# From laboratory mixes to full scale test: rutting evaluation of bio-recycled asphalt mixes

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# From laboratory mixes to full scale test: rutting evaluation of bio-recycled asphalt mixes

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**Abstract.** The present paper describes the rutting behavior of innovative mixes incorporating 50% of Reclaimed Asphalt (RA) with bio-materials. They were assessed in the laboratory and in a full-scale accelerated experiment. The innovative mixes studied here contain bio-materials especially designed to help recycling by reactivating the aged binder in RA. Four mixes were evaluated: three of them are manufactured with bio-materials, (two bio-rejuvenators and one bio-binder) and one is a control mix, which is a high modulus asphalt mix (EME2).

In this study, the rutting resistance of the four mixes was first evaluated in the laboratory with both European and US methods. The full-scale test was then performed in order to evaluate the rutting resistance of the bio-recycled asphalt mixes under heavy traffic (200 000 load cycles loaded at 65 kN) and compare it with the control.

A simplified analysis leads to the conclusion that, with the Nantes climate, a daily traffic of 150 heavy vehicles per day applied for 20 years corresponds to approximately 200 000 heavy vehicle loads applied when the surface temperature exceeds 30°C. Therefore, it can be considered that the rutting evaluation made on the carrousel represents almost 20 years of traffic during hot periods.

The results obtained on the test track are consistent with the laboratory rutting tests showing good performance of all the mixes. The materials presenting the best performance on the test track also presented the best performance in the laboratory.

**Keywords:** Bio-materials; Reclaimed asphalt; Accelerated pavement test; Rutting test; Laboratory test

## 1 Tested materials

The aim of the project was to maximise the use of RAP with bio-based materials. For this purpose, three mixes were designed incorporating 50% RAP content, in association with three different and complementary innovative bio-materials [1]:

- Mix1: designed with a bio-based rejuvenator, SYLVAROAD™ RP1000, a performance Additive, from Kraton Chemical used to treat the RAP. It was specifically designed to increase RAP content up to 100 % or to reuse very hard, low quality RAP.
- Mix2: designed with a bio-binder, Biophalt®, from Eiffage Infrastructure, used for total replacement of bituminous binder in recycling techniques.
- Mix3: designed with a bio-based additive from Iowa State University, an Epoxidized Methyl Soyate (EMS) aimed to compatibilize virgin binder and aged binder from RAP.

Aggregate grading curve and binder content were chosen using aggregate packing optimisation concepts (GB5® type material) in order to maximize mix density and particle interlock [2]. The properties of these three GB5-type mixes (mix 1, mix2 and mix3) were compared with the reference high modulus asphalt mix (EME2), commonly used in France.

Before construction, laboratory rutting tests were performed on mixes produced in lab following the European method (French wheel tracking test) and US method (flow number test). Results are presented in Table 1. All three innovative materials gave results well below the European and US specifications for resistance to rutting. According to the European method, the results are similar for the 3 mixes, taking into account the repeatability of the tests.

**Table 1.** Results of laboratory tests for resistance to rutting.

| Mixes | Rut depth EU method<br>NF EN 12697-22+A1<br>30 000 cycles at 60°C<br>Rut Depth (%) | Rutting resistance<br>(flow number)<br>At 7% air void, T=54°C<br>AASHTO TP-79<br>(cycles) |
|---|---|---|
| Requirements for a high modulus Mix | **< 7.5%** | Requirement medium traffic level |
| Requirements for a GB4 Asphalt base course material | **< 10%** | **>190** |
| Mix 1 | 5.6%<br>(void content = 4.4%) | 609 |
| Mix 2 | 4.3%<br>(void content = 3.5%) | 578 |
| Mix 3 | 3.7%<br>(void content = 5.5%) | 668 |
| EME2 | 3.1 %<br>(void content = 4.8%) | 863 |

## 2 Accelerated pavement test

The fatigue carrousel of IFSTTAR is an outdoor road traffic simulator designed to study the behaviour of real scale pavements under accelerated heavy traffic. The fatigue carrousel has a diameter of 40 meters and four loading arms, which can each carry loads up to thirteen tons, at a maximum loading speed of 100 km/h. During loading, a lateral wandering of the loads can be applied to simulate the lateral distribution of loads of real traffic.

In this experiment, the thickness of the bituminous layer is about 90mm. The subgrade includes a stone bed (50/120 mm), and an unbound granular (UGM) subbase. The bearing capacity of the subgrade was measured at different positions on each structure by means of dynamic plate load test, which gave values between 63 and 85 MPa for the stone bed, and between 94 and 103 MPa on top of the UGM layers. The bituminous mixes were produced and the pavements were built on the 30$^{th}$ and 31$^{st}$ of May 2017 by Eiffage. The in situ void contents of the mixes were close to the laboratory values.

