NEW TECHNOLOGY FOR THE MAINTENANCE OF FLEXIBLE PAVEMENTS

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ABSTRACT

The administrators of low traffic flexible pavement networks are constantly confronted to the dilemma of deciding on the most cost efficient maintenance strategy. Maintenance operations can take several forms like punctual repair of potholes or restoring a profile to the laying of a new wearing course.
Within the framework of its research program on vegetable oils and on the diminution of the hot mix asphalt manufacturing temperature, EUROVIA has developed and proposes a new range of products for these pavements maintenance.
An interesting flexibility is brought to maintenance process by adding vegetable oil. The concentration is optimized depending on the importance and nature of the maintenance work to be done. It allows to easily adapting to the large variety of job site situations encountered in practice such as for instance the need to cope with delays between mix manufacturing and laying going from a few hours to several days.
This article presents the results obtained during the optimization of wearing course mixtures design. It further discusses the experience gained from the laying of several jobsites. A synthesis of the behavior of these products after more than 5 years of monitoring is made.
Finally, a life cycle analysis is presented in comparison to a conventional hot mix wearing course.

Keywords: maintenance, flexible pavement, vegetable oil, life cycle analysis

INTRODUCTION

The maintenance of low traffic flexible pavements requires techniques which, to be as cost effective as possible, need to be best fitted to the nature of the distress which is to be corrected. Hence the use of techniques which range from the repair of potholes to re-profiling and, ultimately, the laying of new wearing courses. Research conducted by EUROVIA on the decrease of manufacturing temperature of hot asphalt mixes and on the use of vegetable oils has now also offered new perspectives for the maintenance of low traffic roads. The paper presents this new concept, the corresponding products and the practical experience gained so far.

1- ORIGINS

The first applications conducted by EUROVIA date back to 2005, where teams from EUROVIA proposed to maintain the roads of Brittany islands with a product able to postpone the laying thanks to the use of a vegetable oil.
In the case of these jobsites, the goal was to have a mix that could be manufactured in a mixing plant on the mainland, before being shipped and applied on the islands.
The solution was a formula made of a mix of aggregates, fines and pure bitumen with a vegetable oil at a temperature of about 120°C. This product ensured a workability time of a dozen hours and could be laid at a minimum temperature of 60°C.

2- THE DEVELOPMENT

Since then, the concept gave birth to the range of VIASELF® Fv mixes for which the laying time may be delayed from 4 hours to 2 months by adjusting the oil content and flux and the granular compositions.
Each product of the range has been designed so as to ensure a workability and an appearance similar to those of conventional hot mixes. These products are obtained through a specific production process conducted in conventional continuous or batch mixing plants at a temperature usually between 40 and 100°C. For applications on islands, the production temperature can reach 120°C. Indeed, in such cases, longer delays are made necessary by the loading at the docks on the mainland and unloading at the arrival on these islands.

The great workability of VIASELF® Fv offers great flexibility of use and allows application with a finisher, a grader or manually. The means of compacting VIASELF® Fv are identical to those used for hot mixes. Beside being easily applicable with conventional mechanical means, VIASELF® Fv is especially suitable for the re-profiling of edges, emergency repairs such as potholes, trench filling, footpath repairs, etc.

VIASELF® Fv is made of a 0/4, 0/6, 0/10 or 0/14 dense-graded aggregate skeleton coated with a specially formulated fluxed bitumen. The binder employed to produce VIASELF® Fv is 70/100 or 160/220 bitumen plasticized by a vegetable oil. Unlike petrochemical or petroleum oils, this plant-based oil does not evaporate but hardens in place, on the pavement, through oxidation by air.
The bitumen with vegetable oil used in VIASELF® Fv is produced by a special process in Eurovia binder plants. It is designed so as to achieve a coating viscosity at low temperature which is close to that of pure bitumen used in conventional hot mix processes.
A comprehensive range of fluxed asphalt mixes has been developed by optimizing the nature and the content of the plant-based fluxing agent. The amount of fluxing agent, and hence the binder type, is selected according to the intended use of the asphalt mix.

The VIASELF® Fv range covers thus several products suitable for a variety of applications:

VIASELF® C Fv: for use in surface courses, for which laying may be deferred by up to 12 hours,

VIASELF® R Fv: for re-profiling work, for which laying may be deferred by up to 72 hours,

VIASELF® S Fv: for localized repairs, the mix being storable for up to 2 months before use.

