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RELATIONSHIP OF ROAD PAVEMENT DEFORMATION MODULI, DETERMINED BY DIFFERENT METHODS

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Abstract. Deformations, caused by the axle loads of moving vehicles, are one of the main causes for pavement degradation. Measurement of elastic deflections is the best way to identify this effect. Currently, pavement deflections are most widely measured by the Falling Weight Deflectometer (FWD). Lithuanian standard LST 1360.5 "Soils for the motor roads" defines the measurement of deformations by static testing equipment at the top of each structural pavement layer. Based on the FWD-measured deflections at pavement surface, it is possible to calculate deformation moduli of structural pavement layers. In Lithuania deformation moduli are calculated by the ELMOD (Evaluation of Layer Moduli and Overlay Design) software. The results of experimental investigation of deformations of structural pavement layers by static and dynamic devices showed that the structural strength of road pavement, measured by the FWD, is close to the strength, measured by a static testing device. There is a linear relationship between E moduli, determined by static and dynamic methods. Investigation shows that the Falling Weight Deflectometer is suitable to determine the structural strength of investigated road pavements. However, more detailed investigations are necessary to identify the suitability of FWD to determine the structural strength of the other types of road pavement structures.

Keywords: road pavement deformations, structural layers of road pavement, pavement deformation modulus, compatibility criterion, relationship.

1. Introduction

Road transport is the main communication mode for carriage of people as well as cargo. Road transport in Lithuania is one of the essential factors to determine the economic and social development of the country.

The Lithuanian road network has a rather continuous and sufficiently dense distribution. The current problems of road development are often related to insufficient road capacity or durability of road pavement. Pavement strength is one of the main indicators determining the pavement ability to carry traffic loads; therefore, it is very important to know the bearing capacity of the existing pavement.

Research studies in various countries [1, 2, 3] have indicated the relationships between load size, pavement deflection and deformation (E) moduli of structural pavement layers. These relationships, calculated by using standard load, can be used to evaluate pavement strength.

Deflections, caused by the axle loads of the moving vehicles, are one of the main causes of pavement degradation. Measurement of elastic deflections is the best way to identify this effect. Currently, pavement deflections are most widely measured by the Falling Weight Deflectometer (FWD). FWD measurements allow the road specialists to describe and explain the behaviour of pavement structure. This deflectometer has proved to be a powerful tool for a detailed pavement investigation and evaluation.

At present in Lithuania, when preparing technical projects for the new roads or roads to be reconstructed, pavement structure is selected following the requirements of STR2.06.03:2001 [4]. Construction Technical Regulation "Motor roads" regulates the selection of only typical road pavement structures according to the calculated indicator of heavy traffic, taking no consideration of any other criteria, such as deflections, deformations, pavement performance indicators etc. Frequently, the selected pavement structures do not meet the real operational conditions, therefore, the use of typical pavement structures in road design, reconstruction and repair is often unsubstantiated.

Evaluation of the need for road pavement strengthening is the task of pavement design, only with different initial conditions. When designing pavement strengthening, it is necessary to evaluate the indicators of the existing pavement strength, Lithuanian climatic conditions, specific character of vehicle loads as well as the building materials and technologies. One should also take into consideration the world-wide trends and the achievements in this field. The experience of foreign countries becomes especially important. EU seeks for the harmonisation of normative documents. Creation of common methods for the design of asphalt pavements is one of the objectives of these activities in COST 333 [5].

Lithuanian standard LST 1360.5 "Soils for Motor Roads" [6] defines the measurement of deformations by a static testing equipment at the top of each structural pavement layer. During testing it is necessary to assure the standardised measuring conditions. Such testing methods are used for measuring deformations of structural layers for the new pavements. However, this method cannot be used to determine deformation moduli at the top of each structural layer for the already existing pavements. Based on the FWD-measured deflections at pavement surface, it is possible to calculate deformation moduli of structural pavement layers. FWD-measured deflections are re-calculated into deflection values meeting the standard measuring conditions, and the deformation modulus is determined, for which a seasonal factor is applied meeting the Lithuanian climatic conditions [7].

