Proceedings of the Institute of Acoustics

THE EFFECT OF ROAD SURFACES ON VEHICLE NOISE IN DRY AND WET CONDITIONS

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1. INTRODUCTION

The UK's legislation and guidance on road traffic noise aims to control the noise from new roads as well as that affecting newly built homes [1],[2]. In both cases, permissible noise levels have been defined which relate to traffic running on dry road surfaces. As a result, research into the effect of road surfaces on traffic noise has tended to concentrate on noise in dry conditions and, in any case, the road is in this state for about three-quarters of the time. However, when wet conditions do occur, the impact of the resultant traffic noise can be particularly disturbing to nearby residents. Not only is it between 1 and 10 dB(A) [3] louder than the noise from a dry road, but it can also present a quite different tonal quality.

Controlling the noise emission from any individual vehicle involves two separate elements, the relative importance of which depends on its operating conditions. At low speeds the noise from a vehicle's power unit, i.e. the engine, gearbox, exhaust and cooling system will usually dominate. At higher speeds, the noise generated by the tyres in contact with the road surface gains importance. The speed at which the tyre noise becomes greater than the engine noise depends largely on the type of vehicle, but it is typically 60 km/h for a light vehicle in top gear. For a heavy goods vehicle the speed is considerably higher. At speeds above 100 km/h, on dry roads, tyre/surface noise is predominant for all but the heaviest diesel-engined goods vehicles. On wet roads however, speeds can be much lower to give the same degree of tyre noise [4].

2. THE MEASUREMENT METHOD

The aim of this experiment was to discover how some of the most commonly used road surfacings could affect vehicle noise in both dry and wet conditions. Seven different surface materials were selected: concrete, hot rolled asphalt (HRA), surface dressing, stone mastic asphalt (SMA), 'Masterpave' which is a proprietary brand of thin surfacing material, and two different porous asphalts; one of which was less than a year old and the other had been laid six years previously in a far from ideal location where there was a tendency for the voids in the material to become clogged with dirt. Details of the measurement sites are given in Table 1. The road surfaces were, in all cases, in a good state of repair, with adequate surface texture and no signs of significant wheel rutting.

Table 1 Surface materials and measurement sites

Ref No.	Type of surface	Aggregate size	Location	Opened to traffic
1	Concrete	-	A303 Ilminster bypass, Somerset	Mar 1988
2	Hot rolled asphalt, HRA	20 mm	A31 Winterborne Zelston, Dorset	Dec 1994
3	Surface dressing	10 mm	B3157 Portesham, Dorset	July 1995
4	Stone mastic asphalt, SMA	14 mm	A37 Melbury Osmond, Dorset	Aug 1996
5	Proprietary surfacing "Masterpave"	14 mm	B3082 Kingston Lacy, Dorset	Mar 1995
6	Porous asphalt, PA(old)	10 mm	A351 Wareham bypass, Dorset	Nov 1991
7	Porous asphalt, PA(new)	20 mm	A331 Blackwater Valley Route, Surrey	July 1996

A statistical pass-by method based on the draft ISO/DIS 11819-1 [5] was used to assess the noisiness of the surfaces. Some modifications were made to the ISO method, particularly to allow its use in wet conditions. In order to be as consistent as possible, wet surface measurements were, in all cases, made during periods of steady rain, which had been falling for several hours prior to the start of the surveys. Measurements were taken on grass verges alongside straight and level sections of carriageway where vehicles were travelling at reasonably steady speeds. In each survey, the pass-by noise of 25 cars and 25 lorries was recorded at a microphone positioned 7.5 metres from the centre of the test lane and 1.2 metres above the ground. Vehicle speeds were also recorded using a hand-held radar device.

The recordings were subsequently analysed to extract one-third octave band and A-weighted maximum pass-by noise levels for each vehicle. For each frequency band between 50 Hz and 10 kHz, a graph of maximum pass-by noise level against the logarithm of vehicle speed was plotted and a regression analysis was carried out in order to derive the maximum pass-by noise level at the reference speed of 90 kph - termed the Statistical Pass-By Level (SPBL). An example of the regression analysis is shown in Figure 1.

