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RESEARCH OF ASPHALT PAVEMENT STRUCTURES ON LITHUANIAN ROADS (I)

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Abstract. The rapid growth of heavy traffic, the increase in the standard axle load make scientists to look forward for new durable road constructing materials and their mixes. The continuously increasing need for strengthening the road pavement structures induces to use new road reconstruction technologies, to search for new methods in constructing pavement structural layers and investigate pavement structures under real conditions. The article presents construction of experimental pavement structures for the first time in the road history of Lithuania. The article also describes the installation process of stress and strain transducers in different layers of experimental pavement structures and initial results of stress and strain measurements. These measurements will be carried out each time after passed 20 000 ESAL's calculated to 100 kN.

Keywords: road pavement structure, test road section, stress, strain, transducer, ruts, skid resistance, roughness of pavement.

1. Introduction

The rapid growth of heavy traffic on the motor roads of Lithuania, the increase in the standard axle load, plastic deformations (ruts, waves) in the wearing courses of road pavement and other defects (cracks, alligator cracking, potholes) induce the scientists to look for new durable road building materials and their mixes (Čygas *et al.* 2004; Oginskas, Laurinavičius 2005; Radziszewski *et al.* 2007). A fast increase in the prices of road building materials create a necessity to look for new cheaper possibilities of using local materials and their mixes in building, reconstructing and repairing roads and streets (Čygas *et al.* 2005). In order to increase the strength of road pavement structures and their separate layers the requirements for road building materials and their mixes are getting more and more strict (Čygas *et al.* 2007; Laurinavičius *et al.* 2006a), geosynthetic materials are installed between the pavement structural layers (Laurinavičius *et al.* 2006b; Vaitkus *et al.* 2006, 2007). Various laboratory investigations showed that the mentioned measures are efficient and gave a positive effect (Vervečkaitė *et al.* 2007). However, Lithuania still lacks experimental investigations to model the performance of new materials, their mixes and the combinations of separate pavement structural layers under real conditions.

The scientists of other countries made an attempt to determine the performance of road pavement structures under real conditions by constructing and testing them in special test polygons. One of the largest test polygons of road pavement structures was established in 1989 in the French Central Laboratory of Roads and Bridges project OECD (Organisation for Economic Co-operation and Development). Here the scientists of various European countries tested and evaluated the performance of 3 different pavement structures under the effect of different loads, the readings of the transducers of stresses, pressure, temperature and moisture were recorded, the tendencies for defects' development in the wearing courses were identified, etc.

In 2006–2007 the test of road pavement structures was carried out in the University of Maine by using 6 different transducers (Lauren, Swett 2007). The transducers were installed in different pavement structural layers to determine seasonal effects on the structural strength of road pavement.

Within the framework of the SPENS project (Sustainable Pavements for European New Member States) WP 4 (Work Package 4), materials and pavement layers appropriate for road upgrading, considering the conditions in New Member States are evaluating (Tusar *et al.* 2008). The project is focused on modified bitumen as asphalt binders and high modulus asphalt mixtures.

In USA the investigations of experimental pavement structures were carried out in order to find out the change in the strength of separate layers during freeze–thaw periods (Janoo, Berg 1992). The Falling Weight Deflectometer (FWD) was used to measure pavement structures in differ-

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ent periods of the year and to define the resistance of each pavement layer to frost effect.

2. The aims of erecting a test section and the program of experimental investigations

The structural strength of road pavements depends directly on the strength of subgrade, thickness and composition of pavement structure. The strength of pavement structures of the same thickness (of the same class of pavement structure), but erected from different materials have significantly differ strength and durability. The use of high-strength or high quality materials (for example, granite, modified bitumen, etc.) for the construction of sub-base and pavement layers increases the costs of road construction. Therefore, there is a continuous search for techniques to construct the pavement structure of the required strength and durability either using the local cheaper road building materials or the expensive high-strength materials to achieve the largest possible economic effect.

This research is carried out to confirm or deny suggestions made after a lot of laboratory researches on the use of road constructing materials and to seek for the most suitable and economically effective pavement structures.

