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The use of accelerated circular track for performance evaluation and validation of technical specifications for the asphalt mixes stabilized with various fibers, in Romania

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Summary

The research presented in this paper has been undertaken in the frame of Accelerated Load Testing (ALT -LIRA) facility at the technical University "Gh. Asachi" of Iassy, for performance evaluation and validation of national technical specifications for the asphalt mixes stabilized with various fibers, used for the construction of bituminous road pavements in the actual effort of road rehabilitation in Romania. The performance of five types of mixes involved in this research has been monitored and evaluated at various stages of the accelerated experiment before reaching the complete failure and compared between them and with the performance of a reference mix on a witness sector. Finally, specific failure criteria and valuable recommendations have been proposed for the use of practice industry, in this country.

KEYWORDS: stabilized asphalt mix, accelerated performance testing, permanent deformation, failure criteria.

1. INTRODUCTION

Since the year 1993, marking the beginning of a huge and resolute effort of National Administration of Roads, directed towards the rehabilitation the public road network, the Romanian specialists have been confronted with the difficult task of selection and implementation of new asphalt technologies, in order to replace the old and outdated ones, and to permit the design and construction of stronger and better flexible pavements. These new pavements were seek to exhibit a better performance of the existing road network, to the severe traffic and climatic conditions, characterized by the sudden increase of the traffic volume, parallel with the adoption of the axle load of 115KN, and by huge temperature gradients between the hot and cold seasons.

A first and successful step realized in the frame of this strategy, was the research and implementation in the current road rehabilitation practice of the MASF16/8

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type mixes [1], [2], stabilized with various fibers, customized to the specific technical properties if the Romanian aggregates and binders. The application of these superior mixes is now generalized on all road rehabilitation projects, in this country.

A second step was the adoption and implementation of the specific testing technology [3] for assessing the susceptibility of these mixes to rutting, in the conditions of very high temperatures reached in the asphalt pavement during the summers, for some regions, these temperatures over passing 65°C, according SHRP Algorithm [4].

A third and very important step was the undertaking of accelerated testing of these type of mixes, stabilized with indigenous or imported fibers, in order to assess and validate, in a short time, their behavior and performance under the specific new adopted axle load of 115 kN. This paper describes the approach and presents the results of a two year research study undertaken in the frame of Accelerated Load Testing (ALT) facility at the Technical University "Gh. Asachi" of Iassy, for performance evaluation and validation of technical specifications for the asphalt mixes stabilized with various fibers, used for the construction of bituminous road pavements in the frame of the ongoing effort of road rehabilitation in Romania. Five types of mix have been selected for this study. The performance of those five types of mixes involved in this research has been monitored and evaluated at various stages of this experiment, under loading on the accelerated circular track, before reaching the complete failure and compared between them and with the performance of classical reference mix, laid on a witness sector. Finally the study was completed with the laboratory investigations on cores in order to assess the evolution of the asphalt mix properties under the total of 2,2 x 10^6 passes of the standard axle load of 115 kN.

