

# A review of current research on road surface noise reduction techniques



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**Transport Research Laboratory**



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**A review of current research on road surface noise reduction techniques**

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**A REVIEW OF CURRENT RESEARCH ON ROAD SURFACE NOISE REDUCTION TECHNIQUES**

**Client: Rural and Environment Research and Analysis Directorate, Research and Science Division (Linda Story)**

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## Glossary of symbols and acronyms

$\lambda$	Texture wavelength (mm)
$\Omega$	Residual void content
a	Texture amplitude (mm)
d	Layer thickness (mm)
$C_{road}$	Road surface correction used in the Dutch Road Traffic Noise Prediction Model "Reken-en Meetvoorschrift Wegverkeerslawaaai 2002"
$D_{StrO}$	Road surface correction used in the German Road Traffic Noise Prediction Model "RLS90"
$H_1$	Commercial trucks with 2 axles and greater than 3.5 tonnes unladen weight (HAPAS nomenclature)
$H_2$	Commercial trucks with more than 2 axles and greater than 3.5 tonnes unladen weight. (HAPAS nomenclature)
Hz	Hertz (cycles per second)
$L_1$	Light vehicles including passenger cars and car derived vans, excluding vehicles towing trailers or caravans (HAPAS nomenclature)
$L_{Amax}$	A-weighted maximum sound level (dB).
$L_{Amax,m}$	Maximum A-weighted pass-by noise level for vehicle category, m (dB).
$L_{Amax,m,v}$	Maximum A-weighted pass-by noise level for vehicle category, m (dB) at speed v km/h.
$L_{veh,L}$	Maximum A-weighted pass-by noise level for vehicle category $L_1$ (dB) (HAPAS nomenclature).
$L_{veh,H1}$	Maximum A-weighted pass-by noise level for vehicle category $H_1$ (dB) (HAPAS nomenclature).
$L_{veh,H2}$	Maximum A-weighted pass-by noise level for vehicle category $H_2$ (dB) (HAPAS nomenclature).
M1, M2,... M7	CPX measurement microphone positions
$T_{surface}$	Temperature of the road surface (HAPAS nomenclature)
$T_{air}$	Temperature of the air (HAPAS nomenclature)
APAT	Acoustic Performance Assessment Table
BASt	Bundesanstalt für Strassenwesen (Federal Highway Research Institute), Germany
BFC	Braking Force Coefficient
BPS	Building Prioritisation Score
BRRC	Belgian Road Research Centre, Belgium (Company Name)
CBA	Cost Benefit Analysis
CEN	Comité Européen de Normalisation (European Committee for Standardisation)
CNMA	Candidate Noise Management Area
COP	Conformity-Of-Production
CPX	Close-proximity (tyre/road noise measurement)

CSS	County Surveyors Society
dB(A)	Decibel (A-weighted)
DAC	Dense Asphalt Concrete
DBM	Dense Bitumen Macadam
DMRB	Design Manual for Roads and Bridges
DRI	Danish Road Institute, Denmark (Company Name)
EAC	Exposed Aggregate Concrete
END	Environmental Noise Directive
ENEVAL	Environmental Noise Evaluation model
EU	European Union
HAPAS	Highway Authorities Product Approval Scheme
HEATCO	<i>Project Acronym:</i> Harmonised European Approaches for Transport Costing and Project Assessment
HRA	Hot-rolled Asphalt
HSA	High Specification Aggregate
IPG	<i>Project Acronym:</i> Innovatieprogramma Geluid (Noise Innovation Programme), the Netherlands
ISO	International Organisation for Standardisation
LCPC	Laboratoire Central des Ponts et Chaussées (Company Name)
LGAP	Local Geodiversity Action Plan
MS	Micro-Surfacing
MSD	Multiple Surface Dressing
NEF	Noise Exposure Factor
NMA	Noise Management Area
NPV	Net Present Value
NTM	National Traffic Model
OBSI	On-Board Sound Intensity
PA	Porous Asphalt
PCC	Porous Cement Concrete
PIARC	World Road Association
PLSD	Paver-Laid Surface Dressing
PSV	Polished Stone Value
RSI	Road Surface Influence (generally written as RSI <sub>H</sub> for high-speed roads and RSI <sub>M</sub> for medium speed roads)
SCRIM	Sideways-force Coefficient Routine Investigation Machine
SEA	Strategic Environmental Assessment
SFC	Sideways Force Coefficient
SILVIA	<i>Project Acronym:</i> Sustainable road surfaces for traffic noise control
SLPA	Single-Layer Porous Asphalt

SMA	Stone Mastic Asphalt
SMTD	Sensor Measured Texture Depth
SPB	Statistical Pass-By (traffic noise measurement)
SPBI	Statistical Pass-By Index
SPL	Sound Pressure Level
SPS	Source Prioritisation Score
SRS	Danish Task Force
TAC	Thin Asphalt Concrete
TLPA	Two-Layer Porous Asphalt
TM	Traffic Management
TMfS	Transport Model for Scotland
TPMAC	Thin Polymer-Modified Asphalt Concrete
TRL	Transport Research Laboratory (Company Name)
TSMA	Thin Stone Mastic Asphalt
UDC	User Delay Costs
ULM	Ultra-thin Mastic Asphalt
WGHEA	EC Working Group on Health and Socio-Economic Aspects
WLC	Whole Life Costing
WTP	Willingness To Pay



## Glossary of terms

**A-weighting:** Human hearing is less sensitive at very low and very high frequencies. In order to account for this, weighting filters can be applied when measuring sound. A-weighting, which provides results often denoted as dB(A), conforms approximately to the human ear.

**Air-pumping:** Air pumping is one of the phenomena implied in tyre/road noise generation. It is created by successive compression and release of air volumes at the entrance and the exit of the tyre/road contact zone. Air pumping noise is reckoned to be radiated in the medium and high frequency range (800 Hz and above).

**Asphalt mat:** The asphalt pavement layer which is a result of the asphalt laying process. This definition applies to both compacted and uncompacted layers.

**Bitumen film:** The covering of binder which surrounds the surface of each aggregate particle within an asphalt mixture.

**Decibel:** The decibel is a unit of level which denotes the ratio between two quantities that are proportional to power; the number of decibels corresponding to the ratio of two amounts of power is 10 times the logarithm to the base 10 of this ratio.

**Delamination:** The loss of a surface treatment or surfacing layer that occurs by the material breaking away in relative large platelets, within which aggregate particles are still stuck together.

**Dense layers:** Road surfaces which have an air-void content of 4-9%.

**Fatting Up:** The migration of the binder (or binder/filler mortar) up through the aggregate skeleton, generally in hotter weather, to form deposits on the surface.

**Frequency:** Inverse of the (shortest) time interval between periodically repeated parts of a sinusoidal signal.

**Fretting:** The loss of aggregate particles from asphalt which leaves adjacent, and therefore (partially) unsupported, particles more susceptible to also be lost.

**Hertz (Hz):** Unit of frequency, equal to one cycle per second.

**Microtexture:** (1) Surface irregularities of a road pavement with horizontal dimensions ranging between 0 and 0.5 mm and vertical dimensions between 0 and 0.2 mm. Microtexture is related to the asperities of the coarse aggregate, the sand particles and the road surface in contact with the rubber of tyres. It makes the surface feel more or less harsh but is normally too small to be observed by the eye (PIARC). (2) Deviation of a pavement surface from a true planar surface with the characteristic dimensions along the surface of less than 0.5 mm, corresponding to texture wavelengths up to 0.5 mm expressed as one-third-octave centre wavelengths (ISO, CEN).

**Macrottexture:** (1) Surface irregularities of a road pavement with horizontal dimensions ranging between 0.5 and 50 mm and vertical dimensions between 0.2 and 10 mm. Macrottexture is related to aggregate size, mixture design and laying (compaction), as well as to the surface treatment applied (if any). It has wavelengths in the same order of size as tyre tread elements in the tyre-road interface (PIARC); (2) Deviation of a pavement surface from a true planar surface with the characteristic dimensions along the surface of 0.5 mm to 50 mm, corresponding to texture wavelengths with one-third-octave bands including the range 0.63 mm to 50 mm of centre wavelengths (ISO, CEN).

**Megattexture:** (1) Surface irregularities of a road pavement with horizontal dimensions ranging between 50 and 500 mm and vertical dimensions between 10 and 50 mm. This type of texture has wavelengths in the same order of size as a tyre-road interface (PIARC); (2) Deviation of a pavement surface from a true planar surface with the characteristic dimensions along the surface of 50 mm to 500 mm, corresponding to texture wavelengths with one-third-octave bands including the range 63 mm to 500 mm of centre wavelengths (ISO, CEN).

**Noise:** Unwanted sound.

**Open layers:** Road surfaces which have an air void content greater than 19%; these are also referred to as 'porous layers'.

**Porosity:** Synonymous with void content, i.e. the ratio of the volume of voids to the whole volume of the mix (generally expressed as a percentage).

**Power train noise:** See 'Propulsion noise'.

**Propulsion noise:** Noise generated by those sources which are controlled by *engine speed*: These sources include the power unit (engine, air inlet and exhaust), cooling fan and transmission (gearbox and rear axle). Propulsion noise is often referred to as "power train noise".

**Rolling noise:** Noise generated by those sources which are controlled by *road speed*: These sources include tyre/road surface interaction, aerodynamic, body rattle and payload.

**Semi-dense layers:** Road surfaces which have an air void content of 9-14%.

**Semi-open layers:** Road surfaces which have an air void content of 14-19%.

**Surface texture:** (1) Surface irregularities of a road pavement with horizontal dimensions ("wavelengths") ranging between 0 and 500 mm. Note: texture is divided into microtexture, macrotexture and megatexture (ISO). (2) Deviation of a pavement surface from a true planar surface, with a texture wavelength less than 0.5 m (ISO).

**Tyre/road noise:** Noise generated by the interaction of vehicle tyres with the road surface.

**Unevenness:** (1) Surface irregularities of a road pavement with horizontal dimensions greater than 500 mm and vertical dimensions exceeding the tolerance of the design specifications. Note: unevenness is usually identified in two forms: longitudinal or transverse. The former is associated with riding comfort and the latter with rutting (ISO). (2) Deviation of a pavement surface from a true planar surface with the characteristic dimensions along the surface of 0.5 m to 50 m, corresponding to wavelengths with one-third-octave bands including the range 0.63 m to 50 m of centre wavelengths (ISO, CEN).

**Vehicle noise:** Noise generated by all sources on a vehicle. These sources are generally sub-categorised as 'rolling noise' sources and 'propulsion noise' or 'power train noise' sources.

## Executive summary

The EU Environmental Noise Directive (2002/49/EC; END) requires Member States to produce Noise Action Plans which, amongst other things, aim to reduce environmental noise where necessary. The Scottish Government has produced Noise Action Plans which have been published on the Scottish Government Website. Road and rail noise reduction methods need to be evaluated and, in the case of the former, one potential option is the use of low-noise surfaces.

The Scottish Government commissioned the Transport Research Laboratory (TRL) to undertake a review of the different low-noise road surfaces currently available and comment on their relevance and suitability for use in Scotland taking into account not only acoustic performance but also the following factors:

- Safety and skid resistance
- Structural durability
- Environmental sustainability
- Whole life costing

An important part of the work was to include the views of the various stakeholders particularly those local authorities who have had experience in using low-noise surfaces.

Based on the findings of this review, the following conclusions are drawn:

### **The potential acoustic benefits of using low-noise road surfaces in Scotland**

While noise reduction benefits are not, as yet, considered a major factor for Local Authorities when selecting road surface material (see below), it is important to first assess the potential acoustic benefits of using low-noise road surfaces in the Candidate Noise Management Areas (CNMAs) identified in the Action Plans. Based on modelling scenarios, the following potential benefits have been identified:

- For the CNMAs within the Edinburgh and Glasgow agglomerations, noise modelling has shown that replacing an HRA (Hot Rolled Asphalt) surface with a TSMA (Thin Stone Mastic Asphalt) surface would achieve an initial reduction of between 1 to 4 dB(A) depending on the mean traffic speed (10 to 60 km/h – 5 to 40 mph) and traffic composition. These reductions are found to be independent of aggregate size in the range 6 to 14 mm
- For the CNMAs associated with the major road routes, similar reductions are estimated as above for the agglomerations where mean traffic speeds are below 60 km/h (40 mph). As mean traffic speeds increase, higher reductions are estimated and found to be dependent on aggregate size, at 110 km/h (70 mph) reductions of 4, 5 and 6 dB(A) as aggregate size decreased from 14, 10 and 6 mm, respectively

### **The current experiences of Scottish local authorities**

The survey of local authorities identified the following key points:

- The materials commonly used for road surfaces in Scotland are Hot Rolled Asphalt (HRA) Thin Stone Mastic Asphalt (TSMA) and Dense Bitumen Macadam (Bitmac/DBM)
- It was clearly indicated that noise reduction benefits are not, as yet, considered a major factor when selecting road surface material
- Most local authorities report that HRA is considered to be the most cost-effective surface material. Although the initial costs are higher, there is a longer life

expectancy than for TSMA which means less maintenance and therefore reduced costs in the longer term

- All local authorities reported problems with the structural durability of TSMA

### **Advice on using low-noise road surfaces in Scotland**

It is important to recognise the need to strike the balance between policy, practical and financial considerations.

Information on both acoustic performance and non-acoustic characteristics has been summarised in an Acoustic Performance Assessment Table (APAT), providing an indicative evaluation of surface types. This includes assessing typical noise reductions for a range of traffic speed/composition combinations.

More detailed assessments of surface selection by experienced practitioners and/or appropriate experts in the relative fields would be required as part of the design process prior to implementation for a specific situation.

### **Supplementary information on low-noise road surfaces**

#### *Acoustic performance*

Experience in the UK on the acoustic performance of low-noise surfaces in general has shown that when initially open to traffic significant reductions in overall traffic noise can be achieved compared with 20 mm HRA (the standard UK reference surface). The following additional comments can be made:

- *Initial noise reductions:* Single layer porous asphalt surfacings have been shown to achieve reductions in traffic noise levels of about 6 dB(A) on high speed roads with corresponding reductions of between 2 to 5.5 dB(A) for thin surfacings. Corresponding comparisons from research carried out in other countries generally support these findings although direct comparisons are difficult to establish because of variations in reference surfaces and measurement methods. Trials of twin-layer porous surfaces in the Netherlands have shown noise reductions are generally of the order of 2 dB(A) greater than that achieved on single layer porous surfacings.
- *Acoustic durability:* Research carried out in the UK and in other European countries demonstrates that the acoustic performance of all surface types deteriorates with the age of the surface. Generally, it has been shown that there is a simple linear relationship between noise increase and age. Different surface types deteriorate at different rates; existing/ongoing research suggests the following:
  - *Dense surfaces:* For surfacings such as 20 mm HRA the acoustic deterioration is approximately 0.2 dB(A) per year for high speed roads
  - *TSMA-type thin surfacings:* The acoustic deterioration is approximately 0.5 dB(A) per year
  - *Porous asphalt (PA) surfacing:* These deteriorate with age at a similar rate as thin surfacings when used on high-speed roads, but for low speed roads the deterioration for light vehicles is increased to approximately 0.9 dB(A) per year.

The reasons for the increase in noise with age are not fully understood and could be confounded by factors relating to changes in vehicle design or, more likely, changes in tyre design over the past 10 to 15 years.

### *Safety and skid resistance*

Skid resistance is probably the road surface characteristic of the greatest importance in relation to safety since it directly influences drivers' ability to control their vehicle. On a wet road, as a vehicle's speed increases, the available grip decreases. The texture depth of the road surface is an important factor and surfaces with low texture depth tend to offer much less grip at higher speeds. A feature of noise reducing surfaces is that they tend to have lower texture depth than traditional materials and there are therefore concerns about their potential safety performance, especially on high-speed roads. Research has shown that low-noise surfaces can be made with adequate skid resistance performance but they can sometimes be less durable than traditional surfacings. Early-life skid resistance can be affected by the film of bitumen binder that occurs on new low-noise surfaces. Typically, this film wears away in about six months on well-trafficked roads. On remote and lightly-trafficked routes, such as can be found in Scotland, the effects could be long lived and present a potential increased accident risk, albeit small, over a longer period.

Transport Scotland is currently trialling the performance of new SMA surfacings with a dense structure and small aggregate particles. These surfacings should have comparable durability with HRA, whilst providing good noise attenuation, making them more suitable for use on parts of the trunk road network. Included in these trials are investigations into methods of improving early-life skid resistance.

Investigations for improving early-life skid resistance have also been undertaken on twin-layer porous asphalt surfaces in the Netherlands.

Low-noise surfaces can lead to a reduction in spray generated by vehicle tyres and this is a potential safety advantage of such surfaces. However, in heavier rain, the texture on some types of low-noise surfacings can be rapidly flooded; this might have implications for an increased risk of aquaplaning (if adequate surface levels are not designed), which is relatively rare on older types of surfacing.

It has also been speculated that low-noise surfaces could lead to increased risks because of the way in which drivers might respond. For example, the quiet, smooth ride that these surfaces offer could lead some drivers to increase speed. This could negate any advantages of improved skid resistance (such as might be offered by smaller aggregates) or exacerbate the effects that are already known, thus increasing skidding accident risks.

### *Structural durability*

The main defects that occur in asphalt surfacings are, in order of frequency, fretting (the loss of aggregate particles from the asphalt) and cracking. Knowledge as to when the defects will lead to failure is limited because there are so many issues that affect the durability. However, the principal issues associated with helping to improve durability are producing a dense, well compacted layer (which usually needs a high binder content and small nominal aggregate size), good bonding between layers, good bonding of joints and well-maintained drainage. However, it should be noted that optimising for durability may not be consistent with optimising for skid-resistance and/or noise-reduction. Poor weather conditions during paving, e.g. rainfall and low temperatures, are also a factor that can affect structural durability.

### *Environmental sustainability*

The use of low-noise surfacings (both thin surfacings and porous asphalt) have been compared with the use of HRA and the following conclusions drawn:

- In-use vehicle emissions from the road network would not be significantly affected by the use of low-noise surfacings

- In relation to resource use, the use of low-noise surfacings (thin surfacings in particular) requires higher overall use of high specification aggregate (HSA) relative to HRA, and therefore more pressure is exerted on HSA resources. Concentrated use of one source of aggregate over another can also affect geodiversity. Scotland is well resourced in terms of quarries which can supply HSA, therefore there should be no exceptional transport impacts associated with the supply of material to use in thin surfacings
- Some of the pressure on HSA resources can be relieved by optimising the recycling of thin surfacings back into thin surfacings which is a viable option
- The low durability of some low-noise surfaces (particularly porous asphalts) in relation to HRA is a factor which can also increase environmental impacts

### **Cost-benefit analysis and whole life costs**

#### *A review of cost-benefit analysis*

A selection of reports including cost-benefit analyses of alternative pavement surfacing options has been reviewed to identify the different ways in which noise impacts and any other costs were considered within the analyses.

The monetary values of noise are generally based on the 'annoyance' caused. The negative impacts of high noise levels on health have also been considered, but this is generally a percentage increase to the monetary value assigned rather than a separate calculation. The monetisation of noise is based either on the indirect effects on house prices or direct willingness-to-pay surveys.

Although some methodologies calculate the benefits of low-noise surfaces on a 'per vehicle kilometre' basis, most concentrate on benefit per household. This usually involves comparing dwelling density maps with noise propagation models to calculate the number of residences affected by a certain level of noise. In Denmark, a Noise Exposure Factor calculated as the weighted sum of the noise loads on individual dwellings has been used to calculate the overall impact.

The other costs considered in the analyses varied between the case studies. Some simply considered general works and ongoing maintenance costs, whereas other more detailed analyses included initial construction, maintenance and user delays as well as cleaning, alert costs and special winter maintenance.

#### *Whole life costs*

Over the last few years there has been a move, particularly in the public sector, towards appraising investment options on the basis of whole life cost rather than just the initial cost. Whole-life costing (WLC) is the systematic consideration of all projected significant and relevant costs incurred by an asset over a period of analysis expressed in monetary terms. An approach to incorporate the effects of noise within the WLC framework has been developed. The approach is built around the DfT tables (in webtag) containing monetary values assigned to changes in noise level. This is currently a framework within which comparisons of different options can be carried out but it provides a basis for a comprehensive modelling of the effects of noise and demonstrates the feasibility of such analyses.

Some simplified 60-year WLC analyses have been carried out to demonstrate the potential benefits of low-noise surfaces. In the particular examples considered, the combined works, traffic management and user delay costs of the lower-noise surfacings is higher than traditional HRA options but when the monetised benefit of reduced noise levels is taken into consideration, the position is reversed.

It should be noted that the test analyses make assumptions that may not be appropriate for all cases. The actual benefits (or otherwise) of low-noise surfaces will vary depending on location- and scheme-specific factors. Some of the relationships used (e.g. between surface condition and noise) have not been formally investigated; more research would be required before the modelling can be considered comprehensive and robust.

### **Recommendations for further investigations**

Experience using thin layer surfacings elsewhere within the UK differ from those noted by some Scottish Local Authorities, and are in general more positive. For such surfaces to be successfully used by all Local Authorities in Scotland, further investigation is required to understand the reasons for the poor structural durability noted by Scottish Local Authorities in these cases. For such surfaces to be successfully applied in Scotland, further investigations are required to understand the reasons for the poor structural durability observed in Scotland in many cases.

The Acoustic Performance Assessment Table (APAT), based on traffic speed/composition, has been derived based on a limited dataset. Further work is necessary to expand the table for a wider range of surface types or individual proprietary products available for use in Scotland.

Consideration needs to be given as to whether HRA is suitable for continued use as a reference surface. If there is a significant reduction in the usage of HRA over time, a reference surface which is representative of the current most commonly used surface may be more appropriate. Whilst a change in the standard reference surface is a wider, UK issue (since the reference is defined in the standard UK traffic noise prediction model, CRTN), local conditions may influence the choice of reference surface for Scotland. Within the European HARMONOISE project, a virtual reference was proposed which would allow all European member states to use a common reference; such an approach might need to be considered.



## 1 Introduction

Under the terms of the European Directive on the assessment and management of environmental noise (END; 2002/49/EC), all Member States were required to produce strategic noise maps for major agglomerations and major roads, rail, airports, and industry (including port area if appropriate) by the end of June 2007. In Scotland, the Directive has been transposed into the Environmental Noise (Scotland) Regulations 2006 and the data, as required under Article 10(2) of the END, was submitted by the Scottish Government on the 19th December 2007 to the European Commission.

In response to the noise maps, the END requires the preparation of Noise Actions Plans which aim to reduce levels where necessary, and to preserve environmental noise quality where it is good. Three Noise Action Plans have been prepared in respect of the Glasgow and Edinburgh agglomerations and major transportation routes (road and rail). However these currently only identify those areas where action is required, and not the methods that will be used to achieve any necessary mitigation. The methods for this will be developed by the working groups set up to prepare and deliver the Action Plans, and supported by Technical Guidance. Road and rail noise reduction methods need to be evaluated and, in the case of the former, one potential option is the use of low-noise surfaces.

The Scottish Government has commissioned the Transport Research Laboratory to undertake a review of the different low-noise road surfaces currently available and comment on their relevance and suitability for use in Scotland taking into account the factors shown in Figure 1.1.



**Figure 1.1: Factors associated with low-noise surfaces investigated in this report**

The review includes taking account of the views of the key stakeholders, namely

- Transport Scotland, who play an important role in transport delivery, both nationally and internationally. They work in partnership with other transport providers and wider government in their planning and delivery.
- Those Local Authorities who have had experience in using low-noise surfaces.

This report presents the findings from this review and is structured as follows:

- PART 1 discusses the potential implications of using low-noise road surfaces as a mitigation tool within Scottish Noise Action Plans and presents the results of a survey of local authority experiences with using such surfaces. Advice on how to make a preliminary selection of appropriate low-noise surfaces is also set out, based on indicative acoustic and non-acoustic characteristics
- PART 2 of the report provides further information should the reader seek a greater understanding of the issues associated with low-noise surfaces. It describes the mechanisms of traffic noise generation, the properties of the road surface which affect noise generation, and the methods that are currently available for the assessment of surfaces. An overview of the different low-noise surface technologies that are presently available is presented together with information on their acoustic performance (in terms of initial noise reduction and acoustic durability). Information is also presented on the factors identified above, i.e. safety and skid resistance, structural durability, and environmental sustainability
- PART 3 of the report provides an overview of cost-benefit analysis and whole life costs analysis, in terms of how such methodologies might be applied. The text is not specific to low-noise surfacing, but such surfaces are included in any examples
- The Appendices within the report present further information on tyre/road noise generation, how traffic noise is assessed throughout the EU and the individual questionnaire responses from the local authority consultations.

# **PART 1**

## *Advice on low-noise road surfaces for use in Scotland*

Part 1 discusses the potential implications of using low-noise road surfaces as a mitigation tool within Scottish Noise Action Plans and presents the results of a survey of local authority experiences with using such surfaces. Advice on how to make a preliminary selection of appropriate low-noise surfaces is also set out, based on **indicative** acoustic and non-acoustic characteristics.



## 2 The impact of low-noise surfaces in Scotland

This section provides feedback from Local Authorities with experience in using low-noise surfaces in Scotland. This is followed by a section on the impact of low-noise surfaces on Noise Action Plans as part of the EU Environmental Noise Directive (END).

### 2.1 Current experience

The Roads and/or Transportation Departments of all 32 Local Authorities in Scotland were contacted and a survey was undertaken via telephone calls. Responses were obtained from 27 of the 32 Local Authorities. Copies of all responses are included in Appendix C. It was found that, in general, most Departments were aware that there were some requirements imposed on them in terms of the END in the long term, i.e. during the second round of noise mapping. However nearly all the Departments stated that no strategic action was currently being taken to assess or reduce noise levels and that noise pollution did not factor highly into their decision making when specifying road surfacing.

*Prior to summarising the results of the survey it is stressed that the responses do not appear to be on the basis of Local Authority policy decisions but represent the general consensus of staff within the authorities deemed to have experience in this area.*

The survey revealed that the materials commonly used in road surfacing are Hot Rolled Asphalt (HRA), Thin Stone Mastic Asphalt (TSMA) and Dense Bitumen Macadam (Bitmac/DBM).

Most Departments report that HRA is the most cost-effective surface material. It was believed that, although the initial costs are higher, there is a longer life expectancy for HRA than TSMA which means less maintenance and therefore reduced costs in the longer term.

All Local Authorities reported problems with the durability of TSMA. Most local authorities found that TSMA required maintenance two years after laying, with the greatest life expectancy being six years. The Local Authorities did state that TSMA had lower installation costs but that the subsequent maintenance led them to favour the more conventional HRA. DBM is used in some of the more rural authorities e.g. Authority #20 and Authority #24. It is used in these areas due to the fact that asphalts are not best suited to the prevailing weather conditions. In addition it is easy to lay and is treated with a surface dressing 2 years after being first laid, and then is treated when required.

The Local Authorities were asked about experience/concerns with the manufacturing/procurement of material/specification of lower noise surfaces compared with traditional surfaces. It was reported that there are no real problems with the manufacturing of material except for Local Authority #5 where there is only one supplier. Local Authority #19 advised that the aggregate type present in the west of Scotland could be accountable for the poor life expectancy of TSMA. In relation to procurement all Local Authorities will, where possible, source material from quarries located within their own area. However some have entered in to an agreement with TARMAC to supply all their materials and others have a contract with the Scottish EXCEL group for the procurement of materials. When specifying materials all Local Authorities follow the guidelines set out in DMRB (Design Manual for Roads and Bridges) augmented with practical experience, research, industry guidance and acquired local knowledge.

Construction issues were highlighted by two Local Authorities, namely Local Authority #4 and Local Authority #5. Local Authority #4 claim to have inherited poorly constructed roads and have problems with lateral tensions and stiffness, while Local Authority #5 have issues as a consequence of the peaty ground conditions in the areas which provide a poor foundation material.

In summary the Local Authorities do not seem to have any specific statistical information on different types of surfaces (e.g. durability and skid resistance), the majority relying

on SCRIM (Sideway-force Coefficient Routine Investigation Machine information) to provide any information on carriageway defects, all Local Authorities advised that cost, durability and maintenance are all key factors when specifying road surfaces. The noise reduction benefits are not, as yet, considered a major factor when determining road surface material.

## **2.2 The impact on Noise Action Plans**

Under the terms of the (END), now transposed into the Environmental Noise (Scotland) Regulations 2006, all member states were required to produce strategic noise maps for major agglomerations and major roads, rail, airports, and industry (including port area if appropriate) by the end of June 2007. The Scottish Government met this target and the data, as required under Article 10(2) of the END, was submitted by the Scottish Government on the 19th December 2007 to the European Commission. Three Noise Action Plans were submitted in respect of the Glasgow and Edinburgh agglomerations, major transportation routes (road and rail).

The END requires that the Noise Action Plans aim to reduce levels where necessary, and to preserve environmental noise quality where it is good. In order to identify areas that may require noise intervention or management, in what order and by what process a prioritisation matrix was developed. In line with the aim of Article 1 of the END, a prioritisation matrix (using Source Prioritisation Scores, SPSs) has been developed to evaluate strategic noise levels within the first round noise maps in terms of the road and railway sources.

