Protection of Pavement Systems to Prevent and Combat the Phenomenon of Freezing-Thaw

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ABSTRACT: In the paper is presented an analysis of the behaviour of several types of pavement systems to the phenomenon of freezing-thaw. Diagrams are shown representing the state of stresses and strains for the most representative types of pavement systems and also graphs of the resulting link between the state of systems deformation and various parameters considered specific in each situation (dynamic modulus of elasticity in the road bed, the maximum tensile strain at the base of asphalt mixture layer). It proposes a methodology that put at the disposal of those dealing with roads maintenance, the limit values of deflection measured on the pavement surface, from which must taken the protective measures.

KEY WORDS: Pavement systems, freezing-thaw protection.

1 ASSESSING THE REACTION TO FREEZE-THAW OF THE PAVEMENT SYSTEMS BY ANALYZING THE STATE OF STRESS AND STRAINS

In the present work were analyzed 4 (four) representative types of pavement structures for the national roads in Romania (corresponding to the traffic classes T1 - Very Heavy, T2 - Heavy, T3 - Middle, T4 - Light); the same type of pavement structures were chosen for easier comparison, i.e. a package of 8.5 to 19 cm asphalt layers placed on granular materials (e.g. crushed stone and ballast).

It was considered state of stress and strains under a static circular load corresponding to the standard axle load of calculation in our country of 115 kN (characterized by pressure on the tire-road contact surface p = 0.625 MPa and footprint radius r = 0.171 m), in several climate periods (winter, spring and summer) represented by different values of the mechanical characteristics of the materials of component layers.

The calculation was conducted in the elastic domain using a finite element program, emphasizing the values of stresses σ_r, σ_z, σ_θ and τ_{rz} and strains ϵ_r, ϵ_z, ϵ_θ, γ_{rz}, in the critical points of pavement structures (characterized by maximum values of the stress and strains state) and the effective elastic deformed shape under load.

Representative charts presented as isocurves (Figures 1, 2, 3 and 4) reveal not only the loading axis values, but values within a radius of action influence and a deep enough so that the effect are diminishing.

Charts are presented for the extreme situations both in terms of climate (winter - frozen material and spring - the thaw) and the composition of pavement structures (related to traffic classes T1 - Very Heavy and T4 - Light, following the amounts of intermediate situations be used only in composition of the graphs considered later in the comments.

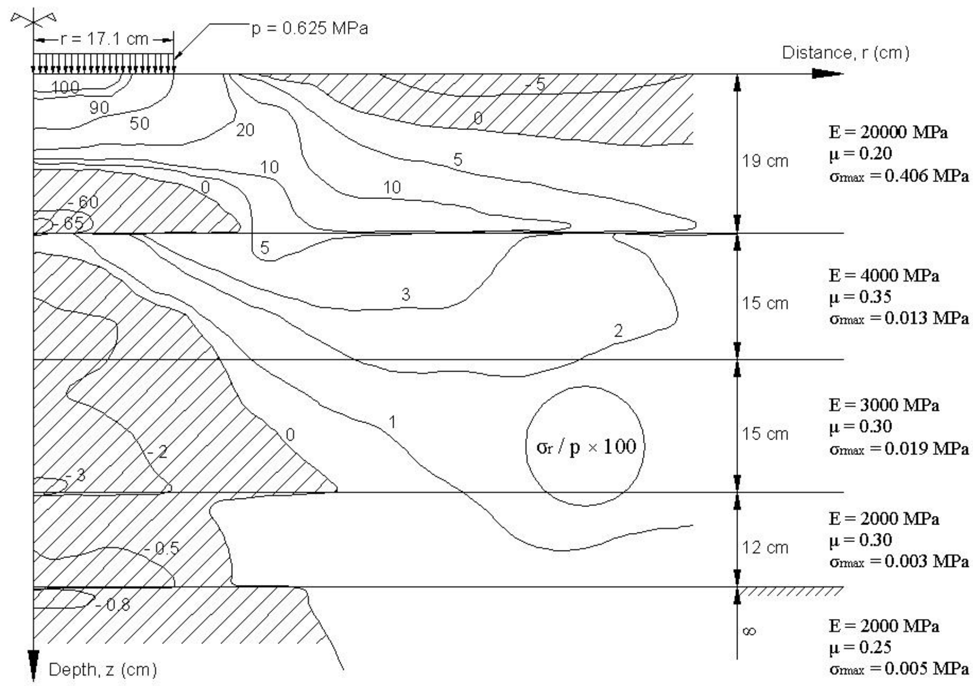

Figure 1: The Pavement Structure type 1 (PS 1) winter.

