THE CONTRIBUTION OF PERVIOUS MACADAM SURFACING
TO THE STRUCTURAL PERFORMANCE OF ROADS

by

J F Potter and A R Halliday

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Department of the Environment or of the Department of Transport

Pavement Design Division
Highways Department
Transport and Road Research Laboratory
Crowthorne, Berkshire
1981
ISSN 0305–1293
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THE CONTRIBUTION OF PERVERIOUS MACADAM SURFACING TO THE STRUCTURAL PERFORMANCE OF ROADS

ABSTRACT

Although the spray-reducing properties of pervious macadam surfacing are well known, there is a distinct lack of information available about its structural performance. As a result its structural contribution is not considered in the design of new roads or bituminous overlays.

The structural strengthening brought about by laying pervious macadam surfacings on existing roads has been assessed by using linear elastic theory to compute the stresses and strains induced in the pavements by vehicle loading before and after surfacing with the pervious macadam. These computations predicted a significant reduction in the magnitude of stresses and strains after surfacing, a result which was confirmed in practice by direct measurement on a full-scale road pavement. Stress and strain computations were then used to determine the structural contribution of 40 mm of pervious macadam surfacing in terms of equivalent thicknesses of rolled asphalt surfacing and rolled asphalt and dense bitumen macadam roadbases for the present recommended designs of road pavements.

1. INTRODUCTION

Pervious coated macadam surfacing was developed to reduce the potential accident hazard of spray rising from wet roads and to reduce the likelihood of aquaplaning. The material has a high void content so that the surface water drains away rapidly and its relatively rugose surface texture provides pressure relief channels between vehicle tyres and the road surface. It also has the additional advantage of generating significantly less tyre noise than other surfacings with comparable high speed skid resistance. The ability of open-textured macadam surfacings to maintain these desirable properties under traffic are being assessed at several sites on public roads where the macadams were laid on the impermeable surfacings of existing pavements in sound structural condition. A specification for pervious macadam surfacing was developed from these trials based on long term performance in reducing spray; no account was taken of any structural benefit provided by the pervious macadam and at present it is recommended that pervious surfacing should be laid only on existing roads in sound structural condition or as an addition to new roads constructed to the current design recommendations, including the full thickness of rolled asphalt surfacing.

Clearly, like any other surfacing, pervious macadam has to have a high resistance to internal deformation and cracking. In addition it should contribute to the structural performance of the road by reducing the levels of stress and strain in the sub-base and soil foundation and, by reducing tensile strains in the roadbase, minimise the possibility of fatigue cracking in the pavement.

It is in the light of these design considerations that the structural contribution of pervious macadam surfacing has been assessed using structural design principles. Its contribution to load spreading and to
minimising fatigue cracking has been determined by considering the road as a multi-layer structure and computing the transient stresses, strains and deflections generated by a wheel load before and after surfacing with pervious macadam. The accuracy of the analysis was checked by comparing the computed values with those measured in an instrumented full-scale pavement.

2. ASSESSMENT OF THE STRUCTURAL CONTRIBUTION OF PERVERSIVE MACADAM SURFACING

2.1 Analytical assessment using linear elastic theory

2.1.1 Principles and materials characterisation. Stresses, strains and deflections generated by a wheel load were computed for a series of pavements with different thicknesses of rolled asphalt roadbase before and after surfacing with 60 mm of pervious macadam. Computations were made at locations in the road considered to be important in relation to pavement performance: the horizontal tensile strains at the bottom of the roadbase are related to its fatigue life and vertical stresses and strains in the subgrade give a measure of the load spreading capabilities of the pavement. In addition the surface deflection measured under a wheel load at creep speed is a good general indicator of pavement performance.

The elastic constants, pavement temperatures and loading criteria required for the computations were appropriate to the materials and the test conditions used in the trial. Young's moduli of the various pavement layers were determined in the laboratory on samples taken from the road or by in situ measurements on the pavement. For the bituminous bound materials, effective moduli were determined by flexure of rectangular beam samples subjected to sinusoidal loading (the method of measurement is described in the Appendix). Moduli appropriate to the pavement temperature and the rate of loading, ie vehicle speed, were used in the computations. Some indication of the in situ modulus of the unbound granular layer was obtained using surface wave propagation techniques, although it was known that the value could not fully represent the non-linear elastic behaviour of the material. The modulus of the subgrade was calculated from measured values of three orthogonal components of normal stress and strain.

