Ten Years' Experience of Porous Asphalt in Belgium

G. VAN HEYSTRAETEN AND C. MORAUX

Porous asphalt is a bituminous mix that because of its composition contains about 22 percent voids after compaction. In rainy weather, this results in the absence of aquaplaning, increased skid resistance, and reduced splash and spray behind vehicles. Additional advantages are reductions in rolling noise level, light reflection, and rolling resistance. In Belgium, this type of surface is used not only on roads, but also on airfields and in tunnels. The Belgian Road Research Centre has been conducting extensive research into various aspects of its use, such as mix design, the influence of binder type, manufacture and laying, the gradual loss of permeability, winter behavior, acoustic properties, specific features of applications in built-up areas and tunnels, and maintenance. Some of these aspects are briefly discussed in this paper.

The first application of porous asphalt in Belgium occurred in 1979 as part of a research project conducted by the Belgian Road Research Centre (BRRC).

It was a small job involving only 2,700 m^2 of two-lane pavement carrying daily traffic volumes of 700 vehicles in each direction. This first experiment immediately indicated all the benefits that could be expected from this new technique. As a result, new and more ambitious applications started to develop in 1981, this time on motorways.

The technique has been developed well beyond the experimental stage, and about 70 jobs have been conducted. At the end of 1988, the total surface area of porous asphalt laid in Belgium was about 2 million m^2. This puts Belgium and the Netherlands in the lead in Europe, especially when considering the relatively small areas of the two countries.

PRINCIPLE

Porous asphalts are bituminous road mixes designed so that after laying and compaction, they form a surface with a voids ratio of about 22 percent. They are used for wearing courses and are always laid on an impervious base (Figure 1).

With such a percentage of voids, a network of channels is created in the layer, which is capable of conveying the water that has fallen on the pavement during a rain shower and penetrated the surface.

Of course, the design of the road structure itself must enable this water to be drained off through the porous layer to the lateral collecting devices or the shoulders. This makes it necessary to have an impervious underlying layer with some crossfall to prevent the water from reaching the subbase and stagnating in the porous layer.

G. Van Heystraeten and C. Moraux, Belgian Road Research Centre, 42 Boulevard de la Woluwe, B-11200, Brussels, Belgium.

That is also why the lateral collecting devices or the shoulders must not be situated higher than the top of the underlying layer. This may seem quite obvious, but already design engineers have been found to overlook this essential requirement.

PROPERTIES OF POROUS ASPHALT

As just explained, porous asphalts are designed to allow free passage of rainwater. Furthermore they make it possible for the vehicle tires to maintain contact with the pavement surface under any circumstances, and thus to avoid the aquaplaning that may occur on conventional pavements at high speeds under wet conditions.

Porous asphalt also eliminates splash and spray behind vehicles (especially trucks) (Figure 2) and avoids reflections from the surface of the pavement at both day and night (Figure 3), thus making road marks more visible.

The draining capacity of porous asphalt surface, of course, depends on the percentage of voids. It is, therefore, important that this percentage be high when the pavement is opened to traffic. This is also necessary to prevent rapid clogging by dust or mud entering the layer.

Another important property of porous asphalt, which accounts for a great part of the success of the technique, is that it considerably reduces rolling noise both inside and outside vehicles (Figure 4). As demonstrated by research carried out at the BRRC, this reduction in noise levels results from:

- Sound absorption in the voids of the layer,
- Elimination of air pumping at the tire-pavement interface, and
- The good surface evenness of this type of wearing course.

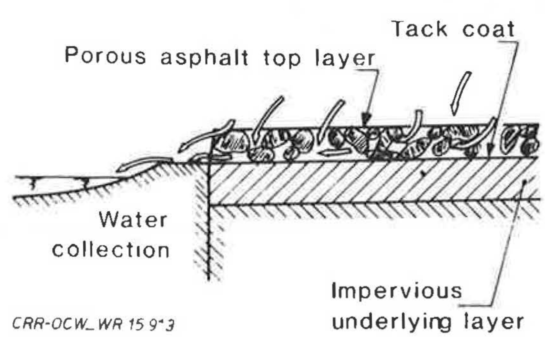

FIGURE 1 Example of a road structure with porous asphalt.