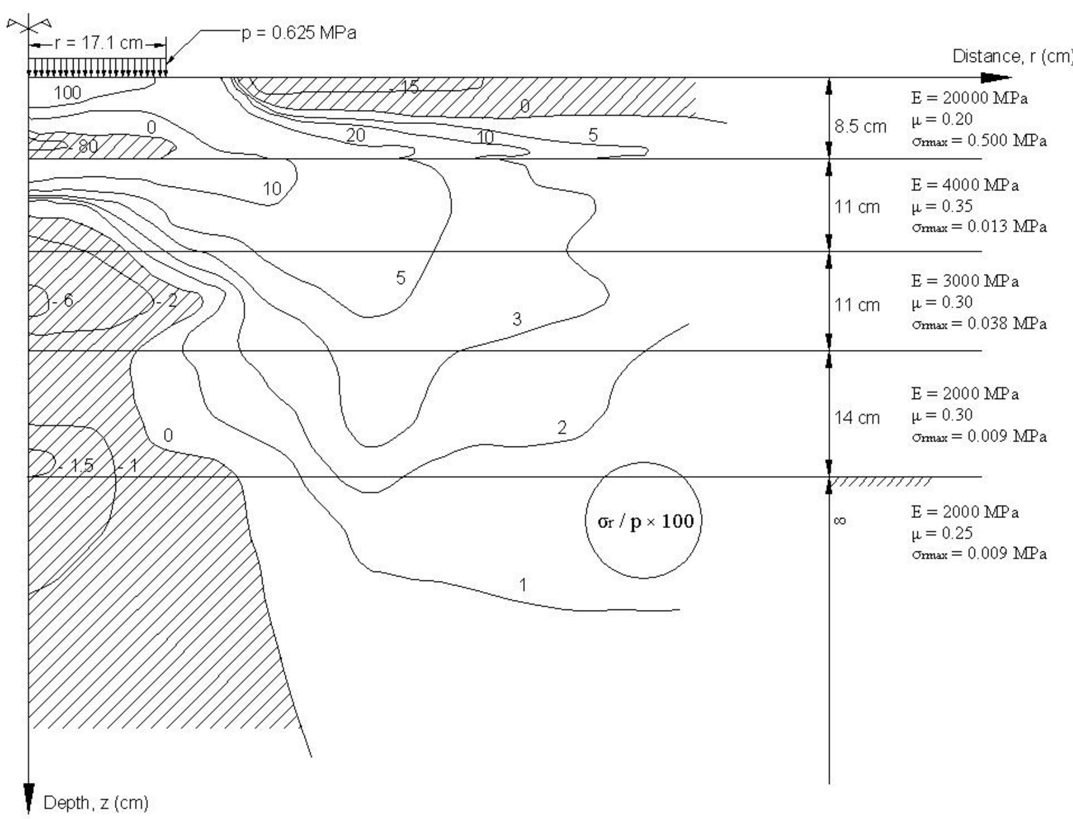

Figure 2: The Pavement Structure type 4 (PS 4) winter.

