Case studies & non-highway applications; Success and failure from real practice

From 9 field demonstrators to many lab studies: Sustainability of the Multirecycling process through the PN MURE Project

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Abstract

A collaborative national research project, known as MURE (which stands for the multirecycling of asphalt) got under way in France in 2014. Its aim is to demonstrate know-how in the area of high recycling rates coupled with techniques that lower temperatures, and to forecast the consequences of recycling asphalt that already contain high proportions of RA, reclaimed asphalt, i.e. multirecycling Nine field demonstration sites were created between 2015 and 2018 with either 40 or 70% RAP content, wearing courses. Both hot and warm mixes were manufactured.. Three of these sites (an additive warm asphalt with 40% RA rate, a foam warm asphalt with 70%RAP, an additive warm asphalt with 40% RA including PMB) were constructed in four stages in order to simulate the construction of a new wearing course followed by three recycling operations, i.e. approximately 40 years of service. This paper will set out the aims of the field demonstration sites. The industrial accelerated ageing method used to simulate 10 or so years of service will be described. Results that demonstrate the ability to forecast the thermoviscoelastic properties of the asphalt using the 2S2P1D model will be presented. The rate of mixing between the binder in the RA and the added bitumen will be adressed. To date the main conclusions of the project are: up to 40% RAP, no issue. Tests methods, scientific concepts are pertinent to characterize and modelize the asphalt properties. Whatever the way of manufacturing the asphalt, a quasi perfect blending between the new and the old bitumen can be achieved and this fact cand be tested. For the 70% RA asphalt studies are still under way. The nine demonstrators wil be followed up until 2025 to secure these conclusions.

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1. THE GENESIS OF THE PROJECT. THE OBJECTIVES.

At the end of the 2000s, road construction stakeholders voluntarily committed themselves to reducing the environmental impact of their activities. Recycling and the use of warm mixes have been chosen to achieve this. However, little by little, it became clear that the confidence of the project owners was not sufficient to consider in a generalized and regular way the joint practice of these two techniques.

After sharing this observation, the technical directors of road construction companies in the Auvergne Rhône Alpes region have engaged in a reflection to find a way out of this impasse. The INDURA cluster (www.indura.fr) was the matrix of this work that would have the technical, social and economic objectives of winning the confidence of project owners. These goals could be achieved by demonstrating in a collaborative and transparent manner that all the issues raised by this theme of warm mix recycling had answers. These answers would be validated by all the project partners and that could also be implemented by all road companies.

Discussions for the research project design took place from 2011 to 2013. During this period, the first maintenance work on asphalt layers already containing significant amounts of reclaimed asphalt, RA, was carried out. It therefore became clear that the project could not avoid the issue of multi-recycling. Can asphalt containing RA themselves be used at will to produce asphalt with conformal and suitable properties for wearing courses? Can a contracting authority consider that the asphalt that make up the infrastructure for which it is responsible, constitute a resource that it can exploit at will?

These reflections also revealed that the issues to be addressed could be divided into two subsets.

A package that would address concerns regarding technical and operational know-how, compliance and adequacy of responses to the specifications of a current asphalt project. This first set of questions was the subject of a proposal. It was labelled MURE National Project at the end of 2013 by the ministry in charge of the road infrastructures. MURE is an acronym for multirecycling of asphalt.

A second set of questions which would aim to base know-how on scientific knowledge that would ensure its sustainability. This part was the origin of a proposal that was selected by the National Research Agency and became the IMPROVMURE project, led by Eiffage Infrastructure

2. THE PRINCIPLE FOLLOWED

The cases studied in the project are characterized by two parameters a recycling rate and a production technique for asphalt.

Two rates were used. The first recycling rate, 40%, was chosen because it represents an ambitious target in the short to medium term compared to the current consensus on high RA rate in France, set at 30%. About half of the asphalt plants currently in operation in France have this capacity to incorporate such a RA rate into asphalt production. To process higher rates, it is necessary to have specific asphalt plants that constitute 2 to 3% of the asphalt plants in France. Therefore, the second recycling rate chosen for the MURE Project, 70%, is useful for special projects.

