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Road and Rail Infrastructure III

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SUBGRADE BEARING CAPACITY INFLUENCE ON FLEXIBLE PAVEMENT STRUCTURES BEHAVIOUR

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Abstract

The design methodology of a flexible pavement structures is extremely laborious and complex requiring several work steps. Thus initially are required conducting field studies on the composition and volume of traffic, geotechnical characteristics of subgrade soil, hydrological regime of pavement system. Then follow the itself design of the pavement structure which involves the following steps: establishing the calculation traffic, determining the bearing capacity of the road bed, the choice of an embodiment of the pavement structure, pavement structure analysis at the standard axle loading, establishing the pavement structure behaviour under the traffic. In general, in the pavement design practice is considered that the choice of a pavement structure embodiment with thicknesses as great for pavement layers and constituent materials as best ensures a good behaviour of in service pavement structure. Unfortunately is overlook the variation of the subgrade soil bearing capacity during a year due to variations in environmental conditions (humidity, temperature, freeze-thaw) specific for the road site. This paper aims to highlight the magnitude of the subgrade bearing capacity influence on the flexible pavement structures behaviour. In the study it will be shown that the stress and strain state in the pavement structure is a very sensitive indicator of the importance of road bed soil condition and quality, and as such, it is very important to take this aspect into account in order to have not surprises during the pavement exploatation.

Keywords: flexible pavement structures, subgrade soil, bearing capacity

1 Introduction

The design methodology of a flexible pavement structures is extremely laborious and complex. In general, in the pavement design practice is considered that the choice of a pavement structure embodiment with thicknesses as great for pavement layers and constituent materials as best ensures a good behaviour of in service pavement structure. Unfortunately is overlook the variation of the subgrade soil bearing capacity during a year due to variations in environmental conditions (humidity, temperature, freeze-thaw) specific for the road site.
At international level there are numerous studies regarding the subgrade bearing capacity influence on flexible pavement structures behaviour [1, 2, 3]. For example, to characterize the subgrade soil behaviour during a year, in states such as Washington and Minnesota from USA are used seasonal adjustment coefficients for subgrade elasticity modulus value (Pierce and Mahoney, 1996 [1]).
Aim of this paper is that based on numerical simulations performed on a computer program to analyze how the loss of subgrade bearing capacity affects the operational behaviour of pavement structures. Will be determined the strain level in the critical points of two flexible pavement structures for five possible operation situations. The CALDEROM 2000 computing program used, the composition of flexible pavement structures analyzed, the calculation

vehicle and traffic classes are the ones specific for Romanian norms in force PD 177 [4] and CD 155 [5].
The input data used in the CALDEROM 2000 calculation program are the thickness of the layers, the material deformation characteristics of road layers (the dynamic elasticity modulus and Poisson's ratio) and the 115 kN standard axle characteristics (the contact pressure and the radius of the contact surface between the road and tires). The results are the full stress and strain state conforming to the Burmister model [6] for the analysis of pavement structures.

2 Calculation assumptions

This paper aims to highlight the magnitude of the subgrade bearing capacity influence on the flexible pavement structures behaviour. For this purpose have been taken into account two pavement structures: one with a structure allowing the movement of a Light traffic class and one for a Heavy traffic class. The composition of the analyzed flexible pavement structures, as well as the characteristics of their component materials are presented in Tables 1 and 2.

Table 1 Characteristics of the pavement structure for Light traffic (PS1).

Material in pavement structure layer	Layer thickness, h [cm]	Dynamic elasticity modulus, E [MPa]	Poisson's ratio, μ
Asphalt concrete, BA 16	4	3600	0.35
Bituminous coated, AB 2	8	5000	0.35
Granular material, Ballast	15	191	0.27
Subgrade soil	∞	100	0.27

Table 2 Characteristics of the pavement structure for Heavy traffic (PS2).

Material in pavement structure layer	Layer thickness, h [cm]	Dynamic elasticity modulus, E [MPa]	Poisson's ratio, μ
Asphalt concrete, BAR 16	4	3600	0.35
Binder, BAD 25	5	3000	0.35
Bituminous coated, AB 2	8	5000	0.35
Granular material, Crushed stone	12	400	0.27
Granular material, Ballast	15	191	0.27
Subgrade soil	∞	100	0.27

In Tables 1 and 2, the deformation characteristics of the pavement structure component materials and the deformation characteristics of the subgrade soil have design values according to the Romanian norm PD 177-2001 [4]. In Table 3 are presented the traffic classes from Romania based on standard axle load of 115 kN used in pavement structures design.

