# BITUMEN EMULSIONS: MEETING THE PAVEMENT PRESERVATION CHALLENGE

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## ABSTRACT

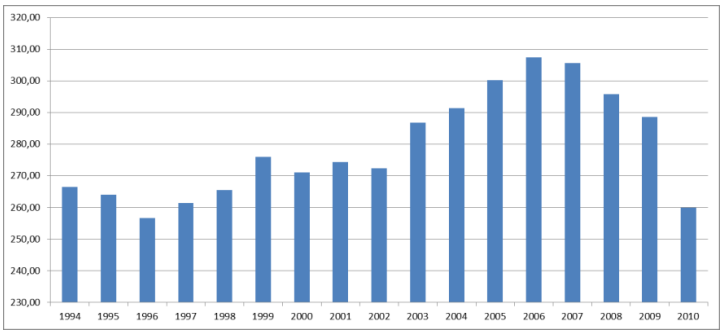
*This paper aims at describing the pavement preservation challenge: funds restriction, social demands and environmental regulations.*
*Thanks to their moderate cost, bitumen emulsion techniques are back on the stage. Technical developments have been carried out in the past years with remarkable achievements such as:*
*- Trackless tack coat*
*- Cold in place recycling 2nd generation*
*- Heavy duty chip seal*
*The specific characteristics of the bitumen emulsion techniques also contribute to implement safe and environmentally sound solutions.*

**Keywords:** bitumen emulsions, energy savings, greenhouse gas emissions, pavement preservation

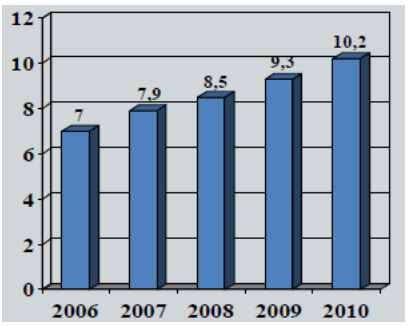
## 1. INTRODUCTION

The European road network comprises 6.1 million km of roads that carried 73.8% of the good transport inland and 85.3% of the passenger transport in 2009[1] Such a road asset needs to be maintained in order to ensure the growth of the economy and the welfare of the population.

However, the economic crisis that hit the World in 2008 has had a negative impact on the public budgets devoted to road maintenance. One of the visible consequences of such restriction is the decrease of the hot mix production[2]. Another way to assess the growing maintenance backlog is to assess the ageing of the road networks. The example below right shows a 3 year ageing within only a 5 year period[3].

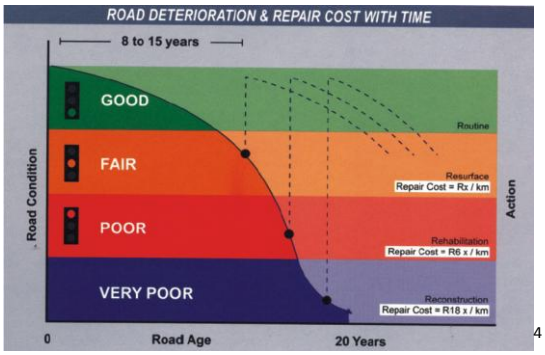



HMA production in the EU 27




Average age of the wearing course

In other words, road owners are facing a growing challenge: how to maintain the road assets they are in charge of before it is too late. We all know that the longer we wait the higher the bill will be.

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For that reason, road owners have been forced to optimize the use of the funds they are in charge of by implementing pavement management systems that include the selection of techniques within a vast portfolio of reliable techniques.

As a result, the emulsion based techniques are back on the stage, thanks to their reasonable cost, provided that their technical characteristics are appropriate and validated. As an example, the results of a comprehensive study titled "Emulsified asphalt mixes: towards a complete design method" has recently been released by USIRF[5], with an introduction by its president, Jean-Louis Marchand, followed by further results of tests carried out by French Road Authorities[6]. Similarly, successful experimentations on cold mixes using 100% RAP have been reported in the United Kingdom[7].

