

## **ASPHALT EMULSIONS: BEYOND PAVEMENT PRESERVATION**

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## **ABSTRACT**

Asphalt emulsions are mainly used for pavement maintenance, including both surface maintenance (e.g. surface dressing, micro-surfacing) and structure maintenance (e.g. cold in place recycling, gravel emulsion).

Versatile and adaptable, asphalt emulsion techniques can be used in a wide variety of situations and are very attractive from an economic viewpoint.

These techniques are well known and enjoy ongoing improvements through the use of new chemistry, new formulae and design, not to mention new manufacturing and laying equipment.

Beyond pavement maintenance and sustainable pavements, asphalt emulsions contribute to sustainable development by reducing energy consumption and emissions of greenhouse gases. Models have been developed and assessed that show the positive impact of the use of asphalt emulsions on these parameters, fully in line with the “Declaration on Environment and Climate Change” adopted by the Group of 8 (G8) in June 2008.

## INTRODUCTION

Pavement preservation is a global concept. In fact, road network operators have the responsibility of maintaining the asset they are in charge of, but such a responsibility goes far beyond the mere preservation of pavements.

Primarily, road users' safety should be ensured at all times. This social – and financial - requirement will be translated by road engineers into technical parameters such as evenness and skid resistance.

Beyond the road users, it is the needs of the whole community which have to be addressed. This is the societal responsibility of the road network operators. Such responsibility may cover several aspects:

- Noise emission and limitation for inhabitants who live in the vicinity of the roads,
- Impact of road work on people,
- Safety of the workers in charge of the roadwork,
- Environmental impact of road works,
- Environmental impact of traffic.

Last but not least, the financial constraints lead the operators to search for the best compromises, by selecting the most appropriate technologies.

## BACKGROUND

### Road networks: an asset to be maintained

“Roads: Primary Asset of Nations”. This was the motto of the 15<sup>th</sup> International Road Federation World Meeting that was held in Bangkok, Thailand in June 2005.

Like any asset, it has to be maintained. This is pavement preservation. The budgetary expenses that need to be devoted to pavement preservation should be compared to the actual value of the asset. Beyond this single consideration, one should realize that expanding a road network means that the maintenance needs will be automatically and proportionally increased.

Like any asset, a road network will deteriorate if left without maintenance. Initially, the main part of a road budget is devoted to construction of new roads. The more developed a road network, the more maintenance it will require.

However, “Roads in many parts of the world are poorly managed and badly maintained, usually by bureaucratic government road departments. The poor state of the road network is reflected in the large backlog of deferred maintenance. [...] Even in industrial economies such backlogs are common and becoming more so. For example, in 1996 a survey conducted by the U.K. Institution of Civil Engineers found that in Great Britain there was a \$5.61 billion maintenance backlog on local government roads (69 percent of the total public network). Because countries have consistently spent far too little on routine and periodic maintenance in the past 20 years, much of the large amount of money already invested in roads has been eroded” [1].

Surprisingly (or not?), reliable data about road expenditure are available, while it is quite difficult to assess the value of the capital investment involved. It becomes, therefore, impossible to evaluate the relative cost of road maintenance (maintenance cost v/s asset value).

As an example, the International Road Federation issues periodic “World Road Statistics” that include, *inter alia*, countries profiles, road network, road traffic, vehicles in use [2].

On the other hand, data about the road capital are quite scarce. In most cases, that asset belongs to the Government (National or Local Road Authorities and Agencies), and it is, therefore, an inalienable asset, even if its management can be entrusted to third parties (concessions and other PPP).

In France, for instance, the value of the 28,000 km national road network (including the toll free motorways) that is managed by the Ministry of Transport is assessed at €125 billion [3], figure to which one can add the value of the conceded motorway network, of about €55 billion [4].

On top of this, one can add the value of the road networks that are managed by local authorities and councils (close to 1 million km as a whole). Using the above figures, the value of the total French road network can be estimated at some €1,000 billion [5]. Even if the accuracy of the estimate may be questioned, such an enormous amount represents approximately two thirds of the yearly GDP of France (1€ = 1.4023 US\$ July 1<sup>st</sup> 2009). Similar calculations may be done for other countries, and would likely lead to similar conclusions. But, of course, if any road network requires decades to build, it has also been built to last for decades.

