



International Bitumen  
Emulsion Federation

# SUSTAINABILITY OF BITUMEN EMULSIONS

*WHITE PAPER*



*Third EDITION / February 2025*

# FORWARD

Bitumen emulsions play a pivotal role in constructing and maintaining road networks. This approach to asset preservation aligns with the principles of sustainable development on a global scale.

The International Bitumen Emulsion Federation (IBEF) connects bitumen emulsion producers through their national associations and partners. It comprises 35 members from around the world. The IBEF serves as the recognized international authority for enhancing techniques and facilitating information exchange related to bitumen emulsions.

*This white paper aims to describe the actions and movements of the bitumen industry within this context. It is written in memory of Carl Robertus, a former member of the IBEF executive committee, whose contributions led to the completion of this document.*



## CONTRIBUTORS

AEMA	Arlis A Kadrmas
AEMA	Mike Tyree
AEMA	George Mariani
ARKEMA	Abdeltif Belkahia
REPSOL	Lucía Miranda Pérez
ATEB	Patricia Lameda Febles
IBEF	Carl Robertus
IBEF	Xavier Guyot
IBEF	Etienne Leboutteiller
IBEF	Hamidreza Sahebzamani
Ingevity	Stephane Charmot
SFERB	Brice Delaporte
REA	Dennis Day
SABITA	Phil Hendricks

## CONTENTS

Introduction	4
<b>1. Pavement durability</b>	6
1.1. Construction: Prime coat and bond coat roles in pavement durability	8
1.1.1. Prime coat	13
1.1.2. Tack/Bond coat	13
1.2. Preservation and maintenance: the main playground of bitumen emulsion	14
1.2.1. Preventative treatments effectively reduce the embodied carbon.	18
1.2.2. Products and Processes for Surface Treatment	20
1.2.3. Unique and specific characteristics of gravel emulsion and microsurfacing.	23
1.2.4. Single surface treatments	24
1.2.5. Life Cycle Analysis	26
<b>2. Structural improvement</b>	30
2.1. Techniques and Processes for Pavement Structural Improvements	31
2.2. In-place vs In-plant applications	33
2.3. Focus on the energy, GHG emissions and cost savings done when completed "in-place, on the road" vs. haul distance	34
2.4. HSE aspects focused on application including non-haul, resource savings, etc.	36
<b>3. Environmental and social impact</b>	40
3.1. Saving energy and lowering carbon footprint	42
3.2. Recycling options that save virgin materials (and energy + carbon footprint) multiple recycling feasible.	44
3.3. HSE aspects	46
3.4. Social Impact of bitumen emulsion technologies and their applications	47
3.5. Economics: Result of the aforesaid topics: saving material and energy	47

### References

## INTRODUCTION

This activity's objective is to define and emphasize how bitumen emulsions contribute to sustainability, sustainable development, and/or reducing environmental impact to promote their use in road construction.

## The key pillars of bitumen emulsions in terms of sustainability are as follows:

### **Pillar 1 – Pavement Durability:**

- The primary aim is to optimize or maximize pavement durability and lifespan.
- Bitumen emulsion applications and treatments play a crucial role in achieving this goal.
- Sub-pillars further describe the strategies for enhancing pavement durability.

### **Pillar 2 – Pavement Structural Improvement:**

- Rehabilitation focuses on restoring the structural capacity of distressed pavements that go beyond routine maintenance or preservation efforts.

### **Pillar 3 – Environmental and Social Impact:**

- This pillar considers the global environmental and social impact of bitumen emulsion technologies and their applications.

**1**

**PAVEMENT  
DURABILITY**

## 1.1 Construction: Prime coat and bond coat roles in pavement durability

### 1.1.1 Prime coat

**When it comes to newly constructed or reconstructed roads, waterproofing and stabilizing the aggregate road base are crucial. A well-bonded hot mix asphalt layer over a primed aggregate road base reduces the likelihood of the asphalt overlay slipping, cracking, and breaking apart, all of which can incur significant repair costs.**

Prime coats are specifically designed to enhance adhesion between hot mix asphalt layers and the aggregate or stabilized base, creating a stronger and more structurally sound foundation.

A prime coat involves applying a bituminous binder to a non-bituminous granular pavement layer as a preliminary treatment before applying a bituminous base or surfacing.

The primary purposes of a prime coat are to:

- Promote adhesion between the base and the newly applied bituminous base or surfacing.
- Inhibit rainwater ingress into the base while allowing water vapor evaporation from the base layer.
- Minimize binder absorption into the base during subsequent spray operations.
- Bind the finer particles on the surface of the base to accommodate light traffic temporarily until the new surfacing can be placed.

For a long time, fluxed bitumen or cutbacks were widely used for priming treatments due to their effectiveness and relatively simple manufacturing process. However, they come with numerous disadvantages, such as the risk of explosion due to low flash point values, solvent loss through heating, and long curing times (Ref. 1).

In contrast, emulsion prime coats offer several advantages:

- No risk of fire or explosion.
- Minimal harm to the environment.
- Improved wetting and adhesion.
- Faster curing time.

Because of these practical advantages and safe application, emulsion prime coat is a suitable binder for mandatory construction phases, contributing significantly to pavement durability. (Ref. 2, 3).



Figure 1 – Application of prime coat

## 1.1.2 Tack/Bond coat

**Pavement thickness design assumes that all layers of a pavement function collectively as one unified layer, rather than as a series of independent layers stacked on top of each other. Tack coats serve as bonding layers between each lift of pavement to create the desired monolithic pavement structure.**

If a proper bond is not established between the existing pavement surface and the new asphalt pavement layer, delamination may occur, resulting in the separation of layers. Delamination can lead to various structural distresses, with the primary types being slippage cracking and fatigue cracking (Ref. 4).

These failures necessitate expensive maintenance, as either a reinforcement layer or the poorly bonded layers will need to be milled off and replaced. The significance of the quality of bond coats cannot be overstated. The consequences of omitting or underapplying a bond coat are far more significant than any initial apparent cost savings (Ref. 5).

Several tried-and-proven solutions exist for bond coats, depending on the country or local specifications. However, the best recommended practices for achieving high-quality bonding interfaces are as follows (Ref. 6, 7):

- Cationic Rapid Setting Bitumen Emulsion is a traditional product for bond coats, typically containing 50% to 65% bitumen. Polymer-modified emulsion, with the addition of latex or modification of the base bitumen before emulsification, is highly recommended, especially under thin asphalt-wearing courses.
- The rate of spread of the bond coat should be at least 0.30 l/m<sup>2</sup> of residual binder and should be increased under thin or open-graded wearing courses to a minimum of 0.40 l/m<sup>2</sup> of residual binder.

- The binder should be applied, preferably by a calibrated spraying machine wherever possible, as evenly as possible to achieve complete and uniform coverage of the existing surface.
- Before applying the bond coat, the surface must be free of all loose or adhering material, dry, and any damp areas should be completely free of standing water.

A significant advancement in bond coat technology is the development of “Trackless” or “Non-tracking tack coats,” specifically designed to improve pavement performance by minimizing tracking problems associated with traditional products. These materials are typically formulated to harden quickly and adhere minimally to tires (Ref. 8).



Top: Figure 2 – Application of tack coat Bottom: Figure 3 – Trackless Tack coats – The emulsion is not picked up by truck tyres



## 1.2 Preservation and maintenance: the main playground of bitumen emulsion

### 1.2.1 Preventative treatments effectively reduce the embodied carbon.

**Preventative treatments effectively reduce the life-cycle embodied carbon of existing pavement and the use of natural resources through increased durability. Pavement preservation treatments have experienced an uptick in use recently due to agencies considering life cycle costs at various levels. These agencies now evaluate the entire financial burden of maintaining a road over a longer span of time, as opposed to the traditional approach of waiting for the road to fail before removal and replacement. By delaying major rehabilitation, pavement preservation conserves energy and virgin materials, making it inherently sustainable.**

The material production phase is the biggest contributor to CO<sub>2</sub>e emissions in the road life cycle. This phase includes the extraction of raw materials, manufacturing of mixtures, and transportation of both materials to manufacturing sites. The second biggest contributor to CO<sub>2</sub>e emissions in the road life cycle is the use phase. Fuel consumption in vehicles slightly increases due to pavement roughness, measured by the International Roughness Index (IRI) (Ref. 9). Although the effect is small per vehicle, it has a significant impact on the total emission when applied to high volume roads. In a study, the authors were able to create a fuel consumption factor for different IRI values (Ref. 10).

Some current agency practices use the “worst first” approach, which means they only maintain roads when major rehabilitation is required. However, during the first 75% of a road’s life, its quality drops by 40%, followed by another 40% in just an additional 12% of its life (Source: roadresource.org). This “worst first” approach fails to maximize the initial materials production phase or use phase. Additionally, when a road deteriorates significantly and remains in place, the additional fuel consumption in vehicles continues to increase.