The purpose of this paper is to show how emulsions will contribute to meet the pavement preservation challenge, within the frame of a difficult context: today, the challenge is to protect the existing road network by waterproofing it as a priority mission that will make possible to postpone major repair works until appropriate funding is available.

| technique | Slurry seal | Micro surfacing | Chip seal | UTFC | HMA |
|---|---|---|---|---|---|
| cost / $yd^2$ $ | 0.75 - 1.00 | 1.50 - 3.00 | 1.50 - 2.00 | 4.00 - 6.00 | 3.00 - 6.00 |

[8]

| technique | Micro surfacing | Micro surfacing 2 layers | Chip seal | Very thin asphalt concrete | HMA |
|---|---|---|---|---|---|
| cost / $m^2$ € | 2.04 | 3.04 | 2.33 | 6.20 | 7.90 |

[9]

| technique | chip seal one layer | chip seal two layers | micro surfacing | HMA 30 mm |
|---|---|---|---|---|
| cost / $m^2$ € | 2,30 | 4,00 | 2,45 | 4,14 |

[10]

Such data are intended to show that each road technique has its own field of use. An appropriate pavement management system will allow selecting the right technique at the right place at the right time[11].

## 2. THE GLOBAL CHALLENGE

The economy is one side of the three fold global challenge:

- Economy
- Social demands
- Environment protection

This challenge was brightly described by Mr. Rt Hon Philip Hammond, Secretary of State for Transport (United Kingdom), said during a speech he delivered in September 2010[12],

« […] the Coalition Government is committed to the sustainability agenda in everything it does, including transport. […] we are all too conscious of the fact that sustainability means so much more than simply "carbon reducing".

Sustainable solutions have, of course, first and foremost to be environmentally sustainable. But they must also be fiscally and economically sustainable - affordable to the taxpayer in the long-term and compatible with an economic growth agenda.

And they must be socially sustainable as well - promoting social mobility and recognizing the aspirations of the least-advantaged in our society and of the billions of people trying to improve their quality of life in the less-developed nations of the world ».

This statement does not apply to Europe only. World leading economies such as the USA are facing the same challenges: "To meet the technical demands of Green Paving Industry, FIU established a Green Paving program in 2011. With some 2.7 million miles of paved roads in the United States, oil prices going up, roads aging and financial resources dwindling, Highway Agencies are faced with the challenge of sustaining such a vast asset. There are clear ways out of this mess:

1. Technologies to reuse existing material,
2. Technologies to prolong the life of roads, and
3. Technologies to reduce cost and energy demand of current construction process.

Benefits of these technologies are estimated at 40% cost savings, 70% emissions savings and 100% reuse of existing materials. At a national level, these can translate into annual savings of $18 billion of highway maintenance cost and thousands of tons of pollutants a year"[13].

Emulsion based techniques often meet the sustainability challenge. Their global efficiency is constantly improving as shown is the following examples. More than a technique, bitumen emulsion is part of systems addressing the problem of pavement preservation.

### 2.1. Trackless tack-coat: a major innovation for motorways and urban roads

Trackless tack-coat provides a full even bonding and contributes to an optimum worksite management:

The performance of an asphalt mixture overlay depends on the interface bond strength between the newly constructed asphalt mixture lift and the underlying pavement layers. A tack coat, which typically consists of bitumen emulsion, has been commonly used to achieve the necessary bonding between pavement layers and to ensure that they behave as a monolithic system that withstands traffic and environmental stresses. Poor interface bond strength may accelerate the appearance of distresses such as slippage and surface cracks. Several factors have been considered to affect the bond performances. Those are tack coat material type, tack coat application rate, pavement surface type, temperature, construction site conditions, and others.

One of the main problems the industry had to face used to be the integrity of the bond coat during the road works operations: using a rational pavement design method[14] shows that a poor tack coat will have a direct impact on the lifespan of the layer placed on it, up to 4 times less[15].

