Maintenance and Rehabilitation

Life extension of porous asphalt pavements through the application of a rejuvenating bituminous emulsion

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Abstract

The BCR - Brisa Concessão Rodoviária network has about 422 km of surface course with porous asphalt, corresponding to 38% of its total extension (1 100 km). The main objective of this paper is to present the study to be developed by LNEC together with BRISA and Latexfalt Ibéria for the characterization and monitoring of the application of a bitumen rejuvenation solution in this type of bituminous mixture, located in the BCR network. One of the most frequent pathologies in this type of surface layer is ravelling, usually due to the premature aging of the bitumen that surrounds the aggregates. This type of pathology leads to increased noise and loss of grip due to the presence of loose aggregates. One of the methods to avoid the increasing of ravelling of the surface layer material, and therefore to increase its life cycle, is to apply a modified emulsion with rejuvenating characteristics of the bitumen of the porous asphalt, preventing the progression of ravelling. The presented solution is a non-evasive method, without the use of milling or the placement of new bituminous mixtures. This technique consists of the rejuvenation of the binder (bitumen) in the porous asphalt mixture, increasing its life cycle. The product used was a rejuvenating bituminous emulsion for porous asphalts, which main function is to return elasticity to the bitumen of the porous asphalt, to avoid ravelling and without reducing its draining capacity.

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1. INTRODUCTION

Porous asphalt (PA) pavements are a type of flexible pavements where the surface asphalt layers typically present an open-graded surface, with a high porosity and a strong water permeability.

This pavement solution has some advantages and also some drawbacks. As major advantages can be referred the contribution of the surface layer to the aquaplaning mitigation under rainy conditions, preventing the reduction of traffic flow volumes. In addition, the porous asphalt has noise reduction properties and presents an important environmental impact, namely by conserving water, reducing runoff and promoting infiltration and replenish aquifers [1-5].

On the other hand, porous asphalt presents some problems, that affect both its performance and its service life. The expected service life of this type of pavement solution is on average 10-11 years for standard porous thin layer on the slow lane [6]. Surface properties of porous asphalt pavements decay over time as a function of the pavement type, position in the lane, type of lane, hydrological parameters and position of the road [6].

The open-graded surface exposes a large area to the effects of water and the climatic impacts, leading to early ageing of the bitumen. The clogging of the pores that can reduce the functionality of the layer prematurely, mainly due to deposition of sand and debris inside the pores, must also be referred. Regular maintenance actions are advisable to minimize this situation [7].

As a result of the premature ageing of the bitumen that surrounds the aggregates, reducing the grain-to-grain contact, one of the most frequent pathologies in this type of surface layer is ravelling. This type of pathology leads to increased noise and loss of grip due to the presence of loose aggregates.

One of the methods to avoid the increasing of ravelling of the surface layer material, and therefore to increase its life cycle, is to apply in situ, by means of spraying, an emulsion with rejuvenating capabilities of the aged bitumen of the porous asphalt, preventing the progression of ravelling [5-7]. With this kind of solution, it is expected the product to penetrate into the aged bituminous binder and rejuvenated it [8], i.e., giving it “new” cohesion, adhesion, rheological and durability properties. It is also expected a capability to fill and heal micro-cracks and add bitumen to the mortar bonding bridges [4].

The *BCR - Brisa Concessão Rodoviária* network has about 422 km of surface course with porous asphalt, corresponding to 38% of its total extension (1 100 km). The first porous asphalt layer was built in 1993 and 1994 at A3 highway (Cruz/Braga), with 12 km length [9].

The main objective of this paper is to present the study methodology to be developed by National Laboratory of Civil Engineering (LNEC) together with BRISA and InovRoute for the characterization and monitoring of the application of a bitumen rejuvenation solution in this type of asphalt layers, located in the BCR network.

The adopted solution is a non-evasive method, without the use of milling or the placement of new asphalt layers. This technique consists of the rejuvenation of the bitumen in the porous asphalt mixture, increasing its life cycle. The product used is a rejuvenating bituminous emulsion for porous asphalts, which main function is to return elasticity to the bitumen of the porous asphalt, in order to avoid ravelling and without reducing its draining capacity.

2. METHOD OF APPLICATION OF A REJUVENATOR

The system rejuvenator is a bituminous emulsion binder which can be applied at a clean and dry surface, under dry and stable weather conditions. Its application will only be done at environmental road temperatures of > 5ºC and <25ºC at a RH of <85%.

