Experiments with Porous Asphalt on the Nantes Fatigue Test Track

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Within the framework of an agreement between the French Public Works National Research Institute, SCREG Routes et Travaux Publics, and its regional subsidiary SCREG Ouest, comparative experiments were carried out on several porous asphalts using the Nantes circular fatigue test track. This facility is designed to accelerate the effect of heavy traffic, making it possible to compare different pavement structures. Although this has never been done before, SCREG Routes et Travaux Publics and French highway authorities decided to use this equipment to follow the evolution of porous asphalts under traffic. Four mixes were selected, differentiated by the nature of the binder and the grading curve. One had a base of pure asphalt cement, two of elastomer (SBS) modified binder, and the last, developed by SCREG Routes et Travaux Publics, was pure bitumen and fiber based. After a short description of the test facility, the methodology developed for investigating the on-site properties of porous asphalts and presenting the results is defined. It is concluded that the experiments made it possible to observe trends in porous bituminous mixes under traffic, demonstrate the influence of mix design parameters on the stability of properties, and confirm the excellent performance of fiber-based porous asphalt.

Porous asphalts have been developing rapidly in France. Their high void content (about 20 percent) gives them hydraulic and acoustic characteristics that provide user safety and comfort. Several variants are available, provided by both government departments and industry. They differ by their grading curve, binder content, or binder specification, as well as in some cases by their additives. Whatever the mix design, however, the aim is to obtain sufficiently good initial draining performance that can withstand traffic use.

The Public Works National Research Institute (LCPC) fatigue test track accelerates the effects of heavy traffic so that structures can be compared. Although the test track had never been used for testing wearing courses, SCREG Routes and the French highway authorities thought it would be interesting to try it out to observe porous asphalts in heavy traffic conditions. Four different mixes were selected and an agreement drawn up between LCPC, SCREG Routes, and its subsidiary, SCREG Ouest.

NANTES FATIGUE TEST TRACK

The LCPC fatigue test track, situated on the Nantes–Bouguenais site of the Central Laboratory, was designed to study the mechanical performance of road structures under accelerated heavy traffic loads. This means in practice that the equivalent of 15 or 20 years of normal traffic can be simulated in a few months.

The units consist of four arms rotated by a central hydroelectric 1,000 hp motor. Loads are attached to the ends of the arms by single or double couplings. The rotation radius of loads can be varied between 15.5 m and 19.5 m by half-meter steps. When working, the loads go around the track and also zigzag to simulate real conditions. Each load can therefore use a surface up to 1.6 m wide.

With a single configuration, the test track simulates axle loads adjustable from 9 to 15 tons. Maximum speed in this configuration is 100 km/hr. A novel suspension device controls load weight at high speeds and on uneven or damaged surfaces. With this device, the load applied to the surface remains near the nominal calculated load at all times.

TEST SITE

The test track is a circular road whose average radius is 17.5 m. It is 6 m wide and can be divided into two concentric tracks each 3 m wide with average radii of 16 and 19 m. The porous asphalts were applied to the inner part of the track, which has an average radius of 16 m and a width of 3 m. This is shown in Figure 1.

MIX DESIGNS

Of the four mixes selected, two were developed by LCPC; the others are the results of the following SCREG ROUTES techniques under development:

- Section 1—grading curve, 0/14 mm; gap grading, 2/10 mm; binder, pure asphalt cement.
- Section 2—grading curve, 0/14 mm; gap grading, 2/10 mm; binder, SBS modified asphalt.
- Section 3—grading curve, 0/14 mm; gap grading, 2/6 mm; binder, SBS modified asphalt cement.
- Section 4—grading curve, 0/14 mm; gap grading, 2/6 mm; binder, pure asphalt cement with mineral fibers.

The SBS modified asphalt cement contains 4.5 percent of SBS. Its penetration at 25°C is 130 (0.1 mm) and its ring and ball softening point is above 65°C. The mixes put forward by the LCPC were designed using a gyratory shearing press. The binder contents are given in Figure 2.

