Proceedings of the Institute of Acoustics

METEOROLOGICAL INFLUENCES ON TRAFFIC AND VEHICLE NOISE

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1 INTRODUCTION

It is an acknowledged fact that variations in the meteorological conditions can greatly affect the propagation of vehicle and traffic noise. Propagation effects are particularly noticeable when the distance ranges are large, i.e. in excess of 300m from the road. Over these ranges both temperature gradients and wind shear can produce large diffraction effects on the propagating sound waves resulting in considerable variation in environmental noise levels. Although such effects have been well documented rather less is known about the influence of meteorological factors on generation and propagation in the region of the road itself. This is particularly important in establishing standard measurement methods for both tyre/road surface noise and overall vehicle noise levels. Existing measurement methods take no account of these different factors.

The ISO Statistical Pass-by (SPB) method[1] is widely used to determine the influence of road surfaces on the noise levels of vehicles in road traffic. The standard includes strict specifications for measurement locations and environmental conditions. However there are concerns that the results obtained from SPB measurements are still influenced by factors which affect the reproducibility and repeatability. These factors include variations in air and road surface temperature and the degree of moisture retained within the matrix of a porous road surface following periods of wet weather. Furthermore, the meteorological conditions required by the ISO standard to obtain consistent results are rarely typical of those under which the road surface would be expected to perform. This paper describes studies carried out by TRL to investigate these factors.

2 THE INFLUENCE OF TEMPERATURE

It is known that both the generation and propagation of tyre/road noise is affected by temperature. The generating mechanisms that are most affected by temperature can be generalised into two groups. These are:

- the tread vibrational inputs which are dependant on the tread compound.
- the vibration transfer characteristics from the tread to the sidewall.

The influence on the overall noise level for each tyre/road noise generating mechanism is dependant on both tyre and road surface characteristics. Therefore it is likely that the influence of temperature will be different for each road surface, although the differences are unlikely to be large in most cases

An additional factor to consider is the temperature gradient existing above a road surface. This is particularly important during hot sunny conditions where the temperature of the road surface may be very high. This produces a very hot layer of air close to the surface and a steep temperature gradient with height above the surface. Since the speed of sound is dependant on the temperature of the propagating medium, i.e. air, a steep temperature gradient above the road surface will tend to produce significant changes in the sound speed with height – the speed decreasing as the temperature reduces. Under such conditions, sound waves propagating over a hot surface will be diffracted upwards by the temperature gradient. This can often lead to reduced noise levels at roadside receiver positions.

The influence of temperature is different from surface to surface, and indeed may vary between the same type of surface due to differences in texture characteristics. For example, bituminous surfacings tend to exhibit greater changes in mechanical impedance with temperature than concrete surfacings. Porous surfaces are known to exhibit different propagation characteristics to dense surfaces.

2.1 Experimental Method

The Statistical Pass-by (SPB) method, described in the international standard ISO 11819-1: 1997[1], is the standard method for the assessment of noise levels produced by vehicles on different surfaces. The basic procedure is as follows:

During an SPB measurement, individual vehicles within the traffic stream are selected and the maximum noise level and speed measured. The traffic population is normally categorised into at least two groups, usually 'light' vehicles (passenger cars and light vans derived from passenger cars) and 'heavy' vehicles (All trucks greater than 3.5 tonnes, excluding buses, coaches and vehicles towing trailers (except articulated vehicles)). For each data set a regression of noise against the logarithm of vehicle speed is calculated.

The measurement microphone is placed at a distance 7.5m from the centre of the near-side lane, 1.2m above the surface level. Figure 1 shows a photograph of a typical set-up used.