In relation to roads the resultant Source Prioritisation Scores take into account the predicted noise contours at each building, the number of people assumed to live in each building and the annoyance response relative to the transportation source in question. The SPSs for roads are based on the roads being segmented into 100 m sections. For each 100 m section of road every building within the segment is assigned a score based on the predicted noise level, number of people living in that building and the annoyance response; these scores are known as Building Prioritisation Scores (BPSs). Every building (with its associated BPS) then effectively assigns itself to whatever 100 m road section is the closest to it and each of the BPSs within that segment is logarithmically summed to give a resultant SPS.

All the SPSs were then required to be prioritised in a manageable list for consideration in the action planning process. Whilst it is clearly desirable to start with the sources which have the highest SPS the question of *"how high does the SPS have to be before consideration is given in the first round of actions?"* arose. Therefore a basic statistical analysis of the SPSs was undertaken and it was found that the top 1% of SPSs (normally distributed) corresponded to the mean SPS plus two standard deviations. Therefore the top 3% of the road network was identified in terms of the top three 1% bands.

Following the process described above, the number of Candidate Noise Management Areas (CNMAs) within the Edinburgh and Glasgow agglomerations associated with roads and the number of CNMAs identified for major road routes outside of the agglomerations, representing the top 1% of SPSs, are shown in Table 2.1. Included in the Table are the corresponding estimates of the number of people exposed.

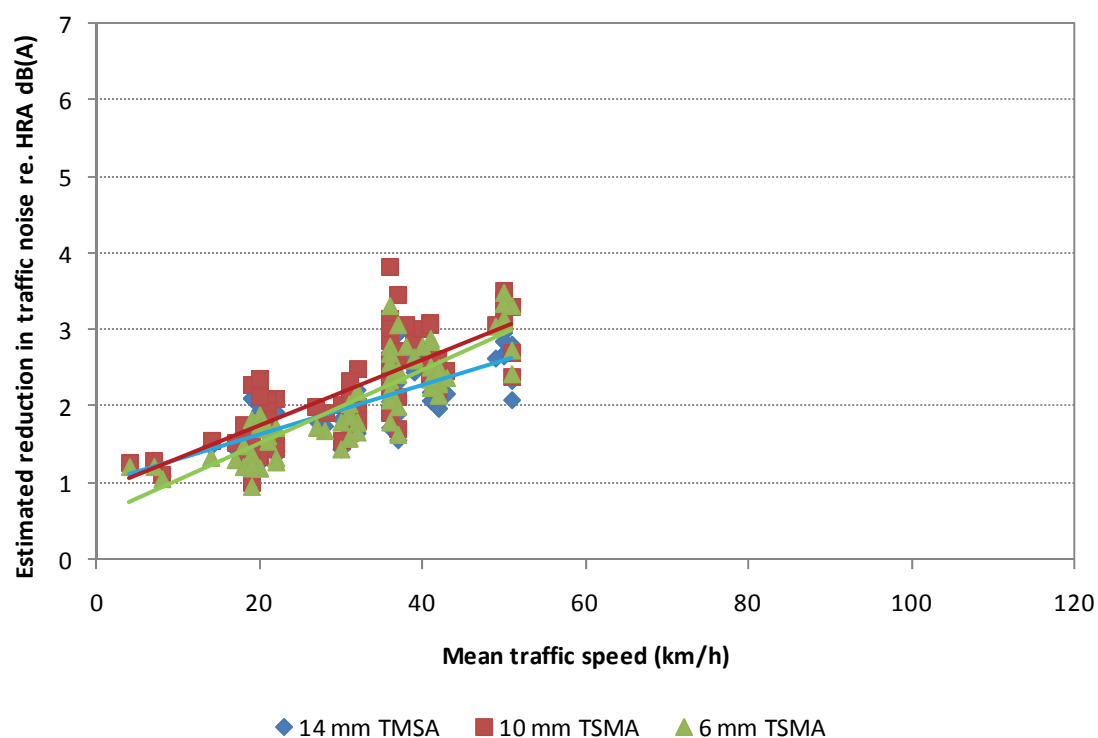
It should be noted that the areas are deliberately not precisely defined. This is because the manner in which CNMAs have been identified is based upon the strategic noise contours and other data, such as population figures, which is less certain at a local level. In addition, during the five years of the Transportation Noise Action Plan, Transport Scotland proposes to conduct an Impact Assessment and Cost Benefit Analysis for each NMA on a trunk road.

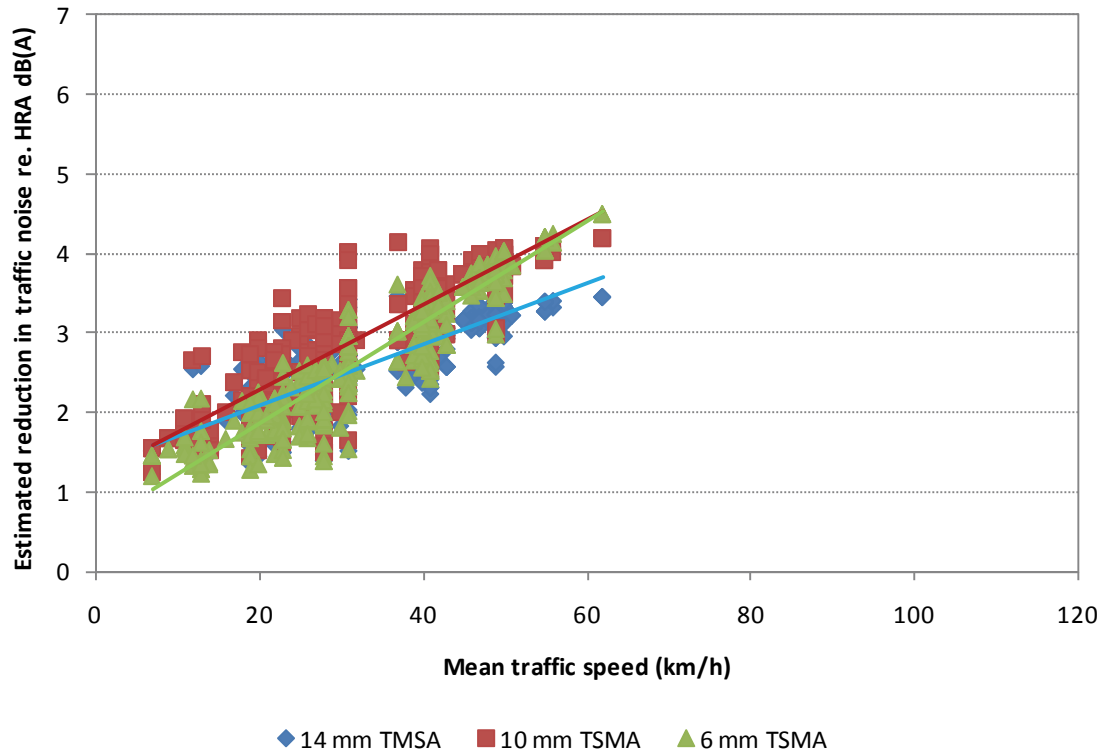
**Table 2.1: Number of CNMAs and estimate of population exposure representing the top 1% of SPS values for roads**

Roads	Number of CNMAs	Estimated population
Edinburgh	19	12,895
Glasgow	42	30,477
Major roads outside agglomerations	38	14,542

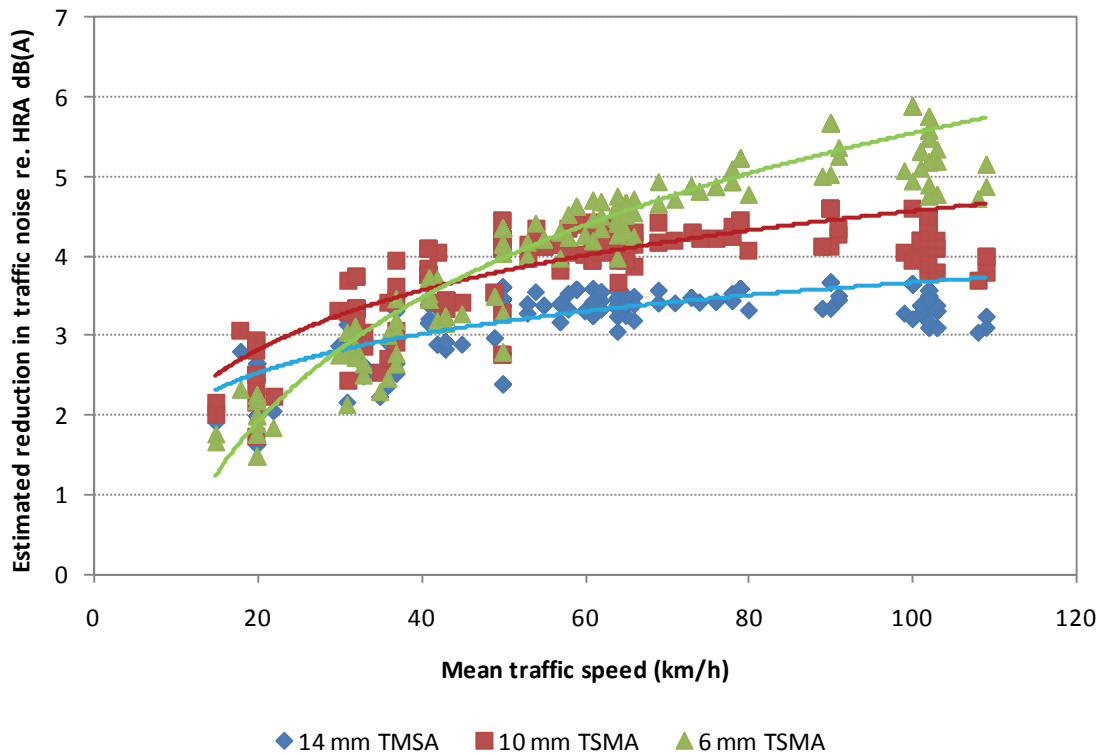
To illustrate the potential impact of mitigation through the use of low-noise surfaces and assuming the roads in the CNMAs are surfaced with a traditional 20 mm HRA (which, in practice, is not always the case), a noise prediction model was developed based on the HARMONOISE/IMAGINE road source model (Peeters and Blokland, 2007).

Figure 2.1 - Figure 2.3 show the estimated reductions in traffic noise levels for each of the CNMAs for the Edinburgh and Glasgow agglomerations and road routes outside of the agglomerations, respectively. A linear regression of the estimated reduction in traffic noise with mean speed for each surface type is shown for the two agglomerations but for the major routes a logarithmic relationship with speed was found to give a better correlation due to the greater range in speeds found for the major routes CNMAs.

**Figure 2.1: Estimated noise reductions for Edinburgh CNMAs**



**Figure 2.2: Estimated noise reductions for Glasgow CNMAs**



**Figure 2.3: Estimated reductions for Major Road Routes CNMAs**

For the Edinburgh CNMAs, the estimated reductions after replacing an HRA surface with 14 mm, 10 mm and 6 mm TSMA are shown in Figure 2.1 plotted against the mean traffic speed for each CNMA. For the range of surfaces examined, the general trend is similar; as the mean speed increases the estimated reduction in traffic noise increases due to the increase in tyre/road noise with speed. The variation in the estimated reduction in noise is due to differences in the number of heavy vehicles in the traffic flow at each site. As the percentage of heavy vehicles increases the influence of tyre/road noise on overall traffic noise is reduced. The estimated reductions in traffic noise levels range from about 1 dB(A) at mean speeds less than about 10 km/h to about 3 dB(A) where the mean speed is about 50 km/h. These reductions appear not to be dependent on aggregate size.

A similar trend is shown in Figure 2.2 for the Glasgow CNMAs. However, the estimated reductions are a little higher, ranging from about 1 dB(A) at 10 km/h to about 4.5 dB(A) at about 60 km/h. A possible reason why the reductions in Glasgow are a little higher than those in Edinburgh is that on average the percentage of heavy vehicles at the CNMA sites in Edinburgh were about twice that at the corresponding sites in Glasgow. Again, as with Edinburgh, there does not appear to be any significant differences in noise reduction across the different surfaces examined.

For the major road route CNMAs (Figure 2.3), noise reductions compared with HRA are again shown to be speed dependent. For speeds below 60 km/h, average reductions in noise increases from about 2 dB(A) at 20 km/h to about 4 dB(A) at about 60 km/h which are marginally higher compared with the reductions found in the agglomerations, particularly at the lower speeds which may be attributed to the higher percentage of heavy vehicles in the agglomerations compared with the major road routes. Again, as for the agglomerations, there appears to be no discernable difference in acoustic performance with aggregate size.

For speeds in excess of about 60 km/h, the acoustic performance of the surfaces begin to show a dependence on aggregate size. At speeds of about 110 km/h, the 6 mm TSMA shows reductions of about 5.5 dB(A), the 10 mm SMA shows reductions of about 5 dB(A) and the 14 mm TSMA shows reductions of about 4 dB(A). These reductions are similar to that derived from the SPB surveys shown in Figure 7.1 when comparing surfaces when relatively new.

The assessment of the acoustic performance of low-noise surfaces at the CNMA sites described above has used input data based on surfaces when relatively new. Clearly, in practice, mitigation through the use of low-noise surfaces would be replacing older surfaces having higher noise levels than that used in the above assessment (see Section 7.1). Initially, therefore, the acoustic performance of the low-noises may be marginally higher than that indicated above and dependent on the age of the replaced surface and its condition.

Preliminary results from work carried out by TRL and supported by work recently published in the EU (see Section 7.2) indicate that the performance of thin surfacings such as TSMA deteriorate at the rate of about 0.5 dB(A)/year compared with about 0.2 dB(A)/year for dense surfacings such as HRA. This relative difference means that, for example, if the noise reduction in replacing an old HRA surface with a low-noise TSMA is 3 dB(A), then after 10 years of trafficking the noise level would be the same had the surface not been replaced.

## SUMMARY

The possible impacts of the use of low-noise surfaces in Scotland have been considered taking into account the results of a telephone survey of the Roads and/or Transportation Departments in the 32 Local Authorities in Scotland.

The responses from 27 Departments revealed that the materials commonly used in road surfacing are Hot Rolled Asphalt (HRA), Thin Stone Mastic Asphalt (TSMA) and Dense Bitumen Macadam (Bitmac/DBM).

Most Departments report that HRA is the most cost-effective surface material. Although the initial costs are higher there is a longer life expectancy than SMA which means less maintenance and therefore reduced costs in the longer term.

All Departments reported problems with the durability of SMA.

It was clearly indicated that noise reduction benefits are not, as yet, considered a major factor when determining road surface material.

It is important for Local Authorities to consider the implications of the use of quieter road surfaces in the Candidate Noise Management Areas (CNMAs) identified in the Action Plans submitted to the European Commission by the Scottish Government in respect of the requirements of the Environmental Noise Directive (2002/49/EC) (END).

In respect of the likely benefits of the use of quieter road surfaces in the identified CNMAs, application of a noise prediction model has shown the following:

- For the CNMAs identified in the Edinburgh and Glasgow agglomerations, replacing an HRA surface with a TSMA surface would achieve an initial reduction of between 1 to 4 dB(A) depending on mean traffic speed (10 to 60 km/h – 5 to 40 mph) and traffic composition. These reductions are found to be independent of aggregate size in the range 6 to 14 mm
- For the CNMAs associated with the major road routes, similar reductions are estimated as that described above for the agglomerations where mean traffic speed were below 60 km/h (40 mph). As mean traffic speeds increased, higher reductions are estimated and found to be dependent on aggregate size, at 110 km/h (70 mph) reductions of 4, 5 and 6 dB(A) as aggregate size decreased from 14, 10 and 6 mm, respectively

### 3 Advice on low-noise surfaces for use in Scotland

It is important to recognise the need to strike the balance between policy, practical and financial considerations. In this regard, the authors recognise that decisions on material choice will be made by the appropriate road authorities, including Transport Scotland and the Local Authorities.

The advice given in this Chapter provides **indicative performance information** based on a review of research carried in the UK and other European countries.

Section 3.1 provides an overview of surface performance in terms of both structural and acoustic durability, skid resistance, whole life costs and sustainability.

Section 3.2 outlines a method for estimating the impact of mitigating noise by replacing an existing surface, for example HRA, with a low-noise road surface.

#### 3.1 Overview of road surface performance information

The aim here is to provide guidance to assist the process of selecting appropriate surface types. This advice can only be very general. For specific situations a more detailed assessment for surface selection would need to be carried out by experienced practitioners using appropriate codes, standards, and guidance.

For general comparative purposes, surfaces have been grouped into categories with similar acoustic performances, as follows:

- Reference surfaces: Hot Rolled Asphalt (HRA)
- *Dense surfaces*: Dense Asphaltic Concrete (DAC), Dense Bitumen Macadam (DBM), Stone Mastic Asphalt (SMA), Mastic Asphalt (MA) and Exposed Aggregate Concrete (EAC)
- Thin surfacings: Paver-laid Surface Dressing (PLSD), Thin Asphalt Concrete (TAC), Thin Stone Mastic Asphalt (TSMA), Multiple Surface Dressing (MSD) and Micro-surfacing (MS)
- Porous Asphalt I: Single Layer Porous Asphalt (SLPA)
- Porous Asphalt II: Two-Layer Porous Asphalt (TLPA)

Table 3.1 provides a brief overview of road surface performance for medium- to high-speed roads i.e. for roads with a speed limit in excess of 30 mph, in terms of various important characteristics, relative to the reference surfaces HRA or BC. The table has been compiled based on information contained both within this report and other documents, e.g. Andersen *et al.* (2006) and Morgan *et al.* (2007).

It is important to know that this information is only intended to provide a **general indication of performance**.

In addition to the notes appearing beneath the table itself, the following notes also relate to specific columns of the Table:

*Estimated Reduction in Traffic Noise<sup>1</sup>*: The reduction in traffic noise compared to the acoustic performance when the surfaces are relatively new. The reductions in traffic noise compared with the reference surface provide a range of values dependent on traffic speed and composition. The higher reductions in each range relate to higher speed roads with less than about 10% heavy vehicles i.e. commercial vehicles with unladen weight exceeding 3.5 tonnes. For lower speed roads with a speed limit of 30 mph or less the reduction in traffic noise will be generally lower than those shown in Table 3.1.

<sup>1</sup> Reductions in traffic noise levels relate to either the  $L_{Aeq,T}$  or  $L_{A10,T}$  noise indices.

**Table 3.1: Indicative overview of road surface performance for medium- to high-speed roads**

Surface category	Surface type	Estimated reduction in traffic noise dB (A) <sup>1</sup>	Durability		Skid resistance	Whole life cost		Environmental Sustainability
			Acoustic (years)	Structural (years)		Incl. noise	Excl. noise	
Reference	HRA, BC	0	0	> 20	0	0	0	0
	DAC, DBM							
Dense	SMA, MA, EAC	2 – 3	10 – 30	> 20	0/- <sup>2</sup>	+	-	0
	PLSD, TAC, TSMa, MSD, MS	3 – 6	6 – 15	7 – 15	0/+ <sup>3</sup>	+	-	-
PA I	SLPA	5 – 6	10 – 15	10	+ <sup>3</sup>	-	-	-
PA II	TLPA	6 – 7	10 – 15	7-10	X	XX <sup>4</sup>		-

*Key to nomenclature for skid resistance, whole life costs and environmental sustainability:*

- 0** Performance similar to reference surface; **+** Performance better than reference;
- Performance worse than reference; **X** Comparison could be achieved but no information available;
- XX** Comparison not possible

*Accompanying Notes* (further notes are also included the main text of the report):

- <sup>1</sup> The noise reduction results in the table are derived from a report prepared as part of the SILVIA project (Andersen *et al.*, 2006) which compiles European experiences on a range of surfaces. In the case of PA II, for individual vehicle categories there is a wide variation in the performance which is a result of the wide specification of aggregate sizes for that surface type.
- <sup>2</sup> Provided that appropriate PSV aggregate is used, low-speed skid resistance will be similar. For some, high-speed skid resistance may be worse because texture depths tend to be low
- <sup>3</sup> Provided that appropriate PSV aggregate is used and appropriate texture depth levels are maintained. Some new experimental designs may perform better than the reference surface, but research is ongoing
- <sup>4</sup> No UK experience with twin-layer porous asphalt

*Acoustic Durability:* For the purposes of comparing the acoustic performance of road surfaces, acoustic durability is defined in the following way. If a road surface is replaced by a reference surface the overall traffic noise level is given by  $L_{ref}$ . However, if a lower noise surface is used the overall traffic noise is  $L_{low}$ . The acoustic durability of the lower noise surface is defined as:

$$\text{AcousticDurability} = \frac{L_{ref} - L_{low}}{R_{low}} \text{ years} \quad (3.1)$$

where

$L_{ref} - L_{low}$  = Estimated reduction in traffic noise (Table 3.1) and

$R_{low}$  is the rate traffic noise increases per year from traffic on the lower noise road surface due to age effects.

This definition assumes the following rates of change in noise with age based on the work described in Chapter 7:

- *Dense surfaces:* 0.1 to 0.2 dB(A)/year
- *Thin surfacing:* 0.4 to 0.5 dB(A)/year
- *Porous Asphalt I:* 0.4 to 0.5 dB(A)/year
- *Porous Asphalt II:* 0.4 to 0.5 dB(A)/year

*Structural durability:* This will be the typical structural durability observed for the most heavily trafficked lanes.

*Skid resistance, whole life costs and sustainability:* The following nomenclature is used to provide a qualitative analysis for these characteristics:

- 0 Performance similar to reference surface
- + Performance better than reference
- Performance worse than reference
- X Comparison could be achieved but no information available
- XX Comparison not possible

### 3.2 Multiple scenario evaluation of acoustic performance

Table 3.1 provides broad indications of the reductions in traffic noise that might be achieved using these different types of low-noise road surface. However, since traffic conditions may vary considerably from one scenario to another, it is considered that it may be more beneficial to consider acoustic performance for a range of different traffic conditions and traffic compositions (% heavy vehicles). This would provide stakeholders with a quick means of undertaking a preliminary evaluation of acoustic performance. Considering performance in terms of speed and composition is more representative of the approach used to assess the effects of mitigation measures for noise action plans.

Using the same broad surface categories as presented in Section 3.1, an Acoustic Performance Assessment Table (APAT) has been derived. This is presented in Table 3.2 and provides indicative noise reductions for a range of mean traffic speeds, covering low-, medium- and high-speed roads, considering six different traffic compositions in each case. The results have been calculated using a noise prediction model based on the HARMONISE/IMAGINE road source model (Peeters and Blokland, 2007), as in Section 2.2, and are expressed relative to an HRA reference surface.

These results are based on a limited number of surfaces within each category, and are therefore average values and not definitive indications of acoustic performance.

**Table 3.2: Acoustic Performance Assessment Table (APAT)**  
(Noise reductions, relative to HRA, for different road surface categories as a function of mean traffic speed and traffic composition)

Mean Traffic Speed	Surface Type	Estimated reduction in Traffic Noise Level dB(A) for range of traffic compositions (% heavy vehicles) re. HRA					
		0	5	10	20	30	40
20 mph	DENSE	4.1	3.4	2.8	2.2	1.8	1.5
	THIN	3.6	3.0	2.6	2.0	1.7	1.4
	PA I	1.8	1.6	1.4	1.1	1.0	0.9
	PA II	3.5	2.8	2.3	1.8	1.4	1.1
30 mph	DENSE	4.5	4.0	3.5	2.9	2.4	2.0
	THIN	4.2	3.7	3.3	2.7	2.3	1.9
	PA I	3.4	3.1	2.8	2.3	1.9	1.7
	PA II	4.6	4.1	3.6	2.9	2.4	2.0
40 mph	DENSE	4.7	4.3	3.9	3.3	2.8	2.4
	THIN	4.4	4.1	3.7	3.2	2.7	2.3
	PA I	4.7	4.3	4.0	3.4	2.9	2.6
	PA II	5.4	5.0	4.5	3.9	3.3	2.9
50 mph	DENSE	4.7	4.3	4.0	3.4	2.9	2.5
	THIN	4.6	4.3	3.9	3.4	2.9	2.5
	PA I	5.7	5.3	4.9	4.2	3.7	3.3
	PA II	6.0	5.6	5.2	4.5	4.0	3.5
60 mph	DENSE	4.7	4.4	4.1	3.5	3.0	2.6
	THIN	4.7	4.4	4.1	3.6	3.1	2.7
	PA I	6.5	6.1	5.7	5.0	4.4	3.9
	PA II	6.5	6.1	5.8	5.1	4.6	4.1

It should also be noted that all of these performances are assessed against a *new-condition* HRA.

The values for estimated noise reductions shown in the Table are conservative (since no allowance has been made for age-related deterioration of the existing surface) and the initial attenuation may therefore be higher than shown. To take account of the age of the surface being replaced, the following relationship can be used to modify the reductions presented in Table 3.2:

$$\text{Noise reduction at time of opening} = C + 0.2A \text{ dB(A)} \quad (3.2)$$

where  $C$  is the noise reduction value from Table 3.2 and  $A$  is the age (in years) of the HRA when replaced.

It should be noted that the rate of ageing is assumed to be independent of road speed category and trafficking. Furthermore, no allowance is made for any effects related to changes in vehicle and tyre design over the past 10 to 15 years.

This argument generally holds regardless of the existing (failed) surface type, although the rate of ageing will be different, since the failed surface is likely to have been laid for some time and will therefore be noisier than when newly laid.

### **3.3 Cost-benefit analysis tools**

While it is recognised that appropriate cost-benefit analysis (CBA) tools are already available to the Scottish Government and Transport Scotland, an example of a simple CBA tool was produced as part of the European SILVIA project (Sælensminde and Veisten, 2005a and 2005b). This tool and the associated reports and examples are available for free download from [www.trl.co.uk/silvia](http://www.trl.co.uk/silvia). It should be noted that to these authors knowledge, no validation of the tool has been undertaken, and that the currency used within the tool is the Euro.

### **3.4 Recommendations for further investigation**

Experiences using thin layer surfacing elsewhere within the UK, differ significantly from those in Scotland, and are in general far more positive. For such surfaces to be successfully applied in Scotland, further investigations are required to understand the reasons for the poor structural durability observed in Scotland in many cases.

The Acoustic Performance Assessment Table (APAT) presented in Table 3.2 has been prepared based on a limited dataset. Further work is necessary to expand the table for a wider range of surface types or individual proprietary products available for use in Scotland.

Consideration needs to be given as to whether HRA is suitable for continued use as a reference surface. If there is a significant reduction in the usage of HRA over time, a reference surface which is representative of the current most commonly used surface may be more appropriate. Whilst a change in the standard reference surface is a wider, UK issue (since the reference is defined in the standard UK traffic noise prediction model, CRTN), local conditions may influence the choice of reference surface for Scotland. Within the European HARMONOISE project (see Section 6.3.3), a virtual reference was proposed which would allow all European member states to use a common reference; such an approach might need to be considered.



# **PART 2**

## *Supplementary information on low-noise surfaces*

Part 2 provides further information should the reader seek a greater understanding of the issues associated with low-noise surfaces. It describes the mechanisms of traffic noise generation, the properties of the road surface which affect noise generation, and the methods that are currently available for the assessment of surfaces. An overview of the different low-noise surface technologies that are presently available is presented together with information on their acoustic performance (in terms of initial noise reduction and acoustic durability). Information is also presented on the factors identified above, i.e. safety and skid resistance, structural durability, and environmental sustainability.



## 4 Influence of road surfaces on vehicle noise

This chapter introduces some of the basic concepts behind the generation and propagation of vehicle noise emissions with particular emphasis on tyre/road noise. Of particular importance is the rank ordering of these sources for different vehicle types and driving conditions and how this impacts on overall noise levels from traffic. The understanding of the mechanisms of tyre/road noise generation and propagation is also discussed together with the properties of the road surface that are important in influencing tyre/road noise levels.

### 4.1 Overview of vehicle noise sources

Road traffic noise is the accumulation of noise emissions from all vehicles in the traffic stream. Each vehicle has a number of different noise sources which when combined give the total vehicle noise emission. An important consideration is understanding the factors which influence noise emissions from these various sources and how they can be controlled. In particular, noise sources associated with the interaction of the vehicle tyres with the road surface, often referred to as "tyre/road noise", are described including its generation, propagation and its significance on overall traffic noise. Noise emissions can be affected by meteorological factors such as rain, wind and air temperature but these influences fall outside the scope of this report.

The main noise sources on a vehicle can be broadly classified into two groups:

- Noise sources controlled by *engine speed*: These sources include the power unit (engine, air inlet and exhaust), cooling fan and transmission (gearbox and rear axle). Collectively, noise from these sources is often referred to as "power train noise" or "propulsion noise"
- Noise sources controlled by *road speed*: These sources include tyre/road surface interaction, aerodynamic, body rattle and payload. Collectively, noise from these sources is referred to as "rolling noise"

Providing the vehicle and road pavement are well maintained and vehicles do not greatly exceed the legal speed limit, the dominant rolling noise source is from tyre/road noise. The relative contributions of propulsion noise and rolling noise (primarily tyre/road noise) to the total noise from the vehicle depend on the type of vehicle, the vehicle's speed, the way the vehicle is driven and the acoustic performance of the road surface.