The location in Pagiriai settlement was selected for constructing a test section. This location fulfil all the conditions required for such an experiment: it has a sufficient heavy traffic volume, lies in an open terrain, has no horizontal plan curves or vertical curves in longitudinal section and could be distinguished by the same irrigation conditions within the whole route of the road section. The cross-section parameters of a test section of experimental pavement structures meet the road category III and class III of pavement structure according to the *Regulation of Motor Roads STR 2.06.03:2001*. A test section, the total length of which is 710 m, consists of 24 segments of the same length (30 m) and 1 segment – 20 m long. In each segment the pavement structure of different composition was constructed. Three 30 m long segments are of the same pavement structure with the different type of geosynthetic materials installed in asphalt layers and sub-base. As the main (base) structure for the investigation purposes the most widely used pavement structure was assumed (Čygas *et al.* 2008). The cross-section of the base pavement structure and the required values of static deformation modulus of the sub-base and subgrade are given in Fig. 1.

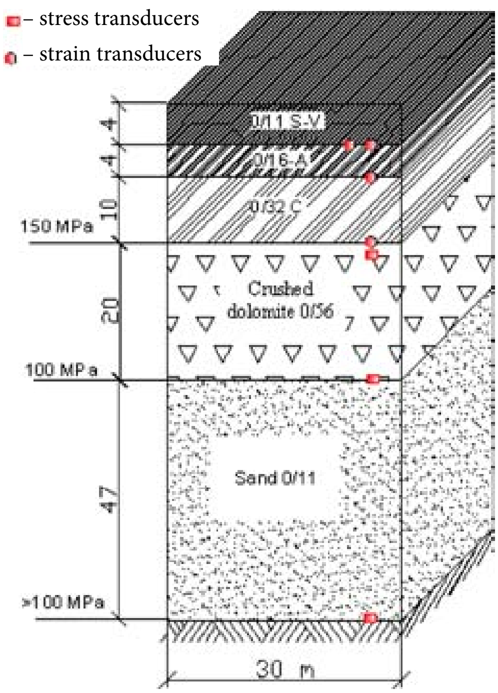

Fig. 1. The base structure of experimental pavements and positions of transducers

Other pavement structures were selected by varying the materials of all structural pavement layers compared to the base structure.

For the frost blanket course sand 0/11 and 0/4 were used.

For the base layer were used: crushed dolomite mix 0/56; crushed granite mix 0/56; crushed granite and sand mix 0/32; crushed fine sand mix 0/32; gravel and sand mix 0/32; aggregate – milled asphalt concrete.

For asphalt base course were used: 0/32 C crushed dolomite; 0/32 C crushed gravel; 0/32 C crushed dolomite and crushed gravel.

For asphalt binder course were used: 0/16 A crushed dolomite; 0/16 A crushed dolomite with PMB (Polymer Modified Binder); 0/16 A crushed granite and crushed dolomite; 0/16 A crushed granite and crushed gravel; 0/16 A crushed dolomite and crushed gravel; 0/16 A crushed granite and sand; 0/16 A crushed granite; 0/16 A crushed gravel.

For asphalt wearing course were used: 0/11 S-V crushed granite; 0/11 S-M; 0/11 S-M with PMB; Confalt.

The aims of constructing a test section were as follows:

1) to analyze and evaluate the design methods of road pavement structures under Lithuanian conditions;
2) to evaluate suitability of materials suggested for constructing road pavement structures;
3) to determine the impact of heavy vehicles on pavement structures.

The following investigations will be carried out to reach defined aims:

1) taking of subgrade soil from each separate segment, determination of soil type;
2) during the construction of pavement structure taking of materials from sub-base layer and frost blanket course from each separate segment, determination of grading and filtration coefficient;
3) taking asphalt concrete specimens from each pavement layer to determine mechanical properties;
4) taking asphalt concrete cores, determination of compaction, type of mixtures, physical and mechanical properties of all asphalt concrete layers in each separate segment;
5) measuring deformation modulus of subgrade, frost blanket course and sub-base layer in each separate segment by static beam;

6) measuring of evenness of the asphalt concrete wearing course in each separate segment;
7) measuring of the asphalt concrete wearing course in each separate segment by the FWD;
8) measuring of the asphalt concrete wearing course in each separate segment by the Light Weight Deflectometer (LWD);
9) measuring of the cross-section, longitudinal section and texture of each separate segment;
10) measuring of skid resistance of asphalt concrete wearing course in each separate segment;
11) measuring of stresses and strains in the structural layers of pavement of each separate segment each time after the passage of 20 000 ESAL's calculated to 100 kN.

