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THE ANALYSIS OF THE UNRIGID ROAD SYSTEMS BEARING CAPACITY FROM THE FOREST ROADS THROUGH THE ACTUAL DIMENSIONING METHODS

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Abstract: *In order to correspond to the actual traffic necessities, the forestry roads must present some adequate road systems. The present paper presents some road systems which are common to the forestry roads, through a bearing capacity analysis.*

Key words: *bearing capacity, road systems, new traffic necessities.*

1. Introduction

Presently, the road systems dimensioning is done by using the critical deformation method or the standard axle method. The last one is law-enforced in two variants. A first variant, described through "The normative for supple and semi rigid road systems dimensioning (the analytical method)" [4], takes into consideration the roads designed with bituminous covers; the second variant [5] is referring to the dimensioning of the granular materials layers for earth roads reinforcement, which, in perspective could be upgraded with asphaltic coverage. In both variants the calculations are made in the CALDERON software.

In the present paper there is presented a comparison between the critical deformation method and the analytical method (variant 1), followed by the presentation of the second variant application in a distinct paper.

The present paper takes into consideration the unrigid road systems with asphaltic covers.

For the realization of the mentioned comparison, there have been selected 8 road systems, specific to the main forest roads, presented in the Figure 1.

The analyzed road systems were sampled from the most frequently field situations, from the road systems which were proposed for the normative and from the CESTRIN catalogue.

2. Calculus and Determinations

Yet, from the beginning, the comparison realization presented a lot of difficult problems because the two compared methods are using different calculus parameters, different measure units for the traffic quantification, and different verification modalities for the adopted solution.

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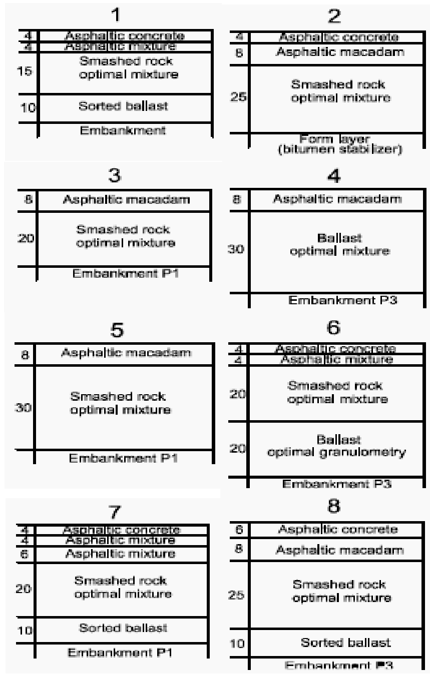

Fig. 1. *The composition and the dimensions of the selected road systems - variant 1 - thicknesses in cm*

A first difficulty concerned **the calculus traffic determination**, in the absence of some circulation census data. For this, there was considered that the selected road systems are corresponding, according to the critical deformation method, to a certain traffic intensity, expressed in etalon vehicles A13/24 hours quantified by the necessary deformation modulus (E_{nec}).

The necessary deformation modulus is determined in function of the permissible deformation, number of lanes and the traffic intensity expressed in etalon vehicles (Eq. 1):

$$E_{nec} = \frac{\pi p}{2\lambda}[0.5 + 0.65 \lg(yN)]\,\mu\,, \qquad (1)$$

where p is the etalon vehicle unitary pressure on the contact surface; λ - the permissible deformation; γ - a coefficient which takes into consideration the number of lanes; N - the traffic intensity in etalon vehicles.

The verification of the adopted dimensions is made by the condition:

$$E_{nec} \geq E_{eq}, \qquad (2)$$

where E_{eq} was established by considering both, the deformation modulus of the materials from the road layers (Table 1), and bilayer principia.

By considering the above presented equivalence and determining, for each selected road system, the equivalent modulus (E_{eq}), there was established the traffic intensity which was considered for the selected road systems dimensioning, by using the Eq. (3):

$$\lg(\gamma N) = \frac{2\lambda E_{eq}}{0.65\pi p\mu} - 0.77\,. \qquad (3)$$

The obtained results are presented in Table 2, ant they are based on the dimensioning calculations effectuated through critical deformation method.

