Maintenance and Rehabilitation

Cold-in-place rejuvenation of aged bituminous pavements using bio-based emulsions.

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Abstract

This paper deals with a new cold-in-place recycling solution of aged bituminous pavements combining the use of a bio-based emulsion with a specific train in order to achieve the French energy transition law objectives that promotes sustainable development, preservation of natural resources and low footprint constructions. This innovative process was laureate in 2017 of the ‘Streets & Roads” innovation projects competition promoted by the French public institute CEREMA (Ministry of the ecology and the sustainable development), This solution allows 100% RAP recycling by rejuvenating aged bitumen of the existing old pavement. The main components of the bio-based emulsion are plant-origin and more particularly by-products from paper industry derived from forest holdings (free from competition with the food chain). Furthermore, laboratory tests were performed in order to compare bio-based emulsion with traditional coating bitumen emulsion (acting as a reference). Various cold mixes asphalts including 100% RAP contents (grave emulsion and cold asphalt mixes) were evaluated according to the French Guide (Setra, “Cold-in-place recycling of old bituminous pavements”, 2003). The results showed that the performance of the bio-based emulsion is similar than the traditional bitumen emulsion. In addition, a comparative natural aging follow-up of aforementioned cold-mixes was carried out. Rheological parameters (stiffness evolution) and chemical indicators (oxidation, hydrolysis and esterification) confirmed the bio-based emulsion ability to be used in 100% RAP cold mixes design. Moreover, several comparative experimental worksites were realized using cold-in-place recycling train. Base courses containing 100% RAP mixes with bio-based emulsion or bitumen emulsion were implemented in various French areas thus confirming the suitability and the good performances of cold mixes asphalt based on bio-based emulsion. Follow-up is very encouraging.

This paper was first published in 2020 in version 1.0 of the proceedings of the 7th E&E Congress. This second edition (version 1.1.) of the proceedings is published in June 2021. The content of this paper has not changed, but the author(s) may have provided additional information in the form of an annex.

4. INTRODUCTION

Regarding the actual technical and environmental issues of roads maintenance, it is essential to propose to our contractors, technical,environmental and economical efficient solutions.
In this context, we have developed a specific cold-in-place recycling solution which allows to regenerate old bituminous pavements by using a vegetable-based emulsion in order to reduce our environmental footprint.
Cold-in-place recycling with a pure or a flux modified bitumen emulsion is a widely used solution [1] [2]. This technology is carried out using specific engines which includes an emulsion tanker, a milling machine, a chamber mixing, sometimes a crusher and a screen, and an asphalt paver. All of these operations are performed at ambiant temperature.
This process combine several benefits:

- Timeliness execution,
- No use of virgin and non-renewable aggregates (resources saving)
- Reduction of energy consumption and greenhouse gas emissions,
- Low traffic disruption during jobsites,
- Cost reduction.

5. COLD-IN-PLACE RECYCLING USING VEGETABLE-BASED EMULSION

The innovative solution presented in this paper, has been awarded in 2017 of the 'Streets & Roads Innovation" competition promoted by the French public institute CEREMA (Centre d'Etudes et d'Expertise sur les Risques, l'Environnement, la Mobilité et l'Aménagement).
This process combines the use of a specific and powerfull engine (figure 1) and a vegetable emulsion (figure 1).