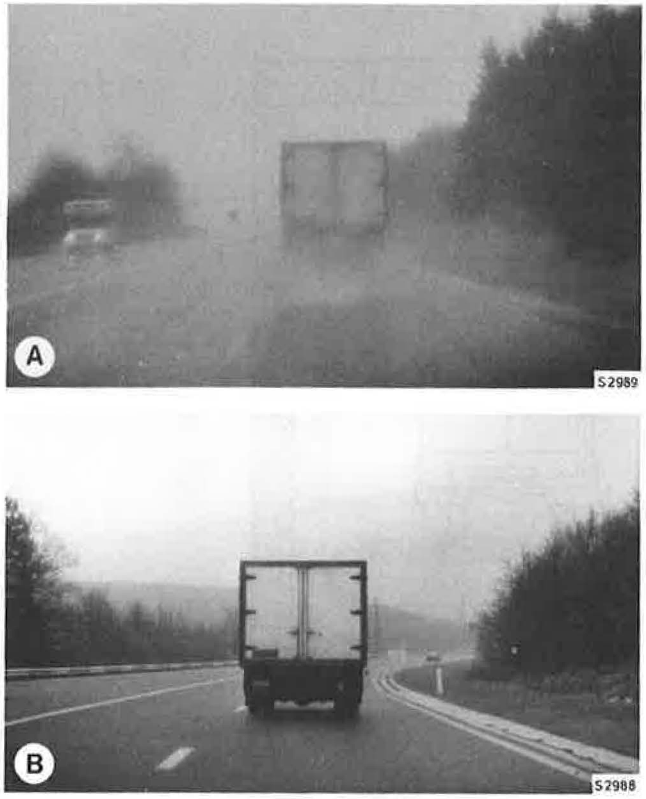

FIGURE 2 Splash and spray behind a vehicle under identical weather conditions on dense asphalt concrete (A) and on porous asphalt (B).

These findings were made with a standard vehicle traveling with its engine off at 80 km/hr over a measuring test section.

In real traffic, however, engine noise also plays a part. Porous asphalt partly absorbs this noise in the voids of the layer.

When considering the various applications of porous asphalt in Belgium, it can be seen that two different designs have been used: either 2.5-cm-thick layers or 4-cm-thick layers. It has become clear that, to ensure high draining capacity and a substantial reduction in rolling noise and to preserve these properties over a longer period, the 4-cm thickness must be recommended.

WHERE TO USE POROUS ASPHALT

Porous asphalt is most commonly used in areas where water tends to stagnate, such as changes of superelevation, wide pavements (motorways and airfield runways), and sags in the longitudinal profiles of roads in hilly regions.

Another interesting application is in tunnels whose invert is situated below the phreatic surface. Water accidentally rising through cracks in this invert will damage the asphalt pavement and lead to water stagnancy in the tunnel. An overlay of porous asphalt can cause this unwanted water to be drained off to the sides of the pavement (Figure 5).

Other applications are made to solve problems with rolling noise. A frequent case is that of crosstown express roads or motorway links with a transversely grooved concrete surfacing. Overlaying such concretes with porous asphalt has

FIGURE 3 Difference in reflection of the headlights of a car on a wet road surface. In front, dense asphalt; behind, porous asphalt.

