ASSESSMENT OF RESISTANCE TO RUTTING OF HIGH MODULUS BITUMINOUS MIXTURES USING FULL-SCALE ACCELERATED LOADING TESTS.

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ABSTRACT

In anticipation of the introduction of high modulus materials in the Swiss standards, a research project has been carried out for the evaluation of these bituminous mixtures. These mixtures make possible to reduce rut in base courses. With a temperature of 50°C, three test sections (two with high modulus and one with a reference material for base layer), were built in a building for ALT and were submitted to traffic loads corresponding to those of heavy vehicles. The behaviour of the test sections corresponds to the results provided by laboratory test made with LCPC rutting tests. The section designed to have a strong rut resistance has no rut in the base layer. The two others sections present important permanent deformation, even the one using hard bitumen (in this last case, the mixture was mainly designed to have high fatigue resistance). A second experience shows that rutting increases strongly with addition of transverse loads.

Keywords: Permanent Deformation, Performance testing, Mixture design, Design of pavement

1. INTRODUCTION

Swiss design method for flexible pavement is based on ASSHTO results. In this method, bituminous mixes are not designed to have specific behaviour against particular deterioration. It is possible to design mixes to obtain particular performances, as high fatigue or rut resistance. For instance, high modulus materials can have this kind of performances

The program includes two stages: a laboratory study on the mix design with an assessment of the mechanical performances of the mixtures and then a full scale test, in order to evaluate their response and the behaviour of the test sections under different loading and temperature conditions. The project includes an assessment of the fatigue and of the rutting resistance (Perret, Dumont et al. 2001). This paper is focusing on the results from the second part of the experience, about rutting, whereas the first part, about fatigue, is presented in another paper in this conference (Perret, Ould-Henia et al. 2004).

Three test sections were built in a pit for the full scale test. They were designed to have an equivalent resistance to fatigue. Two sections have high modulus materials as base layer, whereas the third one, used as reference, has a standard Swiss bituminous mixture called HMT 22s. The two high modulus materials correspond to the EME1 and EME2 designation in the French standards. They have a high resistance to rutting and a high resistance to fatigue respectively.

First, evaluation of rut resistance was made using LCPC rutting tests in laboratory. These tests were made on materials compacted in laboratory and on materials coming directly from the test sections. In a second stage, the test sections have been submitted to continuous and repetitive loads at high temperature (50°C at 3 cm depth). Two different ways for loading the structures were used. First, traffic loads were applied with a lateral distribution. On a second step, structures were loaded without any lateral distribution.

This paper describes and compares the results obtained by this different ways to evaluate rut resistance. It underlines in particular the excellent performance against rut of the EME1.

3. GENERAL DESCRIPTION OF THE FULL SCALE TEST SECTIONS

3.1 Structures

Three full-scale test sections were built in the Halle-fosse at the Federal Institute of Technology at Lausanne, Switzerland. The structures are constituted with a flexible pavement of two bituminous layers (wearing course and base course), a subbase of unbound granular material and a subgrade of fine sand. The bottom of the pit is a concrete slab.

In the three structures, the kind of mixture and the thickness of the base course only vary as shown in figure 1.

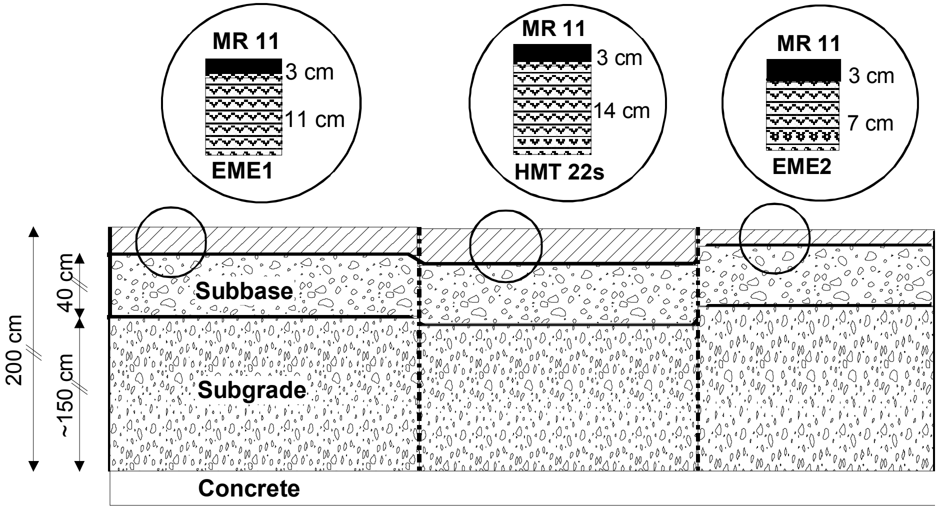


Figure 1: Tests sections built in the Halle-fosse for the full scale test of high modulus materials

Loads are applied with a simulator, which consists of an axle of a heavy lorry that tracks backwards and forwards along the test pavement in a straight line. The length of the test is 4 m in length and the speed of the axle is constant over the central 2 m.

