Saulius BUTKEVIČIUS

IMPACT OF HEAVY WEIGHT VEHICLES ON DURATION OF SERVICE LIFE OF ASPHALT CONCRETE ROAD PAVEMENT

Summary of Doctoral Dissertation
Technological Sciences, Civil Engineering (02T)

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LEIDYKLA
Vilnius TECHNIKA 2007

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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1. General Characteristic of the Dissertation

Scientific problem. Due to the geographical location of Lithuania in the Baltic Sea Region, development of global economy as well as its membership in the European Union, Lithuania has become a transit state, while Lithuania's transport sector has become a part of the trans-European transport network between the West and the East, the North and the South.

In recent years the main problems in Lithuanian‘s roads supervision sector are related to the increasing number of transportations by means of heavy weight vehicles and insufficient funding of the road sector. Taking account of the road parameters (width and evenness of a pavement, strength of a pavement construction, etc.) roads are not capable to withstand a markedly increased traffic of heavy weight vehicles as well as increasing axle loads, thus at present due to international transit haulage our road pavements suffer from an over-damaging effect, even when the number of heavy weight vehicles in the overall vehicle flow is relatively small.

It is important to improve methods for evaluation of damaging effects of heavy weight vehicles on a road pavement construction as well as to propose ways and means that will allow to avoid its early deterioration. This would allow to make objective plans as well as organize the traffic of heavy weight vehicles on roads with weaker constructions or sections of them and to foresee repair works on them or, if necessary, to limit such traffic during unfavourable seasons of the year completely.

Up until today there is no methodology in Lithuania which would allow fairly precise evaluation of the impact of heavy weight vehicles on a road pavement, thus it is difficult to make rational plans and implement road repair works relying on changes in the traffic of heavy weight vehicles only. The methodology for evaluation of pavement stresses and deformations as well as design of a pavement according to ODN and VSN instructions and HDM models are not adequately objective and precise, thus application of them does not allow to predict with adequate preciseness the changes in pavement strength, its service life and to calculate the admissible intensity of heavy weight vehicle traffic taking into account the present state of pavements and seasonal peculiarities of traffic.

The use of elasticity characteristics of a road pavement construction (elasticity module or elastic deflection) to evaluate the state of a road pavement is not a novelty: in recent years this method has been used in the world as well as in Lithuania, however, the use of this method was only theoretically grounded. No detailed theoretical and experimental research has been carried out that would allow to determine with adequate preciseness for practical reasons the remaining strength of a road pavement construction, evaluate its state and suggest rational and timely means to extend the real service life of this pavement construction in each individual case as well as necessary measures to stop early and too speedy deterioration of a construction.

The objective and the task of work. Examine, taking account of Lithuania's climate conditions, the damaging effect of heavy weight transport traffic on strength and service life of asphalt concrete layers in a road pavement by determining the admissible loads for a road pavement as well as present the methodology for evaluation of material loss resulting from heavy weight transport traffic and for its compensation.

Tasks:

1. Create the model for deterioration, remaining strength and service life of asphalt concrete in a road pavement in the presence of repeated loads of vehicle wheels taking account of ground, hydrological and climate conditions of the locality, which could be applied in Lithuania's conditions.
2. Determine the admissible intensity of heavy weight transport traffic and admissible axle load for a road pavement taking account of the state of stresses and deformations of a pavement, non-binding layers of a road pavement construction and ground in a roadbed and their resistance.
3. Suggest a methodology for determining the inter repair periods for asphalt concrete layers in a road pavement as well as parameters of the strengthening layers.
4. Check by means of experimental and laboratory examinations of selected composition asphalt concrete and by means of visual and instrumental examinations of state of the selected road sections in Lithuania the methodology for determining deterioration and remaining strength of asphalt concrete.
5. Suggest ways to reduce the damaging effect of heavy weight transport traffic on an asphalt concrete pavement of Lithuania's roads by limiting traffic.

Scientific novelty

1. This study is the first to present the methodology for evaluation of the damaging effects of heavy weight vehicle traffic and loads on Lithuania's road pavements taking account of seasonal peculiarities of traffic, strength of a pavement, remaining strength of asphalt concrete layers in it as well as changes in stressed and deformed state of a pavement.
2. Research on the remaining strength of a road pavement construction (particular road sections investigated).
3. Calculation of the necessary values of pavement construction strength coefficient and the remaining of this strength, resistance of material in an asphalt concrete pavement to bending tension, resistance of this material to

fatigue coefficient as well as admissible value of pavement construction deterioration extent.

4. Use of exploration results in calculation methods for a road pavement construction.

5. Model for practical application of exploration results.

The objective of the researches and methods. Objective of research: road pavement construction that experiences actual loads of heavy weight vehicle traffic. Methods of research: theoretical and experimental exploration, analysis of results using methods of mathematical statistics, set up of experimental calculation models and their application to justify calculation of the remaining strength of a road pavement.

Approval of the results of the work. The main statements and proposals of the thesis have been presented and discussed at 6 conferences and there have been published 9 articles.

Structure and size. The dissertation contains 162 pages. There are 50 figures and 17 tables. It consists of: introduction, five parts and general conclusions. The structure of dissertation:

Chapter 1. Analysis of investigations aimed to determine and evaluate the state of a road pavement. Review of Lithuania and world-wide experience as well as research on work conditions of a road pavement construction. Analysis of key factors determining the state characteristics of asphalt concrete layers of a road pavement and changes during operation as well as damaging effect of heavy weight vehicle loads on a road pavement construction. Aim and tasks, novelty of the paper.

Chapter 2. Modelling of damaging impact caused by heavy weight vehicles. Modelling of damaging impact of heavy weight vehicle traffic on a road pavement construction. Selection of parameters to justify the model of road pavement service life, set up of a model and determination of service life and remaining strength of asphalt concrete layers in a road pavement.

Chapter 3. Experimental investigations to determine the remaining strength of a road pavement. The object of research and its characteristics are presented. Statistical analysis of experimental data are accomplished and dependencies between variables are established.

Chapter 4. Data on service life and remaining strength of asphalt concrete layers in a road pavement and its analysis. Possibilities to apply experimentally data in Lithuania are described, economical benefit is calculated.

Chapter 5. Suggested concepts for limiting traffic of heavy weight vehicles and loads. Concepts for calculating losses resulting from heavy weight vehicle traffic to be compensated as well as for determining limits for heavy weight vehicle traffic during unfavourable seasons.

2. Main Results of Dissertation

Determination of elasticity characteristics (elasticity module or elastic deflection) of a road pavement construction is one of the ways to evaluate the state of ir. Until now no systematic research has been carried out neither in a world wide nor in Lithuanian practice that would allow to evaluate the state a pavement by means of objective strength criteria (elasticity characteristics of a pavement construction, seasonal peculiarities of traffic, changes in strength of materials in asphalt concrete layers during their operation time and fatigue reserve coefficient of those materials).

Aiming to optimize the discussed factors, theoretical research had been carried out, changes in strength of asphalt concrete layers of a pavement during their operation time were determined and a new (not used in Lithuania) model of deterioration extent in asphalt concrete layers of a pavement was suggested (Fig 1).