2. THE ACCELERATED TESTING FACILITY

Full scale accelerated pavement is defined [5] as "the controlled application of a prototype wheel loading ,at or above the appropriate standard (legal) load limit, to a particular structural pavement system, in order to determine the pavement response and performance under a controlled, accelerated, accumulation of damage in a compressed time period". The research facility of Technical University "Gh. Asachi" of Iassy is an experimental site, named LIRA (Laboratorul de Incercari Rutiere Accelerate) housing a full-scale accelerating circular testing track, its name and main technical parameters being described also in the related literature[6], among those 32 accelerated facilities developed all over the world after the 1962 year. In fact the first generation of this facility has been developed at the Iassy Technical University, since 1957 year, and the actual third generation is the only existing facility of this type in this country and also in the South-East European Region, now being actively involved in the EC research transport program: COST 347.[7] The accelerated road research facility from Iassy University is one of those provided a circular track dedicated to the experimentation of various road pavement structures. The main modifications brought to the initial facility along the last 45 years, consisted mainly in the increase of the loading capacity and the extension of the length of running truck [8], [9]. Thus, with the first generation facility, which was functioned during the years 1957…1983, the length of the running arm was of 10 meter, and its mass of 4.6 tone transmitted to the investigated road structure a load of 23kN by two simple wheels, placed at the ends of the metal arm, the total length of the circular track being of 31.4 meter. With the second generation, built on a new location and made functional since 1983 year, the new running installation had a total mass equal with that of the standard design vehicle: A13, and transmitted to the road structures a load of 45.5 kN by two groups of twin wheels. The length of the arm has been increased to 15 meter, so that the total length of the circular track have reached to 47.1m, thus becoming possible the simultaneous testing of many sectors with representative lengths, and with a greater number of measuring points, in order to get sufficient data for statistical interpretation. The adoption in of the new standard axle load of 115 kN, in the 1997 year, led to the development of the third generation facility [10], [11], equipped with a new arm with a sufficient mass, capable to assure this new load. The running speed during the loading was maintained at 20 Km/h, from both security and technical reasons (the applied frequency of loads 4.25^{-1} sec, is quite sufficient).

3. INSTRUMENTATION

Even the instrumentation was not at the level of other similar accelerated facilities from abroad, the quantification of the main test parameters has been achieved, in order to get significant conclusions. These parameters, the instrumentation used and their precision and other useful information are given in Table 1.

Table 1. The main parameters investigated during the accelerated testing on the circular track

No	The investigated parameter	The instrumentation	Precision	Number of investigated points on the circumference	Position	The level from the pavement surface
1	Total deformation (wearing + permanent deformations)	The reference straightedge	0.01mm	40	Transverse profile	At the pavement surface
2	Elastic deformations (deflections)	Soiltest/ Benkelman beam or FWD	0.01mm	All	In the middle of the circulated strip	At the pavement surface
3	The radius of curvature	Device for measurement of the radius of curvature	0.01mm	All	In the middle of the circulated strip	At the pavement surface
4	The bearing capacity of the bearing structure	Loading plate	0.01mm for deformations	8	In the middle of the circulated strip	At the subgrade level and at the surface of each layer
5	The level of the underground water	Straightedge	5mm	4	At the inner circumference of the track	0.5….1.5m
6	The temperature	Thermocouple (copper/ constantan)	0.5ºC	4	Any point	0.5….1.5m
7	Soil moisture content in subgrade	Normal soil sampling/ using standard methods/ drying)	0.1%	4…10	Any point	0.5….1.5m

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4. PLANNING THE EXPERIMENT

Five sectors having an identical road pavement structures, each one equipped with a wearing course having the same thickness (4 cm) but realized from a specific mix; four of them has been equipped with asphalt mixes stabilized with indigenous or imported fibers, selected from those currently used in the road rehabilitation practice and the fifth one was equipped with a classical mix (asphalt concrete type BAR16) and considered as an witness, reference sector. All five experimental sectors have been subjected to accelerate testing, on the circular track, under the repeated axle load identical with that of the standard vehicle. The adopted road pavement structure corresponded with that currently used in the ongoing road rehabilitation program, phase II, with a small reduction (20 cm instead of 23 cm) brought to the thickness of the foundation layer constructed from granular materials (ballast) stabilized with cement, as consequence of the reconsideration of the higher bearing capacity of the subgrade soil in the process of verification of the standard structural design. Finally, the following pavement structure has been adopted:

- subgrade layer (ballast): 25 cm;
- base course layer (natural aggregates stabilized with 5% cement): 20 cm;
- asphalt base course layer: 8cm;
- asphalt binder course: 4cm;
- asphalt wearing course: 4cm;

For the construction of the experimental sector on the circular track have been accepted and used only those materials proving to meet the quality conditions specified by the legal technical norms. As the objective of the research was the performance study of asphalt mixes with better resistance to the rutting phenomena induced by the heavy traffic, four types of asphalt mixes stabilized with various fibers, having compositions as shown in Table 2, have been selected.