For the asphalt production techniques, the project's stated ambition is that the recommendations resulting from it will be transposed as quickly as possible into future asphalt markets. So, two warm techniques were chosen because they are accessible to all companies: warm foam and warm with additive. In order to ensure traceability with previous know-how, the hot production technique was also chosen.

2.1. The site as the driving force and heart of the project

While laboratory studies are necessary, they alone do not ensure that all the questions raised by the operational implementation of a technique have been satisfactorily answered.

It therefore seemed obvious that efforts should be concentrated on carrying out experimental jobs. These worksites would be both demonstrators proving the efficiency of the technique and a source of samples for the various laboratory studies.

In addition, looking for real worksites was an excellent way to convince project owners to become partners in the project. Finally, the choice of maintenance sites of wearing courses was guided by the fact that they already represent and will represent, in France at least because the infrastructure network is almost mature, the majority of asphalt sites in the coming years.

The typical construction sites

To demonstrate the feasibility of multi-recycling, the project sites were carried out according to a specific protocol. Considering the various parameters to be controlled during asphalt production and application operations, it became clear that the site had to correspond to an area to be paved of about 2000 m^2 and that the thickness of the asphalt layer had to be about 8 cm.
Most of the work carried out as part of the project is in the form of a wearing course section approximately 400 m long, at least 5 m wide.

Step 1

For the first 100 m, an asphalt mix, E0, without RA is applied and manufactured according to the production technique tested for the site in question. The remaining 300 metres are E1 asphalt mixes with 40% or 70% conventional RA, AE0, as found in material recycling centres.

Step 2

Some time after the application, the last 200 metres are milled. Milling is carried out in a gentle way in order to produce a granularity of 0/10 mm. The milled asphalt, about 120 tonnes, is then aged by heating to transform the bitumen so that its properties are close to those of the original conventional RA. The artificial RA, AE1, is then used, at a rate of 40%, respectively 70%, to prepare an E2 asphalt mix that is used to reconstitute the 200 metres previously milled on the site. Two days later, the last 100 meters of the site are milled. The ageing process is repeated. An AE2 artificial RA is produced and then used to manufacture an E3 asphalt containing 40%, respectively 70% AE2. The 100 metres of the missing wearing course is reconstructed.

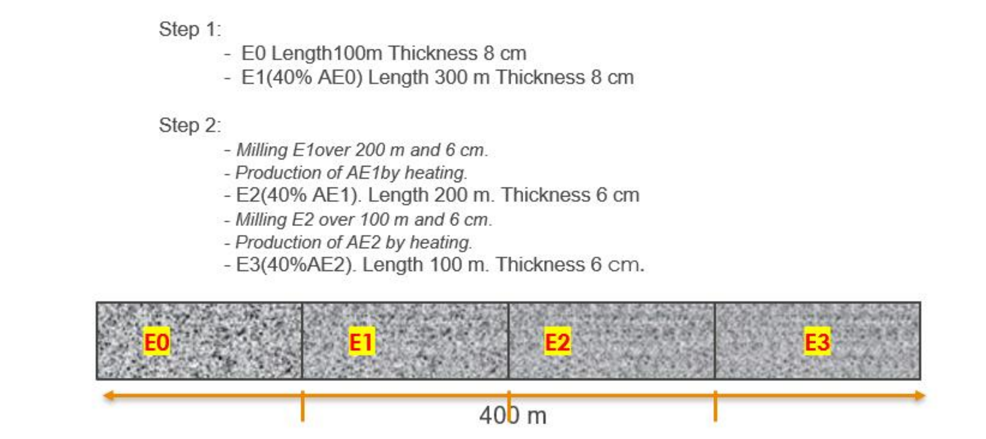

Figure 1: The construction method. The final work site. Case of 40% RA content.

The final work site

In the end, the experimental wearing course is composed of 4 sections of 100 m each, reproducing a new construction stage followed by 3 maintenance stages (figure 1).