Assuming constant speed operation and a particular reference surface (see Section 6.3.3), Table 4.1 provides an indication of the relative contributions propulsion noise and tyre/road noise make to the overall pass-by noise level for three categories of vehicles, based on the application of the recently developed European HARMONOISE/IMAGINE traffic noise model (Peeters and Blokland, 2007). The categories used are defined below; further details can be found in Peeters and Blokland (2007):

- *Vehicle Category 1*: This category comprises light vehicles and car-based vans. Propulsion noise for these vehicles contributes about 40% of the acoustic output at low speeds (40 km/h) compared with only about 20% at higher speeds (100 km/h). Clearly, at the higher speed, the tyre/road noise component for category 1 vehicles is the dominant noise source
- *Vehicle Category 2*: This category comprises 2-axle medium heavy vehicles including buses. Propulsion noise for these vehicles is more dominant, particularly at lower speeds (40 km/h), contributing about 90% of the acoustic output

**Table 4.1: Contribution to overall noise level from propulsion and tyre/road noise sources for different vehicle categories at constant speed**

Vehicle speed (km/h)	Contribution to overall total energy from propulsion (P) and tyre/road (R) noise sources for different vehicle categories at constant speed <sup>1</sup> (%)							
	Category 1: Light		Category 2: Medium-Heavy (2 axles)		Category 3 Heavy (> 2 axles) <sup>2</sup>			
	P	R	P	R	P	R		
40 (low-speed)	40	60	90	10	80	20		
100 (high-speed)	20	80	70	30	60	40		

<sup>1</sup> Values based on source noise algorithms developed for the HARMONOISE model

<sup>2</sup> Values calculated assuming a 4-axle vehicle

- *Vehicle Category 3:* This category comprises heavy vehicles with 3 or more axles. A slightly lower contribution, about 80%, at low speeds is shown in the Table for propulsion noise these vehicles.

For both vehicle categories 2 and 3, as vehicle speeds increase the distribution of acoustic energy shifts towards tyre/road noise. At vehicle speeds of about 100 km/h, the contribution from the propulsion noise, although reduced, is still the dominant noise source at about 70% and 60%, respectively. The slightly higher contribution from the tyre/road noise for category 3 vehicles compared with category 2 vehicles, illustrates the influence of the extra number of tyres on category 3 vehicles.

For other surface types the contribution of acoustic energy from the different noise sources may be different and its overall acoustic performance on traffic noise levels compared with the reference surface will depend on vehicle speed and on the traffic composition. For example:

- On a road where the traffic consists mainly of heavy vehicles and where traffic speeds are low, the acoustic performance of a surface designed to reduce tyre/road noise would provide little benefit in reducing overall traffic noise levels. Although the noise from category 1 vehicles may be significantly reduced, the low percentage of these vehicles in the traffic stream results in an insignificant influence on overall traffic noise levels
- If the percentage of category 1 vehicles is significantly increased, the acoustic benefits of the low-noise surface may be realised. It should be remembered though that the overall noise emissions from category 1 vehicles are generally lower than that of vehicles in the heavier vehicle categories. At high speeds, however, the sound power of category 1 and category 3 vehicles tends to become similar
- For situations where traffic is congested and where vehicles are not travelling at constant speed, the contribution from propulsion noise sources will be more dominant than that illustrated above and therefore, for these conditions, the acoustic benefits from low-noise surfaces tend to be reduced.

The main factors which influence tyre/road noise include:

- *The design of the tyre* where tread pattern, materials, construction together with the overall width are important contributing elements

- *The influence of vehicle speed*
- *Parameters associated with the road surface.* These are the most influential set of parameters. Whilst tyre design and vehicle operation affect the levels of noise generated, the design and construction of the road surface can affect both the generation and propagation, involving several complex mechanisms. The principal factors are the roughness or texture of the surface, the texture pattern and the degree of porosity of the surface structure

The following section discusses the mechanisms associated with the generation and propagation of tyre/road noise.

## 4.2 Generation and propagation of tyre/road noise

Tyre/road noise is the result of a complex interaction between the rolling tyre and the road surface. It is a major cause of noise from road traffic particularly for vehicles travelling at moderate to high road speeds as illustrated in the previous section. Clearly, in order to design low-noise road surfaces with both predictable and optimised noise reducing properties it is necessary to obtain a thorough understanding of the mechanisms governing the generation and propagation of tyre/road noise.

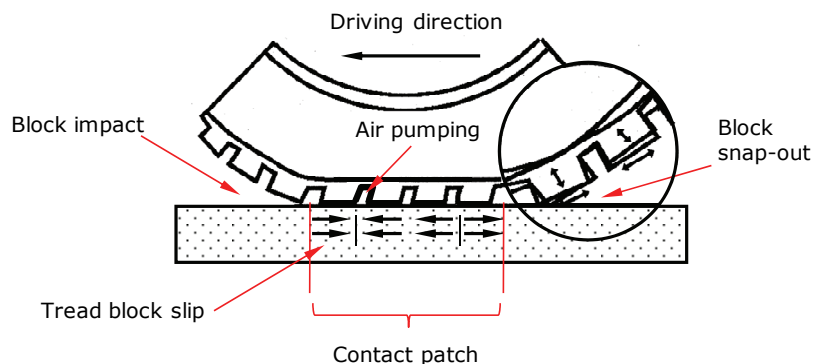
The references cited in the following sections of this chapter of the manual have been selected to illustrate approximately when the mechanisms governing the generation and propagation of tyre/road noise were first investigated. Clearly, these mechanisms have been well understood for many years and much progress has been made in the intervening years to optimise the acoustic benefits of low-noise surfaces. A comprehensive bibliography of the research carried out in this field has been published (Sandberg and Ejsmont, 2002).

### 4.2.1 The mechanisms of tyre/road noise generation and amplification

#### 4.2.1.1 Tyre/road noise generation

Tyre/road noise is considered to result from a combination of physical processes that are categorised by convention into three distinct classes of mechanism. These mechanisms, shown in and more fully discussed in Appendix A, are:

- *Impacts and shocks* caused by the variation of the interaction forces between the tyre tread and the road including the vibrational response of the tyre carcass (block impact and block snap-out)
- *Aerodynamic processes* between, and within, the tyre tread and road surface (air pumping)
- *Adhesion and micro-movement effects* of tread rubber on the road surface (tread block slip)



**Figure 4.1: Tyre noise generation mechanisms**

It is reckoned that for standard rolling conditions, the tyre/road noise is mainly composed of "impact and shock" noise and "air pumping" noise, with the first mainly occurring below 1000 Hz and the second mainly occurring above 1000 Hz.

#### 4.2.1.2 Tyre road noise amplification

Noise generated at or near the contact patch can be exaggerated due to the shape of the region between the tyre and road surface immediately to the rear (or front) of the contact patch. In this region multiple reflections between the tyre and road surface occur which focus the sound. The process is referred to as the "horn effect" (Nilsson *et al.*, 1980). Laboratory studies by Schaaf and Ronnenberger (1982) investigated the influence of the horn effect by measuring the noise levels from an omni-directional impulsive noise source placed close to the rear of the contact patch of a stationary tyre. The measurements were then repeated with the tyre removed and the differences between noise levels across the spectral range determined. The largest amplifications were reported to occur in the region of 2000 Hz. Amplification of the noise levels measured at this frequency and to the rear of the contact patch, where the influence was found to be greatest, was found to be 22 dB(A). It was found that substantial amplification occurred at frequencies from 1000 Hz up to approximately 10 kHz.

#### 4.2.2 Tyre/road noise propagation

This section illustrates the importance of the road surface on the propagation of tyre/road noise as it travels away from the vehicle.

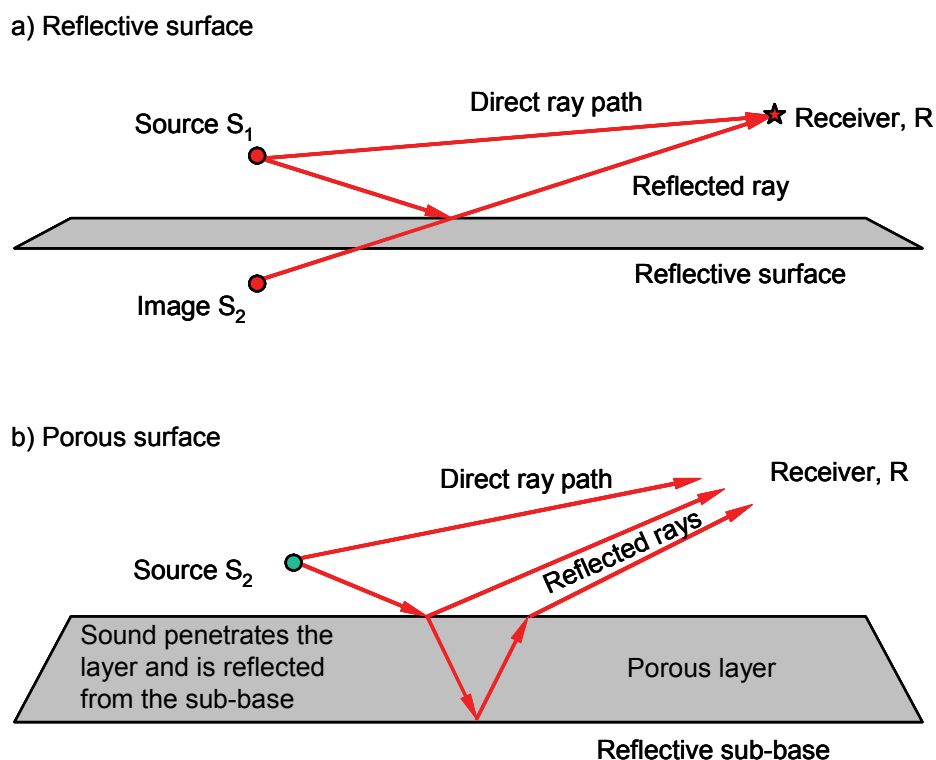
Figure 4.2(a) shows a typical example of the way noise propagates from a source  $S_1$  to a distant receiver, R, where the source and receiver are positioned above a hard sound reflecting surface such as a tyre travelling over a road surface constructed from concrete or hot-rolled asphalt (HRA). At the receiver, the total noise received is the combined noise from that which travels along the direct path,  $S_1R$ , and the noise that is reflected off the road surface which appears to emanate from an image source  $S_2$  located below  $S_1$ , analogous to an image reflected in a mirror.

When the surface layer is replaced with a porous surface i.e. a surface where there are air paths through the surface layer, part of the reflected noise penetrates through the porous layer and is reflected off the sub-base as it travels towards the receiver. This situation is typical for porous asphalt road surfaces where the structure of the road surface is fairly open allowing sound to penetrate through the material to the sub-base.

Figure 4.2(b) shows the principal acoustic ray paths governing wave propagation from the source to the receiver located above a porous surface layer.

Determining the acoustic field strengths at the receiver for propagation over both types of surfaces is complex and depends on how the sound waves of the direct and reflected noise interfere with each other when reaching the receptor. This interference in sound waves can cause increases or decreases in noise level and is governed not only by the type of intervening ground but also on the source and receiver heights and the source-to-receiver distance.

When the road surface is highly reflective and for distant receptors, the interference between the direct and reflected noise is primarily constructive in the frequency range typical of tyre/road noise, causing overall noise level to increase above that which would have been received if the reflected noise was not present. When the surface layer is porous, the presence of the additional reflected noise causes destructive interference to occur typically within the frequency range of tyre/road noise causing the overall noise level to be lower than in the case where the road surface is not porous. The frequency range over which this reduction in noise level occurs can to some extent be controlled by the thickness of the porous layer. The thicker the porous layer the lower the frequency range the destructive interference occurs.



**Figure 4.2: Geometry for a source and receiver in the vicinity of a ground plane**

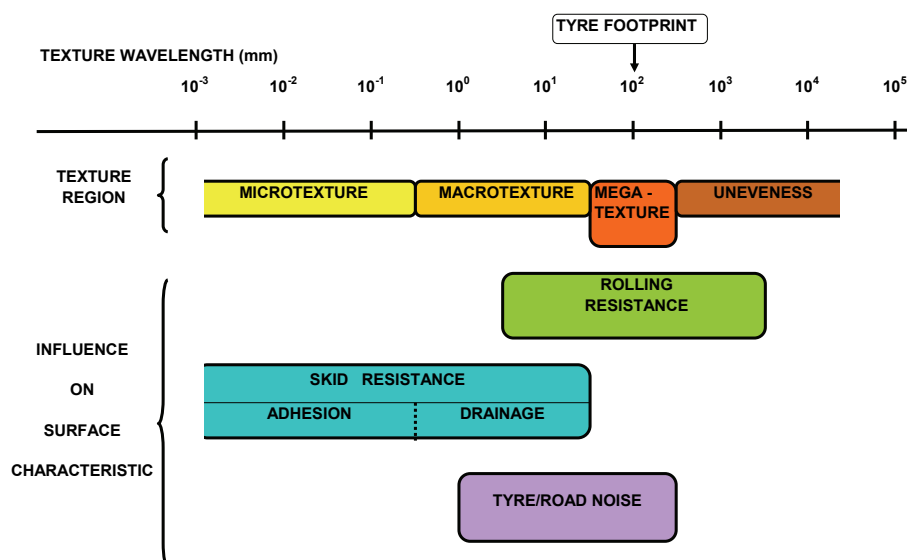
### 4.3 Properties of road surfaces that influence tyre/road noise

The following sections deal with the surface parameters that are important in characterising a road surface and which not only influence the surface's acoustic performance but also rolling resistance, skid-resistance and surface durability.

As an introduction, the influence of surface texture, in particular, the way it is defined and the range of textures which have an influence on the different surface parameters is first discussed.

The road surface profile can be visualised as a continuous series of peaks and troughs which may typically be randomised or alternatively reasonably well defined as in the case of transverse textured surfacing, i.e. surfaces where the grooves in the surface run at  $90^\circ$  to the direction of travel. Nevertheless, any type of profile shape can be described as the summation of a number of sinusoidal variations differing in both amplitude and wavelength. This process of reducing a complex profile shape into its component cyclic waveforms is known as "Fourier Analysis", each waveform has associated with it a texture amplitude ( $a$  mm) and texture wavelength ( $\lambda$  mm)

Work carried out by Sandberg and Descornet (1980) and later developed by PIARC (1987) have identified certain ranges in texture wavelengths which are influential on the surface characteristics related to noise, tyre rolling resistance and skidding resistance. The results of this work are summarised in Figure 4.3.



**Figure 4.3: Influence of surface texture on the characterisation of road surfaces**

It was found that it is convenient to divide the range of texture wavelengths into four regions, shown in the upper half of Figure 4.3. These texture regions have been defined by the texture wavelength ( $\lambda$  mm) of the surface irregularities as follows:

- Microtexture:  $\lambda < 0.5$  mm
- Macrotecture:  $0.5 \text{ mm} < \lambda < 50$  mm
- Megatexture:  $50 \text{ mm} < \lambda < 500$  mm
- Unevenness :  $\lambda > 500$  mm

The lower half of Figure 4.3 illustrates the approximate range in texture wavelengths which influence surface parameters including rolling resistance, skid resistance and tyre/road noise. For example, texture wavelengths in the macro- and megatexture range i.e.  $0.5 \text{ mm} < \lambda < 500$  mm, are important for controlling tyre/road noise. The figure also shows that texture wavelengths in this region are also important in controlling both rolling and skid resistance. Clearly, an understanding of the relationship between texture wavelength and the various surface parameters described in Figure 4.3 provides the basis for characterising road surfaces that provide lower noise levels without compromising durability and, importantly, skidding performance and safety.

The following section examines the surface properties which are most important in controlling the acoustic performance including texture, porosity and stiffness. This is followed by a section which examines the importance of other properties which influence rolling resistance, skid resistance and durability.

#### 4.3.1 Texture

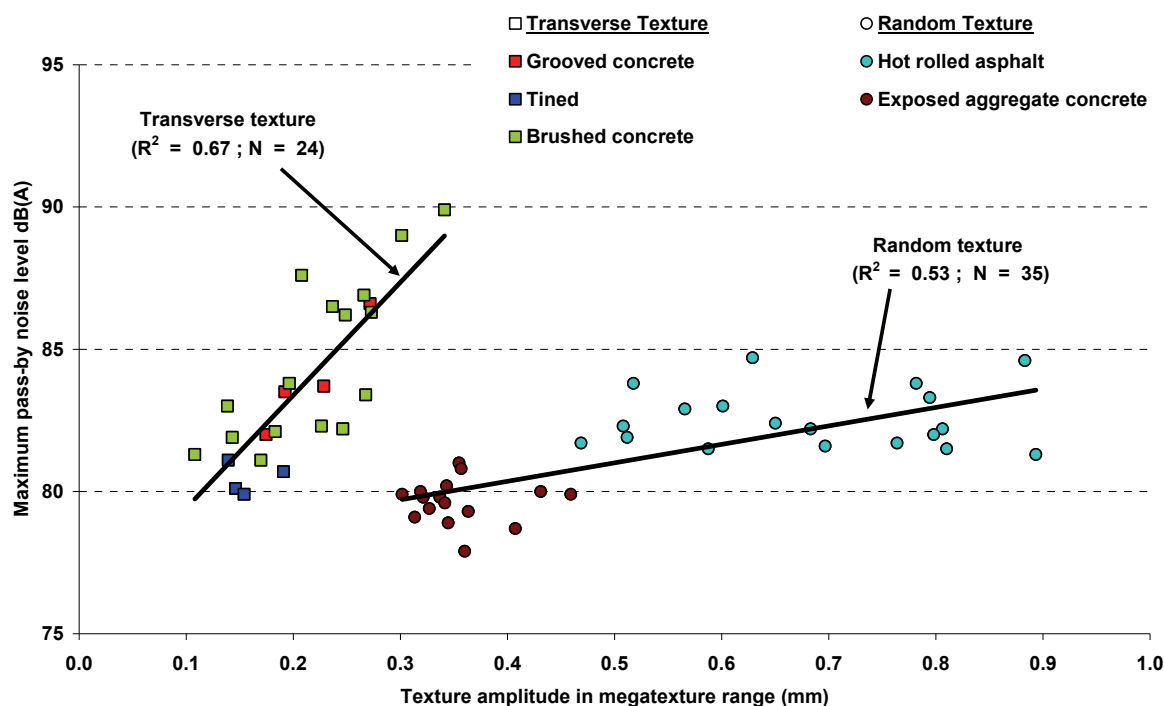
The relationship between surface texture and tyre/road noise is complex. It has been shown earlier that texture wavelengths in both the macrotecture and megatexture range influences the generation of tyre/road noise.

Research has shown that increasing texture amplitudes at wavelengths in the range 0.5 to 10 mm may reduce noise generation particularly at high frequencies generally above 1 kHz (Sandberg and Descornet, 1980). Texture wavelengths in this range accord with dimensions associated with the small asperities in the surface which are thought to have an influence on the aerodynamic mechanism of tyre/road generation, particularly air

pumping (see Section A.2). Increasing texture amplitudes at wavelengths in the range 0.5 to 10 mm reduces the air resonating in the grooves of the tread pattern of the tyre and the surface of the road as the tyre passes through the contact patch. The increase in texture allows the air trapped between the tyre and the road surface to be released less suddenly and therefore generates less noise.

In addition to this high frequency noise effect there is a low frequency component which behaves differently. Increasing texture amplitudes at wavelengths in the range 10 to 500 mm causes noise levels to increase, particularly at frequencies generally below 1 kHz. The tyre mechanism affected by texture amplitudes in the 10 to 500 mm wavelength range is thought to be associated with tyre tread impacts with the road surface (see Section A.2). As the texture increases, the vibration levels set up in the tyre carcass due to the tread impact increases causing higher levels of noise to be generated, particularly at frequencies below 1 kHz.

A further important consideration with respect to texture is in the way the texture is applied. The relationship between texture amplitudes in the megatexture range with noise is different for randomly textured surfaces than compared with surfaces with a transverse texture such as brushed concrete. Figure 4.4 illustrates this effect for a range of surfaces identified with either transverse or random textures.



**Figure 4.4: Variation in vehicle pass-by noise level and texture amplitudes in the megatexture range for typical light vehicles travelling at 90 km/h at 7.5 m**

The figure shows the results from measurements of vehicle pass-by noise levels derived using the Statistical Pass-By (SPB) method (ISO, 2001) and typical for light vehicles travelling on medium to high speed roads. The figure shows that for both transverse and random texturing for a range of surface types, the maximum pass-by noise levels are well correlated with texture amplitudes in the megatexture range. Clearly the regression lines drawn through the data corresponding to the method of texturing are very different, showing that noise levels on transverse textures are significantly higher for a given amplitude compared with corresponding noise levels for randomly textured surfaces.

The explanation for this effect is that the forces acting on a tyre travelling on a transverse texture are more synchronised across the width of the tyre than for random texturing and therefore enhance higher vibrations in the tyre and produce more noise. A similar result has been found for heavy vehicle pass-by noise levels (Hewitt *et al.*, 1997).

The ways in which texture is formed also differ in the vertical plane and, in this report; the terms positive or negative are used to describe them:

- *Positive* texture is formed by particles or ridges which protrude above the plane of the surface. Typically, such textures are formed by applying chippings to an essentially smooth surface and rolling them (as in rolled asphalt or surface dressing, for example). Positive texture may also be formed by removing the surrounding matrix to expose aggregate particles (such as in exposed-aggregate concrete or a weathered asphalt). The term also describes the texture formed on transversely brushed concrete
- *Negative* texture is a term often applied to materials in which the texture largely comprises voids between particles whose upper surfaces form a generally flat plane, typical of thin surface systems. It can also be used to describe grooved concrete, especially where the grooves have been sawn after the original brush-marks have been worn away by traffic

Depending on the size of the chippings, positive texturing encourages higher levels of vibration in the rolling tyre than compared with negative textures, which has contributed to the lower noise levels associated with thin surfacing systems.

#### **4.3.2 Porosity**

It was shown earlier in Section 4.2.2 how porous surfaces play an important role in reducing the noise propagated away from the road by sound absorption. But porous surfaces also reduce the generation of noise by several mechanisms related to the surface porosity.

A measure of porosity can be defined as the percentage of voids that are open to the air in a given volume of total pavement mix, sometimes referred to as the residual air void content,  $\Omega$ . Although defining a porous surface in terms of its void content has not been internationally established the following guide has been suggested by members of the SILVIA consortium:

- Dense layers (air void 4-9%)
- Semi-dense (air void 9-14%)
- Semi-open (air void 14-19%)
- Open layers (air void over 19%) which are porous layers

Increasing the porosity of the surface reduces the compression and expansion of air trapped in the tyre tread, reducing the noise generated by aerodynamic mechanisms (see Section A.2). Porosity is also important in sound absorption: increasing the porosity generally increases the acoustic absorption and, by consequence, reduces the horn effect (see Section 4.2.1.2).

Porosity is not, however, the only parameter that influences sound absorption. Additional parameters have been identified from results of modelling sound absorption effects (Attenborough and Howarth, 1990; Hamet and Bérengier, 1993) and include:

- *Thickness of the porous layer* ( $d$  mm) which influences where the maximum absorption occurs in the frequency spectrum. Increasing layer thickness lowers the fundamental frequency of maximum absorption together with its harmonics
- *Air flow resistance* is important in governing the air flow in the pores of the surface. A high air flow resistance is favourable to sound energy dissipation, but a too high air flow resistance prevents the acoustic waves to penetrate into the

layer. The optimum range of the air flow resistance depends on the thickness of the layer. It can be shown that the shape of the absorption curve in the frequency domain depends on the total air flow resistance of the layer, i.e. on the product of the specific air flow resistance of the porous medium by the thickness of the layer (Hamet *et al.*, 1990)

- *Tortuosity* is a measure of the curved/meandering nature of the air path through the surface layer. In practice the air path through the layer will be dependent upon the shape of the interconnecting voids. The more tortuous the air path, the lower the fundamental frequency of maximum absorption. The fundamental frequency is therefore governed by both the tortuosity and the layer thickness (Hamet and Bérengier, 1993)

Results from a number of different sources when combined, indicate that the noise reduction of porous surfaces is statistically highly correlated with the product of residual air voids ( $\Omega$ ) and layer depth ( $d$ ). As the product  $\Omega d$  increases the noise also increases in a roughly linear fashion. The relationship appears to hold for values of  $\Omega d < 30$  mm (when  $\Omega$  is expressed as a fraction). By taking into account the size of the aggregate, improvements in the correlation are obtained, i.e. surface with similar  $\Omega d$  but with smaller chippings provide greater noise reductions. For values of  $\Omega d$  above about 30 mm there was found to be no significant increase in noise reduction (Sandberg and Ejsmont, 2002).

#### **4.3.3 Stiffness**

The property of the surfaces referred to as the mechanical impedance or stiffness of the surface has also been associated with noise generation relating to impact mechanisms. Generally the mechanical impedance of the road surfaces is several orders of magnitude higher than that of the rubber in the tyre tread. Lowering the road mechanical impedance will tend to reduce the tread block impact forces transmitted into a tyre which in turn will reduce tyre vibration levels and hence noise generation. This seems to be the case of surfaces made of poro-elastic material which are designed to have a rubber content of at least 20% by weight.

The surface parameters that have been discussed above have been related to the acoustic properties of the surface. However, the overall performance of a road surface needs to consider other parameters relating to safety, fuel economy and overall cost-life benefits which should not be sacrificed purely to reduce noise. The aim of this section is to discuss these non-acoustic properties of the surface and to identify how they may influence acoustic performance.

#### **4.3.4 Skid-resistance**

Road surfaces are primarily provided with surface texture in order to provide a safe running surface that provides adequate resistance to skidding particularly when the road surface is wet. For dense surfaces the microtexture helps break down the surface film of water whilst the macrotexture helps "store" excess surface water thereby improving the contact between the tyre and the surface and preventing aquaplaning. Porous surfaces provide additional advantages in helping to dissipate excess surface water by virtue of their rapid drainage properties.

Research in understanding the relationships between surface texture, skid-resistance and the acoustical properties of road surfaces have to some extent been confounded by several factors. Limiting the range of surface types within a study can bias results and the different ways skid-resistance is measured and used as an indicator of safety can produce conflicting results (Sandberg, 1987).

The sideways-force coefficient (SFC) is generally a low speed measure of surface friction using a wheel set at an angle to the direction of travel. Alternative measures of friction involving a locked-wheel allow the relationship between friction and speed to be

examined over a much wider range of speeds. The braking force coefficient (BFC) is a general term often used to describe locked-wheel friction measurements. An important concern with skidding performance of a road surface is that as vehicle speeds increase the frictional properties of the surface generally reduce and that the rate of loss in friction with speed is greater for lower-textured surfaces. Subsequently, skidding performance based on the relative change in friction with speed have provided additional measures for assessing safety performance over and above those based on absolute measures of friction. This plethora of methods for assessing skidding performance and how these different measures are influenced by texture amplitudes at different texture wavelengths may explain why the results of some research indicate a conflict between safety and low-noise surfaces whereas others have found no link. Further insight to this problem may be sought by reviewing Figure 4.3.

The Figure shows that texture wavelengths important for skid-resistance cover a wide range of texture wavelengths from the lower microtexture range to the transition between the macro and megatexture regions. However, increasing texture amplitudes important for maintaining adequate skidding performance may have an ambivalent influence on tyre/road noise. Increasing texture amplitudes at wavelengths in the microtexture range will have little influence on tyre/road noise generation. In the macrotexture range, increasing texture amplitudes may reduce tyre/road noise by reducing the influence of aerodynamic mechanisms that generate noise. Increasing texture amplitudes at wavelengths close to the transition between the macro and megatexture regions may have a negative effect on noise by enhancing tyre vibrations to generate higher levels of tyre/road noise.

Clearly, from the above discussion, it is perhaps not so surprising that research linking safety and noise reduction has not provided a decisive outcome. However, it is equally clear that there is scope for designing road surfaces which have both adequate skidding performance and provide for low-noise levels. The solution is to ensure that the texture amplitudes contributing to the desired safety requirements of the surface are at texture wavelengths which don't enhance tyre/road noise and preferably have a positive influence in reducing tyre/road noise.

#### **4.3.5 Rolling resistance**

Rolling resistance has a significant impact on both fuel economy and exhaust emissions, particularly CO<sub>2</sub>. Consequently, much research has been carried out to reduce rolling resistance, particularly by the tyre industry. Fortunately, it appears from the available research that tyre rolling resistance is not strongly correlated to tyre noise levels. In fact some research has shown that tyres with low rolling resistance also generate low-noise levels (Sandberg and Ejsmont, 2002). Similarly, the influence of surface texture on rolling resistance does not conflict with the desire for low-noise surfaces as can be seen from Figure 4.3. Reducing texture amplitudes at wavelengths important for low rolling resistance will tend to reduce noise generated by texture wavelengths associated with tyre vibration in the megatexture range.

As rule of thumb, a certain difference in rolling resistance implies a difference in energy consumption of the vehicle (and thus CO<sub>2</sub>, NO<sub>x</sub> and fine particle emission) of ¼ of this. Thus 32% difference in rolling resistance leads to about 8% lower fuel consumption.

#### **4.3.6 Acoustic durability**

Durability here is defined as the effect of ageing due to trafficking and weathering on the acoustic performance of a road surface. This process and its affect on acoustical performance is complex and dependent on a number of parameters including surface type, the porosity of the road surface, the degree of trafficking and exposure to weathering. Generally, the trend is for the acoustic performance of surfaces to stabilize after an initial period of 1 to 2 years of trafficking. Those surfaces which provide for low

levels of tyre/road noise tend to increase in noise over this initial period, whereas surfaces which exhibit higher levels of tyre/road noise have shown some noise reductions (Sandberg and Ejsmont, 2002).