Table 2. The asphalt mixes involved in the accelerated experiment

The component	Type of ix involved in the accelerated experiment				
	MASF 16 stabilized with imported cellulose fiber 1	MASF 16 stabilized with imported cellulose fiber 2	MASF 16 stabilized with indigenous textile fiber 3	MASF 16 stabilized with indigenous textile fiber 4	Classical asphalt concrete BAR 16
Chippings 8/16 (%)	41.8	41.9	37.5	37.5	42.5
Chippings 3/8 (%)	27.2	27.3	25.3	25.3	22.0
Quarry crashed send 03 (%)	16.1	16.2	24.4	24.4	22.8
Filler-lime stone (%)	8.3	8.4	6.6	6.6	7.6
Bitumen D60-80 (%)	6.5	6.2	6.2	6.2	5.1
Fibers (% from mix)	0.3	0.3	0.3	0.3	–

The imported (Germany) cellulose fibers used in the experiment have dimensions of the order of microns, whereas the indigenous textile fibers are obtained by whirling of individual threads, their length being of 15..30 mm and the diameter of over 1mm. Laboratory studies for establishing the mix composition has been undertaken for each type of mix, taking into consideration the provisions of the existing technical specifications (SR 174/97 for mixes and Technical Agreement for cellulose fibers), and seeking to obtain a volume of air voids in the compacted mix of around 3.5%. Thus the bitumen content considered during the study was in the range of 6.2% to 7.2% for the MASF type mixes and in the range of 5.7% to 6.2% for the BAR16 mix. The percent of fiber was 0.3% from the mass of mix. At least three alternatives of bitumen content have been studied for each type of mix , the maximum limits (7.2% for the asphalt mixes stabilized with cellulose fibers and 7.2% for the mixes stabilized with textile fibers) being established in accordance with the requirements imposed by the Schellenberg Test (maximum 0.2%) [12].

The asphalt mixes have been prepared in a DS158 installation with a productivity of $40m^3/h$, the fibers being introduced directly in the mixer, the mixing time for the dry mix (aggregate + filler + fiber) being of 30 seconds, the mixing being continued after the adding of bitumen for another 30 seconds. The laying of the asphalt mix has been made manually, followed by compaction with the vibrating roller with a total mass of 1500Kg. The wearing layer, in those five alternatives has been laid accordingly, each sector having a total length of 9.5 m. The temperature conditions were carefully observed and recorded during al the process and the required compaction degree for each layer has been achieved. Samples taken from each mix during the laying process have been investigated in terms of composition and mechanical characteristics.

5. CONDUCTING THE EXPERIMENT

All five sectors have been subjected to the accelerated testing under the running installation having a total weight equal with that of the standard axle load (115kN), this load being transmitted to the pavement through a set of twin wheels placed at the end of the running installation. By the symmetric assembly of this installation, a circulated on strip o of 65 cm width, on which the wheels are passing two times with each complete rotation of the installation arm, with a frequency of load of 4.25 sec^{-1} for the running speed of 20Km/h. The total number of $2,2x10^{6}$ have been achieved during a period of 22 months (January 2000…October 2001), this period including two hot and two cold seasons, the temperature recorded in the closed space of the accelerated facility being in the range of 10°C to 15°C during the cold season and of 35°C to 37°C during the hot one.

As it was mentioned before, one of the aims of the experiment was the testing of the capacity of the investigated asphalt mixes stabilized with fibers to resist the rutting trend and in this respect the main parameter monitored during the test was the permanent deformation of the pavement, measured at various stages of loading. Thus measurement of the surface level of the wearing course has been performed, with the precision of 0.1 mm, in a number of eight transverse profiles for each sector, the distance between the measured points on the same profile being of 20mm, as shown in Fig.1.