Each site is subject to a preliminary lab study. Samples are taken throughout the production stages. They are subject to controls or studies in order to ensure that the site is carried out in accordance with the study and to reproduce part of the tests on industrial asphalt in order to establish the link between the lab sample properties and the industrial ones.

3. THE WORKING GROUPS

The project consists of different tasks. Each of them is dealt with by a working group made up of representatives of the project partners. The group is led by a tandem composed of a representative of a road constructor company and a representative of a public body.

4. THE INTERACTION BETWEEN MURE AND IMPROVMURE

The two projects are autonomous but interdependent so that the results produced by one can be aggregated with those produced by the other. Great care has been taken in the synchronization of studies and the distribution of samples.

5. ACCELERATED AGEING: THE TECHNICAL CHALLENGE

The challenge was to find a way to age the asphalt E1 by about 10 years in a time frame compatible with the progress of the project. It also had to be able to process between 100 and 150 tonnes at a time to be able to supply artificial RA AE1, and AE2 to the worksites.

This question of accelerated ageing of asphalt had already been the subject of much research work; a consensus was reached on a laboratory protocol designed and validated within the framework of RILEM [1]:

- Mixing temperature: 165 °C;
- Short Term Ageing: 1.5 hours at 135°C;
- Long Term Ageing: 9 days at 85°C.

It makes it possible to produce in a few days a few kilograms of artificial RA, enough to feed laboratory studies. The ageing thus obtained represents the thermo-oxidative part of ageing. The possible changes in bitumen properties linked to the alternation of mechanical stresses induced by traffic, temperature variations imposed by weather conditions and water interactions could not be simulated and were not taken into account.

Furthermore, it was not possible to implement the number of ovens that would have been required for the 100 tonnes destined for the sites.

5.1. Preliminary test

Figure 2: Colas Genève Amman mix plant used to test the ability of the warming tube to produce artificial reclaimed asphalt

To anticipate the difficulty of achieving accelerated aging, part of the “Projet National”, PN, preparation step was to evaluate the ability of an heating tube, as found on a parallel tube Amman coating plants, figure 2, to change the properties of the bitumen, 50/70, in freshly manufactured, applied and milled asphalt.

The asphalt was passed through the heating tube three times, which was set to raise the temperature of the asphalt to 130°C. The evolution of the penetrability and ring ball temperature of the asphalt binder is reported in Table 1. The bitumen has aged very little. While this observation is good news for the production of asphalt including RA by this method (the RA binder does not oxidize in this way to heat it up), it was not a good news for the project. This path has therefore been abandoned.

Table 1: Variation of the consistency parameters of the RA Binder versus the number of heating steps in a RA warming tube of an Amman mix plant

Type of binder	Initial bitumen 50/70	After the mixing process	After the 1rst passage in the heating tube	After the 2nd passage	After the 3rd passage	Target (RILEM Method)
Pen, 1/10 mm	58	39	32.5	31	28.5	20.5
Ring and Ball, °C	48.8	56	57.2	58.2	58.4	64.6

Several other methods have been devised that have not been possible to implement due to cost considerations.

5.2. The chosen solution

The project finally turned to the use of a Wirtgen HM 4500 machine, which is relatively common in Germany. It is a self-propelled machine that is equipped with a gas tank and radiant panels. It is initially designed to circulate on the surface of the wearing course to be maintained. It heats up the asphalt mixes and facilitates in-place milling and hot recycling.

Figure 4: Wirtgen HM 4500 used to heat and age the loose milled mix E1 and E2

The project used this equipment to heat the milled asphalt produced during the step 2 of the sites. They were transported and placed in an loose state 4 cm thick on a runway provided by Transpolis, on the site near Lyon Saint-Exupéry airport, figure 4. Advancing at a rate of a few metres per minute, the machine made four passes over the milled layer. After each pass the layer is stirred by a shovel loaded into the bucket of a truck and then reapplied to the paver. The objective is to homogenize the mix and limit the impact of the temperature gradient imposed by the heating method. Indeed, to reach a core temperature of around 80°C, it is necessary to heat the surface of the asphalt to around 200°C. It is certain that the bitumen that has been brought to these temperatures has been profoundly transformed. However, it can be reasonably assumed that this altered bitumen represents only a small proportion of the total bitumen in the future asphalt aggregate.

