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THE BEHAVIOUR OF A FLEXIBLE ROAD PAVEMENT UNDER ACCELERATED LOADING TEST

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Abstract: *The accelerated loading test (ALT) facility of the Technical University of Iași was included in the COST 347 database under the name of LIRA (Iași) and it is an intermediate step between laboratory studies and roadway experiments. Road traffic is evolving constantly, the characteristics of heavy vehicles lead to high stresses in the road pavement and the experimental duration is shortened with both the random composition of the traffic and the use of equivalence coefficients are provided. The flexible road structure that was subjected to the accelerated loading test responded improperly, at first, but after reaching a low traffic volume it has shown some progress.*

Key words: *roads, accelerated loading test, traffic, flexible pavement structures, deflection, deformations, bearing capacity, skid resistance test, macrotexture depth.*

1. Introduction

Accelerated testing utility was highlighted in the conclusions of the World Congress (AIPCR/PIARC) in Tokyo, Sydney and Brussels for the validation of the road design methods by assessing long-term behaviour of road pavements, under the influence of high axle loads [1].

The accelerated loading test (ALT) of experimental road pavements is an intermediate step between laboratory studies and experimental sectors - generally of an integrated type - in the current pathway.

The ALT facilities can be:

- With controlled hydro-climatic conditions (example: Pilot Station U. Th. Iasi);
- With random hydro-climatic conditions (example: LCPC Nantes track).

The track that shapes the traffic action can be:

- linear (example: Delft University);
- circular (at most ALT installations);
- quasi-elliptical (example: CEDEX Madrid).

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2. The Execution of the Experimental Pavement from ALT LIRA

The ALT facility of the "Gh. Asachi" Technical University of Iași, is at the third generation, its parameters being improved in 1981-1982 (2nd generation) and 1996-1997, respectively.

This research station was included in the COST 347 database [7] under the name of LIRA (Iași).

In our country, the requirements of a pilot research station for accelerated pavement testing have been identified since the foundation of the first generation (1957), and have been fully valid for over 6 decades [2].

In Figure 1 it is presented the ALT LIRA facility and in order to ensure the reliability of the traffic simulation system, the mechanical part consisted of three subassemblies:

(a) the metal structure;
(b) wheels subassembly;
(c) two beams that provide elastic support for the arm of the dual wheel assembly.

In Figure 2 it is shown the pavement structure with the types of materials used and the thickness for each layer.

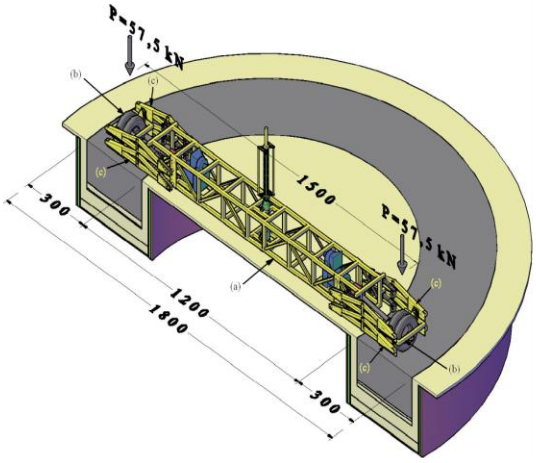

Fig. 1. *Image of the ALT-LIRA facility* [1].

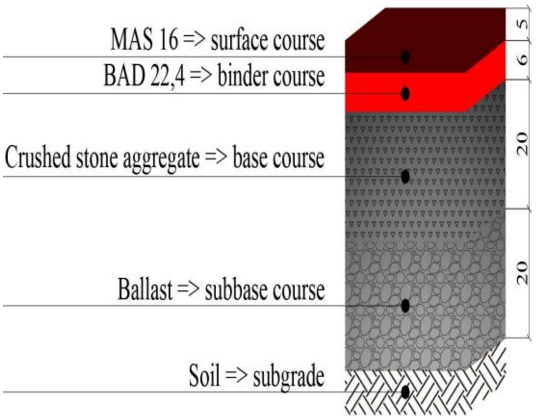

Fig. 2. *Image of the pavement structure used for accelerated loading test*

2.1. Execution of the subgrade

The geotechnical characteristics of the earth, used as subgrade, are:

- grading composition by fractions: clay 28%; silt 58%; sand 12%; gravel 2%.
- natural humidity 30.4%; free swelling - 65%; humus 0 - 1%;
- maximum dry bulk density: ρ_{dmax}= 1664 kg/m^3;
- optimal compaction humidity: w_{opt}= 15.90%.