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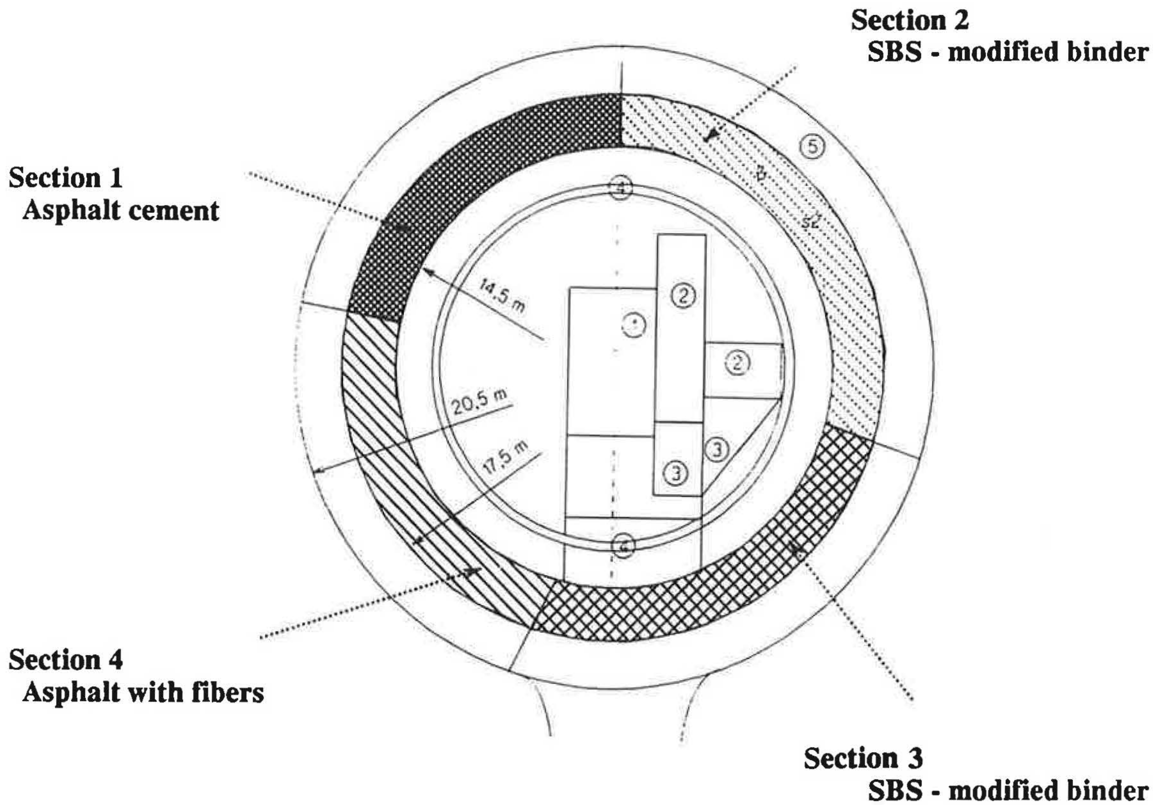

FIGURE 1 Test setup showing the different types of binders used in porous asphalts.

Section		1	2	3	4
Binder type		Pure Asphalt Cement	SBS-Asphalt Cement	SBS-Asphalt Cement	Pure Asphalt Cement
Binder content	pha	4.5	4.5	4.5	6.0
Fibers	%	-	-	-	1
Material		Diorite	Diorite	Diorite	Diorite
Origin		La Noubleau	La Noubleau	La Noubleau	La Noubleau
Grading curve		0/14	0/14	0/14	0/14
Gap		2/10	2/10	2/6	2/6
Quality Control					
Binder content	pha	4.1	4.8	4.2	5.6
Filler Content	%	5.4	5.6	5.6	9.5
Grading curve					
Passing at 2 mm	%	13	15	16	14
Passing at 6 mm	%	17	17	24	23
Passing at 10 mm	%	24	24	57	55
On-site Thickness	cm	4.2	3.4	3.8	4.2

FIGURE 2 Details of the trial sections.

MANUFACTURING AND APPLICATION

Manufacturing and application were carried out by Screg Ouest in July 1987. Section-by-section control results are shown in Figure 2.

RESULTS

The experiment took place between August 17 and October 22, 1987. It was thus started three weeks after the asphalt was laid. The total number of loads was 1,100,000.