Duration of investigations will depend on pavement condition and the passage of equivalent axles of heavy vehicles but not less than 5 years.

3. Investigation methods and measuring equipment

The strength of road pavement and its separate structural layers in Lithuania is regulated by a static deformation modulus. Most frequently the deformation modulus is determined by non-destructive static and dynamic methods. In static method deformation modulus is determined using the Benkelman Beam (for flexible pavements) and static press (for sub-base layers from unbound materials). In the dynamic method the following equipment is used: light dynamic device (for sub-base layers from unbound materials) and FWD (for all pavement structural layers). When taking measurements by dynamic devices, a load pulse is imparted on the pavement surface. The load is produced by dropping a large weight and transmitted to the pavement through a circular load plate. The dynamic load causes the deflections in the pavement structure. When taking measurements by static device, a certain area of the pavement structure is being gradually loaded and unloaded.

When constructing a test section of experimental pavement structures, the deformation module of separate structural layers and of the whole pavement structure were determined by static and dynamic methods using the following equipment: in the static method – static press „Strassentest" and Benkelman Beam „Infratest; in the dynamic method – light dynamic device „ZORN ZSG 02", LWD „Prima 100", FWD „Dynatest 8000".

In each different pavement structure of a test road section the stress and strain transducers were installed. At the bottom of the asphalt wearing course, binder course and base course special strain transducers were installed (Fig. 2). They were installed in the right-of way, along which the loaded heavy-weight vehicles travel from the query, in the axis across the first track from the road shoulder at a 0,7 m distance from the road edge. Totally, 80 strain transducers were installed in asphalt pavement layers of a test road section. On the surface of the crushed stone sub-base, frost blanket course and subgrade of specific and the main pavement structures 11 stress transducers were used (Fig. 3). The stress transducers were also installed in the axis of the first track from the road shoulder. The cables of transducers erected in a different pavement structural layer were connected to the data registration boxes erected in the roadside of a test section. When connected to a special equipment, the boxes register the transducer readings. During this investigation readings of the transducers will be registered each time after the passage of 20 000 ESAL's (estimated to 100 kN) of the loaded heavy-weight vehicles travelling along the right-of-way from the query.

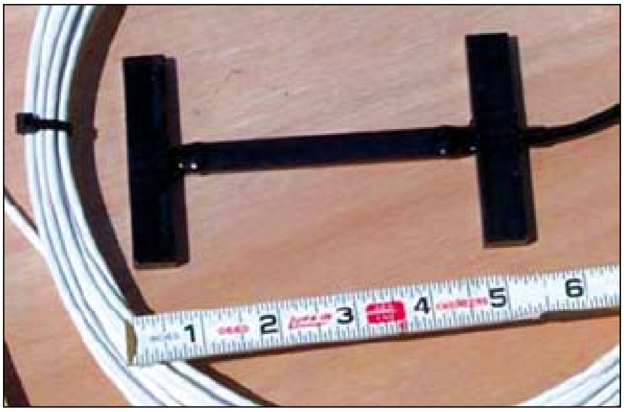

Fig. 2. Strain transducer installed in experimental pavement structures

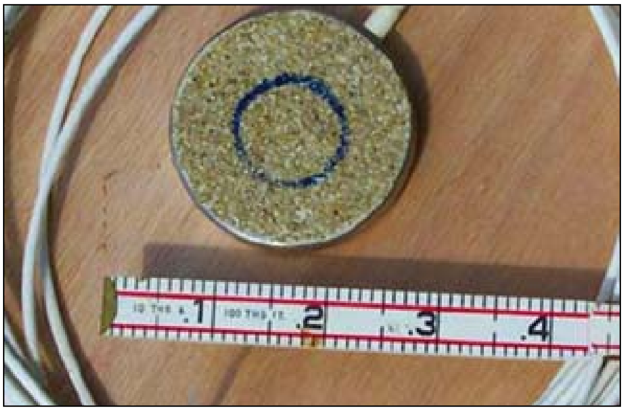

Fig. 3. Stress transducers installed in experimental pavement structures

4. Initial results of measuring strength, stresses and strains of a test road section

This chapter gives the results of measuring strength, stresses and strains of experimental pavement structures. The strength measurements were carried out during the construction of pavement structures and after final completion of a test road section. Measurements of stresses and strains were taken before the opening of the road section to traffic. Fig. 4 gives the distribution of the mean values of equivalent deformation modulus of different pavement structures measured by the FWD on the asphalt wearing, binder and base courses. Measurements by the FWD were taken in 3 points in each section of a different asphalt courses pavement structure.