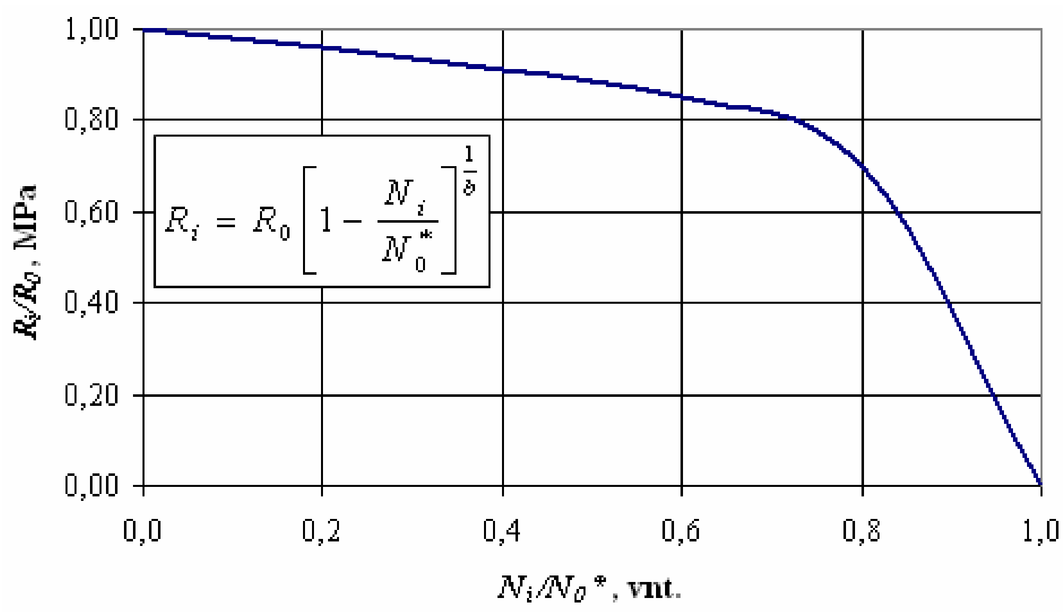

Fig 1. Changes in strength of an asphalt concrete layer in a pavement: R_i / R_o – relative strength (MPa), N_i / N_i^* – relative number of added loads (units)

In the first stage the damaging effect of a moving vehicle on a road pavement was evaluated. Since there are only minor differences in ground, hydrological and climate conditions of individual regions of Lithuania, it was deemed that changes in seasonal factors can be described by means of average one month values. The design axle loads for further research were chosen such as the pavement deformations and stresses due to the bending tension of asphalt concrete layers in a road pavement will not exceed the admissible norms and shearing stresses in a bed ground will not exceed the designed resistance of ground to shearing during the period when its dampness parameter is the highest.

Aiming to determine the changes in strength of a road pavement construction by means of the proposed model, the admissible traffic intensities of designed vehicles were determined according to three limit state criteria that nowadays are applied when designing pavements taking account of:

a) elastic deformation condition:

$$N_{pE}^{(l)} = 10^{\frac{1}{A}\left(\frac{E_b}{K_{st}} - B\right)} \text{, vehicles per 24 hours;} \quad (1)$$

b) comparative cohesion conditions of ground (or admissible shearing stresses):

$$N_{p\tau}^{(l)} = \left(2{,}45\,\frac{k_1 k_3}{K_{st}} \cdot \frac{C_{gr}}{\tau}\right)^b \text{, vehicles per 24 hours;} \quad (2)$$

c) conditions of admissible bending tension in asphalt concrete layers of a pavement (taking account of fatigue deterioration):

$$N_{p\sigma}^{(l)} = \frac{k_n^b \cdot \beta_{sk}}{365 \cdot T_f}\left(1 - t_\alpha V\right)^b \text{, vehicles per 24 hours,} \quad (3)$$

here: E_b – common elasticity module of a road pavement construction, MPa; A and B – coefficients (for vehicle loads of groups A and B: A = 70 MPa; $B_A = 56$ MPa and $B_B = 0$ MPa); K_{st} – strength coefficient of a road pavement construction; k_1 – coefficient that takes into account the damaging effect of repeated short-term loads, $k_1 = 0{,}6$; k_3 – coefficient, describing the conditions of ground performance in a road pavement; C_{gr} – comparative cohesion of ground, MPa; b – parameter characterizing fatigue of service life of asphalt concrete in a road pavement in the presence of level of loads σ / R; τ – active shearing stresses in ground of a roadbed in the presence of short-term load, MPa; k_n – fatigue resistance margin coefficient; β_{sk} – coefficient evaluating vehicle wheel track deviation from the expected path (distributed according to the regular rule); T_f – rational service life of a road pavement construction in years; t_α – standard deviation coefficient that is determined taking into account the designed reliability level; V – strength variation coefficient.

Then the change in the remaining equivalent thickness of asphalt concrete layer in a road pavement was determined and an equation for calculating the necessary thickness of the strengthening layer for a pavement was suggested:

$$\Delta H^{(T)} = H_1^{(0)} - H_1^{(T)} = H_1^{(0)}\left[1-\left(1-\frac{T}{T_f}\right)^{\frac{1}{2b}}\right], \text{cm}, \tag{4}$$

here: $H_1^{(0)}$ – thickness of the layer designed to strengthen a pavement with parameters E_1, ν_1, b, that are analogous to the upper layer (1st asphalt concrete layer) and that ensure the acceptable service life of asphalt concrete layers in a pavement during the period of time T_f, in the presence of traffic intensity of designed vehicles N_p (vehicle per 24 hours) in cm; $H_1^{(0)}$ – thickness of equivalent layer in a road pavement when its initial strength is R_0 in cm; T – moment of strengthening a pavement expressed in years.

According to research and analysis of a world wide practice the optimal moment for strengthening a pavement is:

$$T_{rem}^{(opt)} = f\left(\sum H \to \min, \sum C \to \min, \Delta h \to opt\right), \tag{5}$$

here: $\sum H$ and $\sum C$ – relative thickness of layers designed to strengthen the construction and relative cost of repair work on layers corresponding to expenditure period T_Σ (T_Σ is a period of 35−40 years during which qualitative changes will take place in vehicle stock, their weight and size, manufacturing technology for heavy weight vehicles and their price, construction methods and design of a road pavement construction); Δh – thickness of the layer designed to strengthen a pavement ($H_1^{(0)}$), that depends on the remaining strength of asphalt concrete layers and technology for construction of layers designed to strengthen a pavement in cm.

Experimental research was carried out to check the practical applicability of the suggested model for pavement failure accumulation (deterioration extent).

During the first stage experiments on asphalt concrete in a laboratory were performed: asphalt concrete mixtures to strengthen a road pavement were designed as well as optimal designed composition of mixture of asphalt concrete was selected on the basis of which samples of asphalt concrete were formed and optimal load parameters (extent and time of exposure) for them were determined. Next, on the basis of these parameters asphalt concrete samples were formed and factors of their service life (Fig 2) and remaining strength (Fig 3) were determined. The resulting equations (Fig 2) indicate a very close relationship between the results.