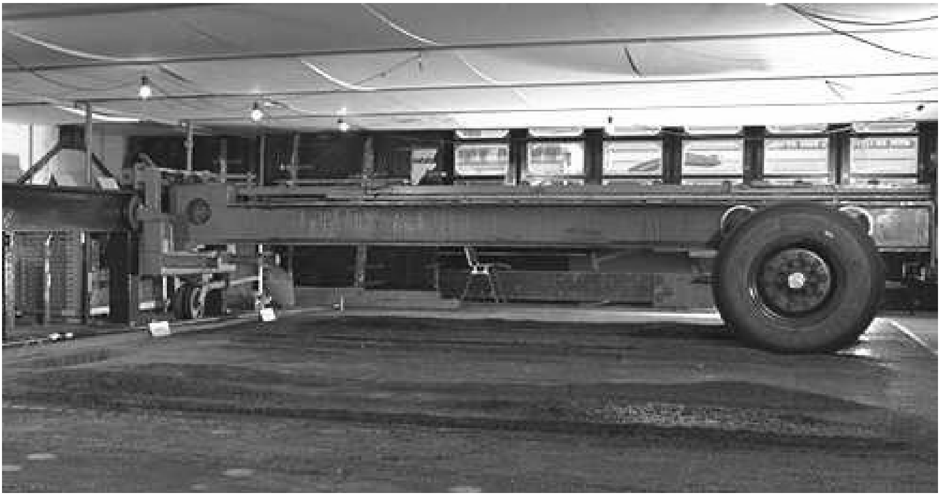


Figure 2: Traffic simulator of the Halle-fosse

As traffic loads are applied using a full axle with two tires, it is possible to have comparative tests with results obtained under the same condition for the two tested sections.

3.2 Mixes composition and mechanical performance of the bituminous mixes used for the base layers

Binder of high modulus materials are low penetration grade bitumen. Depending on the content of the mastic (bitumen and fines), those mixtures show a high performance towards rutting (EME1) or towards fatigue (EME2). The composition of the three bituminous mixtures used as base course is given in table 1 and compared with results obtained with mixture design. The main properties of the binders are given in table 2.

Sieve size (mm)	**HMT 22s**		**EME1**		**EME2**	
	design	**analysis**	**design**	**analysis**	**design**	**analysis**
0.09	6,5	6,9	6,5	7,0	8,0	9,4
2.8	32,5	29,8	32,5	30,0	32,5	37,8
5.6	48,0	43,7	48,0	42,2	48,0	54,7
11.2	70,0	66,4	70,0	66,7	70,0	77,1
16.0	81,0	83,3	81,0	78,8	81,0	89,5
22.4	100,0	96,5	100,0	96,8	100,0	97,4
Binder content (on mix), %	4,30	4,13	4,50	4,25	5,60	5,70

Table 1: Compositions of the mixes used for the test sections built for the full scale test

	HMT 22s	**EME1**	**EME2**
Designation	B80/100 (Shell)	BP Structur 15/25	Mixelf 10/20
Penetration, 1/10mm	89	21	18
Ring & Ball, °C	47,8	67,8	64,7
Penetration index	-0,3	0,5	-0,3
Frass breaking point, °C	-19	-5	-8

Table 2: Main characteristics of the binders used for the mixes

Regarding the binder content, the differences between the receipt and the analysis results of the materials placed in the sections are consistent with the requirements of the Swiss standards (SN_640431). However, EME1 and HMT 22s have lower binder content regarding the mix receipt, as it is the contrary for EME2.

Regarding the granular composition, the analysis results are also consistent with the receipt considering the requirements of the Swiss standards. However, EME2 shows a smaller content of fines (fraction from 0 to 0,09 mm) regarding the receipt. Combined with the binder content, the mastic content (binder and filler) of this mixture is somewhat high regarding the receipt.

4. LABORATORY TESTING

Rut resistance was assessed in laboratory with the LCPC rutting test. For each bituminous mixture, testing was carried out on 3 kinds of specimen:

- slabs made of material prepared in the laboratory during the mix design and compacted with the LCPC compactor
- slabs made of material taken during the construction of the test sections and compacted with the LCPC compactor
- slabs specimen cut in the test sections.