Much more, the table includes the subsequent transcalculations in order to be possible to evaluate the traffic and to make the dimensioning of the selected road systems through the standard axle method.

The deformation modulus of the road layers for the road systems 1…8 Table 1

	Material denomination	**Deformation modulus, [MPa]**
1	Sorted ballast	60
2	Ballast, optimal admixture	70
3	Smashed rock, optimal admixture	90
4	Asphaltic macadam	200
5	Asphaltic admixture	220…260
6	Asphaltic concrete	280
Note: For earth was considered the deformation modulus according to the earth type		

The equivalent deformation modules for the analyzed road complexes and the calculus traffic intensities Table 2

Road system	M.U.	1	2	3	4	5	6	7	8
$E_{eq} = E_{nec}$	MPa	62	59	28	36	56	50	45	48
Traffic intensity	No. A13/24 hours	4457	2723	17	63	1667	622	274	449
Transcalculated traffic	No. o.b./24 hours	557	375	7	19	254	116	87	90
CESTRIN predictions	No. o.b./day	150-550	50-150	20-50	-	-	-	-	-
	No. o.s./lane	0.3-1.0	0.1-0.3	0.03-0.1	-	-	-	-	-
A specific traffic for a magisterial forest road	No. A13/24 hours	341							
	No. o.s./24 hours	72							

Calculus values of the deformability characteristics for the principal supple road systems materials Table 3

	Material denomination	Dynamic elasticity modulus, [MPa]	Poisson coefficient
1	Asphaltic concrete	3600	0.35
2	Asphaltic admixture	3000	0.35
3	Asphaltic macadam	1000	0.27
4	Macadam	600	0.27
5	Great smashed rock (40/63)	400	0.27
6	Smashed rock (optimal admixture)	500	0.27
7	Raw rock bottoming	300	0.27
8	Ballast (optimal admixture)	300	0.27
9	Ballast	210	0.27
10	Cobble	200	0.27

Note: In the case of the earth the dynamic elasticity modulus varies from 50 to 100 MPa, in function of the climatic type, the zonal hydrologic regime, as well as the earth type (P1…P5). The Poisson coefficient varies in function of the earth type, between 0.27 (for P1) and 0.42 (for P5).

As it can be observed in Table 2, along with the two calculus parameters (E_{eq} and the traffic intensity in no. A13/24 hours), there were introduced the following: the traffic intensity in o.s./day, as well as the CESTRIN previsions for the first 3 road systems, whose composition was taken from the catalogue; the intensities, expressed in billion standard axles (m.o.s.)/traffic lane, are referring to a 10 years period:

$$\lg N = \eta \lg N_i + 0.77\,(\eta - 1), \tag{4}$$

where N and N_i represent the traffic intensities, expressed in number of vehicles/24 hours, in the two hypotheses, and η is the transformation coefficient calculated with the relation:

$$\eta = \frac{p_i D_i}{pD}, \tag{5}$$

where the road - wheel contact characteristics are appearing. In the case of the traffic transformation with etalon vehicles A13 (contact characteristic 170) in standard axles traffic (contact characteristic 21.75), the transformation coefficient is:

$$\eta = \frac{170}{213.75} = 0.79532, \tag{6}$$

which shows that, in a given case, the number of standard axles (115 kN) which are the equivalent of the tensions provoked by the etalon vehicle A13 (which has the weight on the rear axle of 91 kN) is more reduced compared with the A13 etalon vehicle.

For a more accurate image upon the traffic on a magisterial forest road with bituminous cover, in the wood transportation activity, in Table 2 was included (the last row) the specific traffic for roads such these.

