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Study concerning the cause of degradation in a road section in the proximity of the town of Oravita

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Abstract: The paper aims at underlining the important role of the foundation soil in producing and deteriorating the degradations on DN 57 on the section between km 153+000 and km 158+000. To this purpose, a relatively large number of field and laboratory geotechnical investigations have been realized. The correlation of the high activity potential of the clay layer immediately under the road pavement with the preponderance of the road degradations such as longitudinal cracking, led to the conclusion that the high thermal and pluviometric variations cumulated with the active and very active character of the clay in the road bed was one of the causes leading to the occurrence and development of degradations on the investigated road section.

Keywords: cracking, embankment, setting, geotechnical research.

1. INTRODUCTION

Several degradations and damages of the road pavement have occurred on the analyzed road section in the proximity of the town of Oraviţa (Fig. 1), especially longitudinal cracking, both on the edges (Fig. 2) and on the road axis (Fig. 3). Also, in many places on this section, severe local settlements and rutting have occurred (Fig. 2 and Fig. 3). On several areas of the analyzed section the water collection and evacuation systems were found to be damaged or even missing, the water drainage being not ensured longitudinally in places where the road is at grade or in light embankment.

Fig. 1. Site location

In order to determine the role of the foundation soil in the producing and aggravating the road degradation on this section, and to offer the designer of the strengthening complex and clear geotechnical data a relatively high volume of field and laboratory geotechnical investigations have been realized.

2. GEOTECHNICAL INVESTIGATIONS

The field geotechnical investigations were open drillings to determine the composition of the existing

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road pavement, drillings to determine the nature and condition of the soil in the layers of the foundation ground and dynamic cone penetration drillings to complete the drilling investigations concerning the layering and the deformability characteristics of the foundation ground. The dynamic cone penetration drillings and the processing of the obtained data were realized according to the "Technical instructions for the research of the foundation ground through the cone penetration method – indicative C 159-89" [1], using the light dynamic penetrometer (M_{ram} = 10 kg), as well as the average dynamic penetrometer (M_{ram} = 35 kg).

The laboratory tests, realized on the samples taken from the drillings, aimed at determining the geotechnical characteristics in the foundation ground, absolutely necessary in designing and dimensioning of any road structure [2].

The open drillings realized in the road pavement showed the following general composition:

- coated macadam in 2…3 layers, with 20…40 cm total thickness;
- crushed stone and gravel, total thickness 35…45 cm.

Fig. 2. Cracking with settlement

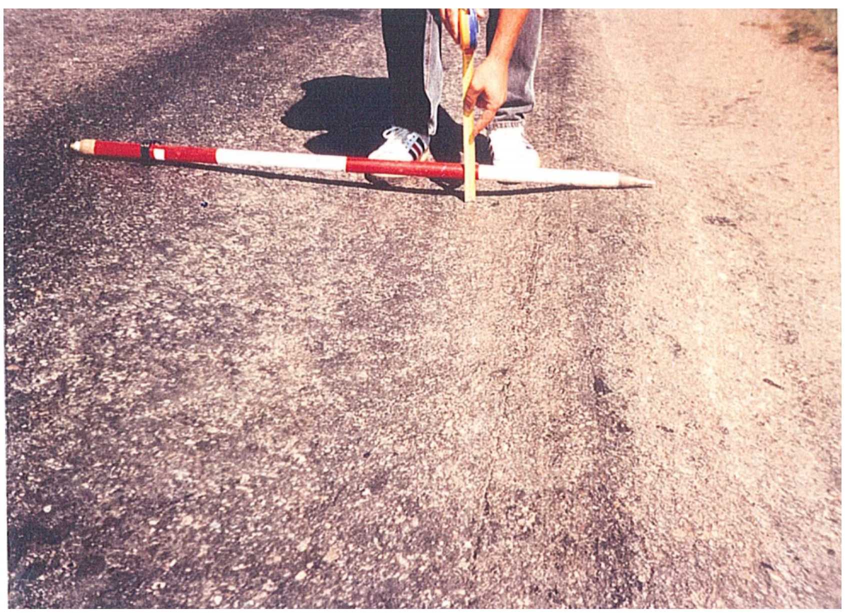

Fig. 3. Local settlement and rutting

Table 1 Table presenting the values of several geotechnical characteristics of clay soils in the foundation ground – DN 57 km 153+000 and km 158+000