To maximize the initial investment in CO<sub>2</sub>e in our

pavements and maintain roads in good condition, pavement preservation must be included. Pavement preservation treatments effectively utilize two materials that help reduce greenhouse gases: bitumen emulsion and recycled asphalt pavement. These materials reduce the consumption of virgin bitumen and virgin aggregate. Many pavement preservation treatments also do not require the use of a mix plant. In addition to reducing the use of virgin materials and plant operations, pavement preservation keeps good roads in good shape, maximizing the initial investment in both money and CO<sub>2</sub>e emissions.

The time required for treatment, the years of service added, and the CO<sub>2</sub>e contribution vary for each situation. Roadresource.org provides a calculator to determine the monetary and sustainability values of various treatments, which can be found here: <https://roadresource.org/preservation/calculator>. For example, a study compared three preservation treatments (crack seal, thin-lay, and chip seal), all of which resulted in reductions in IRI and CO<sub>2</sub>e emissions over the life cycle of the road (Ref. 11). Many of these treatments also offer faster return-to-traffic times compared to hot mix mills and fills or overlays.

## 1.2.2 Products and Processes for Surface Treatment

Road pavements globally are impacted by various factors, primarily influenced by local climate and traffic levels. These factors contribute to distress mechanisms that include surface wear or polishing, which reduces friction, as well as aging caused by excessive sunlight that leads to the formation of surface cracks. Other distress mechanisms include adhesive failure and structural weakness due to water ingress and ground movement, resulting in deeper crack formation. Additionally, traffic stresses can cause aggregate loss and deformation, and the binder also ages over time.

If these distress mechanisms are left untreated, the pavement can fail prematurely, leading to costly and resource-intensive remediation. However, there are several maintenance treatments available that utilize bitumen emulsions. When applied at the appropriate time, these treatments can help arrest the rate of surface cracking, restore skid resistance, seal the surface to protect against sunlight and water ingress, and withstand heavy traffic. Implementing these treatments not only helps extend the lifetime of the pavement but also reduces resource consumption and costs to varying degrees.

Surface sprays, such as fog seals, and rejuvenating seals, can indeed be applied early to protect the existing pavement surface from surface oxidation and crack formation. These types of surface sprays do not typically include additional aggregates or mineral products. Surface seals can be applied on top of surfaces to prevent mineral loss. This can include dust suppression and locking in aggregates on newly applied surface dressings (Ref. 12). Surface sprays which don't include aggregates don't improve friction and are not suitable on very dense surfaces or surfaces which have lost texture. The use of fog seals has been demonstrated to reduce the early onset of surface cracking extending pavement life and reduce early chip loss on newly laid surface dressing.

A recent study published in 2023 (Ref. 13), concluded that the use of fog seal prevented the formation of 20% surface cracking to a minimum of eight years. In another study (Ref. 14), the use of fog seal arrested surface oxidation, water ingress on old surfaces and reduced early life chip loss on newly laid surface dressing.

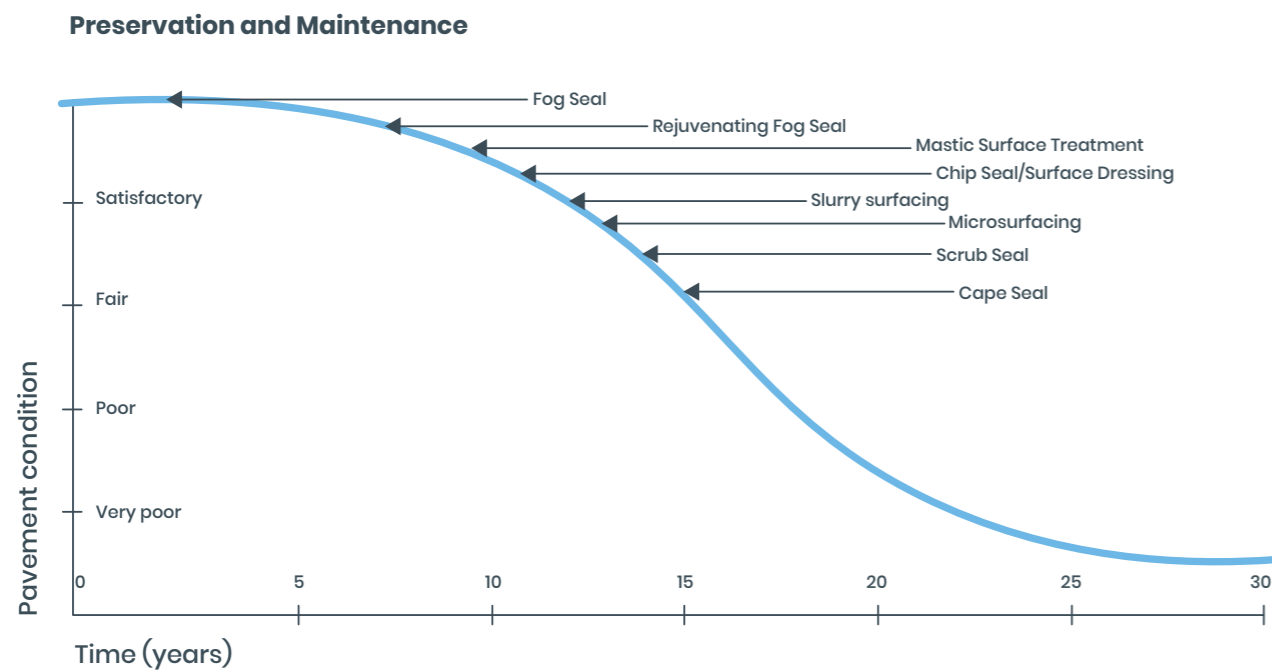


Figure 4- Treatment matrix, pavement condition over time



Figure 5 - Fog seal on surface dressing in rural setting

Surface sprays which include additional aggregates or minerals would be Surface Dressing, mastic seals and scrub seals. The application method and timing of application will depend on the site characteristics road category and distress type. All three maintenance techniques will improve skid resistance amongst other sustainability benefits. Using a rejuvenating scrub seal has demonstrated cost savings by reducing the need for a mill and fill crack treatment whilst adding friction to a heavily trafficked road (Ref. 15). Surface Dressing or Chip Seal design and application is dictated by substrate properties, local climate and traffic levels (Ref. 16, 17). Surface Dressing can prevent the formation of potholes by sealing surfaces preventing water ingress and extending the life of the road sustainably and cost-effectively (Ref. 18).

The use of Surface Dressing or Chip Seal as part of a planned maintenance program and used at the correct interval can extend the road lifetime up to 60 years. This results in a cost saving of 70% and a 69% reduction in CO2e compared to no treatment (Ref. 18).



Top: Figure 6 - Application of chipping in surface dressing  
Bottom: Figure 7 - Scrub seal overview

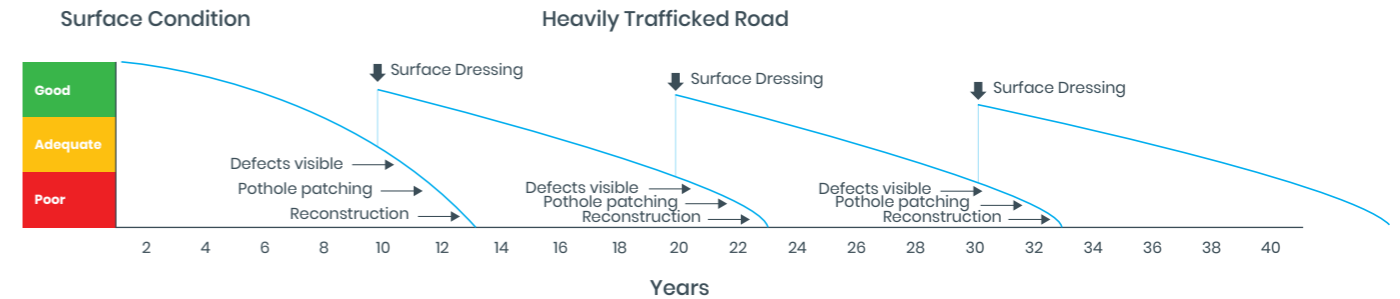


Figure 8 - Pavement maintenance routine - Image courtesy of RSTA

Mixtures of emulsion with aggregates can often offer better durability compared to surface sprays and are often classed as “cold asphalts”. The slurry surfacing materials can be applied by hand or by machine.

A study (Ref. 19) has demonstrated how Microsurfacing can extend the life by 15 years or more in one application and has enabled the local road authority to re-allocate substantial funds onto other projects from the savings achieved.

While the techniques mentioned above all work well in extending pavement life and offer various sustainability benefits as individual treatments, some treatments involving combinations of one or two of the processes can be more advantageous. Cape Seal, for example, is a combination of surface dressing and Microsurfacing, which offers greater durability and lower road noise. Additionally, the application of fog seal on fresh surface dressing can reduce early-life chip loss and increase the durability of the surface dressing.

A report (Ref. 20) on the use of Cape Seal as part of a maintenance program concluded that the process was net positive to the tune of 60-mile road years of extended life.