Plant-based fluxing agents have many advantages compared to those of petroleum origin:

- Conservation of natural resources
- Reduced greenhouse gas emissions (GHG)
- Removal of Volatile Organic Compounds
- Removal of safety issues related to flash point (> 160°C versus 70 to 80°C for a petroleum flux)
- Respect for the natural environment
- Improved working conditions
- Production and laying at a temperature at least 60°C lower than for conventional hot mix

3- MIX DESIGN

The vegetable oils were selected according to their fluxing power, their price and their ability to harden after application so as to allow an adjustment (faster or slower) of the rise in cohesion depending on the end use.

The laboratory study described below focuses on the mix design of an asphalt mix with controlled workability (minimum 12 hours) for a wearing course with low traffic (< 50 trucks per day).

The reference formula has been made with a 70/100 bitumen containing 8% of a petroleum fluxing oil Fp1. Two plant-based oils have been evaluated: Fv1 and Fv2.The oil content has been adapted so as to obtain equi-viscous binders (Table 1). The viscosity curves of these binders are shown in Figure 1.

Table 1: Viscosity STV 10 mm, 40°C of binders (EN 12846-2)

	Viscosity STV 10 mm 40 °C
Binder with 8 % FP 1	421 s
Binder with 6% Fv1	496 s
Binder with 6 % Fv2	503 s

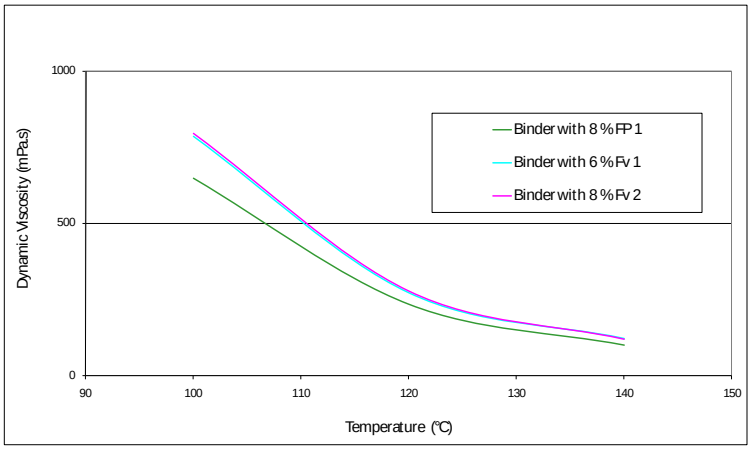

Figure 1: Viscosity curves of binders

The asphalt mix is a SCAC 0/10 (Semi-Coarse Asphalt Concrete) based on dioritic aggregates. Fluxed bitumen content in the asphalt mix is 5.5 %.

The asphalt mixes made with the different equi-viscous binders have all been produced at 120°C and characterized by the following tests:

- Analysis of stabilized binders generated according to two different curing procedures (NF T 66-031, NF EN 13074-1 and 2)
- Workability of asphalt mix (Eurovia method)
- Gyratory shear compactor (NF EN 12697-31)

- Evolution of sensitivity to water at 18°C (NF EN 12697-12)

- Kinetics of cohesion build up (Eurovia method)

Workability

To assess the workability of the asphalt mixes depending on temperature and time, tests were performed using the Nynas workability apparatus (Picture 1). This test consists in moving a plate at constant speed in a volume of asphalt at a controlled temperature. The peak of the resisting force is taken as a measure for mix workability. The test was conducted at different temperatures (Fig. 2).

Picture 1:
Nynas workability measurement tool

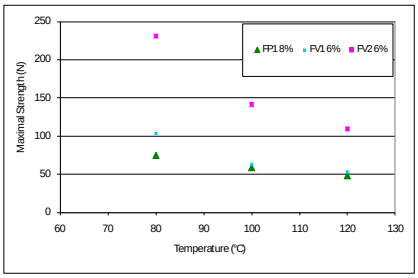

Figure2:
Evolution of the workability

The figure 2 shows better workability with the vegetable oil Fv1.