When measuring stresses and strains, the loading of transducers was carried out by a two-axle vehicle having twin-

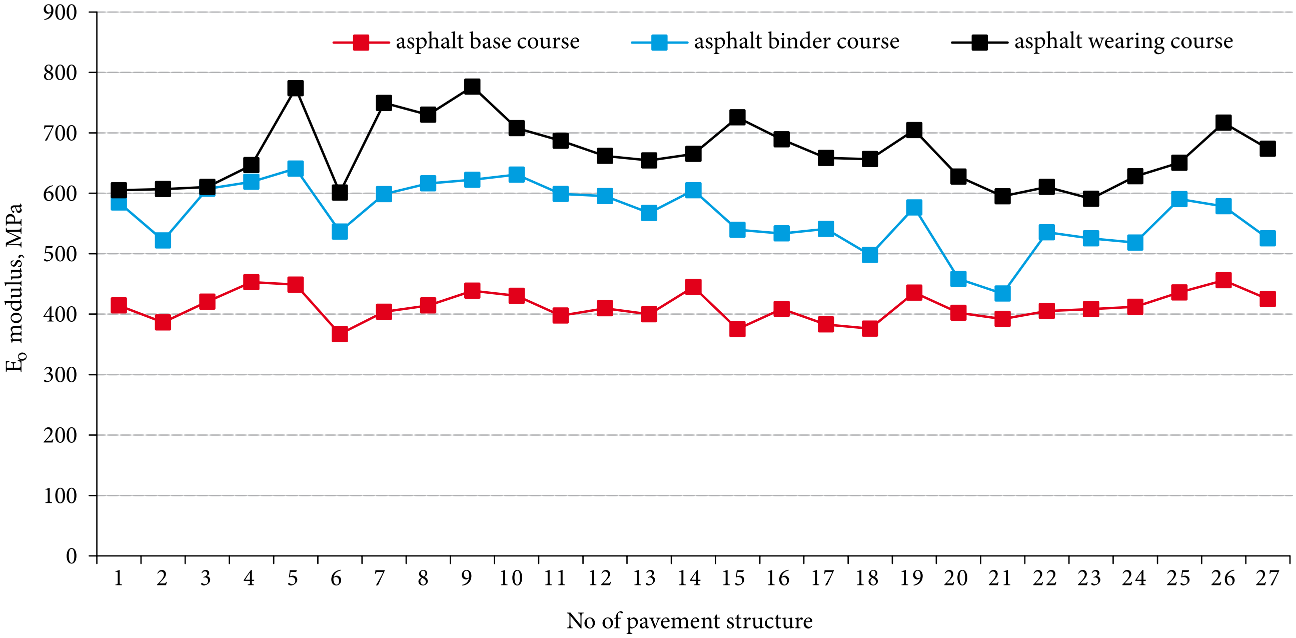

Fig. 4. Mean values of equivalent deformation modulus on the asphalt wearing, binder and base courses of different pavement structures of a test road section

Table 1. Max values of stress and strain of the main pavement structure of a test section

Transducer No	Transducer location in pavement structure	Measuring results	
		Strains, microm/m	Stresses, kPa
19.1 IS	At the bottom of the asphalt wearing course / longitudinal direction	7,99 (tension) –19,17 (compression)	–
19.1	At the bottom of the asphalt wearing course / transverse direction	–26,76 (compression)	–
19.2	At the bottom of the asphalt binder course / transverse direction	–10,26 (compression)	–
19.3	At the bottom of the asphalt base course / transverse direction	38,84 (tension)	–
19.3.7	In the contact of the base course and the asphalt base	–	22,73
19.3.1	On of the sub-base course	–	21,79
19.3.4	On of the sub-grade	–	10,47