So, the first step is to clean the road surface one week before the application of rejuvenator used high water pressed vacuum equipment. The quality of the cleaning is directly connected with the quality and life time extension of the treatment. The system rejuvenator is applied by a computer controlled spraying truck between existing road marking a rate of 0,8 kg/m^2, spreed between 4 to 5 km/h and temperature of 60ºC.

The second equipment is a pneumatic tyred rollermpactor that is used to achieve slight compaction.

The third equipment is an airject or surfacejet. it is a truck with an airplane turbine motor able to blow very hot air (operation at 450ºC) over the PA. The purpose of the airject seal is to blow the sprayed bitumen emulsion deeper into the PA.

At last, the sand spreading truck sprays a calibrated sand of 0/2 mm at a rate of 350 kg/m^2. The main objective of this procedure is to create friction at an early stage. After sanding the pavement, the road can be opened for traffic.

The next figure presents the application of the rejuvenator.

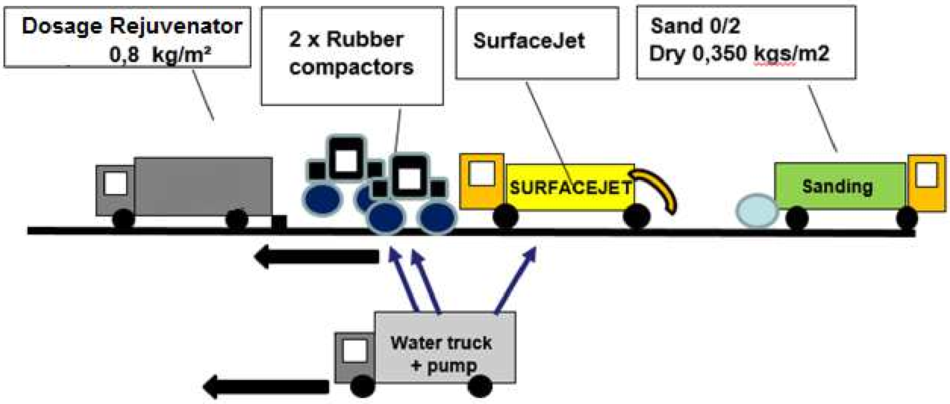


Figure 1: Application of Rejuvenator

3. DESCRIPTION OF THE SITE

The selected site is a section in the Santarém/Torres Novas road section of the main highway in Portugal, A1 - Auto-estrada do Norte, between the kilometers 85 and 90 of the South/North direction and it was selected due to its state of ravelling (average texture value of 2.0 mm) and its age (11 years).

To evaluate the loss of aggregate (ravelling) from the asphalt mixture, after the application of the rejuvenating emulsion, tests were made before the application and will be done after. Five sections in the application site and two out of the application site, for reference, were chosen.

In these sections the survey of the pavement with a high performance equipment (Laser Crack Measurement System - LCMS) was made, on all lanes, and cores were also taken for laboratory testing and the surface drainage was measured, as shown is Figure 2.