A check on the repeatability of the method showed agreement of the A-weighted statistical pass-by levels of two successive samples to be within 0.2 dB(A) for cars and 0.3 dB(A) for lorries, with the one-third octave band levels generally agreeing to within 1 dB. At low frequencies however, particularly around the 100 Hz band, the repeatability of the method was quite poor. For this reason, comparisons between the surfaces have only been made for frequencies above 200 Hz where repeatability was considered acceptable.

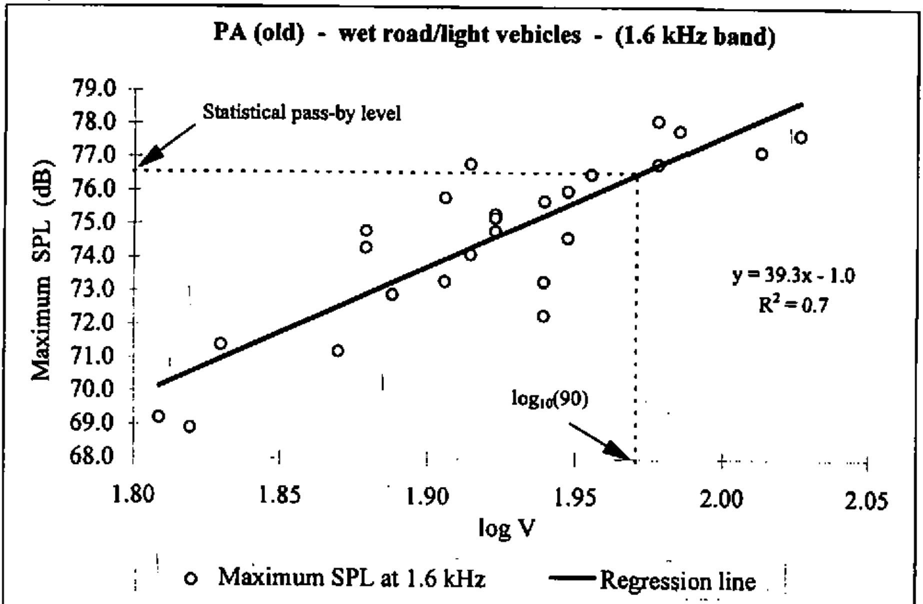


Figure 1 Example of regression analysis

3. RESULTS

3.1 A-weighted noise levels

Figures 2 and 3 show the A-weighted values of Statistical Pass-by Level (known as the Vehicle Noise Level, L_{veh}) for dry and wet surfaces. Clearly, for light vehicles, the newer porous surface produced the lowest levels and the margin by which it does so was greatest in wet conditions. Compared with the standard HRA surface, the newer porous material offered an advantage of 3.6 dB(A) in dry conditions and 4.4 dB(A) in wet conditions. At the other end of the scale, the concrete surface produced the highest A-weighted levels in both dry and wet conditions. The range of values of L_{veh} between the quietest and noisiest surfaces was 6.2 dB(A) in dry conditions and 6.5 dB(A) in wet. The SMA surface was found to be only 2.1 dB(A) quieter than HRA, a considerably smaller advantage than has been attributed to this material in previous studies [6],[7]. The older porous asphalt surface produced only marginally less noise than the surface dressing in wet conditions.

When considering heavy vehicles, the rank order of the surfaces was slightly different, and this is indicative of the fact that, at a given speed, a greater proportion of the noise from a passing lorry is attributable to power train rather than tyre/surface sources. The concrete was still the noisiest in both dry and wet conditions, but in dry conditions at least, the proprietary thin surfacing material 'Masterpave' produced the lowest A-weighted levels.