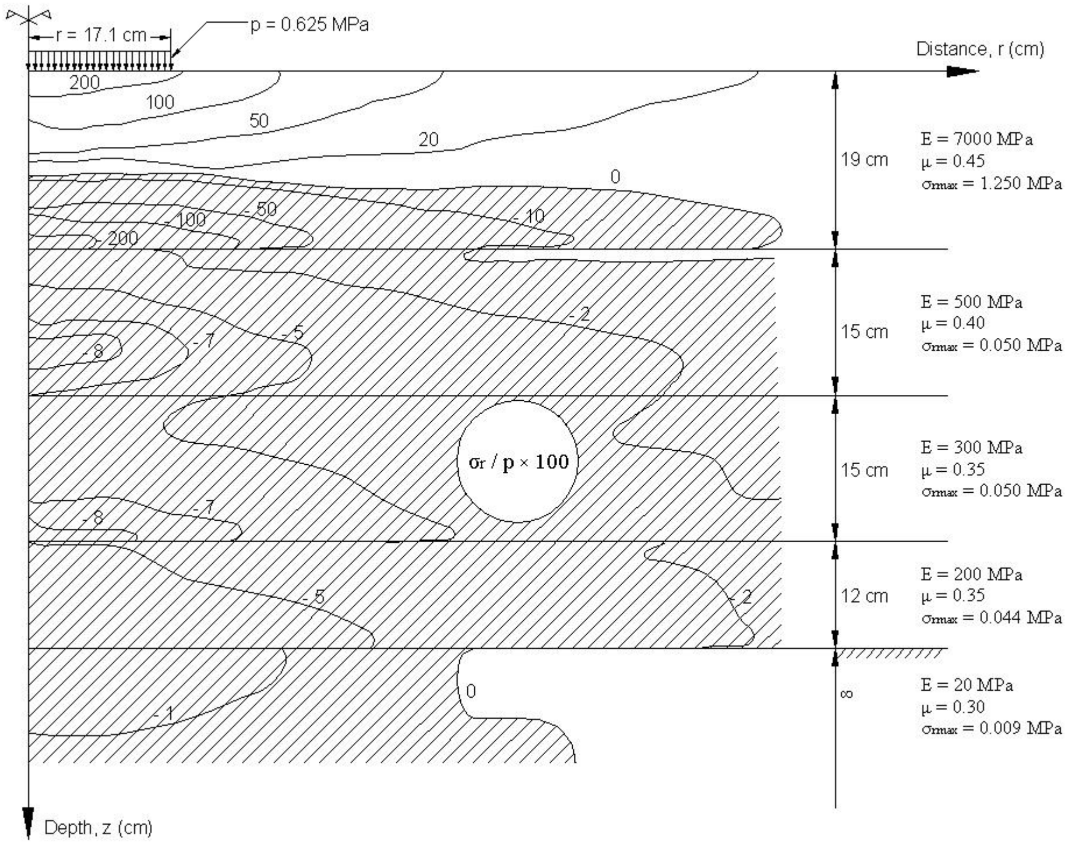

Figure 3: The Pavement Structure type 1 (PS 1) spring.

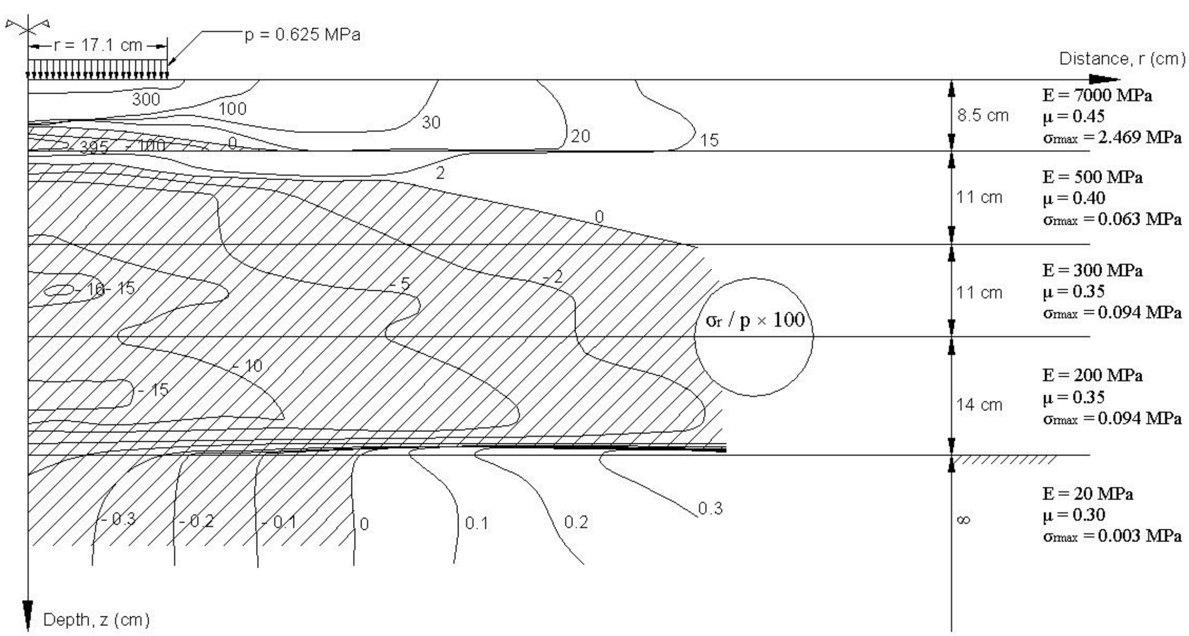

Figure 4: The Pavement Structure type 4 (PS 4) spring.