The argument which leads to the evaluation of this traffic is the following: the forest magisterial road serves an area of forest greater than 10,000 ha and it supports an annual traffic greater than 50,000 tones transported wood with vehicles with an payload of 25 tons (ex: Renault Kerax 450 or ATF25), in a 50 days concentrated period. There results a daily transport of 1000 tons, which means 40 both directions passes, respectively a traffic of 80 passes per day in both ways.

The obtained traffic with forest vehicles of 25 tons (pD = 210) was trans calculated in etalon vehicles A13 (pD = 170) and standard axles (pD = 213.75) resulting daily 341 A13 passes, respectively 72 standard axles.

By an overall analysis of the data established through the critical deformation method (presented in Table 2), there can be observed, despite the approximate character of the forest traffic, that the traffic intensities for the road systems (1), (2) and (5) are greater than those specific to the magisterial roads (which could be bituminous covered). Consequently, the respective road systems represent great consolidations and they are leading to unjustified costs. The road systems (3) and (4) correspond to some very low traffic intensities, and they represent insufficient bearing consolidations even for the magisterial roads traffic.

Anyway, the mentioned road systems do not have to be excluded as possible solutions, because those with great consolidations could be used in the case of some exceptional traffic intensities (roads which serve third persons), and those with reduced consolidations could assure the accessibility of some touristic objectives or hunting cabins with limited access, but which impose, no

Specific deformations. Values recorded in CALDERON lists and maximum permissible values

Table 4

Road system type	Calculus traffic		Total thickness of the road system, [cm]	Specific deformations						Maximum permissible deformation	
	o.s./ 24h	m.o.s./ period		Radial [ε_r]			Vertical [ε_z]			Rad.	Ver.
				level	Deepness [cm]	MD	level	Deepness [cm]	MD	Micro deformations	
1	557	2.03	33	z1	-8	200	z2	-33	480	180	475
2	375	1.37	37	z1	-12	211	z2	-37	296	170	560
3	7	0.025	28	z1	-8	85	z2	-28	521	-	-
4	19	0.07	38	z1	-8	222	z2	-38	510	-	-
5	254	0.9	8	z1	-8	672	z2	-38	348	240	605
6	116	0.42	48	z1	-8	178	z2	-48	274	280	770
7	87	0.32	44	z1	-14	177	z2	-44	271	305	440
8	90	0.33	49	z1	-14	201	z2	-49	244	300	435

Notes:

1. Instead of the horizontal deformation there has been considered the radial deformation;
2. The “–“sign means that the calculus point was situated at the base of the road layer;
3. The distance between the longitudinal profile (R) and the calculus point is, in all the cases, equal to zero, according to the calculus hypothesis (R = 0);
4. The deformations were taken from the lists of the CALDERON software by taking into consideration the E+02 or E+03 indicators which indicate the number of digits which must be taken in order to express the deformation in micro deformation. Ex: 200E+03 means 200 micro deformations, 854E+02 means 85.4 micro deformations ≈85 micro deformations.

matter the reduced traffic intensity, the modernization of the roadway.

The road systems (6), (7) and (8) represent solutions which are more specific to forest traffic, and, in a given case, the thicknesses of the foundation layers could be adjusted in the dimensioning process by respecting the condition:

$$E_{eq} = E_{nec}. \quad (7)$$

A special attention should be given to the road system (7), composed from 3 bituminous layers (base layer, binder and hard covering), but with more rational thicknesses for the mineral aggregates layers, which correspond to a traffic closed to the forest traffic, even in the conditions of a weaker foundation terrain.

Along with the mentioned ideas, from the analysis of the Table 2, there can be drawn the following conclusions:

The realization of the necessary bearing capacity for the roadway (E_{nec}) through the utilization of some successive road layers, with economically acceptable thicknesses, depends to a great extent on the foundation earth quality (layer or form embankment); comparing the road systems 4 and 5, there can be observed that, despite the fact they present the same total thickness (38 cm), and the materials which are composing the foundation present deformation modules relatively equal, the equivalent modules are significantly different (36 MPa and 56 MPa), due the better quality of the earth composing the road bed from the system (5).