As HMT 22s is a standard Swiss bituminous mixture, there was no testing carried out on the first kind of specimen. Rutting tests were carried out on the specimen according to the procedure in the French standard. All requirements were respected and the results are presented in another paper at this conference (Perret, Ould-Henia et al. 2004).

The assessment of the resistance towards rutting is carried out by considering the ratio between the depth rut after 30’000 cycles at a temperature of 60°C and the total thickness of the sample before testing. For such kind of mixture like EME, maximum rutting considering the French standards is 8 %, and it is suggested 5 % for heavy traffic. Results are summarised in table 3.

	HMT 22s	**EME1**	**EME2**
First kind of specimen, 30’000 cycles, 60°C	-	2,0 %	6,6 %
Second kind of specimen, 30’000 cycles, 60°C	3,0 %	1,8 %	6,9 %
Third kind of specimen, 30’000 cycles, 60°C	5,7 %	2,3 %	7,1 %

Table 3: Results of the LCPC rutting tests

Considering these results, the classification of the rut resistance of materials is the same whatever the kind of specimen:

EME1 > HMT 22s > EME2

However, the results on EME2 specimen are close to the trigger limit of 8 %. Such poor performance is certainly related to the high level of mastic in the EME2 mixture. The results of the LCPC rutting tests show also that the re-heating of the material has more effects on the traditional binder B80/100 than on the low penetration grade bitumen.

5. FULL-SCALE ACCELERATED LOADING TESTING FOR THE EVALUATION OF THE RUT RESISTANCE

The full-scale accelerated loading testing carried out at LAVOC aims at providing a comparative assessment of the rutting between the various test sections. It means that the results are assessed from a qualitative point of view.

The test sections were submitted to very hard loading and climatic conditions. Loading was applied with a truck axle loaded at 11,5 to and equipped with two single tires (wheel load of 5,75 to) with 8 bars of inflation pressure. Testing temperature was 50°C measured at 3 cm deep in the pavement (interface between the wearing course and the base course).

In order to compare simultaneously the performance between section with EME and section with the HMT reference mixture, one tire was running on the reference test section with HMT 22s as the other one was running on the EME1 or on the EME2 test section. Consequently, there are four wheel tracks (sections) to be considered. They are referenced as follow:

EME1:	section 3
HMT 22s (tested with EME1):	section 4
HMT 22s (tested with EME2):	section 5
EME1:	section 6

A lateral wandering of the axle can be applied linearly when the traffic simulator of the Halle-fosse is running. In a first stage and, loading was applied with a lateral wandering of ± 40 cm. Then, a second test without lateral wandering was carried out. In total, four experiments have been undertaken:

- Sections with EME1 and HMT 22s, with and without lateral wandering
- Sections with HMT 22s and EME2, with and without lateral wandering

Rut propagation was measured using levelling points and drawing transverse profiles with a profilometer. Levelling provides the depth of rut in the centre of the loading zone, when the second one shows the overall shape of the rut throughout the section. At the end of all the experiments, slabs have been cut transversely to the wheel track in order to assess the rut propagation in the layers (wearing and base course).

5.1 Levelling

Levelling was carried out on various points in the four wheel tracks (sections). Levelling of the rut depth regarding the number of loadings at the central point, which provides the maximal rut depth in all the tracks, is presented in figure 3. As testing was always carried out in parallel on one EME test section and on the test section with the HMT 22s reference mixture, there are consequently two curves for this materials: curve HMT22-4 from the section 4, tested together with the EME1, and curve HMT22-5 from section 5 tested together with the EME2. Figure 3 shows results with and without lateral wandering of the load. With lateral wandering, testing was stopped when the rut depth reached 30 mm. Without lateral wandering, testing was to be stopped when the sides of the tire started to be damaged by the contact with the edges of the rut profiles.