The comparison of results of laboratory examinations and results of calculations (Fig 3) allows us to state that approximately 80 % of material strength is lost in the last (20 %) part of its service life. This tendency is calculated for temperatures of 0 °C and +25 °C and covers the period that lasts around six months in Lithuania.

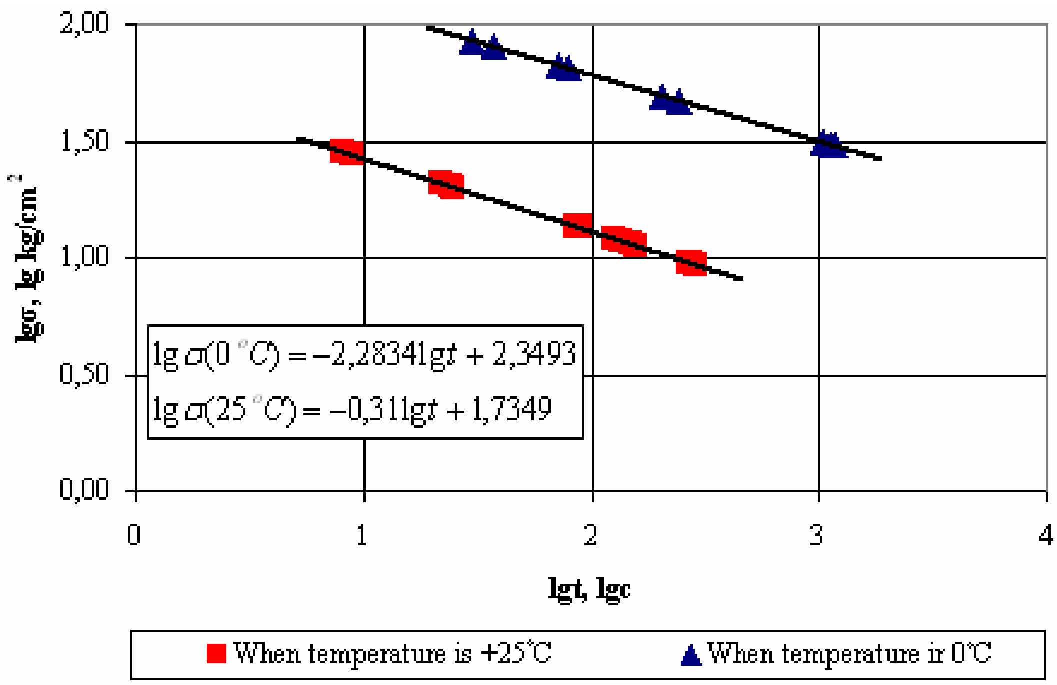

Fig 2. Diagram for determining values for service life of asphalt concrete by means of bending tests when load increases at the same speed: $\lg t$ – service life factor of asphalt concrete, $\lg \sigma$ – resistance to bending factor of asphalt concrete samples when load is increased at the same speed

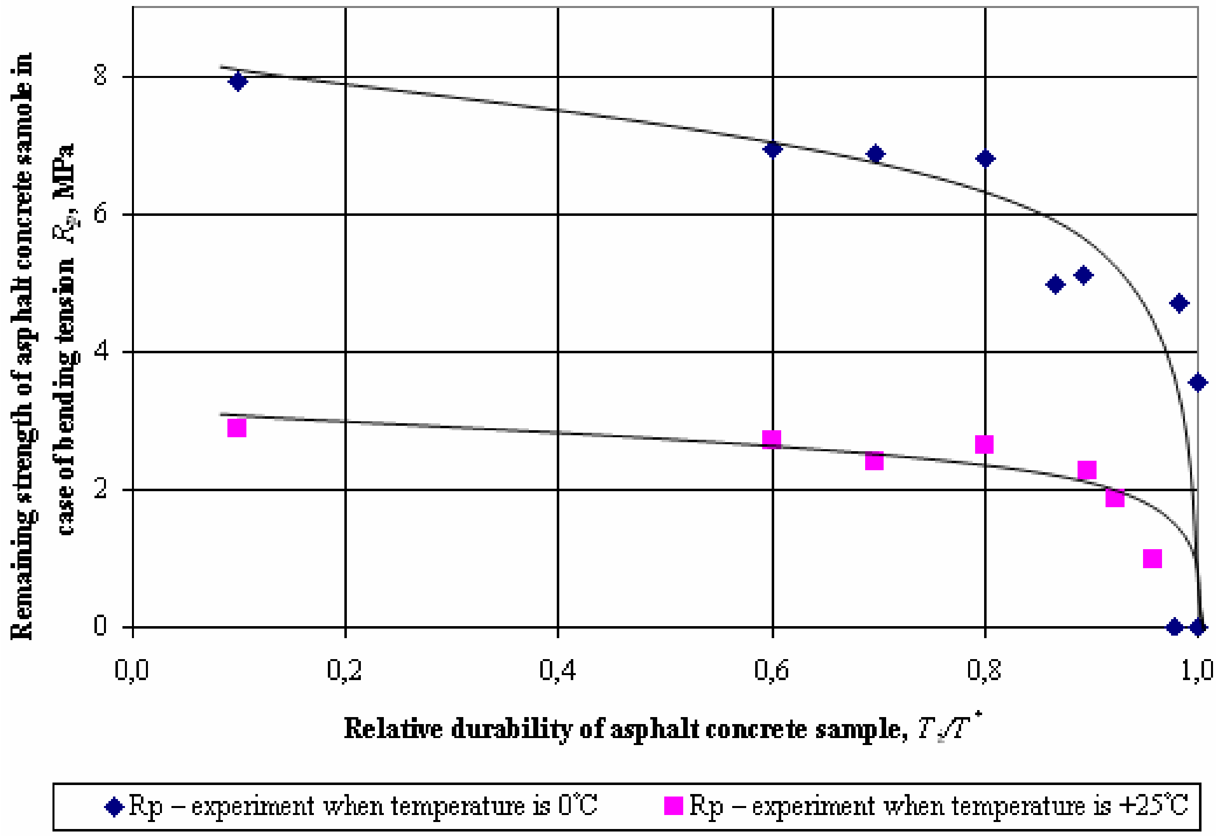

Fig 3. Changes in strength (resistance to bending tension) of asphalt concrete (when temperature is 0 °C and +25 °C): R_p – remaining strength of asphalt concrete sample in case of bending tension (MPa), T/T^* – relative durability of asphalt concrete sample

During the second stage visual and instrumental experiments on the district road Anykščiai–Troškūnai–Panevėžys in Lithuania had been carried out in spring and summer: the road sections with the same or similar structure of a road pavement construction were selected, visual and instrumental experiments of the state of selected road pavement sections were performed and the analysis of results was carried out. Eighteen sections of a road pavement construction (each 100 m in length), characterised by extreme, average and slight deterioration of the pavement were selected on the road. The sections selected were equal in their designed pavement construction and traffic intensity on them. The strength of a pavement construction, thickness of layers and intensity of vehicle traffic on all road sections explored were more or less the same. The road pavement construction of the sections has undergone major repairs long time ago, thus its state was not good. The pavement construction of explored road sections and thickness of its layers is as follows: asphalt concrete layer – 6 cm, gravel base – 22 cm, cold resistant layer – 35 cm, ground of a roadbed – clay sand.