2 THE CHARACTERISTICS OF STRESS CHARTS

It will be present for comments only the σ_r stress situation, basic feature (by its effect, the strain ϵ_r) in estimating the fatigue behaviour under traffic of asphalt layers.

Representative charts are shown in Figures 1 to 4.

Values of the curves are the ratios σ_r/p, and shaded areas show where tensile stresses occur; following remarks will be based, in particular, on the specificity of these areas, the value and the place where tensile stresses occur depending on the type of pavement structure and climate period; comments will be accepted on the basis of maximum tensile stress supported to the asphalt mixture of about 1 MPa; areas where this value is exceeded are considered “areas with degradation risk”.

General feature is that corresponding to known data, meaning that most of the tensile stresses are covered in asphalt mixture layer.

The novelty lies in differentiating the types of structures and concretely values obtained in each case.

For comparison, the σ_{rmax} tensile stress values at the base of asphalt mixture layer and lower the subbase course of granular materials - respectively the subgrade in the road bed have been detained from charts.

A first observation is that during spring, for light pavement structure (type 4) and for the very heavy (type 1), the tensile stresses includes all the layers under the asphalt mixture, with higher values or less, depending on the material, possibly with the concentration of efforts in areas of transition between layers.

The area “of influence”, where the σ_r tensile stress values appear, are manifesting up to approx. 80 cm from the axis of loading (4.7 r) and in depth, although with very low values, the values of tensile faded pretty hard (fact observed, moreover, also for winter period).

Table 1 shows the main σ_r tensile stress values in areas considered representative.

Table 1: σ_r tensile stress values in different areas and climate periods for several types of pavement systems

CLIMATE PERIOD	TRAFFIC CLASS/ PAVEMENT SYSTEM (PS)	CONSIDERED AREA σ_r, MPa		
		Mixture	Subbase	Subgrade
WINTER E_0 road bed =2000 MPa	Very Heavy/ PS 1	0.406	0.019	0.005
	Heavy/ PS 2	0.478	0.025	0.006
	Middle/ PS 3	0.484	0.034	0.008
	Light/ PS 4	0.500	0.038	0.009
SUMMER E_0 road bed =200 MPa	Very Heavy/ PS 1	1.080	0.011	0.003
	Heavy/ PS 2	1.439	0.018	0.004
	Middle/ PS 3	1.813	0.026	0.005
	Light/ PS 4	2.125	0.028	0.005
SPRING E_0 road bed =20 MPa	Very Heavy/ PS 1	1.250	0.050	0.0009
	Heavy/ PS 2	1.650	0.063	0.0013
	Middle/ PS 3	2.013	0.089	0.0025
	Light/ PS 4	2.500	0.100	0.0031

It is observed that in winter period the tensile stresses in the mixture are spreaded in allowed limits of material quality and in the subgrade or granular subbase course, although appearing tractions, they have very small values.

During the spring, however, appears a special element, in that, besides the fact that in all types of pavement structures grow much the tensile stresses values, especially in the light pavement structures (type 4) is charging more than the limit allowed the asphalt mixture layer, while the traction values in the subgrade fall below those recorded even in winter. This decrease, which takes, in fact, to the bearing capacity of road bed, makes to more load of the mixture layer, which ends up to exceed the tensile strength of bending.

So high levels of the traction in the subgrade or subbase of granular materials are not the direct cause of the destruction of pavement structures, but overcoming of the tensile strength of the asphalt mixture layer.

3 THE STRAIN STATE USING IN THE ASSESSMENT OF THE PAVEMENT STRUCTURES BEHAVIOUR

The strain state of the pavement structures analyzed reveal real deformation values d, (elastic deformation, deflection) at the surface of pavement structure as well the ϵ_z strain at the subgrade level (Figure 5).

Whereas mentioned values vary from one pavement structure to another and also depending on the temperature (Winter, Spring), discussion may be bear on the possible link which exist between these parameters.

That the protection measures of the pavement structures against the effects of freeze-thaw phenomenon to be effective, they must be linked with the phenomenon, and it occurs within the layers.

A link between subgrade deformation feature of the road bed, E_0, and deflection, d, and strain values, ϵ_z, to the road bed, could contribute to solving the problem.