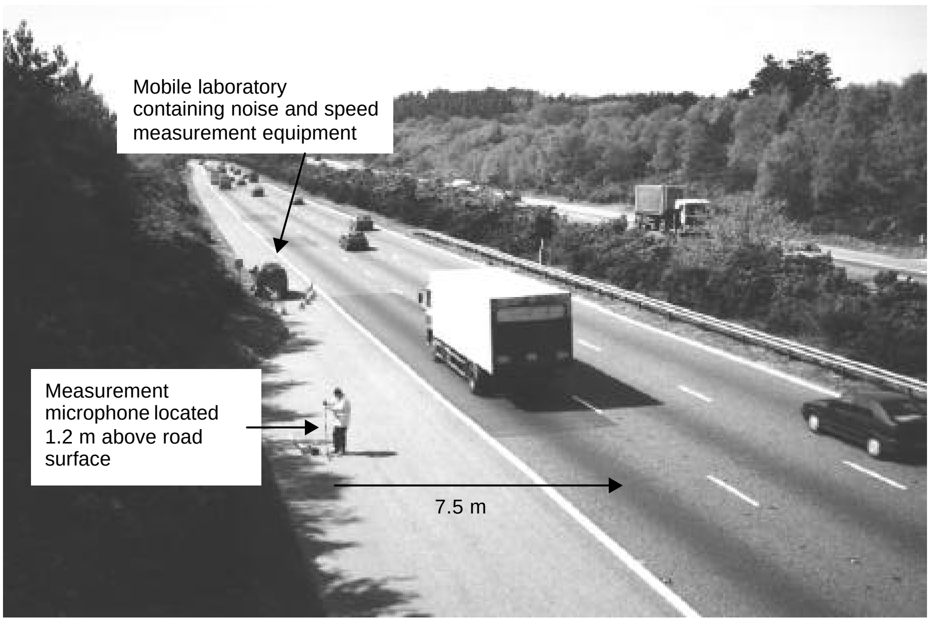

Figure 1: Photograph of typical SPB survey layout

The standard specifies strict meteorological conditions for measurements: the weather must be dry, with an air temperature in the range 5 – 40°C, a similar range for the surface temperature, and a wind speed of less than 5 ms^{-1}.

Results are analysed by carrying out a linear regression analysis of the maximum pass-by noise levels against the logarithm (base 10) of vehicle speed in km/h for each vehicle type. From the regression lines, the SPB noise levels can then be determined for a reference speed of 110 km/h for light vehicles and 90 km/h for heavy vehicles.

To investigate the influence of temperature on the results obtained using the SPB measurement method, a study was undertaken where measurements were taken on several different surfaces encompassing a wide temperature range. It was considered that one possible way of achieving the temperature range desired would be to revisit the sites selected several times during the course of a year.. However the results obtained using this approach would have been prone to influence from additional factors such as the change in surface characteristics due to ageing and trafficking. Instead it was decided to take SPB measurements over a 36 hour period, as opposed to the usual daytime measurement. The total time for each measurement was increased to include the diurnal variation in temperature, so as to be able to correlate SPB results with an overlapping range of temperatures. In this way, any influence on the results due to an ageing effect of the surface could be identified. Each road surface was measured once during the winter and the spring, with the final measurements conducted in the summer.

To take account of the effects of surface type, five types of surface were selected for the study. They were also chosen to represent a cross-section of the major types of surface used on roads carrying high-speed traffic in the UK. These surfaces were Hot Rolled Asphalt (HRA), Stone Mastic Asphalt (SMA), Porous Asphalt (PA), Brushed Concrete (BC) and Exposed Aggregate Concrete (EAC).

2.2 Results and Analysis

The measured data was divided to form subsets of data of vehicles measured in each 1°C temperature band during each visit for surface and air temperature. The data was then analysed following the procedure for conventional SPB measurements, resulting in an SPB noise level for each surface and for each 1°C band in the range of both air and surface temperature for each site visit. The SPB levels were then plotted against temperature (air and surface separately), combining all three site visits before deriving a regression line for the data.

Figure 2 shows a plot of the surface temperature (T_s) versus noise data for light vehicles on EAC.