In Lithuania deformation moduli are calculated by using the ELMOD (Evaluation of Layer Moduli and Overlay Design) software, created by the company DYNATEST. This software enables to calculate the deformation modulus of each layer in two-, three- or four-layer pavement structures, using the transformed section method of Odemark–Boussinesq [8–11].

The objective of the scientific research, presented in this paper, is to carry out measurements of deformations (deflections) of the structural layers of flexible pavement by the static measuring device "Strassentest" and the dynamic device – Falling Weight Deflectometer (FWD). Also, to conduct a statistical evaluation of the relationship between the calculated deformation moduli, based on the results of the static measuring method, regulated by LST 1360.5 [6] and the FWD, used in Lithuania.

2. Investigation of structural pavement strength

For a more accurate determination of relationship between E moduli, obtained by applying the static (the static testing device "Strassentest") and the dynamic (FWD) method, 2 types of road pavement structure were selected:

- 6,86–7,24 km test section of the road A5 Kaunas–Marijampolė–Suwalki (Fig 1);
- 36,00–37,00 km test section of the road 225 Raseiniai–Baisogala (Fig 2).

To determine E moduli of individual pavement layers 20 measuring points were measured on the test section of the road A5 Kaunas–Marijampolė–Suwalki. On the test section of the road 225 Raseiniai – Baisogala only 6 measuring points were measured, since, due to the changes of meteorological conditions, it was not purposeful to continue measurements as the results would be unreliable.

To assure the reliability of measuring data by different devices, deflections of road pavement structure were measured under the same climatic conditions at the shortest possible time interval.

During the measurement of deflections of structural pavement layers the temperature of air, pavement surface and asphalt concrete layer was recorded. It was used for calculating E moduli of individual structural layers. The results obtained are presented in Tables 1 and 2 and in Figures 3 and 4. It can be seen that E moduli above the individual layers of Type I road pavement structure meet the requirements of technical regulation STR2.06.03:2001. However, the frost-resistant layer of Type II road pavement structure does not meet the requirements of the aforementioned regulation.