The deterioration extent D of a pavement was measured on all the area of pavement construction sections; seven types of failures were noticed as well as the state of a pavement was evaluated. After analysis of visual investigation results, elastic deflection of a pavement construction was measured in spring in compliance with the requirements by means of the Benkelmann beam; vehicles with rear axle load of group A of 100 kN (MAZ−5551) were used as load on a pavement construction. During the experiment on 198 points the elastic deflection of a road pavement construction was measured (in eighteen sections, 11 measurements on each of them) and its elasticity module E (Fig 4), strength coefficient K_{st} and extent of pavement deterioration D (Table 1) were determined. Moreover, aiming to determine how the strength a pavement construction declines depending on its deterioration extent D, measurements were performed on road sections that had no failures.

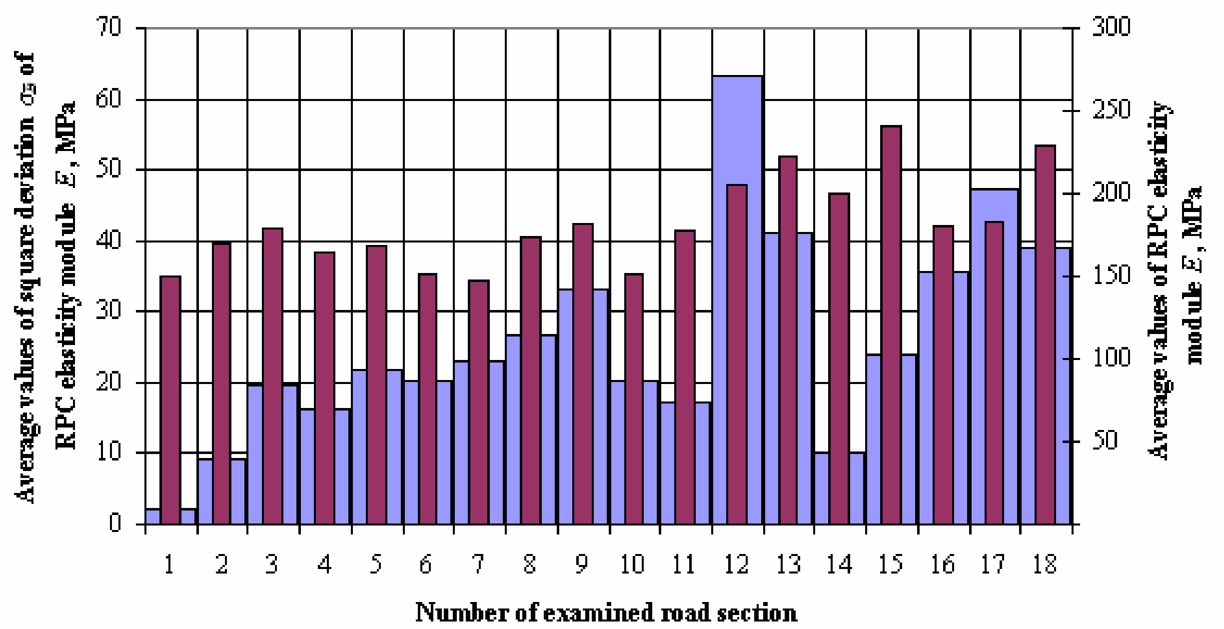

Fig 4. Diagram of average values of road pavement construction (RPC) elasticity module E and values of its average square deviation σ_E on the explored road sections

Fig 4 indicates that there had been significant changes in average values of pavement construction elasticity module E on individual sections of the road investigated; values of standard deviations of these factors have changed as well. This indicates that during operation of the road, road pavement construction lost considerable part of its strength in certain road sections due to its decreased elasticity module E.

Table 1. Quality factors of pavement on the explored road pavement construction (RPC) sections

RPC quality factors		Average values of quality factor		
		Pavement deterioration extent D and need for repair		
Name	Compulsory value	D= 5–8 % minor repair of a RP is necessary, n=38	D= 8–16 % preventive repair of a RP is necessary, n=65	D>16 % major repair of RPC is necessary, n=95
Elasticity module E in MPa	218	208	187	174
Strength coefficient K_{st}	1,00	0,95	0,86	0,80

The results of our study indicate (Table 1) that 48 % of the explored pavement construction sections need major repair, 33 % sections need preventive repair and 19 % sections need minor repair on the pavement. Our experiments give an objective indication that by determining the values of deterioration extent D or strength coefficient K_{st} it is possible to foresee rational and timely measures for repair on a road pavement construction as well as to extend its actual service life. The analysis allows to state that experimental data is reliable and individual units are homogeneous. This data can be used for further calculations.

Seasonal factors that influence pavements were determined: fluctuations of traffic throughout the year, changes in average temperature of weather and asphalt concrete layers in a pavement in certain months of the year as well as elasticity modules of pavement construction layer materials (elasticity modules of cold resistant layer and ground of a roadbed were not evaluated due to unmarked changes in their values). During explorations ground samples of explored road sections were taken (aiming to determine dampness in ground and its granulometric composition and plasticity (dampness of fluidity and plasticity) and changes in factors of a roadbed ground on explored road sections during months were calculated.

After the seasonal factors that influence pavements were determined, changes in strength of pavement construction layers during the year was calculated on the base of which the admissible traffic intensity of designed vehicles for explored sections was determined (Eqs. (1), (2), (3) and Fig 5).

It was determined (Fig 5, $N_{p\sigma}^{(l)}$), that according to the admissible σ criteria for asphalt concrete layers in a pavement, the most unfavourable time of the year is rather long and lasts for seven months (from October to December and from January to April). According to the pavement elasticity module E (Fig 5, $N_{pE}^{(l)}$), summer season is the most unfavourable period (from June to

August) during which the decrease of elasticity module of pavement construction layers is influenced by increase in temperature of weather and asphalt concrete pavement. It was approved (Fig 5, $N_{p\tau}^{(l)}$) that according to the criterion of shearing stresses in a roadbed ground τ, spring (April and May) and autumn (October and November) are the most dangerous periods.