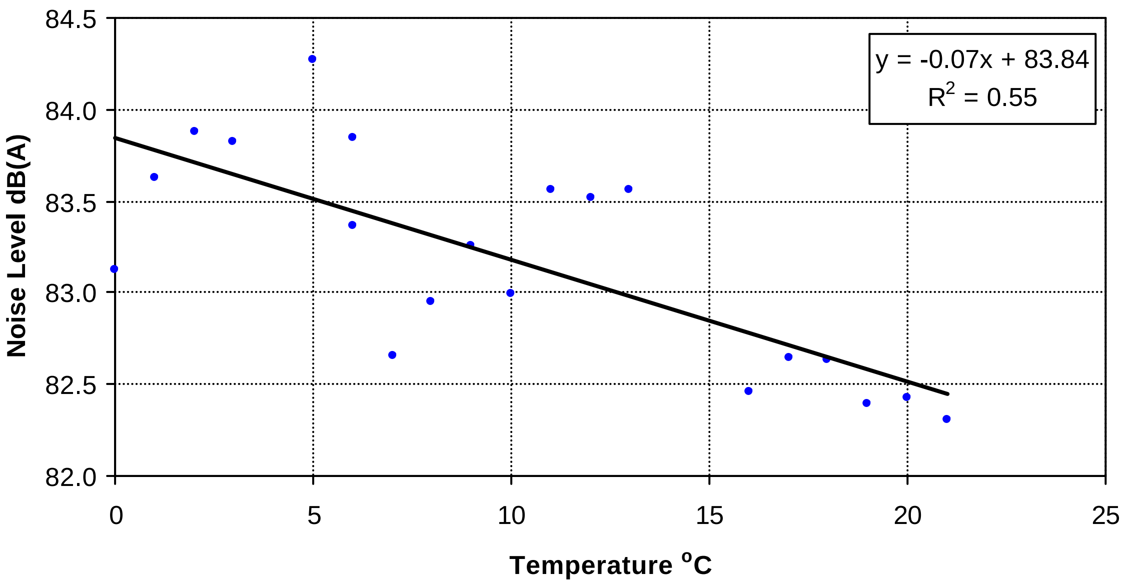

Figure 2: Light vehicle noise and surface temperature for exposed aggregate concrete

The air temperature (T_a) versus noise data for light vehicles on PA is plotted in Figure 3. It can be seen that although the correlations are not particularly strong there is a distinct trend in both examples of a reduction noise with increasing temperature.

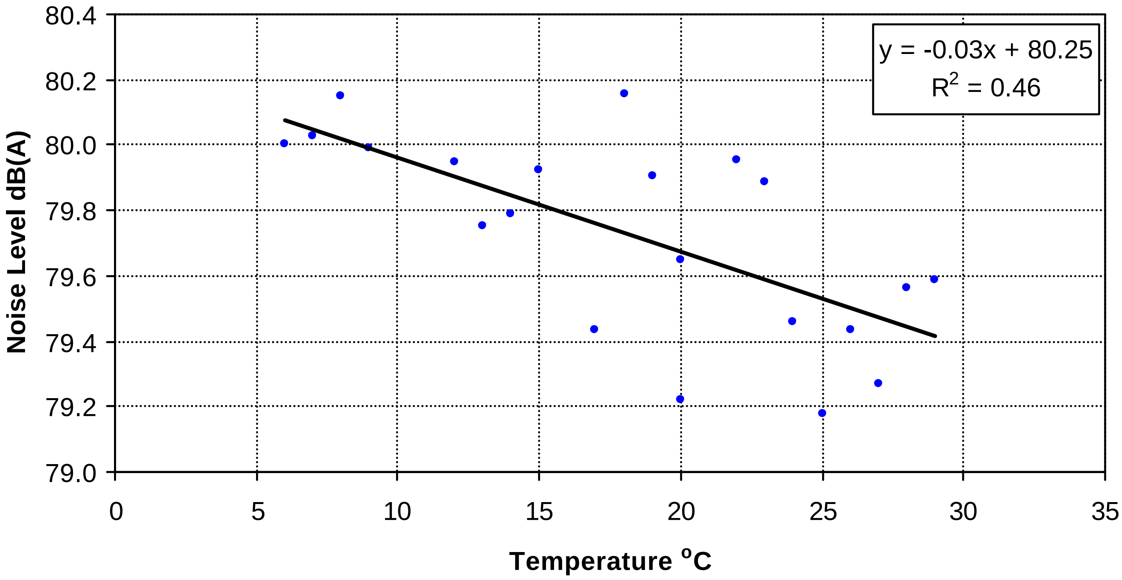

Figure 3: Light vehicle noise and air temperature for porous asphalt

Table 1 summarises the regression statistics for all 5 of the surfaces considered. The slopes of the regression lines are consistent. The results in the table show that the noise/temperature coefficients are negative for all the surfaces studied indicating that noise levels decrease with increasing temperature. It can also be seen that the coefficients are contained within a relatively narrow range.