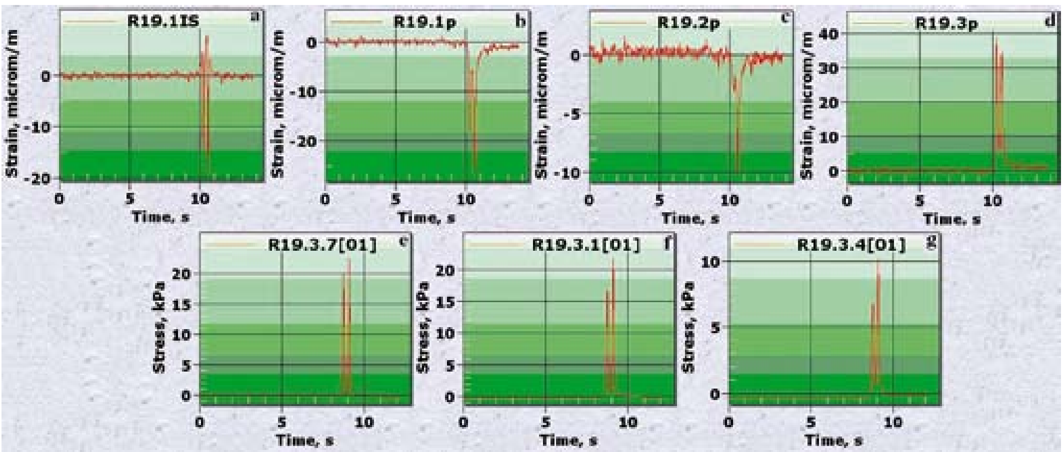

Fig. 5. The charts of stresses and strains of the main pavement structure of a test road section: a) longitudinal strain* at the bottom of the asphalt wearing course, b) transverse strain** at the bottom of the asphalt wearing course, c) transverse strain at the bottom of the asphalt binder course, d) transverse strain at the bottom of the asphalt base course, e) stress in the contact of the asphalt base course and the base, f) stress on of the sub-base course, g) stress on of the sub-grade. * strain measured along wheel travel direction; ** strain measured across wheel travel direction

wheels of the rear axle. The load of twin wheels was 50 kN. The tyre pressure was 0,65 MPa. The speed of the moving vehicle – 50 km/h, mean temperature of the pavement surface +5,6 °C. Transducer readings were registered by a universal digital measuring device "Spider 8" and a computer program „CatmanEasy". The max values of stresses and strains of the main pavement structure of a test section are given in Table 1, variation charts of stresses and strains are in Fig. 5.

5. Initial measurements of test section pavement surface characteristics

The road pavement condition and material properties gradually change through the usage. Initial measurements of the test road pavement section enable to forecast the quality of pavement surface under concrete transport loading and climatic conditions. Before opening the test section to traffic, the following pavement characteristics were measured in the mobile research laboratory RST 28: longitudinal and transverse cross fall, pavement roughness, ruts, pavement friction and skid resistance, pavement defects.

Having opened the test section to traffic, rutting was measured as well.

The results of measurements of the transverse cross falls of a test road sections are presented in Fig. 6, and the results of longitudinal cross fall measurements are in Fig. 7. Fig. 8 presents the results of measuring the roughness of a test road sections. Measurements were carried out under a right and a left wheel of the vehicle on the loaded traffic lane.

Rutting is defined as a permanent pavement layers deformation occurring due to traffic loads and the interaction of vehicle wheels with pavement in situ. Their formation depends on the pavement surface wear, pavement structural strength and layers resistance to displacement and deformations. In the beginning of the exploitation of newly laid pavements, rapid rutting is noticed, which, in the course of time, stabilizes and slows down. Having opened the test road section to traffic, rutting was measured on every road lane by mobile road research laboratory RST 28. Fig. 9 presents the rutting measurement results on the test road section pavement 1 traffic lane and 2 (loaded) traffic lane.

During construction of test road section and the first research the measurements of separate pavement structural layers, total pavement structural strength, stresses, strains and pavement surface characteristics were carried out.