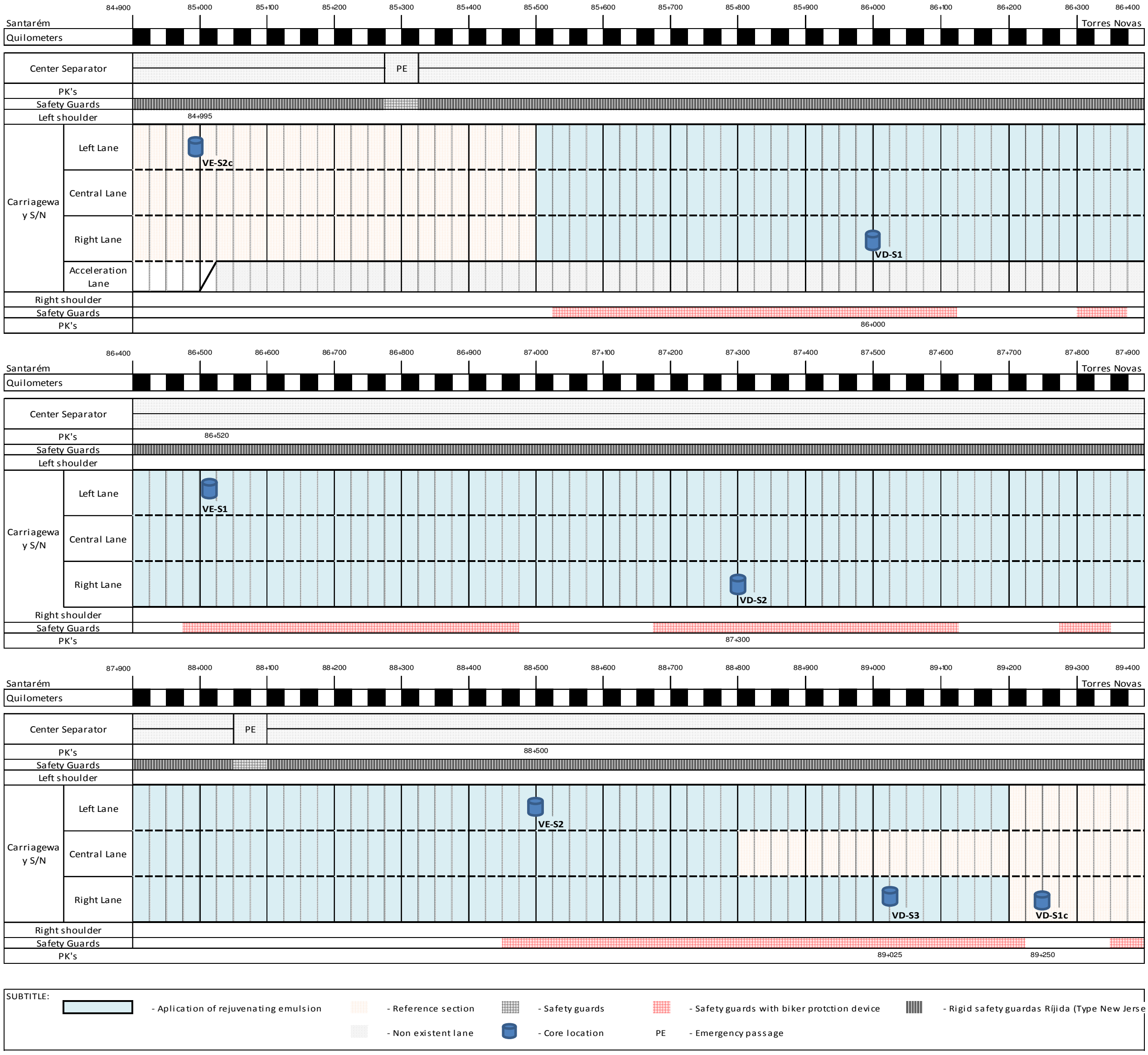


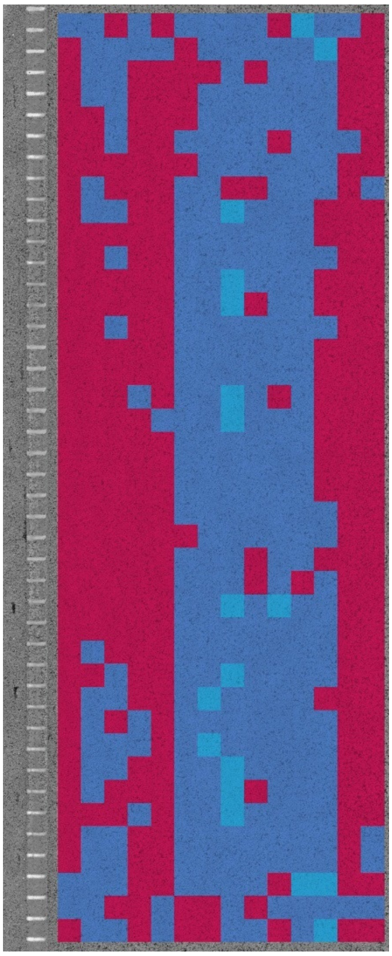
Figure 2: Plan of the site location

In Table 1 the tests results, measured in situ, are presented, before the application of the rejuvenating emulsion, allowing to evaluate the initial pavement conditions.