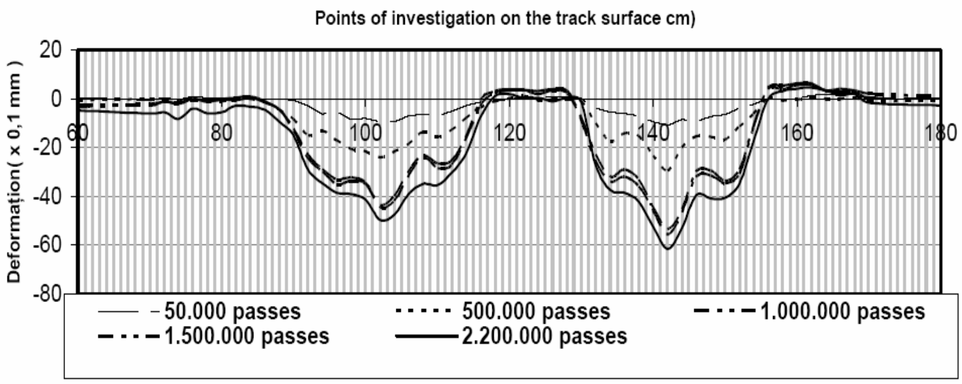

Fig. 1 Average permanent deformations - Sector 1, Asphalt mix with cellulose fiber 1

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By making the difference from the initial recording, made just before submitting the pavement to the accelerated traffic, the value of permanent deformation recorded for each stage of loading has been obtained, the measurements being performed at the following loading stages: 10,000, 100,000 passes, and then at each additional $100x10^3$ passes till the achievement of the final traffic of 2,2 $x10^6$ passes of the standard axle load of 115kN.

Fig.1 presents the permanent deformations recorded during the test for the experimental sector equipped with an wearing course realized from asphalt mix type MASF16, stabilized with cellulose fiber type 1, after five significant stages (e.g. after 50,000, 500,000, 1,000,000, 1,500,000 and 2,200,000 passes). For the other investigated mixes have been recorded diagrams with similar shapes with different values. In relation with the Fig.1, one may observe that the main permanent sag deformations have been recorded on the strips corresponding to the wheel passes, whereas on the areas between the wheels and on the exterior of the circulated strips, rejection of material in the form of crests, specific to the rutting phenomena, have been recorded. The highest deformations observed on the right side of the diagram are corresponding to the inner wheel from the running assembly, this wheel being a motor one.

Further on, the evolution of the permanent deformations obtained by statistical processing of recorded data is presented in Fig.2, each of the five investigated mix being represented by distinct conventional signs:

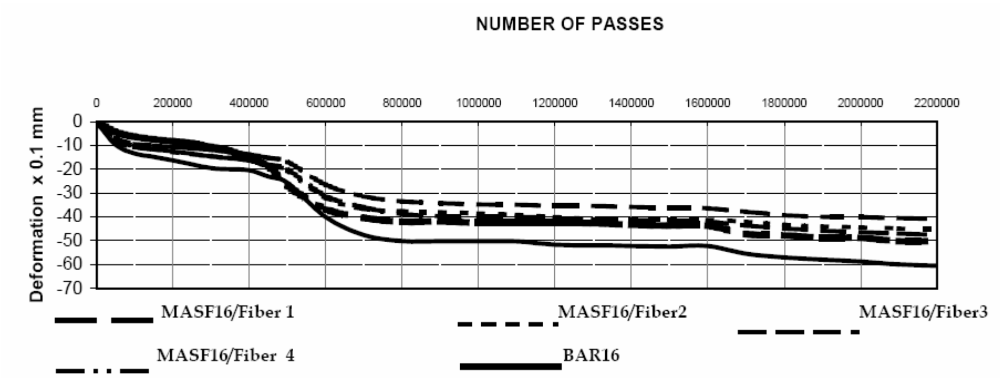

Fig. 2 Evolution of permanent deformations

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From the analysis of this diagram one may observe the following:

- there is a significant difference between the behavior of the mixes stabilized with fibers and that of the witness mix (BAR16) which presents the highest permanent deformations;
- five distinct stages can be observed in the evolution of the permanent deformations, in accordance with the number of cumulated number of passes as follows:
    - stage I: with a traffic between 0 and 50,000 passes, representing the supplementary consolidation of the mix, under traffic, characterized by a significant rate of development of the permanent deformations;
    - stage II: with a traffic between 50,000 and 400,000 passes, realized during the cold season of the year 2000 (February…May), characterized by a reduced rate of permanent deformations;
    - stage III: with a traffic between 400,000 and 800,000 passes, realized during the hot season of the year 2000 (June … September), characterized by a relative greater rate of the development of deformations;
    - stage IV: with a traffic between 0.8 x 10^6 and 1.7 x10^6 passes, realized during the cold season (October 2000 … May 2001), characterized by a very low rate (near zero) of development of permanent deformations;
    - stage V: with a traffic between 1.7x 10^6 and 2,2 x 10^6 passes, realized during the a relative hot period (June…September 2001), characterized by a rate of deformation higher then the preceding one;

For the quantification of the rate of accumulation of the permanent deformations, for each stage the slope of the specific evolution curves (deformation/ number of passes) have been calculated, these slopes being shown in Table 3.

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Table 3. The slopes of the evolution curve of the permanent deformations, on various stages of the experiment

The experimental sector	The type of mix in the experiment	The stage				
		I	II	III	IV	V
1	MASF16 with cellulose fiber 1	0.220	0.045	0.155	0.004	0.020
2	MASF16 with cellulose fiber 2	0.240	0.040	1.108	0.007	0.018
3	MASF16 with cellulose fiber 3	0.200	0.063	0.108	0.004	0.018
4	MASF16 with cellulose fiber 4	0.180	0.057	0.090	0.007	0.022
5	BAR16 (witness sector)	0.380	0.066	0.152	0.011	0.028

This evolution demonstrates the very strong influence of temperature reached in the asphalt layer on the development of the rutting phenomenon, this being also confirmed by similar experiments, conducted on the accelerated circular track at LCPC Nantes [14], where for the asphalt binder used in their experiment (penetration 50/70) a temperature level of 45°C, has been defined as a critical one for the initiation of the rutting phenomenon.

As the rutting distress was developed also along the circulated strips, longitudinal profiles have been performed along this direction, based on the maximum deformation values recorded during various stages of the experiment. Fig.3 presents the average permanent deformations of the pavement, in longitudinal profile, recorded during the testing on the experimental sector 1.

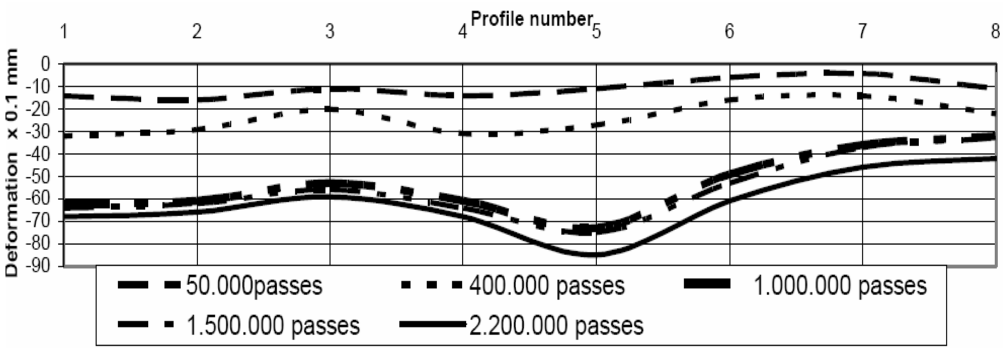

Fig.3. Average permanent deformations of the pavement, in longitudinal profile, recorded during the testing of the experimental sector 1

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The maximum values of the depth of the rutting, recorded in longitudinal profile, at various stages of the experiment for each experimental sector and circulated strip are presented in Table 4. Table 5, presents the differences between the maximum a minimum depths of rutting, recorded in longitudinal profile on these sectors.