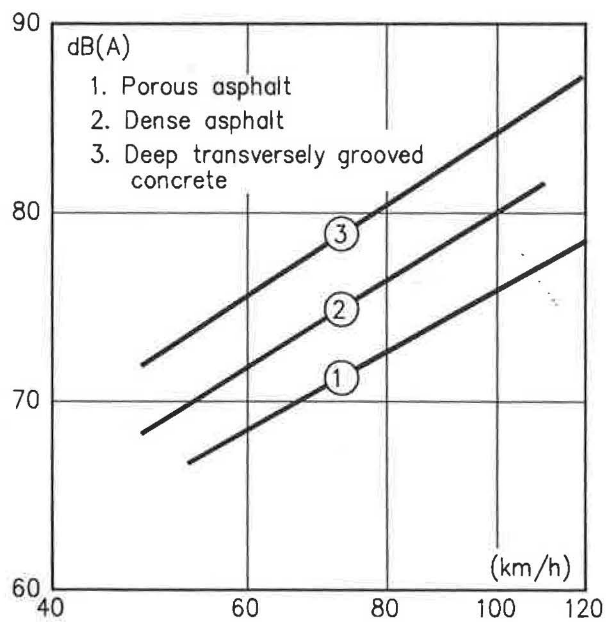

FIGURE 4 Rolling noise versus speed on three types of surfaces.

remarkable effects: under the measuring conditions described earlier, a noise reduction of 6 to 10 dB(A) was observed 7.5 m from the measuring vehicle and 1.2 m above the pavement.

The use of porous asphalt in tunnels also leads to considerable reduction of rolling noise not only for vehicle passengers, but also—and especially—in the vicinity of the approaches.

A more frequent application of porous asphalt is on particularly noisy arterials in urban areas. Because the pavement is generally boxed in between two curbs, lateral drainage must be correctly designed.

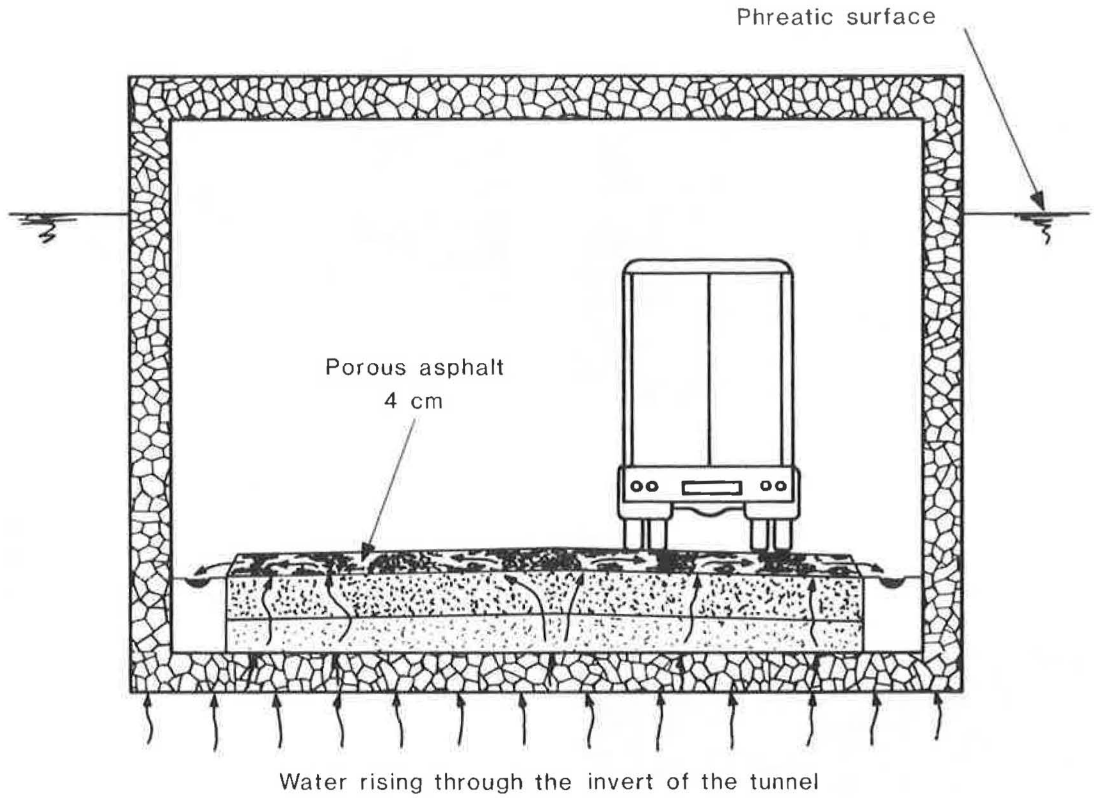

FIGURE 5 Overlaying an existing pavement in a tunnel with porous asphalt.