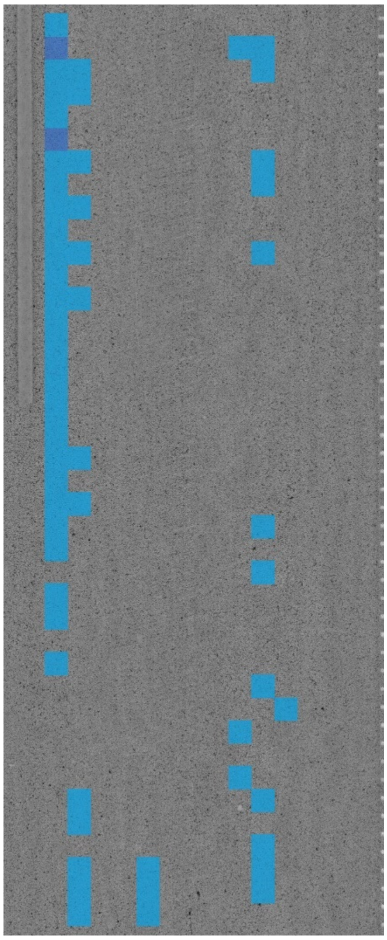
Table 1. Data collection

Section	Lane	Segment	Location	LCMS (fev. 2019)			Texture (2016)	Texture (2018)	Skid resistance (2016)	Before application Surface drainage (s)	
				PKi	PKf	Ravelling Index (RI)				1	2
Section to be intervened	Right Lane - VD	VD-S1	Between wheels. km 86+000	85+990	86+000	229,19	1,8	1,8	57	45	62
				86+000	86+010	242,60	1,7	1,8	56		
		VD-S2	Between wheels. km 87+300	87+290	87+300	232,23	1,8	1,7	58	66	68
				87+300	87+310	258,57	1,8	1,7	56		
		VD-S3	Between wheels. km 89+025	89+020	89+030	471,51	2,1	2,2	59	37	31
	Left Lane - VE	VE-S1	Between wheels. km 86+520	86+510	86+520	300,01				75	38
				86+520	86+530	315,12					
		VE-S2	Between wheels. km 88+500	88+490	88+500	343,04				90	57
				88+500	88+510	331,80					
Contiguous section (reference)	Right Lane - VD	VD-S1c	Between wheels. Place to define [89+250]	89+240	89+250	398,97	2,2	2,1	57		
				89+250	89+260	408,66	2,3	2,2	58		
	Left Lane - VE	VE-S2c	Between wheels. 84+995	84+990	85+000	438,13				36	28

In the next figure (Figure 3) are presented two examples of the measurement results with the LCMS equipment, where the left image presents an area with more ravelling (red zones) and the right image an area with much less disaggregation.



Disaggregated zone



Zone with few disaggregation

Figure 3: Images of results output with LCMS, 10 m long and per lane

4. RESEARCH PROGRAM

The research program will be developed in several phases with the main objective of making an assessment over time of the properties of the pavement wearing course, the porous asphalt, including the characterization of the extracted bitumen, after the application of the rejuvenating bituminous emulsion Modimuls® *Z*V. The program will comprise the following phases:

- 1st phase – Study of the pavement wearing course before the application of the rejuvenating bituminous emulsion;
- 2nd phase – Study of the pavement wearing course after the application of the rejuvenating bituminous emulsion;
- 3rd phase – Characterization of the rejuvenating bituminous emulsion;
- 4th phase – Study of the rejuvenated bitumen fabricated in the laboratory;
- 5th phase – Study of the pavement wearing course one year after the rejuvenating bituminous emulsion application (1 year in service);
- 6th phase and subsequent phases – Study of the wearing course of the pavement after 2 years up to 5 years of service after the application of the rejuvenating bituminous emulsion.

4.1. First phase

In order to register the experimental section pavement surface properties to be intervened, before the application of the bituminous emulsion, a prior visit for summary observation of the wear course state was made. To characterize the porous asphalt of the pavement wearing course of the experimental section it is planned to take cores from segments of both right and left lanes in, at least, two trial sections (Table 2). It is also considered in the research program the analysis of a contiguous section with porous asphalt wearing layer that will not be intervened (identified as "reference section") to compare the evolution over time of the wearing layer, porous asphalt and bituminous binder properties.

The characterization of the wearing course will be carried out *in situ,* with the performance tests to evaluate the surface properties (skid resistance and macrotexture), as well as the permeability (Figure 4). The cores taken from the pavement will be cut in laboratory in order to characterize the porous asphalt layer for determination of bulk and maximum densities, particle loss of cohesion (particle loss of porous asphalt - Cantabro test) and strength by axial compression (indirect tensile strength test). The composition of asphalt, loosen from the porous asphalt layer, will be determine in terms of binder content and aggregates particle size distribution after the extraction of the bitumen.