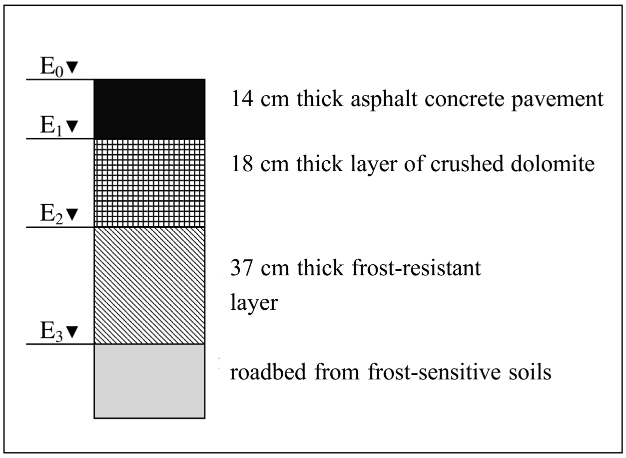

Fig 1. Type I road pavement structure

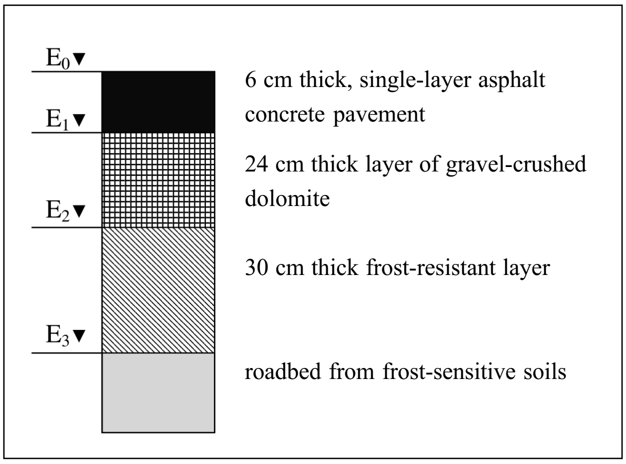

Fig 2. Type II road pavement structure

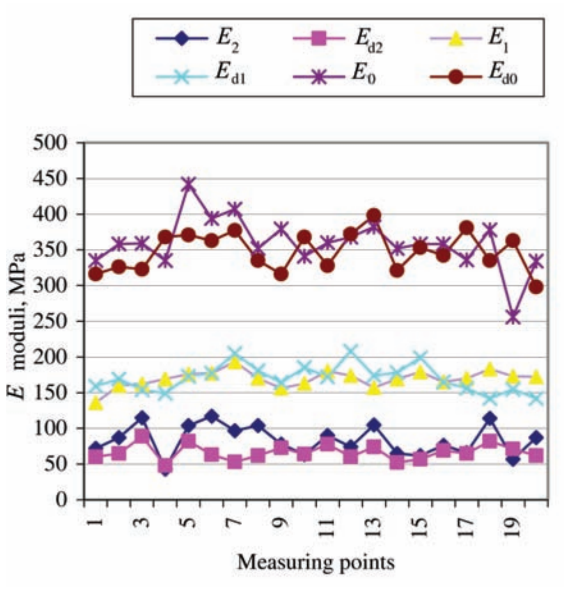

Fig 3. Distribution of E moduli of Type I road pavement structure (E_0, E_1, E_2 – obtained by applying the static method and E_{d0}, E_{d1}, E_{d2} – obtained by applying the dynamic method)

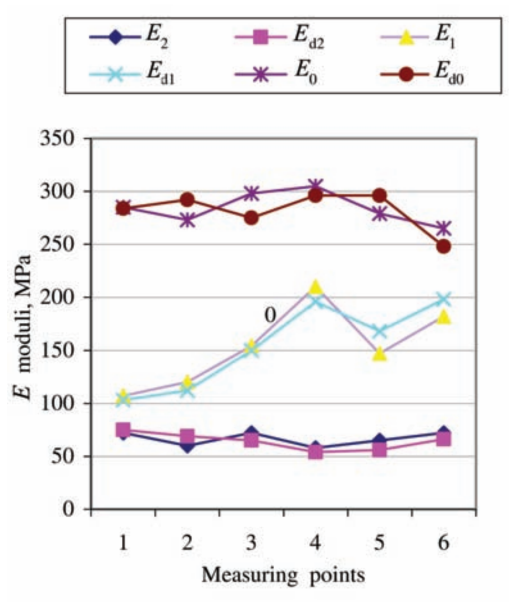

Fig 4. Distribution of E moduli of Type II road pavement structure (E_0, E_1, E_2 – obtained by applying the static method and E_{d0}, E_{d1}, E_{d2} – obtained by the dynamic method)

Table 1. Results of measuring data analysis

Road pavement structure	Measuring point	Deformation moduli	Compatibility criterion	The average	Standard deviation	Variation coefficient	Normal distribution
I	Above frost-resistant layer	E_2	7	84	21	25,65	+
		E_{d2}	4	66	11	16,26	+
	Above base layer	E_1	1	169	12	7,10	+
		E_{d1}	6	170	19	11,16	+
	Above asphalt concrete layer	E_0	7	359	36	10,12	+
		E_{d0}	6	348	27	7,80	+
II	Above frost-resistant layer	E_2	7	67	6	9,69	+
		E_{d2}	5	64	8	12,37	+
	Above base layer	E_1	2	153	38	24,97	+
		E_{d1}	3	155	41	26,33	+
	Above asphalt concrete layer	E_0	3	284	15	5,32	+
		E_{d0}	4	282	18	6,54	+

Table 2. Values of deformation moduli and their relationship

Road pavement structure	Measuring point	E moduli, MPa		Relationship $K_E = E / E_d$
		E	E_d	
I	Above frost-resistant layer	84	66	1,27
	Above base layer	169	170	0,99
	Above asphalt concrete layer	359	348	1,03
II	Above frost-resistant layer	67	64	1,05
	Above base layer	153	155	0,99
	Above asphalt concrete layer	284	282	1,01
The average				1,06
Standard deviation				0,11
Median				1,02
Minimum				0,99
Maximum				1,27
Variation coefficient				10,29
Correlation coefficient				0,998
Confidence interval (with 95 % probability)				0,85–1,27

3. Analysis of results

When making analysis of measuring results it is necessary to determine the data compatibility criterion χ^2

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i} = \sum_{i=1}^{k} \frac{\left(O_i - np_i\left(\overline{X}, S\right)\right)^2}{p_i\left(\overline{X}, S\right)}, \quad (1)$$

where: χ^2 – compatibility criterion, O_i – observable interval values, E_i – probable interval values, $\overline{X}, S$ – values of normal distribution average and standard deviation, $p_i\left(\overline{X}, S\right)$ – i-interval probability of normal distribution with parameters $\overline{X}$ and S.