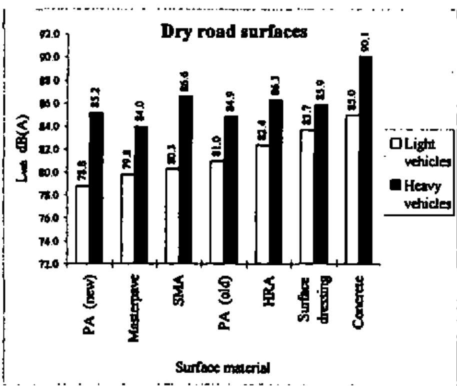


Figure 2 Vehicle noise levels - dry conditions

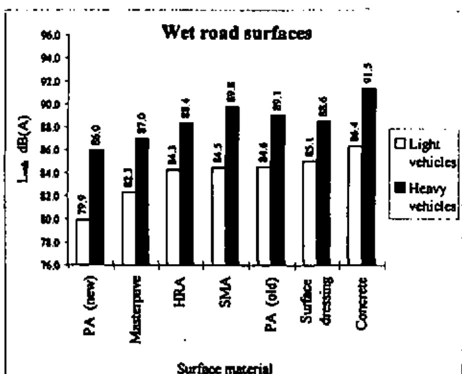


Figure 3 Vehicle noise levels - wet conditions

3.2 One-third octave band analysis

The 1/3 octave band spectra for light vehicles in both dry and wet conditions are shown in Figures 4 and 5. They show a characteristic shape, common to all the surface materials, porous and impervious, with peaks around the 80 - 100 Hz and 1 kHz regions. A narrow band analysis revealed that the lower frequency peak is generally made up of one or two narrow peaks, around 10 Hz wide, associated with the fundamental firing frequency of vehicle engines, whilst the higher frequency peak is of a broadband nature.