2.1.2 Comparison of vertical stresses and strains in the subgrade. Figure 1 shows the relationship between the computed vertical stress at a depth 150 mm below formation level and the total thickness of rolled asphalt for pavements both with and without pervious macadam surfacing. The wheel load was 45 kN applied over a contact area of 0.074m, the thickness of the sub-base was 150 mm and the temperature of the bituminous materials was constant at 30°C. These conditions corresponded to those of the full-scale trial. Over the range of asphalt thicknesses considered the relationships shown in Figure 1 are linearly logarithmic and of similar gradient; this enables the structural contribution of pervious macadam surfacing to be compared readily with that of rolled asphalt. The computations showed that in order to maintain the same level of vertical stress in the subgrade (and thus the same contribution to load spreading), 60 mm of pervious macadam surfacing was equivalent on average to 35 mm of rolled asphalt roadbase. The same result was obtained if the computed vertical and horizontal strains in the subgrade were used as load spreading criteria.

2.1.3 Comparison of horizontal tensile strains in the roadbase. Figure 2 shows that, for thick pavements, the general form of the relationship between the computed horizontal tensile strain at the bottom of the roadbase and the asphalt thickness was similar to that for subgrade stress and strain. However as the asphalt thickness was reduced the computed strain passed through a maximum. The size of this strain maximum and its associated asphalt thickness was a function of the modular ratio between the
roadbase and sub-base layers. At the low modular ratio appropriate to the reasonably high road temperature and slow vehicle speed (10 km/h) used for the computations the maximum occurred at an asphalt thickness corresponding to a design to carry approximately one million standard axles. As the modular ratio was increased the strain maximum occurred at lower asphalt thicknesses. In practice the actual relationship will not follow precisely the pattern suggested by linear elastic theory because the behaviour of unbound granular materials is non-linear, their elastic moduli and thus the modular ratio between roadbase and sub-base being a function of the applied stress. For the thicker pavements carrying heavy traffic in which the role of the sub-base is less important, and on which a pervious macadam surfacing is most likely to be laid, the computations suggest that, for the test conditions considered, 60 mm of pervious macadam gives the same structural contribution as 45 mm of rolled asphalt. Thus the pervious macadam provides a greater contribution to reduction of fatigue failure at the bottom of the roadbase than to load spreading.

2.1.4 Comparison of surface deflections. Vertical deflection of the pavement under a moving wheel is a good general indicator of the structural behaviour of the road and foundation; it is usually measured by the Deflection Beam. Deflections were calculated and related to the values measured by a beam to account for any movement of the feet supporting the beam, which may have been within the area of influence of the bowl of deflection on stronger pavements. These calculated deflections were related to asphalt thicknesses in a similar manner to that adopted for the soil stresses. The comparisons were made at a pavement temperature of 20°C, the standard adopted for measurements with the Deflection Beam. It was found that, to maintain the same computed surface deflection, 60 mm of pervious macadam surfacing was equivalent to 36 mm of rolled asphalt roadbase. This is a result similar to that determined earlier from comparisons on the basis of soil stress and strain.

2.2 Full-scale trial

The analytical assessment indicated that pervious macadam surfacing does provide a significant contribution to the structural performance of road pavements. To examine the validity of the results, measurements were made of transient stresses, strains and deflections on a full-scale road before and after surfacing with pervious macadam.

2.2.1 Experimental conditions. A 60 mm thickness of pervious macadam surfacing (see Appendix) was laid on an extensively instrumented asphalt pavement that had been used previously for other studies. This pavement was built under cover in a bay 28m long by 7m wide. It consisted of 200 mm of hot rolled asphalt roadbase laid in two layers on 150 mm of limestone wet-mix macadam. The foundation was a clay subgrade with a California Bearing Ratio of 5.5 per cent. During construction, gauges were installed to measure vertical and horizontal stress and strain in the subgrade and horizontal strain at the bottom of the asphalt. Thermocouples were also positioned to measure the temperature distributions within the bituminous layers.