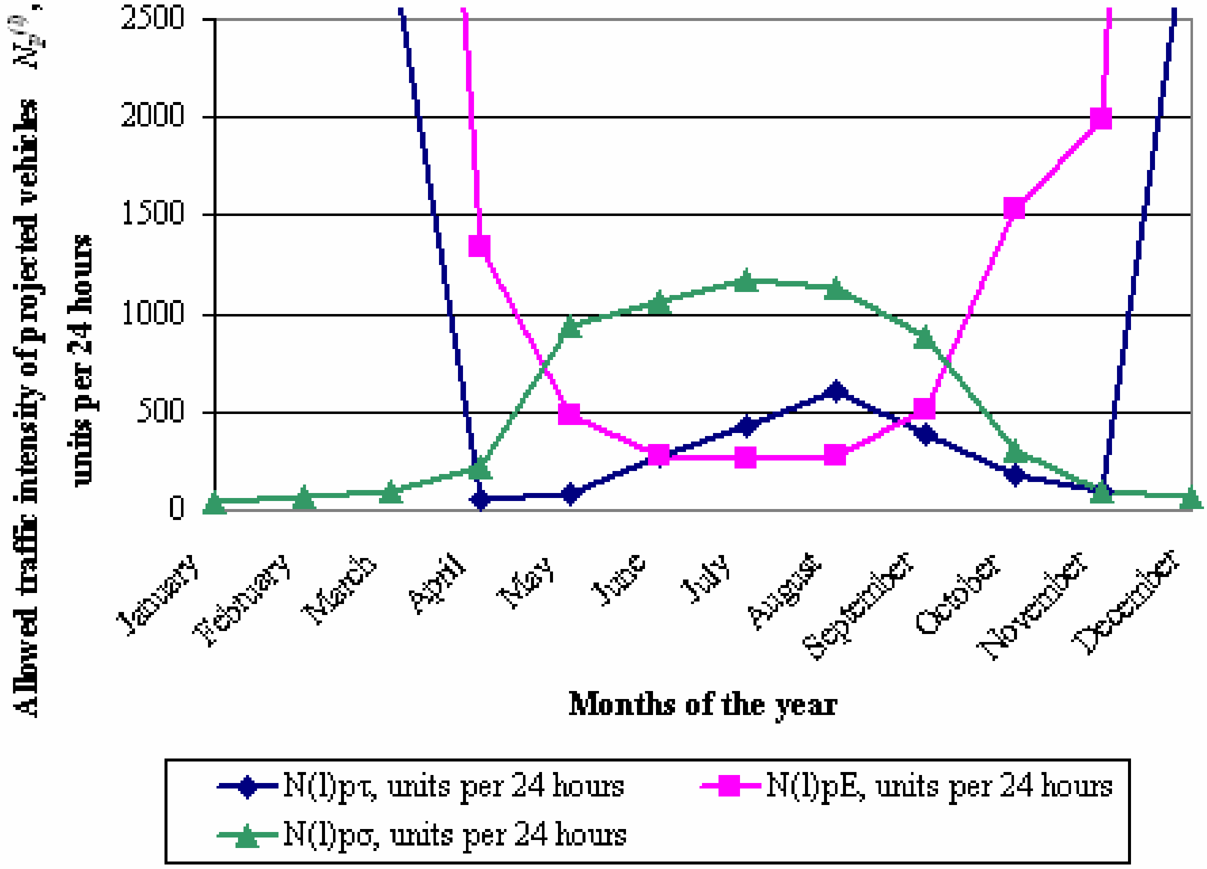

Fig 5. Diagram of a change in admissible traffic intensity $N_{p\tau}^{(l)}$, $N_{pE}^{(l)}$, $N_{p\sigma}^{(l)}$ of designed vehicles on explored road sections in certain months of the year, that complies with road pavement construction strength criteria τ, E , σ

These results (Fig 5) evidence that because the inter repair period for pavements was extended due to the lack of funding, their state on the majority of Lithuania‘s roads of national importance (in particular regional and district roads) is only satisfactory and often bad.

On the basis of the proposed model of pavement deterioration extent, an analysis was carried out on the way the duration of service life of pavement construction layers in explored sections changes. It was calculated that if the traffic intensity of designed vehicles does not exceed $N_p^{(l)} = 100$ vehicles per

24 hours, the pavement of explored sections will serve for $T_f^{(\max)} = 12$ years (Fig 6).

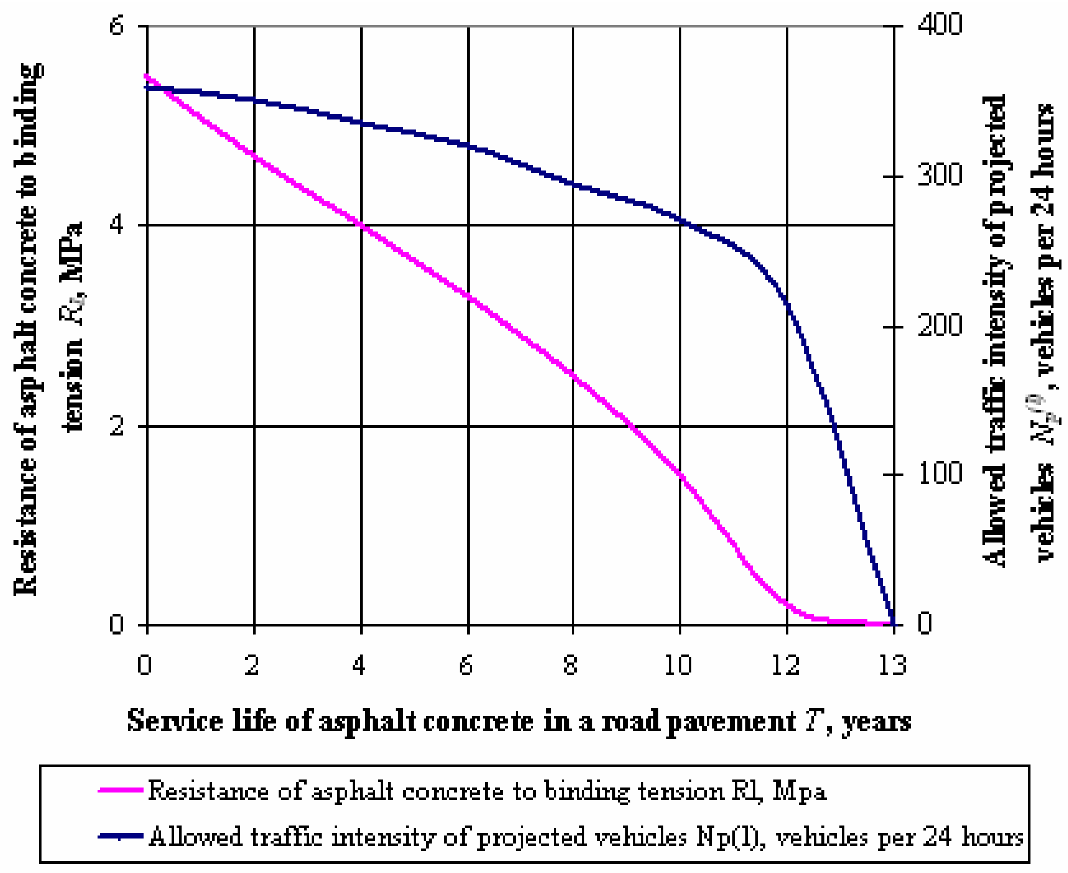

Fig 6. Change in strength and durability of asphalt concrete layers in the explored sections of a district road pavement during a year

It was determined that aiming to ensure the acceptable state of the explored pavement construction sections when the traffic intensity of designed vehicles is $N_p^{(l)} = 100$ vehicles per 24 hours, $T_{rem} = 10$ years (Fig 6) should be considered an optimal inter repair period, i. e. if the road pavement construction on the explored sections is strengthened once in ten years by the asphalt concrete layer of 2 cm in thickness ($H_i = 2$ cm) or other layer equivalent in strength, it is possible to maintain the necessary strength of asphalt concrete layers in a pavement construction and there will not be more cracks in these layers than it might be, when reliability index is $\alpha = 0{,}85$.

