

## A comparative high-modulus asphalt experiment in Belgium

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### Abstract

In April 2006, test sections in high-modulus asphalt were constructed on the Brussels-Antwerp motorway (E19). Nine variants of high-modulus asphalt and one conventional asphalt concrete (as a reference) were used in the binder course. Among the parameters tested in the variants are the type of mixture (stony or sandy skeleton), the type of binder, binder content and the addition of RAP (reclaimed asphalt pavement). The variants were chosen after extensive research in the laboratory to assess the effects of various parameters on the mix performance. The main conclusions drawn from the laboratory research program are presented in this paper.

The construction of the test sections was carried out in successive steps including the removal – by milling – of the existing layers to a depth of 12 cm, the laying of a 9 cm thick binder course in high-modulus asphalt, and the application of a 3 cm thick surface course in stone mastic asphalt (SMA). Measurements during construction mainly focussed on production and paving conditions (composition, temperatures, compaction, density). With a view to monitoring the behaviour of the test sections, the site was equipped with temperature gauges and loop sensors to record climate and traffic data. After construction, the conformity of the mixes with the laboratory mix designs was checked and the characteristics of the layers (void content, resistance to rutting, etc.) were determined on core samples. Visual aspect, rutting and evenness are being evaluated every six months.

Although it is too early to compare the long term performance of the various sections, the abundant data collected in the laboratory study and the construction of the sections make it possible to draw already a number of important conclusions and to set up recommendations and specifications as to the appropriate use of high-modulus asphalt in Belgium.

### 1. Introduction

The constantly increasing intensity of heavy traffic explains why rutting remains one of the major causes of damage on the Belgian highways. Knowing that the binder courses, situated

between 5 and 12 cm below the road surface, are subject to the highest stresses, BRRC decided to concentrate on the development of mixes for binder courses, with a very high resistance to permanent deformation. High stiffness is probably the most important requirement for such mixes, which explains the name “high-modulus asphalt”.

A 4-year research project was dedicated to this subject, which involved the following aspects:

- mix design and laboratory study, to compare different variants and to investigate the impact of material characteristics and mix composition on mix performance;
- construction of highway test sections, to acquire know-how on production and paving and to compare the performance of various high-modulus asphalt mixtures under equal conditions;
- follow-up of the test sections to compare the in-field performance of the different variants;
- development of recommendations and specifications, to stimulate the use these mix types.

## 2. Selection of the variants

The highway test sections allowed the comparison of ten different mixes. A pre-selection of the most interesting variants was made (see table 1), to be further optimized in the laboratory study [1]. Two families of high-modulus asphalt mixtures were considered. The first family includes mixtures with a stony skeleton, which are similar to the French EME (Enrobé à Module Elevé). The second family comprises mixtures with a sandy skeleton. The selection of the binders followed from an enquiry among the bitumen producers to propose a suitable high-modulus binder for this project.

Table 1. Selection of the ten variants for the test sections (HMA = high-modulus asphalt)

Variant	Type	Binder	Variant	Type	Binder
1	Reference mix: asphalt concrete	B50/70	6	HMA stony skeleton	Binder 2
	AC 0/20 (+ 40% RAP)		7	HMA stony skeleton	Binder 3
2	HMA sandy skeleton	Binder 1	8	HMA stony skeleton	Binder 4
3	HMA sandy skeleton (+ 25% RAP)	Binder 1	9	HMA (slightly more sensitive to rutting)	Binder 1
4	HMA stony skeleton	Binder 1			
5	HMA stony skeleton (+ 25% RAP)	Binder 1	10	HMA (slightly more sensitive to cracking)	Binder 1

## 3. Mix design and laboratory study

The mineral aggregates (limestone) for the test sections were selected by the contractor. The RAP was provided by the old binder course, which was milled before construction of the test sections. BRRC measured the characteristics of all the constituents and used these as input to the mix design software PradoWin. The volumetric composition of the mix variants, as calculated in PradoWin, was verified using the gyratory compactor. The mix design aimed at a low void content (2.5 to 4.5 % at 100 gyrations), to obtain a good fatigue resistance and durability.