The grading curve and plasticity characteristics allow the soil (silty clay) to be included in the type 4b – the material quality is mediocre for earthworks, according to Table 1b, from Roman. Doc. STAS 2914-84 [8].

Figure 4 shows the grading curve of the earth, Figure 4 shows the ternary diagram, and in Figure 5 the normal / modified Proctor diagram.

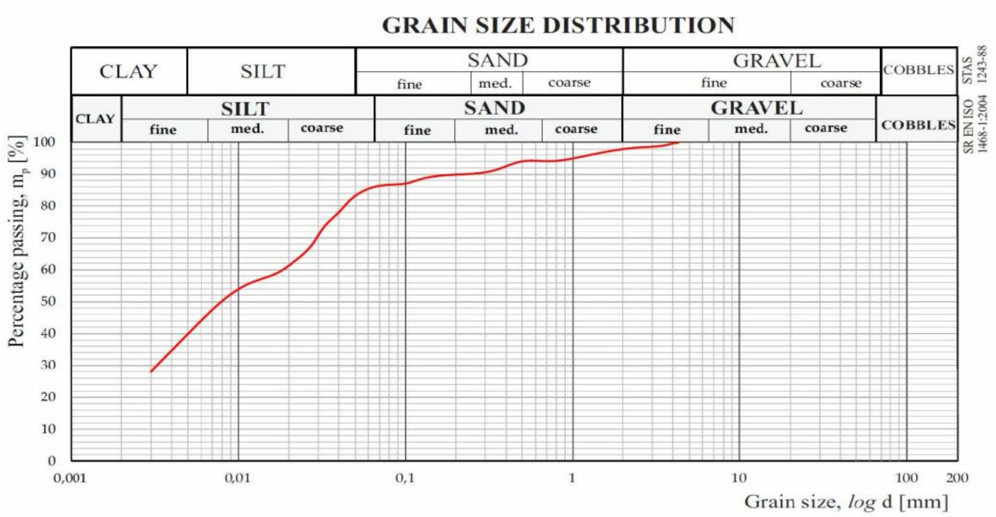

Fig. 3. *Image of the grading curve of the earth used for subgrade*

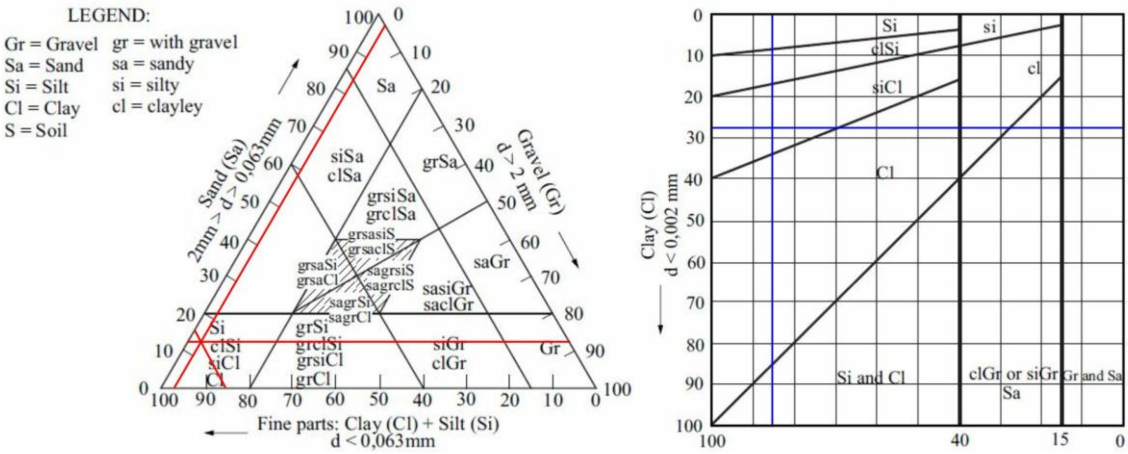

Fig. 4. *Image of the ternary diagram*

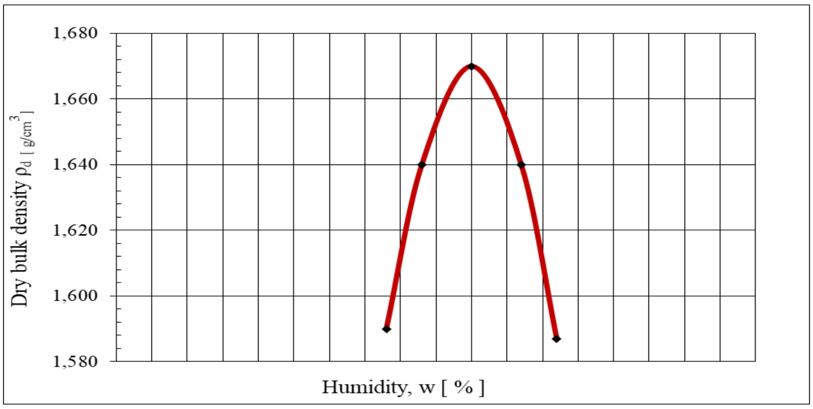

Fig. 5. *Image of the grading curve of the Proctor diagram*

The elasticity modulus at the subgrade level was determined with the light weight deflectometer ZFG 3000 GPS [4], and the obtained values are presented in Table 1.

Elasticity modulus values at subgrade level Table 1

Nr. crt.	E_{vd} [MN/m²]	s/v [ms]	s_1 [mm]	s_2 [mm]	s_3 [mm]	E_{v2} [MN/m²]
1	**34.83**	3.459	0.656	0.647	0.636	**74.05**
2	**37.31**	3.250	0.609	0.612	0.589	**79.68**
3	**33.99**	3.419	0.661	0.677	0.649	**72.15**
4	**34.09**	3.577	0.675	0.66	0.645	**72.37**

According to the Technical Approval 004-07/919-2007 [3], approved for the ZFG 3000 GPS equipment, the compaction rate is greater than 99 %.

2.2. Execution of the subbase course

For the subbase course it was used ballast from the Cristești quarry. Figure 6 shows the grading curve of the aggregate, and in Figure 7 the modified Proctor diagram.

