layers, AC type, etc.);
- development and introduction of the vehicle weight control system.

7. Conclusions

Properties of the unmodified bitumen binder B70/100 and the SBS polymermodified bitumen binder have been experimentally determined. The results confirm the higher indirect viscosity indices of the modified bitumen binder at high performance temperatures (penetration at 25 °C = 59 × 0.1 mm, the softening point temperature = 68 °C), in comparison with B70/100 (71 × 0.1 mm and 59 °C), though the Frass breaking point temperature is higher – (–16 °C) (–21.1 °C for B70/100).

Two unconventional asphalt mixtures have been created: AC 11/Ref with the MSS aggregate and SMA 16/Mod with the SBS modified bitumen aggregate, as well as five mixtures with conventional aggregates: AC 11/Lim, AC 8/Lim and AC 16/Lim with dolomite, AC 11/D and SMA 11/D with diabase. To determine the optimum content of the aggregate, the volumetric analysis (V, VMA and VFB) has been done with the help of the Marshall method. With the optimum content of the aggregate, SMA 16 has larger content of permanent voids – 4.7%, and the AC 11 mixture with the MTS aggregate has larger resistance when being statically loaded at the temperature of 60 °C (Marshall stability) – 13 kN.

By using modern performance test methods (UCCT and TCCT), plastic deformation values have been experimentally determined for unconventional (etalon mixtures) and conventional asphalt mixtures. By analysing the obtained results, it has been established that at similar testing circumstances under cyclic axial and triaxial loads, the conventional asphalt mixtures, in comparison with the reference mixtures, demonstrate 3–10 times larger plastic deformation. No deterioration zone has been established for the unconventional mixtures. Under triaxial load at +60 °C, permanent strain is 0.1%, which is three times less than that of the SMA 11/D and AC 16/Lim (0.3%) mixtures and more than ten times less than that of the AC 11/Lim, AC 11/D and AC 8/Lim mixtures (1.2%).

When analysing the wheel tracking slope WTS_{air} (mm/1000 cycles) obtained by means of the wheel tracking test (WTT), it has been established that for three asphalt mixtures – AC 11/Ref, SMA 11/D and SMA 16/ModBit – the wheel tracking slope is less than one ($WTS_{air} = 1$ is the max category of the *LVS EN 13108-1 standard*). However, only the SMA-16/ModBit mixture with $WTS_{air} = 0.06$, in accordance with requirements of the *Autoceļu specifikācijas 2010*, is appropriate for being laid on the streets and roads which are intensively loaded with traffic, i.e. where traffic volume $AADT > 3500$ vpd. The unconventional AC 11/Ref mixture has WTS_{air} of 0.56, WTS_{air} of the conventional SMA 11/D is 0.49, and the wheel tracking slope WTS_{air} of other conventional AC mixtures is 1.5 to 6.86.

By using the data obtained from the traffic statistics station on the Riga detour road A4, as well as the air temperature data for the period of 2001–2008, the equivalent single-axle load value has been estimated for the period with the road pavement high performance temperature. As in the future the traffic volume data may differ from observations of recent years, the *ESAL* value is estimated on the basis of several assumptions: the annual traffic volume increase is 2%, the asphalt pavement service life is 20 years, and the number of days a year with asphalt pavement high performance temperature is 2%. These assumptions are based on observations of the recent years and the results of many experiments.

Methods based on the *VESYS* calculation model with the *ESAL* values calculated for the hot (spring-summer) period has been offered which allows, by considering the traffic load expressed in *ESAL* units and the local climatic conditions, to predict permanent strain in the laboratory circumstances. By predicting permanent strain of the conventional and etalon mixtures characteristic for Latvian circumstances, it has been established that the conventional AC mixtures have ruts ≥ 13 mm deep, which is dangerous when the driving speed exceeds 80 km/h, and this will be reached already during the first year of the road pavement service.

Asphalt pavement quality provision system has been developed and, by analysing its separate stages related to selection of the asphalt mixture type, manufacturing, design and quality control, recommendations have been provided to minimise rutting on Latvian streets and roads.

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