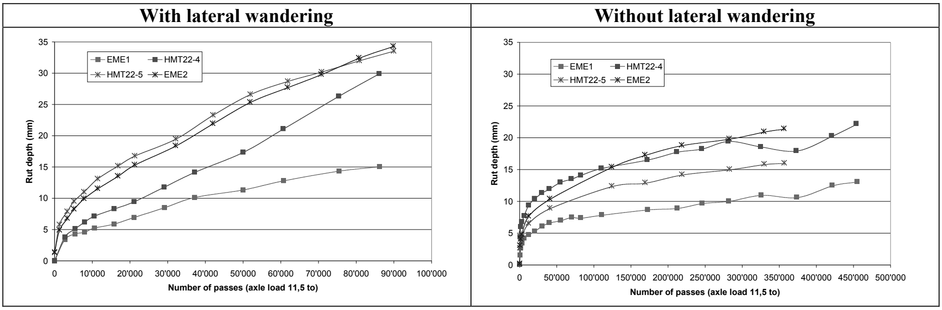


Figure 3: Rut depth considering the number of loads (axle load of 11,5 to)

For all tests, rutting can be divided into two phases: an initiation phase and a propagation phase. During the first passes, the fast increase of the rut depth is due to post compacting. As there is no significant difference between all the wheel tracks, it is assumed that this phenomenon mainly occurs in the wearing course. In the propagation phase, it is supposed that rutting initiates in the base layer. So the difference in the performance of the different mixtures can be observed. In this phase, rutting on the EME1 test section propagates less rapidly than in the others sections, in particular when no lateral wandering was applied.

In the contrary, the rut depth propagation is faster when a lateral wandering is applied: these experiments were stopped before 100’000 passes, as the ones without lateral wandering were interrupted over 300’000 passes and with smaller rut depth. This phenomenon can be explained by the following consideration: the lateral wandering of the load induces horizontal stresses in the upper part of the pavement. Consequently, the material is pushed out on both sides of the wheel track. This phenomenon clearly underlines the effect of the horizontal stresses on the rut propagation.

These results also confirm the excellent performance of the EME1 mixture, which is specially designed for strong rut resistance. Moreover, the maximal rut depth with or without lateral wandering is more or less similar. This probably means that rutting in this section mainly occurs in the wearing course.

5.2 Transverse profiles

Transverse profiles were carried out after various loadings. The first range of profiles, up to 1500 loadings, shows the propagation phase. The second one shows the propagation phase up to a depth, which can be considerate as failure of the structure.

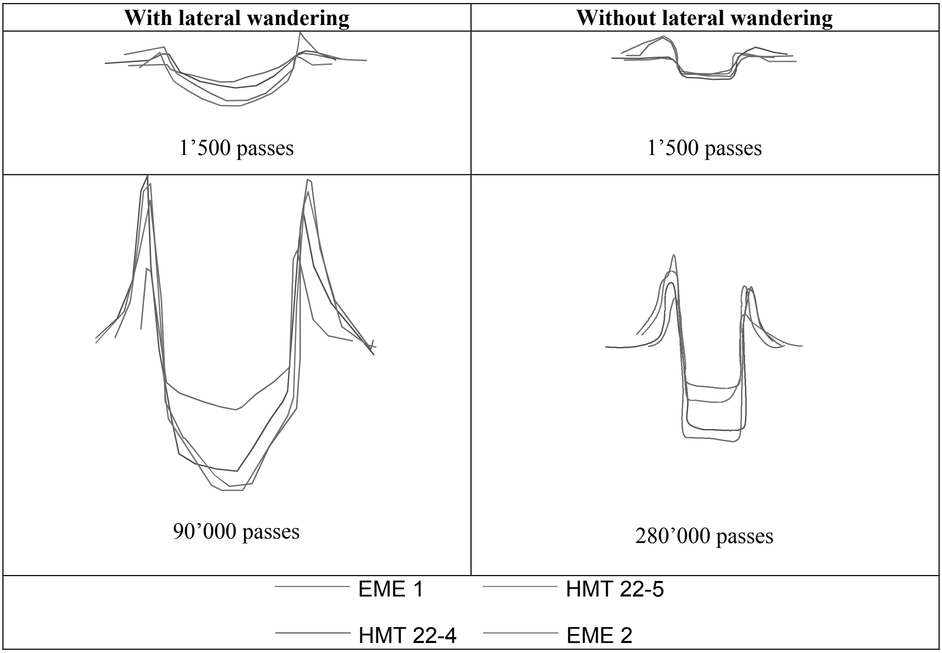


Figure 4: Transverse profiles regarding loading

These profiles clearly confirm the strong influence of the lateral wandering on rut propagation. After 1’500 passes, there is only a small difference between rutting in the various wheel tracks when no lateral displacement is applied. This tends to confirm that rut mainly appears in the wearing course during the initiation phase. On the other hand, when lateral wandering is applied, the wheel tracks on the EME1 test section show only small rut depth when the others already show more important permanent deformations. It means that in this case, rut has also started in the base layers, underlying the influence of the transversal load on rut propagation.