One of the ways to deal with such is to use specific pavers, equipped with an integrated spray bar. However, such a solution means that all the conventional pavers should be replaced at high cost by a new generation of machines.

An alternative to this option is to play with the emulsion design, in such a way that the binder will not stick to the truck tires and the paver caterpillars or wheels, while adhering to the existing layer. As a result, the environment of the worksite will not be spoiled by bitumen that might have been taken off by the wheels.

Several techniques have been developed in order to reach this goal. All these techniques are based on two principles:

- Quick breaking emulsions
- Increased softening point of the residual binder

Increasing the softening point of the residual binder may be achieved either by the use of a hard grade bitumen (say 35/50) or by the modification of the binder with a polymer.

Specifications have been developed in some countries like Japan in order to characterize this type of emulsions, together with appropriate tests to qualify the “adhesion ratio to tires”[16].

Some experiences are also reported about slow setting emulsions used on milled surface that give much better results that quick set emulsions. In that case, the emulsion remains unbroken and not damaged by the traffic, thanks to the shallow cavities left by the milling operation[17]. Such a system contributes to neutralize the remaining dust particles that cannot be removed by the sweeping equipment.

Rapid Setting emulsion 65 %

Slow Setting Emulsion 60%

### 2.2. Cold in place recycling

With more and more stringent requirements dealing with Health & Safety, cold in place recycling is back in the picture. Moreover, it meets the challenge of protecting the environment, reusing natural resources, valorizing the materials in the existing roadway, while limiting the need to use new materials.

The technical characteristics of the recycled materials are now used in the rational pavement design methods.

Numerous studies have been performed on that subject As an example, the average modulus measured on cores by the Ponts et Chaussées Regional Laboratories for bitumen emulsion recycled asphalt mix is roughly 4,000 MPa (direct traction test at 15°C and 0.02 seconds). It is important to note that the level of modulus does

however depend on the type of materials being recycled (untreated aggregates in particular). As an example, measured in diametral traction, the equivalent modulus at 15°C, 10 Hz of materials recycled after 9 and 10 years under traffic is shown in the following data. The structural effect is very satisfactory and suited to the traffic levels the roadway must bear[18].

| location | Age (year) | Compaction ratio (%) | E* (15°C 10 Hz) MPa |
|---|---|---|---|
| RN 20 | 10 | 90.0 | 4,050 |
| RN 145 | 9 | 89.2 | 6,500 |

From an environmental point of view, the advantages of recycling techniques are known:

- Saving of virgin materials
- Saving of transportation
- Saving of energy

Such positive impact has been assessed by the use of the SEVE tool, developed by the French Road Industry (Union des Syndicats de l'Industrie Routière Française) within the frame of the CEV [Voluntary Commitment Agreement], signed on 25 March, 2009 in order to be able to present environmental comparisons of the technical solutions they are offering to project owners by creating an "Eco-comparer" shared by the companies.

The USIRF has been given the task of arranging the development of this tool that enables the signatories to compare the environmental impacts of the offers for their customers. The software is called SEVE (Système d'Evaluation des Variantes Environnementales) [System for assessing eco-friendly alternate bids].

The initiative is based on two main aspects:

1. Setting up a set of guidelines that are auditable and validated by an external body such as the ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie) [Environmental Agency Responsible for Energy], using current standards (Life Cycle Analysis, etc.) and based on values and coefficients set by recognized professional bodies;
2. Development of a software tool implementing these guidelines and enabling them to be put to practical use. Such guidelines relate to environmental impacts connected with roadworks and environmental indicators deal with greenhouse gas emissions (in kg equivalents of CO2, energy consumption), the preservation of natural resources and consumption of RAP (for recycled asphalt pavement)[19].

SEVE has been extensively used within the frame of the European TRACC project (Road techniques adapted to climatic changes). It is a transnational project, with members from Spain, Portugal and France[20].