Between each run, samples are taken and analyzed. The results of these analyses are reported in Table 2. The target has almost been reached. The artificial RA is then loaded and transported to the asphalt plant where it is incorporated into the E2 or E3 asphalt.

Table 2: Characterization of the binder after the accelerated ageing protocol. ICO stands for the oxidation index as determined by Infra Red Spectrometry [2]

Binder	E1 Mix (after 2 year service)	Target: Binder after the RILEM oxidative procedure	Loose Mix E1 after the heating procedure
Pen, 1/10ème mm	24	16	18
R&B, °C	63	68	66
ICO, arbitrary units	5.2	7.5	5.8

It was necessary for one site (Portet-sur-Garonne) to pass the artificial RA through a crusher in order to reduce the agglomerates that had formed during the heating process.

6. RESULTS

6.1. The building sites

Table 3 lists the characteristics of the worksites carried out during the project.

5 sites are located in the Auvergne Rhône Alpes region, numbered from 1 to 5, and are special in that the materials used come from the same sources. The aggregates were supplied by Lafarge's Cusset quarry. The bitumen comes from the Total refinery in Feyzin. Finally, the AE0 stock required for sites 1 to 3 has been built up, homogenised and carefully stored by Axima. This choice of a single source was an heavy constraint, but in return it made it possible to reduce the causes of variation in the parameters to be controlled.

Table 3: List of the sites constructed in the PN MURE framework

Site	Contracting Authority	Location	Step 1	RA Rate	Mixing Process	Special Features	Step 2
1	Métropole Lyon	Villeurbanne, Rue du Canal	15/09/2015	40%	Warm additiv	Additive INGEVITY	None
2	CD 69	Ronno, RD 313	16/09/2015	40%	Hot	None	0ct 2017
3	CD 63	Moriat, RD 909	17/09/2015	40%	Warm foam	None	None
4	Agglomération du Muretain (34)	Portet-Sur-Garonne, Avenue de la Saudrune	16/08/2016	40%	Chaud,	PMB,	None
5	Agglomération du Muretain (34)	Portet-Sur-Garonne, Avenue de la Saudrune	16/08/2016	40%	Warm additiv	PMB, Additive INGEVITY	April2018 and Sept 2018
6	CD 33	Arsac RD 121	01/10/2016	50%	Warm foam	Rejuvenating agent by TOTAL	None
7	ATMB	RN 205. Parking de l'Abbé Roland	04/10/2016	70%	Warm foam	None	Oct-2017
8	ATMB	RN 205. Aire de Régulation	05/10/2016	70%	Chaud,	None	None
9	CD 92	Neuilly-sur-Seine. Boulevard Bineau	01/08/2018	40%	Warm foam	None	None

2 jobs, number 4 and 5, involving the application of polymer-modified binder asphalt mixes were carried out at Portet-sur-Garonne, near Toulouse (31).

Site number 6 is in Arsac (33). On this occasion a rejuvenating agent was used.

As for site n°9, carried out in Levallois-Perret, it is of particular importance. It was intended to confirm the conclusions drawn from the various projects at 40%.

On these 9 sites, three were carried out according to steps 1 and 2 described above.

The other 6 were performed according to step 1 only. They are made up of sections E0 and E1.

6.2. Asphalt

The asphalt of the project, whether manufactured in the laboratory or industrially, were qualified in terms of their technical properties, compactibility, rutting, water resistance and thermomechanical properties: complex modulus, fatigue behaviour. The results of the formulation studies were compared with those of the asphalt collected during applications to validate the relevance of the formulation method.

6.3. Blending of bitumen

The topic of recycling is accompanied by several questions. One of them, perhaps the most significant, is the blending between the binder of the RA and the new bitumen. During the formulation study it is assumed that the blending is perfect. For laboratory manufacturing it was possible to show that this hypothesis was verified at least up to RA rates of 50% [3].

