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Active zone impact on deformation state of non-rigid pavement

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Abstract

The paper deals with the design of non-rigid pavement, with emphasis on the effect of active zone on its deformation state. The concepts of determination of active zone are described. The results of numerical modelling of pavement laying on elastic subgrade are presented in the paper.

Key words: road, pavement, active zone, modelling

1 Introduction

The modeling of the elastic half-space is based on the mathematical theory of elasticity, which are valid for a number of well-known assumptions. It's consider that roadway is elastic element, consisting of n homogeneous layers of constant thickness h, which lies on the n+1 layer homogeneous half-space. Each homogeneous layer is formed from elastic isotropic materials characterized by computing modulus E and Poisson's ratio μ. Subgrade of the road is modeled with an infinitely large thickness, see *Figure 1* The result of the analytical modeling is stress and deformation courses under different conditions (states).

Perhaps, the approach of subgrade modeling can be described as innovative. It consists of compacted soil under the pavement construction and it is affected by road load. Properties and load history of active depth, corresponding to the deformation zone of soil influence tense state of road construction. Half-space below the active zone is modeled as a non-deformable - *Figure 2*.

2 Determination of the active zone depth

There are few concepts and approaches for the determination of the active zone depth. Depending on the mode of assessment they can be organize as follows:

1. Determination of the active zone depth below site of load action in which the additional load stress (σ_z) reaches 20 % of the original load. When there is highly compressible soil at this depth, the lower limit of the active zone depth is defined by site with additional load is only 10 % (*Figure 3*).
2. Numerical determination of the active zone depth H_A is made from equation for vertical component of additional stress σ_z from object base and the original geostatic stress, which greatly depends on the level of ground water. The application of this approach in the mechanics of roads has its limitation in terms of road is in the cutting conditions.
3. Determination of the active zone methodologies of determining the deformation characteristics of the subgrade. These are the load tests:
   - Impact load test define the modulus of elasticity of the subgrade. Short pulse load (for single-mass impact device it is about 0.025 s) causes half-space compression is registered at the deflective line but it occurs only to a limited depth (the half-space is compressed by short impact up to a depth of 3 m). Therefore this phenomenon advisable is modeled by the introduction of solid half-space from a depth of 3 meters (introducing the modulus from that depth in value 10 000 MPa) [1].
   - Static load test provides the deformation modulus of pavement subgrade. Active depth is the depth corresponding to 3 % of the load stress applied to boards, but at least to a depth of 4 times the diameter of the board. The remaining half-space is modeled as a non-deformable with modulus 10 000 MPa [1].