The TRACC Project deals with the promotion and the development of road techniques adapted to climatic changes. It started with an assessment of the environment friendly road techniques already currently used in the program area. Then a special work on innovating techniques and a socio-economic and environmental study was conducted. Amongst its deliverables, it included a guide for road owners, aiming at integrating environmental aspects in their road projects. Most of the techniques that have been studied within the frame of TRACC deal with bitumen emulsions that save energy, materials, and use recycled materials and, as a result, generate less pollution.

The project ended in December 2011. Its main outputs have been presented in Toulouse (France) on March 2nd, 2012.

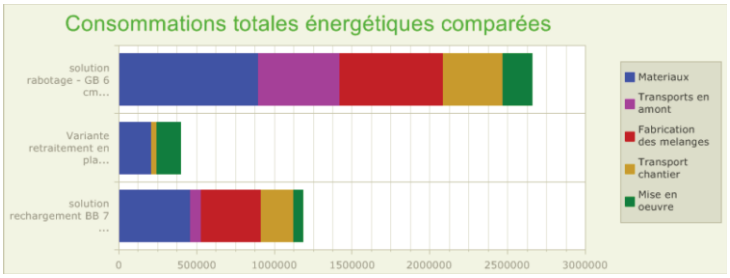
One of innovations that were presented is the "second generation" cold in place recycling process, that consisted in assessing the feasibility of recycling of an already recycled pavement. The trial site was done on RD 125 (Haute Garonne, France), dealing with 8000m$^2$ of pavement. The technical solution was:

- Cold in place recycling using emulsion 8 cm deep
- Wearing course using a micro surfacing

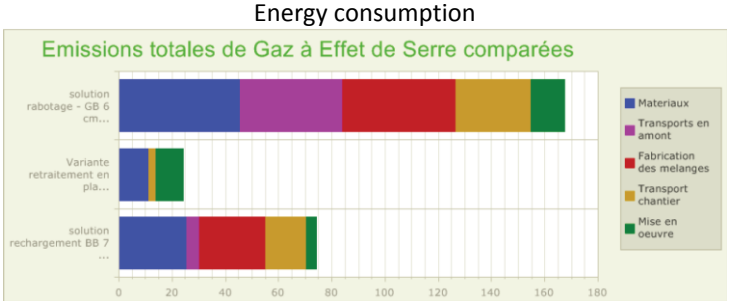
Two technical equivalent solutions were considered:

- Placing a 7 cm thick layer of hot mix asphalt
- Milling and placing a 6 cm of road base asphalt + very thin overlay (2.5 cm).

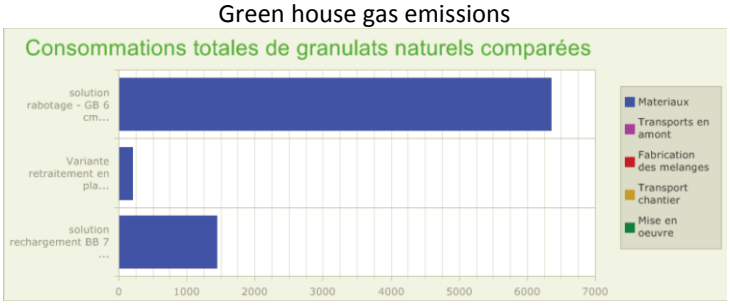
Once the technical feasibility has been demonstrated, the environmental assessment was conducted with the following results[21]:




Energy consumption




Green house gas emissions




Aggregate consumption

All graphs clearly show the positive impacts of the cold in place recycling technique. But more than that, it quantifies such impacts, translated into figures.

### 2.3. A new generation of chip seal: new equipment, improved components

A new panel of modified emulsions and the contribution of fibers have totally changed the technical acceptance from road owners and engineers for the chip seal techniques, which remain amongst the most economical for pavement preservation.