This is in part confirmed by an experimental observation made in France on two techniques (with respect to passenger pass-by noise): Porous Asphalt 0/10, over a 10 years period, and Asphalt 0/6 class 2, over a 7 years period (Besnard *et al.*, 2005). The analysis concluded the following:

- Porous Asphalt 0/10: Despite a rather heterogeneous behaviour of all the sections tested, a great part of them showed a noise level increase for cars, by +5.5 dB(A) between 1 and 10 years. It was noted that the noise levels on those sections with the lowest initial noise levels tended to increase over the time period, whereas those on the sections with the highest initial noise levels tended to remain stable during the first years
- Asphalt 0/6 class 2: A rather regular increase in noise levels was observed: +3 dB(A) between 1 and 7 years

Initially as the surface wears, texture amplitudes associated with the shorter wavelengths can be worn away by the action of traffic resulting in higher noise levels associated with the aerodynamic mechanism of tyre/road noise generation. To reduce this effect aggregate with high PSV (polished stone value) are sought which also have the benefits in retaining high skidding performance.

The effect of ageing can be particularly dramatic on the acoustic performance of some porous surfaces. Trafficking and weathering causes the voids in the surface to become clogged with detritus reducing acoustic absorption, resulting in increased noise levels. The use of de-clogging machines using water under high pressure to flush out the detritus has only been partially successful. Alternative designs using double-layer porous systems have proved to be more successful. The top porous layer consisting of small chippings acts as a filter, accumulating most of the detritus and leaving the lower larger aggregate size porous layer relative detritus-free. This design allows the cleaning process to be more efficient in retaining surface porosity than compared with single layer designs and can therefore extend the lifetime of its acoustic benefits.

However, after a period of stabilization some surfaces can exhibit significant increases in noise, particularly as the surface reaches the end of its life. Bituminous surfaces which exhibit surface fretting (loss of stone) after long periods of heavy trafficking, the appearance of cracks and the hardening of the bitumen due to long-term exposure can all contribute to higher levels of tyre/road noise. Concrete surfaces can also exhibit similar characteristics, for example, grooved concrete where after a period of heavy trafficking causes fraying of the grooves resulting in shallow/wider spacing which can promote higher noise levels (Franklin *et al.*, 1979).

The results from research highlighted above illustrate the importance that the acoustic performance of road surfaces should not only be assessed on their initial performance but over the whole life time of the surface.



## 5 The assessment of noise from road surfaces

This chapter reviews the ISO methods that have been developed for assessing the influence of road surfaces on traffic noise levels. The ISO methods form the basis of the methodology used in many countries in the EU including the UK, for assessing the acoustic performance of low-noise surfaces. This is particularly relevant in establishing appropriate mitigation for the purposes of Noise Action Plans which forms part of the requirements in the EU Environmental Noise Directive (END; EC, 2002). Appendix A provides more detailed information on how these methods have been adapted to meet the different requirements found in other countries throughout the EU.

### 5.1 Statistical Pass-by method

The Statistical Pass-By (SPB) method was developed to assess the road surface influence on road traffic noise and the methodology is defined in ISO 11819-1 (ISO, 2005). For details regarding to instrumentation, site selection, measurement procedures including traffic and meteorological conditions, the ISO standard should be consulted.

#### 5.1.1 Vehicle noise and road speed

In Chapter 4 of this report, it was explained that road traffic noise is the accumulation of noise emissions from all vehicles in the traffic stream and is dependent on several factors including vehicle type and speed. To develop a method of classifying the acoustic properties of road surfaces it is therefore important for comparison purposes to be able to normalise for both vehicle type and speed.

The basic principle of the SPB method is to measure the maximum A-weighted sound pressure levels,  $L_{Amax,m}$ , of a statistically significant number of individual vehicle pass-bys at a specified road-side location together with the vehicle speeds. Measurements are carried out at a reference distance of 7.5 m from the centre of the vehicle lane at a standard height of 1.2 m. Each vehicle is classified into one of three vehicle categories,  $m$ , and are described in the ISO Standard as follows:

- Vehicle Category 1: Passenger cars
- Vehicle Category 2a: Dual-axle heavy vehicles with more than 4 wheels, including commercial trucks, buses and coaches
- Vehicle Category 2b: Multi-axle heavy vehicles with more than 2 axles including commercial trucks, buses and coaches

This classification system assumes that vehicles with common physical features correspond to similarities in their sound emission when driven under the same operating conditions.

The recommended number of vehicles selected for measurement from each vehicle category is:

- Vehicle Category 1: 100 vehicles
- Vehicle Category 2a: 50 vehicles
- Vehicle Category 2b: 50 vehicles

Each individual maximum pass-by noise level together with the vehicle speed is recorded, and a regression line of the maximum A-weighted sound pressure level versus the logarithm of speed is calculated for each vehicle category,  $m$ , using the method of least squares.

The general form of the regression line for each vehicle category  $m$ , may be expressed as:

$$\text{Maximum Noise Level, } L_{Amax,m,v} = a_m + b_m \cdot \log_{10}(v) \text{ dB(A)} \quad (5.1)$$

where  $a_m$  and  $b_m$  are the intercept and slope derived from the regression equation for each vehicle category,  $m$ , and  $v$  is the corresponding vehicle speed (km/h).

The next stage of the process is to estimate the traffic noise level as described in the next section using the regression equations to determine the maximum pass-by noise levels for each vehicle category in the traffic stream according to their nominated road speeds

### 5.1.2 Traffic noise levels

As the acoustic performance of a road surface will be dependent on traffic speed and composition, the influence of the road surface on traffic noise is classified by the type of road based on typical speeds for each vehicle category and typical proportion of each vehicle category in the traffic stream. Three road speed categories are defined:

- *Low*: where the reference speed for each vehicle category is 50 km/h
- *Medium*: where the reference speed for vehicle category 1 is 80 km/h and for both vehicle category 2a and 2b is 70 km/h
- *High*: where the reference speed for vehicle category 1 is 110 km/h and for both vehicle category 2a and 2b is 85 km/h

To obtain a measure of the overall traffic noise level, the Statistical Pass-by Index (SPBI) is calculated as follows:

$$SPBI = 10 \log_{10} \left[ W_1 \times 10^{L_1/10} + W_{2a} \left( \frac{v_1}{v_{2a}} \right) \times 10^{L_{2a}/10} + W_{2b} \left( \frac{v_1}{v_{2b}} \right) \times 10^{L_{2b}/10} \right] \text{ dB(A)} \quad (5.2)$$

where

- $L_1$ ,  $L_{2a}$  and  $L_{2b}$  are the maximum noise levels derived from equation 3.1 at the relevant reference speeds,  $v_1$ ,  $v_{2a}$  and  $v_{2b}$  respectively for the required road category
- $W_1$ ,  $W_{2a}$  and  $W_{2b}$  are weighting factors representing the typical proportion of each vehicles category in the traffic stream relevant to each road speed category.

This equation effectively adds together the noise contribution from all the vehicles in the traffic stream.

To assess the acoustic performance of a road surface, a reference road surface needs to be established where the  $SPBI_{ref}$  for each road speed category has been derived.

The acoustic performance of a road surface,  $A$ , is then derived relative to that of the reference surface by the equation:

$$\text{Acoustic performance} = SPBI_A - SPBI_{ref} \quad \text{dB(A)} \quad (5.3)$$

Different countries use different reference surfaces which makes it difficult to compare the acoustic performance of surfaces across different countries. Further details on which reference surfaces are used in different countries is given in Section 6.3.

For surfaces within the same road speed category, differences in the SPBI values for different road surfaces provides an estimate of the influence difference in traffic noise levels expected for typical traffic conditions.

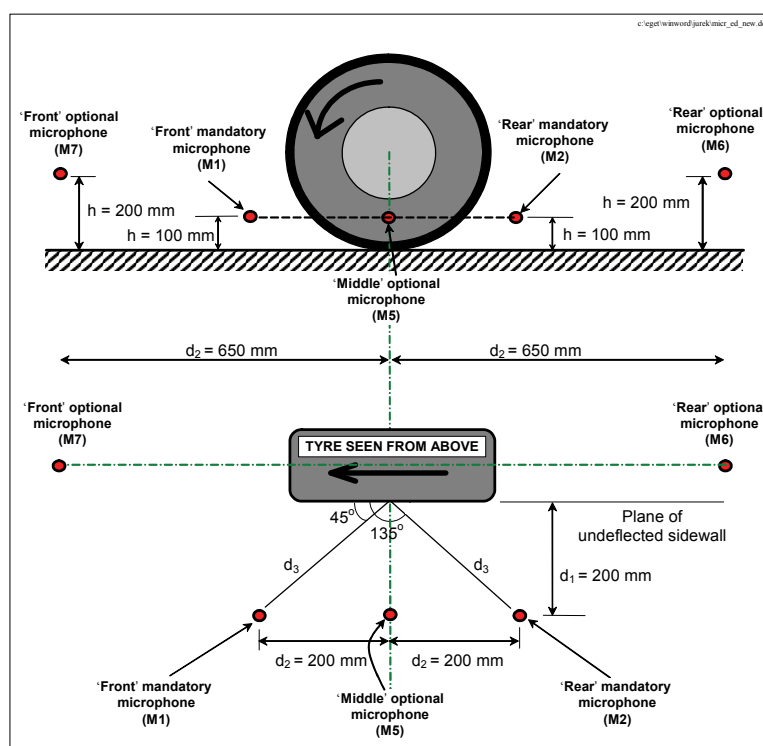
The main disadvantage of this method is that only a small area of a road scheme can be assessed at any one time, about 20m either side of the measurement location. A more cost-effective method is provided by the Close-proximity method which allows monitoring of several kilometres of a road scheme to be carried out more efficiently.

## 5.2 Close-proximity method

The Close Proximity (CPX) method described in ISO 11819-2:2000 (ISO, 2000) is designed to assess the acoustic properties of road surfaces by measuring the rolling noise of a set of standard tyres at two microphone positions located close to the tyre/road contact patch.

Since the Standard was first published, the set of reference tyres have been replaced by the ASTM standard reference test tyre (a Uniroyal Tigerpaw 225/60/R16, specified in ASTM F2493-06 (ASTM, 2006)). This tyre has been selected as a reference tyre for CPX measurements and shown to produce noise levels typical of car tyres on a range of different surfaces (Schwanen *et al.*, 2007, Schwanen *et al.*, 2008).

The measurements are taken at two microphones mounted at 20 cm from the tyre side wall 20 cm in front and behind the centre of the contact patch and 10 cm above the road surface. Figure 5.1 shows a general view of the measurement layout.



**Figure 5.1: General layout for CPX measurements showing reference tyre and positions of microphones**

For each individual test run and for each microphone, the average noise level over each 20 m segment is recorded over the entire length of the road section of interest together with the corresponding vehicle speed. The noise level of each segment is normalised to the nominated reference speed and averaged over the length of the road section. The results from both microphones are then averaged to give the tyre/road noise level,  $L_A$  dB(A) at the nominated reference speed. For each road section, two test runs are carried out and the average  $L_A$  value from both test runs are calculated. This procedure is carried out for to nominated reference speeds of 50 and 80 km/h.

### 5.3 The relationship between SPB and CPX

Both the SPB and CPX methods have certain advantages when assessing tyre/road noise depending on the objectives of the assessment and equally both have disadvantages.

The main advantages are:

#### *SPB method*

- For the purpose of developing traffic noise models, results from SPB measurements can be used as direct inputs to models for predicting the influence of road surfaces on traffic noise levels as illustrated in Appendix B.1.1.
- The results are based on measurements using actual vehicles selected from the traffic stream and providing a sufficient number of vehicles are selected, the results are reasonably representative of the vehicle population at the time of measurement

#### *CPX method*

- The method allows monitoring of tyre/road noise to be carried out over the entire length of a road scheme and could be adopted for the purposes of checking conformity of production (COP)
- It has the potential to be used for routine monitoring of the whole road network
- When assessing the change in tyre/road noise over time the results are not confounded by changes in design of the vehicle fleet

The main disadvantages are:

#### *SPB method*

- The site layout requirements are restrictive and the results are only relevant over a small section of the road scheme.
- Because the measurement is based on actual vehicles selected from the traffic stream, comparing results over the lifetime of a surface may be influenced by changes in the vehicle fleet. For example, over the past 10 or 15 years, the design of tyres has changed, particularly for light vehicles, with higher percentage of vehicles having low-profile tyres. This effect will have increased on average tyre/road noise
- Difficult to carry out in built-up areas (see Appendix B.1.)

#### *CPX method*

- The results from CPX measurements cannot be used directly as input to traffic noise prediction models
- The reference tyres used in the measurement of CPX must be representative of the tyre fleet both for light and heavy vehicles
- The availability of reference tyres need to be assured by manufacturers. This has proved to be difficult in the past
- The reference tyres must conform to certain specifications which influence tyre/road noise such as the hardness of the tyre. This can lead to expensive storage requirements, e.g. it may be necessary to store tyres under controlled, refrigerated conditions

A way forward to overcoming the problem associating with using CPX results to provide input to traffic noise prediction models is to examine the relationship SPB and CPX. Providing there is a good correlation between SPB and CPX, CPX values can be used to predict SPB levels which can then be used as direct input to traffic noise models. An example of the relationships between SPB and CPX is further discussed in Section B.1.

## 6 Overview of low-noise road surfaces and reference surfaces

This chapter describes the different low-noise road surfaces that are currently available, as well as surfaces which are still under development and unlikely to be available in the short-term. Information on some of the different reference surfaces that are specified within Europe also is included for comparison.

For the purposes of this report, a low-noise surface is defined, in accordance with DMRB (Highways Agency *et al.*, 2008)<sup>2</sup>, as being a surface having an RSI value of -3.5 dB or lower (RSI being the 'Road Surface Influence' as defined in the HAPAS guidelines for the assessment and certification of thin surfacing systems (BBA, 2008); see Section B.1.1).

Specific information on the acoustic performance of these surface types is included in Chapter 7.

It is noted that in Scotland HD36/06 allows HRA to be used without restriction, whereas in England approval to proceed is required. Scotland has an approval system that ensures that the material is fit for purpose, and if there is a noise attenuation requirement use of the appropriate materials would be advised. The use of surfacing systems that are not HAPAS certified is permitted on Trunk Roads, but only with the approval of Transport Scotland.

### 6.1 Existing/currently available low-noise road surfaces

#### 6.1.1 Porous surfaces

##### 6.1.1.1 Single-layer Porous Asphalt (PA or SLPA)

Porous asphalt is designed to have a very high stone content (typically 81-85%) with a typical grading of 0/11, 0/16 or 0/20 with a gap at 2/7, which provides a high void content (usually > 20%). As a wearing course, the layer thickness is typically 40 mm.

In Europe, porous asphalt was developed by TRL in the UK in the late 1950s for use on airport runways and trialled for use on public roads in the 1960s. The first pervious surface was laid on the M40 in the UK during 1967 (Please *et al.*, 1970). Originally the surface was developed to reduce surface water and spray on high-speed roads during periods of heavy rainfall. However, following the road trials it was found that this type of surface also offered acoustic benefits. Subsequently, experiments with porous asphalt were carried out in many other countries in Europe and in other parts of the world. On highways in The Netherlands the use of single layer porous asphalt has become a standard surface. In 2005, approximately 60% of the Dutch network was single layer porous asphalt.

Compared to normal dense asphalt concrete, SLPA offers a significant noise reduction when the surface is in good condition. The acoustic performance tends to deteriorate if the pores become clogged with detritus.

The use of porous asphalt surfaces leads to a reduction in splash and spray, and aquaplaning since water is not accumulated on the road surface but drains away. This therefore results in improved visibility and reduced glare and improved skidding resistance in wet conditions.

There are problems with the durability of porous surfaces due to the more rapid aging of the binder. In addition, the skid resistance of SLPA has been reported to be poorer than Dense Asphalt Concrete (DAC) under locked wheel braking; for example, it has been found that under heavy braking, stopping distances can be 20-40% longer than on DAC

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<sup>2</sup> The overseeing organisations of England, Scotland, Wales and Northern Ireland.

(PIARC, 1995) due to the breakdown of the bitumen layer. This problem only exists in the first months after opening to traffic. During this period there is a thick bituminous layer around the aggregate at the surface of the asphalt layer. This bituminous layer wears off after a few months.

The pores of the surface tend to get clogged by dirt and detritus which has a tendency to spoil those properties that are dependent upon drainage and porosity. Although the passage of vehicle tyres will generate some degree of self-cleaning in the wheel tracks of high speed roads, these surfaces require periodic specialist cleaning to prevent clogging of the surface as a whole. It is recommended that the surfaces be cleaned approximately every two years.

There are problems with winter maintenance, since the porosity of the surface means that greater and more frequent salting is required than for dense surfaces since PA is more prone to coverage by ice (due to moisture in the pores and the lower thermal conductivity of the surface).

Routine repairs of the surface, i.e. patching up, are also more difficult than for dense surfaces since such maintenance often impairs the essential drainage through the surface leading to reduced acoustic performance.

#### 6.1.1.2 *Twin-layer Porous Asphalt (TLPA)*

Twin-layer porous asphalt, which was first developed in the Netherlands in 1990, is an advance on single-layer porous asphalt (SLPA), comprises two different layers of porous asphalt, namely:

- A coarse, open-graded bottom layer: This typically uses 11-20 mm aggregate and a layer thickness of 35-65 mm;
- A fine-textured upper layer: This typically uses 4-8 mm aggregate and a layer thickness of 20-30 mm.

Typically the porosity of the surface is 20-25% with a binder content of 5.7-6.0% based on aggregate size and weight. The binder is generally polymer modified.

The advantages of TLPA are that the high noise reduction performance can reduce the need for other mitigation measures, such as noise barriers or insulation at roadside properties, and it is feasible to use TLPA surfaces in urban areas as well as on high speed roads. Furthermore, because of its open structure, TLPA minimises splash and spray, increasing the level of comfort and safety for road users. The run-off from TLPA also has the advantage of being cleaner than that from dense asphalt concrete due to the filtering nature of the surface.

Based on experiences with the surface in Europe, problems have been experienced with the durability of TLPA. The surface is known to have a typical structural lifetime of approximately 7 years (based on the structural durability of the upper layer), although sections are known of that have been in place for longer periods. Based on recent Dutch experiences to optimise structural durability, it is potentially feasible that structural lifetimes of the order of 10 years might be achieved (Morgan, 2008). For high life expectancy, care must be taken in selecting where the surface is used, e.g. it should not be used on sharp bends or at junctions (where the increased frequency of vehicle acceleration/deceleration and increased steering leads to an increase in stresses, thereby increasing the likelihood of ravelling). The costs of TLPA pavements can also be quite high as a result of increased construction and maintenance costs compared to more traditional pavement types.

## **6.1.2 Thin surfacings**

### **6.1.2.1 Paver-laid Surface Dressing (PLSD): Ultra-thin surfacings developed in France.**

Laboratoire Central des Ponts et Chaussées (LCPC) in conjunction with SCREG Routes developed an ultra-thin surfacing, classified as PLSD in the UK, as a process which would not have the drawbacks associated with surface dressing and it may be considered as a paver-laid hot mix surface dressing. The material is a hot bituminous mixture spread directly over a sprayed bond coat. A purpose built machine incorporates a binder sprayer and material distribution system to lay the mixed material. The long length of the machine enables an excellent longitudinal profile to be achieved. The sprayed binder is a modified emulsion, containing approximately 70 % solids, and is sprayed at a rate of 1 L/m<sup>2</sup>. The mixed material specification was originally to a French design, although subsequently modified for the UK market. The aggregates used are of a high quality and high PSV in order to achieve a good skid-resistance.

### **6.1.2.2 Thin Asphalt Concrete (TAC): Generally with polymer-modified binder**

The French developed Very Thin Surface Layers through the Avis Technique system, which were then imported into the UK as proprietary products under the TAC classification. A typical TAC is basically a gap-graded mixture (and hence not truly an asphaltic concrete) with a relatively small aggregate size and a modified binder. The material is bonded to the road surface by prior application of a tack or bond coat sprayed at a rate depending on road porosity. The binder is polymer modified at a binder content within the range 4.5 to 7.0 %, depending on the mixture. The material is laid using conventional paving equipment to a nominal thickness of 20 mm.

### **6.1.2.3 Thin Stone Mastic Asphalt (TSMA): Generally unmodified bitumen with fibres**

Stone mastic asphalt (SMA) has a stone skeleton of interlocking crushed rock coarse aggregate, comprising largely single sized stone of a size appropriate to the laying thickness and required surface texture. A TSMA is an SMA that is classified as a thin surfacing system for certification. The single sized nature of the aggregate skeleton leaves a relatively high voids content between the aggregate particles which is partly filled with a binder rich mastic mortar. As such, the aggregate grading is similar to that of porous asphalt, but with the voids filled with mortar. The mortar comprises crushed rock fine aggregate, filler, bitumen or modified bitumen and a stabilising additive, generally fibres. The composition of the mortar is very important in determining the performance of the SMA; very high binder content is essential to ensure durability and laying characteristics. Sufficiently high binder contents cannot be achieved using unmodified or unstabilised bitumens without binder drainage; hence the need for a fibre stabiliser, or absorptive fillers or modified binders.

### **6.1.2.4 Multiple surface dressing (MSD): Binder and aggregate applied separately**

The multiple surface dressing process developed in Norway and brought to the UK under license. A typical MSD consists of successive applications of polymer-modified bitumen emulsion at 1.1 L/m<sup>2</sup>; 14 mm chippings at 12 to 15 kg/m<sup>2</sup>; 10 mm lightly coated chippings at 11 to 13 kg/m<sup>2</sup>; polymer-modified bitumen emulsion at around 2.3 L/m<sup>2</sup>; and 6 mm chippings at 7 to 9 kg/m<sup>2</sup>.

Rolling using 8 to 10 tonne vibratory rubber-tyred rollers is applied both after the 10 mm and after the 6 mm chippings have been laid, although only for a limited number of passes – as with surface dressing, slow-moving traffic is the preferred method of finishing. Other chipping sizes can be used, with each successive application employing chippings one nominal sieve size smaller. The rate of spread for the second application of

binder is selected to fill a proportion of the voids in the dry aggregate skeleton already applied as well as acting as the binder for the final aggregate layer.

#### 6.1.2.5 *Micro-surfacing (MS): Thick slurry surfacing, generally with modified binder*

Slurry surfacings are mixtures of bitumen emulsion and aggregate, generally to a relatively fine grading. Cationic bitumen emulsions are the most widely used binders in the manufacture of slurry surfacings, in which the positive charge of the cationic emulsion reacts immediately with the negative charge of the mineral aggregate producing a rapid breaking asphaltic matrix. Microsurfacing is a proprietary machine-applied thick slurry surfacing system that is applied in two layers and which use aggregates of up to 10 mm nominal size and polymer-modified bitumen emulsion.

## 6.2 Future developments in low-noise road surfaces

The following surfaces are experimental and have not been widely evaluated. As such, they are not expected to be readily available in the short-medium term. However, they potentially offer noise reductions equivalent to or in excess of the current state-of-the-art.

### 6.2.1 *Poro-elastic asphalt (PERS)*

A poro-elastic road surface is a wearing course that has a very high content of interconnecting voids, so as to facilitate the passage of air and water through it, but also possesses some elasticity due to the use of rubber granules or fibres (e.g. scrap tyres, "new" rubber or other elastomeric products) as a main aggregate, sometimes supplemented by sand, stones or other friction-enhancing aggregates.

PERS surfaces are generally designed with an air void content of at least 20% by volume and with a rubber content of at least 20% by weight. In trials of poro-elastic surfaces reported to date, a polyurethane binder is used to hold the mix together with the binder content ranging from 5-15% by weight. Additional binder is also required to fix the poro-elastic material onto the existing road base course. This may be the same binder as that used to hold the mix together, but epoxy resins have also been used in the past for this purpose.

The surface was originally developed in Japan. Trials of the surface type have, for example, been reported by Sandberg and Kalman (2005) and Sandberg *et al.* (2005) and more recently as part of the Dutch noise innovation project, IPG (Morgan, 2008). At the current time, only small length test sections have been trialled, and further development of the concept is required before it can be routinely used. Although the acoustic performance offered is generally in excess of that offered by the current state-of-the-art in low-noise pavements, the structural durability of the surface is poor and requires further development. A project to further develop the poro-elastic concepts is currently being undertaken in the Netherlands as part of the Super Silent Road Traffic programme.

### 6.2.2 *Porous cement concrete (PCC)*

Porous cement concrete surfaces are still at a relatively early stage in development. Porous concrete has an open, self-draining structure similar to porous asphalt, however in this case the binder is cement mortar rather than asphalt.

In recent years, experiments have been conducted in several countries (Germany, the Netherlands, France and the USA) using PCC pavements to reduce traffic noise, e.g. Sandberg and Ejsmont (2002). It is suggested that the problems of clogging that are traditionally associated with porous surfaces will be less pronounced in porous cement concrete. However, this has yet to be shown to be the case experimentally.

Nevertheless, it has been reported, e.g. Riffel (1996), that void contents of 25-30% are possible with PCC without any structural problems which suggests that this type of surface would be less prone to clogging than conventional porous asphalt pavements where a void content of greater than 20% is not presently possible.

Trials undertaken in the Netherlands using PCC pavements have demonstrated that a similar noise reduction to porous asphalt can be achieved if the accessible porosity of the cement concrete is at least 25%.

Although there may be some reduction in clogging on PCC, the problems of winter maintenance described earlier for PA surfaces also apply to PCC surfaces

Modular porous concrete road surfaces have also been trialled in the Netherlands (Morgan, 2008).

### **6.3 Reference surfaces**

Reference surfaces are used to provide a baseline against which the acoustic performance of other surfaces road surfaces can be evaluated. At the present time, there is no common European-wide reference surface; each EU member state has its own reference surface based on the common surface of the road network. The following sections provide an overview of some of the different reference surfaces that are presently in use.

#### **6.3.1 United Kingdom: Hot rolled asphalt (HRA)**

Until recently HRA was one of the most common road surfaces in use on high-speed roads in the UK. The surfacing is laid with a maximum aggregate size of 14 mm and pre-coated chippings with a nominal size of 20 mm are then rolled into the surface. The chippings are added to the surface to provide it with good high speed skidding resistance properties. The specifications for the surface are given in BS 594 (BSI, 2005).

#### **6.3.2 The Netherlands: Dense asphalt concrete**

Dense asphalt concrete (DAC) is used as the definition for the Dutch reference surface. However, it is important to note the reference noise levels on this surface, which are specified in Dutch noise legislation, are actually based on SPB measurements on 11 Dense Asphalt Concrete surfaces (9 surfaces with an 11 mm maximum chipping size, DAC11, and 2 surfaces with a 16 mm maximum chipping size, DAC16), all surfaces being less than 2 years old. The SPB measurements are performed using a 5 m microphone height, rather than the 1.2 m height stated in the associated ISO standard; this higher microphone height is the one specified in Dutch legislation.

Since 16 mm DAC surfaces are dominant in terms of noise emission on high-speed roads, then the reference surface can be referred to as a 16 mm DAC pavement.

It is noted that noise levels on DAC are slightly lower than on HRA. However the surface has not traditionally been used in the UK.

#### **6.3.3 The HARMONOISE project virtual reference surface**

The reference surface in the HARMONOISE model is defined as a virtual reference surface on which the basic values of HARMONOISE are based. It is the *average of SMA 0/11 and DAC 0/11 of one year or older but not at the end of its life time.*

The HARMONOISE project also provided a procedure to enable measurements for a reference surface on other, similar, road surface types to be used. In this way, for example, specific country characteristics on the vehicle and tyre population can be accounted for, although the DAC 0/11 and SMA 0/11 may not be available in that

country. The procedure is that SPB measurements on the following road surfaces are possible:

- DAC 0/11, DAC 0/12, DAC 0/13, DAC 0/14, DAC 0/16
- SMA 0/11, SMA 0/12, SMA 0/13, SMA 0/14, SMA 0/16

Then, depending on the actual reference surface used in a particular country and in a particular situation, one may make small corrections that normalize the chosen reference surface to the HARMONOISE virtual reference surface.

## 7 Acoustic performance of low-noise surfaces

This Chapter reviews the acoustic performance of low-noise surfaces from both the UK and other European perspectives.

### 7.1 UK experience / research

#### 7.1.1 Assessment of acoustic performance after opening to traffic

The acoustic performance of road surfaces was first examined in the UK in the 1970's when the road traffic noise prediction method was first published in 1975 (Department of Transport and Welsh Office, 1975). At that time there were concerns about the noise from traffic travelling over deeply grooved concrete surfaces. Re-texturing worn brushed concrete by grooving the surface was used at that time as a technique to re-instate the surface with improved high-speed skid resistance, with the result of generating high levels of tyre/road noise.

During the 1980's with the introduction of porous asphalt surfaces and later in the 1990's as thin surfacings became more available there was a need to develop a method for classifying the acoustic performance of road surfaces for the purposes of noise prediction. The method adopted was based on the SPB method as described in Section 5.1 and forms the basis of the Highway Authority Product Approval System (HAPAS) which is described in Appendix B (BBA, 2008).

During this period a databank of SPB measurements was commissioned by the Highways Agency and carried out by TRL with the purpose of deriving generic corrections to the traffic noise prediction model, CRTN, to allow the acoustic performance of different road surfaces to be taken into account when assessing the noise from new road schemes.

