# Reuse of very hard Reclaimed Asphalt – Field results

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## ABSTRACT

The reuse of Reclaimed Asphalt, (RA), is now a common practice, bringing economic and environmental benefits. Most of RA, used today, is from pavements laid down 10 to 20 years ago. Over the last decade, the trend was using harder binder grades and Polymer modified Bitumen (PmB). This leads to RA becoming harder. Such binders face difficulties in processing at the mix plant and in full mobilisation. To overcome these issues, the use of a rejuvenating additive can provide a positive benefit and bring recycling to the next level.

This paper is related to a full-scale project where 40 % of hard RA was successfully used and paved. A preliminary laboratory evaluation was performed on the binder and asphalt mixture. These results were then compared with characterisation of the materials from the full-scale production. In addition, the degree of blending, from in plant manufactured mixes, was carried out using sequential extraction.

The outcomes have shown some very consistent test results between the lab studies and the field material evaluation. The use of rejuvenator helped to restore the properties of the hard RA comparably to a more standard RA quality that can be processed in a normal asphalt mix.

**Keywords**: Reclaimed Asphalt, Rejuvenation, Asphalt binder, Bitumen, Binder mobilisation

## 1 INTRODUCTION - BACKGROUND

Economic and environmental constraints have pushed the asphalt pavement industry to value more and more Reclaimed Asphalt, RA. Asphalt pavement is one of the most recycled and reusable materials in the world. Today it is widely accepted to use 30 % of Reclaimed Asphalt into new hot mix asphalt [1]. The need for tomorrow may face some new challenges with higher RA content, above 30 % or even up to 70-100 %, and RA quality. While today the RA available is from the roads made 10 to 20 years ago, the RA for tomorrow will be different. There was a trend to use more harder bituminous binder grades, Polymer modified Binder (PmB), as well materials having gone through second or third recycling cycles. This implies a shift in the RA quality towards harder RA binder which may be outside of current specifications for its normal reuse and require different process at the mix plants. It was already noticed in certain countries like Japan, France, Germany [2], with implication for certain usage and or need for new technologies.

In this context, the use of rejuvenating additive can help to overcome this problem ensuring constant quality for final asphalt mix on the road. For this purpose, a full scale project from laboratory evaluation to job site evaluation was made in France to investigate if such technology can insure proper quality materials, meeting standard specifications and facilitate the processing at the mix plant ensuring a good mobilisation and blending of the aged binder in the final mix.

In France the use of RA is in average 18 % with practice up to 30 %. Most often, the use of standard bituminous binder or one grade lower is enough to meet the specifications. However for very hard RA, there is some national restriction [3], including penetration value < 5 x0.1mm or softening point temperature > 77 °C. A stockpile of about 5 000 t of RA was identified and classified with a penetration value as low as 4 x0.1mm and a softening point temperature above 80 °C. As these properties were largely out of the range of common RA quality for a normal reuse, it was aimed to be downgraded for lower value application.

In this context, a bio-based rejuvenating performance additive was used in order to restore enough properties of the aged binder to meet the ones from a standard RA quality. This specific bio-based rejuvenating additive is a liquid additive that will, with its specific amphipathic chemical structure, disperses the highly polar fractions of bituminous binder, limiting the agglomeration of asphaltenes [4]. Table 1 presents the main properties.

**TABLE 1. Typical values of properties of the rejuvenating additive**

| Flash point | Viscosity at 60 °C | Cloud point | Density |
|---|---|---|---|
| > 280 °C | 22 Cst | < -25 °C | 0.93 |

The project focused on demonstrating the feasibility of the reuse of 40 % of this RA at mix plant. The scope was firstly to determine the optimum dosage at laboratory scale based on binder evaluation with empirical properties. A second objective was to check the characteristics of asphalt mix made in the lab towards specifications, including compactability, water sensitivity, modulus and rutting resistance. With these results, a full scale production of 320 t was manufactured at a mix plant and post evaluation made for compaction, stiffness modulus and also determination of the degree of blending based on sequential extraction.

## 2 PRELIMINARY LABORATORY EVALUATION

A dosage study was first performed on the binder to determine the optimum dosage. Two different dosages of the rejuvenating additive was used, 5 % and 10 % on the RA binder alone and on the combined treated RA and a virgin binder. The goal was to target a penetration value of 16-18 0.1xmm of the treated RA, value comparable to a “normal” RA used at 40 % in asphalt mix with a 35/50 bitumen. The evaluation encompassed empirical properties with penetration value at 25 °C (EN 1426) and softening point temperature (EN 1427) on the original blends, and after RTFOT (EN 12607-1) short term aging. The results are shown in Table 2.