A preventive repair strategy was proposed for calculation of economic benefits. Having performed calculations (taking account of norms used in practice) it was determined (Fig 7) that it is advisable to calculate the necessary thickness of asphalt concrete layers in the explored pavement construction sections for a designed service life of a pavement $T_f = 9$ years, when the inter repair period $T_{rem} = 7$ years. In this case the initial thickness H_o of asphalt concrete layers in a pavement would be $H_o = 7{,}5$ cm and the thickness H_i of planned layers for strengthening the pavement would be $H_i = 1$ cm of upper layer of (fine) asphalt concrete. Such strategy for strengthening a pavement and its maintenance (for defined conditions) is most economic and easily implemented from the technological point of view.

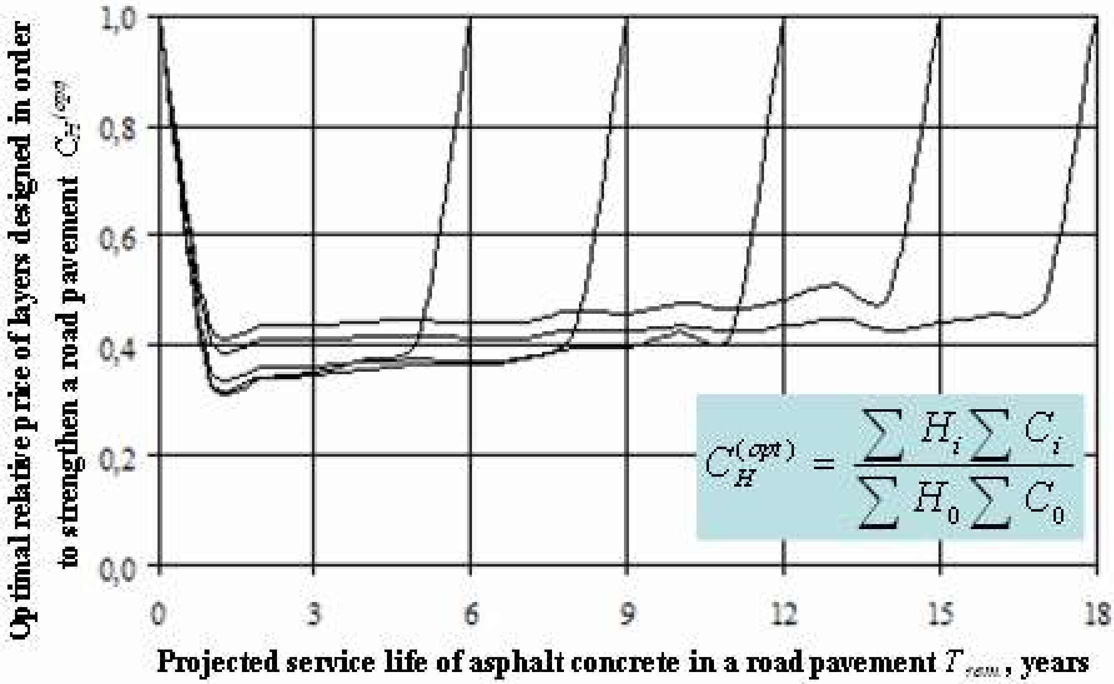

Fig 7. Optimal relative price of layers designed to strengthen asphalt concrete in a road pavement when different repair strategies are applied and different designed service life period T_Σ for asphalt concrete layers in a pavement is foreseen

It was determined that from economy of materials point of view the most efficient way is to construct thinner upper asphalt concrete layers in a pavement and to foresee often repetition of their strengthening; such an approach would require less investments when compared to traditional strategies for pavement repair, when the designed period of its service life is $T_f < 12$ years.

This study does not include costs related to road pavement maintenance and repair; the experimental research illustrates only one year service life of a particular district pavement, thus it is rather difficult to forecast the way the strength of a road pavement construction on the explored sections will change in the coming years of service life (or after preventive repairs performed). These economic characteristics are worth calculating only in possession of multi annual research and exploration data, thus wishing to perform the abovementioned calculations for a particular group or all of Lithuania‘s roads a complex exploration is necessary.

3. General Conclusions

1. Model for deterioration, remaining strength and service life of asphalt concrete in a road pavement in the presence of repeated loads of vehicle wheels, applicable in Lithuania's conditions was created. The suggested model allows to determine the extent of road pavement deterioration, its rational service life and its remaining strength. Taking account of solutions that evolved from experiments performed, a novel method (in Lithuania) for determining the rational service life of a road pavement was suggested that allows to calculate the optimal thickness of asphalt concrete layers in a road pavement and to foresee the rational strategy for preserving the characteristics of these layers.
2. The proposed model of the remaining strength of asphalt concrete in a road pavement and their service life evaluates the parameters of heavy weight vehicle load and intensity of its impact, composition of vehicle flow, admissible axle load, state of a road pavement, design characteristics of materials used for constructing asphalt concrete layers in a road pavement and for strengthening it, changes in strength of materials in asphalt concrete layers, stresses in pavement construction layers and ground of a roadbed as well as price of pavement repairs and economic effect when strengthening road pavement construction.
3. Methodology for determining the inter repair periods for asphalt concrete layers in a road pavement and parameters of the strengthening layers was suggested. On the basis of experimental results it was determined that the strategy on early strengthening of a road pavement is more beneficial from the economic point of view when compared to traditional practice applied for pavement strengthening and use of inter repair periods. We have determined that it is advisable to determine the strength of a road pavement construction and the initial thickness of asphalt concrete layers for a construction service life of $T \le 12$ years. In order to preserve the strength of asphalt concrete layers in a road pavement we advise to perform preventive repair works by repeatedly constructing thin H = 1,5 cm÷3,0 cm layers to strengthen a road pavement.
4. Experimental laboratory examinations of asphalt concrete of selected composition and visual and instrumental examinations of state (in 198 points, 11 measurements in each of 18 sections) of the selected sections (18 sections,

each 100 m in length) on a road (Anykščiai−Troškūnai−Panevėžys) in Lithuania allowed to prove that the proposed methodology for determining the deterioration and remaining strength of asphalt concrete in a road pavement is suitable to be used in Lithuania. It was proven that being aware of the extent of road pavement deterioration, elasticity module E and strength coefficient K_{st} of its construction it is possible to make objective evaluation of the state of a pavement and demand for repair work, nature and scope of such a work. Visual evaluation of the state of a road pavement is necessary but not sufficient as grounds justifying the necessity of repair works on a road pavement.