Eurovia has developed a test that characterises the quality of the binder mixture [4]. For this purpose, the asphalt to be qualified is placed in a device that allows the binder to be gently leached with the aid of a solvent. The solvent is collected in a series of vials. At the end of the test all the binder was dissolved. In general, the bitumen solution is dispatched in a dozen of vials. The solutions are analyzed by infrared spectrometry. This determines the carbonyl index of the binder contained in each solution. [2]. If the manufacturing operation has produced a homogenization of the binders, then the value of the index is almost constant from one vial to another.

We were thus able to show that in the case of 40% of the sites, there was always good homogeneity (Figure 5). This is one of the main outcomes of the project.

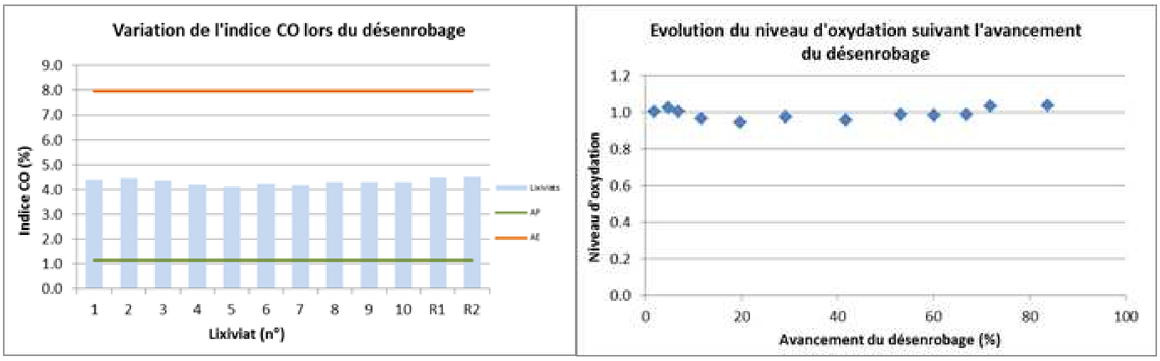

Figure 5. Left graph: Variation of carbonyl index versus the vial number of the controlled leaching test. The green line is related to the new bitumen, the blue bars refer to the gradual leaching solutions, the orange line refers to the RA binder. Right graph: Evolution of the blending ratio.
Data issued from the site#1. Warm process 40%RA.

Thanks to this test it is now possible to demonstrate on experimental evidences that a given coating plant is capable of correctly mixing binders.

6.4. Manoeuvrability

On several sites, it was possible to measure the handling of asphalt (the ability of an asphalt to be applied by manual means. This characteristic is different from the compaction capability as assessed by the gyratory compaction test). Different methods were used. They do not all give identical results. However, they are comparable and give converging conclusions.

That is, the higher the RA rate, the shorter the handling time; the handling time is longer for hot production than for warm production. This would be a research topic to be undertaken because this phenomenon will likely limit the development of high rate recycling for worksites involving manual application.

6.5. Environmental impact

The quantities of asphalt produced during the construction sites were not sufficient to qualify the emissions into the air. This parameter could not be measured.
On the contrary, the release of dangerous substances into the water could be qualified [5]. Samples were collected and used for tests that were conducted at the Ecole Spéciale des Ingénieurs des Travaux de la Construction. The operating method used is that described in standard prEN 16637-1 to 3, which will come into force in 2020. These results are therefore all of normative relevance. For asphalt with a 40% RA content, regardless of the production method, it can be observed that the hazardous substances released are released in very small quantities and well below the thresholds defined in the guide for the use of alternative materials [6]. From this point of view, there are no adverse consequences to using high recycling rates.

7. THE CONSEQUENCES OF THE PROJECT

7.1. Technical and operational conclusions

The major assumption underlying recycling is that the bitumen of the RA and the new bitumen in the sense that it has not yet been used to bind aggregates into asphalt, added at the time of asphalt production, are mixed during this operation and become a binder with the properties appropriate for the intended use. There is now a test capable of qualifying the mixing ratio between these two binders. A given asphalt plant and a given RA introduction mode can then be characterized.