**TABLE 2. Main binder properties on the different blends with rejuvenating additive**

| Blends | Penetration value at 25 °C, x0.1mm | Softening point temperature, °C |
|---|---|---|
| RA binder | 4 | 89.2 |
| 50/70 binder | 59 | 48.6 |
| RA + 5% | 14 | 71.2 |
| RA + 10% | 35 | 60.8 |
| 40%(RA+5%)+50/70 | 27 | 59.0 |
| 40%(RA+10%)+50/70 | 38 | 54.8 |
| After RTFOT | | |
| 40%(RA+5%)+50/70 | 21 (78 %) | 64.0 (+5.0) |
| 40%(RA+10%)+50/70 | 30 (79 %) | 60.2 (+5.4) |

Figure 1 displays the effect of the rejuvenating additive on the penetration value and the softening point temperature as part of European specifications for bituminous binder. Clearly the RA binder was extremely hard and far away from any paving grade binder type. On the RA binder itself, it shows that a dosage of 5 % can change the properties by two grades softer. While targeting a penetration value of about 16-18 x0.1mm after treatment with the additive, an intermediate dosage of about 7 % could be used. Considering the final blend of treated RA binder with 50/70 virgin binder, in a ratio of 40 % / 60 %, it was confirmed that an intermediate dosage of 7 % dosage can restore the properties close to a 35/50 pen grade bitumen.

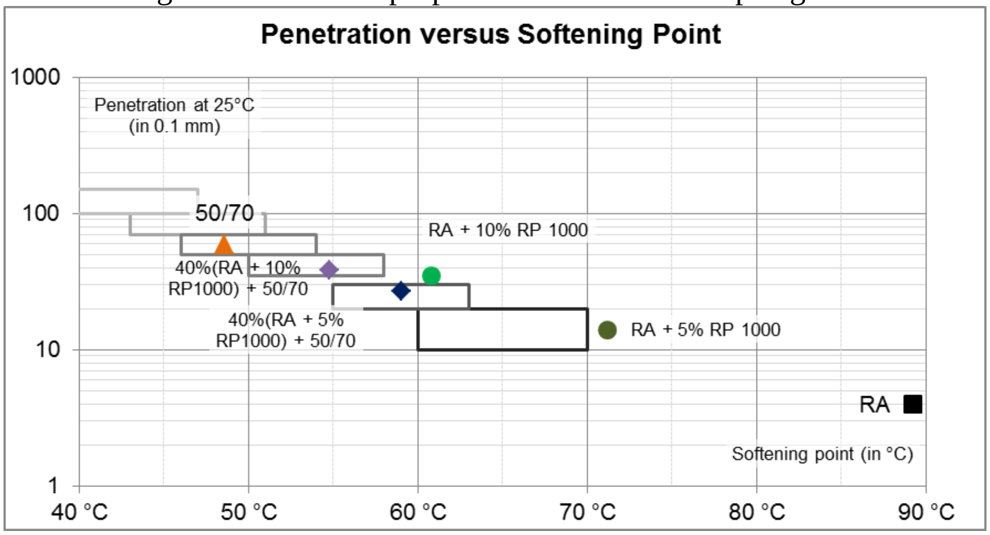


**FIGURE 1. Effect of rejuvenating additive on penetration and softening point**

Using these initial results the study scaled up to asphalt mix lab evaluation using 40 % RA. For this project, as the RA binder was very hard, the final mix with 40 % RA treated with the rejuvenating additive and 50/70 pen grade bitumen was compared with a mix made with 40 % of RA without rejuvenating additive but using softer grade 70/100 bitumen. The grading curve was kept similar for both mixes with same total binder content, taken into account the additive is contributing to the binder content, as shown in Table 3.