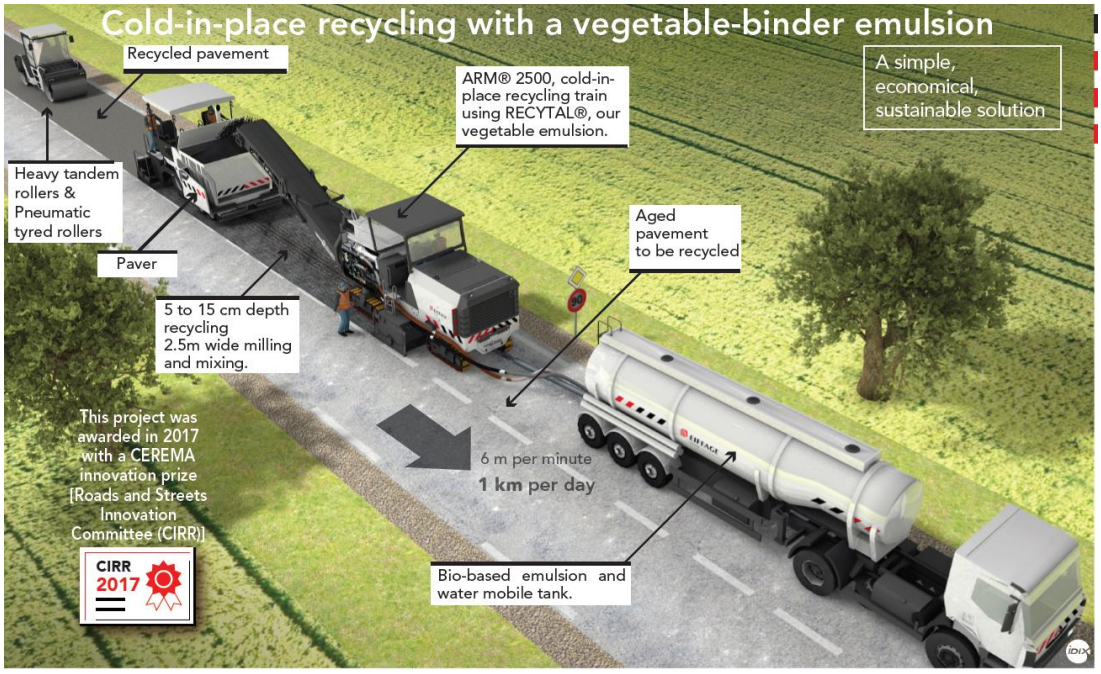

Figure 1 – Cold-in-Place recycling principel with a vegetable-binder emulsion.

The engine is characterised by its reverse rotating direction milling (from the top to the bottom) without an integrated paver. These differences give it two main benefits:

- Higher mixes homogeneity,
- Better control of eveness (independent paver)

Furthermore, the process describe above was developed in order to satisfy the following guidelines:

- To propose an in-situ recycling technic,
- To reduce costs transportation and fuel consumption,
- To promote vegetable-based products as an alternative to petrochemical products (bitumen),
- To use mainly vegetable origin and renewable compounds (lack of competition with the food chain),
- To design cold mixes with technical performances in accordance to the specifications required by the Guide SETRA "Cold-in-place recycling of old bituminous pavements".

Photo 1 – Vegetable emulsion used for cold-in place recycling operations.

The vegetable-based emulsion has been certified "bio-based product" in 2018 by an indenpendant organization.

Also, this solution is developed to satisfy the French sustainability and environmental convention (2009-2017) and the French transition energy law [3] requirements for green growth (2015, August).

5.1 Laboratory studies

Several comparative studies were carried out in our Research Center located in Lyon's area (France) in order to compare vegetable and bitumen emulsions performances.
The main objective, in accordance with the French Guide Sétra (2003) [4] which sets the performance requirements for a partial cold-in-place recycling, was to achieve a category III for both mixes design.

5.1.1 Emulsions characteristics

As stated previously, two cold mixes which should be used in the different trial sections, were designed and evaluated. The main characteristics of the two emulsions are shown in table 1.

	Bitumen emulsion (C60B5)	**vegetable-based emulsion (C55B5)**	**French Standard EN 13808** [10]
Water content (%) [5]	39.4%	45.0%	37.0% to 47.0%
Residue on sieving 0,500 et 0.160 mm Storage stability after 7 days (0,500 mm) (NF EN 1429) [6]	0.00% 0.00%	0.02% 0.00%	≤ 0,1% ≤ 0,2%
Forshammer Breaking index of cationic bitumen (NF EN 13075-1) [7]	180	177	≥ 170
STV – 2 mm (NF EN 12846-1) [8]	30 s	32 s	15-70
pH value (NF EN 12850) [9]	2.5	2.0	-
Particle size analysis	7.7 µm	2.0 µm	-

Table 1 – Vegetable-based and bitumen emulsions characteristics.

The analysis results show that the two emulsions present very similar characteristics and are both in compliance with the EN 13808 European standard " Bitumen and bituminous binders — Framework for specifying cationic bituminous emulsions".

5.1.2 Mixes performances

Furthermore, two cold mixes were prepared with the aforementioned emulsions. The two comparatives formulae are presented in table 2.

	Mix 1	Mix 2
Reclaimed asphalt pavement (RAP)	100%	100%
Bitumen emulsion (60% binder content)	2,8%	-
Vegetable emulsion (55% binder content)	-	2.8%
Total mixes water content	7%	7%

Table 2 – Cold mixes compositions.

Study results

The manufacture of the RAP-based emulsions mixes was carried out at the ambient temperature (~20°C) . Mixes performances have been compared to the French guide Sétra specifications.
The main study results are shown in table 3.