Table 3 Traffic classes according to Romanian norm CD 155-2001 [5].

Traffic class	Traffic volume, Nc [millions of standard axles of 115 kN]
Exceptional	3.0…10.0
Very Heavy	1.0…3.0
Heavy	0.3…1.0
Middle	0.1…0.3
Light	0.03…0.1
Very Light	‹ 0.03

The characteristics of the standard axle load of 115 kN are as follows:
· twin wheels load: 57.5 kN;
· contact pressure: 0.625 MPa;
· the radius of the contact surface: 17.1 cm.

In operation, due to the traffic loads, the environmental conditions variation (humidity, temperature, freeze-thaw), the possible problems of execution and a poor quality of road maintenance, the subgrade bearing capacity can decrease. Table 4 shows how the decrease of the subgrade dynamic elasticity modulus value immediately influences the value of ballast module from the subbase course, according to the Romanian design norm PD 177-2001 [4].

Table 4 Assumptions for calculation.

Computing hypothesis	I	II	III	IV	V
Ep [MPa]	100	80	60	40	20
Eb [MPa]	191	153	114	76	38

Where:
Ep the subgrade soil dynamic elasticity modulus;
Eb the dynamic elasticity modulus of ballast.

Also in Table 4 are presented the five calculation assumptions corresponding to the subgrade dynamic elasticity modulus values, on which will be developed the present study. In order to establish the influence of the subgrade bearing capacity on flexible pavement structures behaviour, will be analyzed the two pavement structures (PS1 and PS2) in the five possible situations adopted. To determine the state of stress and strain in the five calculation situations was used the computer program CALDEROM 2000, that is integral part of the “Normative for flexible and semi-rigid pavement structures design” [4]. CALDEROM 2000 program is based on analytical solving of the stress and strain state of a pavement structure under load, by using the Burmister multilayer elastic model [6]. In the Burmister model, pavement structure is modeled by linear elastic isotropic and homogeneous layers infinite in plane, of finite thickness, with the exception of semi-infinite subgrade soil, and tire loading are treated as circular static loads, exerted as vertical efforts (the vehicle weight).

3 The study results

In the present study it was intended the estimation of flexible pavement structures response in their critical points:
· ε_r = the horizontal tensile strain at the base of bituminous layers;
· ε_z = the vertical compressive strain at the level of road bed.

The analysis results of flexible pavement structures PS1 and PS2 in the five hypotheses are presented in Tables 5 and 6. The analysis results of the strain state variation in the flexible pavement structures PS1 and PS2, conducted with the program CALDEROM 2000, are presented graphically in Fig. 1 and 2.Analyzing the strains variation in the critical points of the pavement structures, are found the following increases towards computing hypothesis I (the ideal situation) taken as a reference (Tables 7 and 8). From Figs. 1 and 2, and the analysis of tables 8 and 9 results that the subgrade bearing capacity variation influence is higher on pavement structures with smaller thicknesses. For example, for a subgrade bearing capacity decrease of 80%, is found that the magnitude of the horizontal tensile strain increase at the base of bituminous layers is about double size (79 %) for PS1 pavement structure (of smaller thickness) towards that observed for PS2 pavement structure (of higher thickness) (41 %).

Table 5 CALDEROM 2000 results for pavement structure PS1.

Computing hypothesis	Horizontal tensile strain at the base of bituminous layers, ε_r* [microdef.]	Vertical compressive strain at the level of road bed, ε_z* [microdef.]
I	272.00	967.00
II	300.00	1110.00
III	338.00	1310.00
IV	393.00	1630.00
V	488.00	2330.00
* absolute values		

Table 6 CALDEROM 2000 results for pavement structure PS2.

Computing hypothesis	Horizontal tensile strain at the base of bituminous layers, ε_r* [microdef.]	Vertical compressive strain at the level of road bed, ε_z* [microdef.]
I	170.00	456.00
II	179.00	520.00
III	191.00	611.00
IV	208.00	757.00
V	240.00	1050.00
* absolute values		

Table 7 Strains variation for the pavement structure PS1.

Computing hypothesis	Horizontal tensile strain variation at the base of bituminous layers, $\Delta\varepsilon_r$ [%]	Vertical compressive strain variation at the level of road bed, $\Delta\varepsilon_z$ [%]
I	0	0
II	10	15
III	24	35
IV	44	69
V	79	141

Table 8 Strains variation for the pavement structure PS2.