Table 2. Identification of testing sections

<table>
<tr><th>Sections</th><th>Lane</th><th>Segment</th><th>Location</th></tr>
<tr><td rowspan="5">Section to be intervened</td><td rowspan="3">Right lane - VD</td><td>Section 1 - VD-S1</td><td>Between wheels.
km 86+000</td></tr>
<tr><td>Section 2 - VD-S2</td><td>Between wheels.
km 87+300</td></tr>
<tr><td>Section 3 - VD-S3</td><td>Between wheels.
km 89+000</td></tr>
<tr><td rowspan="2">Left lane - VE</td><td>Section 1 - VE-S1</td><td>Between wheels.
km 86+500</td></tr>
<tr><td>Section 2 - VE-S2</td><td>Between wheels.
km 88+500</td></tr>
<tr><td rowspan="2">Contiguous section (reference)</td><td>Right lane - VD</td><td>Section 1c - VD-S1</td><td>Between wheels.
To be defined</td></tr>
<tr><td>Left lane - VE</td><td>Section 2c - VE-S2</td><td>Between wheels.
To be defined</td></tr>
</table>

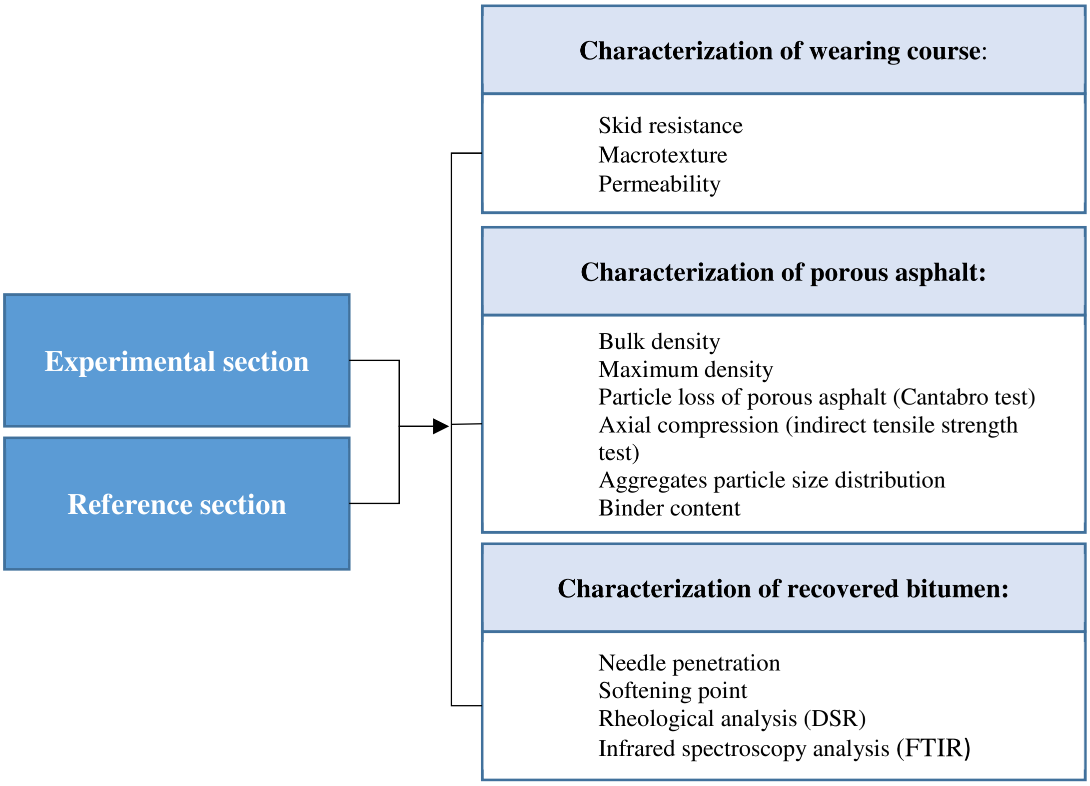


Figure 4: Experimental program for the characterization of the wearing course, porous asphalt and recovered bitumen

Another component of the study comprises the analysis of the bitumen extracted and recovered from the porous asphalt. The consistency of the bitumen at high and intermediate temperatures, will be determined, respectively, by the softening point (ring and ball method) and needle penetration. The rheological analysis, with the Dynamic Shear Rheometer (DSR), will allow to study the viscoelastic behaviour of the bitumen. Being the oxidation, by reaction of bitumen compounds with oxygen, one of the major causes of ageing of the bitumens it is of the utmost importance to monitor the formation of carbonyl and sulfoxide functional groups by Fourier transform Infrared spectroscopy (FTIR) [10-13].