Surface	**Temperature Range**				**Temperature Gradient in dB(A)/°C**			
	T_a		T_s		T_a		T_s	
	Min	Max	Min	Max	Slope	R^2	Slope	R^2
PA	6	29	4	38	-0.03	0.46	-0.02	0.35
HRA	3	22	3	31	-0.01	0.02	-0.02	0.18
EAC	0	22	0	21	-0.09	0.70	-0.07	0.55
SMA	1	22	1	32	-0.03	0.12	-0.02	0.08
BC	0	19	-4	21	-0.02	0.06	-0.01	0.03

Table 1: Temperature range and gradients for light vehicles

Finally, the correlation between the measured air and surface temperatures was determined, combining the results for all five surfaces into a single data set, as shown in Figure 4. It can be seen that the relationship between air and surface temperature can be approximated by

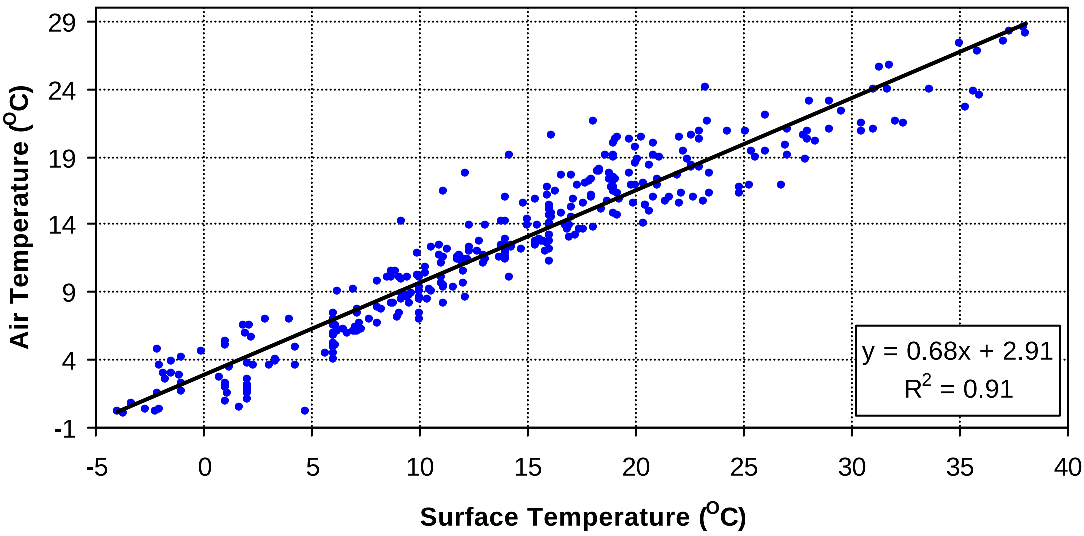

Figure 4: Air temperature versus surface temperature for all surfaces

$$T_a \propto 0.7 \times T_s \quad (1)$$

It is concluded from the results obtained that both air and road surface temperature corrections for SPB pass-by noise levels are negative, and relatively small (e.g. in the range –0.2 to –0.6 dB per 10°C change in air temperature). In practice these corrections could be important when extremes of temperature occur and where measurements need to be quoted to the highest accuracy, such as for road surface product approval purposes. It would seem, therefore, that the way forward is to introduce correction factors similar to those indicated above, which would be applied to all SPB measurements. Further analysis of the data to examine the influence of temperature on the frequency characteristics of pass-by noise levels may provide further insight into the processes involved. However, although pass-by noise levels are undoubtedly affected by temperature, the dependencies are relatively weak and hence difficult to demonstrate with statistical certainty. In addition the need to adopt different correction factors according to the road surface type is not proven.

For the purposes of certifying road surfaces, where more stringent controls are required to prevent operators selecting conditions more appropriate for their surface it was decided that a temperature correction based upon both air, T_a, and surface temperatures, T_s, would be appropriate. An appropriate correction for light vehicle noise levels would be of the form

$$\text{Temperature correction} = 0.03 \times \left[0.5(T_a + 0.7T_s) - 20\right] {}^{\circ}\text{C} \quad (2)$$

3 THE INFLUENCE OF WET SURFACES

Generally, for non-porous road surfaces carrying high-speed traffic, the action of the tyres can rapidly dry the road surface following a period of rainfall. However, for Porous Asphalt, the open structure of the material allows moisture to reside in the voids for longer periods. It is acknowledged that the presence of water in the surface voids can reduce the noise reduction performance of porous surfaces. However little is known about how long the surfaces take to dry out sufficiently for accurate and repeatable surface noise measurements to be taken. The ISO standard specifies that for porous surfaces (defined as those with a void content > 8%) a period of 4 days since precipitation should be allowed before any measurements are carried out. Given the uncertainties of the British climate this guidance has, in practice, proved quite restrictive.