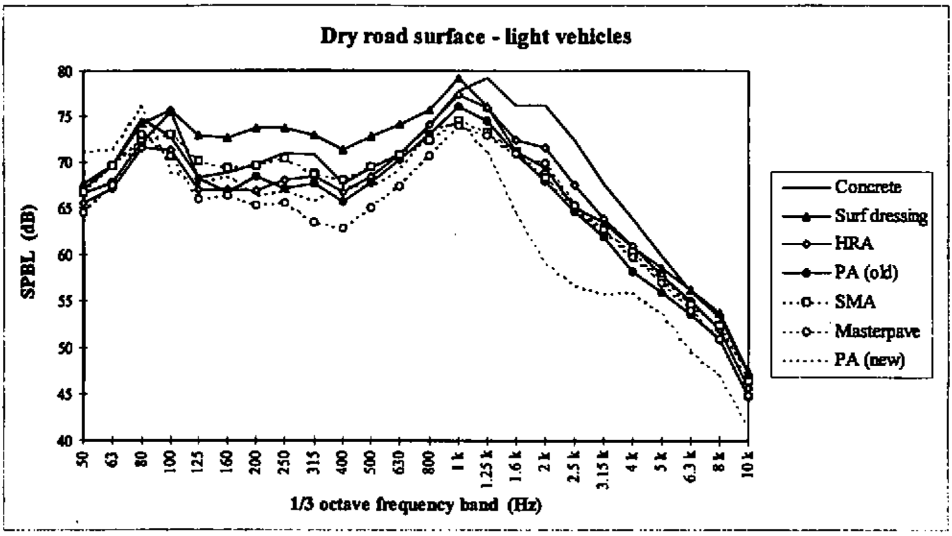


Figure 4 One third octave band pass-by noise spectra - dry conditions

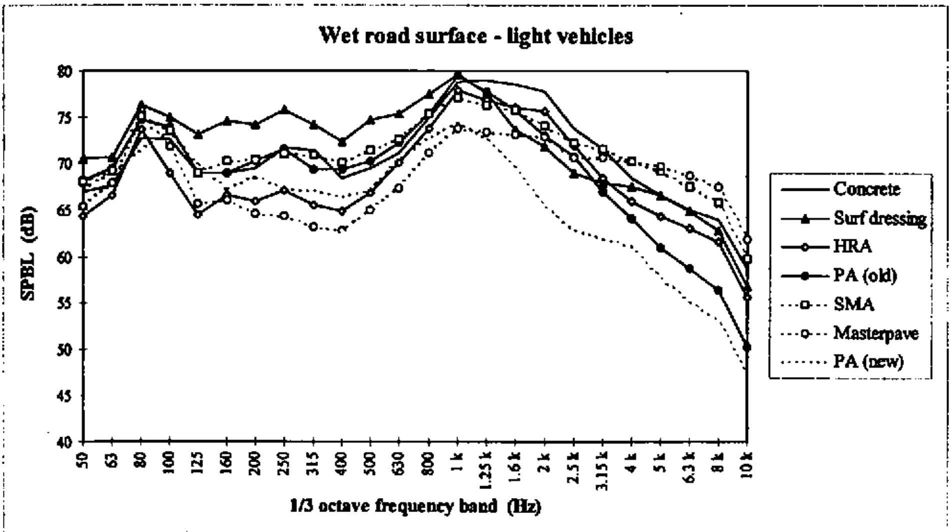


Figure 5 One third octave band pass-by noise spectra - wet conditions

The frequency region above about 1 kHz is associated with the so-called "air-pumping" phenomenon, which is noise caused by the movement of air which has become trapped and compressed in the spaces between the tyre and the texture of the road. In dry conditions, the concrete surface was considerably noisier than all of the other surfaces over a large part of this region. Conversely, the PA (new) surface produced the lowest noise levels above 1 kHz and its spectrum exhibits a marked dip between 1 kHz and 4 kHz which is absent from those for the other surfaces. This is due to a combination of the network of interconnecting voids in the material which limit the build up of air pressure and hence air pumping noise and its relatively high acoustic absorption over this part of the frequency spectrum. The remaining five surfaces, including the older porous asphalt, produced similar levels of high frequency noise in dry conditions.

Frequencies between approximately 250 Hz and 1 kHz are chiefly associated with noise radiated from tyres which have been set into vibratory motion by impacts with the texture of the road surface. As might be expected, the surface dressed road, which presents a comparatively rough profile to the passing vehicle tyre, produces high levels of noise in this region. The Masterpave surface, on the other hand, has a 'negative texture', produced by rolling the aggregate into the binder leaving a narrow shallow gap around the periphery of the particles (see Figure 6), so that the texture is below the notional plane of the surface. It consequently presents a very smooth profile and levels of tyre vibratory noise were the lowest of all the surfaces tested. The spectra for the remaining five surfaces, including the older porous asphalt, were quite closely grouped between these two extremes.

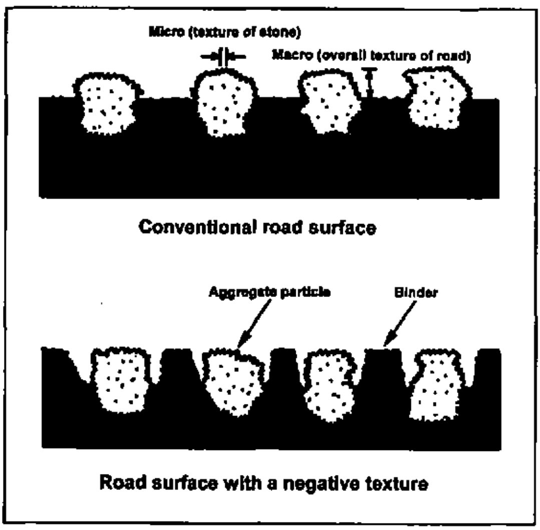


Figure 6 Illustration of negative surface texture

At frequencies below 1 kHz, both the rank order and the absolute levels of the one-third octave band spectra were relatively unaffected by the presence of surface water. At higher frequencies, in wet conditions, the newer porous asphalt was again the quietest surface by a considerable margin. Interestingly, the Masterpave surface, which produced the lowest noise levels in the bands below 1 kHz, produced the greatest amount of noise at the highest frequencies. The SMA surface, which also has a negative texture, performed similarly poorly in this region. The source of this high frequency noise is most likely to be the 'splash' of vehicle tyres through surface water and the results therefore suggest that this type of texture is less efficient than a conventional texture pattern at dispersing water away from the contact point with the tyres.