	Mix 1 Bitumen emulsion (C60B5)	**Mix 2** Vegetable emulsion (C55B5)	***Sétra Guide specifications (category III)***
Maximum density (NF EN 12697-5 water method) [11]			
ρ_{mv} (Mg/m^3)	2.506	2.516	**-**
Shear Press compaction (NF P 98-252) [12]			
Air void content (%) at 100 girations	16.4	16.7	**≤ 25%**
Sensivity to water (NF P 98-251-4) [13]			
Air void content (%)	11.7	8.1	**≤ 15%**
Air compressive strength (R in MPa)	7.01	7.28	**≥ 3 MPa**
Water compressive strength (r in MPa)	4.08	5.96	**-**
r/R	0.58	0.82	**≥ 0,65**

Table 3 – Tests results.

As shown in Table 3, the Mix 2 (100% RAP + vegetable-based emulsion) is compliant with the French Sétra Guide for requirement (category III) and present better performances than the Mix 1.
In order to complete the initial study, we have carried out stiffness measurements (T= 10°C, t = 124 ms) according to the European standard (EN 12 697 – annex C) at several natural ageing durations. The results are shown in figure 2.

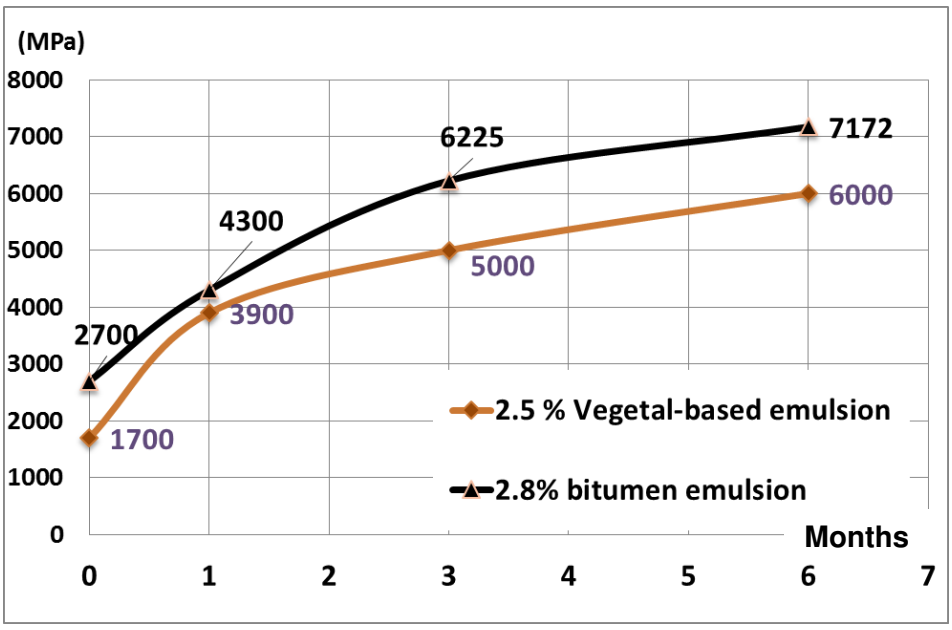

Figure 2 – Stifness tests results vs natural ageing duration.

It can be noticed that the two cold mixes stiffness increase over time. Also, the vegetable-based emulsion mixture behaviour (cohesion increase) is close to the bitumen based emulsion mix. Both mixtures present satisfactory modulus levels after 1 month, i.e. superior to 4000 MPA as required in the French Guide Sétra.

Considering these encouraging laboratory results, we have decided to realize several on-site experimentations in order to complete the evaluation of the vegetable-based solution.

5.2 Trial sections

5.2.1 Context & worksite experimentations

Several County Councils have chosen to evaluate this cold-in-place recycling solution using a vegetable-based emulsion. Their objectives was to promote alternative solutions in accordance with the sustainable development challenges and the circular economy:

- To reduce or even remove waste production during worksite,
- To not use of non-renewable materials (aggregates),
- To promote circular economy and local materials reusing
- To reduce gas emissions (greenhouse gases) and energy fossil consumption.

In this context, three experimentations were carried out in France between July, 2017 and August, 2018 (figure3).

Figure 3 : Location of the different experimental worksites.

The existing pavements screened in the different areas were mainly composed by hot mixes asphalt (~SMA) or surface dressing or microsurfacing. Most of the monitored road sectionsllo present several defects like fatigue and thermal cracking, bitumen oxidation, peeling and bleeding (photo 2).

Photo 2 – Damages noticed before rehabilitation : cracking, peeling and bleeding.