Figure 9 - Application of microsurfacing

### 1.2.3 Unique and specific characteristics of gravel emulsion and Microsurfacing.

**“Gravel emulsion is the best suited material for regulating.” This is a statement from an executive of the French road administration.**

The reasons for this special quality lie in the fact that gravel emulsion is a two-phase material: a skeleton of large elements (from 10 to 20 mm) in a residual-bitumen rich mortar. High internal friction from the large elements enables the materials to resist rutting, even with varied thickness values. On the other hand, the mortar makes it possible for the materials to bond to the regulating course directly, which means added savings in materials when regulating is the main goal.



Figure 10 - Application of gravel emulsion

Gravel emulsion is an anti-cracking material; therefore, its use in sufficient thickness can allow to avoid an “anti-reflective cracks” system (SAMI, fibers, geo-textile, grid, etc.). When road diversions are difficult to set up, gravel emulsion can be trafficked even during its placement, thanks to its cohesion. This is the case of roads in hilly areas. In such regions, an ideal pavement consists in a gravel emulsion layer as a base course, overlaid with a Microsurfacing. Credentials show that such a system is very resistant to the blades of snow ploughs, when access always needs to be ensured, e.g. to ski resorts. In remote areas, long hauling distances can hinder hot mix temperature control, often with no nearby asphalt plants. In hilly regions, installing diversions is nearly impossible, but gravel emulsion remains trafficable during placement.

For roadworks in an area away from asphalt plants, using a mobile plant for the manufacturing of gravel emulsion can be an economical option, not to mention the only option. This is very often the case in mountainous areas and in general in regions that have low population density.

Micro-surfacing provides the pavement with an appearance that is similar to that of a conventional asphalt mix (cold, warm or hot). However, its thickness makes it much more cost-effective than many other techniques. Microsurfacing is a cost-effective technique when appropriately used. As an example, in the Versailles district (France) the use of emulsion-based techniques (Microsurfacing and surface dressing) has led to a saving of 25% for the maintenance budget (Ref. 21).

Microsurfacing makes it possible to carry out sites without any preliminary grading (when the base is satisfactory). Microsurfacing also allows for works to be done without covering or modifying road markings, signs, surface signals and utilities.

Moreover, for slightly deformed pavement, regulating can be done by the same plant as the cold micro asphalt. Lastly, one of the main advantages of maintenance techniques on trafficked roads is the fact that the road can be very quickly re-opened to traffic after micro surfacing has been placed (less than 30 minutes).



Top: Figure 11 - gravel emulsion road

Bottom: Figure 12 - Microsurfacing texture over gravel emulsion

## 1.2.4 Single surface treatments

### Bitumen emulsion offers a wide range of surface treatments, including scrub seal, fog seal, surface dressing, slurry seal, and Microsurfacing.

Each of these surface treatments can be used in combination with another, such as:

- Double-course surface dressing
- Cape Seal
- Double-course Microsurfacing

Selecting the most suitable treatment, or combination of treatments, will depend on factors such as:

- Pavement condition
- Expected traffic
- Maintenance budget

It is important to note that a surface treatment is a thin layer and should not be considered a reinforcement process. However, applying a surface treatment improves the watertightness of the pavement and reduces the water sensitivity of the subgrade, thereby preserving its bearing capacity.

The pavement condition is primarily determined by the surface condition, including factors such as skid resistance, slight deformation, and whether the surface is dry or rich in bitumen. The wide range of surface treatments allows for the selection of the most appropriate one. Many countries, including the USA, have developed manuals and guidelines for surface treatments (Ref. 22).

The resistance of any surface treatment is closely linked to the expected traffic it will have to bear. The use of a modified binder can improve its shear resistance, and incorporating fibers into the system can also enhance shear resistance.

Using a thicker system, or applying a thicker layer of the

surface treatment, can increase the lifetime of the treatment.

When considering the lifetime of any surface course, a typical range of 10 to 15 years should be taken into account. (Ref 23).

Budget is always a key factor for road agencies when selecting the right treatment. Generally, choosing a thin system that is less costly than a thick system will result in a shorter durability. The selection process should prioritize finding the most cost-effective solution.

Microsurfacing is particularly well-suited for rural areas. On the other hand, surface dressings are useful when the pavement surface is slightly deformed without any structural issues.

Comparatively, it has been shown that the risk of failure is significantly lower with bitumen emulsion-based surface dressing compared to cutback-based surface dressing (Ref. 24).

Microsurfacing is a highly versatile system that can be applied on top of porous asphalt experiencing premature failure, such as aggregates stripping or raveling. Porous asphalt can become fragile under high traffic conditions. In such cases, applying microsurfacing on damaged porous asphalt improves the surface cohesion, allowing for potential replacement at a later stage based on the financial resources of the road agency (Ref. 25).

Bitumen emulsions have been increasingly used worldwide, replacing hot spray systems. The main reasons for this shift are the hazards associated with hot systems and adhesion issues. The development of modified emulsions, which exhibit high cohesion of the residual binder (up to 1.2 J/cm<sup>2</sup>) and fast cohesion build-up, has facilitated the quick reopening of the traffic road. When it comes to single-course surface dressing, using the racked-in system is considered the best option (Ref. 26–29). A "racked-in chip seal" refers to a type of chip seal where a first layer of larger aggregate is applied lightly, then a second layer of smaller aggregate is added to fill the gaps between the larger chips.



Figure 13 - Cape seal, South Africa



Top: Figure 14 - Polymer modified emulsion for surface dressing  
Bottom: Figure 15 - Microsurfacing in quick break systems



### 1.2.5 Life Cycle Analysis

---

**Life cycle analysis should be performed to determine the optimum timing for preservation and maintenance treatments and assess their effectiveness.**

The timing of preservation treatments can have a significant impact on the value they provide to the pavement. Some agencies prefer to wait for light deterioration before applying a surface treatment, while others opt to apply it soon after an overlay or thicker maintenance application. A trial conducted in Minnesota, United States, demonstrated the benefits of earlier application (Ref. 30 ,31).

Maintenance treatments such as Cold in-place recycling (CIR) and Full-depth reclamation (FDR) are typically performed when a pavement has deteriorated beyond the point where a surface treatment alone would be cost-effective. The timing of these applications is usually determined based on the road's ride quality, increased traffic, and the structural capacity requirements of the pavement. Comparing the life cycle and sustainability aspects of using recycled materials is an effective approach (Ref. 32).

Implementing a well-planned pavement maintenance program, with timely applications targeted at addressing specific distresses, can lead to cost savings and overall improvement in the road system managed by the agency (Ref. 33).



2

**STRUCTURAL  
IMPROVEMENT**

## 2.1. Techniques and Processes for Pavement Structural Improvements

Rehabilitation aims to restore the structural integrity of distressed pavements that require more than routine maintenance or preservation methods. Effective techniques that can be used depend on project conditions and needs. These techniques include:

- Cold In-place Recycling (CIR) – Partial Depth
- Cold Central Plant Recycling (CCPR)
- Base Stabilization
- Full-Depth Reclamation (FDR)
- Cold and Half Warm Recycling
- Cold Patching (spray and hand mix)

Cold recycling refers to the rehabilitation of asphalt pavements without the use of heat during the construction process. Recycling alternatives can include full-depth or partial-depth methods (Ref. 34-37). Full-depth CIR is commonly known as Full-Depth Reclamation (FDR). CIR and CCPR partial depth techniques typically involve treating and replacing the old distressed asphalt concrete layers. FDR, on the other hand, involves a complete replacement of asphalt concrete while including the aggregate base.

### Cold In-place Recycling (CIR) – Partial depth

CIR is the process of in-place recycling of asphalt pavement with single or multi-unit trains. CIR partial depth typically recycles the top 5 to 12 cm asphalt concrete using a continuous train operation from processing to compaction. CIR greatly reduces trucking, time, natural resources usage and cost mainly by re-using the existing material in situ.

### Cold Central Plant Recycling (CCPR)

CCPR (Cold Central Plant Recycling) is a process where asphalt recycling occurs at a central location using a stationary cold mix plant and an existing stockpile of RAP (Reclaimed Asphalt Pavement) that can be further fractionated into different RAP sizes. The stationary plant can be specifically designed with RAP cold bins and a pugmill, where

RAP, water, active filler, bitumen emulsion, and other additives are mixed. It can also be a CIR (Cold In-place Recycling) train without the milling machine, set up in a stationary configuration.

Typically, CCPR involves placing layers with a thickness ranging from 75 to 150 mm (3 to 6 inches), and multiple lifts can be applied. CCPR is a suitable option when an existing pavement cannot be recycled in-place due to logistical reasons, or when the existing asphalt concrete needs to be removed for the treatment of underlying materials. Additionally, as RAP stockpiles are accumulating from milling asphalt concrete pavements, CCPR can effectively utilize this available RAP to produce a high-quality, cost-effective, and environmentally friendly paving material.