**TABLE 3. Job mix formula of mix with 40 % RA with and without additive**

| | Specifications | Reference mix 40%RA 70/100 | Mix 40% RA+RP1000 and 50/70 |
|---|---|---|---|
| Grading curve | | | |
| 14mm | 100.0% | 100% | 100% |
| 10mm | 90-100% | 95% | 95% |
| 2mm | 10-60% | 32% | 32% |
| 0.063mm | 2-12% | 8% | 8% |
| Binder content | | 5.3 % | 5.3 % |
| From RA | | 2.3 % | 2.3 % |
| Form virgin binder | | 3.0 % | 2.84 % |
| From additive | | | 0.16 % |

This mix evaluation encompassed compactability based on gyratory compaction (EN 12697-31), water sensitivity through Duriez test (EN 12697-12), rutting resistance (EN 12697-22) using large device and stiffness modulus (EN 12697-26). The results are presented in Table 4. They were very consistent between the two mixes based on lab mix production and met the specifications. However the use of soft binder with extremely hard RA has been experienced by the mix plant to be extremely difficult to operate resulting in incomplete and heterogeneous mix.

**TABLE 4. Asphalt mix characteristics of mix with 40 % RA with and without additive**

| | Specifications | Reference mix 40%RA 70/100 | Mix 40% RA +RP1000 and 50/70 |
|---|---|---|---|
| Gyratory compaction at 60 gyrations | 5-10% | 9.0 % | 8.9 % |
| Water Sensitivity, Duriez | > 70 % | 85.7 % | 87.4 % |
| Wheel Tracking Test after 30000 cycles | < 5 mm | 2.3 % | 2.6 % |
| Stiffness modulus at 15 °C | ≥ 7000 MPa (at 5-8 % voids) | 9300 (8 %) | 9400 MPa (6.7 %) |

From this initial lab evaluation, it was confirmed that on binder evaluation the use of the rejuvenating additive helps to obtain similar properties as standard 35/50 pen graded binder by adjusting the RA binder closer to normal values, usually seen for such aged material. The mix evaluation also showed that specifications can be achieved and comparable to the use of a much softer virgin bituminous binder. Thus the project was approved to move to full asphalt plant production.

## 3 ASPHALT MIX PRODUCTION AND EVALUATION

The asphalt production was made late in the season in October 2016 with reasonable weather conditions for the season, air temperature between 5 to 15 °C. The paving job site was at 100 km from the production site which took about two hours for trucks to drive there.

A continuous mix plant was used with a recycling ring for the RA introduction. The production rate was set at 120 t/h for a final mixing temperature of 160-170 °C. The RA stockpile was sampled for final characterisation. The properties were slightly different with a penetration value at 25 °C of 6 x0.1mm and softening point temperature of 78 °C. These variations are not uncommon in RA stockpile. Finally the dosage of the additive during the production was 5.5 % of the binder content from the RA. For the purpose of this production, the additive was spread directly on the RA on the conveyor belt through a spreading bar with nozzles. Before to arrive to the recycling ring, the RA went through two other conveyor belts ensuring a residential mixing time of 15-20s for the additive on the RA before to go in the drum and mixed with virgin hot aggregates.

The pavement was for an industrial area with heavy trucks driving at low speed and turning. The final thickness was 7 cm asphalt mix on a granular unbound subgrade layer with bearing capacity of 60-70 MPa. Despite weather conditions and long-haul transportation, the asphalt mix on the job site displayed a good workability even for hand application.

From the materials produced at the mix plant, samples were collected for further analysis in terms of quality with compaction and as well for advanced testing.

**FIGURE 2. RA treated at the mix plant and job site application**

Binder was extracted and recovered from the mix and empirical binder properties measured. Table 5 compares the binder from mix plant manufactured with lab RTFOT aged binder from the initial evaluation. Despite some variation in terms of RA stockpile, mix production and final dosage, the values are in the same magnitude of range between lab aging conditioning and plant production.

**TABLE 5. Binder properties from mix production compared to RTFOT aged binder**

| Binder from | Penetration value at 25 °C, x0.1mm | Softening point temperature, °C | Binder content |
|---|---|---|---|
| RA * | 6 | 78 | 6.01 % |
| Mix production | 19 | 62 | 5.27 % |
| From lab initial binder evaluation after RTFOT | | | |
| 40%(RA+5%)+50/70 | 21 | 64.0 | -- |

* from sample collected during mix production

Furthermore asphalt mix sample from job site cores were evaluated towards stiffness modulus using Indirect Tensile Stiffness and compared with the lab mix evaluation. Again considering variability from plant production, the results are in the same magnitude of range and meet the specifications, with a bit lower stiffness value and lower void content. If the dosage would have been kept at the same level as in the lab study, the modulus would have been even lower. This is an important learning between lab mix evaluation and mix production that a reduction of the theoretical dosage does not harm the characteristics. A statistical analysis of the results would have valuable but the number of measurement was not enough for such analysis.