## **Maintenance principles**

Maintenance principles follow the pavement concept principles: a pavement is made of two parts:

- The structure
- The surface

The structure is the major part of the pavement. Its role is to transfer the traffic loads to the subgrade. The design of the structure derives from this concept: it is made of a base and a sub-base course. The thickness of each of these layers will respectively depend on the traffic and the bearing capacity of the subgrade. The load transfer induces repeated stresses within the materials, leading to failure by fatigue after a certain number of loads without maintenance. Maintaining the structure will therefore will be carried out according to the following principles:

- Thickness increase
- Restoration of the mechanical characteristics of the materials

Pavements are usually designed for a 20-30 year lifetime.

The surface is meant to ensure an adequate interface between the pavement itself and the vehicles' tires, thus providing the vehicle and its occupants with:

- Safety: skid resistance, evenness,
- Comfort: noise reduction, evenness.

From a design point of view, this interface is made of a wearing course, its thickness aimed to be minimum, as its composition requires the use of high quality materials (aggregates, asphalt). In practice, this thickness is a combination of the characteristics of the associated product used as a wearing course, and the profile of the surface on which it has to be laid. Traffic induces the wearing of the materials which will have to be replaced, renewed, and/or overlaid, by a new wearing course. The lifetime of wearing courses usually ranges between 5 and 15 years.

## A short history of asphalt emulsion

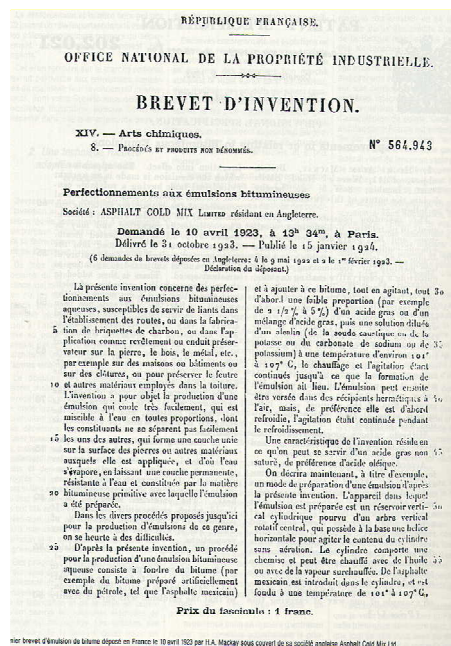


Figure 1.

Asphalt emulsion has become a technical product, used in technical systems. This achievement has only been made possible thanks to the commitment of the industry as a whole: road industry, emulsifier and asphalt suppliers and equipment manufacturers. Recognition of such commitment was realized with the World Emulsion Congress [7], initiated in 1993 by COLAS [8]. The fifth congress is to be held in Lyon (France) in October 2010.

## ASPHALT EMULSIONS AND PAVEMENT PRESERVATION

### Surface and structure

As described above, design and maintenance principles lead to systems (materials and techniques) that suit specific needs. In this respect, asphalt emulsion techniques fulfill the requirements of both structural and surface maintenance principles:

- Grave emulsion and cold recycling are used for structural maintenance
- Micro surfacing and surface dressing are used for surface maintenance

These are not the only asphalt emulsion based techniques. Intermediates such as stabilization, improved cold mixes, Cape seal and fog seals are available within a large technical portfolio.

Asphalt emulsion is a worldwide technology, initially developed in the 20's. Since the first patents were filed in Europe, world production has grown steadily, reaching 7.8 million metric tons in 2005 (i.e. a 23% increase within a 15 year period) [6]. This figure is still relatively low, compared with the consumption of liquid asphalt for road works, which represents some 80 million tons. However, new requirements in the field of Health Safety and Environment should boost emulsion volumes.

A brief description of some aspects of the emulsion techniques is proposed hereafter. International and national associations (US [9], France [10] and many others) have made available some technical handbooks that describe the various options in details.

## **Structure improvement**

### ***Grave emulsion***

Grave emulsion is obtained by dispersing a controlled slow-breaking emulsion into an aggregate mix and then cold-mixing the combination. In terms of maintenance, this material is suited for:

- Reprofilings,
- Local repairs,
- General overlaying and reinforcement.

A specificity of grave emulsion is that it enables bevel joints with existing pavements, thus saving in the materials used. This quality is unique to grave emulsion.

It is a typical reinforcement system, in which the pavement resistance has been improved by the use of a thick overlay.