Hot spray and emulsion based chip seals have been used for years throughout the world, with a heavy trend in favor of emulsions, thanks to three main factors:

- The cost of fluxes and solvents used in hot sprays has been permanently increasing during the past years
- Safety regulations make hot spray uneasy to handle, while emulsions are used at ambient temperature
- Environmental demands from the various stakeholders, translated into regulations, lead the professionals to more and more consider the use of bitumen emulsion, including in countries such as South Africa, New Zealand and Australia that have a long tradition of hot spray[22]. In countries such as the United Kingdom and Ireland, bitumen emulsion is the sole material used for chip seal.

Moreover, within the frame of budget restrictions, many road owners are moving back to this technique, using advanced systems:

- Installation equipment

A new generation of spraying machines and spreading devices has been used now for several years. Such equipment includes integrated systems combining the binder spraying and the aggregates spreading. Such systems allow reaching an optimum wetting of the aggregates by the emulsions and, as a result, an optimum adhesion between the aggregates and the remaining binder. Moreover, IT systems are used that guaranty a constant rate of binder whatever the spraying width and the equipment speed. Some systems are even fitted with an ultrasonic gauge that permanently measures the distance between the spray-bar and the surface, a back regulation ensuring this distance to be constant. Such a system contributes to obtain a fully even distribution of the binder on the surface.

Computerized system

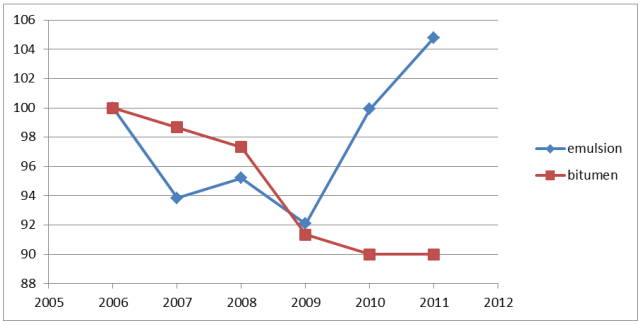
Dual machine

- Design

The increasing loads that the surface wearing courses have to bear request the use of improved binders, such as:

- Modified emulsions using natural latex (SBR) or synthetic polymers (SBS)
- Combination of emulsion and fibers

The use of modified emulsion has been significantly developed in countries where the technique is properly mastered and implemented. This is the case in the United Kingdom where 80% of the emulsions used for chip seal are modified. Such a control has contributed to the success of the emulsion industry, within a depressed road industry, as shown in the diagram below.




Variations of emulsion and bitumen uses in the UK

Chip seals contribute to the imperviousness of the pavement. They also restore the skid resistance of the surface, contributing to the safety of the road users. They can also be used as SAM and SAMI, with additional resistance brought by fibres that are added into the sprayed emulsion. In a single operation, specialist machinery cuts and applies the glass fibres between two layers of emulsion to form a sandwich type matrix. Selected aggregates are then added via a purpose built or conventional chipping spreader. Application is completed by rolling and sweeping, leaving a crack and fatigue resistant surfacing characterised by enhanced tensile strength. These techniques have been used in Europe and also in the USA, with official recognitions such as publications by US Authorities[23] and "avis technique" in France[24].

Such technique is also used as a SAMI when reflective cracking issues needs to be addressed[25].

## 3. CONCLUSION

In many countries, pavement preservation budgets are hit by budget restrictions and most likely this situation will last for the years or decades to come. Moreover, social demands from the stakeholders and environmental requirements have added to the technical challenge the road industry has to meet. In the meantime, the duty of the governments, at each stage, is to ensure that the road networks are kept in good condition.

Within the frame of such a stringent context, road owners, road authorities and the road industry have worked for years for the development of technically sound products and processes that will contribute to make the best use of the allocated budgets.

Bitumen emulsions are part of these solutions, with developments that contribute to address the multiple issues. A new generation of tack coats – bond coats - , cold in place recycling and a range of improved chip seal systems are examples of such developments.

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