The compatibility criterion shows the correspondence of the data values being analysed to the law of normal distribution. If the compatibility criterion meets certain conditions (for 20 measuring values the compatibility criterion shall be ≤ 7,815, for 6 measuring values the compatibility criterion ≤ 5,991), it is possible to conduct a statistical analysis of the measuring results by calculating the averages, standard deviations, variation coefficient etc.

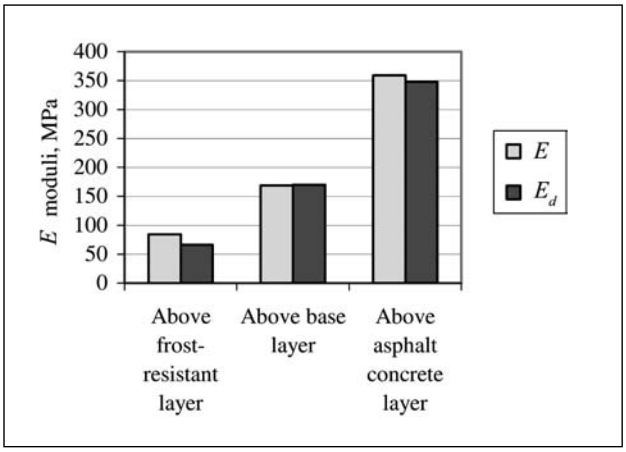

Fig 5. Distribution of the average *E* moduli of Type I road pavement structure

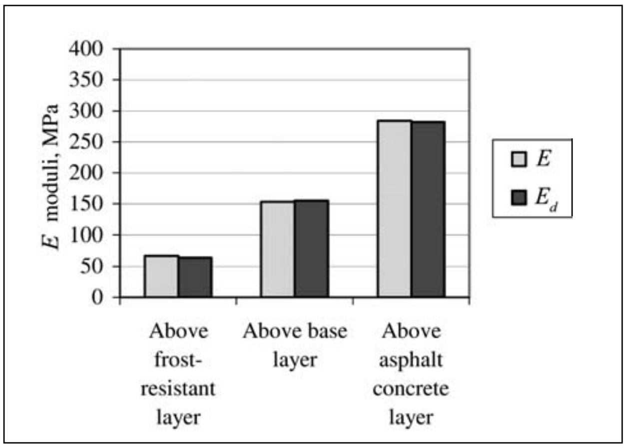

Fig 6. Distribution of the average *E* moduli of Type II road pavement structure

After checking the data compatibility criterion it was determined that the investigation data can be used for a statistical analysis. Results of the analysis are given in Table 1. They show that the structural strength of road pavement, measured by the FWD, is close to the strength, measured by a static testing device.

In order to determine the relationship between *E* moduli (Figs 5 and 6), calculated from the deflections of road pavement structure and obtained by static and dynamic methods, it is necessary to determine the coefficient K_E of deformation moduli. Table 2 shows the calculation results.

The calculated correlation coefficient allows to state that there is a linear relationship between *E* moduli, determined by static and dynamic methods.

Having measured deflections with the use of FWD, *E* moduli can be calculated as follows:

$$E = K_E \times E_d, \quad (2)$$

where: *E* – deformation moduli according to the requirements of STR2.06.03:2001; K_E – coefficient of relationship $\frac{E}{E_d}$, E_d – *E* moduli, determined by FWD.

Relationship coefficient K_E (Table 2), determined during this investigation, is suitable to Type I and Type II road pavement structures (Figs 1 and 2). When performing investigations of the other type of road pavement structures, it is necessary to determine the corresponding values of coefficient K_E.