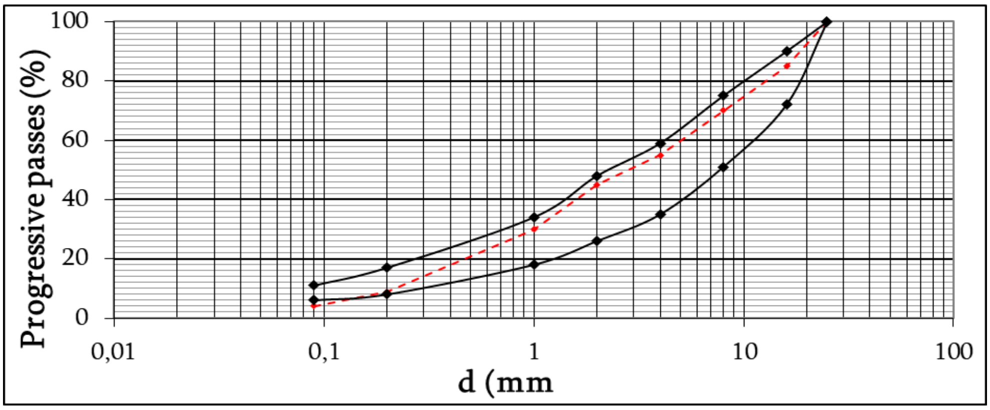

Fig. 6. *Image of the grading curve of the ballast used for subbase*

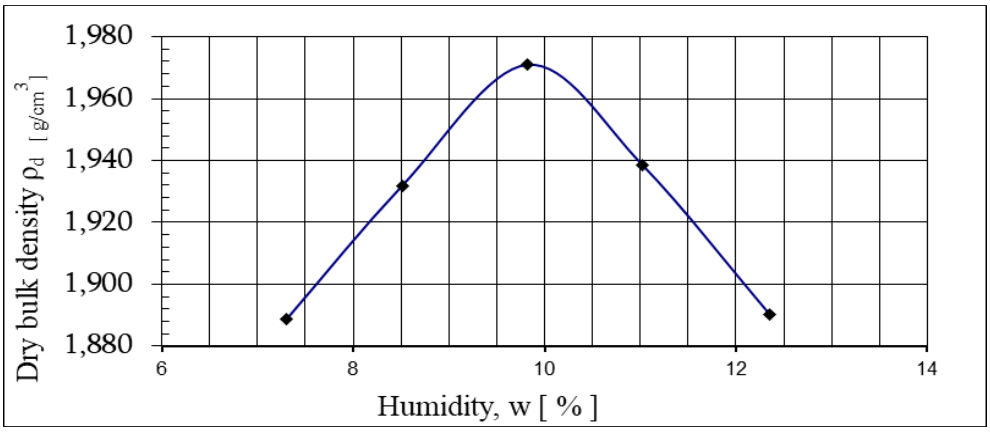

Fig. 7. *Image of the grading curve of the Proctor diagram*

The elasticity modulus at the subbase level was determined with the light weight deflectometer ZFG 3000 GPS, and the obtained values are presented in Table 2.

Elasticity modulus values at subbase level Table 2

Nr. crt.	E_{vd} [MN/m²]	s/v [ms]	s_1 [mm]	s_2 [mm]	s_3 [mm]	E_{v2} [MN/m²]
1	**98.25**	2.371	0.237	0.229	0.221	**238.05**
2	**98.68**	2.425	0.232	0.228	0.223	**239.33**
3	**96.15**	2.213	0.24	0.241	0.222	**231.84**
4	**85.88**	2.360	0.274	0.255	0.257	**202.35**
5	**105.14**	2.265	0.216	0.211	0.216	**258.90**
6	**130.81**	2.365	0.176	0.171	0.169	**343.66**
7	**118.42**	2.284	0.199	0.194	0.177	**301.25**

According to the Technical Approval 004-07/919-2007 [3], approved for the ZFG 3000 GPS equipment, the compaction rate is greater than 100 %.

2.3. Execution of the base course

For the base course it was used crushed stone aggregate from the Dornișoara quarry.

Table 3 shows the grading (particle size analysis) of the aggregate.

Grading of the crushed stone aggregate Table 3

	Sieve / screen passes														
Sieve size [mm]	>63	63	45/50	40	31.5	25	16	8	4	2	1	0.5	0.25	0.125	0.063
Obtained values	-	100	96.2	88.8	74.6	68.7	60.1	49.4	32.5	26.3	19.5	13.8	6.6	5.1	1.6

The elasticity modulus at the base level was determined with the light weight deflectometer ZFG 3000 GPS, and the obtained values are presented in Table 4.

Elasticity modulus values at subgrade level Table 4

Nr. crt.	Evd [MN/m²]	s/v [ms]	s1 [mm]	s2 [mm]	s3 [mm]	Ev2 [MN/m²]
1	**120.97**	2.383	0.202	0.178	0.179	**309.74**
2	**130.81**	2.365	0.176	0.171	0.169	**343.66**

According to the Technical Approval 004-07/919-2007 [3], approved for the ZFG 3000 GPS equipment, the compaction rate is greater than 100 %.

2.4. Execution of the binder course

For the binder course it was used asphalt mixture, type BAD 22.4 [5], from the Eky-Sam mixing plant. Table 5 shows the grading of the used aggregates.