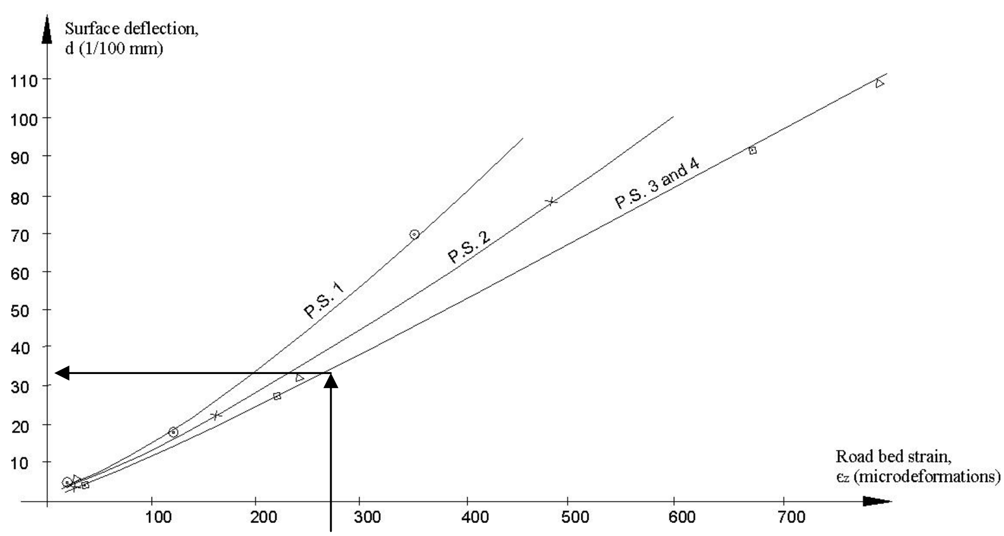

Figure 5: Strain at the subgrade level versus real deflection of the pavement surface.

4 CONCLUSIONS. ESTIMATING THE OPTIMAL PERIOD TO ESTABLISHING RESTRICTIONS ON VEHICLE MOVEMENT; MEASURES FOR THE DESIGN OF NEW PAVEMENT STRUCTURES

In the following it is proposed to use relations that exist between E_0 (elasticity modulus of subgrade in the road bed), ϵ_z (compression strain) at the subgrade level (Figure 6) and d (deflection) at the pavement surface, so, for a value of deflection measured at surface can be estimated what is the situation at the subgrade level and to take appropriate action.

Figure 7 is the link between maximum tensile stress σ_{rmax} in the asphalt mixture layer and ϵ_z value in the bed.

From this relationship, whether it is impose a limit value of tensile stress, will result a value $\epsilon_{z\ lim}$.

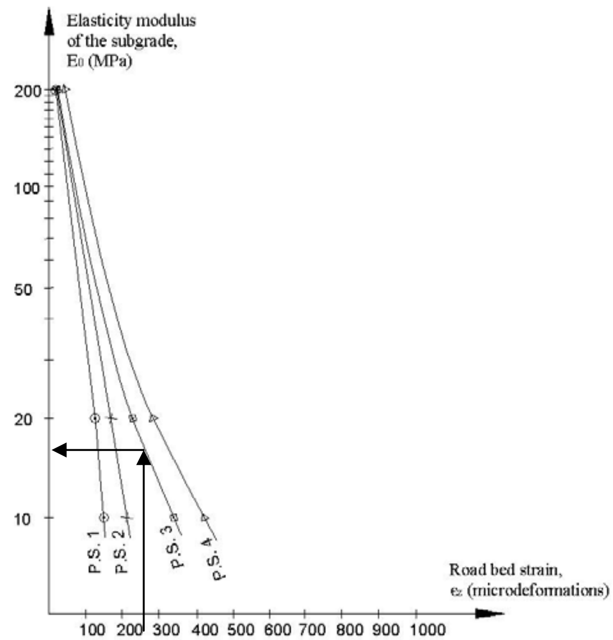

Figure 6: Elasticity modulus of subgrade versus the compression strain at the subgrade level.