The full scale experiment was realized in two phases: The first phase was performed between July and September 2017, to evaluate rutting resistance under a 65 kN dual wheel load, with a speed of 43km/h and a narrow transversal wandering (+/- 26cm). The second phase was performed between November 2017 and March 2018, to evaluate fatigue resistance of the pavements, also under 65 kN load. This second phase will not be detailed here, but is presented in [3]. During the rutting test, loads were applied only when the pavement surface temperature exceeded 30°C, which is the procedure generally used for rutting tests on the IFSTTAR APT. 200 000 loads were applied. The pavement temperatures varied between 30 °C and 40 °C, with some short periods with higher temperatures, especially at the start of the test, where a maximum temperature of 53 °C was recorded on the surface of the pavement. Four different structures corresponding to materials described above, mix1, mix2, mix3 and EME2, were tested simultaneously.

## 3 Representativeness of the rutting test

A histogram of the surface temperature distribution during the loading phases of the rutting test is presented on Fig. 1. Most of the loads (81 %) were applied when the surface temperature in bituminous layer was between 30 and 54°C. An analysis was conducted to evaluate how many years of traffic at high temperature, on a real pavement, could correspond to the 162 205 loads applied in the APT experiment, with a surface temperature higher than 30°C.

To do this, we used:

- Typical pavement surface temperature variations recorded during one year in Nantes on a bituminous pavement (from February 22th 2017 to February 21th 2018)
- A reference traffic: a traffic of 150 heavy vehicles/day (class of traffic T3, in France) was considered, which corresponds to a medium traffic level, on a secondary road [4].
- A typical mean daily distribution of traffic, representative of traffic on French roads, determined using data from several vehicle counting stations [5].

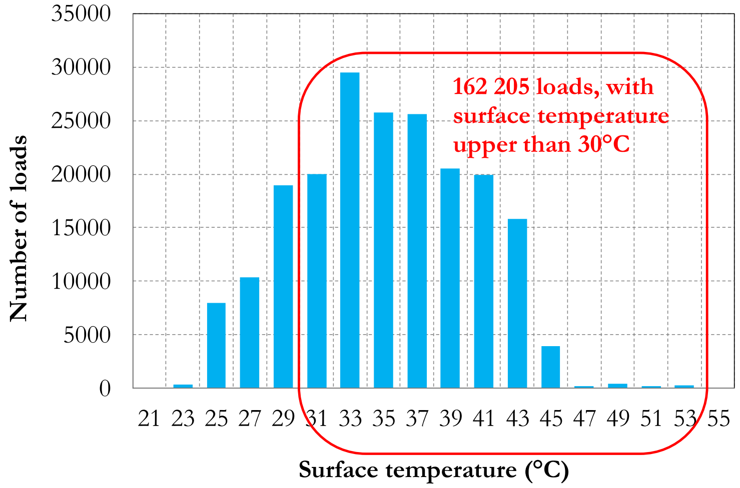


**Fig. 1.** Histogram of surface temperature distribution during the loading phases of the rutting test

With the data presented above (number of heavy vehicles per day, mean daily distribution of traffic and surface temperature variations), it is possible to calculate a histogram of the number of heavy vehicle passes, as a function of the surface temperature, for the studied pavement. This histogram was calculated for a period of 20 years, which corresponds to the usual pavement design life in France. In this calculation, it was considered that the traffic and the temperature variations are the same each year.

This simplified analysis leads to the conclusion that, with the Nantes climate, a daily traffic of 150 heavy vehicles per day applied during 20 years corresponds, to approximately 177 500 heavy vehicle loads applied when the surface temperature exceeds 30°C. Therefore, it can be considered that the rutting evaluation made on the carrousel represents approximately 18 years of traffic (almost 20 years) during hot periods, on a road with a daily traffic of 150 heavy vehicles per day. This result is obtained for the Nantes climate, which is a mild oceanic climate, with air temperatures varying typically between about 5 °C in the winter and 25 °C in the summer. Of course, the number of years of traffic simulated would be lower for a hotter climate. The same type of analysis could be easily applied to another climate, providing that the necessary pavement surface temperature data are available.

## 4 Results and conclusion

Rut depth measurements were made with a profilometer developed at IFSTTAR, equipped with a laser sensor, which can measure the vertical rut depth with an accuracy of 1 mm. The transversal profile of the pavement was measured on a width of about 1.4m. The maximum rut depth value was then determined for each profile. The

measurements (4 or 5 measurements per section) were performed on each section. Rut depth was measured at 0, 10 000, 20 000, 40 000 load cycles, and then each 40 000 cycles up to 200 000. Temperature measurements, at the bottom, in the middle of the bituminous layer and at the surface, were also performed during the whole duration of the experiment, at time intervals of 10 minutes.
The evolution of mean rut depths (in %) during the test is presented on Fig. 2, as well as the recorded temperatures. The final percentages of rutting are quite the same for the Mix 1 and EME2 sections (about 5%). Percentages of rutting of the Mix 2 (10.9%) and Mix 1 sections (10.0%) are more important.