On a larger scale, i.e. cold mixes, some significant technical developments have been conducted in the past decades, such as the OPTTEL project, initiated within the 4<sup>th</sup> European R&D framework programme Brite-Euram III. The prime ambition of the OPTTEL project (Slow Setting Cationic Bituminous Emulsions for Construction and Maintenance of Roads) was to improve our fundamental understanding of the various underlying phenomena. This leads to the design of a more rational formulation and optimization methodology for cold mixes and thus to foster a broader use of this technique [11].

### ***Cold in-place recycling***

This consists in the retreatment all, or part, of a carriageway with asphalt emulsion, rejuvenating or not, with or without addition of granular materials. Such a process leads to formation of a sub-base layer or base course layer, depending on the conditions. This layer then requires a suitable wearing course, such as surface dressing or micro surfacing.

In such a case, the pavement lifetime has been improved by processing the material itself, without the addition of a significant extra-layer.

Cold in-place recycling has been developed over the past 30 years, with consistently growing interest from the owners and communities. In Europe, the European Commission decided to finance a research project on in-place cold retreatment called SCORE (Superior Cold Recycling) based on the benefits of bituminous emulsions [12].



Figure 2.

## Surface treatment

### *Micro surfacing and surface dressing*

As their names imply, these layers are thin (say 10 to 20 mm). They are meant to restore the superficial characteristics of the surface, thus providing it with adequate skid resistance and waterproofing.



Figure 3.

*Micro surfacing* is a mixture of asphalt emulsion (usually modified), selected mineral aggregates, water and specific additives in set proportions, mixed and applied evenly onto a clean, prepared surface. All the operations are made on site, using a single dedicated machine. This allows for quick laying, with low traffic disruption, which might be a specific requirement from the owner. As a matter of fact, professionals know how to design mixes that allow for traffic reopening within 30 minutes max

*Surface dressing* is a thin wearing course consisting of superimposed layers of chippings and asphalt emulsion. The composition of the surface dressing, the quantity of materials per unit surface area and the desired qualities depend on the requirement for a particular situation. A number of different parameters must be taken into consideration for each specific pavement, for example: type of substrate, traffic level, etc. The optimum technical solution, in line with economical considerations, is selected from the possible binder – aggregate combinations.

Surface dressing is known to be the most economical surface technique; this is a reason why it is widely used worldwide, in both industrialized and developing countries [13]. Since its early days, the technique has been improved throughout the world, using various techniques. Such development and variety lead the ARRB to organize the 1<sup>st</sup> sprayed sealing conference in Adelaide, Australia, in July 2008 [14].

### *Expanding structural lifetime*



Although these techniques are meant to restore the surface characteristics of a pavement, they also improve the waterproofing of the whole structure. As a result, the characteristics of the materials are preserved while reducing the water content of the sub grade. In case of materials sensitive to water content, such protection will have a considerable impact on the lifetime of the pavement, as the latter may be endangered by the weakness of the subgrade. This is typically the case for clayish or silty materials.

The following example shows the impact of the bearing capacity of the subgrade, when the latter is altered from 50 to 25 MPa (Using the French pavement design method [15]):

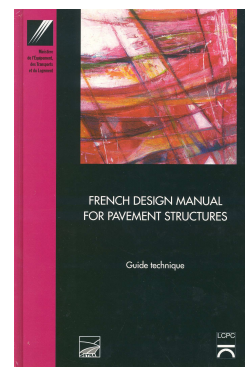


Figure 4.

	Lifespan (10T standard axle load)	
Bearing capacity (subgrade)	50 MPa	25 Mpa
Rural road	27 000	2 500
National road	750 000	675 000

Table 1

Such figures are significant. For rural roads, it is one of the reasons why SABITA [16] is steadily promoting the surfacing of gravel roads [17]. This interest is shared by the International Road Federation which will be organizing the 2009 convention on rural roads (Arusha, Tanzania, 25 November 2009 - 27 November 2009), in cooperation with TARA (Tanzania Roads Association).

## DEVELOPMENTS

### Standardization and common understanding

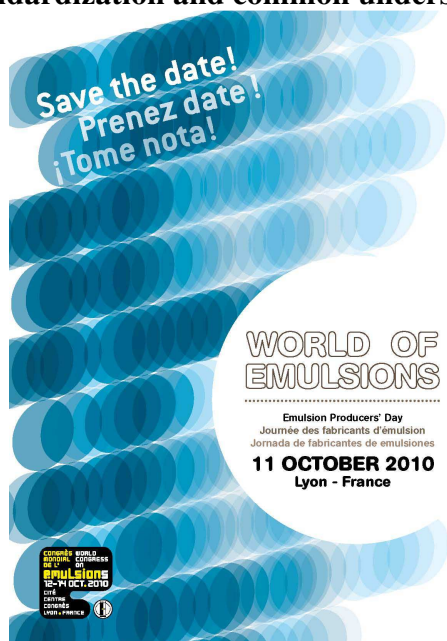


Figure 5.