When the porous asphalt layer is placed on top of the existing pavement, a drainage channel may be left between the porous asphalt and the curb, but this solution may cause pedestrians or cyclists to fall and may be very inconvenient for the disabled; moreover, the curb is no longer sufficiently effective as an obstacle to stop slipping vehicles.

Another solution is to extend the porous asphalt layer to the curb and level the grids of the gulleys with the surface of the pavement. Holes (25-mm diameter) must then be drilled in the upper part of the side wall of each gulley to allow gradual disposal of the water caught in the porous layer. Simple saw cuts in the upper part (Figure 6) are generally inadequate because they will be blocked rapidly. When carried out as an overlay, this design reduces the protection provided by the curb for pedestrians; the best way to proceed, therefore, is to remove 4 cm of the existing pavement by milling before laying the porous asphalt.

Another technique, already used but applicable only when the pavement must be fully reconstructed, is to provide, along the curb at the lower side of the crossfall, a trench fitted with a longitudinal drain at the bottom and backfilled with porous asphalt. This drainage trench constitutes a buffer store in which surface water is allowed to accumulate until it can be carried off by the drain (Figure 7).

Finally, to facilitate lateral drainage in areas with zero crossfall, a solution has been tried consisting of making grooves in the layer to be covered by porous asphalt. These grooves become deeper as they approach the side of the pavement where lateral drainage is to be provided and are also filled with porous asphalt.

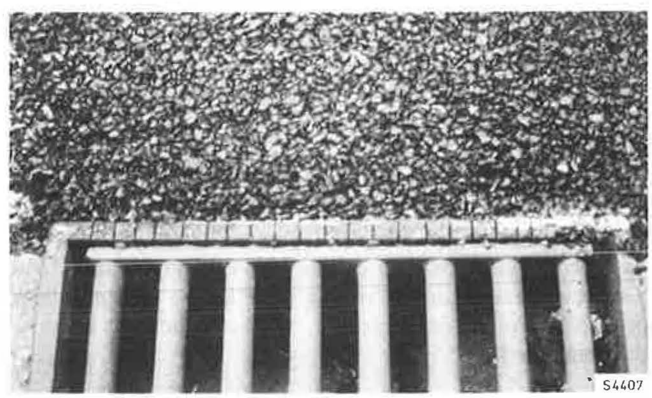

FIGURE 6 Saw cuts in the upper part of a gulley.

WHERE NOT TO USE POROUS ASPHALT

Although applications in urban areas require special care—as indicated—in designing the project, there are other sites where the use of porous asphalt should be avoided.

One example is roads that are frequently soiled with a variety of wastes. This is the case with roads in farming areas, where so much mud is left by tractors that a porous asphalt surface could be rapidly clogged.

Another example is low-volume or slow-traffic roads. This is because traffic ensures some self-cleaning of the surface of porous asphalt courses. Dust, which inevitably accumulates in the voids at the surface, can be swept only by the suction