4. Conclusions

1. The investigation showed that:

– The layers of Type I road pavement structure meet the requirements of technical regulation STR2.06.03:2001.

– The frost-resistant layer of Type II road pavement structure does not meet the requirements of technical regulation STR2.06.03:2001.

2. Analysis of investigation results shows that there is a linear relationship between E moduli, determined by static and dynamic methods.

3. The relationship of E moduli of structural pavement layers, determined by static and dynamic methods, shows that the Falling Weight Deflectometer is suitable to determine the structural strength of both types of investigated road pavements. However, more detailed investigations are necessary to identify the suitability of FWD to determine the structural strength of the other type of road pavement structures.

References

1. AASHTO Guide for Design of Pavement Structures. Washington AASHTO, 1993. 319 p.
2. PUODŽIUKAS, V. Bituminous Pavement Evaluation and Strengthening Needs Assessment in Lithuania. Summary of Doctoral Dissertation. Technological Sciences, Civil Engineering (02T). Vilnius: Technika, 2000. 42 p.
3. Guidelines for Road Network Condition Monitoring: Part 3 – Pavement Strength. Austroads, 2005. 86 p.
4. STR2.06.03:2001 Regulation on Motor Roads (Techninių reikalavimų reglamentas. Automobilių keliai). Vilnius, 2002. 77 p. (in Lithuanian).
5. COST 333 Development of New Bituminous Pavement Design Method. 373 p.
6. LST 1360.5 Soils for Motor Roads. Testing Methods (Automobilių kelių gruntai. Bandymo metodai). Vilnius, 1995. 14 p. (in Lithuanian).
7. ŠIAUDINIS, G.; ČYGAS, D. Investigations and Determination of Seasonal Effect on Road Pavement strength. In: 6th International Conference of Environmental Engineering. Vilnius: Technika, 2005, p. 783–786.
8. Analysis of Methods for the Calculation of Flexible Road Pavements, Evaluation, Calculation of Deformation Moduli of the Road Structure, Analysis of Investigation Results, Presentation of Recommendations and Conclusions. Investigation report. Transport and Road Research Institute (Automobilių kelių nestandžiųjų dangų skaičiavimo metodų analizė, įvertinimas, kelio konstrukcijos deformacijos modulių skaičiavimas, tyrimo rezultatų analizė, rekomendacijų ir išvadų pateikimas. Tyrimų ataskaita. VĮ Transporto ir kelių tyrimo institutas), 2003. 50 p. (in Lithuanian).
9. Results of Measuring Deflections of Individual Layers of Flexible Road Pavement Structure and the Results of Laboratory Investigations of the Materials of Roadbed and Pavement Layers. Investigation Report. Transport and Road Research Institute (Nestandžiųjų kelio dangų konstrukcijos atskirų sluoksnių įlinkių matavimo bei sankasos ir dangos sluoksnių medžiagų laboratorinių tyrimų rezultatai. Tyrimų ataskaita. VĮ Transporto ir kelių tyrimo institutas), 2003. 31 p. (in Lithuanian).
10. Measurement of Deflections of Individual Layers of Flexible Road Pavement Structure by the Falling Weight Deflectometer DYNATEST FWD 8000 and a Static Device and Calculation of Deformation Moduli. Investigation Report. Transport and Road Research Institute (Nestandžiųjų kelių dangų konstrukcijos atskirų sluoksnių įlinkių matavimas su krintančio svorio deflektometru „DYNATEST FWD 8000“ ir statiniu prietaisu bei deformacijos modulių skaičiavimas. Tyrimų ataskaita. VĮ Transporto ir kelių tyrimo institutas), 2003. 22 p. (in Lithuanian).
11. Calculation of Flexible Pavement Structures in Test Sections by Determining Thickness of Individual Layers and Their Strength Indicators. Investigation report. Transport and Road Research Institute (Nestandžiųjų dangų konstrukcijų bandomuosiuose ruožuose skaičiavimas atskirų sluoksnių storiui bei jų stiprumo rodikliams nustatyti. Tyrimų ataskaita. VĮ Transporto ir kelių tyrimo institutas), 2003. 42 p. (in Lithuanian).

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