Stresses and strains generated by a two-axle lorry were measured after the construction of each layer of the road. The rear axle was fitted with single wheels and carried 90 kN (45 kN on each wheel), the maximum legal axle load for a lorry fitted with these wheels and tyres. The bituminous materials were heated to a uniform 30°C to facilitate later comparisons of the results and the lorry was driven at 10 km/h along the test bay. Deflections of the road surface produced by a lorry moving at creep speed were measured using the Deflection Beam. For these tests, the standard test lorry fitted with twin rear wheels on its single rear axle was used and the pavement was at a constant 20°C, the standard temperature.
2.2.2 Comparison of vertical stresses and strains in the subgrade. Figure 3 shows the relationship between the measured vertical stress in the subgrade and asphalt thickness for the two thicknesses of asphalt in the test bay and for a third pavement with an asphalt thickness of 295 mm. This latter pavement is part of the full-scale pavement design experiment on the A1 trunk road at Conington Lodge \(^{11}\) with sub-base thickness and sub-base and subgrade strengths nominally the same as those in the test bay at Crowthorne. Measurements showed that the stress decreased when the asphalt thickness was increased and when overlaid with pervious macadam. Although the absolute values of measured stress differed from those computed (see Figure 1), the relationship between measured stress and asphalt thickness was also linearly logarithmic for the pavements without pervious macadam. It seemed reasonable therefore, to assume that a similar linearly logarithmic relationship existed between the measured stresses and asphalt thickness for pavements with pervious macadam surfacing as shown for the computed values in Figure 1. On this basis, 60 mm of pervious macadam surfacing may be seen to be equivalent to 35 mm of rolled asphalt, the same result obtained by computation. Comparison on the basis of the measured vertical component of strain in the subgrade also gave the same result.

2.2.3 Comparison of horizontal tensile strains in the roadbase. The longitudinal and transverse horizontal components of strain measured at the bottom of the rolled asphalt roadbase under the same conditions of load and temperature as the subgrade stresses and strains are given in Table 1. These results are the mean values from five gauges in the pavement at Conington and from ten gauges in the pavements in the test bay.

<table>
<thead>
<tr>
<th>Pavement structure</th>
<th>Tensile strain $\mu$m/m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Longitudinal</td>
</tr>
<tr>
<td>80 mm rolled asphalt</td>
<td>450</td>
</tr>
<tr>
<td>200 mm rolled asphalt</td>
<td>245</td>
</tr>
<tr>
<td>295 mm rolled asphalt</td>
<td>55</td>
</tr>
<tr>
<td>200 mm rolled asphalt + 60 mm pervious macadam</td>
<td>150</td>
</tr>
</tbody>
</table>

Differences between the measured transverse and longitudinal components of strain are typical of those generated by a single wheel and result in part from its elliptical tyre contact area. The computations however predict transverse and longitudinal strains of equal magnitude because they are based on an assumed circular tyre contact area.

Table 1 shows that the measured strains were very dependent on the total thickness of bituminous material, more in fact than was indicated earlier by linear elastic theory. This difference probably occurred because a constant value of Young's modulus was assigned to the granular sub-base for the computations and clearly could not describe its actual non-linear behaviour. The measured strains suggest that the relationship is not linearly logarithmic over the full range of thicknesses considered, but may tend to reflect the general shape of the predicted curve in Figure 2. However if it is assumed that it is linearly logarithmic for the
thicker pavements (i.e., those with more than 200 mm of asphalt), these measurements suggest that 60 mm of pervious macadam is equivalent to either 30 mm or 40 mm of rolled asphalt, based on the longitudinal and transverse strains respectively; slightly less than predicted by Figure 2. These equivalences are, of course, applicable only to the conditions of the test.

2.2.4 Comparison of surface deflections. Deflections were measured using the Deflection Beam at twelve positions on a regular grid in the test bay and an average deflection was determined. Measurements were made first on the sub-base and then on each of the bituminous layers. The results are shown in Figure 4 together with the computed values discussed earlier. The relationships were linearly logarithmic and showed that, 60 mm of pervious macadam was equivalent to 35 mm of rolled asphalt, the same result as obtained by computation.