5. By applying the suggested measures of heavy weight vehicle axle load, air pressure in tyres and speed control at the same time (during dangerous seasons of the year when failures appear and develop) it is possible to avoid early deterioration of asphalt concrete layers in a road pavement. In case there is lack of funds to strengthen a road pavement construction and if there are no possibilities to limit axle loads of heavy weight vehicle during unfavourable seasons of the year or to direct the traffic of heavy weight vehicle to other roads, one of the effective means to preserve pavements of Lithuania and/or to ensure adequate state of them is the introduction of a tax system on the basis of the concepts suggested which would compensate for the losses (that occur due to a much worse state of road pavements) and, on the basis of it, the collection of taxes imposed on the traffic of heavy weight vehicle in Lithuania.

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Saulius Butkevičius was born in October 4, 1972 in Panevėžys.

In 1996 graduated from Vilnius Gediminas Technical University and was awarded the Bachelor Degree of Civil Engineering. In 1998 he received the Master Degree in Civil Engineering. Since 2000 he worked for Vilnius Gediminas Technical University in the Department of Roads. In 2000–2007 he was a doctorial student (PhD) at Vilnius Gediminas Technical University.

SUNKIASVORIO TRANSPORTO ĮTAKA AUTOMOBILIŲ KELIŲ ASFALTBETONIO DANGOS FUNKCIONAVIMO TRUKMEI

Mokslo problema. Pastaraisiais metais Lietuvoje kelių priežiūros didžiausios problemos yra susijusios su vežimų sunkiasvoriu transportu skaičiaus augimu ir kelių ūkio nepakankamu finansavimu. Pastaruoju metu gabenant tarptautinio tranzito krovinius, mūsų kelių danga patiria pernelyg didelį ardymo poveikį net tada, kai visų transporto priemonių sraute yra santykinai nedaug sunkiasvorio transporto.

Iki šiol Lietuvoje dar nėra metodikos, kurią taikant būtų galima pakankamai tiksliai įvertinti sunkiasvorio transporto poveikį kelių dangai, todėl pagal jo eismo pokyčius yra sunku racionaliai planuoti bei vykdyti kelių remonto darbus. Kelių dangos įtempiams ir deformacijoms įvertinti ir jai projektuoti metodika, aprašyta ODN ir VSN instrukcijose, bei dangų būklės valdymo sistema, aprašyta HDM modeliuose, nėra pakankamai objektyvios ir tikslios. Jas taikant negalima pakankamai tiksliai prognozuoti kelių dangos stiprio kitėjimo ir jos funkcionavimo trukmės bei apskaičiuoti sunkiasvorio transporto leistinąjį eismo intensyvumą, atsižvelgiant į dabartinę kelių dangos būklę bei eismo sezoniškumą.

Kelių dangos konstrukcijos tampros charakteristikos (tampros modulio arba tampriojo įlinkio) panaudojimas dangos būklei įvertinti yra ne naujas reiškinys: paskutiniaisiais metais tiek pasaulyje, tiek Lietuvoje šis būdas yra naudojamas, tačiau šio metodo naudojimo pagrįstumas buvo tik teoriniame lygmenyje. Nebuvo atlikta išsamių teorinių ir eksperimentinių tyrimų, leidžiančių su pakankamu praktinėms reikmėms tikslumu nustatyti kelių dangos konstrukcijos stiprio likutinį resursą, įvertinti jos būklę ir kiekvienu konkrečiu atveju pasiūlyti racionalias ir savalaikes priemones jos realiai funkcionavimo trukmei prailginti bei būtinas priemones ankstyvai ir pernelyg greitai dangos irčiai sustabdyti.

Darbo tikslas ir uždaviniai. Ištirti sunkiasvorio transporto eismo ardomojo poveikio, įvertinant Lietuvos klimato sąlygas, įtaką kelių dangos asfaltbetonio sluoksnių stipriui ir funkcionavimo trukmei, nustatant kelių dangai leistinąsias apkrovas bei pateikti metodiką dėl sunkiasvorio transporto eismo patirtiems materialiesiems nuostoliams įvertinti bei jiems kompensuoti.

Uždaviniai:

1. Sukurti kelių asfaltbetonio dangos suirties, likutinio stiprio ir funkcionavimo trukmės, veikiant automobilių ratų pasikartojančioms apkrovoms, modelį, taikytiną Lietuvos sąlygomis, įvertinant vietovės gruntų, hidrologines ir klimato sąlygas.

2. Nustatyti kelių dangai sunkiasvorio transporto eismo leistinąjį intensyvumą bei leistinąją ašies apkrovą, įvertinant kelių dangos, kelių dangos konstrukcijos nerišlių sluoksnių bei žemės sankasos grunto įtempių-deformacijų būvį ir jų atsparumą.

3. Pasiūlyti metodiką kelių dangos asfaltbetonio sluoksnių tarpremontiniams laikotarpiams bei stiprinimo sluoksnių parametrams nustatyti;

4. Parinktos sudėties asfaltbetonio eksperimentiniais laboratoriniais tyrimais bei parinktų Lietuvos kelio ruožų natūriniais vizualiais ir instrumentiniais būklės tyrimais patikrinti asfaltbetonio suirties ir likutinio stiprio nustatymo metodiką.

5. Pasiūlyti būdus sunkiasvorio transporto eismo ardančiajam poveikiui, tenkančiam Lietuvos kelių asfaltbetonio dangai, sumažinti, ribojant eismo intensyvumą bei kompensuojant patiriamus nuostolius.

Darbo mokslinis naujumas

1. Pirmą kartą pateikta metodika sunkiasvorio transporto eismo ir apkrovų ardančio poveikio Lietuvos kelių dangai, priklausomai nuo eismo sezoniškumo, dangos stiprio, jos asfaltbetonio sluoksnių likutinio stiprio bei dangos įtempto-deformuoto būvio kitėjimo, įvertinti.

2. Kelių dangos konstrukcijos likutinio stiprio tyrimai (konkretūs tyrimų ruožai).

3. Kelių dangos konstrukcijos stiprio koeficiento, dangos asfaltbetonio medžiagos atsparumo tempimui lenkiant bei šios medžiagos atsparumo nuovargiui koeficiento būtinųjų verčių, taip pat dangos konstrukcijos suirties masto vertės nustatymas.

4. Gautų tyrimų rezultatų pritaikymas kelių dangos konstrukcijos skaičiavimo metoduose.

5. Gautų tyrimų rezultatų įdiegimo į praktiką modelis.

Tyrimo objektas ir metodai. Tyrimų objektas – faktinių sunkiasvorių transporto eismo apkrovų veikiama kelių dangos konstrukcija. Tyrimo metodai – teoriniai ir eksperimentiniai tyrimai, jų rezultatų analizė naudojant matematinės statistikos metodus, eksperimentinių skaičiavimo modelių sudarymas bei jų taikymas kelių dangos likutinio stiprio nustatymui pagrįsti.

Darbo rezultatų aprobavimas. Pagrindiniai disertacijos teiginiai ir siūlymai buvo pristatyti ir aptarti 6 konferencijose ir išspausdinti 9 straipsniai.