Visual Appearance

From the beginning, differences in appearance were visible and continued to be so throughout the experiment. These differences were related to different grading curves. The two asphalts with a 2/10 gap had a seemingly more porous appearance than those with a 2/6 gap. At the end of the experiments, after 1,100,000 cycles, the four asphalts showed no surface deterioration.

Void Content

The initial values and their changes were calculated using apparent density from three or four core samples. The results are given in Figure 3 and the corresponding graph in Figure 4. It appears that highly discontinuous 0/14 formulations lead to a considerable reduction in void content (reduced by 28 percent and 21 percent in relative value, respectively, for the pure asphalt mix and for SBS asphalt). On the other hand, asphalt, with fibers that had a high void content at the start, remained at its initial level throughout the experiment. Section asphalt based on SBS-modified binder and a 2/6 gap provided an intermediate result.

Number of loads	Section 1	Section 2	Section 3	Section 4
4,000	17.1	21.3	19.4	23.2
24,000	17.3	18.3	18.8	23.2
100,000	16.9	17.5	19.8	23.9
600,000	13.3	18.7	16.8	22.0
1,100,000	12.4	16.7	16.4	23.8

FIGURE 3 Void content of core samples.

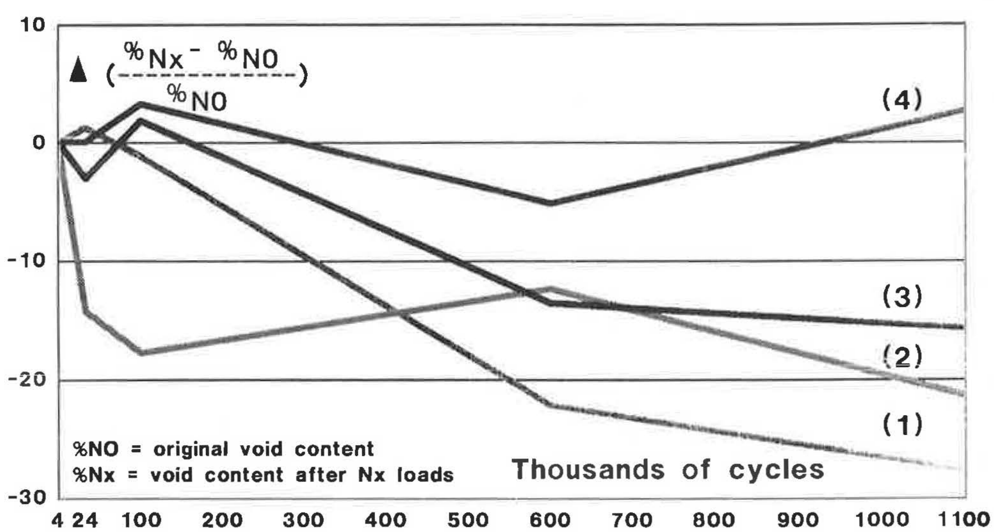

FIGURE 4 Relative change of void content during the experiment.

Rut Depth

Measurements taken by "transversoprofilograph" at various stages of the experiment led to the calculation of the average rutting for each section. The graph in Figure 5 shows the results obtained and points out greater speed of deformation at the beginning of the experiment. Beyond 600,000 cycles, stabilization can be seen for all the asphalts. This could have been influenced by the ambient temperature during the experiment. With time, rut depth divides the asphalts into two distinct groups. The first includes the asphalts based on pure asphalt cement and SBS modified binder (2 and 3). Overall rut depth is about 5 mm with a slight advantage going to the SBS modified binders sections. This could result from the high ring and ball softening point of this binder. The second consists only fiber-based asphalt which had a very slight deformation of 2 mm after 1,100,000 cycles.

These results are consistent with the change in void content, thus tending to prove that the rutting observed partially corresponds to the increasing density of the asphalt, probably related to postcompacting. Calculations indicate, however, that this phenomenon is not the only reason for deformation.

Hydraulic Properties

Effective Porosity and Horizontal Permeability

Figure 6 illustrates how the results evolve under traffic conditions. A clear advantage of between 5 and 7 percent can again be noted in favor of fiber-based asphalt. The other three mixes perform similarly. After swift change at the beginning, porosity, as with rutting, stabilizes; in this case, after 100,000 passages.