### 3.1 Resistance to permanent deformation

The resistance to permanent deformation was measured using the wheel tracking test according to NBN EN 12697-22 (large size device), at a temperature of 50 °C. Mixes with less than 5 %

proportional rut depth after 30 000 cycles are classified in the best category for resistance to permanent deformation. As seen in figure 1, all variants belong to this category, except for the reference AC mix and the high-modulus mix designed for a higher sensitivity to rutting.

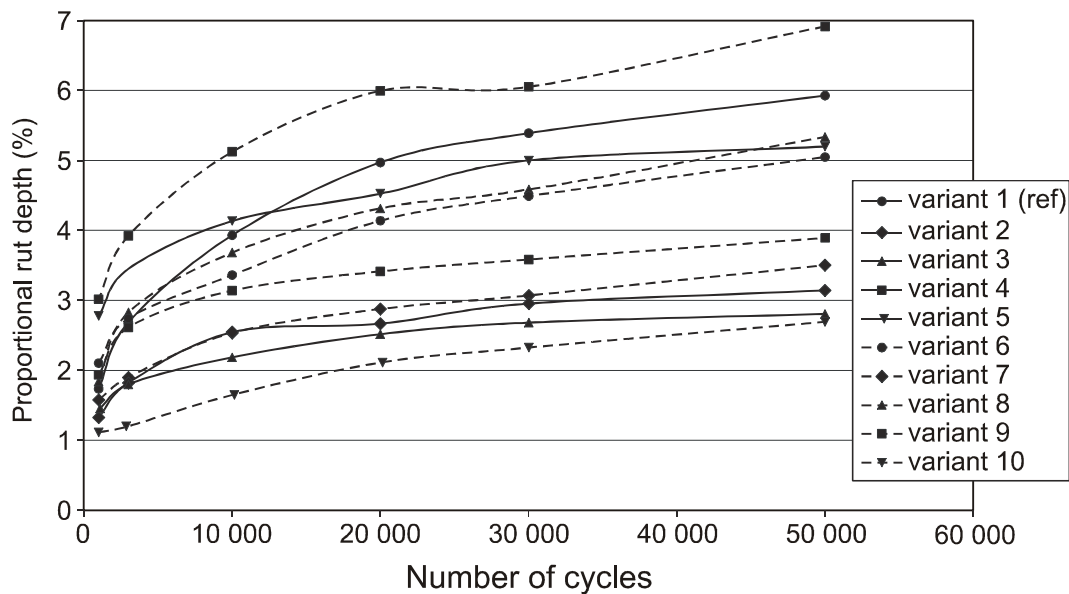


Figure 1. Wheel tracking tests on the variants for the test sections

### 3.2 Water sensitivity

The water sensitivity was evaluated by indirect tensile strength (ITS) measurements according to NBN EN 12697-23, carried out on unconditioned specimens and on specimens conditioned in water, according to NBN EN 12697-12. The ratio of the ITS of the conditioned samples to the ITS of the unconditioned samples is considered as a measure for the water sensitivity.

All variants designed for the test sections showed a very high ITS-ratio (> 89 %), except for the reference AC mix (76 %) and the crack sensitive high-modulus mix (67 %). This is explained by the less effective coating of the aggregates due to the lower binder content. The void content also has an important impact: the ITS-ratio drops significantly when the samples are less compacted. Poor compaction means higher void content, so that the mixture is more exposed to the action of water. Another important conclusion was also that the use of RAP has no adverse effect on the water sensitivity.

### 3.3 Stiffness

The stiffness was measured at different temperatures (from -20 to 30 °C) and for different frequencies (from 1 to 30 Hz) by the two point bending test on trapezoidal specimens according to NBN EN12697-26 annex A.

The difference between the reference AC mix and the high-modulus asphalt was significant at a temperature of 30 °C, while at 15 °C, the difference was less. Knowing also that 30 °C is a more critical temperature with respect to permanent deformation and bearing capacity, it would be better to impose specifications for stiffness of high-modulus asphalt at 30 °C, instead of 15 °C.