An SPB measurement survey was carried out alongside high-speed roads surfaced with a range of different surface types. All the SPB measurements were carried out within the first year of opening to traffic. A total of 33 sites were selected for measurement with 6 different types of surfaces (Abbott and Nelson, 2001). The results from this survey are shown in Table 7.1, the results for each surface type being based on the average SPB level across all sites paved with that surface.

For each surface type the average Road Surface Influence value,  $RSI_H$  has been calculated according to the HAPAS method as described in Appendix B. The  $RSI_H$  is the estimated difference in traffic noise levels expected from a high-speed road surfaced with a given surface type relative to a new road surfaced with 20 mm HRA assuming typical traffic conditions for high speed roads.

Table 7.1 also includes RSI values calculated for two-layer porous asphalt surfaces (Morgan *et al.*, 2007), derived from SPB data taken at single sites as part of the Dutch road traffic noise innovation programme, IPG (Innovatieprogramma Geluid; e.g. Morgan, 2008), together with RSI values for several proprietary thin surfacing systems as reported on the associated HAPAS certificates (available at [www.bbacerts.co.uk](http://www.bbacerts.co.uk)).

The results show that compared with the reference surface assumed in the HAPAS method ( $RSI_H = 0$  dB(A)) there is reasonable agreement with the 20 mm HRA surfaces that were selected in the survey ( $RSI_H = -0.6$  dB(A)). For the thin surfaces the ultra-thin surface, 10mm ULM, gave the highest reduction with  $RSI_H = -5.5$  dB(A) with the 14 mm SMA next, providing an  $RSI_H = -4.8$  dB(A). The two Safepave surfaces followed with  $RSI_H$  values of  $-2.8$  dB(A) and  $-1.8$  dB(A) for the 10 mm and 14 mm size aggregates, respectively. The 20mm porous asphalt surface gave the highest reduction with  $RSI_H$  value of  $-6.3$  dB(A).

**Table 7.1: Comparison of the acoustic performance of different new surfaces**

Type of surface		Average RSI <sub>H</sub> dB(A)		
		TRL data (Abbot & Nelson, 2001)	Dutch data (Morgan <i>et al.</i> , 2007)	Current HAPAS certificates
Reference Surfaces	20 mm Hot Rolled Asphalt	-0.6		
Thin surfaces	10 mm ULM [PLSD]	-5.5		
	10 mm Safepave	-2.8		
	14 mm Safepave	-1.8		
	14 mm SMA	-4.8		
	14 mm Viatex			-2.7
	14 mm Tuffpave			-3.3
	14 mm Durafalt			-4.6
	10 mm Stratagem			-7.2
Porous surfaces	20 mm single layer porous asphalt	-6.3		
	Twin-layer porous asphalt 2/6 upper layer, 11/16 lower layer		-11.5	
	Twin-layer porous asphalt 4/8 upper layer, 11/16 lower layer		-10.5	

The results show that porous asphalt provides the largest reductions in traffic noise levels compared with the thin surfaces. Within the thin surface types, the reductions in traffic noise does vary depending on the type of surface and that for a particular surface type higher noise reductions are inversely proportional to aggregate size.

RSI values can be used to derive road surface corrections for use in the UK national traffic noise prediction method, "Calculation of Road Traffic Noise", CRTN (Department of Transport and Welsh Office, 1988). The Design Manual for Roads and Bridges (DMRB; Highways Agency *et al.*, 2008) has recently been revised to allow the surface correction in CRTN to be calculated using a modified relationship, based on a reduced RSI value. This is in recognition that over the period of the assessment the acoustic performance of the surface will deteriorate with time. This is further discussed in Section 7.1.2. For existing thin surfacings where the RSI is unknown an RSI value of -3.5 dB(A) should be assumed, whereas, for future thin surfacings an RSI value of -5 dB(A) is to be used which is the lowest RSI value allowed. This is equivalent to a surface correction of -3.5 dB(A) which is the correction allowed for porous asphalt surfacings.

The acoustic performance of road surfaces described above are assessed under dry conditions.

To place these noise reductions into context, reducing the traffic flow by 50% would give a 3 dB(A) reduction in noise and a 75% reduction in flow would equate to a 6 dB(A) reduction.

### **7.1.2 Assessment of acoustic performance over time**

An important consideration when assessing the acoustic performance of road surfaces is the age of the surface. Earlier work on porous surfaces had shown that the acoustic performance deteriorates with time (Nicholls, 1997). The main cause for this deterioration is due to clogging of the voids with detritus which reduces the benefits provided by sound absorption. Porous asphalt trials carried out on the A38 at Burton-on-Trent showed that traffic noise levels when compared with 20mm HRA under the same traffic conditions, reductions in noise level fell by about 3 to 4 dB(A) over a period of 8½ years.

A research programme monitoring the acoustic performance of low-noise SMA thin surfacings over time is currently underway. The results of the work are presented here. However, as the research programme is still on-going the results are only indicative of the final outcome.

Figure 7.1 shows the relationship between  $RSI_H$  and the number of months after opening to traffic for a selection of low-noise surfaces of varying aggregate sizes 14 mm, 10 mm and 6 mm at 26 sites. For comparison purpose, a 20 mm HRA site was also chosen.

Within the first 12 months after opening, the  $RSI_H$  values varied from about -1 dB(A) for 20mm HRA to about -4.5 dB(A) for the 14mm aggregate and about - 6.5 dB(A) for both the 10mm and 6mm aggregate.

Over the intervening period of trafficking it can be seen that for all surfacings the  $RSI_H$  values increased by about 2 dB(A) for the 20 mm HRA after about 160 months of trafficking whereas for the 14 mm and 10 mm surfaces, the  $RSI_H$  values increased by about 4 dB(A) over the first 120 months of trafficking. A similar trend is indicated for the 6mm aggregate surface but more data is required to confirm this.

This result indicates that traffic noise on the 20mm HRA increases by about 0.2 dB(A)/year compared with an annual rate of about 0.5 dB(A) for both the 14 mm and 10 mm low-noise surfacings.

Clearly this has important implications for assessing the acoustic performance of low-noise surfaces over the lifetime of the surface.

Figure 7.2 shows the estimated change in traffic noise levels relative to the 20 mm HRA surface. For the 14 mm aggregate surface, initial noise levels at the time of opening are on average about 4 dB(A) below the corresponding level for HRA where traffic conditions are similar.

After about 10 years of trafficking the reduction in noise levels has dropped to only about 1 dB(A). Similarly, for the 10mm aggregate, initial noise levels at the time of opening are on average about 6 dB(A) below the corresponding level for HRA where traffic conditions are similar. After about 10 years of trafficking the reduction in noise levels has dropped to about 2.5 dB(A).

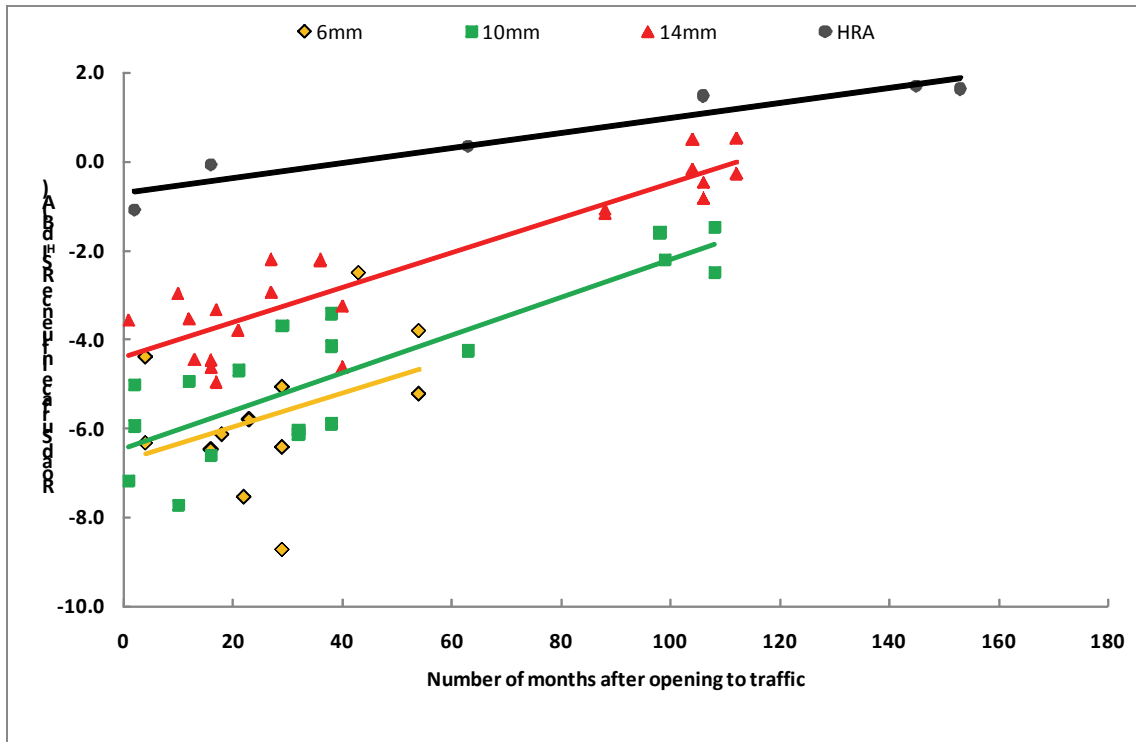


Figure 7.1: Acoustic performance of road surfaces with time

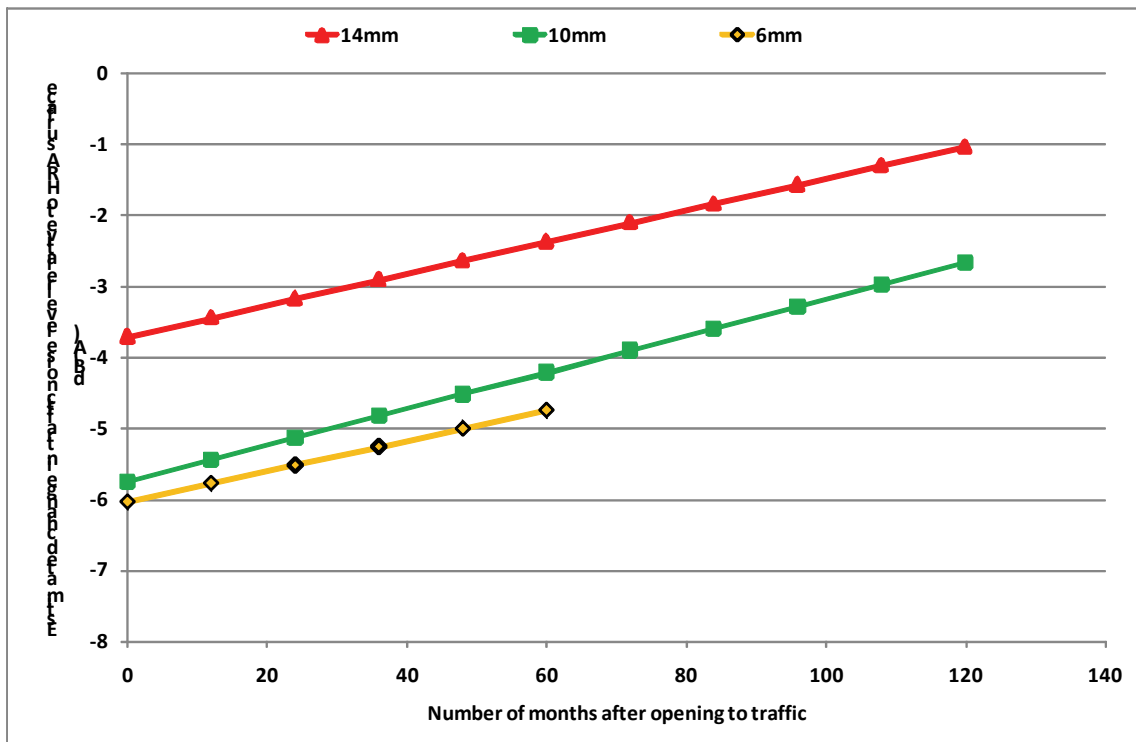


Figure 7.2: Acoustic performance relative to HRA

## **7.2 European experience / research**

Comparing the acoustic performance of different surfaces across the various different countries is extremely difficult. The main reasons why this is so problematic are:

- Different countries use different reference surfaces
- Surfacing types are not comparable
- The same name may refer to different materials/specifications
- Noise reductions may refer to specific vehicle types or traffic flows with different compositions
- Different countries use different types of assessment e.g. CPXI, SPB or overall traffic noise.
- Different countries adopt different measurement procedures e.g. For SPB measurements the preferred reference microphone used in the Netherlands is at 5m above the ground compared with 1.2m generally used elsewhere throughout the EU.

It is therefore difficult when comparing the acoustic performance of low-noise surfaces across different countries that equivalent noise reductions are being compared.

There have been some attempts to address this problem in comparing Dutch/German and Dutch/Danish SPB levels for light vehicles at 120 km/h and 110 km/h respectively (Rovers and Doorschott, 2005; Kragh, 2007b) but no similar comparisons have been carried out for the UK or when reductions are expressed in terms of traffic noise levels. The reference surface used in the UK is of a larger aggregate size, 20mm, compared with the reference surface used in other countries which generally range between 11 to 16mm. Therefore reductions in noise levels quoted from research carried out abroad will tend to under estimate the acoustic performance had a similar comparison been carried out in the UK. This is important to bear in mind when quoting the acoustic performance of surfaces based on research carried out in other countries.

### **7.2.1 Assessment of acoustic performance after opening to traffic**

#### *7.2.1.1 Twin-layer porous asphalt*

Research carried out in the Netherlands under the Dutch Noise Innovation Programme on noise mitigation (IPG) has shown that it is possible for twin-layer porous asphalt to achieve traffic noise reductions of 6 dB(A) with an average expected life time of 7.2 years on heavily trafficked roads. This result is based on research carried out on surfacings consisting of a fine graded (2/6 or 4/8) top layer and a coarse (11/16) bottom layer. The main function of the top layer is to prevent clogging of the lower layer by passing traffic and allows cleaning by high-pressure spraying to be more effective. The reference surface used for comparison purposes under the IPG programme is a mixture of 11 and 16mm DAC (Morgan, 2008)

#### *7.2.1.2 Single-layer porous asphalt*

Research carried out in the Netherlands has shown that the acoustic performance of single layer porous asphalt on high-speed roads to be about 3 to 4 dB(A) lower than the Dutch reference surface, typically for a gap-graded (6/16) surface. The use of this type of surface in the Netherlands is common with over 60% of the network covered (Morgan, 2008).

### 7.2.1.3 Thin surfacings

In Denmark, relative to a reference surface DAC 11, noise reductions of 1 to 3 dB(A) have been measured on urban roads as well as on higher speed roads. In the Netherlands, initial reductions of 4 dB(A) have been obtained for the SMA type surfacings and 5 dB(A) for porous thin surface thin surfacings (Morgan, 2008).

### 7.2.2 Assessment of acoustic performance over time

The European project SILENCE contained a task to provide models for the effect of pavement ageing on the acoustic performance of different surfaces. Part of this project was to review existing data to examine whether there was a simple relationship between surface age and performance (Kragh, 2008).

The review examined in total 9 different databases as follows (where these databases are publically available, references have been cited):

- The database established in the SILVIA project (Anderson, 2005)
- The French LCPC database of SPB values for passenger cars on different road surfaces
- The German BAST database with SPB values for passenger cars and trucks on porous asphalt surfacings
- Danish roads with single layer porous asphalt (Kragh, 1998) and twin layer porous asphalt (Kragh, 2006; Kragh and Thomsen, 2007)
- Belgian roads with twin layer porous asphalt
- CPX data from Denmark as part of IPG programme (Kragh *et al.*, 2006)
- California OBSI (On-Board Sound Intensity) data (Kohler, 2007)
- CPX data from Swedish roads
- SPB data from the Danish Road Institute within the SILENCE project (Kragh, 2008)

The findings from this analysis are as follows:

- For both light and heavy vehicles a simple linear relations between vehicle noise level and surface age. All surfacings for both vehicle categories showed noise levels increasing with age. Although it was observed that there was a large scatter in the results
- It was speculated that a clear pattern may have appeared if each surface type had been separated by total traffic load rather than just by age
- For both light and heavy vehicles the estimated rate of change in noise level for dense asphalt surfacings is an increase of about 0.1 dB(A) per year. This applies to high speed roads as well as low speed roads
- For thin surfacings, results for light vehicles and medium speed roads show an estimated increase in noise of 0.5 dB(A) per year. There were no results available for other speed roads or for heavy vehicles
- For porous or open graded asphalt surfacings, light vehicles can be expected to increase by about 0.4 dB(A) per year at high speeds and by 0.9 dB(A) per year in urban areas with low traffic speeds. The estimated increase for heavy vehicles is estimated to be about 0.2 dB(A) per year

### **SUMMARY**

Experience in the UK on the acoustic performance of low-noise surfaces has shown that when initially open to traffic, significant reductions in overall traffic noise can be achieved compared with the UK reference surface, 20 mm HRA.

Single layer porous asphalt surfacings have been shown to achieve reductions in traffic noise levels of about 6 dB(A) on high speed roads with corresponding reductions of between 2 to 5.5 dB(A) for thin surfacings. Corresponding comparisons from research carried out in other countries generally support these findings although direct comparisons are difficult to establish because of several factors. Different countries use different reference surfaces when assessing the acoustic performance of low-noise surfaces and differences in methods of measurement also confound comparisons in performance. In the Netherlands where twin-layer porous surfaces have been trialled, their performance is generally been found to be about 2 dB(A) higher than that achieved on single layer porous surfacings.

From research carried out in the UK and in other European countries, the acoustic performance of all surface types deteriorate with surface age. Generally, it has been shown that there is a simple linear relationship between noise increase and age. Different surface types deteriorate at different rates. Indicative results from an on-going research programme in the UK suggest that for dense surfacings such as 20 mm HRA the acoustic deterioration is about 0.2 dB(A) per year for high speed roads and for SMA type thin surfacings the acoustic deterioration is about 0.5 dB(A) per year. These rates are supported from a much wider study which analysed data from 9 different databases across 5 different countries. This larger study also showed that the acoustic performance of porous asphalt surfacings also deteriorated with age at a similar rate as thin surfacings for high-speed roads but for low speed roads the deterioration for light vehicles increased to about 0.9 dB(A) per year.

The acoustic performance of road surfaces described above are assessed under dry conditions.



## 8 Non-acoustic performance of low-noise surfaces

This Chapter reviews aspects related to the non-acoustic performance of low-noise road surfaces, namely safety and skid resistance, structural durability, whole-life costing and environmental sustainability, and highlights any issues that may be relevant to Scottish conditions.

### 8.1 Safety and skid resistance

Skid resistance is probably the road surface characteristic of the greatest importance in relation to safety since it directly influences drivers' ability to control their vehicles, especially in wet conditions. However, there are a number of other aspects of road surface characteristics that have indirect implications for safety. These include attributes such as unevenness and rutting but of perhaps greater significance, particularly in relation to low-noise surfaces, is spray.

Section 4.3.4 described the main properties of road surfaces relating to skid resistance that are of importance because of their effect on tyre/road noise generation.

In this section of the report, the discussion focuses on how safety factors are influenced by those characteristics which give surfaces favourable acoustic performance. It is important to be aware, when reading the detailed and very specific observations in this Chapter, that the skid resistance of Trunk Roads is closely monitored and maintained by a tightly controlled Skid Resistance Survey Regime designed to maintain the fitness for purpose of the road surface.

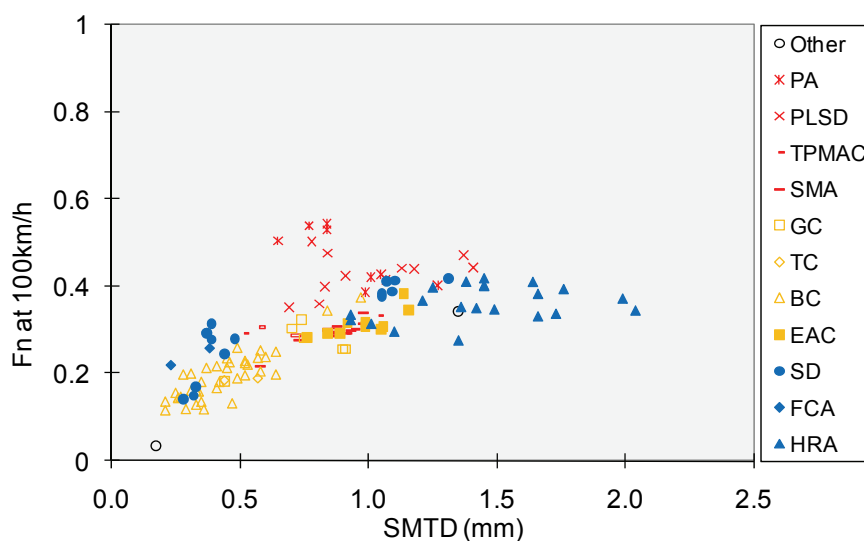
#### 8.1.1 Texture depth and high-speed skid resistance

The requirements for texture depth included in the Manual of Contract Documents for Highway Works are designed to reduce the effects of decreasing skid resistance with increasing speed. However, the values set were originally based upon research that was carried out at a time when the vast majority of UK road surfaces had a surface texture that was "positive" in form.

When low-noise surfaces were first introduced in the UK it was clear that the European designs tended to have relatively lower texture depths and there were concerns that this might have safety implications, primarily as a result of reduced high-speed skid resistance. A programme of research was carried out by TRL for the Highways Agency in the late 1990s (Roe *et al.*, 1998) in which the influence of texture depth on high-speed skid resistance was explored for a wide range of surfaces. Most of these were traditional asphalt or concrete surfaces but some were examples of (then relatively new) thin surfacing materials. The study included examples from roads in Scotland, including the A1, A90, A702 and A766.

Figure 8.1, derived from Figure 11 in the report by Roe *et al.* (1998), illustrates some of the typical results obtained. The graph shows the relationship between locked-wheel wet friction ( $F_n$ ) and texture depth measurements made at 100 km/h for over 140 examples of different types of surfacing. For ease of identification, the main types of texture have been colour-coded, with traditional asphalt surfaces (random positive texture) shown in blue, concrete surfaces (transverse positive texture) in orange and porous and thin surfacing systems in red (the two "other" surfaces shown in black in the figure are special surfaces on the TRL test track).

The key feature of this graph, which is typical of speeds above about 50 km/h, is the noticeable reduction in friction at texture depths below about 0.75 mm SMTD (sensor-measured texture depth). The potential lower-noise surfaces in this graph (PA, PLSD, TPMAC and SMA) show a range of behaviours. Most appear to behave in a similar manner to traditional surfacings but some of the porous asphalt surfaces (PA) do not show so marked a reduction in skid resistance as the other surfaces.



**Figure 8.1: Relationship between locked-wheel friction ( $F_n$ ) at 100 km/h and texture depth (Roe *et al.*, 1998)**

Based on this evidence, lower-noise surfaces were accepted for wider use on the HA network but the 1.5 mm (patch method) initial texture depth requirement was retained. However, experience has shown that striving to achieve this level of texture depth (typically using 0/14 mm mixtures) can have an adverse effect on durability and so the initial texture requirements have recently been reduced, although the levels would keep new surfaces to the right-hand side of Figure 8.1.

### 8.1.2 Use of smaller aggregate sizes

In recent years there has been increased interest in the use of smaller aggregate sizes in thin surfacing systems, especially in continental Europe. The smaller aggregates are associated with reduced noise. It has also been known for many years that the use of smaller aggregate particles in the surface course, in surface dressing chippings for example, usually leads to a small increase in skid resistance (at least at low speeds). However, the associated reduction in texture depth leaves concerns regarding high-speed skid resistance.

In the UK, the main driver for smaller aggregates has been a desire in the industry to make use of aggregate fractions that are a by-product of producing the coarser 10 mm and 14 mm sizes usually used and are currently stockpiled at quarries. This has a sustainability benefit in that it makes better use of premium aggregates that are used throughout the surface course layer in thin surfacing systems. In principle, allowing the use of smaller aggregates could also encourage recycling of premium aggregates recovered from existing thin surfacings.

Since 2004, as part of the Collaborative Programme of research sponsored jointly by Highways Agency, the Refined Bitumen Association and the Quarry Products Association (now Mineral Products Association), TRL has been investigating the performance of thin surfacing systems with aggregate sizes as small as 6 mm in comparison with 0/10 and 0/14 surfacings on a number of trial sites. The purpose of the work has been to investigate the scope for using smaller aggregate sizes, particularly in situations involving higher-speed traffic.

This research is ongoing but early indications are that the 0/14 and 0/10 mm materials tend to exhibit behaviour similar to that shown in earlier studies. However, by contrast,

in spite of lower texture depth, high speed friction performance of some of the 0/6 mm systems has been better than might be expected and comparable with that of many conventional surfacing materials (Roe *et al.*, 2008). Subjectively, the 0/6 mm materials on the trial sites appear to exhibit noticeably less tyre/road noise than their 0/14 or 0/10 mm counterparts.

The study continues in order to assess the way in which performance progresses as the surfacings age and the aggregates polish under the action of heavy traffic (the trial sections were less than two years old when the report by Roe *et al.* (1998) was written). At the time of writing the indications are that the good high-speed performance is being maintained, particularly on surfaces where there is a high proportion of the 6 mm aggregate in the surface and there is a good matrix of drainage channels between the particles.

### **8.1.3 Early-life skid resistance**

One aspect of low-noise asphalt materials is that the polish-resistant aggregate that provides skid resistance in the long term is an integral part of the mixture (as opposed to chippings spread over the surface of the asphalt mat in most traditional materials). Consequently, there is a significant film of bitumen binder left on the running surface of the newly-laid material that can take some time to weather away or be worn off by traffic to expose the microtexture on the surface of the aggregate particles. Newly-laid HRA also has a bitumen film on its surface and on the surface of the pre-coated chippings but this is much thinner and is typically removed more rapidly than that on lower-noise surfacing systems.

The presence of this bitumen film affects skid resistance early in the life of the surfacing and there have been concerns from findings on trunk roads in England that this can lead to increased accident risk. TRL has been carrying out research into these phenomena since 2001. There are two principal physical effects that give rise to concerns. The first of these is a softening of the bitumen that can occur in dry locked-wheel skid conditions resulting in a reduction (by about 20%) in friction compared with a normal well-worn dry road surface (Roe and Lagarde-Forest, 2005). The other effect is the blinding of the aggregate microtexture by the bitumen film which can result in a more-rapid reduction in wet friction with increasing speed.

Research into accident risk (Greene and Crinson, 2008) has shown that on English trunk roads there is a small increase in accidents overall during the first six months or so of the life of newly-laid surfacings in some situations. Within this overall increase, the increases tend to be in the "slight injury" category and occur on otherwise low-risk sites (such as non-event dual carriageways and motorways). There is also a significant *reduction* in fatal accidents in the same period. There are also other complex interactions that are not discussed here but will be covered in future reports.

Typically, the bitumen film that gives rise to "early-life" effects wears away in about six months on well-trafficked roads. However, the effects have been observed on roads up to eighteen months old and it is considered that in places such as Scotland, which has considerable lengths of remote and lightly-trafficked routes, the effects could be long lived, presenting a potential increased accident risk, albeit small, over a longer period.

Although longer-lived on thin surfacing systems, the physical phenomena have also been observed on traditional asphalt materials, including HRA and on temporary surfacings such as dense bitumen macadam binder courses.

It is important to recognise the overseeing organisations' individual approach and requirements regarding surfacing material approval. For example, in DMRB Volume 7, Section 5, Table 2.2E of HD36/06 (Surfacing Materials for New and Maintenance Construction; Highways Agency *et al.*, 2006) allows the "*use without restriction*" of Thin Surface Course Systems in England, whereas Table 2.2S requires "*approval to proceed*" before these materials can be used in Scotland.

It is noted that in addition to work carried out in the UK (see below), investigations for improving early-life skid resistance have also been undertaken on twin-layer porous asphalt surfaces in the Netherlands (Morgan, 2008).

#### **8.1.4 Trial surfacings of SMA on the M8**

Issues with the durability of thin surfacings systems in Scotland (see Section 8.2.7) have led Transport Scotland to explore the use of dense SMA surfacings more typical of those used in Germany rather than the modified SMA materials used in UK proprietary thin surfacings. Trials of potential mix designs are currently in hand on the M8 Duntilland – Newhouse section and these include examples of 0/14, 0/10, 0/8 and 0/6 mm designs.

However, such surfaces, while being low-noise in character, typically have low texture depth and so Transport Scotland are conscious of the need to determine the levels of skid resistance performance, both at high speed in the longer term and in early life. The use of grit rolled into the newly-laid surface as a part of the laying process is being studied within the trial. The idea of the grit is to provide some microtexture on the new surface and to accelerate the removal of the bitumen. In principle, the grit could remain on the surface for some time on lightly-trafficked routes, thus potentially mitigating any risks associated with an extended “early-life” period. However, introduction of the grit could have an adverse effect on the noise-reduction properties of the new surfaces.

Measurements of low-speed and high-speed skid resistance on these sections were made when the surfaces were newly-laid and after three days of traffic. The expected early-life effects were observed on the un-gritted surfaces and the gritting appeared to have had some benefits in improving the friction characteristics, primarily at low speeds and, at least for a short time, at higher speeds. However, the improvements in low-speed skid resistance were largely an increase on an already-high levels. Transport Scotland is therefore giving consideration to when and where to use gritting if this type of treatment is to be pursued. Monitoring of this site, including detailed noise assessment studies of the materials trialled, is ongoing.