Another aspect of relevance concerns the capability of the rejuvenating emulsion to provide bitumen to fill and heal micro-cracks and to add bitumen to the mortar bonding bridges [4]. As reported earlier [4, 8], the X-ray Computed Tomography (CT) and the thin section optical microscopy are powerful techniques that can give this kind of information. So, it will be important to establish a cooperation with a laboratory specialized in those techniques.

4.2. Second phase

In order to monitor the application proceeding of the bitumen emulsion Modimuls® ZV and to record the state of the surface of the experimental section after the intervention, there will be made some visits to the location, in order to obtain a summary observation of the condition of the pavement.

For the characterization of the pavement wear layer of the experimental section after the application of the Modimuls® ZV, as well as for the reference section, it is expected to follow up the same experimental program proposed for the first phase.

4.3. Third phase

The rejuvenating emulsion, Modimuls® ZV, is object of CE marking according to the European standard EN 13808:2013 [14]. The emulsion will be characterized according to the European specification, including tests on the emulsion and on the bitumen obtained from the emulsion by normalized procedures.

The characterization of the emulsion comprises the viscosity, breaking behaviour and bitumen content. A two phase process will be used to recover the binder from the emulsion in the laboratory. The first one comprises the conditioning of a thin layer of the emulsion for a period of 24 h in the laboratory ambient temperature and then in an oven at 50 ºC for the same period of time (EN 13074-1) [15]. The recovered binder is further conditioned at 85 ºC for 24 h, in order to get free from most of the volatile part of the flux oils, obtaining the stabilised binder (EN 13074-2) [16]. The characterization of both recovered and stabilized binder includes the needle penetration, softening point, rheological analysis and FTIR analysis.

The resistance to ageing of the stabilized binder is also evaluated after the Pressure Aging Vessel (PAV) using the same test methodologies.

4.4. Forth phase

The objective of this phase is to study, in the laboratory, the full capability of the bitumen from the Modimuls® ZV emulsion to rejuvenate the aged bitumen extracted from the porous asphalt. This study will be only focused on the bituminous binder and it will not address the bituminous mixture. The rejuvenated bitumen will be fabricated in the laboratory with:

- Aged bitumen - bitumen extracted and recovered from the porous asphalt mixture removed only from the reference section, continuous of the experimental section. This option is due to the large number of cores that are needed to be collected in the experimental section to perform all tests in the different phases of the research program;
- Rejuvenated bitumen – stabilized binder obtained in laboratory from the Modimuls® ZV emulsion by the procedure described in the last section.
- Recycling content – percentage of aged bitumen used in the mixture that is calculated based on the bitumen content in the porous asphalt and the quantity of emulsion applied in the pavement.

The characteristics of the rejuvenated bitumen will be assessed by the same experimental methodology.

If possible, depending on the available quantities of aged bitumen, the study can be extended to the evaluation of the aging resistance of the rejuvenated bitumen after PAV aging.

4.5. Fifth and following phases

The fifth phase comprehends the study of the pavement wearing course after one year of the rejuvenating bituminous emulsion application, i.e., after 1 year of service, maintaining the same experimental program (Figure 4). It is intended to extend study to more years, with the possibility of going up to 5 years, depending on the pavement conditions and on the experimental results obtained.

5. FINAL CONSIDERATIONS

A methodology to be developed by National Laboratory of Civil Engineering (LNEC) together with BRISA and InovRoute for the characterization and monitoring the application of a bitumen rejuvenation solution in this type of asphalt layers, located in the BCR network, is presented.

A non-evasive method without the use of milling nor the placement of new asphalt layers is proposed. This technique consists of the rejuvenation of the bitumen in the porous asphalt mixture, increasing its life cycle. The product used is a rejuvenating bituminous emulsion for porous asphalts, which main function is to return elasticity to the bitumen of the porous asphalt, in order to avoid ravelling and without reducing its draining capacity.