The French specification for EME class 2 ( $E^* \geq 14000$  MPa at 15 °C and 10 Hz) was not always attained. This is most probably due to the type of stone (limestone), since additional tests with porphyry stones (not shown in this paper) did meet the specification. Also, it appears that this limit can be more easily met for the mixes with stony skeleton than with sandy skeleton and French EME class 2 are exclusively mixes with stony skeleton.

Increasing the binder content leads to a reduction of stiffness. The binder type also has an impact on the mix stiffness.

For the test section variants, the use of RAP increased the stiffness. However, the more extensive laboratory research has shown that this is not generally true, as it depends on the properties of the RAP and its binder, and the proportion of new and old binder.

### 3.4 Fatigue

Resistance to fatigue was determined at 15°C and 30 Hz according to the BRRC-method. This test method differs from NBN EN12697-24 (annex A), by the larger size of the samples and the stress controlled mode. Hence, the results cannot be directly compared to the values foreseen in NBN EN13108-1, neither to the French specifications.

All high-modulus mixes performed much better in the fatigue test than conventional AC mixes. As expected, the mix designed for higher sensitivity to cracking was the worst of the high-modulus mix variants. The mixes with sandy skeleton generally performed better than the mixes with stony skeleton. Increasing the binder content leads to a higher resistance to fatigue.

Tests made on high-modulus mixtures with porphyry aggregates showed less resistance to fatigue, compared to the results for the test section variants, which were all made with limestone. This is explained by the binder-aggregate bond, which is stronger with limestone aggregates.

For the test section variants, the use of RAP had a negative impact on fatigue resistance. However, the more extensive laboratory research has shown that this is not generally true, as it depends on the properties of the RAP and its binder, and the proportion of new and old binder.

## 4. Construction of the test sections (see also De Backer C, 2008)

### 4.1 The project

Test sections were constructed in order to compare the performance of various high-modulus asphalt mixtures under realistic and equal conditions of traffic and climate, and to verify whether promising performance obtained in the laboratory is actually achieved in the field. Additionally, they were to provide useful information on possible problems with the manufacture and laying of the tested asphalt mixtures.

The site selected for the experiment was a stretch of about 2 km of motorway E19 (Brussels Antwerp) off Kontich. This stretch combined a number of characteristics that were necessary for the success of the experiment: high-volume, heavy, steady-speed traffic and a pavement with a correctly designed and homogeneous structure.

The project consisted in constructing a 12 cm thick inlay on the right-hand lane of the motorway (carrying virtually all heavy goods vehicles), composed of a 9 cm thick binder course in ten variants (nine high-modulus asphalt and one reference) and a 3 cm thick surface course in SMA-6.3 type 2. Each variant was applied in a test section over a length of 140 m. The mix designs for the variants were developed in the laboratory study (see § 3).

### 4.2 Construction

The work was carried out from 3<sup>rd</sup> through 21<sup>st</sup> April and started by milling in two passes. In the first, the surface course was removed to a depth of 5 cm; in the second, the binder course to a depth of 12 cm. The RAP to be used in some of the high-modulus asphalt mixtures was reclaimed from the binder course.

The high-modulus asphalt mixtures, produced in a batch mixing plant, were laid with a conventional finisher (mean speed: 5.5 m/min). During laying, air temperature ranged between 5 and 12.5 °C, mix temperatures between 163 and 190 °C.

The high-modulus asphalt mixtures were compacted with a pneumatic-tyred roller and a tandem roller fitted with a horizontal vibration system. The density measurements made with a nuclear density gauge during and after the laying of the binder courses in the first three sections with high-modulus asphalt suggested very low void content. This impression was confirmed by the close-textured and sometimes fatty aspect of certain sections. It was, therefore, decided to adapt the original compaction schedule by reducing the number of vibratory passes of tandem roller.

The surface course in SMA was laid simultaneously on the two lanes of the carriageway, with two finishers working abreast.

### 4.3 Characteristics of the high-modulus asphalt layers

Measurements with a three-metre straightedge were made in each section. The results were satisfactory, with individual values not exceeding 5.5 mm.

The deviations of binder content and grading as determined on site samples of the high-modulus asphalt mixtures from the values determined in the mix design study remained within the tolerances set in the tender specifications, for all the mixtures.

The inspection of core samples (nine per section) revealed good homogeneity of the course over its full depth, in spite of the great thicknesses (90 to 99 mm).