Darbo apimtis ir struktūra. Disertacijos apimtis 162 puslapiai. Disertacijoje yra 50 paveikslų ir 17 lentelių. Disertaciją sudaro: įvadas, penkios dalys, bendrosios išvados, literatūros šaltinių ir autoriaus publikacijų sąrašas.

Pirmame skyriuje apžvelgta Lietuvos ir pasaulio patirtis bei mokslo darbai, skirti kelių dangos konstrukcijų darbo sąlygoms. Nustatyti pagrindiniai veiksniai, nulemiantys kelių dangos asfaltbetonio sluoksnių būklės charakteristikas bei jų kitėjimą eksploatavimo procese, išanalizuotas sunkiasvorio transporto apkrovų ardantysis poveikis kelių dangai.

Antras skyrius skirtas sunkiasvorio transporto ardančiojo poveikio kelių dangos konstrukcijai modeliavimui. Sukurtas kelių asfaltbetonio dangos suirties, likutinio stiprio ir funkcionavimo trukmės, veikiant automobilių ratų pasikartojančioms apkrovoms, modelis, taikytinas Lietuvos sąlygomis. Jis pagrįstas kelių dangos asfaltbetonio sluoksnių medžiagų funkcionavimo trukmės bei stiprio pokyčių prognoze ir yra orientuotas į dangos ženklios suirties, nulemiančios jos eksploatacinių savybių blogėjimą, prevenciją.

Trečias skyrius skirtas kelių dangos eksperimentiniams tyrimams. Aprašytas tiriamasis objektas, atlikta gautų tyrimų rezultatų analizė, išvestos regresinės priklausomybės.

Ketvirtame skyriuje pateiktos gautų tyrimų rezultatų taikymo galimybės Lietuvoje. Atlikti ekonominiai skaičiavimai, sukurtas pasiūlytos metodikos taikymo modelis Lietuvos sąlygoms.

Penktame skyriuje gautų tyrimų rezultatų pagrindu pateiktos koncepcijos sunkiasvorio transporto eismo sukeltiems kompensuotiniems nuostoliams apskaičiuoti bei jo eismo apribojimui nepalankiuoju metų laikotarpiu nustatyti.

Galutinės išvados

1. Sukurtas taikytinas Lietuvos sąlygoms kelių asfaltbetonio dangos suirties, likutinio stiprio ir funkcionavimo trukmės, veikiant automobilių ratų pasikartojančioms apkrovoms, modelis. Siūlomas modelis leidžia nustatyti kelių dangos suirties mastą, jos racionalią funkcionavimo trukmę bei jos likutinį stiprį. Pagal tyrimų sprendinius pasiūlytas naujas (Lietuvoje) metodas kelių dangos funkcionavimo racionaliai trukmei nustatyti, kurį taikant galima nustatyti kelių dangos asfaltbetonio sluoksnių optimalų storį ir numatyti šių sluoksnių savybių išsaugojimo racionalią strategiją.
2. Pasiūlytas kelių dangos asfaltbetonio likutinio stiprio ir jų funkcionavimo trukmės modelis įvertina sunkiasvorio transporto apkrovos parametrus bei jos poveikio intensyvumą, automobilių srauto sudėtį, leistinąją ašies apkrovą, dangos būklę, dangos asfaltbetonio sluoksniams įrengti bei jai stiprinti naudojamų medžiagų projektines savybes, asfaltbetonio sluoksnių medžiagų stiprio kitėjimą, dangos konstrukcijos sluoksnių ir žemės sankasos grunto įtempius, dangos remonto darbų kainą ir stiprinant kelio konstrukciją gaunamą ekonominį efektą.
3. Pasiūlyta metodika kelių dangos asfaltbetonio sluoksnių tarpremontiniams laikotarpiams bei stiprinimo sluoksnių parametrams nustatyti. Pagal tyrimų rezultatus nustatyta, kad dangos ankstyvo stiprinimo strategija yra ekonomiškai naudingesnė, lyginant ją su dangos stiprinimo bei tarpremontinių

laikotarpių naudojimo tradicine praktika. Nustatėme, kad kelių dangos konstrukcijos stiprį ir asfaltbetonio sluoksnių pradinį storį tikslinga nustatyti konstrukcijos funkcionavimo trukmei $T \leq 12$ metų. Dangos asfaltbetonio sluoksnių stipriui išsaugoti siūlome daryti prevencinius (profilaktinius) remontus, periodiškai įrengiant plonus, $H = 1{,}5$ cm $\div$ 3,0 cm storio, kelių dangos sustiprinimo sluoksnius.

4. Parinktos sudėties asfaltbetonio eksperimentiniais laboratoriniais tyrimais bei parinktų Lietuvos kelio (Anykščiai-Troškūnai-Panevėžys) ruožų (18-lika vienodo, po 100 m, ilgio) natūriniais vizualiais ir instrumentiniais būklės tyrimais (198-uose, po 11 matavimų kiekviename iš 18-os ruožų, taškuose) įrodėme, kad pasiūlyta kelių dangos asfaltbetonio suirties ir jos likutinio stiprio nustatymo metodika yra tinkama naudoti Lietuvoje. Įrodėme, kad, žinant kelių dangos suirties mastą, jos konstrukcijos tampros modulį E ir stiprio koeficientą K_{st}, galima objektyviai įvertinti dangos būklę ir remonto būtinumą, pobūdį bei darbų apimtis. Vizualus kelių dangos būklės įvertinimas yra būtinas, tačiau nepakankamas jos remonto būtinumui pagrįsti.

5. Naudojant pasiūlytas sunkiasvorio transporto ašies apkrovų ir oro slėgio padangose bei važiavimo greičio apribojimo bei kontrolės priemones vienu metu – pažaidų susidarymo ir vystimosi pavojingais metų laikotarpiais, galima išvengti kelių dangos asfaltbetonio sluoksnių priešlaikės suirties. Stingant lėšų kelių dangos konstrukcijoms stiprinti bei neturint galimybių nepalankiais metų laikotarpiais apriboti sunkiasvorio transporto ašies apkrovas ar nukreipti jo eismą kitais keliais, viena iš efektyvių priemonių Lietuvos kelių dangoms išsaugoti ir/ar reikiamai jų būklei laiduoti yra mokesčių, paruoštų pagal pasiūlytas koncepcijas, kompensuojančių patirtus nuostolius (dėl dangos būklės pablogėjimo), sistemos sukūrimas ir, taikant šią sistemą, mokesčių už sunkiasvorio transporto važiavimą Lietuvoje surinkimas.

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IMPACT OF HEAVY WEIGHT VEHICLES ON DURATION OF SERVICE LIFE OF ASPHALT CONCRETE ROAD PAVEMENT

Summary of Doctoral Dissertation
Technological Sciences, Civil Engineering (02T)

Saulius Butkevičius

SUNKIASVORIO TRANSPORTO ĮTAKA AUTOMOBILIŲ KELIŲ ASFALTBETONIO DANGOS FUNKCIONAVIMO TRUKMEI

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