The evaluation of the porous asphalt condition was performed with a high performance equipment (Laser Crack Measurement System - LCMS), as well as the drainage state in order to characterize the layer before the rejuvenator use, allowing a future comparison.

REFERENCES

[1] Shreyas, K., Lavanya, J., Comparison of flexible (dense graded) & porous (open graded) asphalt surface course with stone dust as a filler in Marshall mix design, International Journal of Application or Innovation in Engineering & Management, volume 6, 2017, pages 94-90, ISSN 2319-4847.
[2] Poulikakos, L., Gubler, R., et al, Mechanical Properties of Porous Asphalt, Recommendations for Standardization, 2006, Mandate 1999/280, 110 pages, At the request of the VSS Association of Swiss Road Professionals.
[3] Jellema, E., Vonk, W., Improving durability and functionality of porous asphalt by using high performance bituminous binders, 6th Eurasphalt & Eurobitume Congress, 2016, dx.doi.org/10.14311/EE.2016.123.
[4] The, P., Voskuilen, J. et al, Life-prolonging preventive maintenance techniques for porous asphalt, 6th Eurasphalt & Eurobitume Congress, 2016, dx.doi.org/10.14311/EE.2016.128.

[5] De Bont, A., Plug, K., et al, Development of a durable porous asphalt with high noise reduction, 6th Eurasphalt & Eurobitume Congress, 2016, dx.doi.org/10.14311/EE.2016.12171.
[6] Voskuilen, J., Verhoef, P., Causes of premature ravelling failure in porous asphalt, 6th RILEM Symposium PTEBM'03, 2003, pages 191-197.
[7] Praticò, F., Colicchio, G., et al, Surface properties of porous asphalt concretes: time, position, and treatment impact, Bituminous Mixtures and Pavements VII, 2019, pages 624-631, ISBN 978-1-138-48028-5.
[8] Zhang., Y.; Extending the lifespan of porous asphalt concrete, Master of Science Dissertation, 2015, 209 pages.
[9] Brejo, L., Evaluation of the influence of water action on draining bituminous mixtures, Master Thesis, Universidade da Beira Interior, 2016, 107 pages (in Portuguese).
[10] V. Mouillet, V.; Farcas, F.; Battaglia, V.; Besson, S.; Petiteau, C.; Lecunff, F.; Identification et dosage des fonctions oxygénées présentes dans les liants bitumineux: analyses par spectrométrie infrarouge à transformée de Fourier, Laboratoire central des ponts et chaussées, Paris, 2010.
[11] Anne, D.; Ziyani, L.; Drouadaine, I.; Pouget, S.; Faucon-Dumont, S.; Simard, D.; Mouillet, V.; Poirier, J.E.; Gabet, T.; Boulange, L.; Nicolai, A.; Gueit, C.; MURE National Project: FTIR spectroscopy study to assess ageing of asphalt mixtures, in: Czech Technical University in Prague, 2016. doi:10.14311/EE.2016.154.
[12] Hofko, B.; Porot, L.; Falchetto Cannone, A.; Poulikakos, L.; Huber, L.; Lu, X.; Mollenhauer, K.; Grothe, H.; FTIR spectral analysis of bituminous binders: reproducibility and impact of ageing temperature, Materials and Structures, 51:45 (2018), doi.org/10.1617/s11527-018-1170-7.
[13] Makowska, M.; Ari Hartikainen, A.; Pellinen, T.; The oxidation of bitumen witnessed in-situ by infrared spectroscopy, Materials and Structures, 51:189 (2017), DOI 10.1617/s11527-017-1058-y.
[14] CEN, EN 13808:2013. Bitumen and bituminous binders. Framework for specifying cationic bituminous emulsions., European Committee for Standardization, Brussels, 2013.
[15] CEN, EN 13074-1:2019. Bitumen and bituminous binders. Recovery of binder from bituminous emulsion or cut-back or fluxed bituminous binders - Part 1: Recovery by evaporation, European Committee for Standardization, Brussels, 2019.
[16] CEN, EN 13074-2:2019. Bitumen and bituminous binders. Recovery of binder from bituminous emulsion or cut-back or fluxed bituminous binders - Part 2: Stabilization after recovery by evaporation, European Committee for Standardization, Brussels, 2019.