Except for the sandy skeleton mixture with RAP, the average void content in all the sections lies between 2.8 and 5.2 %, which is consistent with the Belgian specifications for binder courses. The addition of RAP results in lower void contents.

The rates of compaction all exceed 99 %, except for one section.

Resistance to rutting was determined on cores 400 cm<sup>2</sup> in sectional area, tested at 50 °C (NBN EN 12697-22). It can be seen that, except for one section, all high-modulus asphalt mixtures with a normal binder content are below the limit (5 %) set for heavily trafficked roads in Belgium and perform better than the reference section (with a B50/70 binder). Adding RAP increases susceptibility to rutting. The rutting performance of stony and sandy skeleton mixtures is similar.

### 4.4 Monitoring of the test sections

Performance monitoring focuses on surface condition, longitudinal evenness, and rutting. Observations and measurements are made every six months, i.e., in April and September. Three series had taken place by the time this paper was drafted.

No deterioration (cracking, deformation, stripping) has been found so far.

The CP values (evenness coefficients) for the wavelengths of 2.5 and 10 m, as measured with the APL or the ARAN, have hardly changed since construction and remain below the limits (35 and 70) set in the Belgian specifications.

No actual rutting can be reported at this stage: the average rut depths in the right-hand wheel path as measured in April 2007 are between 2 and 4.5 mm for all high-modulus asphalt sections. The test sections perform better in this respect than the reference section (average rut depth = 6.5 mm).

## 5. Recommendations and specifications

The introduction of high-modulus asphalt in contracts for public road works in Belgium requires the development of specifications. This has been done – while relying on the experience gained – with the appropriate authority of the Flemish Region, for inclusion in their standard tender specifications.

The specifications are of the performance “type” and in keeping with the European standards (of the EN 13697 en 13108 series). They apply to layers of a constant thickness between 70 and 110 mm.

No specific requirement is made for the components of the mixture, except that the binder must be either a hard-grade bitumen or a bitumen with a positive penetration index. The contractor is free to choose his mix design (as far as binder content is not lower than 5.2 % in proportion to the mixture), but it must meet a series of requirements for void content, rigidity modulus, water sensitivity, and resistance to rutting and fatigue. The use of RAP is prohibited in a first stage. Any proposal for a mix design is to be approved by the administration after a study involving tests for compliance with the performance requirements stated above.

## 6. Conclusions

Test sections comprising nine variants of high-modulus asphalt and one reference section with conventional asphalt concrete were constructed with success on one of the most heavily trafficked motorways in Belgium. The variants were chosen after extensive research in the laboratory. Among the parameters tested in the variants are the type of mixture (stony or sandy skeleton), the type of binder, binder content, and the addition of recycled materials or not.

The manufacture and laying of the various mixtures did not raise any particular difficulties. Compaction was performed with conventional equipment. Limit values for mix temperature, which depend on the special binders used, must, however, be strictly observed.

The measurements and analyses made have shown that the characteristics (more particularly void content and evenness) of the high-modulus asphalt layers meet the requirements set in the Belgian specifications for conventional binder courses.

After over a year of service, the pavements perform perfectly. No significant difference has been found so far between the various sections.

With the experience gained through four years of research and the successful outcome of the experiment, high-modulus asphalt may well become the recommended mixture for base courses of heavy-duty pavements in Belgium. Requirements for the standard tender specifications, based on fundamental requirements, have been set up in order to allow the use of these mixes in the future.

## 7. References

1. De Visscher, J, Vansteenkiste, S, Vanelstraete A, May 21-23, 2008. “Test sections in high-modulus asphalt: mix design and laboratory performance testing” *4<sup>th</sup> Eurasphalt & Eurobitume Congress “Asphalt – Roads For Life”, EAPA/Eurobitume, Copenhagen.*
2. De Backer, C, Glorie, L, Reynaert, R., May 21-23, 2008. “Test sections in high-modulus asphalt: a comparative experiment with ten variants” *4<sup>th</sup> Eurasphalt & Eurobitume Congress “Asphalt – Roads For Life”, EAPA/Eurobitume, Copenhagen.*