#### **8.1.5 Spray**

Low-noise surfaces can lead to a reduction in spray generated by vehicle tyres and this is a potential safety advantage of such surfaces. This is thought to be a result of interconnected voids in the surface (the same voids that reduce noise-generation effects such as air-pumping) being able to store water within rather than on top of the surface. With porous materials, the water is drained away from the surface.

Clearly, porous surfaces have the best spray-reduction effect. However, it has been suggested that some non-porous thin surfacings have better spray-reducing properties than others. Within the Collaborative Research programme referred to in Section 8.1.2, a short study was undertaken to assess this but no real differences could be observed.

Furthermore, in heavier rain, the texture on thin surfacings can be rapidly flooded leading to a thick film of water running over the road surface and this might have implications for an increased risk of aquaplaning (if surface levels are not adjusted accordingly), which is relatively rare on positively-textured surfaces. Another consequence of the storage of water within the surface texture is that water can be drawn out of the texture by the passage of vehicle tyres to keep the wheel paths wet (hence lower skid resistance) and generate some spray for some time after rain has ceased and the rest of the road surface appears dry.

#### **8.1.6 Other implications**

As well as the specific physical effects that are known to affect safety, it has been speculated that low-noise surfaces could lead to increased risks because of the way in which drivers might respond.

For example, the quiet, smooth ride that these surfaces offer could lead some drivers to increase speed, which would then negate any advantages of improved skid resistance (such as might be offered by smaller aggregates) or would exacerbate the effects that are already known, thus increasing skidding accident risks.

### SUMMARY

Skid resistance is probably the road surface characteristic of the greatest importance in relation to safety since it directly influences drivers' ability to control their vehicle. On a dry road, the level of grip (coefficient of friction) is similar at both low and high speeds. However, when the road is wet, not only is the level of grip reduced compared with a dry road, it decreases as speed increases. The skid resistance of Trunk Roads is closely monitored and maintained by a tightly controlled Skid Resistance Survey Regime designed to maintain the fitness for purpose of the road surface.

The texture depth of the road surface is an important factor and surfaces with low texture depth tend to offer much less grip at higher speeds when the road is wet. A feature of noise reducing surfaces is that they tend to have lower texture depth than traditional materials and there are therefore implications for their potential safety performance, especially on high-speed roads.

Research has shown that low-noise surfaces can be made with adequate skid resistance performance but they can sometimes be less durable than traditional surfacings. Some modern materials using very small aggregate particles (6 mm maximum size) are currently the subject of research. They are effective low-noise surfaces but they also have less texture depth than surfaces currently in use. Research is ongoing but indications are that some surfacings of this type can have better skid resistance than might be expected from the low texture depth and high-speed skid resistance can be comparable with that of many conventional surfacing materials.

When low-noise asphalt materials are new, the polish-resistant aggregate that provides skid resistance in the long term is covered by a significant film of bitumen binder left on the running surface of the newly-laid material. This bitumen film, which can take some time to weather away or be worn off by traffic, affects skid resistance in the early life of the surfacing through a complex interaction of physical effects.

The binder film effect also occurs on traditional surfacing, such as HRA, but here it tends to be shorter-lived, due to the lighter binder coating of coated chippings and the way that they are rolled.

While the wet skid resistance may be initially reduced, it is usually adequate. Accident studies on Trunk Roads in England have shown that on new surfacings up to about six months old there is a small but statistically significant increase in accident risk in some situations in both wet and dry conditions (categorised as "slight injury"). It was also shown that there was a *significant* reduction in fatal accidents in the same period.

In general, the binder film wears away in about six months on well-trafficked roads but the physical effects have been observed on roads up to eighteen months old. Where there are considerable lengths of remote and lightly-trafficked routes, the effects could be long lived and present a potential increased accident risk, albeit small, over a longer period but this has yet to be demonstrated by research.

Transport Scotland is currently investigating the performance of new more durable, and lower noise, surfacings. These materials typically have a denser structure and smaller aggregate size than more traditional materials. A graded range of these materials is currently being investigated in a trial on the M8 motorway in which durability and skid resistance performance, both in early life and the longer term, are being measured.

The trial includes the application of grit to the new surface as a technique for enhancing early life skid resistance, and the effects of this treatment on noise reduction are also being monitored.

Low-noise surfaces can lead to a reduction in spray generated by vehicle tyres and this is a potential safety advantage of such surfaces. However, in heavier rain, the texture on some types of low-noise surfacings can be rapidly flooded; this might have implications for an increased risk of aquaplaning (if adequate surface levels are not designed), which is relatively rare on older types of surfacing.

It has also been speculated that low-noise surfaces could lead to increased risks because of the way in which drivers might respond. For example, the quiet, smooth ride that these surfaces offer could lead some drivers to increase speed. This could negate any advantages of improved skid resistance (such as might be offered by smaller aggregates) or exacerbate the effects that are already known, thus increasing skidding accident risks.

## **8.2 Durability**

### **8.2.1 Scottish surfacings**

The approximate proportions of the various types of surface used on the Trunk Road network in Scotland are shown in Figure 8.2. Although details of the surfaces on a large part of the network are unknown, this information is being continuously updated as data is received. The Figure indicates 23% of the network is surfaced with SMA (a relatively quiet surface).

### **8.2.2 Best practice for durability**

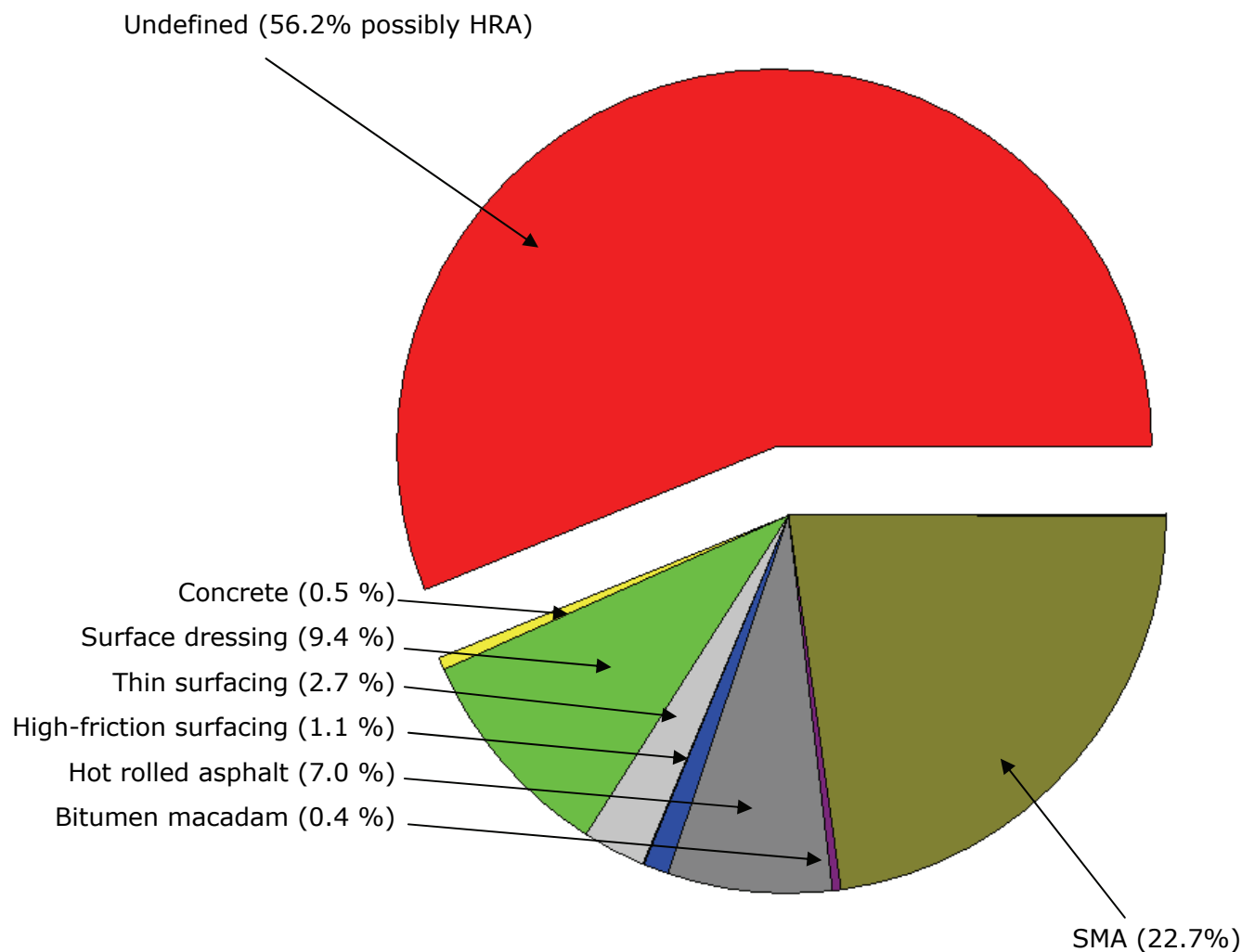
Durability as an overall concept is an issue that was investigated recently by TRL as part of the collaborative research programme for Highways Agency, Quarry Products Association (now Mineral Products Association) and Refined Bitumen Association. The research was based around workshops with practitioners from all sides of industry that produced a best practice guide for the durability of asphalt pavements (Nicholls *et al.*, 2008). The definitions of durability developed within the report were:

- *Asphalt durability*: Maintenance of the structural integrity of compacted material over its expected service-life when exposed to the effects of the environment (water, oxygen, sunlight) and traffic loading
- *Pavement durability*: Retention of a satisfactory level of performance over the structure's expected service-life without major maintenance for all properties that are required for the particular road situation in addition to asphalt durability

The report is intended to cover the concepts needed in order to maximise the durability of any pavement, whether new construct or remedial. As such, it does not include specific problems for different surfacing, or other layers in the pavement. The main concerns that are discussed include co-ordination, drainage, sealing, planning and compaction.

### **8.2.3 Single-layer porous asphalt**

TRL has undertaken extensive research for the Highways Agency (and their respective predecessors) on the durability of single layer porous asphalt, which have been compiled into a single report (Nicholls, 1997). The durability is inferior to other surfacing types because of its high voids content, but the use of a thick binder film did allow for a service life of over ten years on heavily trafficked roads that permitted its inclusion in the *Specification for Highway Works* (Highways Agency *et al.*, Undated).



**Figure 8.2: Trunk road network surfacing in Scotland**

Several major schemes were constructed with a porous asphalt surfacing, including sections of the M4, M25, M40 and A34. However, some of these contracts had problems, in particular the A34 Newbury bypass, and the use of porous asphalt withered in favour of thin surfacing systems. Porous asphalt was considered as the more problematic, more expensive and less durable option whilst most of its advantages were also present in thin surfacings, if not to quite the same extent. Therefore, its use in the UK was never extensive and, hence, experience is limited.

#### **8.2.4 Twin-layer porous asphalt**

Whilst TLPA has yet to be used in the UK, there are considerable experiences with the surfacing in the Netherlands. Durability has generally proved to be poorer than single-layer porous asphalt, currently being of the order of 7 years for the upper layer in the most heavily trafficked lane. However, as part of the Dutch noise innovation programme, IPG, investigations have been carried out to optimise structural durability. Based on the resulting surfaces, it is potentially feasible that structural lifetimes of the order of 10 years might be achieved (Morgan, 2008).

Winter maintenance and potential cleaning (to unblock the pores of the surface) also need to be taken into account to maintain the durability of porous asphalt surfaces in general.

### **8.2.5 Monitoring thin surfacings in England**

The first proprietary thin surfacing systems were introduced into the UK in 1991 with the use of such systems becoming prevalent in the mid 1990s (Nicholls, 2002). Since then, they have become the principle surfacing material for many roads authorities, including the Highways Agency, who currently require a departure from standard before any other type is used on the English trunk road network. Because of its relatively quick introduction, the Highways Agency has commissioned TRL to monitor the service lives achieved by thin surfacing systems. The research has been carried out by monitoring a series of sites around England and Wales on an annual basis; the roads monitored vary from motorways to "B" roads. The research will finish at the end of 2009, having started in 2000, with the results being reported regularly (Nicholls *et al.*, 2002; 2004; 2007).

The conclusions after eight years of monitoring thin surfacing system sites for durability, supported by earlier monitoring of early life performance, are:

- The visual condition of most thin surfacings deteriorates in a linear manner with age when measured using the seven-point scale, with the rate of change in visual condition tending to be dependent on aggregate size
- The time in service for the condition of a surfacing to become unacceptable depends on the standard set, which was found to vary significantly between highway authorities and situations. However, the typical time for the most severe criterion was between 2½ and 14 years depending on the type of thin surfacing system and the aggregate size (the lowest value is for micro-surfacings, whose visual appearance generally starts poorly but deteriorates relatively slowly)
- The principal observed fault of thin surfacing systems is fretting; with it being evident on nearly 90 % of all sites visited by the time they were 12 years old, followed by cracking, with a significant proportion (18 %) of sites showing signs of cracking after three years in service.
- The average service life of sites monitored which have reached the end of their service life (and, hence, form a biased sub-set) was still 9 years with a standard deviation of 3 years.
- Thin surfacings are unlikely to fail prematurely due to loss of skid resistance. Reduction in skid resistance, through polishing in the normal manner, appears to take at least 14 years to develop.
- There is no significant overall change in texture depth after up to 14 years of monitoring for the hot mix systems with some minor exceptions. There are also indications of an increase in texture depth on specific sites when they approach the end of their serviceable lives. This increase is probably due to significant particle loss as a result of fretting

Chipping loss and cracking were the first and second most common defects in the surveys, with delamination only becoming more prevalent than fatting up after about 6 years when any excess binder had been worn off. The appearance of cracks takes longer than chipping loss to become visible. Of these modes, fatting up is least likely to lead to failure because it is a transient defect (the fatted up binder gets worn away by the traffic in time). The CSS undertook a study of thin surfacings on Local Authority highways (Biczysko, 2006) which found that fretting (defined as loss of mortar (i.e. binder, fine aggregate and filler) from the surface, usually including the adjacent coarse aggregate) was the most important and frequent single source of deterioration, with cracking as the second and delamination as the third.

### **8.2.6 Minor roads in England**

There are many generic types of surfacing other than thin surfacings which are still used outside the trunk road network in England. However, less research is underway into their durability, if only because their expected service life is presumed from past experience.

For local authority roads, thin surfacing systems have been found to be “performing equally well or better than traditional materials in most circumstances” (Biczysko, 2006) which, implies that the traditional surfacings are sometimes worse. However, when looking at the performance of HRA in the trials on the A38 (Nicholls, 2005), the longevity of HRA was greater to that found here for thin surfacing systems. However, these materials are not generally low-noise surfacings.

### **8.2.7 Monitoring in Scotland**

Thin surfacings have been implemented in Scotland in a very measured way, taking note of developments elsewhere in the UK and Europe, and they have therefore not reached quite the same predominance as in England. Nevertheless, these materials are now used extensively in Scotland (Figure 8.2). The use of these new materials has been generally welcomed in Scotland by both the road industry and road users. However, there have been reported examples of new surfacings fretting and potholing after only short periods in service. Safety concerns have also been expressed regarding the presence of excess binder that could lead to a slippery surface.

A surface assessment study of thin surfacing laid in the North West Unit of Scotland was carried out between 2004 and 2006 (BEAR, 2006). The study was commissioned by the Scottish Executive (now Transport Scotland) following concern about the loss of texture or fatting up of newly laid surfacing. The study estimated that an area representing 1 % to 2 % of the overall surfacing area laid was affected. The report suggested that the quantity of defects could be considered to be similar to chip loss defects associated with the traditionally used HRA surfacing.

In addition, Transport Scotland commissioned TRL to review the performance of thin surfacings laid on the Scottish trunk road network and investigate some of the reported defects. The review made use of the results of surveys from England but had to allow for Scotland’s climate, remoteness and variable traffic levels. For this review, TRL carried out a survey with industry colleagues and then held workshops before producing an unpublished report for Transport Scotland in 2007. The inspections found that most sites were in moderate to good condition up to ten years old, but that there were a significant number of sites in worse condition, including a cluster of materials that were less than two years old that should have been replaced under warranty. The most common faults observed were loss of aggregates and loss of texture. Alternatively, several sites were assessed as having a good visual condition for their age. One site in particular showed no significant effects and had been in service for 10 years. There was a trend to suggest that schemes constructed as part of larger new construction contracts had performed well but there were also examples of smaller maintenance schemes that were assessed as performing well with little or no significant defects demonstrating that thin surfacing systems could perform successfully in Scotland.

The process proved so successful that annual surveys by representatives from Transport Scotland, TRL and the industry are being undertaken and a permanent Surfacing Forum, chaired by Transport Scotland, has been set up.

### **8.2.8 Low-texture SMA**

Transport Scotland are interested in the technique of applying grit to thin surfacings when laid in order to enhance early-life skid resistance. A study tour to Germany was undertaken to acquire further information. Stone mastic asphalt (SMA) surfacings on the Munich ring-road with low nominal aggregate size and low air void content were observed to be performing well in terms of both durability and noise reduction (although the latter was only measured subjectively). One section was still fully serviceable after nineteen years in service. However, the material would not comply with the UK texture depth requirement and the aggregate did not have the UK level of polished stone value required for skid-resistance.

In order to investigate the practicality of such materials being used in Scotland, Transport Scotland has carried out a trial on the M8 with sections of SMA using different aggregate sizes, both gritted and un-gritted (Section 8.1.4; Bird, 2009). The initial monitoring of the site has shown promising results for early-life skid-resistance, but needs a longer time to confirm both the durability and skid-resistance in the medium-term; monitoring of the actual noise characteristics is also planned. In the meantime, a technical specification is being planned to allow the low-texture SMA to be used routinely in Scotland.

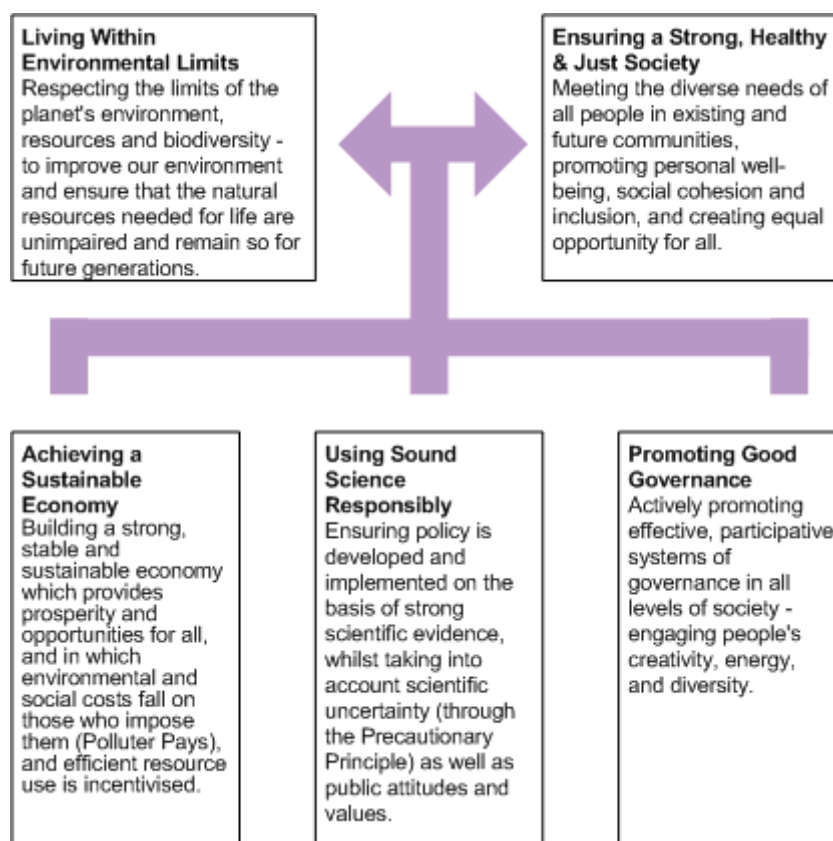
### SUMMARY

The main defects with asphalt surfacings are, in order of frequency, fretting and cracking. The knowledge as to when the defects will lead to failure is limited because there are so many issues that affect the durability.

However, the principal issues are producing a dense, well compacted mat (which usually needs a high binder content and small nominal aggregate size), good bonding between layers and of joints and well-maintained drainage. However, optimising for durability may not be consistent with optimising for skid-resistance and/or noise-reduction.

## 8.3 Sustainability

The terms 'sustainability' and 'sustainable development' are used interchangeably. The Scottish Government, along with the other Governments of the UK, have defined five principles which together define what sustainable development means. These are summarised in Figure 8.3 (Defra, 2008).



**Figure 8.3: The UK's shared principles of sustainable development**

Two of these principles: using sound science responsibly and promoting good governance (which incidentally are satisfied by the original motives for undertaking this report) are added to the traditional three pillars of sustainability: environment, economy and society. Many aspects which are covered elsewhere in this report are in fact sustainability aspects under other guises. Whole life costs and maintenance costs (covered in Sections 11) are factors which would be considered under the economic 'pillar' of sustainability. Safety aspects including skid resistance (Section 8.1.3) and visibility (Section 8.1.5) would be considered under the societal pillar. This leaves environmental aspects (other than noise) to be considered, which can be sub-divided into those which are incurred during the use phase of the road and those which are incurred elsewhere in the life cycle.

To address these issues robustly, Transport Scotland are currently conducting a comprehensive Sustainability Review as part of implementing their Climate Change Action Plan.

### **8.3.1 Emissions incurred during the in-use phase**

One of the principle sustainability considerations in relation to road surfacing is the rolling resistance which it creates for vehicles which operate on it. Any increase in the energy required to move vehicles will have a corresponding increase in emissions. Over the lifetime of the road it is these emissions that will have the most significant environmental and human health implications, contributing to impacts including climate change (CO<sub>2</sub>), acid rain (NO<sub>x</sub> and SO<sub>x</sub>) and summer smog (partially combusted hydrocarbons). However, as indicated in Section 4.3.5, this is not likely to be a significant factor in relation to the use of low-noise surfaces since surfacing with these materials does not significantly alter rolling resistance in comparison to other commonly surfacing materials.

### **8.3.2 Impacts which occur during road construction and maintenance**

Beyond use of the road, the next most significant environmental implications associated with road surfacing are likely to be associated with the road construction and subsequent maintenance interventions. In relation to the use of low-noise surfacing, these will be concerned with both the material constituents of the surfaces and their associated durability. The principle concern with thin surfacings is the volume of high specification aggregate (HSA) which are required to construct them. In relation to porous asphalts the main concern is durability.

#### **8.3.2.1 Resource depletion issues**

HSA is a finite resource in the UK, hence its increased use in surfaces to mitigate noise has to be weighed up against the fact that it will diminish as a resource, thus requiring it to be sourced from further afield in the future or even avoided altogether.

The issue of the increased HSA demand created by thin surfacings is well summarised in a report by Thomson *et al.* (2004). In comparison to hot rolled asphalt with chippings which requires 14 kg/m<sup>2</sup> of HSA, thin surfacing requires 70 kg/m<sup>2</sup> to reach the required polished stone value (PSV) in the coarse aggregate fraction. Alongside the increased use of thin surfacing from the late 1990's onwards, the 'specified' demand for high PSV aggregates (58+) in England has increased considerably, from 2.63 Mt in 1992 to 6.13 Mt in 2002. Overall the use of high PSV aggregates did not increase during this time, but the specified use generated by the increase of thin surfacing did (hence the use of HSA became more efficient at the same time). Surface dressing provides a noisier but less HSA depleting alternative, as a maintenance solution, but is not approved for new road construction.

The use of HSA in different applications also puts pressure on the different size fractions which exist within aggregate. The past prevalence of HRA for surfacing meant that the larger aggregate fractions (14/20 mm chippings) were utilized more while the smaller 6 mm fractions were stockpiled. Now, with the prevalence of thin surfacing (and surface dressing to some degree) over HRA the situation has somewhat been reversed. New ultra-thin surfacings together with surface dressing make good use of the 6 mm fraction, however, if there was a complete shift to these materials in the future, leaving the coarser fractions to be stockpiled, then a higher level of resource efficiency would not be achieved overall (Thomson *et al.*, 2004). Also, if the 6 mm fraction were produced preferentially by grinding, a lot more dust would be produced at the quarry. The most resource efficient solution is to use a mixture of materials which makes approximately equal use of all size fractions of aggregate as generated by quarrying, with minimal requirement for grinding or stockpiling.

Morgan *et al.* (2007) reported on the feasibility of using twin-layer porous asphalt (TLPA) in the UK as alternatives to conventional low-noise thin surfacing. One of the most significant differences between TLPA and thin surfaces is the overall thickness of the TLPA. Use of such a surface will result in a more rapid use of aggregate supplies, particularly if the upper layer is comparable to existing thin layer surfacings, e.g. 10 mm aggregate. The reduced structural lifetime of TLPA relative to thin layer surfacing would further accelerate the use of aggregate supplies.

Research by Carswell *et al.* (2005) has demonstrated the feasibility of recycling thin surfacing back into thin surfacing; a process which has benefits in terms of HSA preservation and lowers the requirement for primary aggregate to be extracted. Mixtures with up to 23% of reclaimed asphalt planings from an expired thin surface have successfully been incorporated into the new surface. It has been demonstrated that the recycling process also has benefits in terms of CO<sub>2</sub> reductions, when compared with asphalt which contains 100% virgin aggregate (Schiavi *et al.*, 2008).

The use of recycled materials is a key feature in any potential long-term use of TLPA. The potential of using recycled materials in TLPA is not one that is discussed widely in the literature. Most studies, e.g. Pucher *et al.* (2004), Sanders (2005), focus on the differences between recycling dense asphalt and porous asphalt surfaces.

In terms of the wider implications of using porous asphalt low-noise surfaces (Veisten and Sælensminde (2004) reported the use of such surfaces instead of dense asphalt may involve the following changes in resources:

- More material use in surfacing and resurfacing
- Lower usage of recycled materials
- Increased use of energy and transport in repairing, eventual cleaning and eventual dumping
- Eventual additional activities/care (involving energy, transport, etc. in waste handling)

### 8.3.2.2 *Geodiversity*

Reduction of particular aggregate sources in an area may also affect the overall geodiversity of a location, which is a conservation issue. Geodiversity has been defined as 'the link between people, landscape and their culture: it is the variety of geological environments, phenomena and processes that make landscapes, rocks, minerals, fossils and soils which provide the framework for life on earth' (Stanley, 2001). Hence preservation of the variety of geology in an area is regarded as important and should be taken into account when determining new areas for the extraction of HSA. One way in which this is achieved is through the use of Local Geodiversity Action Plans (LGAPs). Conversely there is always the chance of new geological discoveries being made in the

course of quarrying too which will enhance the case for the preservation of a particular area.

### 8.3.2.3 Material sourcing

Transport of finite sources of HSA to areas where there are low volumes of indigenous resource is another sustainability issue, since sourcing from distant locations creates environmental implications in the form of increased transport emissions. Since aggregates are used in high volume applications, transport emissions from deliveries become relatively significant in terms of the overall emissions from construction projects. However, compared to some areas of the UK (e.g. South East England), Scotland has very good indigenous sources of HSA. A list of quarries in Scotland which supplied high PSV ( $\geq 58$ ) aggregate in 2003 is presented in Table 8.1 (adapted from Thomson *et al.*, 2004). 25 of the 98 quarries which supplied high PSV aggregate in 2003 were in Scotland. A further list of quarries which has the potential to supply high PSV aggregate is presented in Table 8.2 (adapted from Thomson *et al.*, 2004.).

**Table 8.1: Active quarries providing high PSV aggregate in Scotland**

Site Name 2003	Quarry Operator 2003	'Typical' PSV	Site Name 2003	Quarry Operator 2003	'Typical' PSV
Croy	Bardon Aggregates	61	Clatchard Craig	Ennstone Thistle Ltd	59
Duntilland	Bardon Aggregates	60	Cunmont	Ennstone Thistle Ltd	60
Tormitchell	Barr Quarries	68	Dunduff	Patersons of Greenoakhill	62
Balmullo	Ennstone Thistle Ltd	62	Bonnington Mains	RMC Scotland	60
Brindister	Hanson Aggregates	66	Cowieslinn	RMC Scotland	65
Tam's Loup	Hanson Aggregates	63	Hillend	RMC Scotland	58
Cairneyhill	Tarmac	65	Devon	Skene Group Construction Ltd	67
Cruicks	Tarmac	63	Boards	Tarmac	61
Morrinton	Tarmac	62	Hillwood	Tarmac	61
Balmedie	Aberdeenshire Council	58	Ravelrig	Tarmac	60
Pitcaple	Aberdeenshire Council	60	Lochhead	Tillicoultry Quarries	60
Tongland	Barr Quarries	70	Northfield	Tillicoultry Quarries	60
Ardownie	D Geddes (Contractors) Ltd	59			

**Table 8.2: Inactive quarries with the potential to provide high PSV aggregate in Scotland**

Site Name 2003	Quarry Operator 2003	'Typical' PSV
Vatster	Hanson Aggregates	60
Blairhill	Tarmac	62
Blynee	Tarmac	68
Coatsgate	Tarmac	63
Goat	Tarmac	63
Jericho Bridge	Tarmac	66
Murrayshall	Tarmac	63

On the basis of the information provided in Table 8.1 and Table 8.2, it can be concluded that Scotland is well placed to meet its own needs in terms of the specified high PSV aggregate which it requires. This therefore implies that excessive environmental impacts are not likely to be incurred in transporting aggregate from source to point of use.