3.1 Experimental Method

Consideration was given initially to the requirement that measurements would need to span both wet and dry road surface conditions. Due to the uncertainties in predicting periods of rainfall, it was felt too costly to maintain a measurement team in the field to take SPB measurements following periods of rainfall whilst the surface becomes fully dry. In addition, SPB measurements can take several hours to complete and are therefore not appropriate for monitoring changes in surface conditions. For these reasons, it was decided to monitor both traffic noise and meteorological data, including rainfall, remotely. Traffic noise and meteorological data were continuously monitored for six weeks at three locations. Each site was adjacent to a different road surface and the receiver microphone was located 10 m from the centre of the nearside lane and at a height of 3 m above the level of the road surface. Rainfall was measured at 15 minute intervals using a tipping-bucket rain gauge.

The surfaces chosen for the study three of those used in the temperature study, namely Porous Asphalt (PA), Hot Rolled Asphalt (HRA), which is non-porous, and *Masterpave*, a proprietary thin asphalt overlay developed from Stone Mastic Asphalt (SMA), all located on the M40.

3.2 Results

As traffic noise levels are influenced by traffic flow, speed and composition, it was necessary to normalise the hourly noise levels at each site to the same traffic conditions. The normalisation was carried out using the appropriate formulae contained in the Technical Memorandum; Calculation of Road Traffic Noise[2]. To reduce the errors in normalising, only data representing each hourly period during a typical weekday were selected. The data was analysed where there was a sufficient period of dry weather after it had rained so that the rate of drying could be examined. A period of dry weather of at least 12 hours following rainfall was assumed adequate. In each case, the difference between the normalised noise level recorded after the rain had stopped and the corresponding noise for dry conditions were calculated for each hour over the twelve-hour period following rainfall. The normalised noise levels corresponding to dry conditions were derived only from data taken after 48 hours from the last rain shower.

Figure 5 shows the effect of rainfall on traffic noise levels measured on the PA and HRA surfaces. The figure shows that during periods of heavy rain there is a small decrease in noise level on HRA, but a corresponding increase in noise on the PA. The increase on the PA results from the voids within the surface filling with water. It is believed that the decrease on HRA is primarily the result of a decrease in traffic speed.

Figure 6 shows the average increase in noise compared with the corresponding dry surface for each hour over a twelve-hour period after the rain stops. The figure shows that for PA, noise levels initially increase by about 3.5 dB(A), with a similar increase of about 3.2 dB(A) for the *Masterpave* surface. After the rain stops, the increase in noise compared with when dry for both PA and *Masterpave* surfaces tends to reduce with time in the manner indicated in the Figure by the trend lines. For the HRA surface, noise levels were not significantly different from those derived under dry conditions.