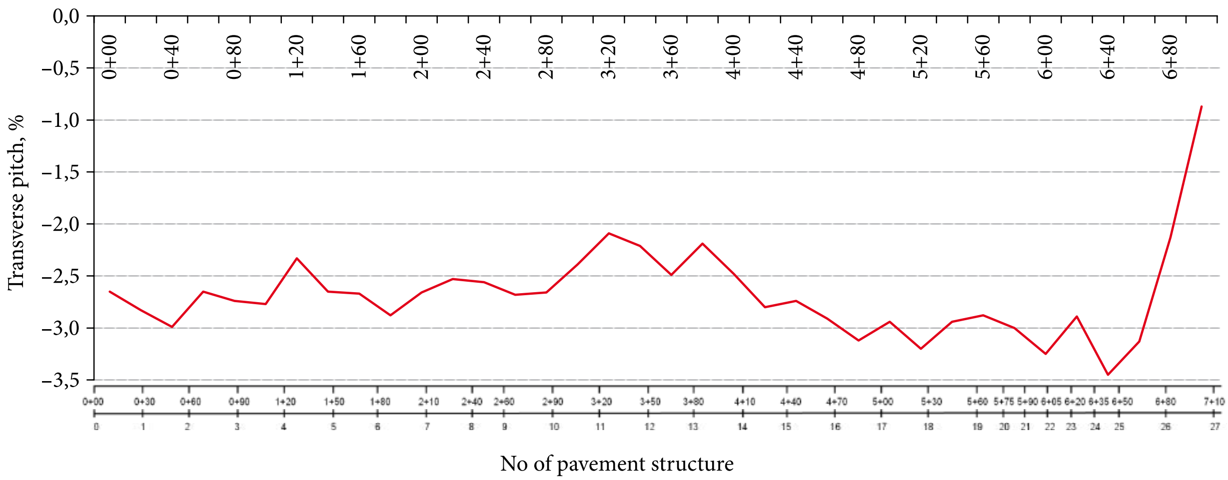

Fig. 6. The chart of transverse cross falls of a test road sections

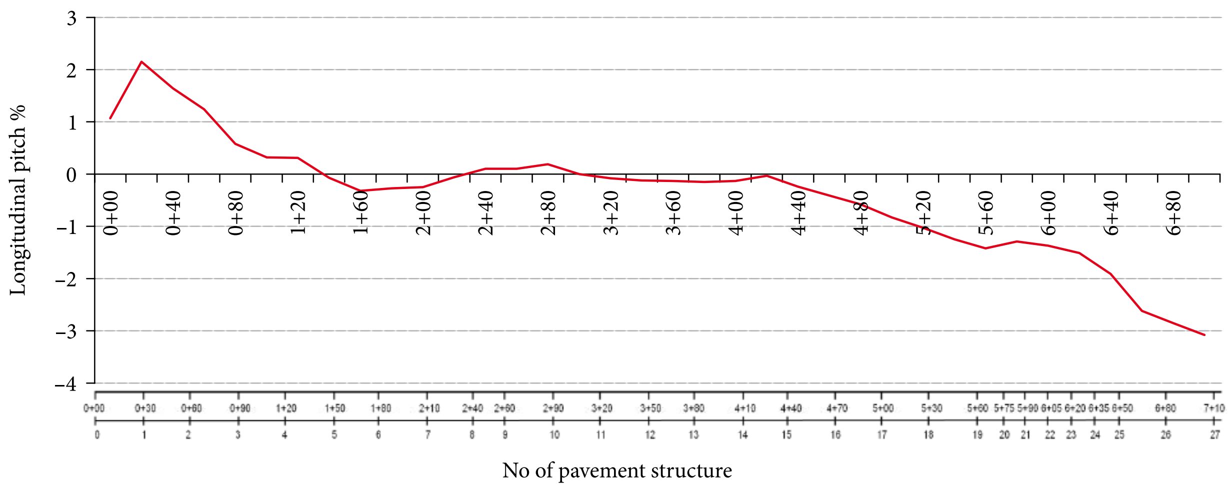

Fig. 7. The chart of longitudinal cross falls of a test road sections

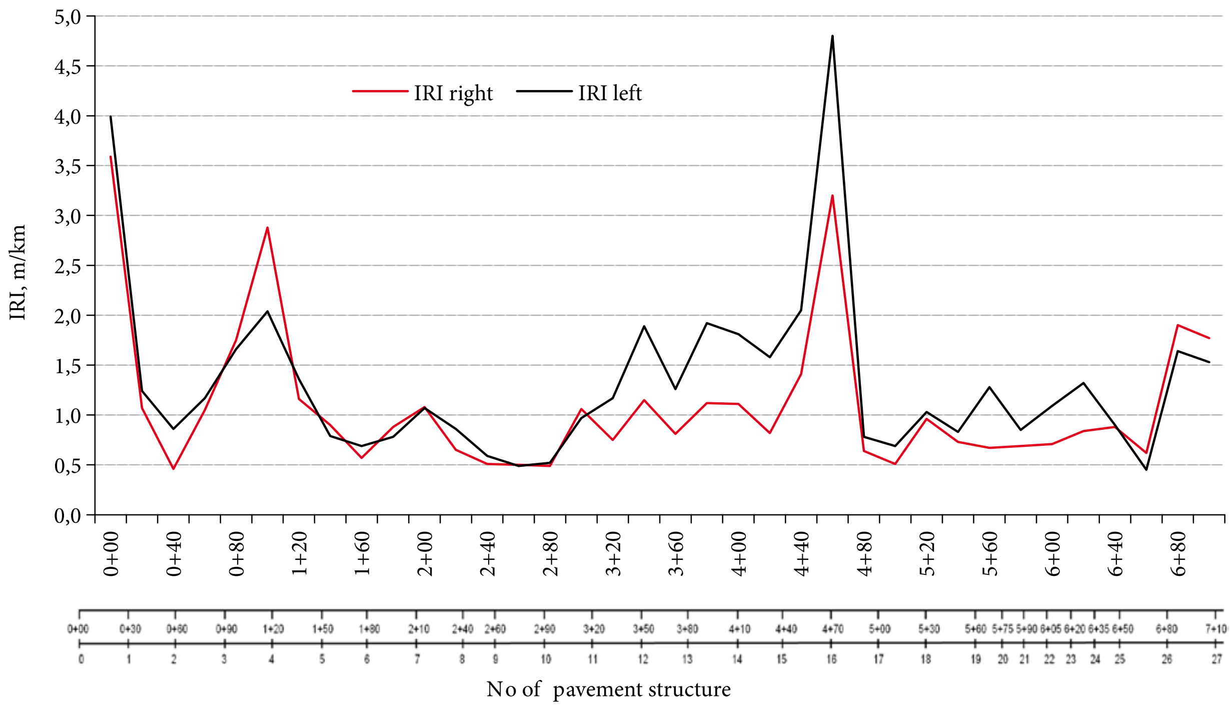

Fig. 8. The chart of roughness of a test road sections

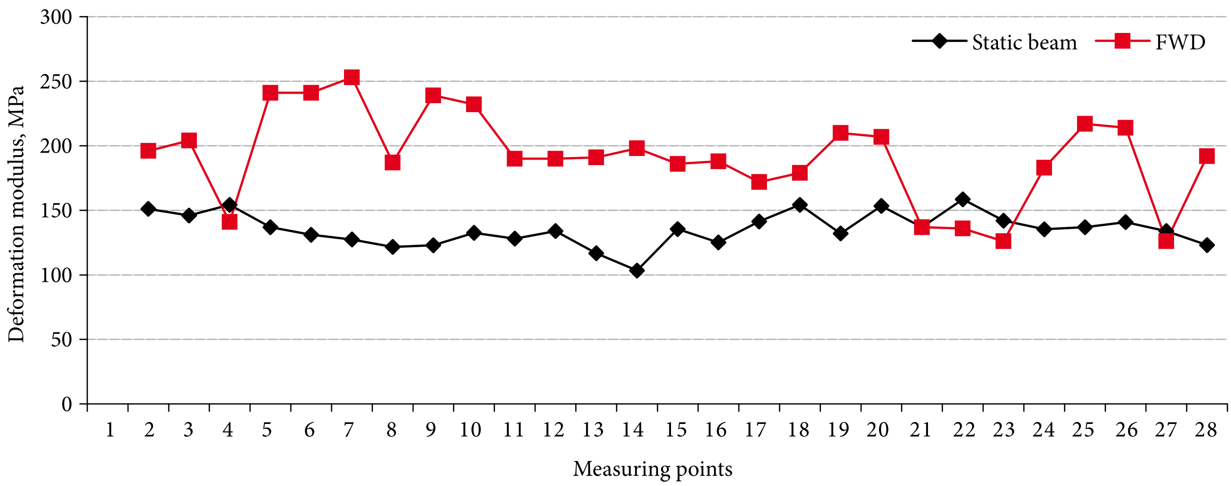

Fig. 9. The chart of ruts of a test road sections

A test road section is divided into separate structural sections and numbered from 1 to 27. The 2nd test road pavement section traffic lane is impacted by several times greater loads than the first traffic lane. The analysis of the obtained research findings shows that he values of the means of deformation modulus of the test section pavement structural asphalt base course measured by the FWD vary from 367 MPa to 456 MPa, asphalt binder course – from 434 MPa to 641 MPa, asphalt wearing course – from 591 MPa to 777 MPa. Deformation modulus shows that the strengths of pavement structures corresponding to the same pavement structure class vary by 25 %.