Computing hypothesis	Horizontal tensile strain variation at the base of bituminous layers, $\Delta\varepsilon_r$ [%]	Vertical compressive strain variation at the level of road bed, $\Delta\varepsilon_z$ [%]
I	0	0
II	5	14
III	12	34
IV	22	66
V	41	130

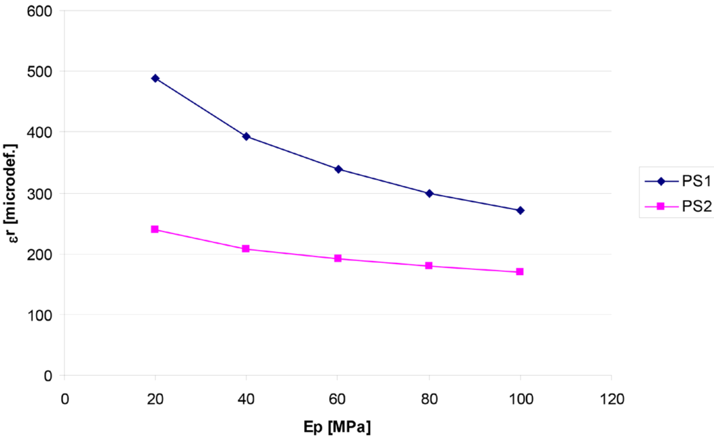

Figure 1 Horizontal tensile strain variation at the base of bituminous layers.

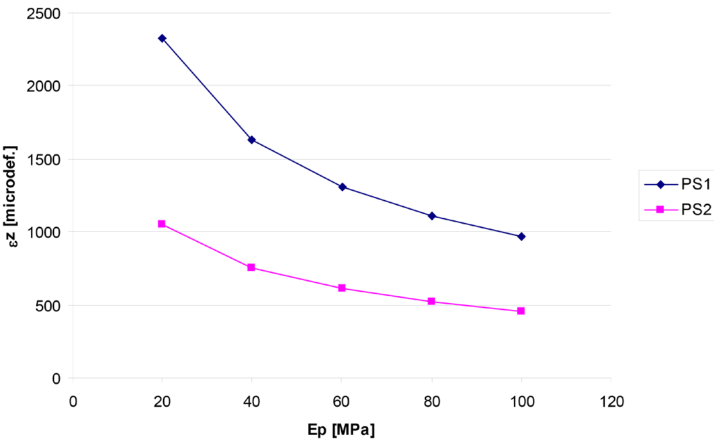

Figure 2 Vertical compressive strain variation at the level of road bed.

When is analyzed the subgrade bearing capacity influence on the compressive strain variation at the level of road bed, differences between the two pavement structures decrease. For example, for a subgrade bearing capacity decrease of 80 %, is found that the magnitude of the vertical compressive strain increase at the level of road bed differs with only 11 %, being registered (141 %) for PS1 pavement structure (of smaller thickness) towards that observed for PS2 pavement structure (of higher thickness) (130 %).

Comparing the tensile strain variation at the base of bituminous layers with the compressive strain variation at the level of road bed, is found that the subgrade bearing capacity influence is higher on compressive strain variation at the level of road bed.

It must shown that if in the hypothesis I (with better subgrade bearing capacity) the pavement structure PS1 could take over a Light traffic class and the pavement structure PS2 take over a class of Heavy traffic, then in the hypothesis V (corresponding to a decrease in subgrade bearing capacity by 80 %) was found the decrease of traffic class to Very Light for PS1, and respectively to Light for PS2. Thus, loss of subgrade bearing capacity entail the decrease of traffic values on which the pavement structures were designed to serve. In such conditions, if not repaired the problem then the pavement structures will be rapidly degrade.

4 Conclusions

This paper highlights the magnitude of the subgrade bearing capacity influence on the flexible pavement structures behaviour. Thus, after performing numerical simulations can be seen that the subgrade bearing capacity influence is higher on pavement structures with smaller thicknesses. Also, having regard the significantly size of the strain level growth in the critical points of pavement structures at the time of subgrade bearing capacity loss, can be emphasize the importance of execution works and roads maintenance quality for their behaviour in service.
In conclusion, the stress and strain state in the pavement structure is a very sensitive indicator of the importance of road bed soil condition and quality, and as such, it is very important to take this aspect into account in order to have not surprises during the pavement exploatation.

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