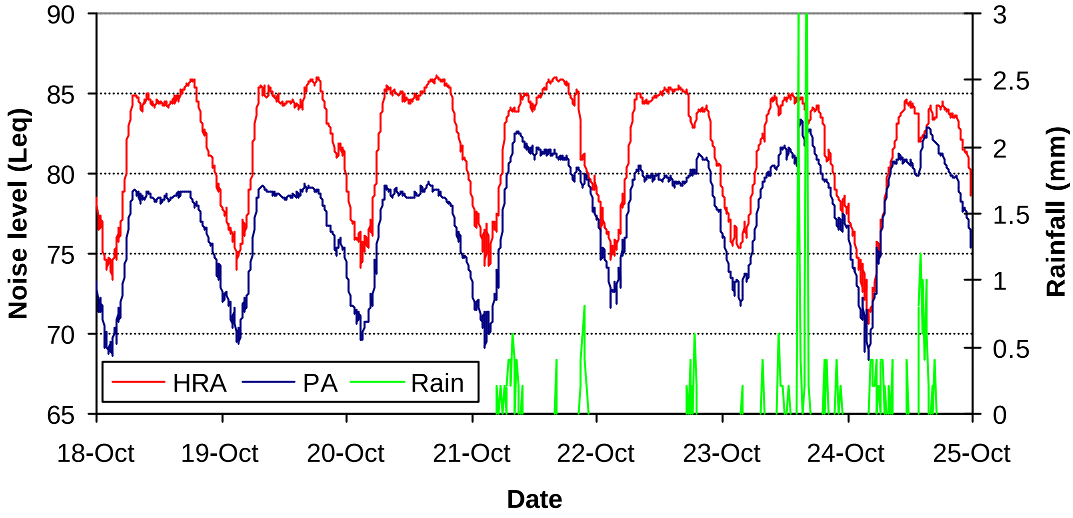

Figure 5: The effect of rainfall on PA and HRA traffic noise levels

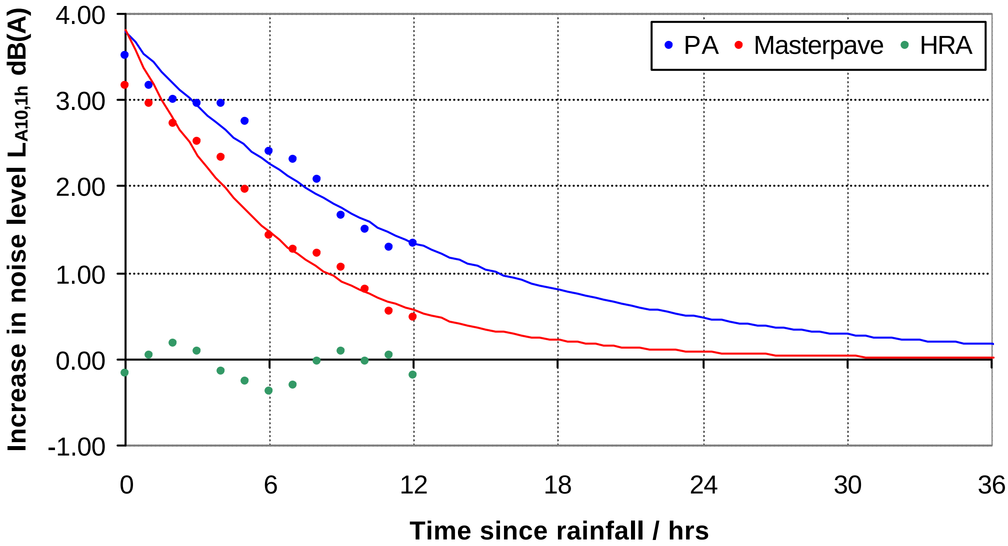

Figure 6: Increase in traffic noise for different surfaces after rainfall

The effect of wet weather on road surface noise is dependant upon the drying process, which varies according to surface type. Impervious surfaces (HRA) rapidly dry due to the action of vehicle tyres on the surface. Porous surfaces (PA) dry mainly by evaporation as the water remains within the voids below the surface. Although *Masterpave* is not porous (having a void content < 5%), it's "negative" texture profile allows moisture to remain in sufficiently deep narrow valleys between the aggregate particles that is not easily removed by the action of the vehicle tyres. Therefore, the drying process may be similar to porous surfaces. Clearly, from Figure 5, the *Masterpave* surface dried at a faster rate than the PA surface. This could be attributed to the increased layer thickness of the PA surface and the fact that a greater volume of water would need to be removed by evaporation..

The trend lines indicate that at least 36 hours of dry weather is required to ensure that the acoustic effects due to surface water are negligible for PA, i.e < 0.2 dB(A). Similarly, for *Masterpave*, at least 24 hours is required. For HRA, at least 12 hours of dry weather would seem adequate given that there is sufficient traffic to dry the surface. The typical 24-hour weekday traffic flow on the motorway at this site was about 10,000 vehicles.

4 CONCLUSIONS

A comprehensive study of factors affecting SPB measurements has been carried out which has highlighted the following aspects:

1. Temperature variations were found to have an influence on standard SPB levels for all surface types studied. A correction can be determined for either air or surface temperature although it is recommended that, for the purpose of certification, a correction factor incorporating both temperatures should be used.

2. The temperature correction proposed for noise vehicles from light vehicles is

$$\text{Temperature correction} = 0.03 \times \left[0.5(T_a + 0.7T_s) - 20 \right] {}^{\circ}\text{C}$$

3. After rainfall, traffic noise levels measured alongside both the *Masterpave* and PA surfaces increased by 3.2 dB(A) and 3.5 dB(A) respectively, compared with when the surfaces were dry. There was no noticeable increase in noise on the HRA surface.

4. At least 24 and 36 hours of dry weather should be allowed for before assessing vehicle noise levels on *Masterpave* and PA respectively, to ensure that the acoustic effects due to surface water are negligible.

5 REFERENCES

1. International Organisation for Standardisation. ISO 11819-1. Acoustics – Method for measuring the influence of road surfaces on traffic noise – Part 1: The Statistical Pass-by method. International Organisation for Standardisation, Geneva, 1997.

2. Department of Transport and Welsh Office. "Calculation of Road Traffic Noise (CRTN)". HMSO, London, 1988.