Special transducers installed in the test road section pavement (load 100 kN, a vehicle moves at the speed of 50 km/h during measurements, pavement surface temperature mean is +5,6°C) showed that the greatest measured transverse strain was in pavement structure No 8 (base course from crushed granite 0/56, base asphalt – 0/32 C crushed dolomite, binder asphalt – 0/16 A crushed dolomite, wearing asphalt – 0/11 S-V crushed granite) – 60,03 (μm/m) tension. The smallest transverse strain was in pavement structure No 3 (the same pavement structure as in No 8 but in base course instead of granite – crushed dolomite) – 12,76 (μm/m) tension. The biggest measured stress was in pavement structure No 22 (the same pavement structure as in No 8, but the geogrid installed between asphalt wearing and binder course) under asphalt base course – 54,5 kPa.

The greatest pavement skid resistance value (SRV) observed was in pavement structure No 9 (base course from crushed dolomite 0/56, base asphalt – 0/32 C crushed dolomite, binder asphalt – 0/16 A crushed dolomite, wearing asphalt – Confalt) – 0,89, the smallest in pavement structure No 7 (base course from crushed granite and sand mix 0/32, base asphalt – 0/32 C crushed dolomite, binder asphalt – 0/16 A crushed dolomite, wearing asphalt – 0/11 S-V crushed granite) – 0,26.

The highest pavement friction measured was in pavement structure No 1 (base course from gravel and sand mix 0/32, base asphalt – 0/32 C crushed dolomite, binder asphalt – 0/16 A crushed dolomite, wearing asphalt – 0/11 S-V crushed granite) – 0,47; the lowest in pavement structure No 9 – 0,28.

The deepest rutting measured on the loaded road lane was in the pavement structure No 7 – 3,5 mm, the least in pavement structure No 13 (base course from crushed dolomite 0/56, base asphalt – 0/32 C crushed dolomite, binder asphalt – 0/16 A crushed dolomite and granite, wearing asphalt – 0/11 S-V crushed granite) – 1,8 mm.

The highest pavement roughness index (*IRI*) measured (on the loaded road side) was in pavement structure No 9 – 4,58. The lowest *IRI* measured was in pavement structure No 15 (base course from crushed dolomite 0/56, base asphalt – 0/32 C crushed dolomite, binder asphalt – 0/16 A crushed dolomite and crushed gravel, wearing asphalt – 0/11 S-V crushed granite) – 0,33.

The carried out visual inspection of the test road section pavement did not show any defects.

6. Conclusions

A test road section was constructed from 24 (27) different pavement structures of the class III. The total length of the section – 710 m. 80 strain transducers and 11 stress transducers were installed in experimental pavement structures of a road section. Based on the test road sections research results analysis, the following conclusions were made.

1. When constructing the sub-grade and the subbase layers in each road segment, the design layer thickness and the deformation modulus were achieved. Thickness of asphalt pavement layers also corresponds to design values. The types and compositions of materials used for constructing different pavement structures correspond to design compositions.

2. When constructing a test section and after it was opened to traffic the strength of the subgrade and of the separate pavement structural layers was measured using different measuring devices, the cross fall and the gradient were determined, also pavement roughness, skid resistance and pavement defects.

3. Before opening a test section to traffic the stress and strain measurements were performed in the structural pavement layers. The measurements carried out each time after the passage of 20 000 ESAL's (estimated to 100 kN).

4. Deformation modulus measurements of test road sections showed that the strengths of pavement structures corresponding to the same pavement structure class vary by 25 %.

5. The smallest transverse strain measured in pavement structure No 3 – 12,76 (μm/m). In this pavement structure base course is from crushed dolomite and the thickness of this layer is 30 cm; it is 5 cm more than in other test road pavement structures.

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