3. STRUCTURAL CONTRIBUTION OF PERVIOUS MACADAM SURFACING TO EXISTING DESIGNS OF PAVEMENT FOR HEAVY TRAFFIC

Pervious macadam surfacing makes a significant structural contribution to the road pavement. Thus the design thickness of roadbase in a new road with a pervious macadam surfacing can therefore be reduced while maintaining the required structural performance. Similarly, the design thickness of a bituminous overlay required for structurally strengthening an existing road can be reduced. In this section of the report linear elastic theory is used to determine by how much the thickness of the rolled asphalt surfacing or bituminous roadbase of current designs of flexible pavements can be reduced when the pavements are surfaced with the present recommended minimum thickness of 40 mm of pervious macadam.

Dynamic stress and strain components considered to be critical were calculated, first for the present designs, then for the same pavements with an additional 40 mm of pervious macadam surfacing and finally with the pervious macadam but with a reduced thickness of underlying bituminous layers. From this data the thicknesses of different bituminous materials equivalent to 40 mm of pervious macadam were determined on the basis of maintaining the critical stresses and strains calculated for the present designs. The critical stresses and strains selected were the horizontal strain at the bottom of the roadbase and the vertical strain at the top of the subgrade. These are related to the fatigue and load spreading properties of the pavement respectively.

Strains were computed for flexible pavements with rolled asphalt, dense bitumen macadam and lean concrete roadbases having design lives of between one million and 100 million cumulative equivalent standard axles and constructed on subgrades with strengths of between 2 and 10 per cent California Bearing Ratio (CBR). To simplify the computations the load of 45 kN was applied through a single wheel having an assumed circular tyre contact area of radius 0.15 m.

In practice the magnitudes of stresses and strains generated by wheel loads are dependent on several factors; the most influential are the thickness of the road layers and the stiffness of the different road materials. Because the stiffness of bituminous materials is temperature dependent, the practical range of road temperatures were considered. The effect of variation in stiffness of the sub-base and subgrade, parameters known to affect pavement performance were also investigated.
3.1 The effect of pavement temperature

Strains were computed for present designs of road pavements that were subjected to temperatures constant with depth in the range 5°C to 40°C. From these results the thickness of the surfacing and roadbase layers were calculated that were equivalent to the dynamic structural contribution provided by 40 mm of pervious macadam surfacing.

Results are presented in Figure 5 for a pavement designed to carry 30 million cumulative equivalent standard axles (a typical design for a trunk road). The pavement had a dense bitumen macadam roadbase and was constructed on a subgrade with a California Bearing Ratio of 5 per cent. The thicknesses of rolled asphalt wearing course and dense bitumen macadam roadbase equivalent to 40 mm of pervious macadam surfacing are shown as functions of pavement temperature. The calculations were based on maintaining constant levels either of the vertical strain at the top of the subgrade, or the horizontal strain at the bottom of the roadbase. Figure 5 shows that as the pavement temperature increases the relative structural contribution of pervious macadam improves; ultimately at extremely high temperatures the structural contribution of all bituminous materials to load spreading would be similar to those of unbound granular sub-bases. It also demonstrates that the contribution of pervious macadam to load spreading is less than its contribution to increasing fatigue resistance. The effect of temperature on the equivalent thicknesses of the bituminous materials in pavements containing roiled asphalt and lean concrete roadbases was similar to the example given in Figure 5.

For design purposes the question arises of how to allow for temperature in selecting a thickness of bituminous material equivalent to 40 mm of pervious macadam surfacing. On the one hand, as the pavement temperature increases, the relative structural contribution of pervious macadam improves but the stresses and strains in the pavement and subgrade increase. On the other hand, at low temperatures the relative structural contribution of pervious macadam is smaller but the stresses and strains are also smaller. For much of the year, the pavement temperature is not constant with depth and during the summer in particular large temperature gradients can occur.