Drilling	Soil name	Sample quota	Granulometry			Category of soil	Geotechnical characteristics				
			Sand [%]	Silt [%]	Clay [%]		Moisture content w [%]	LimitsAtterberg: Liquid limit w_L [%]	LimitsAtterberg: Plastic limit w_p [%]	Plasticity index I_p [%]	Consistency index I_c [%]
F1 153+750	brown clay	-0.80	2	39.5	58.5	P5	25.2	77.4	23.4	54.0	0.96
	yellow clay with limestone inclusions	-2.00	17	29	54	P5	23.3	81.5	21.4	60.1	0.97
	yellow clay	-2.60	10.5	34.5	55	P5	29.5	87.5	27.1	60.	0.96
F2 154+560	brown clay	-1.00	12	33	55	P5	30.9	77.3	23.5	53.8	0.86
	yellow clay with limestone inclusions	-1.80	17	20	63	P5	26.9	77.6	25.2	52.4	0.97
	greenish gray clay	-2.80	9.5	35	55.5	P5	29.7	82.6	28.7	53.9	0.98
F3 155+600	brown clay	-1.00	24.5	29	46.5	P5	23.8	57.7	16.8	40.9	0.83
	yellow clay with limestone inclusions	-2.00	19	30	51	P5	28.4	79.5	24.2	55.3	0.92
	yellow clay	-2.80	14	28	58	P5	27.6	70.7	25.2	45.5	0.94
F4 156+500	brown sandy clay	-1.00	41	26	33	P5	24.9	54.0	17.6	36.4	0.80
	yellow silty clay	-2.00	19	40	41	P5	26.4	74.5	21.3	53.0	0.90
	orange yellow silty clay	-2.80	18.5	44.5	37	P5	23.0	68.5	22.5	46.0	0.98
F5 157+500	silty clayey sand	-0.60	41.5	32.5	26	P4	19.3	40.0	19.0	21.0	0.98
	brown clay	-1.00	19.5	40	40.5	P5	25.8	72.8	23.6	49.2	0.95
	yellow clay with limestone inclusions	-2.00	19	42	39	P5	26.4	65.7	18.1	47.6	0.82
		-3.00	20	42	38	P5	22.9	68.6	21.0	47.6	0.96

As seen in table 1, the drillings in the investigated depth showed a relatively homogeneous layering on the entire length of the analyzed section, the clay layers being present in the entire layering of the ground. With few exceptions, under the road pavement there is a brownish, highly plastic (I_p > 40 %) and highly consistent (I_c > 0,80) clay layer. The depth continuous layering with clay layers, the plasticity and consistency are kept high, only the color shade changing and some limestone intrusions being noticed.

Table 2 Table centralizing the values of certain geotechnical characteristics determined through Processing the results of the dynamic cone penetration tests – PDU on DN 57 – km 153+750…154+560

Penetra-tion and km	Depth H [m]	No. of strikes /10 cm	Penetration resistance		Geotechnical characteristics				
			R_d [daN/cm^2]	R_p [daN/cm^2]	n [%]	e	I_c	M_{2-3} [daN/cm^2]	E [daN/cm^2]
PDU 1 153+750	0,6…1,0	14,25	44,30	34,56	44	0,80	0,81	84,82	110,27
	1,0…1,5	12,80	35,39	27,61	45	0,83	0,72	80,72	104,94
	1,5…2,0	18,20	50,32	39,25	44	0,78	0,87	87,14	130,71
	2,0…2,5	17,60	48,66	37,96	44	0,78	0,85	86,53	129,80
	2,5…3,0	18,20	50,32	39,25	44	0,78	0,87	87,14	130,71
PDU 2 154+560	0,8…1,0	6,50	20,21	15,76	48	0,92	0,76	70,51	97,56
	1,0…1,5	7,40	20,46	15,96	48	0,92	0,76	70,73	98,15
	1,5…2,0	5,80	16,04	12,51	49	0,96	0,70	66,29	92,82
	2,0…2,5	7,25	20,05	15,64	48	0,92	0,76	70,69	97,93
	2,5…3,0	7,80	21,57	16,82	48	0,92	0,76	70,69	98,25

Table 3 Table centralizing the values of certain geotechnical characteristics determined by processing the results of the dynamic cone penetration tests – PDM on DN 57 – km 154+000…155+000