Figure 16 – Cold In Place Recycling, partial depth, multi-unit train

### Full-Depth Reclamation (FDR)

FDR (Full-Depth Reclamation) is a rehabilitation technique that involves pulverizing the full thickness of the asphalt pavement and a predetermined portion of the underlying materials, such as the base, sub-base, or sub-grade. This process creates a homogeneous and upgraded material. The properties of the reclaimed materials can be further improved through bituminous stabilization. FDR is a viable alternative for roadways that are in poor condition or require an increase in structural capacity.

There are various equipment or configurations available for performing FDR work. These include a reclaimer with or without a mounted screed, as well as the option of using a reclaimer to directly feed a paver or not.

### Base Stabilization

Base stabilization is a rehabilitation technique that involves pulverizing and blending the material below the asphalt concrete, which can consist of aggregate base, sub-base, or sub-grade. This process

creates a homogeneous and upgraded layer. The properties of the reclaimed materials can be further improved through bituminous stabilization. Base stabilization is an attractive alternative to increase the structural value of the base layer, to avoid disruptions of utilities below the base layer, and reduce the required thickness of the asphalt concrete overlay.

### Cold and Half Warm Recycling

The use of RAP (Reclaimed Asphalt Pavement) in mixtures brings significant value as the aggregates are already coated with binder, reducing the demand for virgin binder when producing a final mixture that contains relatively large quantities of RAP.

Another option, apart from mixing RAP at ambient or “cold” temperatures, is to utilize half-warm recycling with emulsion (Ref. 38). A half-warm bitumen emulsion mixture is manufactured at a moderate temperature, typically around 80 to 90°C, with properties resembling those of a hot mix. This process consumes less energy and reduces aging. The emulsion is usually fluxed and can achieve some level of blending with the old RAP binder. There are primarily two manufacturing processes involved. The first process gradually warms the previously manufactured bitumen emulsion mixture in a cold mixture plant. With this approach, the RAP content can typically vary between 50 and 100%. The second process involves coating warm coarse and/or fine aggregates with RAP and emulsion, where some or all of the aggregates are heated. These resulting mixtures can contain as much as 60% RAP.



Top: Figure 17 – CCPR plant Bottom: Figure 18 – Full depth reclamation

### Cold Patching

Potholes in asphalt concrete pavement are formed due to the damaging action of traffic, moisture penetration, and repetitive freeze-thaw cycles. These potholes need to be filled to maintain an acceptable pavement ride quality, ensure motorist safety, and minimize vehicle damage. Pothole patching materials can be applied manually or by using spray injection patching equipment (Ref. 39).

Spray injection patching is a process where specialized equipment is used to simultaneously premix aggregate with heated bitumen emulsion. The mixture is then sprayed through a hose and nozzle directly into the pothole. Cold patch mixtures based on emulsion can be produced using either virgin or RAP (Reclaimed Asphalt Pavement) aggregates (Ref. 40).



Top: Figure 19 – Base stabilisation with emulsion  
Bottom: Figure 20 – Spray injection patcher

## 2.2 In-place vs In-plant applications

**It is important to understand and quantify the differences between in-place and in-plant applications in terms of project selection, performance, construction speed, and sustainability.**

One notable advantage of in-plant application is the control over the consistency and quality of the mixture. Fractionation of reclaimed asphalt pavement (RAP) brings consistency, and factors such as moisture content and gradation can be easily measured and calculated for the blend as part of the quality control process (Ref. 41).

Full-depth reclamation (FDR) has shown less temperature dependency and higher stiffness at low reduced frequencies or higher temperatures due to the inclusion of RAP and unbound materials. Conversely, cold central plant recycling (CCPR) and cold in-place recycling (CIR) mainly consist of RAP, which plays a larger role in the temperature-dependent stiffness properties of CIR and CCPR. In some cases, FDR specimens have exhibited lower permanent deformations than CCPR and CIR specimens (Ref. 42).

In-place applications offer significant benefits in terms of energy consumption and CO<sub>2</sub>e emissions compared to in-plant applications, primarily due to reduced transportation impact. The extent of the difference depends on the distance between the plant location and the job site.

Life cycle assessment data shows that cold recycling technologies can reduce energy consumption and greenhouse gas emissions by more than 50% and 40%, respectively, compared to traditional mill and pave methods. CIR has slightly lower energy consumption and GHG emissions compared to CCPR, mainly due to transportation impacts (Ref. 43).

Another benefit of an in-place application is the reduced construction time, which minimizes the impact on the travelling public. This results in shorter user delays and less disruption to road users due to shorter lane closure times.

Granular base stabilization with bitumen emulsion is an effective method for rehabilitating busy city streets. A project in Las Vegas demonstrated that construction time could be reduced from 120 days to 40 days compared to traditional reconstruction approaches. This reduction in time had a positive impact on residents, businesses, and road users near the project. The City estimated savings of approximately \$322,661, which represents a 30% cost reduction (Ref. 44).

## 2.3 Focus on the energy, GHG emissions and cost savings done when completed “in-place, on the road” vs. haul distance

**Cold-in-place recycling (CIR), particularly full-depth reclamation (FDR), is often compared to traditional mill and pave techniques, which involve the complete removal and replacement of damaged asphalt layers.**

Among rehabilitation techniques, cold-in-place recycling remains the most environmentally friendly solution. Various pavement maintenance projects have demonstrated that greenhouse gas (GHG) emissions and process energy consumption (related to materials extraction, asphalt mix production, transport, and application) can be reduced by half when using emulsion-based cold-in-place recycling compared to standard mill and pave methods.

According to roadresources.org, cold-in-place recycling techniques are 20% to 50% less expensive than traditional rehabilitation or reconstruction techniques. These cost savings are achieved through:



Top: Figure 21 - Cold in place recycling, France  
Bottom: Figure 22 - Cold in place recycling, Saudi Arabia

- A significant reduction in material consumption (with recycling rates exceeding 98%) and transport operations (saving over 300 truck movements on a typical project). The primary expenses are associated with added materials such as emulsion, cement, and/or corrective aggregates when necessary.
  - Increased construction speed (20% to 40% faster than traditional techniques).
  - Reduced mobilization of equipment and personnel on job sites.
- Considering all aspects, cold-in-place recycling techniques utilizing emulsion offer the best choice in terms of minimized environmental impact, efficient project management, and cost-effectiveness (Ref. 45-47).



#### 2.4 HSE aspects focused on application including non-haul, resource savings, etc.

**Cold in-place recycling also offers significant health, safety, and environmental (HSE) benefits. In fact, the risks of potential operational incidents on site are drastically reduced since the milling, crushing, and mixing of the road materials are performed by the same machine. Incidents related to trucking and site traffic are also minimized due to the absence of transportation of excavated materials.**

Furthermore, since emulsion is not heated during the recycling operation, it does not generate fumes or Volatile Organic Compounds (VOCs), contributing to a safer working environment for the site personnel (Ref. 48).



Figure 23 - Cold in place recycling, Vietnam

3

**ENVIRONMENTAL  
AND SOCIAL  
IMPACT**



### 3.1 Saving energy and lowering carbon footprint

**Cold asphalt mixes are produced by combining aggregates, which may include reclaimed asphalt pavement (RAP, with a coating emulsion. Unlike conventional hot mix asphalt, cold asphalt mixes do not require a drying or heating stage. This results in energy savings as there is no need to heat the aggregates or evaporate water. From an environmental perspective, cold asphalt mixes are particularly attractive (Ref. 49–53)).**

#### Cold mix asphalt manufactured in plant

The environmental footprint of cold mix asphalt has been quantified in numerous studies. When comparing energy consumption for cold mix and hot mix asphalt production, the following trends can be observed:

- There is a slight increase in the “raw materials” component, which is attributed to the manufacturing of emulsion.

- There is a significant reduction in energy consumption during the production phase at the plant, as emulsion mixes do not require heating.
- Overall, when considering the entire life cycle from cradle to gate or laying, there is a notable reduction in energy consumption in the case of emulsion mixes..

In the case shown in Figure 24, the difference is -33% (from cradle to installation). It can reach -50% in some cases, depending on the components and transport distances considered.