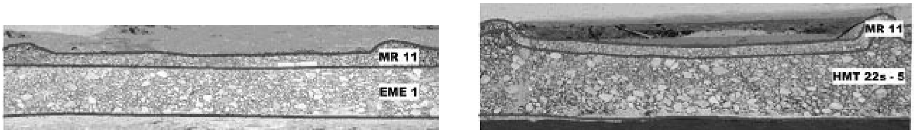
The transverse profiles at the end of the tests underline the excellent performance of the test section with EME1, which shows rutting more or less two times smaller than in the other test sections. On the other hand, it is possible to observe that the rut profiles for EME1 are quite similar for both tests (except the wide of the profile). It probably means that rut appears mainly in the wearing course for this section.

The classification of the tests sections regarding rut resistance is absolutely in accordance with the one based on LCPC rutting tests:

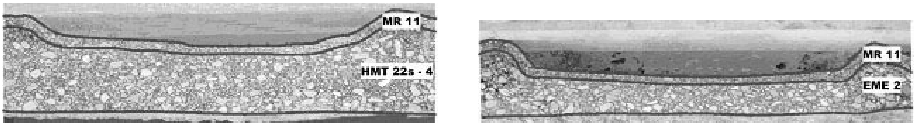
EME1 > HMT 22s > EME2

5.3 Pavement beams cut in the transverse profile of the wheel tracks

Beams were cut at the end of the tests in order to assess the propagation of rutting in the different layers. Interface between layers are drawn on the pictures (Figures 5 and 6).

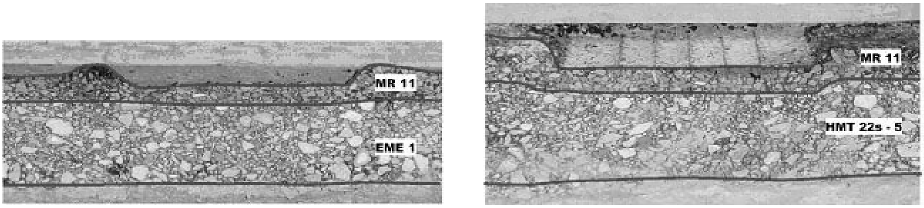


Section 3: EME1 Section 5: HMT 22s

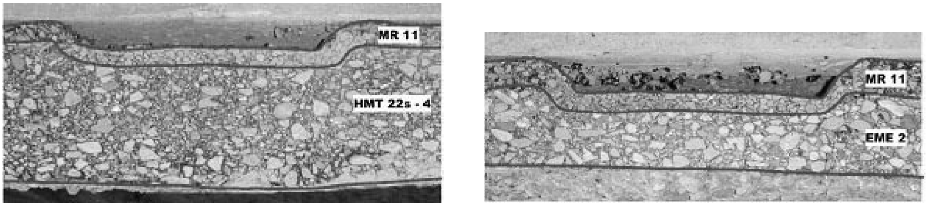


Section 4: HMT 22s Section 6: EME2

Figure 5: Cuts in the wheel tracks at the end of the first testing phase with lateral wandering



Section 3: EME1 Section 5: HMT 22s



Section 4: HMT 22s Section 6: EME2

Figure 6: Cuts in the wheel tracks at the end of the second testing phase without lateral wandering

These pictures clearly underline the difference in the performance of the section with EME1 compared to others. In both testing phases (with and without lateral wandering), the EME1 section shows rutting only in the wearing course as the base layer has fairly no permanent deformation. For both testing phases, all the others cuts show important rutting in the two layers (wearing course and base course). The section with EME1 clearly shows the best performance regarding rut resistance. For the others section, it is hard to make a classification between the HMT 22s and the EME2. However, considering the proportionality of rutting to the thickness of the base layer, EME2 shows the greatest susceptibility to rutting.

6. CONCLUSION

The main result of this study is the very high performance of high modulus bituminous mixtures based on the French standards for EME regarding rut resistance. This excellent performance was assessed by laboratory tests (LCPC rutting tests), and also by full-scale accelerated loading testing carried out at high temperature (50°C). With the EME2, designed to have a high fatigue resistance, it was observed that a high content of mastic (binder and filler) can strongly reduce the resistance to rutting, even when

the result of the LCPC rutting test is in accordance with the specifications. But one should point out that this mixture shows a result above the 5 % that are generally recommended for very heavy traffic.
For such mixture, a little modification of the mastic content has a significant impact on rut resistance. Therefore, it is recommended to assess carefully the results of the mix design and to control vigilantly the real composition of the mixture during works.

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