Because pervious macadam contributes less to load spreading than to fatigue resistance, calculation of the equivalent thickness of conventional wearing course or roadbase was carried out in terms of load spreading, a parameter related to deformation behaviour. In the absence of an authoritative model linking the dynamic response of pavements to their deformation behaviour and, bearing in mind that the analysis adopted simplified temperature distributions, it is prudent to adopt a conservative approach to quantifying equivalence thicknesses of wearing course and of roadbase. The equivalences adopted are therefore based on comparisons at the low pavement temperature of 5°C although it is realised that, in practice, pavement deformation develops only under medium to high temperature conditions that give more favourable equivalences; for the sake of completeness results at both 5 and 30°C are presented in considering the effects of pavement structure, sub-grade strength and sub-base stiffness in the following sections of the Report. On the basis of comparison at 5°C the pavement examined in Figure 5 indicates that 40 mm of pervious macadam surfacing provides the same structural contribution as 16 mm of rolled asphalt wearing course or 20 mm of dense bitumen macadam roadbase.

3.2 The effect of pavement structure

The thickness of rolled asphalt wearing course that provides the same structural contribution to load spreading as 40 mm of pervious macadam surfacing was calculated for a wide range of road designs. Results are given in Table 2 for pavements constructed on subgrades having a 5 per cent California Bearing Ratio and subjected to a high and to a low temperature.
TABLE 2
Thickens of rolled asphalt wearing course equivalent to 40 mm of pervious macadam surfacing

<table>
<thead>
<tr>
<th>Design life (Cumulative equivalent standard axles)</th>
<th>Equivalent thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rolled asphalt</td>
</tr>
<tr>
<td></td>
<td>5°C</td>
</tr>
<tr>
<td>5 x 10⁶</td>
<td>16.7</td>
</tr>
<tr>
<td>30 x 10⁶</td>
<td>16.3</td>
</tr>
<tr>
<td>100 x 10⁶</td>
<td>16.3</td>
</tr>
</tbody>
</table>

They show that for practical purposes the thickness of rolled asphalt wearing course equivalent to 40 mm of pervious macadam is independent of the design life of the pavement and roadbase material employed. This is particularly important for overlay design where the construction of the original pavements may vary widely. In pavements with lean concrete roadbase in the uncracked state the major contribution to load spreading is provided by the roadbase so that any differences between the negligible effects of bituminous materials are suppressed. However, in service, lean concrete develops cracking and the contribution of lean concrete to load spreading is reduced; it is then reasonable to suppose that the equivalent thickness of rolled asphalt will be broadly similar to that obtained when laid on a bituminous roadbase.

Table 3 shows that equivalent thickness of bituminous roadbases depends on the material. The results given are for pavements designed to carry 30 million equivalent standard axles.

TABLE 3
Thickens of rolled asphalt and dense bitumen macadam roadbases equivalent to 40 mm of pervious macadam surfacing

<table>
<thead>
<tr>
<th>Roadbase material</th>
<th>Equivalent thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5°C</td>
</tr>
<tr>
<td>Rolled asphalt</td>
<td>16.3</td>
</tr>
<tr>
<td>Dense bitumen macadam</td>
<td>19.7</td>
</tr>
</tbody>
</table>

Equivalent thicknesses of lean concrete roadbases were not calculated because in practice reduction in thickness of lean concrete for a particular design life would be very small.

The values given for the two temperatures in Tables 2 and 3 merely confirm the effects demonstrated in Figure 5 and give some idea of the range of equivalences which may occur in practice.
3.3 The effect of sub-base quality

In all the computations already discussed the elastic modulus assigned to the sub-base layer was held constant at $1.5 \times 10^8$ N/m$^2$, a typical value derived from wave propagation tests on a reasonable quality sub-base, and supported by simple triaxial testing in the laboratory.

The effect of sub-base quality was assessed by changing its modulus in the stress computations. A range of moduli was considered to describe sub-bases varying from good to poor. The calculations showed that for any chosen design life of the pavement, the effect of varying the sub-base modulus on the structural contribution of pervious macadam surfacing was negligible.

3.4 The effect of subgrade strength

Computations were made to determine the effect of subgrade strength on the structural contribution of pervious macadam surfacing. Results are given in Table 4 for pavements with a rolled asphalt roadbase designed to carry 30 million cumulative equivalent standard axles according to the design recommendations in the third edition of Road Note 293. These show that the structural contribution of pervious macadam increased slightly with subgrade strength, the change being greater at the higher temperature. Some change would have been expected because the equivalences were based on the vertical strain in the subgrade and would therefore be influenced by change in soil strength.