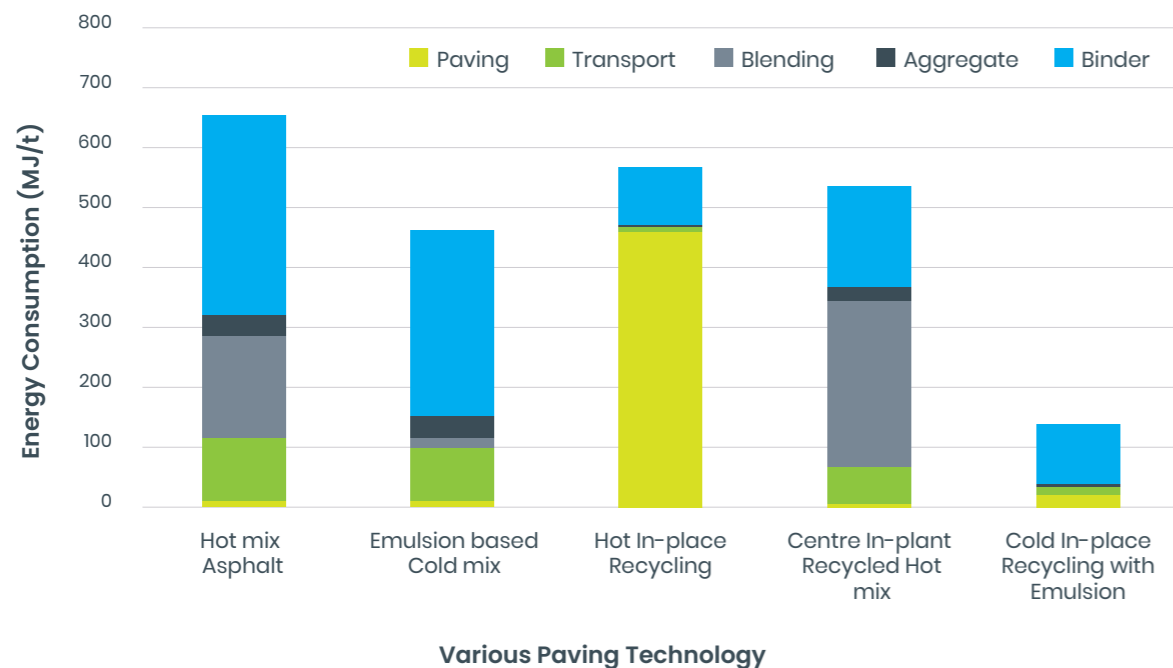


Figure 24 - Energy consumption of various paving technologies

Greenhouse gas (GHG) emissions are also significantly affected by the cold mix production process. Jain et al., for example, have estimated the difference between the GHG emissions of an emulsion mix and those of a hot mix to be -32% in terms of “raw materials, manufacture, transport and laying” (Figure 25). In some studies, the difference is as much as -60%.

In France, a life cycle analysis study carried out by Routes de France has led to the publication in 2022 of an EPD (Environmental Product Declaration) for “Cold mix asphalt pavements for light vehicles”. On a “cradle-to-gate” basis, compared with conventional hot-mix asphalt, the impact reduction per ton of asphalt is around 21% in terms of energy consumption (process energy) and 31% in terms of greenhouse gas emissions.

The French guide entitled “Cold mix asphalt manufactured in plant” published by IDRRIM (Institute for Roads, Streets and Infrastructures for Mobility) in 2020 presents several comparisons of environmental impacts on the scale of materials and worksites using the SEVE eco-comparator. The example shown in the Table 1 concerns a typical new pavement project of 1,000 m<sup>2</sup> comparing a 13 cm Gravel Emulsion structure, with a variant on the transport distance, and a 12 cm Gravel Emulsion structure, both surfaced with a two-layer surface dressing (ESU). The difference in GHG emissions was around -37%.

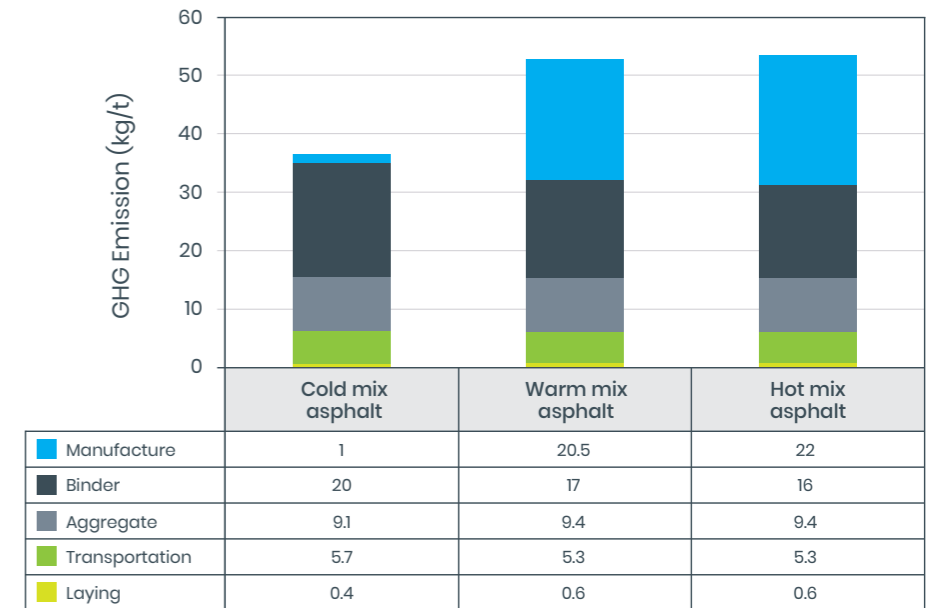


Figure 25 - Greenhouse gas emissions from various asphalt mixes

Solution	Material	Up stream transport	Manufacturing of mixture	Site transport	Laying	Total	Comparison
12GB3+ESU two layers	4,3	1,7	4,8	0,7	0,0	11,5	
13GE3 (40km emulsion)+ESU two layers	4,6	1,5	0,4	0,8	0,0	7,3	-36,8%
13GE3 (0km emulsion)+ESU two layers	4,6	1,4	0,4	0,8	0,0	7,2	-37,4%

Table 1 - Comparison of GHG emissions (in tCO<sub>2</sub>e) from a 1,000 m<sup>2</sup> jobsite of different pavement structures

### Case studies by type of structure

A study comparing the environmental impact of different types of structure was carried out by the SFERB according to traffic class. It has been found, for example, that emulsion techniques high modulus asphalt and gravel emulsion (BBE/GE) reduce GHG emissions linked to pavement construction by more than 50% compared with hot mix techniques of the total hot mix pavement (BB/GB3) type (Figure 26). The reduction is around 30% compared with a high-modulus asphalt pavement. Results are also available for the energy consumed indicator.

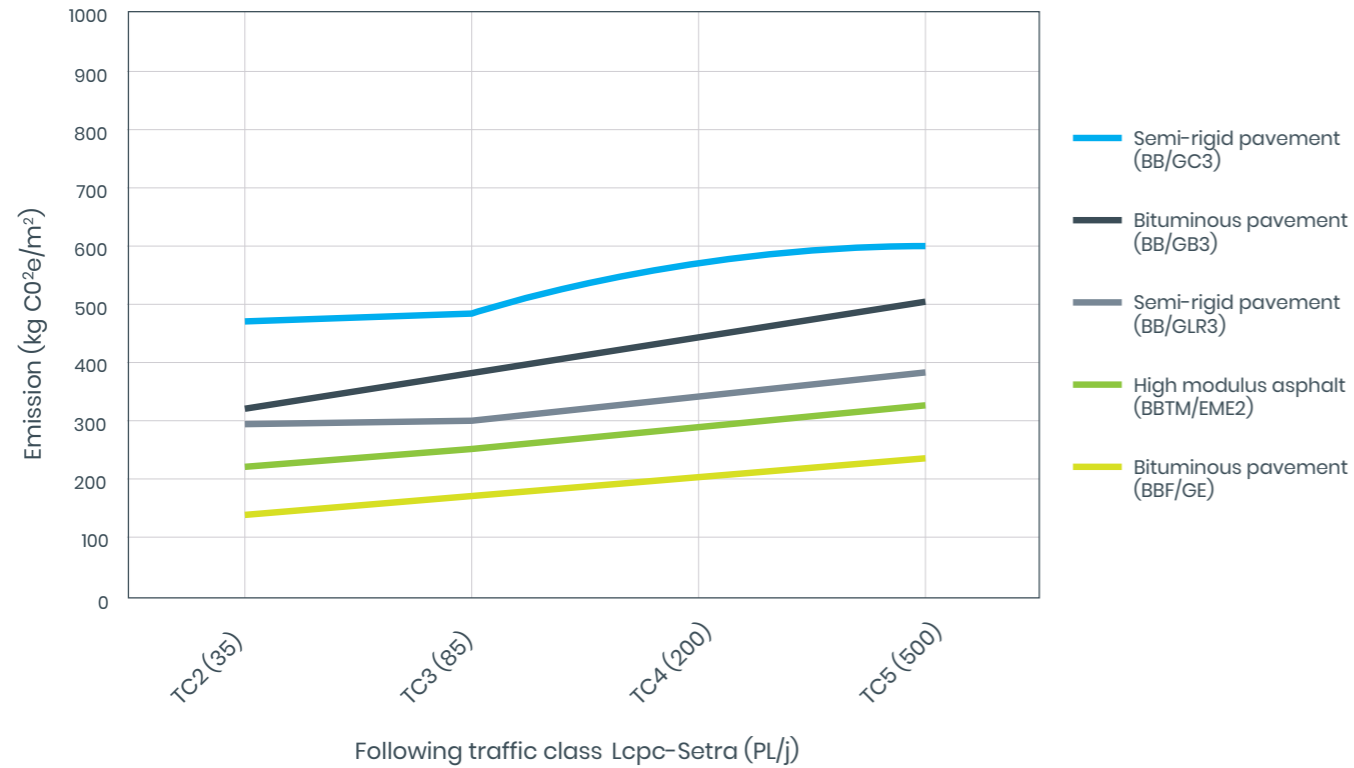


Figure 26- GWP emissions for pavement construction, according to traffic class, per m<sup>2</sup> of pavement structure, on PF2 platform

### Cold-In-place recycling

Compared to emulsion mixes produced in plants, the cold-in-place recycling technique offers two complementary advantages in terms of environmental impact:

- It helps preserve new materials resources.
- It eliminates the need for material transportation, except for a small proportion of “corrective” materials such as binder and aggregate.