5.2.2 Implementation

The three experimentations were achieved between July 2017 and Agust 2018.
They have consisted in reprocessing about 15 000 m² each (7 000 m² with the vegetable-based emulsion + 7 000 m² with the bitumen-based) involving 5 to 12 cm depth recycling.
Milling, emulsions injection, mixing and paving operations were carried out consecutively by the cold-in-place recycling train (Photo 3 and 4).

Photo 3 – Cold-in-place recycling train.

Photo 4 – Mix appearance after milling : beige-brown colour.

We have observe a better surface cohesion with the cold mix asphalt containing the vegetable-based emulsion.
Implementations was carried out using a conventionnal paver (Photo 5) completed with two different compactors: three-wheels compactor and roller compactor (Photo 6).

Photo 5 – Vegetable-based emulsion mix paving.

The paver operational spread has been adjusted on the recycling train speed (6 m/min).

Photo 6 –Roller compactor used for mixes compaction.

The compaction plan was the following:

- Three-wheels compactor : 12 passes
- Roller compactor : 6 passes

During the vegetable-based cold mix implementation a slight bonding was observed at the beginning of the compaction. This phenomenon disappeared with the tire humidification of the three-wheels compactor.

However, visual observations after compaction, indicate that both asphalt mixes (vegetable-based and bitumen-based cold mixes) has a very satisfactory surface aspect (Photo 7).

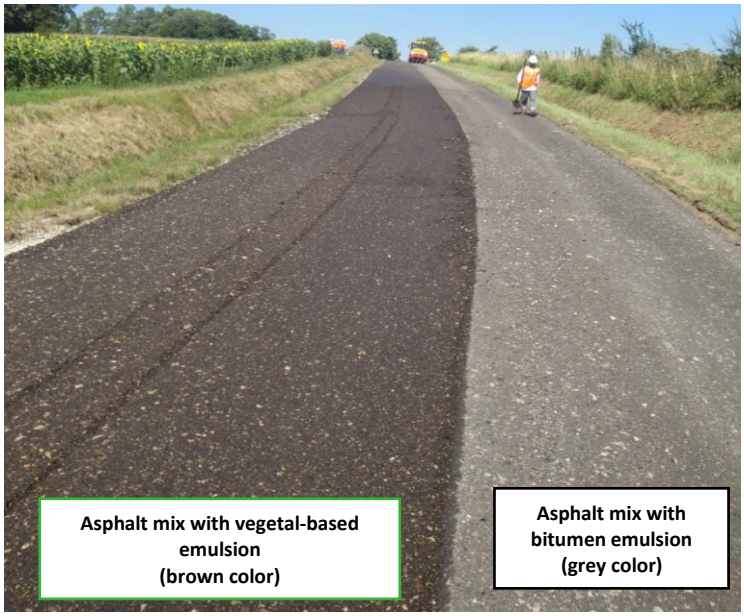

Photo 7 – Pavement aspect after compaction.

Worksites monitoring on asphalt mixes and final pavements have led to conform results in terms of binder content, airvoid content and macro-texture.

5.2.3 Environnemental performances

As mentioned above, an environnemental comparison between the cold in-place recycling with vegetable-based emulsion and a conventional technic (bitumen based) has been carried out.
The conventional solution is the following:

- bitumen emulsion tack coat (400 g/m²) covered by a continuous grade hot mix asphalt 0/10 (~ 100 kg/m²) with a 35/50 pen grade bitumen and 20% of RAP content.
- manucfature in a conventional mixing plant with materials transportation between the mixing plant and the worksite.

The two solutions were evaluated by using the French environnemental comparator SEVE® (Système d'Evaluation des Variantes Environnementales). The results are presented in figure 4.