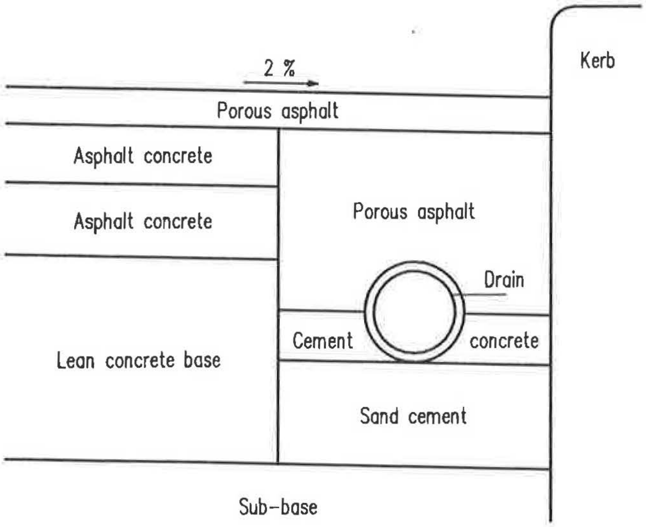

FIGURE 7 Application of porous asphalt in built-up areas involving the use of a collector drain.

effect of the tires of numerous vehicles traveling at fast speeds over the pavement.

Finally, it is preferable not to use porous asphalt in areas where the surface of the pavement is subjected to very high tangential loads, because relatively little is known about the resistance of porous asphalt to this type of loading.

COMPOSITION AND MIX DESIGN

Several principles must be respected to obtain the high percentage of voids required:

- A Sufficient quantity of "stones"—experience has shown that the aggregates should contain more than 80 percent of particles ≥ 2 mm;
- A gap grading, to be obtained, for example, by omitting the 2/7 or 2/10 mm fraction from a 0/14 mm mixture; and
- A limited quantity of binder, in order not to fill the voids yet ensure cohesion.

The Belgian specifications for the composition of porous asphalt are summarized in Table 1 (*1*). They relate to a 0/14 gap-graded mix to be laid in courses 4 cm thick, with a voids ratio that is to lie between 16 and 28 percent in each individual core sample and average between 19 and 25 percent over the various samples. This means that the mixture sought has an initial voids content of 22 percent. In addition, draining capacity is checked in situ by means of an outflow meter (Figure 8).

The mix design method proposed by the BRRC consists of first determining the voids in the coarse aggregate ("the stones") and then measuring, on Marshall samples with various binder contents, the voids and the percentage of wear after rotation in a Los Angeles cylinder without abrasive charge.

Binder content should be such that the granular materials are coated correctly but not excessively, because this would reduce the percentage of voids to below the desired minimum and lead to segregation during transport and laying. Moreover, there would be a risk that the porous asphalt would become postcompacted by traffic.

Except for lower-volume roads—for which porous asphalt is not recommended—Belgian specifications require an elastomer-bitumen type of binder. Two alternatives exist:

- Bitumens with newly manufactured elastomers (mainly SBS), for which the required binder content is 4.0 to 5.0 percent, and
- Bitumens with recycled elastomers (bitumen admixed with powdered rubber and an aromatic oil), with binder contents between 5.5 and 6.5 percent.

The possibility of using higher contents with recycled elastomers derives from the higher viscosity of the binder. This has the advantage of enabling the aggregates to be coated with a thicker film of binder which, in principle, should be less sensitive to aging. A disadvantage, however, is the risk of reducing the initial percentage of voids in the layer or of facilitating clogging by postcompaction.

The share of each of these various types of binder in the total surface area covered with porous asphalt in Belgium is currently 10 percent for bitumen 80/100, 30 percent for bitumen with new elastomers, and 60 percent for bitumen with recycled elastomers ("rubber-bitumen").

FIGURE 8 In situ measurement of the draining capacity of porous asphalt.

TABLE 1 BELGIAN SPECIFICATIONS FOR THE COMPOSITION OF POROUS ASPHALT

Property	Specification
Grading	0/14 mm gap
Stones (≥ 2 mm)	83 %
Crushed sand (0.080 mm - 2 mm)	12 %
Filler (< 0.080 mm)	5 %
Binder	
- bitumen 80/100	4 to 5 %
- modified bitumen	4 to 5 %
- rubber-bitumen	5.5 to 6.5 %
Thickness	4 cm
Voids ratio	
- average	19 to 25 %
- individual	16 to 28 %
Draining capacity (for 1,4 l water)	
- average	≤ 60 s
- individual	≤ 180 s

The various jobs were completed too recently to allow firm conclusions about the service lives achieved with the three types. Two experimental jobs done in 1983 and 1985 on the Philippeville-Couvin highway should yield important information on this subject within a few years.