<table>
<thead>
<tr>
<th>Subgrade strength (CBR per cent)</th>
<th>Thickness of rolled asphalt equivalent to 40 mm of pervious macadam surfacing (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>$5^\circ$C: 15.3</td>
</tr>
<tr>
<td>5</td>
<td>$5^\circ$C: 16.3</td>
</tr>
<tr>
<td>10</td>
<td>$5^\circ$C: 18.0</td>
</tr>
</tbody>
</table>

Some idea of the effect of subgrade variability likely to be encountered in practice on a road to a given design was also obtained. Stresses and strains were computed to allow for changes of between ±1 per cent about a central value of CBR of 5 per cent. It was found that such variations did not alter the structural contribution of pervious macadam surfacing in relation to that of rolled asphalt.

3.5 Resistance of pervious macadam to deformation

In the United Kingdom flexible pavements generally fail by excessive deformation in the wheel tracks, a proportion of which generally takes place in the wearing course. It was therefore important to determine whether pervious macadam maintained the same resistance to deformation as the rolled asphalt wearing courses used in present recommended designs.

Deformation resistance was measured in the laboratory by the TRRL wheel tracking test$^{12}$. Measurements made on several samples of pervious macadam surfacing removed from the test pavement produced
an average rate of deformation of 1.5 mm per hour. This was rather better than the 2 mm per hour required for conventional rolled asphalt wearing course laid on roads carrying heavy traffic\textsuperscript{13}, the roads on which pervious macadam is most likely to be used.

These results have been supported in practice by the pervious macadam surfacings that have been laid in full-scale experiments on public roads for up to 13 years\textsuperscript{14,15,16}. Generally its deformation in service, as measured in the wheel tracks under a 2m straight edge, has been superior to that of conventional rolled asphalt wearing course laid on the same lengths of road and thus subjected to the same traffic. However the life of pervious macadam surfacing is shorter than that of rolled asphalt and generally it fails by disintegration due to embrittlement of the binder. To put this into perspective, on a heavily trafficked road pervious macadam surfacing carried 17 million equivalent standard axles after five years before it was replaced.

4. CONCLUSIONS

Structural design methods have been used to evaluate the contribution which pervious macadam surfacing could make to the overall strength of a road pavement. This assessment of pervious macadam to a typical specification was based on maintaining vertical strain at the top of the subgrade at the same level as in a conventional pavement: as a consequence the use of the pervious macadam surfacing led to lower horizontal tensile strains at the bottom of the roadbase. The resistance to deformation of the pervious macadam surfacing was shown by a standard laboratory test to be marginally better than for rolled asphalt wearing course.

Examining the performance of the pervious macadam surfacing laid on roads containing rolled asphalt, dense bitumen macadam and lean concrete roadbases designed according to the recommendations of Road Note 29, it was calculated that 40 mm of the pervious macadam would allow a reduction of either 16 mm of rolled asphalt or 20 mm of dense bitumen macadam. The structural contribution of the pervious macadam surfacing did not vary for a wide range of pavement designs, neither was it greatly affected by variations in strength of the sub-base or subgrade.

5. ACKNOWLEDGEMENTS

The work described in this report forms part of the research programme of the Pavement Design Division (Division Head: Mr J Porter) of the Highways Department of TRRL. Use of the wheel tracking test facility was arranged by Mr F A Jacobs of Materials Division of the Highways Department.

6. REFERENCES


Fig. 1 Effect of 60mm of pervious macadam surfacing on the computed vertical stress in the sub-grade
Fig. 2 Effect of 60mm of pervious macadam surfacing on computed horizontal tensile strain at the bottom of the roadbase
Fig. 3 Effect of 60mm of pervious macadam surfacing on measured vertical stress in the subgrade
Fig. 4 Effect of 60mm of pervious macadam surfacing on computed and measured surface deflections
Fig. 5  Estimated effect of temperature on the structural contribution of pervious macadam surfacing.
7. APPENDIX

CONSTRUCTION OF PERVIOUS MACADAM SURFACING USED IN THE FULL-SCALE TRIAL AND MEASUREMENT OF STRUCTURAL PROPERTIES OF THE MATERIAL