The introduction of a base layer in the road system structure, with a thickness of 6 cm, executed from asphaltic admixture, permits the reduction of the total thickness of the road layers executed from quarry or gravel pit aggregates, with app. 25% in the case of road systems (6) and (7).

The asphaltic macadam, used as cover and settled directly on a smashed rock or ballast foundation (optimal admixtures) does not ensure the necessary bearing capacity for the forest traffic on the main roads; it can be used as base layer.

The total thickness of the bituminous road layers assembly (base layer, binder and hard covering), varies, from 8 to 14 cm.

The necessary deformation modulus (E_{nec}), when the supple road system corresponds to asphalted magisterial forest roads usually traffic solicitations, can be considered as being of 45…50 MPa.

Considering as a result of the transcalculations the calculus traffic expressed in m.o.s./lane, specific to the standard axle method the verification for the selected road systems dimensions through the mentioned method has been carried out.

The behavior verification, under traffic, for each road system has been carried out through the determination of the specific elongation deformations (ε_r) and compression deformations (ε_z) for the road system and their comparison with the maximum permissible deformations.

The maximum permissible deformations, expressed in micro deformations, were established, in function of the calculus traffic, with the diagrams form the P.D 177-2001 normative, and they are presented in Table 4.

In the first part of the table there are written the 8 road systems, total thicknesses and the calculus traffic for each system. The traffic was determined with the critical deformation method and transcalculated, in equivalence conditions, from traffic with A13 etalon vehicles in traffic expressed in standard axles/24 hours and m.o.s/10 years.

Expressing the traffic in o.s./24 hours presents the advantage to permit some compensations between the two analyzed methods, compensations which can be performed only in equivalence conditions in order to use identical measure units.

The specific deformations taken from the calculus lists of the CALDERON software, are those corresponding to z_1 level (at the bituminous layers base), for specific elongation deformations (ε_r), respectively z_2 (at the road bed level), for specific compression deformations (ε_z).

The maximum permissible deformations are presented in the last columns of the Table 4.

The data presented in the mentioned table confirms, to a great extent the observations presented from the Table 2 analysis.

In the case of the road systems (1), (2) and (5), where the calculus traffic was situated over the specific calculus traffic for a magisterial forest road, the radial deformations, and sometimes the vertical deformations, which are generated by the traffic solicitations, are greater than the maximum permissible deformations.

The road systems (3) and (4), with a very reduced calculus traffic, were not analyzed in the normative diagrams for the established permissible deformations.

The fact that in the case of the road systems type (1), (2) and (5) the overruns of the permissible deformations are more pronounced in the case of the specific vertical deformations in comparison with the radial deformations, shows that the thicknesses of the natural aggregates foundations (20…25 cm) are too reduced.

The road systems (6), (7) an (8) - inspired from practice - do satisfy the condition of not overrunning the permissible deformations, but the total thicknesses are with 20…25% greater than the rest of the types and the thicknesses of the bituminous layers are of 14 cm.

Generally, there can be observed, from the Table 4 analysis, that the choice for the bituminous road layers of a total thickness of 8 cm, as it appears in the catalogue, can be sufficient only in the conditions in which the foundation layers present thicknesses of 40…50 cm or possibly a base layer is introduced.

3. Conclusions

1. The forest roads were dimensioned only in certain situations, by using the road systems from the normative or road systems verified in practice.

2. Familiar road technique dimensioning methods were used when necessary the critical deformation method, law - enforced for public roads with local interest and extended in the case of the forest roads with unrigid road systems.

3. The critical deformation method, used for many years in the unrigid road systems dimensioning for the forest roads, presents the advantage that permits both analytical determinations and graphical determinations and it can be applied for different traffic intensities.

4. In the case of public roads, is used the analytical method, is used called the standard axle method [4].

5. Despite the fact that the mentioned ideas constrain, from the beginning, the applicability of the standard axle method, the research carried out aimed at first to establish the measures and conditions in which the method can be applied in the case of forest roads.

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