As a result, the reduction in environmental impact compared to hot-mix techniques is even greater.

Xiao et al. have demonstrated that cold-in-place recycling

can reduce energy consumption by over 75%. In France, the SEVE eco-comparator can be used to estimate a reduction in greenhouse gas (GHG) emissions ranging from 55% to 70%, depending on the specific case and reprocessing conditions. Conducting a parametric study would help assess the difference in environmental benefits between these two practices.



### 3.2 Recycling options that reduce virgin materials (and energy + carbon footprint) multiple recycling feasible.

**A key element of sustainability, which has been emphasized in sustainability policies for decades, is the conservation of resources for future generations. Recycling more and reducing the use of natural resources are crucial factors in achieving this goal. The use of treatments and processes that involve bitumen emulsions allows road owners and constructors to either recycle roads on-site or utilize end-of-life road materials, including secondary aggregates from industrial processes, in rehabilitation or maintenance projects. These projects have the added benefit of reducing energy consumption and carbon emissions that would otherwise be associated with quarrying and transporting materials.**

#### Surface Treatments

##### - Aggregates

Historically, road sweepings from surface dressing or chip seal applications were typically disposed of in landfills or used for other purposes. However, the development of mobile recycling and washing plants now enables road sweepings to be stockpiled and washed, making them suitable for future surface dressing contracts. In 2023, one local authority in the UK (Ref. 54) utilized 21,000 tons of aggregates in its surface dressing program, out of which 12,000 tons were recycled. This represents a significant 57% reduction in the use of virgin materials for the surface dressing program, covering a total of 220 km of road. Additionally, any excess aggregates used during installation can be recovered as new road sweepings, further contributing to multiple recycling of surface dressing road sweepings. This cumulative approach leads to long-term savings in raw material use.

Steel slag, which is a secondary aggregate produced during the steel-making process, has been successfully utilized in surface dressing for several decades. Its usage offers not only sustainability benefits in terms

of increased skid resistance but also reduces the need for quarried aggregates, thereby saving energy and preserving virgin resources.

##### - RAP

The utilization of reclaimed asphalt pavement (RAP) and reclaimed asphalt pavement aggregate (RAGG) in surface treatments has been examined in a report (Ref. 55) that reviews the benefits of incorporating RAP or RAGG in various treatments such as scrub seal, chip seal, slurry seal, microsurfacing, and microsurfacing over CIPR (Cold-In-Place Recycling). Los Angeles County has established sustainability targets for its highways, focusing on three key areas: preservation, reuse, and fortification. In 2018, approximately 35% of Los Angeles County's pavement program budget was allocated to RAP-based pavement preservation treatments. The report, concluded that the incorporation of RAP in their sustainability program resulted in cost savings of \$52 million, an 84% reduction in greenhouse gas emissions, an 80% reduction in energy consumption, and a landfill deposition reduction of 765 cubic meters compared to conventional approaches.

#### Rehabilitation

##### - CCPR

Cold central plant recycling (CCPR) is a well-established process that has been utilized internationally for decades. It involves mixing reprocessed asphalt particles and other recycled materials ex situ using bitumen emulsion. In 2008, a contract for a major highway in Scotland (Ref. 56) included the installation of cold mix asphalt

over an 800-meter stretch of road. This approach resulted in a saving of 43 tons of CO<sub>2</sub>e, and the use of Tayset recycled cold mix saved 25 kilograms of CO<sub>2</sub>e per ton compared to conventional materials (Ref. 57). In a study conducted in Sweden (Ref. 58), comparing CCPR production and transportation over a distance of 48 kilometers to a standard material using the same traveling parameters, Lundberg et al. found that

CCPR reduced CO<sub>2</sub>e emissions per ton of asphalt by 68% and energy consumption by 50%. After pavement installation, the CO<sub>2</sub>e emissions per square meter of asphalt were reduced by 64%, and energy consumption by 48%. Furthermore, in both examples, the CCPR materials showed good performance in situ even after ten or more years of service.



Figure 27 - CCPR production



Figure 28 - CCPR installation



Figure 29 - CCPR final surface

##### - CIR

Cold in-place recycling using bituminous emulsions involves the pulverization and grading of an existing road in situ. The process includes mixing the pulverized material with a bitumen emulsion and compacting it without removing any material from the site.

In some cases, small quantities of aggregates may be added to achieve the desired grading during installation.

Due to its inherent nature of recycling all materials on-site, this process significantly reduces the need for virgin aggregates, as well as the associated energy

consumption and emissions from the delivery of fresh materials to the site. According to Lysenko (Ref. 59), cold in-place recycling reduces the overall energy required for constructing a pavement by 84.3% and CO<sub>2</sub>e emissions by 85%.

### 3.3 HSE aspects

**Emulsions provide various HSE benefits, including fume reduction during application and improved working conditions. Their environmental impact can be quantified through LCAs and communicated through EPDs, ensuring transparency, and promoting sustainable practices in the road construction industry.**

#### Less fumes, dust, and low VOC emissions

Emulsion-based materials are handled at lower temperatures than usual bitumen-based materials, which decreases the fumes emissions including volatile organic compounds (VOCs), and it potentially reduces the production of dust during application.

#### Improved working conditions

The reduced temperature requirements contribute to a safer working environment; bituminous emulsions are often easy to handle and apply, which can lead to increased efficiency and reduced physical strain on workers. In their emulsified state, bituminous emulsions are non-flammable, which enhances safety during storage and handling. It also can be applied in a variety of weather conditions, providing more flexibility in scheduling, and reducing downtime for workers. Anyway, it may depend on several factors, including the specific application, the type of emulsion used, and the overall safety measures implemented in the work environment.

#### Environmental Impact quantification

The environmental impact quantification of construction materials through life cycle assessment (LCA) involves evaluating the environmental burdens associated with the entire life cycle of the product, from raw material extraction and production to use and disposal. LCAs provide a comprehensive approach to assess the environmental impact of a product or process. It is important to note that specific LCAs may vary depending on the type of bituminous emulsion, production methods, and regional factors. Researchers and practitioners may conduct LCAs tailored to their specific context to obtain accurate and relevant results. The availability of Environmental Product Declarations (EPDs) for bituminous emulsions may vary, and the specific content of an EPD would depend on the manufacturer or organization producing the emulsions. EPDs are documents that provide information on the environmental performance of a product throughout its life cycle in compliance with standards. Remember that the availability of EPDs may vary by region, and not all products may have associated EPDs.

Some sources to find EPDs or information on the environmental performance of materials:

- *Manufacturer Websites*
- *Industry Associations*
- *Sustainability Certification Programs*
- *Government or Environmental Agencies*
- *Third-Party Certification Organizations*
- *Research Studies and Literature*



Figure 30 – Road stabilisation with bitumen emulsion

### 3.4 Social Impact of bitumen emulsion technologies and their applications

**Bitumen emulsion used in road construction not only improves the effectiveness and sustainability of the construction process but also brings several social impacts to road users and the community (Ref. 62, 63). The main social impacts include:**

#### Reduction in smell

The smell of bitumen emulsion applications is generally less intense than that of hot bitumen. The reduction in odor on road construction sites contributes to a more favorable working environment for construction teams and an improved quality of life for nearby communities.

There are several reasons for the reduction in odor. Bitumen emulsion is applied at ambient or slightly elevated temperatures, resulting in less bitumen fume generation.

#### Improved skid resistance

In bituminous pavements, skid resistance depends on factors such as the aggregate type, mix grading, and surface micro-texture and macro-texture. Bitumen emulsion is used in various applications which improve or restore skid resistance by influencing the pavement surface characteristics that are crucial for friction.

Typical examples of maintenance applications using bitumen emulsion include:

**Surface Treatments:** This includes chip seals, slurry seals, and microsurfacing, where the surface aggregate particles provide increased micro-texture and potentially enhance skid resistance. Bitumen emulsion can also be utilized as a rejuvenator in surface treatments, restoring the properties of aged bitumen in the surface layer and maintaining the pavement's texture.