The pervious macadam was mixed at TRRL using Croft granite aggregate and 100 pen. Middle East straight run bitumen. Croft was selected because it was an aggregate frequently used for research purposes\(^\text{17}\) and its behaviour as a road-making material has been well characterised\(^\text{18,19}\). The average production temperature of the mix was 135\(^\circ\)C. The pervious macadam was laid in the test bay in two widths using a Blaw Knox PF 90 paver. Compaction to a finished mean thickness of 60 mm was achieved by an 8 ton 3 wheeled steel-tyred roller. The rolling was carried out at temperatures falling between 90\(^\circ\)C and 70\(^\circ\)C.

Twenty-four samples were taken from the mixing plant for analysis. The grading, given in Table 5, was typical of other pervious macadam surfacings laid in earlier trials on public roads\(^\text{20}\).

### TABLE 5

<table>
<thead>
<tr>
<th>Passing BS sieve</th>
<th>Percentage by weight (%)</th>
<th>Average</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 mm</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 mm</td>
<td>97.4</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>14 mm</td>
<td>66.7</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>6.3 mm</td>
<td>31.5</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>3.35 mm</td>
<td>10.0</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>75 (\mu)m</td>
<td>2.5</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>Binder content</td>
<td>3.8</td>
<td>0.2</td>
<td></td>
</tr>
</tbody>
</table>

After the \textit{in situ} stress and strain measurements were completed, cores of 150 mm diameter were removed to obtain samples for density, void content and resistance to deformation measurements. Cores with a diameter of 450 mm were also removed to provide samples for the determination of dynamic modulus.

The mean density determined by the standard technique of weighing the sample in air and water was 1.82 gm/cc and the mean void content was 25.2 per cent. A comprehensive check of variations in \textit{in situ} density was made using a gamma ray backscatter Troxler gauge\(^\text{21}\). Measurements were taken along the centre lines of the two widths and the results showed the density to be uniform within the accuracy of the instrument.

Samples were tested to determine the resistance to deformation on the wheel tracking apparatus as described in Section 3.5. The deformation rate so determined was 1.5 mm per hour.

The dynamic stiffness of the pervious macadam surfacing was determined on beams 400 mm long, 100 mm wide and 50 mm deep which were cut from the 450 mm diameter cores. The beams were simply supported and sinusoidally loaded in a temperature controlled bath. Tests were conducted at temperatures...
between $-9^\circ\text{C}$ and $33^\circ\text{C}$ and at loading frequencies between 0.1 Hz and 80 Hz. The applied load, beam displacement and their relative phase angle were measured for each test and the results were analysed to produce a relationship between dynamic stiffness and frequency at a temperature of $10^\circ\text{C}$. This relationship is shown in Figure 6a. The elastic modulus at any other temperature within the range covered may be determined using the shifting factor curve in Figure 6b. A typical dynamic stiffness curve is shown also for rolled asphalt wearing course; it is noticeably stiffer than the pervious macadam surfacing.

7.1 References


Fig. 6a  Variation of dynamic stiffness with frequency referred to 10°C
Fig. 6b  Frequency shifting factor as a function of temperature
ABSTRACT

The contribution of pervious macadam surfacing to the structural performance of roads:
J F POTTER and A R HALLIDAY: Department of the Environment Department of Transport, TRRL Laboratory Report 1022: Crowthorne, 1981 (Transport and Road Research Laboratory). Although the spray-reducing properties of pervious macadam surfacing are well known, there is a distinct lack of information available about its structural performance. As a result its structural contribution is not considered in the design of new roads or bituminous overlays.

The structural strengthening brought about by laying pervious macadam surfacings on existing roads has been assessed by using linear elastic theory to compute the stresses and strains induced in the pavements by vehicle loading before and after surfacing with the pervious macadam. These computations predicted a significant reduction in the magnitude of stresses and strains after surfacing, a result which was confirmed in practice by direct measurement on a full-scale road pavement. Stress and strain computations were then used to determine the structural contribution of 40 mm of pervious macadam surfacing in terms of equivalent thicknesses of rolled asphalt surfacing and rolled asphalt and dense bitumen macadam roadbases for the present recommended designs of road pavements.

ISSN 0305-1293