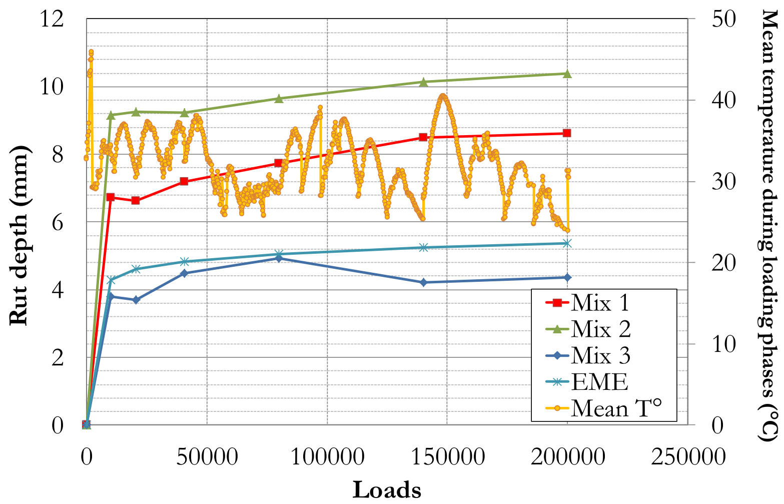


**Fig. 2.** Evolution of rutting with the number of load cycles

At the end of the test, it could be concluded that:
- Rut depths increased rapidly on all sections during the first 10 000 cycles. This rapid increase could be due to post compaction, and also to the higher temperatures observed during these first 10 000 cycles (up to 53 °C).
- After 10 000 cycles, rutting continued to increase, but at a much lower rate, about 1 % of increase, until 200 000 loads for the EME2 and Mix 3 sections, and 2 % for the Mix 1 and Mix 2 sections. This indicates good performance of all the materials. It is important to note that, in France, for pavements with medium trafic (150 trucks per day), rutting is considered like a severe damage if the rut depth exceeds 20 mm (in our case, about 20% of rut depth).
- The results obtained on the test track are consistent with the laboratory rutting tests. The materials presenting the best performance on the test track (EME2 and Mix 3 sections) also presented the best performance in the laboratory. During the deconstruction, trenches were cut in the pavements to evaluate the deformations of the different pavement layers and conclude about the origin of the rutting. The pavement profiles at the end of the rutting test are presented on Fig. 4. Rutting of the EME2 and Mix 3 sections could be explained by a post compaction of the granular layers. The

rut depth is about 6mm for these 2 sections. For Mix1 and Mix2, measured rut depths are respectively 11 and 12.5mm. It seems that for these two sections, rutting could be explained by a post compaction of the granular layer (estimated at 6mm, like for the other sections) and a shear flow mechanism, limited to the top layer, of about 5 and 6.5 mm, which can be considered very low for 20 years of trafic with high temperatures on a pavement.

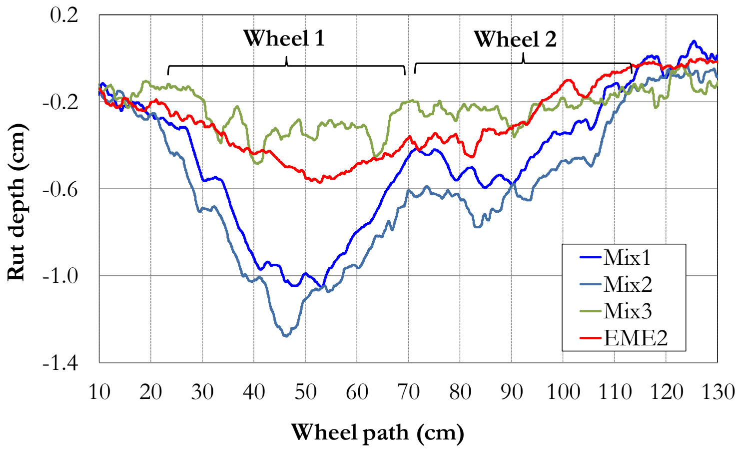


**Fig. 4.** Pavement transverse profiles at the end of the test

It is possible to conclude that the carrousel test shows that all the bio-recycled asphalt mixtures performed very satisfactory and that the predictions obtained with the laboratory wheel tracking tests were confirmed by the results obtained during the full scale experiment.

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