#### Increase working season

- **Extending Construction Time:** Bitumen emulsions can be applied at lower temperatures compared to hot asphalt mix. This allows construction during cooler temperatures when hot-mix paving would not be feasible, providing more flexibility to the work schedule.
- **No Specialized Equipment/Less Workforce:** Bitumen emulsions do not require specialized heating equipment or large numbers of workforce, resulting in easier transportation and logistics issues.

#### Improved safety

There are many ways in which the use of bitumen emulsion contributes to improved safety during construction and maintenance:

- Bitumen emulsion does not require heating and generates fewer fumes during application.
- The lower application temperatures and reduced volatility of emulsions reduce the risks associated with transporting and handling. This also decreases the danger of spills or splashes, enhancing safety.
- The environmental risks are also reduced during transport and construction operations.

### 3.5 Economics: Result of the aforesaid topics: saving material and energy

**Bitumen emulsions are used in various surface treatments and recycling applications that have been proven to save costs by reducing material and energy usage.**

Surface treatments can be used alone or combined to increase the lifespan of existing pavement and reduce energy usage. Applications such as Cold In-Place Recycling (CIR), Base Stabilization, and Cold Central Plant Recycling (CCPR) utilize existing materials from the road. Base Stabilization and CIR help decrease haul costs by milling, mixing, and placing the recycled materials directly on the road.

Presentations that define the performance and cost savings of these applications have been utilized to assist users in understanding their benefits (Ref. 65, 66).

By reducing the mixing temperatures, bituminous emulsions contribute to energy savings in the production of these mixtures. This is especially noticeable in Cold Mix, CIR, and CCPR applications. The energy savings achieved with these mixtures do not compromise the final product's performance.

The lower application temperature of surface treatment emulsions also serves as a significant incentive, as it showcases their reduced energy usage (Ref. 64).



Figure 31: Recycling project

## Table of Acronyms

Acronym	Definition
<b>GHG</b>	Green House Gases
<b>HSE</b>	Health Safety Environment
<b>CIR /CIPR</b>	Cold In place Recycling
<b>FDR</b>	Full-Depth Reclamation
<b>CCPR</b>	Cold Central Plant Recycling
<b>RAP</b>	Reclaimed Asphalt Pavement
<b>EPD</b>	Environmental Product Declaration
<b>BBE</b>	<i>Béton Bitumineux à l'Émulsion</i> Emulsion Cold Mix
<b>GC3</b>	<i>Grave Ciment 3</i> Cement Treated Base Class 3
<b>GLR3</b>	<i>Grave au Liant Hydraulique Routier</i> Hydraulic Binder Treated Base Class 3
<b>BBTM</b>	<i>Béton Bitumineux Très Mince</i> Very Thin Layer Asphalt
<b>EME2</b>	<i>Enrobé à Module Élevé</i> High Modulus Asphalt Class 2
<b>BBF</b>	<i>Béton Bitumineux à Froid</i> Cold Mix Asphalt
<b>RAGG</b>	Reclaimed Asphalt Pavement Aggregate
<b>LCA</b>	Life Cycle Assessment
<b>BSM</b>	Bitumen Stabilized Material
<b>VOC</b>	Volatile Organic Compounds



Figure 32 - Cold in-place recycling of pavement with bitumen emulsion

## References

1	Congres Mondial Emulsion	CEPSA / Maria del Mar Colas	2006	Spain	New Impregnating Emulsions With Ecologics Fluxes
2	Newsletter Issue 23	Texas Pavement Preservation Center	2011	USA	Evaluation of the Curing Time and Other Characteristics of Prime Coats applied to a granular base
3	Thesis University of Texas	Osman Okuyucu	2014	USA	Comparing Various Characteristics of Oven Cured and Field Cured Prime Coat Materials applied to Granular Bases
4	South African Pavement Engineering Manual	SANRAL	2013	South Africa	Chapter 9 Extract - Materials Utilisation and Design
5	Annexe au Bulletin CRR n 90	Centre de Recherches routieres	2012	Belgique	Les emulsions cationiques bitumineuses en tant que couche de collage
6	National Cooperative Highway Research Program	Danny Gierhart and David R. Johnson	2018	USA	Tack Coat Specifications, Materials and Construction Practices
7	Technical Data Sheet n 5	Road Emulsion Association Limited	2023	United Kingdom	Bond Coating
8	Japan Emulsified Asphalt Emulsion	JEAA	2007	Japan	Trackless Asphalt Emulsion
9	International Journal of Sustainable Transportation	Department of Civil and Environmental Engineering Rutgers University	2020	USA	Quantifying greenhouse gas emission of asphalt pavement preservation at construction and use stages using life-cycle assessment
10	Transportation Research Part D: Transport and Environment	University of South Florida	2012	USA	Life cycle assessment of pavement: Methodology and case study
11	Materials and Structures Journal	LUNAM Université, IFSTTAR	2012	France	Evaluation of the structure-induced rolling resistance (SRR) for pavements including viscoelastic material layers
12	MTAG Volume I Flexible Pavement Preservation 2nd Edition	Caltrans division of maintenance	2007	USA	Chapter 6 - Fog and Rejuvenating Seals
13	NPPC 2023	NCAT - Adriana Vargas	2023	USA	NCAT Preservation Findings
14	Web article	Bituchem	2012	United Kingdom	Fortseal Carriageway Preservation System
15	Web article	Ergon	2015	USA	Scrub seal cuts costs, seals mass cracking
16	TRL	Bateman	2016	United Kingdom	Design Guide for Road Surface Dressing
17	Technical report	Oregon DOT & FHWA	2016	USA	Chip Seal Design and Specification Final Report
18	RSTA Website	RSTA/REA	2023	United Kingdom	The case for surface dressing
19	Road resource.org	Mississippi DOT	2020	USA	Microsurfacing success story
20	Road resource.org	PPRA	2021	USA	cape seal success story
21	Le Moniteur Magazine	Conseil General Yvelines	2012	France	Route - Les defis de l'entretien
22	National Cooperative Highway Research Program	Colorado State University / Texas A&M University	2011	USA	Report 680 - Manual for Emulsion Based Chip Seals for Pavement Preservation
23	Publication	ADEPT / RSTA	2017	United Kingdom	The Service Life of Road Surface Treatments for Asset Management Purposes

## References

24	SaferRoads Internation Conference	Sean Bearsley - Darcy Rogers	2017	New Zealand	Emulsion Chipsealing: Generating Conscious Capital
25	ISSA 50th Annual Convention	Abdeltif Belkahia	2012	France	High performance laboratory tests for microsurfacing
26	European Roads Review	Colas	2013	France	New High Performance emulsions for surface dressings aimed at heavy traffic with heavy constraints
27	ISSA 51th Annual Convention	Abdeltif Belkahia - Christine Deneuvillers	2013	France	French High Traffic Chip Seal
28	RSTA	Paul Boss	2021	United Kingdom	Whole lifecycle cost planning for sustainability
29	RSTA Virtual conference	Roy O'Connor	2021	United Kingdom	Future Con-cerns and Positives for the Road Surface Treatment Industry
30	Asphalt Institute Presentation	Minnesota DOT Zeinali . Blankenship Mahboub	2016	USA	Quantifying the Pavement Preservation Value of Chip Seals
31	Road Materials and Pavement Design	Minnesota DOT Zeinali . Blankenship Mahboub	2016	USA	Evaluation of the DC(T) test in discerning the variations in cracking properties of asphalt mixtures
32	Resources, Conservation and Recycling Journal	Giani and al	2015	Italy	Com-parative life cycle assessment of asphalt pavements using reclaimed asphalt, warm mix technology and cold in-place recycling
33	Brochure	SABITA	2005	South Africa	Why you need to maintain surfaced roads
34	FHWA-HIF-17-042, Federal Highway Administration	Wagner, C.	2018	USA	Over- view of Project Selection Guidelines for Cold In-place and Cold Central Plant Pavement Recycling
35	National Cooperative Highway Research Program	Stroup-Gardiner, M.	2011	USA	NCHRP Synthesis of Highway Practice 421: Recycling and Reclamation of Asphalt Pave-ments Using In-Place Methods.
36	Comite Francais pour les Techniques Routieres (CFTR)	Service d'Etude Techniques des Routes et Autoroutes (SETRA)	2004	France	Guide technique Retraitement en place à froid des anciennes chaussées.
37	FHWA-HIF-14-001	Asphalt Recycling and Reclaiming Association (ARRA)	2015	USA	Basic Asphalt Recycling Manual (BARM)
38	Sustainability	Ana R. Pasandín, Ignacio Pérez and Breixo Gómez-Mejide.	2020	USA	Performance of High RAP Half-Warm Mix Asphalt
39	National Cooperative Highway Research Program 463	McDaniel, RS., Olek, J., Magee, B. J., Behnood, A., & Pollock, R.	2014	USA	Pavement Patching Practices - A Synthesis of Highway Practice.
40	Construction and Building Materials	Bong Ju Kwon, Dahae Kim, Suk-Keun Rhee, Y. Richard Kim.	2018	USA	Spray injection patching for pothole repair using 100 percent reclaimed asphalt pavement.
41	National Cooperative Highway Research Program 569	M. Stroup-Gardiner	2021	USA	Practice and Performance of Cold In Place Recycling abd Cold Central Plant Recycling
42	National Cooperative Highway Research Program 863	Schwartz, C. W., B. K. Die-fenderfer, and B. F. Bowers.	2017	USA	Material Properties of Cold In-Place Recycled and Full-Depth Reclamation Asphalt Concrete.
43	Journal of Cleaner Production	Fan Gu a, Wangyu Ma a, Randy C. West a, Adam J. Taylor a, Yuqing Zhang	2018	USA	"Structural performance and sustainability assessment of cold central-plant and in-place recycled asphalt pavements: A case study"