Grading of the used aggregates for asphalt type BAD 22.4 Table 5

	Sieve / screen passes													
Sieve size [mm]	31.5	25	22.4	16	11.2	8	5.6	4	2	1	0.5	0.25	0.125	0.063
Chippings 16-31.5 mm	-	100	88.9	14.7	0.18	-	-	-	-	-	-	-	-	-
Chippings 8-16 mm	-	-	100	97.3	44.8	5.30	1.13	0.46	-	-	-	-	-	-
Chippings 4-8 mm	-	-	-	-	100	95.9	43.8	4.26	0.56	-	-	-	-	-
Crushed sand 0-4 mm	-	-	-	-	-	100	99.7	95.9	71.2	50.2	35.5	24.8	15.1	8.57
Natural sand 0-4 mm	-	-	-	-	-	100	99.9	99.3	76.4	61.2	49.2	23.7	6.51	0.95
Filler	-	-	-	-	-	-	-	-	-	100	99.5	98.95	98.5	86.0

The physical and the mechanical characteristics of the asphalt mix test specimens prepared in the laboratory with five dosages of bitumen are presented in Table 6.

The characteristics of the asphalt mixture type BAD 22.4 Table 6

Characteristic	UM	Bitumen dosage, %					Acc. AND 605/2016
		4.10	4.30	**4.50**	4.70	4.90	
Stability at 60°C (S)	kN	6.6	7.2	**7.8**	7.4	6.9	6.5 … 13
Coefficient of discharge (I)	mm	2.31	2.58	**2.93**	3.17	3.65	1.5 ... 4.0
S/I ratio	kN/mm	2.86	2.79	**2.66**	2.33	1.89	≥ 1.6
Apparent density	kg/m^3	2.401	2.420	**2.439**	2.436	2.427	-
Water absorption	% volume	3.907	3.114	**2.507**	2.356	2.188	1.5 ... 6
Water sensibility	%	-	-	**75.0**	-	-	≥ 80

Optimum bitumen content, based on the weight of the mixture, is 4.50 %.

The technological recipe for manufacturing the asphalt mixture type BAD 22.4 is presented in Table 7.

The technological recipe of the asphalt mixture type BAD 22.4 Table 7

Aggregates, %	Asphalt mixture, %
Chippings 16-31.5 mm = 22.00	**21.01**
Chippings 8-16 mm = 30.00	**28.65**
Chippings 4-8 mm = 10.00	**9.55**
Crushed sand 0- 4 mm = 17.00	**16.23**
Natural sand 0-4 mm = 17.00	**16.23**
Filler = 4.00	**3.82**
Bitumen D50/70 = -	**4.50**
Total aggregate = **100.00**	**-**
Total asphalt mixture	**100.00**

2.5. Execution of the surface course

For the surface course it was used asphalt mixture, type MAS 16 [5], from the Eky-Sam mixing plant. Table 8 shows the grading of the used aggregates.

Grading of the used aggregates for asphalt type MAS 16 Table 8

	Sieve / screen passes													
Sieve size [mm]	31.5	25	22.4	16	11.2	8	5.6	4	2	1	0.5	0.25	0.125	0.063
Chippings 16-31.5 mm	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chippings 8-16 mm	-	-	-	97.7	-	5.9	-	-	-	-	-	-	-	-
Chippings 4-8 mm	-	-	-	100	-	100	17.7	1.0	-	-	-	-	-	-
Crushed sand 0-4 mm	-	-	-	100	-	100	98.9	82.7	65.4	-	-	26.4	-	18.7
Natural sand 0-4 mm	-	-	-	100	-	100	100	100	100	-	-	91.6	-	75.9
Filler	-	-	-	-	-	-	-	-	-	-	-	-	-	-

The physical and the mechanical characteristics, for different types of fibre dosage, of the asphalt mix test specimens prepared in the laboratory are presented in Table 9.