#### 8.3.2.4 Durability and sustainability

Section 8.2 discusses durability in some detail. In sustainability terms, durability is also an important consideration since more frequent maintenance corresponds to higher resource use and higher energy expenditure with associated emissions releases. In comparison to HRA, porous asphalts have certainly been found to have inferior durability performance. The picture in relation to thin surfacings is less clear, partly due to the fact that many thin surfacings are relatively new and their durability performance has not been fully evaluated. Initial research indicates that the durability of thin surfacings is neither considerably worse nor considerably better than that of HRA.

Not only frequency of maintenance is important. A consideration of the disruption maintenance causes to traffic flows and the resultant congestion is relevant too. Thin surfacings can generally be taken up and relaid within a single night to be trafficked the following morning. HRA maintenance interventions require considerably longer time periods and invariably require rush hour lane closures.

#### SUMMARY

In addition to aspects considered elsewhere in the study, which covered many sustainability aspects (social and economic), the sustainability assessment considered the use of low-noise surfacings (thin surfacings and porous asphalt) in an environmental context and drew comparisons with the use of hot-rolled asphalt (HRA). It was concluded that in use emissions from the road network would not be significantly affected by the use of low-noise surfacings.

In relation to resource use, it was concluded that the use of low-noise surfacings (thin surfacing and twin-layer porous asphalt in particular) specify for higher overall use of high specification aggregate (HSA) relative to HRA, and therefore more pressure is exerted on the resources of HSA if they are the surface of choice. Concentrated use of one source of aggregate over another can also affect geodiversity.

Some of the pressure on resources of HSA can be relieved by optimising the recycling of thin surfacing back into thin surfacing which is a viable option. Scotland is well resourced in terms of quarries which can supply HSA, hence there should be no exceptional transport impacts associated with the supply of material to use in thin surfacings. The low durability of some low-noise surfaces (particularly porous asphalts) in relation to HRA is a factor which can also increase environmental impacts.



# **PART 3**

## *Overview of cost-benefit analysis & whole life costs*

Part 3 provides an overview of cost-benefit analysis and whole life costs analysis, in terms of how such methodologies might be applied. The text is not specific to low-noise surfacing, but such surfaces are included in any examples.



## 9 Introduction to cost-benefit analysis and whole life costing

The growing concern about the negative environmental effects of infrastructure construction and maintenance procedures has increased the awareness of the need to promote methodologies that support a more sustainable way of life. Over the last few years, when evaluating investment options, there has been a move away from selecting the cheapest option and a move towards identifying the best value option in 'whole life cost' terms.

Whole life costing (WLC) is the systematic consideration of all projected significant and relevant costs incurred by an asset over a period of analysis expressed in monetary value. The aim is to identify the true cost, over a fixed period of time, of achieving defined objectives through a particular option. The costs should include direct costs associated with the asset (e.g. construction, maintenance and disposal) as well as indirect costs imposed by the asset (e.g. on the society due to impacts on health, safety, environment etc) on users and other stakeholders. Whole life costing can be used at any time in the life of an asset to examine the future consequences of alternative choices for the construction of new or maintenance of existing asset.

Assigning monetary values to environmental impacts has been fraught with difficulties associated with both obtaining the values themselves and with providing and using them in ways that all stakeholders find acceptable. In the UK, whole life costs of road pavements have generally considered direct costs and a limited set of indirect costs and road user costs (i.e. delays and accidents):

- Cost of initial construction (or major maintenance)
  - Direct costs (cost of carrying out the work, including aspects such labour, plant, materials as well as traffic management)
  - Indirect costs (costs to road users due to delays and accidents during roadworks)
- Cost of future maintenance
  - Direct costs (cost of carrying out the anticipated maintenance over the analysis period, including aspects such labour, plant, materials as well as traffic management)
  - Indirect costs (costs to road users due to delays and accidents at roadworks)
- Residual value at the end of the WLC analysis period (to enable equitable comparison of different options).

However, there is now a growing interest in extending the investment appraisal process of roads to include other key considerations so that the true whole life costs of options can be evaluated.



## 10 A review of cost-benefit analyses

Four key reports (Nijland and Wee, 2008; Larsen, 2005; COWI, 2006; Sælensminde and Veisten, 2005a) describing cost-benefit analyses including the effects of noise were examined to look at the different ways in which noise effects were considered within the analyses. This has been broken down into two broad sections; firstly, the way in which the noise effects are considered directly and monetised and secondly the methodologies used to employ these values in an overall scheme- or network-level cost-benefit analysis.

### 10.1 Monetisation

To carry out a cost-benefit analysis, the effects being considered must have a monetary value attached to them. In this case, currency values are being assigned to changes in noise level.

Countries in Northern Europe and about half in Eastern Europe have reported monetary values for noise. In most cases the monetisation is based on hedonic pricing (using house prices) but the actual values are different between the countries. The differences are not due to differences in the impacts considered or different valuation methodologies but due mainly to different values being applied to same impacts. For instance, the Working Group on Health and Socio-Economic Aspects (WGHSEA) have recommended a flat-rate €25/household/dB/year (Navrud, 2002), calculated from stated preference (willingness to pay, WTP) analysis. By comparison, Nijland and Wee (2008) report WTP from literature ranging from €2 to €112/household/dB/year. The Danish method (Larsen, 2005) uses a more complicated dose-response relationship, where the costs are related to an annoyance factor (NEF, discussed in more detail later) and the value put on noise is €7902 per NEF (based on 2003 prices). There are other differences as well between different countries, e.g. the UK starts valuing noise from 45dB while France and Netherlands value noise from €55dB; UK and France apply growth to the value of noise with time.

It is widely recognised that the value of a 1dB(A) reduction in noise level is not fixed. As sound pressure level (SPL), on which the dB scale is based, is a logarithmic measure, a 1dB(A) change starting at a lower noise level has a smaller reduction in annoyance and health effects than the same 1dB(A) change but starting at a higher noise level. Assigned monetary values reflect this; the Department for Transport (2006) use a linear scale for valuing noise between 45 and 80dB(A), below which the costs are assumed to be zero and above which a constant £98/dB/household/year is applied.

### 10.2 Effects of noise

Noise is recognised to impact in different ways:

- Annoyance
- Cardio-vascular disease
- Cognitive performance impairment, and
- Sleep disturbance

According to Nijland and van Wee (2008), with the exception of France and Denmark, countries considered only annoyance when calculating noise costs and every country considered noise in residential contexts only (e.g. occupational buildings are not included). To take other health impacts into account, a percentage increase to the value calculated is applied in some countries; the French add an additional 30% to costs for noise levels above 70 dB, while the Danish apply a 50% increase across the board. The EU project, Developing Harmonised European Approaches for Transport Costing and Project Assessment (HEATCO) (2006) has developed recommendations for calculating

noise costs in infrastructure. The unit costs presented in the report include annoyance and health impacts. There are no reports of differentiation between day and night impacts of noise on annoyance or health.

### **10.3 Determining values**

The most common methods used to determine monetary values for noise impacts are hedonic pricing (usually looking at house price disparities, with houses in noisy areas being cheaper than those in quieter neighbourhoods) and , 'stated preference' methods. Germany, Finland and Austria used contingent valuation, 'stated preference' (for instance, willingness-to-pay analyses) methods, while Germany also combines contingent valuation with an avoidance cost, using the price of necessary noise abatement measures as a proxy for noise costs. Hedonic pricing requires large amounts of data to separate the price differential due to noise levels from other influencing factors and it is assumed that people only include annoyance in their market preference when buying a house. Contingent valuations rely on asking people directly for their preferences, which has benefits in terms of wide applicability but responses can be biased, requiring further testing and correction.

#### **10.3.1 Benefit per vehicle kilometre**

One option allowed for in the SILVIA project and similar analyses uses the marginal benefit of the Do Something option per vehicle kilometre, including noise and other indirect effects (e.g. safety and air pollution). This method uses no direct information about dwellings in the environment of the road being assessed, although weighting factors can be used to reflect residential dwelling density. However, it does have advantages where other indirect effects (e.g. vehicle speeds) are being considered.

#### **10.3.2 Benefit per household**

A more robust option, used in SILVIA and much more widely (HEATCO 2006; Department for Transport, 2006) is to consider the benefit per household. Simply, or for network-level analysis, this could be a combination of dwelling maps with models of the dispersion of noise with distance from the source. In a scheme-level analysis, dwellings can be considered individually, calculating the noise exposure of each dwelling in the affected area. The difference in noise exposure in dB can then be converted to a financial cost.

One widely-cited example of this type of analysis is the noise exposure factor, or NEF.

#### **10.3.3 Noise Exposure Factor**

The NEF (Larsen, 2005) is a sum of weighted noise loads on individual dwellings within the area being considered. Weighting factors for exterior and interior noise levels at ordinary dwellings or weekend cottages etc. can be used along with the noise level at specified intervals (e.g. 5 dB).

Once the NEF has been calculated for each alternative, overall benefit can be calculated in terms of the cost per reduction in NEF value between the alternatives (e.g. in €/NEF).

#### **10.3.4 Other costs considered**

As part of the CBAs studied, costs other than those from the effects of noise are calculated. Even within one country (in this case, the studies carried out in Denmark (Larsen, 2005)), this can be as simple as just considering the generalised operating and construction costs (Danish noise strategy) or as complex as monetising initial construction, maintenance and user delays as well as cleaning, alert costs and special

winter maintenance for porous surfaces. Including the costs of a range of external factors can improve the overall robustness of the analyses.

## 10.4 Impact analysis

Once costs for different noise levels have been set, the impact must then be calculated to convert unit costs into an overall value to be compared to other cost sources. The methods used in the CBAs studied for this report generally use a comparison with a base case to estimate the impacts of noise; i.e. the cost/benefit is against an alternative. For instance, the spreadsheet developed for the SILVIA project (Sælensminde and Veisten, 2005a and 2005b) compares Alternative 0 (a 'business-as-usual'/'do nothing' option) with Alternative 1 (the noise control/improvement 'do something' option).

Comparison to a base case does mean that an appropriate option needs to be selected; in some situations, this can be difficult. It is important that the base option be appropriate for the scheme being analysed, otherwise the comparison will be meaningless and the calculated NPV will not represent the true value of the works. Therefore, the selected base option has to be a viable alternative to the preferred/"Do Something" option for which the value is being calculated. This way, the differences in noise levels can also be equitably compared with other factors, such as the need for increased maintenance frequency with some low-noise pavements.

As an example, the study on the proposed widening of Motorring3 in Copenhagen, Denmark (Larsen, 2005) compares the effect of low-noise surfacings (one-layer porous asphalt or thin layer pavements) to the materials used for the existing lanes (dense asphalt concrete). For this scheme, the low-noise surfacings are quieter but require more frequent maintenance and, in the case of porous asphalt, extra winter maintenance and cleaning considerations. The difference of noise levels between the surfaces (in dB) are estimated, then the corresponding NEFs are calculated to give the overall noise cost of each scheme option.

In some cases, the base option will be a Do Nothing; carrying on with the current situation can be compared to, for instance, installing a noise barrier. In others, it may be the case that pavement works are required but a "high-noise" surfacing is simply not an option (e.g. where prevented by legislation). In the latter scenarios, the selection of an appropriate base case is much more challenging. However, selecting a "Do Minimum" option (i.e. the least possible expenditure to meet the requirements of the situation) with a more extensive but higher-quality programme of works can give an idea of the most cost-effective overall option.

### SUMMARY

A selection of reports including cost-benefit analyses of alternative pavement surfacing options has been reviewed to identify the different ways in which noise impacts and any other costs were considered within the analyses.

The monetary values of noise are generally based on the 'annoyance' caused. The negative impacts of high noise levels on health have also been considered, but this is generally a percentage increase to the monetary value assigned rather than a separate calculation. The monetisation of noise is based either on the indirect effects on house prices or direct willingness-to-pay surveys.

Although some methodologies calculate the benefits of low noise surfaces on a per vehicle kilometre basis, most concentrate on benefit per household. This usually involves comparing dwelling density maps with noise propagation models to calculate the number of residences affected by a certain level of noise. In Denmark, a Noise Exposure Factor calculated as the weighted sum of the noise loads on individual dwellings has been used to calculate the overall impact.

The other costs considered in the analyses varied between the case studies. Some simply considered general works and ongoing maintenance costs, whereas other more detailed analyses included initial construction, maintenance and user delays as well as cleaning, alert costs and special winter maintenance.

## 11 Applying noise costing methodologies

The generation of traffic noise and the changes in noise levels due to deterioration of road surface over time is a complex process and is influenced by several factors (e.g. surface type, surface condition, other road characteristics, vehicle type, driving condition). Other specific local conditions also have an important bearing on the impact of noise (e.g. rural/urban environment, population density, distance from source, presence of noise barriers etc).

A key aspect of including noise impacts within the WLC framework will be to specify financial rates to account for changes in noise levels with time and traffic conditions for different pavement surfaces. This will allow the impacts of maintenance on noise levels to be taken into account. Including relationships to represent the changes in noise levels into the whole life cost analysis framework has the potential to highlight treatments both in terms of pavement condition indicators that have reached intervention thresholds and also noise levels that require treatment to lower the level of noise that the surface produces.

The impact of the deterioration of the road surface over time on the generation of traffic noise is a complex process. The evaluation of the consequences of changes in noise levels, such as the effects on the surrounding population and the associated costs, requires knowledge of noise deterioration rates for different surfaces. Limited data is available on the acoustic durability performance/behaviour of different surfaces or how the effects of changes in surface characteristics, e.g. texture, impact on acoustic performance. However, the knowledge which is available can be used to extend existing WLC methodologies to include noise impacts. For example an earlier study to examine the cost-benefits of different surface types (FEHRL, 2006) used data from a report by Chandler *et al.* (2003) which provided data for 3 different surface types, from a limited number of sites. The average maximum noise level in dB(A) had been recorded for up to a maximum age of 80 months from the time of construction. The increase in noise levels from the initial measurement was used to derive the average percentage increase in noise level per year and develop preliminary relationships that could be used to demonstrate the impacts of noise levels on the whole life cost of alternative maintenance options.

A potential methodology to compare the whole life costs of using two types of surfacing, HRA and SMA, including the effects of noise within the WLC framework is presented in the following section. The methodology is based on the Department of Transport's noise costing values (derived using a willingness to pay (WTP) analysis). This monetary valuation of a change in noise levels (expressed in pounds sterling per household per dB change per year, with the value per dB depending on the starting noise level) can be used to convert calculated noise levels into a financial cost for inclusion in the overall whole life cost of a given scheme or option.

For this example analysis, noise costs have been expressed as a difference in cost between two options; i.e. comparisons are made with a baseline noise level. In this case, the SMA noise-cost benefit is compared to the base HRA option. The whole life costs have been evaluated over a 60-year analysis period. This is consistent with current DfT recommendations on transport-related scheme WLC analysis.

The analysis is carried out looking at a 600 m wide strip with the noise source at its centre, i.e. 300 m each side of the carriageway. The noise level experienced by each household in this strip is calculated, assuming that there will be attenuation of the noise as you move further back from the road and the cost per household is scaled up based on the population density in that area.

Currently, the modelling is limited by the input data. To carry out a more detailed analysis, specific case studies would have to be considered with accurate values for the noise created by traffic on the road, attenuation of the noise level with increasing distance and the population density. Also, it is recognised that some of the assumptions

made in the model need to be refined; particularly, separating the noise levels for day and night-time.

Traffic noise is related to the number of vehicles (traffic level), the proportion of these which are heavy vehicles (traffic composition), the traffic speed, road geometry (specifically: gradient) and the condition of the surface course (which can be measured or estimated based on deterioration relationships and the time since the surface was last maintained).

Unfortunately, many of the relationships between surface condition and noise have not been formally investigated; more information here would be a significant aid in building a more robust model. The impact on noise of pavement wear can be complex. For example, the smoother surface resulting from polishing due to the flow of heavy vehicles may reduce the skidding resistance (i.e. deterioration in condition) but may also contribute to a reduction in noise (i.e. an improvement).

### **11.1.1 Noise cost sample analyses**

Simplified analyses have been carried out to demonstrate the potential impact of low-noise pavements from a whole-life cost (WLC) point-of-view.

To look at the different effects of low-noise surfacings in different environments, two roads, namely a rural dual carriageway (D2) and urban two-way single carriageway (S2), have been considered; each is costed separately. The population densities and noise attenuation factors which have been assumed are shown in Table 11.1; the urban environment has a much higher population density, but the noise level falls off more rapidly as distance from the road increases.

**Table 11.1: Band properties for the two environments considered**

Band	Distance from road (m)	Attenuation factor		Population density (households per 100m)	
		Rural	Urban	Rural	Urban
1	0-50	1	1	12.5	50
2	50-100	0.9	0.8	12.5	50
3	100-150	0.8	0.6	12.5	50
4	150-300	0.7	0.4	25	100

A 1 km scheme over two (3.65 m wide) lanes, totalling 7,300m<sup>2</sup> of surfacing, has been considered for each road type. This represents resurfacing both lanes of the S2 road and one carriageway of the D2 road.

Two materials, a 'conventional' HRA pavement surface and a lower-noise TSMA thin surfacing, have been compared. Direct works and traffic management (TM) and indirect user delay and noise costs are calculated for each of the options considered over a 60-year period.

The properties used for each of the two materials are summarised in Table 11.2.

**Table 11.2: Properties of the two different surfacing options**

	HRA	T SMA (14mm)	<i>Representative values used for modelling</i>
Works costs (£ m <sup>-2</sup> )	19.20	18.40	19.00
Work rate (m <sup>2</sup> hour <sup>-1</sup> )	500	545	500
Initial noise level (dB(A))	80.0	75.2	
Noise deterioration (dB(A) year <sup>-1</sup> )	0.2	0.5	
Expected life (years)	12	8	

A starting noise level of 80 dB(A) for HRA has been assumed. The 75.2dB (A) for SMA has been derived from the values in Table 7.1, using the offset of -4.8 dB(A) for 14 mm SMA against 20 mm HRA.

The works costs and rates for the two materials are very similar; as a simplification the same values of cost and rates of working (shown as representative values in Table 11.2) have been used and this results in a works cost of £138,700 and duration of 14 hours (represented as two 8-hour day shifts) for each intervention.

Currently, the noise cost calculator used does not separately cost noises occurring in the night-time and in the day-time. Maintenance activities are assumed to be a continuous noise level of 110 dB(A) (the noise of a road drill) for an integer multiple of 24 hours roughly equal to the duration of the works.

User Delay Costs (UDCs) are dependent on traffic flow and composition (particularly the percentage of heavy vehicles), and will vary between the two environments and the two treatment options. The values used for the UDC calculations are shown in Table 11.3. The traffic values are initial (2009) values and a traffic growth of 1.1% per year is applied to these for the UDC calculations for later years.

**Table 11.3: TM, traffic flows and compositions used in the UDC calculations**

Environment	Road type	TM arrangement <sup>3</sup>	Traffic flow (veh day <sup>-1</sup> )	Proportion of heavy vehicles (%)
Rural	D2	D2 1/2	24,000	5
Urban	S2	S2 shuttle-working	8,000	20

A summary of the cost types and the results are shown in Table 11.4. Net Present Value (NPV) is the discounted whole-life cost of a given option, including the works, direct TM and indirect user delay costs. This also includes a measure of residual value (i.e. the remaining value of the treatments applied during the analysis period) to allow equitable comparison between options with different intervention frequencies.

<sup>3</sup> The two TM arrangements are selected to be comparable; each models the close of one lane at a time to carry out the works.

**Table 11.4: Summary of costs for schemes in rural and urban environments**

Cost type	Cost (£k)			
	Rural		Urban	
	HRA	SMA	HRA	SMA
Works (direct)	398	572	398	572
TM (direct)	7	13	7	13
User delay (indirect)	75	115	27	18
NPV (works, TM and user delay)	482	690	434	593

All costs have been discounted back to the base year (2009) using the Treasury Discount Rate of 3.5% for the first 30 years, 3% for the second 30 years.

The shorter expected life of SMA leading to a more frequent treatment pattern results in a higher NPV for the SMA option. Table 11.5 shows the monetary impacts of the different noise levels when surface is 'new' and noise deterioration with time. For the methodology adopted the overall benefits of using SMA with a lower initial noise level are significantly higher than the direct financial and user delay costs. (Note values are negative, as this is a benefit).

**Table 11.5: Summary of noise cost for schemes in rural and urban environments**

Environment	Equivalent noise 'cost' of SMA versus HRA (£k)
Rural	-3,431
Urban	-7,921

The large benefit from lower noise levels can therefore make the SMA an attractive option. The actual benefits (or otherwise) will vary depending on location specific factors.

### SUMMARY

Over the last few years there has been a move, particularly in the public sector, towards appraising investment options on the basis of whole life cost rather than just the initial cost. Whole-life costing (WLC) is the systematic consideration of all projected significant and relevant costs incurred by an asset over a period of analysis expressed in monetary terms. In general, whole life costs of road pavements have considered direct costs and only a limited set of indirect costs; however, there is now a growing interest in extending the investment appraisal process of roads to include other externalities so that the true whole life costs of option can be evaluated.

An approach to incorporate the effects of noise within the WLC framework has been developed. The approach is built around the DfT tables (in webtag) containing monetary values assigned to changes in noise level. This is currently a framework within which comparisons of different options can be carried out but it provides a basis for a comprehensive modelling of the effects of noise and demonstrates the feasibility of such analyses.

Some simplified 60-year WLC analyses have been carried out to demonstrate the potential benefits of low-noise surfaces. In the particular examples considered, the combined works, traffic management and user delay costs of the lower-noise surfacings is higher than traditional HRA options but when the monetised benefit of reduced noise levels is taken into consideration, the position is reversed.

It should be noted that the test analyses make assumptions that may not be appropriate for all cases. The actual benefits (or otherwise) of low-noise surfaces will vary depending on location- and scheme-specific factors. Some of the relationships used (e.g. between surface condition and noise) have not been formally investigated; more research would be required before the modelling can be considered comprehensive and robust.



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## Further reading

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## **Appendix A The mechanisms of tyre/road noise generation**

The main mechanisms described above are illustrated in Figure A.1 on the following page, which shows the various stages of tread pattern rotation and the different noise generation effects at each stage of the process.

It is reckoned that for standard rolling conditions the tyre/road noise is mainly composed of "impacts and shocks" noise and "air pumping" noise, with the first mainly occurring below 1000 Hz and the second mainly occurring above 1000 Hz.

### **A.1 Impacts and shocks**

This mechanism essentially consists of the excitation of the tyre tread elements as they come into contact with the road surface, the vibrational response of the tyre carcass, and the subsequent radiation of sound by an area of the vibrating tyre (Plotkin *et al.*, 1980).

Vibrations are generated in vehicle tyres by the impacts and deflections that occur as the tread blocks enter and leave contact with the road surface, and as a result of movement of the tread elements in contact with the road base. A tread block entering the contact patch impacts the road surface, generating vibrations which are driven radially into the tyre. The tension exerted on the tread block then decreases and increases depending on the frictional forces between the tyre and road whilst the block is passing through the contact patch. As the trailing edge of the block leaves the contact patch, it is released from this tension and rapidly returns to its undeflected rolling radius. The rapid movement occurring during this process, known as block "snap out", excites both radial and tangential vibration modes in the tyre structure (Bergmann, 1980).

Noise that is generated by the tyre as a result of vibrations caused by tyre impacts and "snap out" effects tends to occur towards the lower end of the frequency range below about 1000 Hz. In this frequency range it is known that the amplitude of the longer texture wavelengths in the road texture profile have an important role in controlling noise emissions as explained further in Section 4.3.1

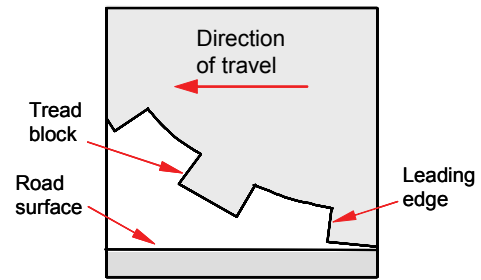
It should be noted that the mechanisms described above are intended to provide a general overview of how noise is generated by a tyre rolling over a road surface. The relative importance of each mechanism in governing the overall levels of noise generated will, in practice, vary greatly between tyre types and designs. For example, the noise generated by truck tyres tends to be more closely related to tangential excitation of the tread than for car tyres where the main mechanisms are often related to excitation of the tyre structure through the generation of normal forces on the tyre belt.

### **A.2 Aerodynamic processes**

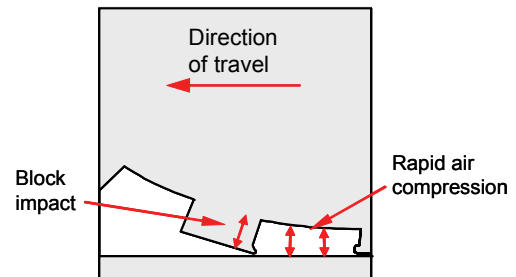
Noise is generated by several mechanisms related to the movement of air in the cavities of the tread pattern. These occur principally in the region of the contact patch. Of these processes the most commonly cited is referred to as "air pumping".

The original air-pumping theory was described by Hayden (1971). This involves the sudden outflow of air trapped in the grooves of the tread pattern or road surface texture when the tyre comes into contact with the road surface, and the sudden in-flow of air when the tyre lifts away from the contact area. It has also been suggested that friction and tangentially excited vibrations could play a role in exciting air-pumping or "air resonant radiation" (Nilsson, 1979; Sandberg and Descornet, 1980). The air pressure modulations caused by these processes have been shown theoretically to cause significant levels of tyre/road noise, particularly when the surface is non-porous and relatively smooth (Hamet *et al.*, 1990).

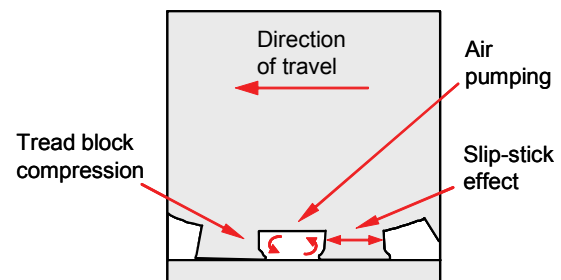
As the tyre rotates there are no forces acting upon the tread block under observation.



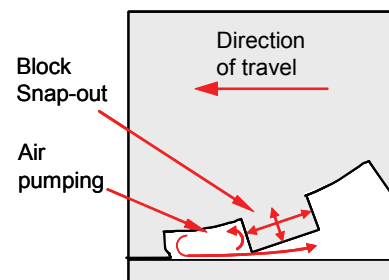
As the tread block impacts with the road surface, shocks are sent through the block which generates vibrations. Air caught between individual tread blocks is compressed



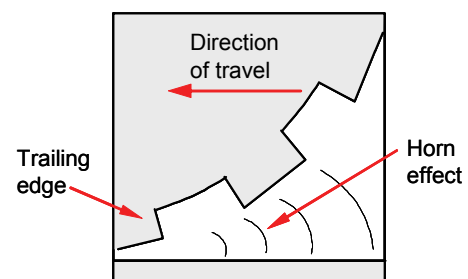
The air trapped between the tread blocks is compressed and decompressed as the tyre passes over the road surface. This is known as "air pumping". Organ pipe resonance occurs in the longitudinal tyre grooves. Friction forces acting on the tread blocks in contact with the road surface cause the "slip-stick" effect.



As the tread block leaves the contact patch, compressed air in the tread cavity is expelled rapidly, resulting in the "air pumping" effect. The tread block itself is returned to its undeflected rolling radius position by "snapping out" from the compressed state in the contact patch.



Noise generated at the contact patch is amplified by the geometry of the tyre and road surface (the "horn effect"). The tread block returns to its steady state as the tyre rotates.



**Figure A.1:** The mechanisms of tyre/road noise generation

The provision of air paths in the road surface layer (i.e. porous and semi-porous surfaces) can help to dissipate air trapped in the tread grooves and therefore largely prevent air pumping occurring.

Sandberg (1987) has also discussed the possibility of noise generation being affected by air resonance in the cavities of the tread pattern by a process similar to the action of a Helmholtz resonator. The phenomenon occurs when the dimensions of the cavities are small in comparison to the wavelengths of sound and is analogous to the resonance of a mechanical system.

Cena and Travaglio (1995) have also described an "organ pipe" effect that occurs due to resonances in the air trapped in the longitudinal grooves in the contact patch. This interpretation was first put forward in 1979 (Fabre, 1979). It is suggested that the mechanism becomes important when the length of the contact patch coincides with half the wavelength of sound in the air. For car tyres these resonances generally occur at frequencies greater than 1700 Hz.

A similar process may be responsible for a cavity air resonance effect reported by Cena and Travaglio (1995) which occurs as a dull drumming noise. The phenomenon arises in the toroidal air space within the tyre. It appears that the interior of the tyre can be considered as a pipe which is bent back on itself. Typically, for a car tyre the main resonances occur at approximately 250 Hz. Vibrations transmitted through the tyre from the contact patch trigger the process.

In general, noise generated by aerodynamic mechanisms tends to be important in the range of frequencies between 1000 and 2000 Hz. In this frequency range it is known that the amplitude of the shorter texture wavelengths in the road texture profile have an important role in controlling noise emissions as explained further in Section 4.3.1.