The older porous surface fared somewhat better in wet conditions than in dry at the higher frequencies, although its performance was considerably worse than that of its newer counterpart. The generally disappointing performance of the six-year-old PA appeared to be largely due to the clogged state of the pores in the material resulting from its being used in an inappropriate location where there was not only a large number of movements of farm vehicles but also an insufficient flow of high speed traffic to produce the required pumping and cleansing action of vehicle tyres.

An attempt had been made in 1992 to clean the surface using a modified suction sweeper, but such techniques are expensive and are known to only partially restore the porosity of the material. The Highways Agency has subsequently produced detailed guidance on the situations and circumstances in which it is appropriate to use porous asphalt surfaces [8].

The effect of the presence of surface water becomes clearer when the dry and wet surface spectra are superimposed onto the same axes as shown in Figure 7. For the new porous asphalt surface, the wet and dry spectra are very similar at frequencies up to approximately 1 kHz. At higher frequencies the wet surface levels are consistently between about 4 dB and 6 dB higher. For the older porous surface there is a fairly uniform increase of between 3 dB and 5 dB over a large part of the frequency spectrum. However, the spectra for the impervious surfaces show, without exception, that the increase in noise due to the presence of surface water increases steadily with frequency above about 1 kHz. This effect is particularly noticeable in the cases of the SMA and Masterpave surfaces where the difference between the one-third octave band levels is as much as 17 dB at the highest frequencies indicating a real potential for additional noise disturbance in wet weather.

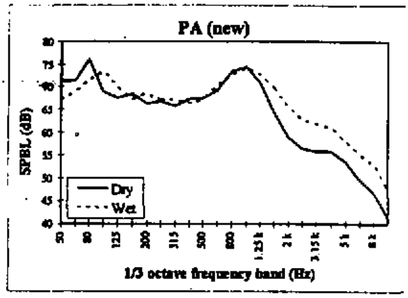
4. CONCLUSIONS

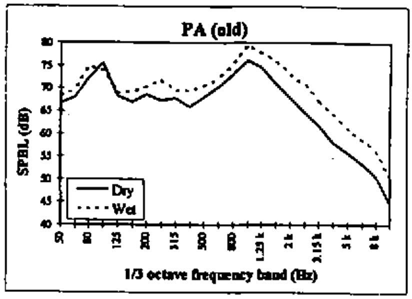
Residents of properties near to main traffic routes will clearly benefit from the selection of quieter road surface materials and the additional cost may be at least partly offset by the reduced need for environmental barriers, noise insulation and/or compensation payments. Porous asphalt surfaces can provide a useful degree of control of tyre/surface noise and many people will find the tonal quality of the noise produced from such a surface more acceptable. However, in order to maximise its long term potential for noise reduction, it should only be used in appropriate locations, in accordance with the currently available guidance.

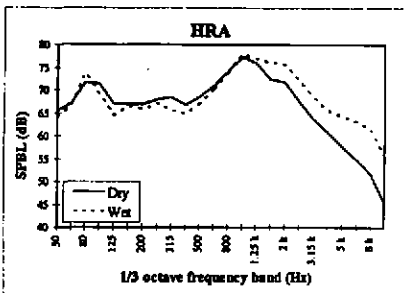
Of course, conditions of noise propagation are different for every house, garden or other sensitive location, and this will affect both the level and character of the received noise. Phenomena such as atmospheric absorption, ground effects and screening are all frequency dependent and will tend to distort the shape of spectra away from those obtained at a roadside measurement position using the statistical pass-by method. Since high frequencies tend to be reduced more readily with distance than low frequencies, the benefits of surfaces such as porous asphalt which reduce high frequencies, but offer little if any advantage below 1 kHz, will diminish at greater distances from the road.