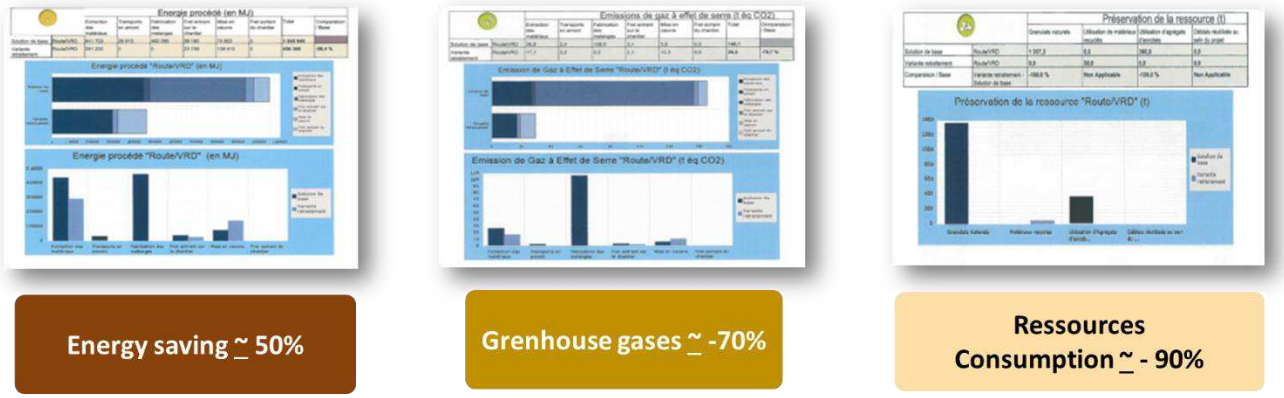

Figure 4 – Environnemetal comparison between basic and vegetable-based solutions.

The comparative results indicate that biobased-solution is more efficient than the conventionnal solution in terms of energy comsumption, greenhouse gas emissions, and resources preservation.
Furthermore, the comparison with cold-in-place recycling using a bitumen emulsion is also possible. In this case we can highlight several benefits by using a vegetable-based emulsion:

- More than 98% of the vegetable-based emulsion components are renewable.
- The vegetable-based components are mainly derivatives of the French forest culture.
- Vegetable-based emulsion components come from local resources which is not the case for crude oil or bitumen.

6. CONCLUSIONS

This paper present a new cold-in place recycling process using a vegetable-based emulsion. The laboratory studies and field implementations confirm the equivalent performances between the vegetable-based emulsion with a conventional bitumen based emulsion.
Also, cold in-place recycling with vegetable-based emulsions offers considerable environnemental benefits in terms of energy consumption, greenhouse gas emissons and non-renewable ressources preservation.
The experimental worksites performed in France with several County Councils partnership demonstrate the feasibility of cold-in-place recycling with alternative emulsions. Laboratory study, in-situ observations, and environmental assessment highlight the efficiency of this solution. This involve to take into account the availability and the variability of the vegetable-based resources.
The worksites will be closely monitored for several years in order to compare the aging evolution of both cold asphalt mixes and corroborate the field observervations with laboratory measurements [14].
Technical, economical and environmental balances of the alternative solution describes in this paper make possible a wider deployment of this technology at a larger national and international scale.

7. BIBLIOGRAPHY & REFERENCES

[1] : « Cold in-place recycling literature review and preliminary mixture design procedure », Salomon and al., Transportation Research Board, 2001.

[2] « Cold in-place recycling : a relevant process for road rehabilitation and upgrading », AA Loudon & DC Collings, 7th Conference on Asphalt Pavement for Southern Africa, 1999.

[3] : Loi Française relative à la transition énergétique n°2015-992 du 17 août 2015

[4] : Guide Sétra, « Retraitement en place des anciennes chaussées bitumineuses », 2003.

[5]:. NF EN16849, « Emulsion water content determination (desiccating balance)», december 2016.

[6] : NF EN1429, « Determination of residue on sieving of bitumen emulsions, and determinatin of storage stability by sieving», august 2013.

[7] NF EN13075-1: «Determination of breaking behaviour - Part 1 : determination of breaking value of cationic bitumen emulsions, mineral filler method», december 2016.

[8] NF EN 12846-1, « Determination of efflux time by the efflux viscometer - Part 1: Bituminous emulsions», april 2011.

[9] NF EN 12850, « Determination of the pH value of bitumen emulsions», august 2009.

[10] Norme NF EN13808, « Bitumes et liants bitumineux — Cadre de spécifications pour les émulsions cationiques de liants bitumineux, août 2013

[11] NF EN 12697-5, « Maximum density of the bituminous materials. Method A using water.», november 2017

[12] NF P 98-252, « Détermination du comportement au compactage des mélanges hydrocarbonés - Essai de compactage à la presse à cisaillement giratoire (PCG) », juin 1999.

[13] NF P 98-251-4, « Essais statiques sur mélanges hydrocarbonés - Partie 4 : essai DURIEZ aménagé sur mélanges hydrocarbonés à froid à l'émulsion de bitume », août 2004.

[14] Frédéric LOUP, Nicolas PEZAS, et al. « RECYTAL®, entretien des chaussées par bio-régénération, Revue Générale des Routes et Aérodromes », n°945, Avril-Mai 2017