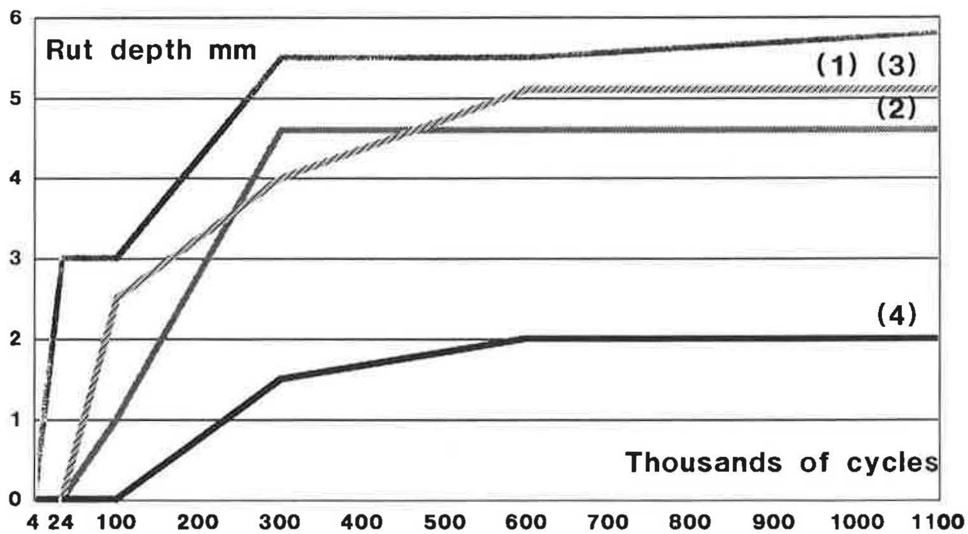

FIGURE 5 Rutting.

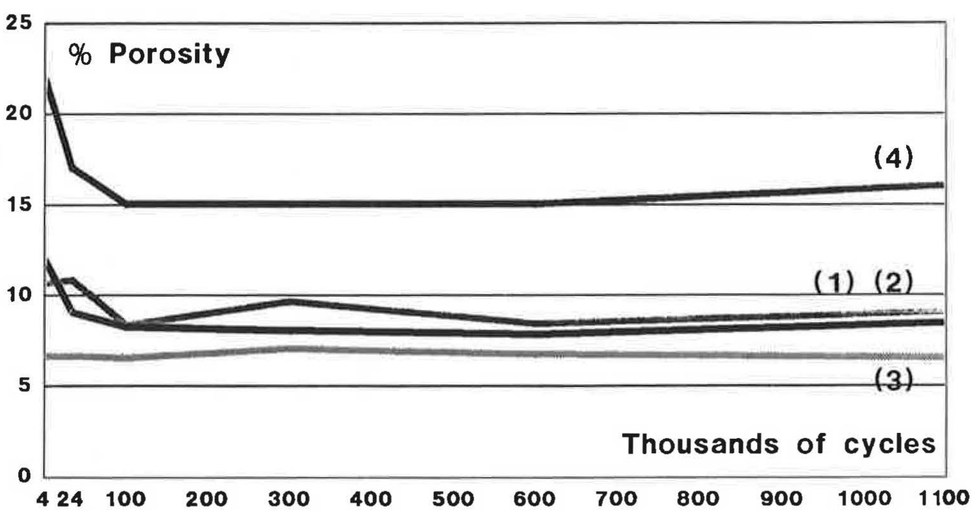

FIGURE 6 Porosity.