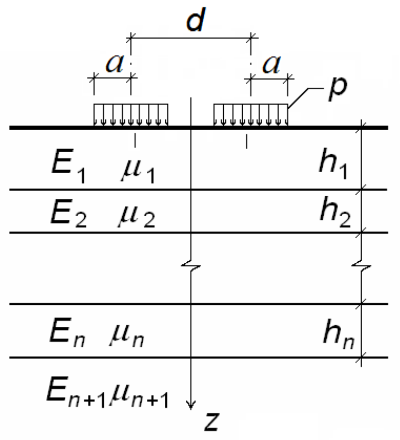

Figure 1: Model of road construction

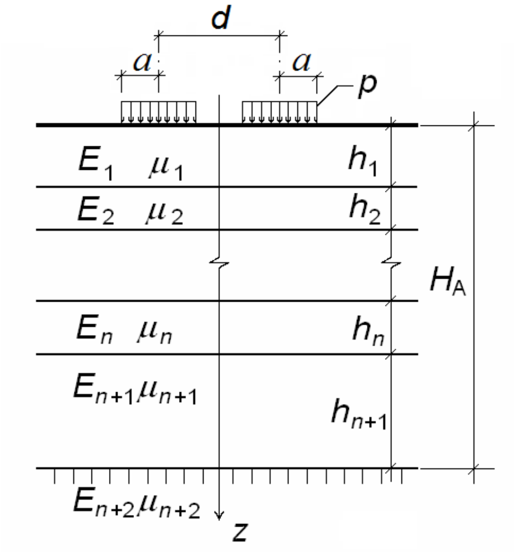

Figure 2: An innovative model of road

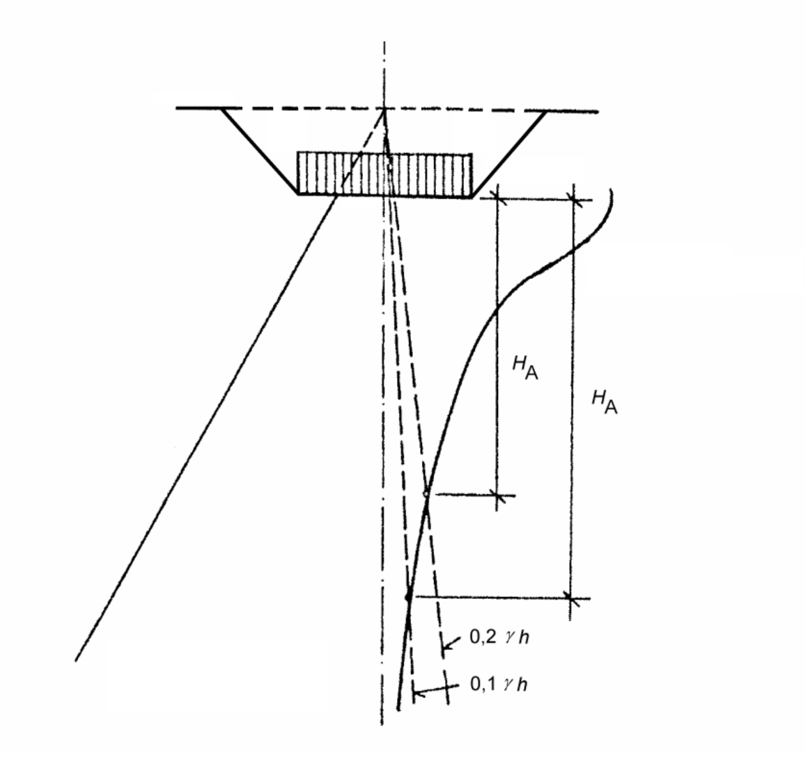

Figure 3: Determination of the active area $\sigma_z = k.\gamma.$h

3 Effect of active zone on deformation conditions of road

It was working-out the numerical experiment for the purpose to point out the fact, that the acceptance of subgrade modeling to the depth of active zone place on non-deformable half-space affect tense-deformation condition of road construction.

Non-rigid pavement design was selected from technical regulations for the road design for the numerical experiment [2] with the following computational parameter values of layers:

1. 40 mm asphalt concrete AC 11 O; II
2. 50 mm asphalt concrete AC 22 L; II
3. 80 mm asphalt concrete AC 22 P; II
4. 150 mm gravel ŠD
5. 200 mm sand-gravel ŠP

Whereas, it won't be assess roadway construction, the calculation of tense and deformation be carried out for the selected layers from a standard axle load $2P$ = 100 kN with parameters: p = 0.60 MPa, a = 115.2 mm, d = 344 mm.
Computation was made by LAYMED program, and deformation parameters for three temperatures: 0 °C, +11 °C and +27 °C of the asphaltic layers were considered.
In short, parameters E (MPa) / Poisson (μ) for each layer follow:

1. layer : 7500 / 0,21 5500 / 0,30 3000 / 0,40
2. layer: 7500 / 0,21 5500 / 0,33 3000 / 0,44
3. layer : 4500 / 0,21 3050 / 0,33 1250 / 0,44
4. layer : 350 / 0,30 350 / 0,30 350 / 0,30
5. layer : 120 / 0,35 120 / 0,35 120 / 0,35

subgrade : 30 / 0,45 30 / 0,45 30 / 0,45

Basement of the road was modeled as:

a) homogeneous elastic half-space of infinite thickness
b) homogeneous elastic layer of soil to a depth of 3 m = H_A lying on deformable half-space with tensile modulus 20 000 MPa,
c) homogeneous elastic layer of soil to a depth of 2 m = H_A lying on deformable half-space with tensile modulus 20 000 MPa, and
d) homogeneous elastic layer of soil to a depth of 1 m = H_A lying on deformable half-space with tensile modulus 20 000 MPa.

Taking into account of result scale there are radial and horizontal stress in the layers 3, 4 and 5, namely, 0 °C, +11 °C and +27 °C shown in the following tables below only. In addition, there are given vertical deformation for selected layers in those tables.

Table 1: Selected values of tense and deformation for road placed on elastic half-space

Layer	z	Temperature	σ_r	σ_z	w
3	17	0	0,7578	-0,0629	0,0719
		11	0,6424	-0,0726	0,0752
		27	0,3271	-0,0960	0,0826
4	32	0	0,0801	-0,0287	0,0688
		11	0,0905	-0,0324	0,0718
		27	0,1138	-0,0413	0,0781
5	52	0	0,0306	-0,0142	0,0629
		11	0,0341	-0,0155	0,0653
		27	0,0416	-0,0182	0,0702

Table 2: Selected values of tense and deformation of road with active zone 3 m

Layer	*z*	Temperature	σ_r	σ_z	*w*
3	17	0	0,6680	-0,0698	0,0318
		11	0,5643	-0,0797	0,0339
		27	0,2842	-0,1034	0,0385
4	32	0	0,0577	-0,0384	0,0287
		11	0,0661	-0,0428	0,0304
		27	0,0858	-0,0532	0,0341
5	52	0	0,0085	-0,0232	0,0230
		11	0,0097	-0,0252	0,0242
		27	0,0124	-0,0296	0,0265