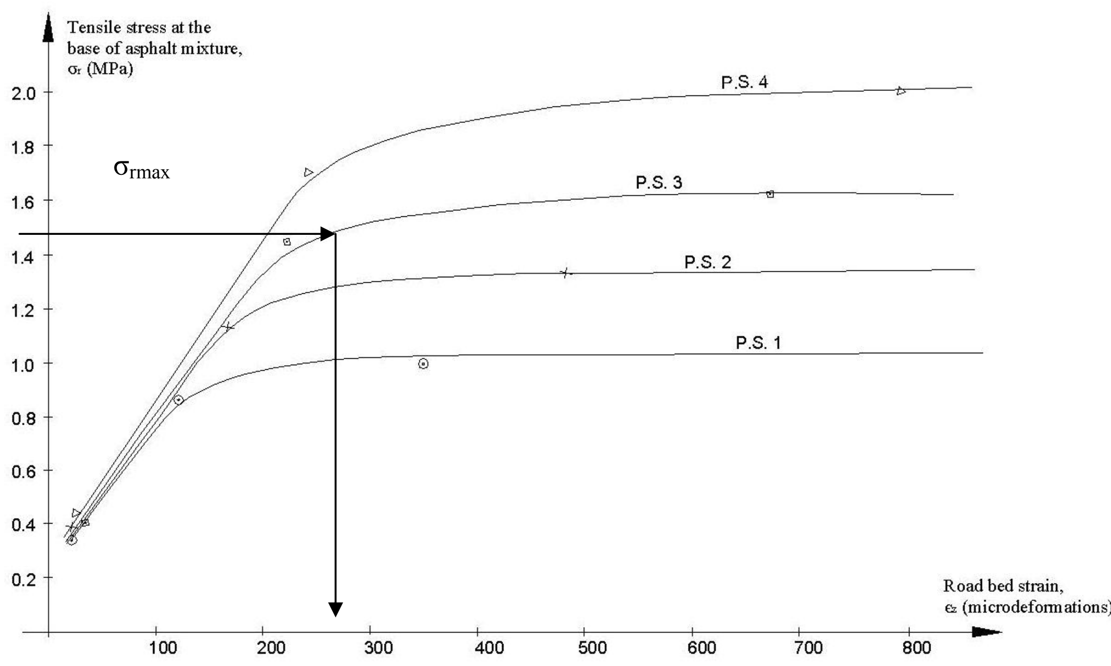

Figure 7: Strain at the subgrade level versus maximum tensile stress σ_{rmax} in the asphalt mixture layer.

4.1 Conclusions for existing pavement structures (Estimation of the optimal period for establishing the vehicle movement restrictions)

For pavement structures in use, this limited value could be used by the graph in Figure 5, in which, for $\epsilon_{z\ lim}$ is obtained, corresponding to the pavement structure type, the amount allowable for d at the surface (d_{lim}).

Practically, the steps would be the following:

1. It admits a limit value for tensile stress σ_{rmax} in asphalt layers; from Figure 7 are obtained informations (appropriate value) for ϵ_z strain at the road bed level.
2. From Figure 5 is obtained, corresponding to this ϵ_z value, deflection value measured at the surface; it is that limit value of deflection, from which the protective measures are imposed, such as the establishment of vehicle movement restrictions; be noted that this value of the "warning" deflection is less than one accepted in design calculations, which limit amount accepted is corresponding to the traffic class (Table 2).

Table 2: Admissible pavement surface deflection d_{adm} corresponding to the traffic class

TRAFFIC CLASS T_i	CALCULATION TRAFFIC N_c, millions of standard axles of 115 kN	ADMISSIBLE PAVEMENT SURFACE DEFLECTION d_{adm}, 1/100 mm
Very Heavy - T1	1.00 ... 3.00	45
Heavy - T2	0.30 … 1.00	60
Middle- T3	0.10 … 0.30	65
Light - T4	0.03 … 0.10	70

4.2 Conclusions for new pavement structures (Determination of the minimum required elasticity modulus at the road bed level)

For the design of new pavement structures could be taken into account the following:

1. It admits a limit value for tensile stress σ_{rmax} in asphalt layers; from Figure 7 are obtained informations (appropriate value) for ϵ_z strain at the road bed level.
2. From Figure 6 is obtained the value of E_0 (elasticity modulus of subgrade in the road bed); it is the minimum amount to be provided to the support level, thus, the pavement structure to be protected against the distress of the thaw period.

REFERENCES

Diaconu, E., 2002. *Risk assesment of inflation to frost phenomenon occurrence*. National Road Congress, Timişoara, Romania.

Diaconu, E., may 2007. *Thaw barriers – solution for pavement design with respect to the action of frost-thaw phenomena*. "Road and bridges rehabilitation" Symposium, Cluj Napoca, Romania.