With the increasing globalization of the markets, it has appeared more and more necessary to develop a common understanding between the professionals. This was one of the reasons why national associations decided, in 1993, to join forces and create the IBEF [6]. In order to promote direct communication between its members, the IBEF organizes, every 4 years, a symposium “World Of Emulsions”, connected to the Emulsion World Congress [8]. The next symposium is scheduled for Oct. 11<sup>th</sup>, 2010.

In Europe, the members of the European Union have struggled hard for years towards unified and common systems that have been materialized by the European Standards. These standards



are based on performance. One should also note that the European standard system requires additional commitments from the industry regarding systematic and audited quality control. This trend is in favor of a real industrial approach of emulsion manufacturing as well as of its uses. Such standards are now in force for Asphalt emulsions, surface dressings and micro surfacings.

This approach is not unique to Europe. In New Zealand, performance-based chip sealing contracts are reported. Since the original “scientific” analysis of chip seals and a development of a design methodology were made by Hansen in the 1930s, some major changes have occurred.

## **Health Safety and Environment**

Growing concerns about the environment, together with improved regulations related to the welfare of workers and the general population have lead professionals to move towards a global and integrated concept of Health, Safety and Environment (HSE).

Until 10 or 20 years ago, a technique was promoted by highlighting its performance and cost, to obtain the best performance v/s cost ratio. Health, Safety and Environment issues did not play the role they do today. When the first meeting of the Asphalt Emulsion Association was organized in 1993, the agenda did not include one single presentation about HSE. However, in his interview, the chairman of the SFERB stated: “Asphalt emulsions contribute to environmental friendliness, since it is one of the most ecological road products. It is, without any doubt, a product with numerous applications and good prospects”. In 1997, two papers were presented about “safety” and “the environment”.

During the 2008 E&E congress in Copenhagen, the moderator for Session 7 (Energy reduction / Lower temperature technologies / Technology transfer) stated in his introduction: “Some twenty years ago, an easy way to start a presentation on paving materials was to state that the road network had to face increasing traffic volumes and axle weights. Nowadays, the new challenges are energy saving, sustainable and environmental-friendly development”.

This confirms that the industry has been taking this third parameter into account for some time, especially through its associations. The balance is no longer just “performance – cost”, but “performance – cost – HSE”.

For instance, tar was used for years in many countries, and was progressively abandoned or even prohibited. The same trend has occurred for the cut backs. On the other hand, the industry has been promoting more and more “green” systems, such as rape seed oil instead of solvent for some surface dressing emulsions.

In Europe, HSE concerns have driven European policy to implement the REACH regulation for the **R**egistration, **E**valuation, **A**uthorization and **R**estriction of **C**hemicals. REACH entered into force on June 1<sup>st</sup> 2007 and places greater responsibility on the industry to evaluate and manage the risks that chemicals may pose to health and the environment. REACH applies to all chemical substances and, thus, to liquid asphalt and emulsifiers. First in-line are the producers and importers of the substances, who have to do the actual registration. But emulsion producers and users will be impacted as well. Some emulsifiers and additives that are currently used may, indeed, disappear from the market. Moreover, emulsion producers and

downstream users will have to contribute to the assessment of risk by estimating and measuring the exposure to substances in relation to emulsion formulations and application.

The incentives to develop energy saving, safe and environmentally friendly techniques are higher than ever, and it is believed that bituminous emulsions are still in a leading position.

## **Equipment**

The past twenty years have seen major improvements in the equipment, thanks to innovative manufacturers and progress in automation engineering and electronics. This applies to manufacturing equipment as well as to laying techniques.

## ***Manufacturing***

Asphalt emulsion is an industry. Therefore, the manufacturers have constantly selected the best suitable available technologies, such as:

- Flow metering (electromagnetic and mass flow meters),
- In line control (pH measurement with automatic acid proportioning),
- Automatic processing, mainly for starting and stopping procedures,
- Electronic data recording of numerous parameters, which makes possible to trace not only the characteristics of the manufactured product, but also the corresponding manufacturing process parameters,
- Remote maintenance of the plants, remote control of the storage (raw materials and finished products).