Table 3: Selected values of tense and deformation of road with active zone 2 m

Layer	*z*	Temperature	σ_r	σ_z	*w*
3	17	0	0,6648	-0,0701	0,0285
		11	0,5622	-0,0799	0,0306
		27	0,2841	-0,1035	0,0351
4	32	0	0,0567	-0,0388	0,0254
		11	0,0652	-0,0432	0,0271
		27	0,0850	-0,0536	0,0307
5	52	0	0,0080	-0,0239	0,0198
		11	0,0092	-0,0259	0,0208
		27	0,0119	-0,0303	0,0230

Table 4: Selected values of tense and deformation of road with active zone 1 m

Layer	*z*	Temperature	σ_r	σ_z	*w*
3	17	0	0,6382	-0,0723	0,0207
		11	0,5411	-0,0821	0,0225
		27	0,2753	-0,1055	0,0265
4	32	0	0,0505	-0,0426	0,0176
		11	0,0588	-0,0470	0,0190
		27	0,0787	-0,0574	0,0220
5	52	0	0,0037	-0,0292	0,0116
		11	0,0048	-0,0313	0,0124
		27	0,0074	-0,0359	0,0140

The deformation course is presented in graphic form in Figure 4 and vertical stress course is in Figure 5.

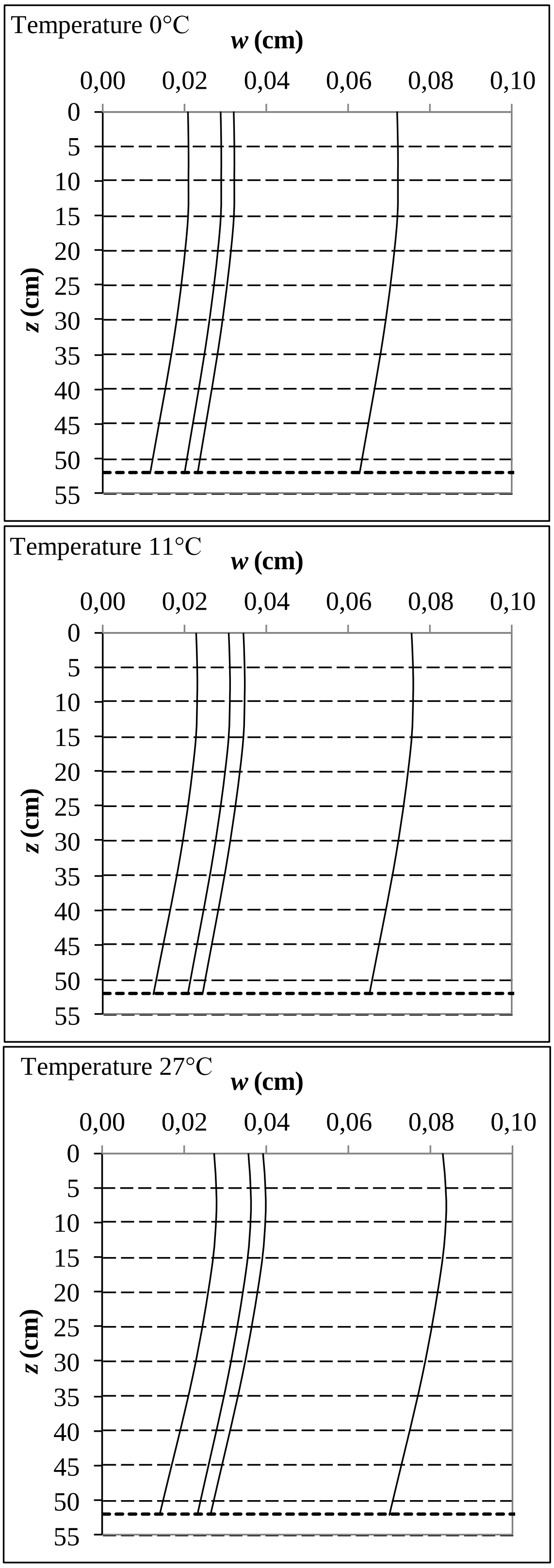

Figure 4: Course w depending up H_A

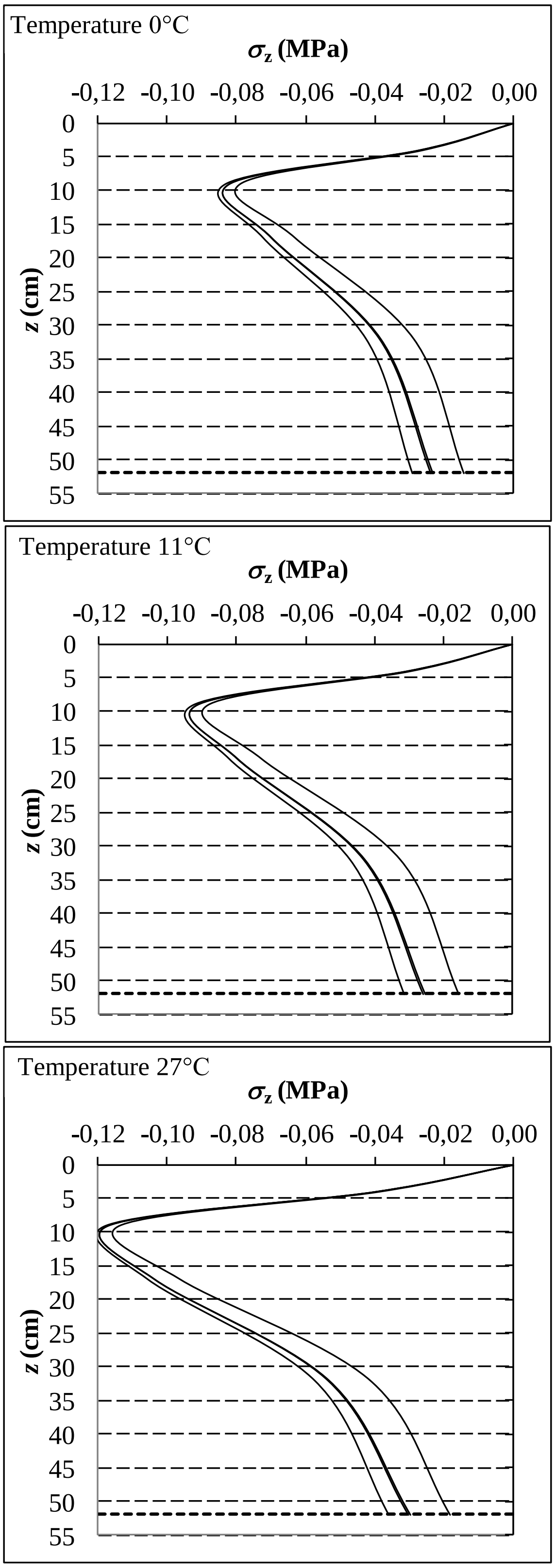

Figure 5: Course σ_z depending up H_A

4 Conclusion

The results of numerical experiments of modeling non-rigid pavement lying on elastic subgrade limited the road formation and the active zone depth lying on the non-deformable half space show that:

- values σ_r decrease at bottom edge of structural layers, if active zone depth decrease,
- but vertical stress σ_z value increase if active zone depth decrease,
- the largest percentage decrease of vertical deformation *w* can be seen when active zone depth approximate to road construction thickness.