Analysis of stabilized binders

Properties of binders after stabilization are presented in Table 2. Two stabilization methods are compared: T 66-031 (14 days at 50°C) and NF EN 13074-1 and 2 (1 day at 25°C + 1 day at 50°C + 1 day at 85°C)

Table 2 : Analysis of stabilized binders

Fluxed bitumen		Penetrability (1/10 mm) NF EN 1426	R and B (°C) NF EN 1427	Dynamic viscosity (mPa.s) NF EN 13302				
				80°C	100°C	120°C	140°C	160°C
8 % FP1	to	>330	-	2506	647	234	100	–
	T 66-031	200,3	38,2	7988	1354	450	176	80
	NF EN 13074-1 et 2	151,6	39	7000	1464	441	188	92
6% FV1	to	>330	-	2506	647	234	100	–
	T 66-031	235	35	6188	1349	441	172	–
	NF EN 13074-1 et 2	317	32,4	4345	1062	347	143	69
6% FV2	to	>330	-	3062	795	278	120	–
	T 66-031	224	39,4	6527	1462	454	186	–
	prNF EN 13074-1 et 2	295	33,8	4505	1114	363	155	80

As expected, the vegetable oil binders stabilized according to standard EN 13074-1 and 2 show a slower build-up of cohesion:

- Penetration of 317 and 295 1/10 mm versus 150 1/10 mm for the FP1 fluxed binder,
- Ring and Ball softening point of 32,4 and 33,8°C versus 39°C for the FP1 fluxed binder.

It is furthermore interesting to notice the differences in the results obtained with the two stabilization methods. Whereas in the case of the petroleum (volatile) flux, the final consistency is more or less equivalent, this is absolutely not the case when using the vegetable (non-volatile) fluxes. For these products, the longer

stabilization time (14 days at 50.°C) of the NF T 66-031 method has obviously a larger impact than the higher temperature (85°C but for only 1 day) applied following EN 13074-2.
In the case of vegetable-oil fluxed binders, it is thus likely that the EN 13074-1& 2 procedure may underestimate the ultimately achievable consistency of the final binder.

Mechanical testing:

The performances of the asphalt mixes produced at 120°C are presented in Table 3. These properties are equivalent for all three mixes.

Table 3: mechanical testing of asphalt mixes

	Mix design with 8% FP1	Mix design with 6% FV1	Mix design with 6% FV2
Duriez (NF P 98 251-4)			
r/R	82	80	76
R (MPa)	1.9	1.9	1.7
GSC (NF P 98-252)			
% voids 10 gyrations	16.7	15.9	15.7
% voids 60 gyrations	9.5	8.5	8
% voids 200 gyrations	5.4	4.4	4

The evolution of cohesion build up is followed by measuring the compressive strength at 18°C of Duriez samples after different periods of curing at 50°C (figure 3) at the same voids content (10 %).

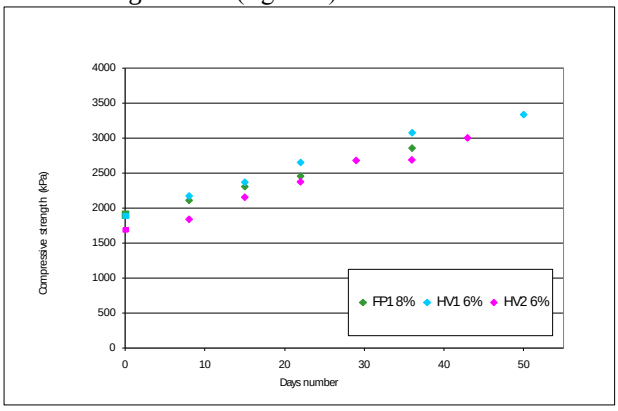

Figure 3: Evolution of the compressive strength at 18°C depending on curing time at 50°C.

The build-up of cohesion for the mixes using vegetable oil fluxed binders proved to be close to the one observed for the reference mix with petroleum oil. This is a positive (although not readily explained) result considering the differences in consistency observed on the stabilized binders (Table 2).

From these different tests, and mainly due to its larger impact on workability, the FV 1 oil has been selected so far to produce the mixes for deferred use for the VIASELF® Fv range.

4- SOME REFERENCES

The first VIASELF® C Fv wearing course job site (traffic volume < 50 tracks per day) was conducted in October 2005 on the Rue du Parc des sports in Landévant (Morbihan-France). The measurements made on cores after 8 months in June 2006 and 5 years in September 2010, are presented in Table 4 below:

- Void contents with a vertical Gamma densitometer (NF EN 12697-7),

- Stiffness Modulus at 15°C and 10Hz (Eurovia method).

Table 4: Mechanical properties

	after 8 months	after 5years
voids content (%)	6.4	7.8
Modulus at 15°C – 10Hz (MPa)	3929	4102

Considering the results obtained, performances at the early age are very similar to those at 5 years, which suggests that the VIASELF® C Fv changes very little and retains its flexibility over time, hence the absence of cracking.