MANUFACTURE AND LAYING

The manufacture of porous asphalt in conventional batch plants raises no particular problems compared with dense bituminous mixes. More attention must be paid, however, to the temperature of the mineral aggregates, which must not exceed 170°C to avoid dripping of the binder from the crushed stone particles and consequent segregation.

The order of entry into the mixer is generally the same as usual: sand, crushed stone, filler, and, finally bitumen. Nevertheless, good results have also been obtained with an alternative procedure, which consists of first introducing and mixing the sand, the filler, and the bitumen, and then adding the coarse aggregate and mixing again.

The risk of segregation during transport increases with the distance of travel, especially with excessive binder contents. This segregation results in materials sliding in large lumps from the trucks, which makes laying more difficult, and in the presence of fat spots in the surface after spreading.

Mechanical laying is normally not more difficult with porous asphalt than dense mixes. Static smooth-wheeled rollers are recommended for compaction. Vibrating rollers are to be excluded, mainly because of the risk of crushing stones; with pneumatic-tired rollers, there is a problem of porous asphalt sticking to the tires.

As do other types of mix, porous asphalt requires particular care as far as longitudinal construction joints are concerned, especially because coating these joints is not allowed here so that drainage is not obstructed.

Finished porous asphalt tends to stick to car tires when first opened to traffic, which may lead to stripping of aggregate in areas where severe tangential loads are applied (for example, in bends and at traffic lights). To prevent this stripping, it is advisable to spread about 50 g/m^2 of filler (fines < 0.080 mm) on the surface before opening it to traffic (Figure 9).

RESEARCH WORK

The BRRC has been conducting laboratory and field research into various particular aspects of this type wearing course (*2*), some of which are briefly discussed here.

Development of Binder Characteristics

Because porous asphalts are by definition rich in voids, the introduction of oxygen and ultraviolet rays into the bituminous layer and the continuing presence of water will lead to a rapid development of the binder's characteristics. Under site conditions, the penetration of pure bitumens has been

FIGURE 9 Spreading filler on a newly laid porous asphalt surface.

found to drop sharply in the first months. It can be said that after 3 years, all bitumens 80/100 have a penetration value below 25/10 mm and a ring and ball softening point exceeding 60°C. Beyond that period, the process appears to stabilize comparatively and it is remarkable that porous asphalt surfacings containing such aged bitumens still hold after 8 years of service.

With bitumens containing recycled elastomers, or "rubber-bitumens," the process is much slower; bitumens containing new elastomers stand midway between pure bitumens and bitumens with recycled elastomers as far as aging is concerned. But observations on test roads have not yet permitted researchers to establish whether improving the characteristics of the binder extends service life.

Acoustic Properties

The noise reduction is related to the high sound absorption coefficient (α) of the material. The coefficient varies with sound frequency and is most favorable at about 1000 Hz (Figure 10), which happens to be the frequency at which tire noise or the rolling noise of traffic has the highest intensity. The absorption coefficient increases with the percentage of voids and the thickness of the layer. Compared with conventional or chipped asphalt, the reduction in noise level at 80 km/hr is generally 2 to 3 dB(A). For transversely grooved cement concrete, the reduction is generally 6 to 10 dB(A).