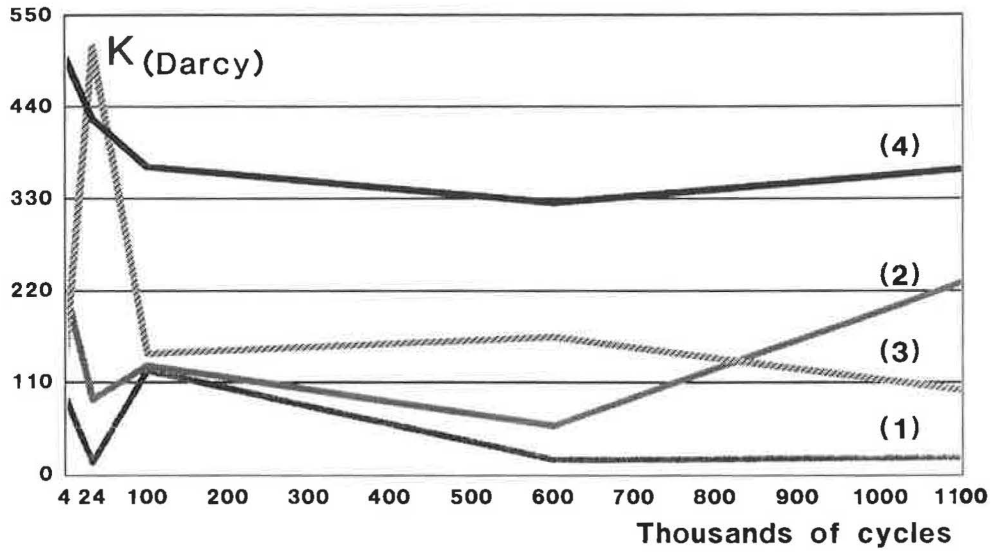

FIGURE 7 Permeability of core samples.

Permeability measurements made in permanent water flow conditions gave tightly grouped results varying over the whole experiment between 2 and 3 $\times$ 10^{-2} m/sec. These results are all satisfactory because it is generally recognized that permeability is adequate when lateral water evacuation exceeds 10^{-4} m/sec.

Vertical Permeability

Whatever the pressure used in laboratory measuring, the results are scattered for cores of Sections 1–3 unlike Section 4. Therefore, they are not easy to interpret. Comparison between the mixes, however, indicates, as in the previous test, a clear advantage in favor of asphalt with fibers, and on the other hand a low level for the highly discontinuous pure asphalt cement formula (Figure 7).

Surface Characteristics

Macrotexture by sand patch test and macroprofilograph: The values obtained are high for all tested porous asphalts, regardless of the number of cycles. It should be noted, however, that the highly gap-graded formulas give better results at the beginning of the experiment as well as after 1,100,000 cycles.

CONCLUSION

This experiment carried out on the LCPC's fatigue test track is innovative for several reasons. The track was designed to assess the fatigue behavior of road structures, and this was the first time wearing courses were studied.

In this series of tests, four porous asphalts were compared. One was based on pure asphalt cement, two were based on modified binders (differing from each other by the gap of the grading curve), and the last was based on asphalt cement with fibers.

Now that the experiment, which took place over 1,100,000 cycles, is finished, a number of conclusions can be drawn:

- Despite their lower mechanical properties compared with dense asphaltic mixes based on identical binders, porous asphalts underwent no surface deterioration during the tests.
- Under traffic conditions, the void content of the porous asphalts generally tends to diminish. As this increased density occurs, there is also slight surface rutting and a reduction in hydraulic properties. Surface characteristics also undergo modifications.
- At the end of the experiment, it clearly appeared that the fiber-based porous asphalt had undergone no reduction in void content; its drainage properties were practically unchanged and rutting was minimal.
- The other three asphalts had lost a considerable proportion of their void content: −28 percent in related value for the porous asphalt based on pure asphalt cement, −21 percent and −16 percent, respectively, for Section 2 and Section 3 asphalt based on SBS modified binders. This change appears to be related to, on the one hand, the size of gap of the grading curve (the void content of the asphalt with a larger gap in the grading curve underwent an even greater change), and on the other hand, the nature of the binder (with the same grading curve, the change in void for SBS modified binder is less than that of pure asphalt cement). This void content drop is accompanied by slight rutting and a reduction in drainage properties. From these two latter standpoints, the differences between the three asphalts are very small.
- Porous asphalts with a large gap in the grading curve have significantly better macrotexture both at the beginning and the end of the trial than those of a smaller gap (2/6).

Although such an experiment cannot simulate all conditions such as the filling-in effect of dust, binder aging, and weather conditions, the operation nevertheless proved useful. The precise test methodology allowed the modification of porous asphalt to be observed under traffic conditions and SBS modified binder-based porous asphalts to be improved. The superior performance of porous asphalt with fibers has been confirmed.