The presented results can be viewed as positive, should be carefully assess. The calculated stress and deformation being assessed, i.e. those values are compared with the critical or limit values. Accepting active depth in modeling road construction requires verification or calibration criteria for assessment.

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References

[1] Kudrna, J., Vébr, L., Luxemburk, F., Racek, I. a kolektív.(2004). *TP 170 Navrhování vozovek pozemních komunikací*. MD ČR.

[2] TP 3/2009 Navrhovanie netuhých a polotuhých vozoviek. SSC Bratislava.

[3] Gschwendt, I. a kol. (1999). *Vozovky*. Bratislava.

[4] Mandula, J. (2011). Vplyv aktívnej zóny na deformačný stav vozovky. *Pozemné komunikácie a dráhy*. Roč. 7 (2), s. 39-46.

[5] Mandula, J. (2012). Vplyv aktívnej zóny na deformačný stav polotuhej vozovky. In konferencia Nestmelené a hydraulicky stmelené vrstvy vozoviek od projekcie po stavbu: zborník z konferencie s medzinárodnou účasťou, 8.-10. februára 2012, s. 43-46. Hotel Permon, Podbanské. DT ZSVTS Košice.

[6] Kudrna, J., Vébr, L., Luxemburk, F., Racek, I. a kolektív.(2006). *TP 170 Navrhování vozovek pozemních komunikací*. MD ČR, upravený dotisk, 09/2006.

[7] Mandula, J. (2012). Vplyv aktívnej zóny na deformačný stav netuhej vozovky. In: 9. International Scientific Conference FCE TUKE: The 35th Anniversary of the Faculty of

Civil Engineering and The 60th Anniversary of the Technical University of Košice, 22. - 25.5.2012, s. 1 - 6. Košice: TU.

[8] Novotný, B., Hanuška, A. (1983). *Teória vrstevnatého polpriestoru*. Bratislava: VEDA.