## ***Laying techniques***

For surface dressings, new machines are now used, which spray the binder and then spread the aggregate immediately afterwards. Such machines prevent any run off of the emulsion on the surface, thus keeping an even transversal distribution of the binder. Moreover, this system ensures that the aggregates will be spread on an unbroken emulsion, thus optimizing the adhesion of the aggregate to the asphalt. Both these factors contribute to the lifetime of the surface dressing.

Improvements in automation engineering and electronics have also helped to optimize the functioning of the machines, improving the flow of materials, while recording the quantities used. Such records are also evidence of the quality of the works. Traceability is thus ensured.

For complex processes, such as cold in-place recycling, profilers are equipped with computers that enable to get the right final mix, ensuring an adequate consistency of the end result.

## **ENERGY SAVINGS AND GREENHOUSE GASES EMISSIONS**

### **Global awareness**

AT the UN conference on human environment held in 1972 in Stockholm, ecological questions appeared for the first time amongst international concerns. The UN program for the environment was created on that occasion. At the same time, the “Club of Rome” issued a famous report entitled “stop growing?” A summit was then held in Nairobi in 1982, but its outcomes were altered by the international context of the cold war.

Since these events, the World summits on sustainable development held in Rio de Janeiro in 1992 and Johannesburg in 2002 have placed environmental issues on the forefront of thinking and concerns, now shared worldwide.

### Tools for the construction industry

For its part, the road community, as a whole, has taken initiatives in order to evaluate its role in this context. As a major and global player, the International Road Federation has joined in this debate, by the means of events such as the “Road and the Environment” seminar, held in Geneva in 2007, that gathered various specialists from international organizations and NGOs such as the Word Bank, PIARC or the Borneo Tropical Forest Foundation.

In the meantime, the international community has started to set standards that are meant to assess the impact of human activities on the environment. Such standards facilitate understanding between players active at a global level. Amongst these standards, one may recall the EN ISO 14040 (June 1997) entitled “Environment management – life cycle analysis – principles and framework”.

Life cycle analysis is a technique for assessing the environmental aspects and the environmental impacts associated with a product, a process, a material. One of its aspects is to identify and select adequate indicators, together with the corresponding measurement methods.

For the construction industry, including road works, the main environmental impacts to be taken into account are the following:

Impact	Unit
consumption of power resource	MJ
depletion of natural resources	kg eq. antimony
water consumption	l
solid waste	kg
climate change factor	kg eq CO <sub>2</sub>
atmospheric acidification	kg eq. SO <sub>2</sub>
air pollution	m3
water pollution	m3
alteration of the ozone layer	kg CFC R11
photochemical ozone creation	kg eq. ethylene

Table 2

This list is part of the French Standard 01-010 (2004) “Environmental quality of construction products – Environmental and health declaration of construction products”.

In France, such impacts have been assessed for asphalt emulsions, within an adapted framework, as shown hereunder [18]:

Impact on environment	Destination of Asphalt emulsion					
	Unit	Emulsion cold mixes	Micro surfacing	Surface dressing	Bond coat	Recycling
Consumption of power	MJ	3.783	4.054	3.964	3.690	3.693

resources						
Climate change factor (GHG)	kg eq. CO <sub>2</sub>	206	221	217	202	202
Atmospheric acidification	kg eq. SO <sub>2</sub>	2.1	2.1	2.3	2.1	2.1
Pollution of air by hydrocarbons	g	26.66	26.66	28.86	26.66	26.66
Pollution of water by hydrocarbons	g	2.67	2.67	2.89	2.67	2.67
Depletion of natural resources	kg eq. antimony	12.8	12.8	13.8	12.8	12.8
Solid waste	kg	22.5	22.8	24.0	22.4	22.4
Radioactive waste (electrical energy consumed)	kg	0.0033	0.0033	0.0033	0.0033	0.0033
Formation of photochemical ozone	kg of eq. ethylene	0.79	0.79	0.86	0.79	0.79

Table 3

These impacts may be classified according to the following criteria:

- Short, medium, long term,
- Local, global.

In this respect, both consumption of energy and climate change may be seen as the most critical areas, as they involve the long term and the whole world community.

### Tools for the road industry

Energy is a major part of the costs borne by the road industry, and therefore by the community. Most of this energy consists in hydrocarbons (fuel, gas) used by trucks for the transportation of materials, as well as by various plants and equipment such as asphalt plants and installation machines (pavers, compactors).