The characteristics of the asphalt mixture type MAS 16 Table 9

Characteristic	UM	Fibre dosage, %		
		0.4	0.5	0.6
Apparent density	Mg/m^3	2.36	2.35	2.33
Voids content	%	2.6	3.3	3.8
Voids content filled with bitumen	%	83.2	79.4	76.9
Max. density	Mg/m^3	2.43	2.43	2.42
Schellenberg test	%	0.12	0.08	0.04

The physical and the mechanical characteristics, of the asphalt mix test specimens prepared in the laboratory with five dosages of bitumen are presented in Table 9.

The characteristics of the asphalt mixture type MAS 16 Table 10

Characteristic	UM	Bitumen dosage, %				
		5.2	5.4	**5.6**	5.8	6.0
Apparent density	Mg/m^3	2.32	2.33	**2.35**	2.36	2.37
Voids content	%	4.5	3.8	**3.3**	2.7	2.1
Voids content filled with bitumen	%	72.3	76.3	**79.4**	83.1	86.8
Max. density	Mg/m^3	2.43	2.43	**2.43**	2.42	2.42
Schellenberg test	%	0.02	0.05	**0.08**	0.11	0.15

Optimum bitumen content, based on the weight of the mixture, is 5.60 %.

Optimum fibre content, based on the weight of the mixture, for the optimum bitumen content of 5.60 %, is 0.50 %.

3. Behaviour of the Experimental Pavement under Accelerated Loading Test

The experimental pavement was monitored under accelerated loading test up to 250000 wheels assembly passes. This traffic is assimilated in the current roadway with a volume of 1,800 m.s.a. (million standard axles) of 115 kN.

3.1. The permanent deformations in the pavement surface course

The permanent deformations, at every 50000 passes, in the pavement surface course, are presented in Figure 8, for the first wheel, and in Figure 9, for the second wheel.

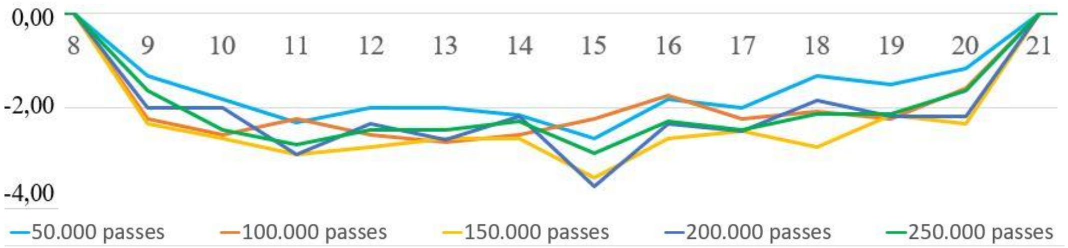

Fig. 8. *Image of the permanent deformations, at every 50000 passes, on the first wheel*

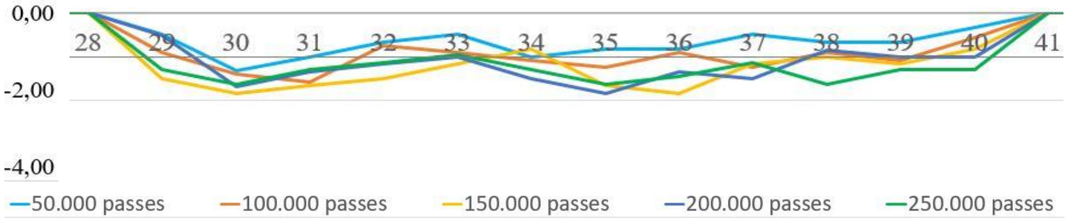

Fig. 9. *Image of the permanent deformations, at every 50000 passes, on the 2nd wheel*

3.2. The bearing capacity of the road structure

The bearing capacity of the road structure was determined with the Benkelman Deflection Beam [6], and the results, at every 50000 wheels assembly passes, are presented in Table 11, and in Figure 10.