The method of asphalt formulation and the technical tests on which it is based remain relevant for the production processes explored by MURE.

If the history of a RA is known, the formulation of the asphalt is carried out with greater confidence in achieving the desired objective. However, it is not necessary to know it to use RA: characterization tests provide the relevant information to formulate effectively. Stock homogeneity remains a key factor in ensuring that the industrial mix will conform to the lab mix.

At the scale of laboratory studies, multi-recycling does not raise unresolved issues other than durability. It is now very clear that the formulation method does not have a test or a set of tests to predict the durability of a mix in a wearing course function and therefore subject to simultaneous climatic and mechanical factors.

7.2. Recycling rate equal to 40%.

Industrial asphalt have a resistance to water damages and thermomechanical properties, in particular the value of the modulus used for pavement design, which are in accordance with and equal to those of laboratory asphalt mixes characterized during the formulation study. Furthermore it was shown that the complex modulus, regardless of the production method, is adequately described by the so called “2S2P1D” model [7]. The normalized modulus graphs of all the mixes are identical.[7]

The project was able to demonstrate that the asphalt plants used for the worksites can mix the fresh binder and the RA binder. There is no fear of a level of heterogeneity that would be introduced by the presence of RA and would be detrimental to the use properties of the asphalt.

There is no influence of the production method, hot, warm, on the properties of the asphalt. For the client, this production method should not be a concern if this method is controlled by the company that implements it.

Adhesion properties are not affected by the production method, the presence of RA or the number of recycling steps.

7.3. 70% recycling rate

The mixing ratio is not as homogeneous as for 40%. The process of introducing RA has a major effect on the homogeneity of the mixture. As part of MURE: only one process was evaluated: parallel tubes used at Colas' coating plant in Bonneville (74). This heterogeneity is not noticeable in the modulus values, which are independent of the asphalt production method. However, there is a trend: the modulus values of asphalt sampled on site are slightly higher than those of laboratory asphalt.

Laboratory studies do not raise any issues. Apart from the already mentioned subject of sustainability, the water resistance, rutting and fatigue properties are identical between laboratory and industrial asphalt mixes.

For the time being, the behaviour of the sites at an early age does not give rise to any particular comments.

7.4. Production and application of asphalt

The experimental sites have shown that compliance with the best practices for the production and application of asphalt ensures that the asphalt applied are in conformity with those of the study. There is no need to invent anything. However, compliance with these rules is all the more constraining as the recycling rate is high. The management of the RA stock, its homogeneity and moisture content is a key factor for success. A high RA content penalizes manual application of asphalt mixes.

8. MONITORING OF THE WORKSITES

The evolution of the worksites is currently almost the only source of observations and data to qualify the durability of asphalt incorporating RA. Once completed at the end of 2019, the project will leave 9 sites with a life expectancy of more than 10 years on the site. To reap the benefits of this investment, the project partners entrusted a group of their representatives with the task of having Cerema monitor the project's work sites, establish their observations and draw conclusions in a collaborative way, which was one of the keys to the project's success. This post-project work will be published using the same validation process as during the project.

9. THE REFERENCE DOCUMENTS

Events, information, site data, test results produced during the 5 years of the project are recorded in deliverables. Synthesis reports have been prepared. They will be accessible to all, partners or not partners during 2020. Some of these reports will be sent to IDRRIM (www.iddrim.com) to translate the major results of the MURE research into daily practice in asphalt work.

10. LEARNING TO COLLABORATE

A consequence of this project is also to have demonstrated that there is an interest in issues that are common to all stakeholders to work collaboratively. This research method has the great advantage of quickly sharing the results and conclusions between all the actors of a project and thus being able to quickly translate them into daily practice. The national project "Lifetime of pavements", which is also conducted collaboratively, is an interesting indication that the road transport industry has grasped the full value of this approach.

11. ACKNOWLEDGEMENTS

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