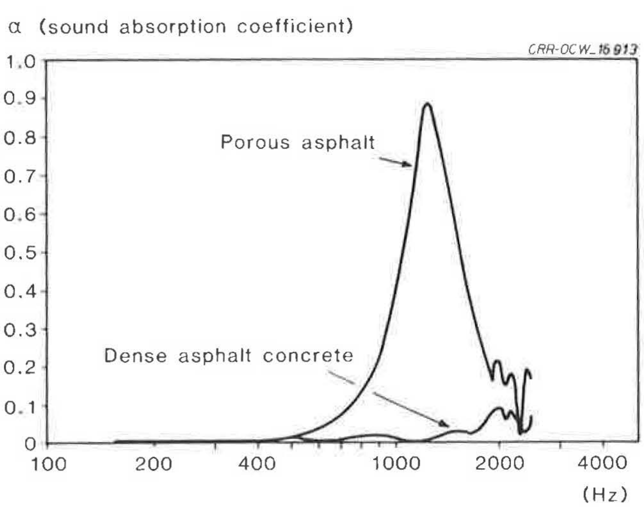

FIGURE 10 High sound absorption coefficient of porous asphalt, primarily at sound frequencies of about 1000 Hz.

Structural Contribution

By determining the moduli, it has been possible to quantify the structural contribution of porous asphalt manufactured with bitumen 80/100; this contribution lies between 73 and 79 percent of that of a wearing course in conventional asphalt concrete.

Winter Serviceability

Studies and observations made by the BRRC have made it possible to draw the following conclusions about the much-debated behavior or porous asphalt. Briefly, it can be said that porous asphalt and dense bituminous concrete do not behave differently in snowy weather when spread intensively with deicing salts. If such is not the case, snow may remain longer on porous asphalt because the brine that is formed under traffic can penetrate the voids in this material. However, this difference in snow-clearing behavior has never been the underlying cause of any accidents recorded in Belgium.

On the other hand, accidents have happened in icy weather on porous asphalt surfaces while the adjacent pavements were not icy, and vice versa. Ice simulation tests have shown that the comparison for skid resistance is sometimes favorable to porous asphalt and sometimes to dense surfacings, depending on ice conditions.

Clogging

It is well known that porous asphalt slowly silts up in places where traffic is not intense. This problem, therefore, does not occur in the traffic lanes of a highway or a motorway, and certainly not with an initial voids content of 22 percent and a 4-cm-thick layer.

The problem is raised by the hard shoulders for emergency stops, which silt up quite rapidly and, as a result, block water drainage from the traffic lanes. To avoid this situation, it is thought useful to provide the porous asphalt surface of the hard shoulder with a waterproofing surface dressing at the time of construction (Figure 11).

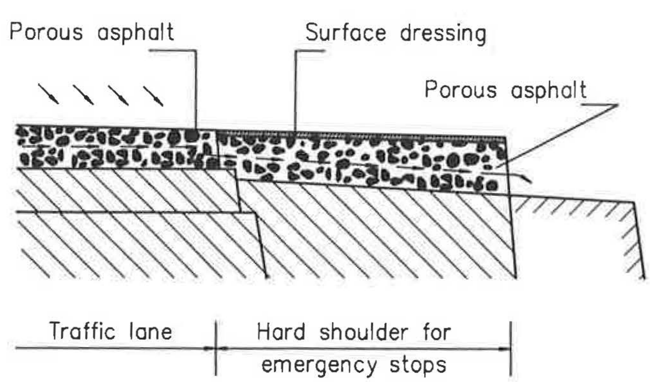

FIGURE 11 To avoid clogging, the surface of the hard shoulder is provided with a surface dressing.

FIGURE 12 Cleaning the surface with an appropriate suction sweeper using a water jet.

Maintenance

Studies have also been conducted into the behavior of porous asphalt courses and their deterioration with time. A joint Dutch and Belgian working group is investigating the specific maintenance problems with this type of surface. This effort has led to the development of cold-laid porous asphalt mixes for filling potholes or for durable local repairs. In addition, trials have been made with overlays in porous asphalt, in situ recycling of old porous asphalt, fog seal sprays, and the cleaning of partially clogged pavement surfaces (Figure 12).

CONCLUSIONS

Porous asphalt makes it possible to improve road safety in a number of critical cases and, by reducing rolling noise, contributes to the comfort of both road users and frontagers. It is not the universal remedy, however, and it should not be forgotten that porous asphalt is only one of the techniques available to contract awarders for designing their road pavements.

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