The bearing capacity of the road structure Table 11

Number of passes	Average values of calculated deflections			Average deflection		Characteristic deflection
	$d_{2.4}$	$d_{5.0}$	d	d_{BM}	d_{BM20}	d_c
	[1/100 mm]			[1/100 mm]		
0	7.57	7.92	8.26	9.50	9.78	14.06
50000	14.47	16.89	19.30	22.20	22.86	27.14
100000	12.06	13.44	14.82	17.04	17.55	36.21
150000	14.82	16.89	18.96	21.80	22.45	37.17
200000	18.61	20.68	22.75	26.16	29.16	36.91
250000	24.13	25.86	27.58	31.72	34.72	41.46

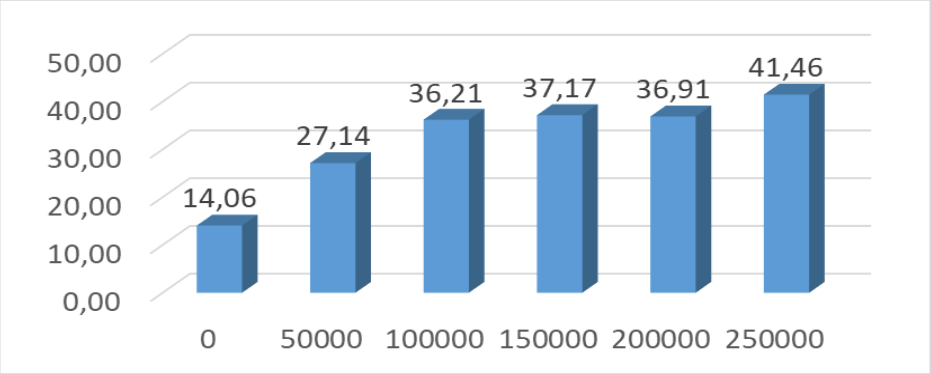

Fig. 10. *Image of the evolution of bearing capacity of the road structure*

3.3. The determination of slip/skid resistance of the surface course

The adhesion of the surface course was determined with the SRT (Skid Resistance Test) equipment, and the results, are presented in Table 12.

The adhesion of the surface course using the SRT equipment Table 12

Number of passes	Cross section	Measured SRT [PTV]					Corrected SRT [PTV]
		1	2	3	4	5	
0	On wheel track	71	70	71	71	72	**71**
	Outside the wheel track	72	71	72	72	73	**72**
150000	On wheel track	53	53	53	53	53	**53**
	Outside the wheel track	unchanged					
250000	On wheel track	52	52	52	52	52	**52**
	Outside the wheel track	unchanged					

3.4. The determination of pavement surface macrotexture depth

The pavement surface macrotexture depth was determined using the volumetric patch technique, and the results, are presented in Table 13.

The pavement surface macrotexture depth Table 13

Number of passes	Cross section	Volume [mm^3]	Measured diameter [mm]				Average diameter [mm]	MTD [mm]
			1	2	3	4		
0	On wheel track	25000	195	200	188	191	194	0,85
	Outside the wheel track	25000	192	198	179	188	189	0,89
150000	On wheel track	30000	255	260	256	258	257	0,58
	Outside the wheel track	unchanged						
250000	On wheel track	16000	200	210	190	205	201	0,50
	Outside the wheel track	unchanged						

4. Conclusions

Road traffic is evolving constantly, both in terms of intensity and composition - where, due to transport efficiency considerations, the characteristics of heavy vehicles lead to high stresses in the road pavement.

Accelerated loading test of the experimental road structures - in pilot stations (such as the Iasi pilot station) - represents an intermediate stage between the laboratory studies and the integrated experimental sectors from the roadway.

It is ensured that the experimental duration is shortened and that both the random composition of the traffic and the use of equivalence coefficients are provided.

Permanent deformations up to 250,000 passes on the same trace, result in values below 5 mm, in all analysed points. The deflection for establishing the bearing capacity of the road structure, is very good at initial determinations and good at the following determinations. The initial roughness, determined with the SRT and the volumetric patch technique, was in limits, but after conducting the test on the same trace, due to the action of the very high tangential forces, is off limits.

Research into the behaviour of the flexible road structure, in time, under the action of accelerated loading test, will continue until bearing capacity is exceeded.

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