All major paving operations performed with conventional hot mix asphalt manufactured in mixing plants located on the Belle-Île-en-mer island have undergone some damage over time (cracking, …). However, the roads paved with VIASELF® C Fv since 2005 show no degradation.

Some examples of works performed with VIASELF® C Fv since 2005 in Morbihan (56) and Calvados (14) (Pictures 2 and 3) are listed hereafter:

- RD30 – Rue du chemin neuf in Sauzon (Belle-Ile-en-mer - 56) in 2006,
- Primary school yard in Locmaria (Belle-Ile-en-mer - 56) in 2007,
- Residential premises Le Plateau à Bangor (Belle-Ile-en-mer - 56) in 2009,
- Local roads in l'Ile-aux-Moines (56) in 2010,
- Local roads in Camors (56) in 2010,
- Urban roads in Argences (14) in 2010,
- Local roads in St Ouen-du-Mesnil-Oger (14) in 2010.

Pictures 2 and 3 : Surface course

In total, to date, more than 10 000 tons of VIASELF® C Fv have been produced and applied in western France.

After five years of field experience, VIASELF® C Fv has constantly proven following main advantages :

- Its workability, whether in manual or mechanized application, for up to a dozen hours after production,
- A wide area of use: secondary roads, local roads and residential premises, schoolyards, parking lots, …

For islands such as Belle-Île-en-mer, the possibility to manufacture VIASELF® C Fv on the mainland per batches of 200 tons and to transport it by sea, has proven to be an ideal solution. Since 2005, road maintenance operations are conducted this way on a regular basis of 1 000-2 000 tons per year.

In addition to this and since 2005, Eurovia produces 15 000 to 20 000 tons per year of VIASELF® S Fv (picture 4), a mix for localized repairs which may be stored for up to 2 months before use. The largest amounts are produced in the west and south-east of France.

Picture 4 : Repair of potholes

Picture 5 : Re-profiling works

Finally, in 2010 in Mayenne (53), Eurovia produced nearly 3,000 tonnes of VIASELF® R Fv, for the re-profiling of edges on secondary roads, with a deferred use of up to 72 hours (picture 5). Examples of two such worksite references in 2010 are :

- RD235 in Evron (53),
- RD153 in Cossé-le-Vivien (53).

5- ENVIRONMENTAL IMPACT

The use of renewable resources, significant reduction of GHG emissions and energy consumption associated with lower production temperatures add a high environmental value to the VIASELF® Fv product range .

In the case of the pavement maintenance on the Brittany islands, the VIASELF® C Fv applied over 30 mm proved to be equivalent in behavior to a SCAC hot mix. This allows a comparative evaluation of the environmental impact to be made on the basis of the following data:

- Basic solution: SCAC produced at 150°C with 5.5% of bitumen 70/100 in a minimum thickness for this product of 50 mm.
- Alternative: VIASELF® C Fv produced at 100°C with 5.5% of binder (including 8 % of vegetable oil) in a minimum thickness for this product of 30 mm.

The environmental study was conducted using the eco-software Gaia of EUROVIA.

To facilitate the comparison, the following example is not taking into account the special case of the islands but on the basis of producing SCAC and VIASELF® C Fv at the same place. The phases considered in this calculation are the raw material extraction, transport upstream and downstream of the production site, producing and laying.

The results are presented in Figure 4.

Environmental indicator	Difference HMA/Viaself
Depletion of resources (ADP) (kg Equ Sb)	-44%
Aggregates consumption (t)	-38%
Energy resources consumption (l)	-45%
Emission of GGH climate change (kg CO2 equ)	-44%

Figure 4 : Environmental indicators

The impact of the use of renewable resources and reduction of producing temperatures are well highlighted, together with the decline in aggregate consumption by 38%.

6- CONCLUSION

With the VIASELF® Fv product range, able to address all kinds of maintenance works and likely to be produced in all types of mixing plants, whether continuous or batch plants, EUROVIA provides a comprehensive and innovative set of solutions for the maintenance of flexible pavements under low traffic (< 50 trucks per day).

An important and genuine asset of the VIASELF® Fv products is the flexibility which they confer to the maintenance of flexible pavements on both aspects of differed use and on the ability to bear large deflections without cracking.

The contribution to the preservation of the environment related to the use of vegetable oil associated with the possibility of incorporating RAP and the reduced production temperatures further guarantee the environmental sustainability of these products, which is one of the guidelines for Eurovia's research and development activities.