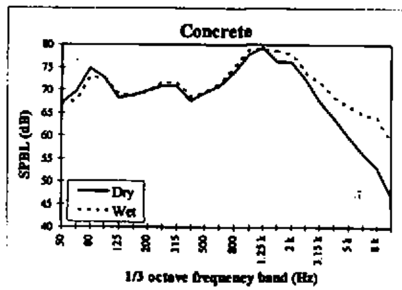
On a cautionary note, it needs to be borne in mind that the selection of a quiet surfacing material at the design stage will not in itself guarantee reduced noise levels if the standard of workmanship at the construction stage is poor. Tests on apparently similar surfaces by different authors show considerable variation in measured noise levels from one site to another. For example the SMA surface tested in this report performed only slightly better in dry conditions than HRA whereas previous studies using the statistical pass-by method, have found it to offer an appreciable noise advantage. Similarly, tests by other researchers on some of the latest thin surface materials such as 'Safepave' have also shown wide variations in noise levels between sites [9],[10].

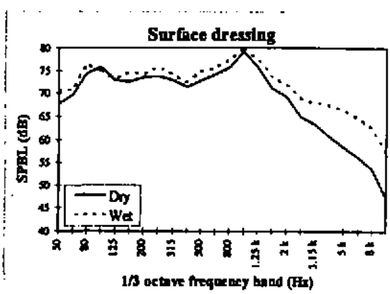
Bearing in mind that the statistical pass-by method has been shown to have a high degree of repeatability, it appears that there are considerable variations between the acoustical properties of materials from one site to another. Careful quality control during surfacing work is therefore critical to ensure that a material's full potential for noise reduction is realised.

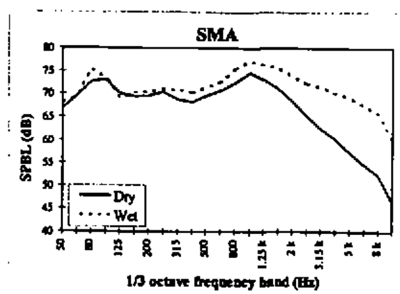












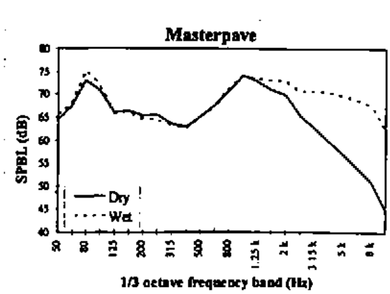


Figure 7 Comparison of wet and dry pass-by noise spectra

5. REFERENCES

[1] The Noise Insulation Regulations 1975, Statutory Instruments, 1975, no.1763 - Building and Buildings, Department of the Environment, HMSO, 1975

[2] Planning Policy Guidance Note 24 - Planning and Noise, Department of the Environment, September 1994

[3] UNDERWOOD, M.C.P., A preliminary investigation into lorry tyre noise, Department of the Environment, TRRL Paper LR 601, 1973

[4] HARLAND, D.G., Rolling Noise and Vehicle Noise, Department of Environment, TRRL report LR 652, 1974

[5] ISO/DIS 11819-1 Acoustics - Method for measuring the influence of road surfaces on traffic noise - The Statistical Pass-by method, International Organisation for Standardisation, 1995

[6] NUNN, M.E., Evaluation of stone mastic asphalt (SMA) - a high stability wearing course material, TRL Project Report 65 - E111 A/HM, 1995

[7] WOODSIDE, A.R., HETHERINGTON, J.O., ANDERSON, G.A., Noise measurements, CSS Conference - Modern road surfacing materials - Latest developments, Nov 1996

[8] Porous asphalt surface course, The Department of Transport, Design Manual for Roads and Bridges, vol.7, Section 2, Part 4 - Pavement design and maintenance, 1994

[9] PHILLIPS, S.M., Case studies of thin surfacings: Noise monitoring, CSS Conference - Modern road surfacing materials - Latest developments, Nov 1996

[10] WOODSIDE, A.R., HETHERINGTON, J.O., ANDERSON, G.A., An ear to the ground, Highways, May 1997