For the road industry, saving energy therefore means costs savings that will be transferred to the owners and to the global community. Another positive consequence is that fuel or gas savings will automatically result in a reduction in CO<sub>2</sub> emissions.

Environmental issues are often perceived as constraints. This should not be the case when a proper holistic approach is adopted. In the field of road construction, it is clear that it is the opposite: an environmental constraint that would lead to energy savings and CO<sub>2</sub> reduction would result in costs savings.

In this way, limiting the consumption of energy as well as the production of CO<sub>2</sub> goes beyond the single pavement preservation concept, and towards a global sustainable development scheme.

This approach has been reinforced in 2008: In June 2008, the Group of 8 adopted a “Declaration on Environment and Climate Change”. Even if it differs from a treaty, this declaration states: “We seek [...] to consider and adopt in the UNFCCC negotiations, the goal of achieving at least 50% reduction of global emissions by 2050 [...]. Substantial progress

toward such a long-term goal requires [...] the acceleration of the deployment of existing technologies, and in the medium- and long-term, will depend on the development and deployment of low-carbon technologies [...]. In this regard, we emphasize the importance and urgency of adopting appropriate measures to stimulate development and deployment of innovative technologies and practices.”

### The “Écologiciel ®”



Figure 6.

Taking these new concerns into accounts, the road industry stakeholders have started to develop dedicated and pragmatic tools meant to assess the impact of road techniques on the environment, as far as energy consumption and CO<sub>2</sub> emission are concerned.

One of this tool is the Écologiciel®, or software developed to assess the performance of any road technique, and which was officially presented to the road community during the PIARC congress in Durban, South Africa, 2003 [19].

### Asphalt emulsions, pavement preservation and sustainable development

Such an approach will definitively boost the development of cold technologies, based on the use of emulsions. As an example, a comparison is made between hot and cold mix manufacturing.

Manufacturing process	Eq. CO <sub>2</sub> (kg/MT)	Energy MJ/MT
Hot mix 160°C moisture content 3%	21	277
Cold mix	3	36

Table 4

This is not theory: in Japan, “JEEA has been promoting that cold mix with asphalt emulsion can be manufactured at low energy consumption and it is effective to decrease CO<sub>2</sub> emission”.

Other comparisons can be made when in-place recycling is used instead of conventional strengthening works:

Manufacturing and laying	Eq. CO <sub>2</sub> (kg/T)	Energy MJ / ton
Bituminous concrete	46	683
Continuous reinforced concrete	165	1586
Cold in-place recycling (emulsion)	8	138

Table 5

As far as surface treatment is concerned, the comparison of various techniques clearly shows the difference between hot and cold techniques, when such parameters are taken into account [19].

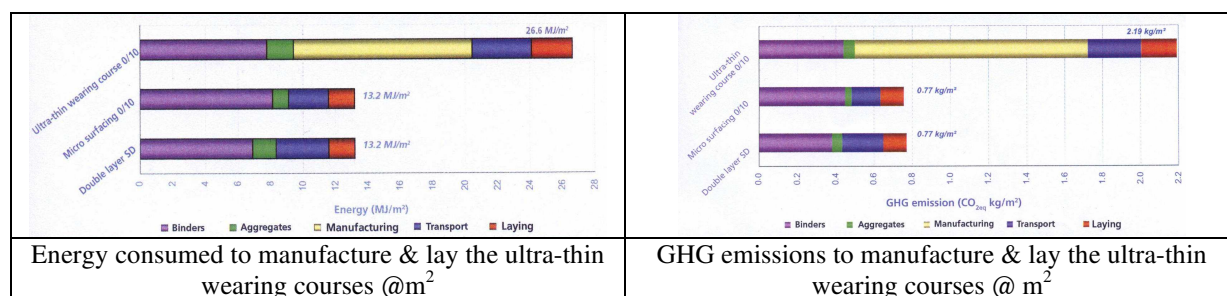


Table 6

## CONCLUSION

Pavement preservation is a national duty. Road owners have a wide portfolio of suitable techniques, which can be optimized so that the whole community gets good value for money.

Beyond such economical efficiency, new requirements have arisen in the field of environment preservation. These new requirements lead to the identification of new criteria which will help select the most appropriate techniques from the available portfolio.

The main new criteria are energy consumption and CO<sub>2</sub> emissions. They are significant and even crucial, as they deal with global and long term impacts. Asphalt emulsion techniques are appropriate answers to such challenges.

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