Table 4. The maximum values of the depth of the rutting, recorded in longitudinal profile, at various stages of the experiment for each experimental sector and circulated strip

The recorded traffic	The circulated strip	The experimental sector				
		1	2	3	4	5
$50x10^3$ passes	Exterior	20	8	16	10	20
	Interior	16	16	20	18	19
$2,2x10^6$ passes	Exterior	74	59	72	60	97
	Interior	85	66	79	68	85

Table 5. The differences between the maximum and minimum deformations recorded in longitudinal profile on each experimental sector

The recorded traffic	The circulated strip	The experimental sector				
		1	2	3	4	5
$50x10^3$ passes	Exterior	20	8	16	10	20
	Interior	16	16	20	18	19
$2,2x10^6$ passes	Exterior	74	59	72	60	97
	Interior	85	66	79	68	85

Finally the study was completed with the laboratory investigations on cores in order to assess the evolution of the asphalt mix properties under the total of $2,2x10^6$ passes of the standard axle load of 115 kN. A number of 36 cores have been taken from the experimental sectors and the mix susceptibility for rutting has been investigated at the Road Laboratory of the Romanian Center for Road Engineering Studies, by using the Wheel Tracking equipment, in accordance with the British procedures [16], adapted to the Romanian conditions [17]. These results [10] are fully confirming the main conclusions drawn from the measurements and investigations made on the wheel track, during the development of the experiment. Based on the general results obtained during this experiment and on other specific literature data [18], specific failure criteria and valuable recommendations have been developed [2],[10],[14],[15], for the use in the planning of new accelerated experiments [19], [20], or for road practice industry, in this country ort abroad [7].

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6. CONCLUSIONS. RECOMMENDATIONS FOR ROAD PRACTICE

The following conclusions and recommendations for practice have been derived from the results of this experiment:

1. The laboratory tests performed with the aim of the design of the various mix compositions, or for their quality control during the process of laying and compaction, are attesting slight improvement of the physic and mechanical characteristics of the asphalt mixes stabilized with various types of fibers in comparison with those of the classical mix BAR16. Marshall stability of the stabilized asphalt mixes is significantly improved, but this can not confirm a possible reinforcement effect in case of the use of the textile fibers;
2. The performance, under the repeated passes of the standard axle load of 115 kN appreciated in terms of the values of permanent deformation(depth of rutting) of the asphalt mixes stabilized with various types of fibers is significantly improved in comparison with that of the classical mix, without fibers. It was difficult to make a performance classification between those four types of mixes stabilized with fibers. But was evident that the behavior of the asphalt mixes stabilized with fibers types 1, 2 and 3 was much better than that of the asphalt mix stabilized with fiber type 4., and this conclusion was made known to the decision factors of the Road Agencies, in order to be considered at the selection of materials in the future rehabilitation works.
3. Related with the evolution of the permanent deformations, in time under repeated traffic, the following conclusions can be drawn:
   - the effect of the supplementary consolidation achieved during the first stage of experiment (50,000 passes) became very clear, despite the fact that the temperature was relatively lower;
   - the development of rutting phenomena is strongly influenced by the high temperatures, the most important values of the rutting depth have been recorded during the first hot season, even so the maximum temperature level recorded during the experiment did nit reached the critical temperature level obtained during the similar French experiments [14];
   - during the second hot period, a new trend for the increasing of the rutting depth has been recorded, but at a lower rate, due to the relative low values of the maximum temperatures and also to the existing consolidation;

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4. The distress condition is characterized by both the shape and the depth of rutting in transverse profile and by its shape and evolution in longitudinal direction, along each sector, where, function of the attained values on may reach the complete failure of the structure. Thus, in case of the witness sector, realized with classical mix BAR16, severe trends of corrugations, with an amplitude of over 5 mm, has been observed after a traffic of $2.2x10^6$ passes of the standard axle load of 115kN, whereas on the other sectors this trend was very small (maximum 2..3 mm).

5. Based on the general results obtained during this experiment and on other literature data, specific failure criteria and valuable recommendations have been developed [2], [14], [15], for the use in the planning of new accelerated experiments [19], [20], or for road practice industry, in this country and abroad [7].

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