Penetration and km	Depth H [m]	No. of strikes/10 cm N 10		Penetration resistance		Geotechnical characteristics				
		N 10 PDM [strikes/10 cm]	N 10 PDU [strikes/10 cm]	R_d [daN/cm^2]	R_p [daN/cm^2]	n [%]	e	I_c	M_{2-3} [daN/cm^2]	E [daN/cm^2]
PDM 1 154+000	0,5…1,0	12,00	29,72	92,40	72,07	40,58	0,68	-	103,92	176,66
	1,0…1,5	4,40	11,38	31,46	24,54	45,98	0,85	0,72	74,28	81,70
	1,5…2,0	4,80	12,41	34,32	26,77	45,58	0,84	0,75	76,96	84,66
	2,0…2,5	5,00	13,41	33,40	26,05	45,71	0,84	0,77	79,36	87,29
	2,5…3,0	5,00	13,41	33,40	26,05	45,71	0,84	0,77	79,36	87,29
PDM 2 155+000	0,5…1,0	19,25	47,68	148,23	115,62	37,85	0,61	-	118,51	201,47
	1,0…1,5	5,6	14,48	40,04	31,23	44,86	0,81	0,79	81,72	106,24
	1,5…2,0	4,2	10,86	30,03	23,42	46,19	0,86	0,71	72,84	80,12
	2,0…2,5	4,4	11,80	29,39	22,93	46,29	0,86	0,73	75,41	82,95
	2,5…3,0	6,6	17,71	44,09	34,39	44,40	0,80	0,86	87,93	131,89
PDM 3 155+000	0,5…1,0	8,4	20,80	64,68	50,45	42,48	0,74	0,93	92,91	157,94
	1,0…1,5	5	12,93	35,75	27,89	45,39	0,83	0,76	78,22	86,04
	1,5…2,0	3,8	9,83	27,17	21,19	46,64	0,87	0,69	69,75	76,72
	2,0…2,5	3,6	9,66	24,05	18,76	47,18	0,89	0,69	69,22	76,14
	2,5…3,0	5,6	15,02	37,41	29,18	45,18	0,82	0,81	82,86	107,71
PDM 4 156+000	0,5…1,0	12,6	31,21	97,02	75,68	40,30	0,68	1,17	105,43	179,22
	1,0…1,5	6,4	16,55	45,76	35,69	44,22	0,79	0,84	85,84	128,77
	1,5…2,0	5,2	13,45	37,18	29,00	45,21	0,83	0,77	79,43	87,38
	2,0…2,5	5,8	15,56	38,74	30,22	45,02	0,82	0,82	83,94	109,12
	2,5…3,0	6,2	16,63	41,42	32,30	44,70	0,81	0,84	86,00	129,00
PDM 5 156+500	0,5…1,0	12,20	30,22	93,94	73,27	40,48	0,68	1,14	104,43	177,53
	1,0…1,5	6,80	17,58	48,62	37,92	43,92	0,78	0,86	87,72	131,57
	1,5…2,0	5,60	14,48	40,04	31,23	44,86	0,81	0,79	81,72	106,24
	2,0…2,5	7,00	18,78	46,76	36,47	44,11	0,79	0,89	89,75	134,62
	2,5…3,0	7,20	19,32	48,10	37,51	43,97	0,78	0,90	90,62	154,05
PDM 6 157+000	0,5…1,0	10,8	26,75	83,16	64,86	41,15	0,70	1,07	100,67	171,13
	1,0…1,5	6,8	17,58	48,62	37,92	43,92	0,78	0,86	87,72	131,57
	1,5…2,0	6,6	17,07	47,19	36,81	44,07	0,79	0,85	86,79	130,19
	2,0…2,5	7,2	19,32	48,10	37,71	43,97	0,78	0,90	90,62	154,05
	2,5…3,0	8,2	22,00	54,78	42,73	43,33	0,76	0,96	94,63	160,87
PDM 7 157+500	0,5…1,0	4,40	10,90	33,88	26,43	45,64	0,84	0,71	72,94	80,24
	1,0…1,5	4,00	10,34	28,60	22,31	46,41	0,87	0,70	71,33	78,47
	1,5…2,0	6,40	16,55	45,76	35,69	44,22	0,79	0,84	85,84	128,77
	2,0…2,5	7,60	20,39	50,77	39,60	43,71	0,78	0,92	92,28	156,88
	2,5…3,0	9,20	24,68	61,46	47,94	42,74	0,75	1,02	98,18	166,91
PDM 8 158+000	0,5…1,0	3,6	8,92	27,72	21,62	46,55	0,87	0,67	66,75	73,42
	1,0…1,5	3,6	9,31	25,74	20,08	46,88	0,88	0,68	68,08	74,89
	1,5…2,0	3,6	9,31	25,74	20,08	46,88	0,88	0,68	68,08	74,89
	2,0…2,5	4	10,73	26,72	20,84	46,72	0,88	0,71	72,47	79,71
	2,5…3,0	5	13,41	33,40	26,05	45,71	0,84	0,77	79,36	87,29

The analysis of the data presented in the tables 2 and 3, particularly the values of porosity and the linear deformation modulus, determined by penetration [2], shows that on the investigated depth the soils in the ground stratification show an average to good consolidation. Nevertheless, the presence of higher porosity values and lower linear deformation modulus values is found on certain depth intervals, certainly contributing to the severe degradations, such as cracking, settling and rutting, occurring on certain areas on the road.