**TABLE 6. Mix characteristics from mix production compared to lab mix**

| | Specifications | Plant produced mix | Lab produced mix |
|---|---|---|---|
| Stiffness modulus at 15 °C | ≥ 7000 MPa (at 5-8 % voids) | 8200 (5.6 %) | 9400 MPa (6.7 %) |

One important point that can be stressed at the early stage of the project is about ability of mobilising the aged binder from the RA especially with very hard binder. At a lab scale, especially for binder evaluation, it is easy to ensure perfect blending between the binders. However at the mix plant, the total mixing time for aggregates, RA and binder are more in the magnitude of range of 50-90 s. Depending on viscosity differences between aged binder and virgin binder how can the RA binder be fully mobilised and blended with the new virgin binder?

In order to address that, a specific protocol has been used. The method consists of washing loose asphalt mix with an appropriate solvent and collecting, along the extraction duration, diluted binder samples at different times [5]. The binder recovered from these diluted solutions are further characterised through Infra-Red spectrometry in order to monitor the Index of Carbonyl, ICO, as an indicator of oxidation. When the binder is aging, the ICO increases. Thus ICO from RA binder is higher than from the virgin binder [6]. The evolution of the ICO along the sequential extraction is recorded. The ICO from the RA alone and the original virgin binder are only used as a reference. Thus they weren't aged from the plant production. If the binder from the RA is not 100 % blended with the virgin binder then the beginning of the extraction will have less footprints of aged RA binder than at the end of the process, which leads to clear variation in the ICO level. Figure 3 displays the full results along the extraction. The bars are the values for each extraction stage. They are all constant with limited variation along the process, showing a good binder homogeneity and so a good degree of blending.

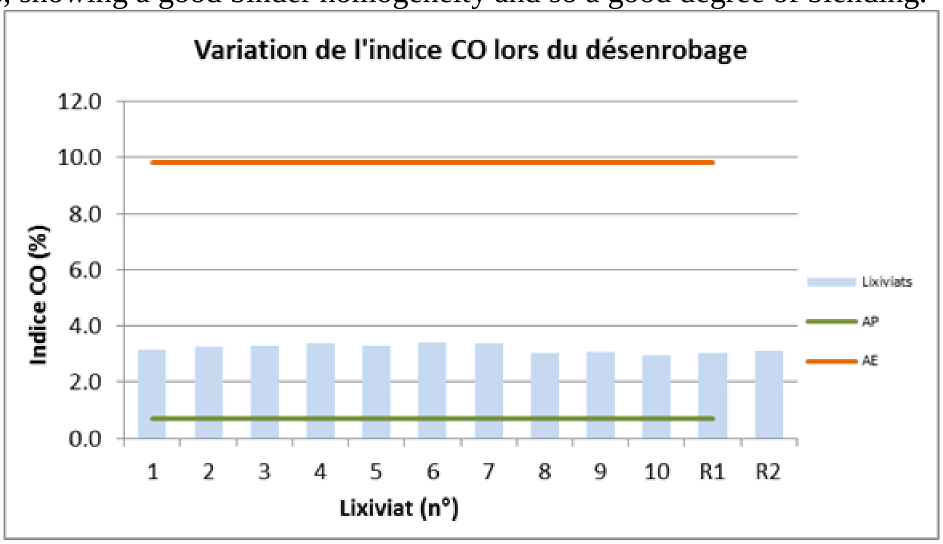


**FIGURE 3.** **Variation of carbonyl Index along sequential extraction of mix binder**

## 4 CONCLUSION

While the reuse of RA is a common practice, in some cases with very hard RA, processing and meeting specification is not possible. The use of rejuvenating additive can help to adjust the quality of the RA to more standard values. This study reflects the outcome of a full scale project using 40 % RA displaying very hard properties that should not be useable in normal conditions.

Based on lab evaluation on binder and asphalt mix, the use of a specific bio-based rejuvenating performance additive helps to meet the standard specifications, at least as good as normal asphalt mixture.

A mix plant production, despite some adverse conditions in terms of weather and logistics, confirmed the mix could meet the specifications. In order to achieve a good mobilisation of the binder from the RA the additive was spread on the cold RA moving on the conveyor belt before mixing with other virgin components. The good degree of blending was confirmed by a specific methodology using sequential extraction and following aging indicator

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