## References

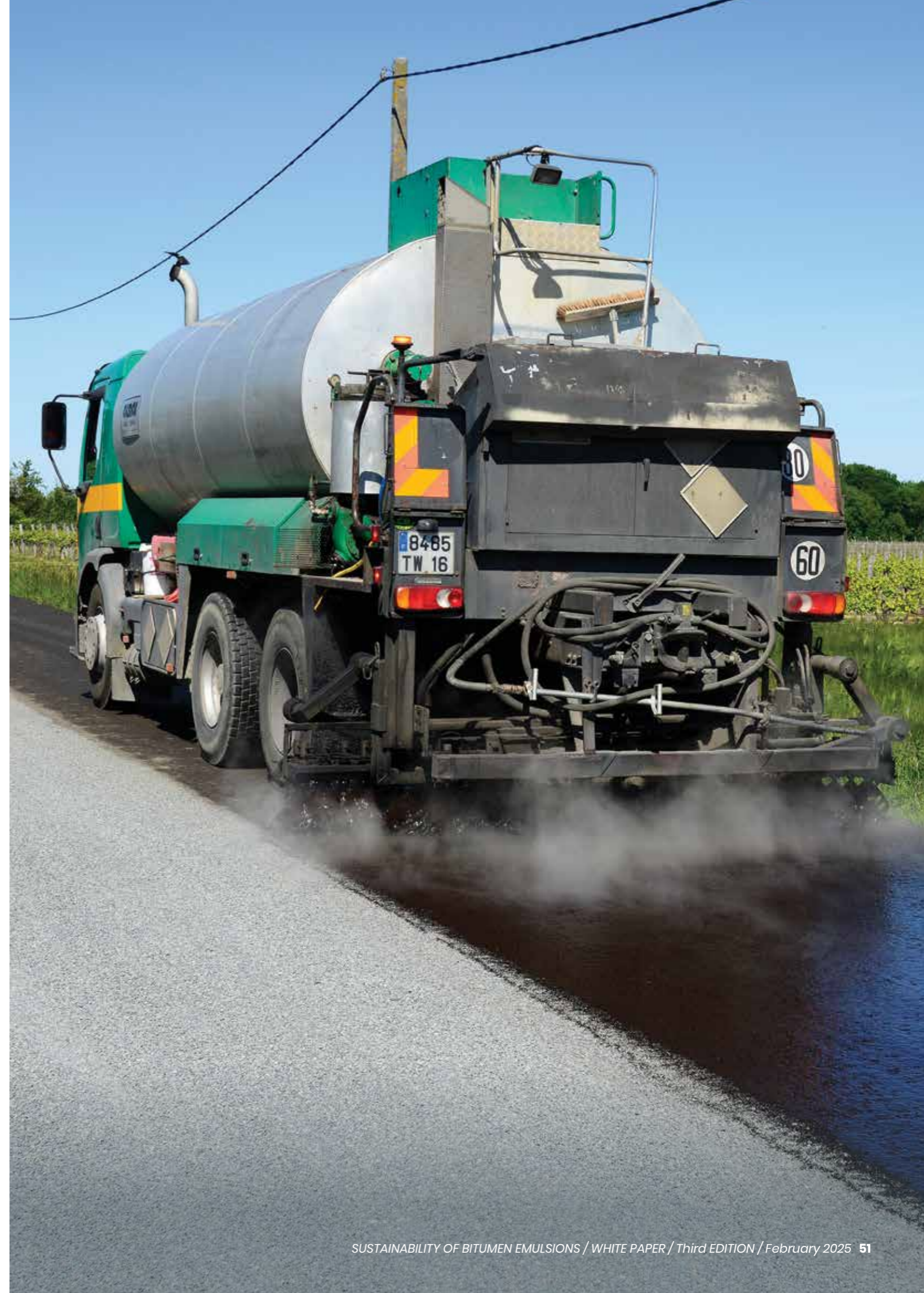
44	Transportation Research Board Annual Meeting	Finberg, Quire, and Thomas	2008	USA	Granular Base Stabilization with Emulsion in Las Vegas, Nevada
45	European Roads Review	S. Bemanian - Optimum Pavement	2007	France	Cold In Place Recycling in Nevada
46	Transportation Research Record 2179	Robinette and Epps	2010	United States	Energy, Emissions, Material Conservation, and Prices Associated with Construction, Reha-bilitation, and Material Alternatives for Flexible Pavement
47	Recycled Materials Resource Center	Dr. Arpad Horvath University of California at Berke-ley	2004	United States	Report Project 23 A Life-Cycle Analysis Model and Decision-Support Tool for Selecting Recycled Versus Virgin Materials for Highway Applications
48	ISAP Conference 2008	Uhlmeyer et al	2008	United States	Case study : Cold In-Place Recycling In Washington State
49	Construction and Building Materials	Xiao et al.	2018	China	A literature review on cold recycling technology of asphalt pavement
50	ISAP Conference 2012	Goyer et al.	2012	France	Environmental data of cold mix using emulsified bitumen for a better selection of road materials
51	SFERB	SFERB	2008	France	Bitumen Emulsions handbook
52	E&E Congress 2016	Lundberg et al.	2016	Sweden	Production and durability of cold mix asphalt
53	Journal of Cleaner Production	Jain et al.	2021	India	Cold mix asphalt: An overview
54	Web	Lincolnshire county council	2023	United Kingdom	Dressing up the roads network
55	FHWA	Gregory Duncan et al	2020	USA	Using reclaimed asphalt pavement in Pave-ment-Preservation Treatments
56	JTTE 2019; 6 (4): 359-365	Day et al	2019	United Kingdom	Emulsion cold mix in the Uk : a decade of site and laboratory experience
57	ISSA world congress 2010	Day D et al	2010	United Kingdom	Developing a Strategy for Sustainable Development and Carbon Management
58	NCC Roads	Lundberg et al.	2016	Sweden	Production and durability of cold mix asphalt
59	World of Emulsion Lyon 2010	Lysenko J et al	2010	Australia	Sustainable Development
60	SABITA	SABITA	2020	South Africa	Technical Guideline TG2 3rd edition Bitumen Stabilised Materials
61	WSP - OPUS Report	Kate Mora, Jeremy Wu, Phil Herrington	2019	New Zealand	Implications of the substitution of Cut-Back Bitumens with bitumen emulsions for chip sealing
62	EDC-4 Pavement Preservation: How   Implementation Plan	US Department of Transpor-tation - FHWA	2017	USA	Pavement Preservation: How
63	Best Practices for EMULSION TACK COATS	NAPA - Author Dale S. Decker, P.E.	2020	USA	Quality Improvement Publication 128
64	E&E Congress 2020	Marimar Colás, Vicente Pérez, Antonio García CEPESA	2020	Spain	High Performance Recycling with Bituminous Emulsions
65	National Pavement Preservation Conference	Adriana Vargas-Nordcbeck - NCAT	2023	USA	NCAT Preservation Findings
66	National Pavement Preservation Conference	Jerry Geib - MnROAD	2023	USA	MnROAD NCAT Preservation Study

### Full Members

 Aema USA	 AfPA Australia	 Amaac Mexico	 Ateb Spain	 Fbk e.V. Germany	 Jea Japan
 PSWNA Poland	 Rea United Kingdom	 Sabita South Africa	 Sferb France	 Siteb Italy	

### Associated Members

 Arkema France	 BASF SE – Asphalt Performance Germany	 BitChem Asphalt Technologies Limited India	 Buckau-Wolf Germany	 Chemoran Ireland	 China Emulsified Asphalt Association China
 Enfalt Turkey	 Hincol India	 Ingevity USA	 Insung Korea	 Kandovan Pars Iran	 Nouryan Sweden
 NTRO Australia	 Ooms Products Netherlands	 Paragon Technical Services USA	 Prasol India	 Patpribor Ltd Bulgaria	 Quimi Kao Mexico
 Rad Group Russia	 SAE Fayat Group France	 SurfactGreen SAS France	 Tipco Asphalt Thailand	 Total BTM France	 VALOCHEM France
	 Vialab France	 VIALIT Austria	 Xi Yuefa Group China		





**International Bitumen Emulsion Federation**

9 rue de Berri – 75008 Paris – France  
Tél. +33 1 44 13 32 81  
[contact@ibef.net](mailto:contact@ibef.net)