The clay samples from the realized drillings were subjected to tests to determinate some of the main geotechnical characteristics [3] proper to highly swollen and contracted soils (PUCM), in order to determine the activity potential of the clay soils found in the stratification of the foundation ground (table 4).

Table 4 Activity assessment of the clay soils found in the foundation ground on DN 57 km 153+000…158+000

Drilling	Sample quota	Geotechnical characteristics specific to active soils				Evaluation of de soil activity
		Plasticity index I_p [%]	Volume contraction C_v [%]	Free swelling U_L [%]	Plasticity criterion C_p [%]	
F 1	-0,80	54,0	84,0	110,0	44,2	Active
	-2,00	60,1	95,8	150,0	47,3	Active
F 2	-1,00	53,8	96,2	135,0	44,1	Very active
	-1,80	52,4	99,7	140,0	44,3	Very active
F 3	-1,00	40,9	85,2	98,0	32,3	Active
	-2,00	55,3	104,4	130,0	45,9	Very active
F 4	-1,00	36,4	72,6	105,2	28,5	Active
	-2,00	53,0	105,0	135,0	41,8	Very active
F 5	-1,00	49,2	98,0	120,0	40,6	Active
	-2,00	47,6	98,6	125,0	35,2	Active

3. CONCLUSIONS

The analysis of the data centralized in table 4 showed that down to the depth of 2,0 m the clay found in the stratification of the foundation ground is active and very active.

The correlation of the high activity potential of the clay layer found immediately beneath the road pavement, with the preponderance of the road degradations such as longitudinal cracking, leads to the conclusion that at high pluviometric and temperature variations the active and very active character of the clay in the road bed represented one of the main causes of the occurrence and development of the degradations on the investigated road section.

The lack of water collection and evacuation systems on certain areas of the road section, respectively the faulty functioning of the existing ones, have accentuated the activity of the clay soil under the road pavement and the loss of its bearing capacity, representing another main cause of the aggravating damage occurring in the road pavement. Therefore, a primary mandatory condition in the rehabilitation of this road section would be to find and apply adequate and efficient technical solutions to evacuate the water in the road area.

Due to local morphological conditions, on certain areas of the drainage, the level of the ground in the immediate proximity of the shoulders is higher than them, creating no possibility to evacuate the water gravitationally [4].

Given the fact that longitudinally too the gravitational drainage is difficult due to the morphology of the grounds, the recommendation was to raise the road on this section, thus creating the possibility to realize water evacuation systems, with a higher longitudinal declivity, as well as to realize underground draining systems (bottom of ditch drains and transversal drains).

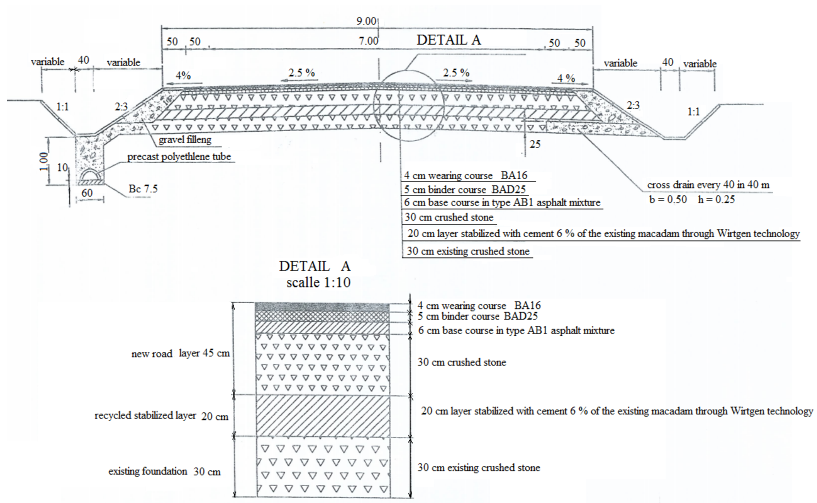

Fig. 4 Cross profile adopted for the rehabilitation of DN 37 km 153+000 and km 158+000

The solution to raise the carriageway (raise of the road) on this section, where most of the pavement is at grade, presents the advantage of eliminating or at least diminishing the negative effect of the high active potential of the foundation ground, by increasing the distance between the active and very active clay layer under the road pavement and its upper structure. Also, by increasing the distance between the level of the carriageway and the clay soil in the road bed, which according to its grading ranges in the category of "very sensitive to freezing", the unfavorable effect of freezing-thawing is reduced or even eliminated.

The conclusions drawn from the studies and research undertaken to clear the main causes of the degradations occurring on this road section of DN 57, the formulated recommendations respectively, have been applied in the feasibility study concerning the strengthening of the section in cause, being concretized through other elements in adopting the cross profile presented in Fig. 4, to be applied between km 153+000 and km 158+000.

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