### **A.3 Adhesion mechanisms**

A further noise generation mechanism is caused by tyre vibrations induced by the frictional forces created in the contact patch between the tyre and road surface. When the tyre flattens in the contact patch, the continually changing radial deflection produces tangential forces between the tyre and road. These forces are resisted by friction and tyre stiffness, and any residual forces are dissipated by slip of the tread material over the road surface.

Forces comprised of hysteresis and adhesion components control friction between the tread and the surface. The adhesion component has its origins at a molecular level and is governed to a large extent by the small-scale roughness characteristics, or microtexture of the road surface. During relative sliding between the tyre and the road base, the adhesion bonds that have been formed between the tyre and road surface begin to rupture and break apart so that contact is effectively lost and the tyre element is then free to slip across the road surface. Contact may be regained as these residual forces are dissipated.

The hysteresis force is due to a bulk phenomenon which also acts at the sliding surface. In the contact zone, tread rubber drapes around asperities (i.e. microtexture) in the road surface and, in the absence of slip, the pressure distribution around each asperity is roughly symmetrical. When slip occurs, tread rubber tends to accumulate at the leading edges of these surface irregularities and begins to break contact on the downward slope of the surface profile. This gives rise to an asymmetric pressure distribution and a net force which opposes the sliding motion; at high speeds this force is largely responsible for the tread element regaining contact with the road surface. The hysteresis component of tyre/road surface friction is largely controlled by the surface macrotexture, which comprises texture wavelengths corresponding to the size of the aggregate used in the surface material.

Clearly, the slippage of tread elements alone cannot give rise to tangential vibrational excitation of the tyre. It is rather the combination of the slip of the tread elements as adhesion is lost in the contact patch and a build up of the hysteresis frictional force as deformation of the tread occurs. This gives rise to a "slip/stick" process in the contact patch and the associated vibration excitation of the tyre. Tyre vibration, and hence noise, generated by this mechanism has been related to the slip velocity of the tread elements (Nelson and Underwood, 1984). The highest velocities tend to be found to the rear of the contact patch and may contribute to block "snap out" effects as the tread elements are released from the contact patch and return rapidly to the undeflected rolling radius of the tyre.

It has also been suggested (Liedl and Denker, 1979) that a surface with high friction (microtexture or adhesion) can generate high frequency noise due to the excitation of "air resonant radiation" in the contact patch tread grooves. It would appear that this relates to the coincidence of high frequency noise generated due to the rapid slip/stick mechanism of the tread block with the resonant frequencies of the tread cavities and grooves.

## Appendix B Noise Assessment throughout the EU

Appendix B examines how the ISO methods described in Chapter 5 have been adapted in various countries in Europe and includes a proposal for use throughout Europe put forward by FERHL, a consortium of European research organisations, that was commissioned as part of the EU 5<sup>th</sup> Framework Project "SILVIA – Sustainable Road Surfaces for Traffic Noise Control".

### B.1 United Kingdom

#### B.1.1 Statistical pass-by method (HAPAS)

In the UK, the Highways Agency (HA) when specifying a low-noise road surface for its road network, requires the contractor to use only surfaces which have been certified under the Highway Agency Product Approval Scheme (HAPAS; BBA, 2008). Under this scheme, low-noise surfaces can be certified for noise by carrying out the measurement procedure described below.

The measurement procedure used in the UK follows closely that described in ISO 11819-1 (ISO, 2005). During an SPB measurement, the maximum pass-by noise levels and speeds of individual vehicles selected from the traffic stream at a reference distance of 7.5m from the centre of the vehicle lane, are measured. The traffic population is classified as follows:

- $L_1$  - light vehicles including passenger cars and car derived vans, excluding vehicles towing trailers or caravans
- $H_1$  - commercial trucks with 2 axles and greater than 3.5 tonnes unladen weight
- $H_2$  - commercial trucks with more than 2 axles and greater than 3.5 tonnes unladen weight

To provide statistically robust results a sample size of at least 100  $L_1$  vehicles and at least 50  $H_1$  and 50  $H_2$  vehicles are required. For each vehicle category, a linear regression equation is derived between the maximum pass-by noise level,  $L_{Amax}$  and the logarithm of the vehicle speed (km/h). For each vehicle category, the estimated noise level,  $L_{Amax,v}$  for a given reference speed,  $v$  km/h, is derived from the regression equation. The values of  $L_{Amax,v}$  for each vehicle category are used as input to the following equations to provide an estimate of the Road Surface Influence, RSI:

For medium speed roads:

$$RSI_M = 10 \log_{10} \left( 11.8 \times 10^{\frac{L_{veh,L}}{10}} + 0.629 \times 10^{\frac{L_{veh,H1}}{10}} + 0.157 \times 10^{\frac{L_{veh,H2}}{10}} \right) - 92.3 \text{ dB(A)} \quad (\text{B.1})$$

where  $L_{veh,L}$ ,  $L_{veh,H1}$  and  $L_{veh,H2}$  are the respective values of  $L_{Amax,v}$  for vehicle categories  $L_1$ ,  $H_1$  and  $H_2$  at speed,  $v = 80, 70$  and  $70$  km/h, respectively.

For high speed roads:

$$RSI_H = 10 \log_{10} \left( 7.8 \times 10^{\frac{L_{veh,L}}{10}} + 0.578 \times 10^{\frac{L_{veh,H1}}{10}} + 10^{\frac{L_{veh,H2}}{10}} \right) - 95.9 \text{ dB(A)} \quad (\text{B.2})$$

where  $L_{veh,L}$ ,  $L_{veh,H1}$  and  $L_{veh,H2}$  are the respective values of  $L_{Amax,v}$  for vehicle categories  $L_1$ ,  $H_1$  and  $H_2$  at speed,  $v = 110, 80$  and  $80$  km/h, respectively.

For light vehicles, noise levels are influenced by variations in temperature and to reduce this variability, noise levels for light vehicles are normalised according to the following equation:

$$\text{Corrected } L_{veh,L} = \text{Measured } L_{veh,L} + 0.03 [(0.7 T_{surface} + T_{air}) / 2 - 20] \text{ dB(A)} \quad (\text{B.3})$$

Where  $T_{surface}$  is the temperature of the road surface and  $T_{air}$  is the air temperature, both in °C

For a given road speed category, the appropriate RSI value provides an estimate of the difference in traffic noise levels for typical traffic conditions on a test surface with that from similar traffic on a reference surface. The reference surface is 20mm Hot Rolled Asphalt (HRA) in new condition (BBA, 2008).

By adopting HRA as the reference surface the above method has been developed so that RSI values could be used as input to the UK national traffic noise prediction method "Calculation of Road Traffic Noise (CRTN)" (Department of Transport and Welsh Office, 1988)<sup>4</sup> to take account of the influence different types of road surfaces on traffic noise levels by replacing the existing surface correction in CRTN which is based on surface texture.

This has important implications for assessing the noise impact from new road schemes as described in the Department for Transport's *Design Manual for Roads and Bridges (DMRB)* which is based on the CRTN method (Highways Agency *et al.*, 2008). The DMRB has recently been revised to allow the surface correction in CRTN to be calculated from RSI values using the following relationship:

$$\text{Surface Correction for thin surfacing systems} = 0.7 \times RSI \text{ dB(A)} \quad (\text{B.3})$$

The surface correction is based on a reduced RSI value in recognition that over the period of the assessment the acoustic performance of the surface will deteriorate with time, this is further discussed in Chapter 7. For existing thin surfacings where the RSI is unknown an RSI value of -3.5 dB(A) should be assumed, whereas, for future thin surfacings an RSI value of -5 dB(A) is to be used which is the lowest RSI value allowed. This is equivalent to a surface correction of -3.5 dB(A) which is the correction allowed for porous asphalt surfacings.

A similar approach could be adopted in future rounds of noise mapping as required by the Environmental Noise Directive (END; European Commission, 2002) which in the UK is currently based on the CRTN method.

For the purposes of HAPAS certification, RSI values for two road sections are required and the average value used. At the time of writing there are 16 propriety surfaces that have HAPAS certificates for noise where the  $RSI_H$  values range from -2.7 to -9.6 dB(A).

### **B.1.2 SPB Backing-Board Method**

The widespread use of features such as safety fences and noise barriers located alongside major roads can reduce the availability of sites where SPB measurements can be taken. Furthermore, in many cases it is also not always possible to obtain the correct separation between the microphone and the centre of the lane, due to the presence of walls, fences etc. This is of particular concern for assessing low-speed roads in urban areas where the presence of garden walls and buildings often prevent the correct location of the measurement microphone

A study for the Highways Agency was carried out to examine possible solutions to this problem (Kollamthodi *et al.*, 2000). The idea examined involved placing an acoustically reflective board directly behind the measurement microphone. This effectively created a controlled acoustic environment. Essentially, the presence of the backing board meant that the unpredictable acoustical effects from roadside features are screened and replaced by a reflective surface whose influence is both consistent and predictable.

<sup>4</sup> CRTN is an empirically based method for predicting noise from road traffic from data collected alongside roads surfaced with HRA.

The ISO Working Group is presently working on an Annex to the SPB Standard which will standardise the backing board method based on measurements taken with the framework of the European SILENCE project (Haider and Sandberg, 2006) and subsequent research by BRRC (Belgian Road Research Centre) in Belgium and BAST in Germany.

### **B.1.3 Close-proximity method**

In the UK, the only purpose-built CPX tyre/road noise vehicle is TRITON which was developed at TRL (Figure B.1). The vehicle is based around a truck chassis and has a specially designed semi-anechoic (soundproof) chamber which encloses a dedicated test wheel and an array of microphones.



**Figure B.1. TRITON shown during data collection**

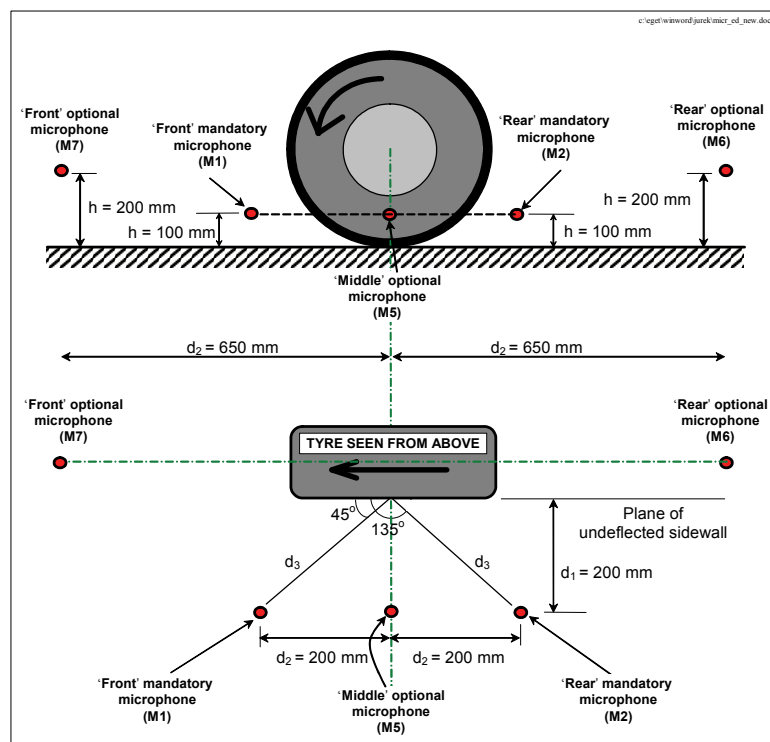
The test wheel runs in the nearside wheeltrack, unlike many other current CPX trailers in use in Europe where the test wheel runs in the middle of the lane. The test wheel can be fitted with a wide range of passenger car and light van tyres, and subjected to a range of loading conditions. The vehicle is designed to travel at the maximum speeds permitted on public roads.

When used to assess the noise from road surfaces the procedure as described in ISO/CD 11819-2:2000 is carried out (see Section 5.2).

Unlike most CPX vehicles, TRITON can accommodate all six microphone positions allowed for in the ISO standard including the mandatory positions M1 and M2 (see Figure B.2)

This has advantages when examining the relationship between the results derived from CPX and SPB measurements.

Although the results from CPX measurements are important in establishing the variation in tyre noise for long sections of a road scheme, unlike RSI values derived from SPB measurements, there is no direct relationship with traffic noise levels. A possible way forward is to examine the relationship between the results derived from CPX and SPB measurements.



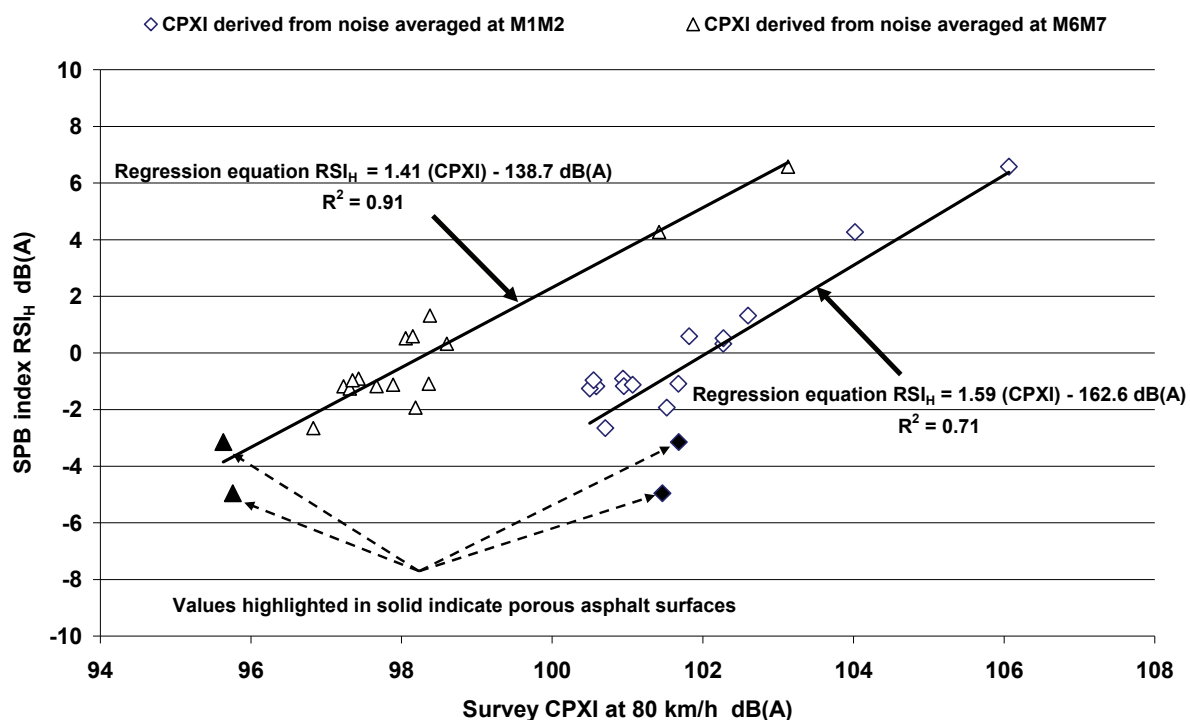
**Figure B.2 Microphone positions in TRITON**

Figure B.3 shows results from CPX and SPB measurements carried out on 17 different types of road surfaces where the CPX values were derived from measurements averaged over a 20m road section adjacent to the SPB site. The surfaces used in the survey ranged from Brushed Concrete (2 sites), Exposed Aggregate Concrete (8 sites), HRA (4 sites), SMA (1 site) and Porous Asphalt (2 sites).

For the mandatory microphone positions M1 and M2 the average CPX values at 80 km/h shows a reasonable correlation with the RSI value derived from the SPB measurements. The linear regression line and equation, shown in the Figure, indicates that about 71% of the variation in RSI can be explained by the regression equation i.e. the variance  $R^2 = 0.71$ . However, the highlighted porous asphalt data points are not well defined by the regression line.

The reason for this poor correlation is partly due to the effects of the sound absorption of porous surfaces on noise propagation. SPB measurements are carried out at the roadside at a distance of 7.5 m from the vehicle where noise propagation is affected by the sound absorption properties of the road surfaces. Due to the close-proximity of the CPX microphones M1 and M2, the influence of the surface on noise propagation is reduced.

Included in the Figure is a similar analysis using CPX values derived from the optional microphone positions M6 and M7 which are placed either side of the contact patch of the test tyre and further away from the contact patch compared with microphones M1 and M2. The linear regression analysis shows a better correlation than that derived from M1 and M2 indicating that about 91% of the variation in RSI values can be explained by the regression equation line, showing that the porous surfaces are better aligned with the non-porous surfaces.



**Figure B.3. Comparing the regression relationship between  $RSI_H$  and  $CPX_I$  derived from averaged noise levels at M1M2 and M6M7 for the survey method at 80 km/h.**

The improvement in the correlation with RSI for CPX measurements at M6 and M7 is partly due to these positions being further from the tyre compared with M1 and M2 allowing the influence of the sound absorption of the surface to influence the correlation. But also sound levels recorded at positions to the rear and in front of the contact patch, M6 and M7, will be influenced by the absorption properties of the road surface due to the so called "horn effect", as described in Section 4.2.1.2. This refers to the amplification of the sound due to multiple reflections occurring between the road surface and the tyre tread either side of the contact patch. The absorption characteristics of the porous asphalt surface significantly reduces the amplification of the noise generated at the front and rear of the contact patch and therefore noise levels recorded at microphone positions M6 and M7 are more likely to be influenced by this effect than at microphone positions M1 and M2 and therefore better correlated with roadside measurements.

## B.2 Methods of assessment used in other European countries

This section briefly describes methods of assessment adopted in other European countries. Only those countries where a noise certification/classification system is in place or being developed are included.

### B.2.1 Denmark

In 2006, the Danish Road Directorate set up a task group, SRS, to provide a system for the specification and documentation of asphalt surfacings exhibiting noise reducing properties (Kragh, 2007).

The current system describes three noise classes based on a noise reduction value,  $x$  dB(A), where:

A: Very good noise reduction:	$x \geq 7$ dB(A)
B: Good noise reduction:	$5.0 \leq x < 7.0$ dB(A)
C: Noise reduction:	$3.0 \leq x < 5.0$ dB(A)

The noise reductions are derived from CPX measurements at two reference speed of 50 and 80 km/h. The reference surface corresponds to a dense graded asphalt concrete with 11 mm nominal aggregate size, approximately 8 years old, or a similar aggregate size SMA.

Surfacings with limited noise reduction properties below 3 dB(A) are not classified as noise reducing surfacings. Currently, surfaces fall within classes B and C. Class A is intended as a driver for future development and improving noise reduction properties.

Prior to using a CPX trailer for the purposes of certification, an annual field calibration of each trailer is carried out and where appropriate a correction to the CPX results is applied.

The SRS system only requires a single road section for type approval. It is a voluntary road standard and unless specified in the contract for new surfacings, has no legal status. The Danish Road Directorate hopes to introduce a system of testing conformity of production. This would ensure that surfaces are laid to an agreed standard of noise reduction which if not met at delivery, the contractor could be required to resurface or pay a fine. Such a system will require sufficient confidence in the system's reliability among the contractors and road administration.

### **B.2.2 The Netherlands**

The Netherlands has the most advanced system for type approval and testing for assessment in Europe. The system is often referred to as " $C_{road}$ ", which is the surface correction used in the Dutch method for predicting noise from road traffic (RMW, 2002).

The Dutch type approval or labelling system requires results from SPB measurements carried out at five different trial sections on five different work sites to determine the road surface correction by averaging the results, providing the variation in site levels are within certain tolerances.

The reference surface used in the Dutch method is a relatively new dense asphaltic concrete with 16mm nominal aggregate size and the vehicle reference speeds are 80 km/h for light vehicles,  $L_1$ , 70 km/h for medium vehicle,  $H_1$  and 70 km/h for heavy vehicles  $H_2$ .

The road surface correction,  $C_{road}$ , is the increase in noise emission as compared with that on the reference surface either expressed as an overall dB(A) level or in terms of a correction to individual octave bands<sup>5</sup> with centre frequencies between 63 Hz to 8 kHz.

For the main road network there is no COP testing system, whereas, for local roads a COP system was operating between 2001 to 2004. The scheme was run by the Dutch Ministry of Housing, Spatial Planning and Environment. The local authority could claim a refund from the Dutch Ministry for laying low-noise surfacings. But in order to ensure that the Ministry's money was well spent a COP system was introduced.

The COP system was based on CPX measurements carried out along the road scheme. The CPX values were converted to SPB values so that the road surface correction  $C_{road}$  could be evaluated. This conversion was either based on a pre-determined relationship between CPX and SPB for the type of surface or derived from site measurements carried out after the scheme was open to traffic. Providing the specified road surface correction  $C_{road}$  was met, the local authority could claim a refund. The contractual arrangement between the local authority and the contractor laying the surface would require the

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<sup>5</sup> Octave band filters allow the distribution of the noise energy at different frequencies to be examined where the highest pass-by frequency is twice the lowest pass-by frequency.

contractor to meet the required noise specification, otherwise there would be a penalty imposed.

### **B.2.3 Germany**

The method adopted in Germany for assessing the influence of road surfaces on traffic noise levels is based on the SPB method as described in ISO 11819-1:2005. By comparing the noise levels derived from SPB measurements on different types of surfaces, a surface correction,  $D_{StrO}$ , is derived which can be used as input to the German road traffic noise prediction method RLS 90 (RLS, 1990). The reference surface used in the German model is a mastic asphalt with a 5mm nominal aggregate size of average age.

The surface correction for each surface type is derived from 5 SPB measurements carried out at different sites and the average value determined at a reference speed 100 km/h. (IPG, 2005).

## **B.3 The SILVIA project**

The objective of the EU funded 5<sup>th</sup> Framework "SILVIA" Project (Sustainable road surfaces for traffic noise control) was to develop proposals for a method for acoustically classifying surfaces and for assessing conformity-of-production which could potentially be used throughout the EU. The following paragraphs provide an overview of the proposed scheme; further details can be found in the SILVIA Guidance Manual on the implementation of low-noise surfaces (Morgan, 2006).

The SILVIA classification system identifies specific measurement procedures necessary for labelling the acoustic performance of a road surface; where possible these are based on standardised, internationally recognised methods. There are two possible labelling procedures:

- LABEL1 (preferred): Assessment based on SPB and CPX measurements
- LABEL2: Assessment based on SPB measurements and measurements of intrinsic properties of the road surface, e.g. texture and sound absorption.

Both noise labels are based on SPB measurements. However, due to the limitations of the SPB method in assessing only a small section of a test surface, additional measurements to assess the acoustic performance over the full length of the trial section are required. LABEL1 includes a direct assessment of noise over the entire length of the trial surface using the CPX method and is the preferred method. LABEL2 allows for an indirect assessment based on measurements of the intrinsic properties of the surface which can be related to the generation and propagation of noise e.g. texture and sound absorption.

For the purposes of assessing conformity-of-production (COP), surfaces with a noise LABEL1 certification should be assessed using the CPX method, whereas, surfaces with a noise LABEL2 certification are assessed according to the relevant measurement of the intrinsic properties of the surface used in deriving the noise label.



## **Appendix C    Response from Local Authorities**



## Noise Pollution Assessment – Task One Output

### Local Authority #1

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) Aware of the Directive, but unknown whether any work has been undertaken with regards to the act.

Q) What surfaces are typically used and why?

A) Granite Sets, Bitmac, DBM, HRA, SMA and other skid resistant (shell grip) materials

Q) Experience of various surface materials?

A) Granite sets are difficult to lay, expensive and are generally used in conservation areas. Bitmac is used in lightly trafficked areas, it is cheaper than alternative materials and is reasonably durable. HRA is used on heavily trafficked roads – no concerns, however it is expensive. Concerns were raised with SMA in relation to durability, and it is a serious concern in the area possibly because of the weather and winter maintenance regimes - gritting. Local Authority put the onus onto Contractors to maintain SMA over longer periods (of up to 3 years) in an attempt to reduce associated maintenance costs.

Q) Concerns with manufacturing of the materials?

A) The mixes differ from manufacturers and this can lead to long term issues.

Q) Procuring of material?

A) Procured via DLO Contractor, material tests are carried out on site.

Q) Specification?

A) As detailed in the Local Authority Guidelines and DMRB.

Q) Construction issues?

A) Application is critical and the weather can again be a major factor at the construction stage.

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) Failures have been noted with SMA within two years following application, these failures normally start at the joints (centre of the carriageway) and break out from there.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Durability and cost – noise is rarely a factor.

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) Statistics may be available.

## Noise Pollution Assessment – Task One Output

### Local Authority #2

Q) Are you aware of the EU Environmental Directive requirements and is action being taken to assess / reduce noise levels?

A) Aware of the Directive but unaware of any steps being taken to assess or reduce noise levels

Q) What surfaces are typically used and why?

A) HRA, SMA, DBM, Granite Sets

Q) Experience of various surface materials?

A) HRA- No Concerns, Durable; SMA – Durability Concerns; Granite Sets – Difficult to lay and expensive

Q) Concerns with manufacturing of the materials?

A) Mixes are not consistent which can lead to problems in later life.

Q) Procuring of material?

A) DLO Contractor

Q) Specification?

A) British Standard - DMRB

Q) Construction issues?

A) Only weather concerns which can lead to laying problems

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) SMA – Short life expectancy, failures witnessed after 2 years

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Durability and cost / manpower

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) Not Aware

## Noise Pollution Assessment – Task One Output

### Local Authority #3

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) The Authority hasn't pursued that route so far (likely because there are not a great deal of trafficked roads in the Authority's area).

Q) What surfaces are typically used and why?

A) Mostly Thin surfacing, but some HRA. Thin surfacing are contractor preferred, less labour intensive, and easier to work from a Traffic Management point of view.

Q) Experience of various surface materials?

A) HRA – there are very few issues with; SMA – mixed results, with some failures.

Q) Concerns with manufacturing of the materials?

A) It was suggested that there was more likely to be a failure with SMA if the quality control on the aggregate is not good.

Q) Procuring of material?

A) Mostly contractor procurement for outside work; for in-house jobs, the council has it's own quarry.

Q) Specification?

A) DMRB

Q) Construction issues?

A) Not really.

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) Some failures with SMA.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Tend to specify BS 1308, or allow contractor to put forward details for an SMA (authority don't normally have HABAS approval).

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) Not really.

## Noise Pollution Assessment – Task One Output

### Local Authority #4

Q) Are you aware of the Noise Pollution Act Requirements and is action being taken to assess / reduce noise levels?

A) The Authority is a rural authority and is aware of the act, however it is not a major concern.

Q) What surfaces are typically used and why?

A) Bitmac but predominantly SMA. This is due to the geometry of the roads and health and safety issues as SMA does not require a chipper.

Q) Experience of various surface materials?

A) SMA is easy to lay and is good due to the narrow roads that the council area is predominately made up of. However there are 2 concerns over SMA: Early life expectancy and its skid resistance.

Q) Concerns with manufacturing of the materials?

A) The Authority has a concern of the variability of supply. They find that there is a problem retaining heat in the material due to some of the excessive distances the material has to be transported.

Q) Procuring of material?

A) 2 main quarries in the council areas are their principle supplier. However they are also part of the Central Scotland Supply Contract.

Q) Specification?

A) DMRB littered with local experience.

Q) Construction issues?

A) They have with the historical past of their roads. Most roads on the network have little or no construction depth and there is some constructional issues with lateral tension and stiffness.

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) Disappointing – There now sees a general trend in the council of moving back to Standard HRA.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Availability. The council also have inherited its traffic management (to close a road would mean large diversionary routes) using SMA means there is no need for any diversions. When SMA was first introduced it was a god send, however due to its durability those thoughts have now changed.

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) Receive SCRIM results every year for all A-class roads and some B-class and C-class roads. They have no specific details on the difference in surfaces.

## Noise Pollution Assessment – Task One Output

### Local Authority #5

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) The council is slightly aware of the regulations but no major action is taking place.

Q) What surfaces are typically used and why?

A) Bitmac 50mm base with 30mm wearing course. Uses a material called High-Tec to reduce noise in towns it is composed of a negative texture.

Q) Experience of various surface materials?

A) Bitmac – soft ground conditions means they have to be careful when laying. They use Bitmac because it provides a good balance between life span, cost and return. Typically has a life expectancy of 6 to 10 years.

Q) Concerns with manufacturing of the materials?

A) One supplier which leads to limited materials.

Q) Procuring of material?

A) Problems with supply, if there is a large contract in the council area there could be a delay in getting the materials.

Q) Specification?

A) DMRB and local input. For new surfaces wearing course is tweaked to cope with weather conditions and foundations.

Q) Construction issues?

A) Soft foundations so have to be carefully when laying

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) Hightec 40mm base is wearing well with a 5+ year life expectancy, however it is very expensive.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) High-Tec was first introduce as a trial it's a hard wearing surface but expensive.

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) SCRIM information is provided every 2 years.

**Noise Pollution Assessment – Task One Output****Local Authority #6**

Q) Are you aware of the EU Environmental Noise Directive and is action being taken to assess / reduce noise levels?

A) The Authority are aware of the Directive, but it is not considered as a specific requirement.

Q) What surfaces are typically used and why?

A) Typically 55/10 HRA, and Bitmac (DBM) (which is also used for patching). For information on SMA, queries would have to be directed ideally to AMEY Highways which is the body responsible regionally for trunk roads.

Q) Experience of various surface materials?

A) No performance experience available.

Q) Concerns with manufacturing of the materials?

A) There are no concerns with material manufacture.

Q) Procuring of material?

A) The material is procured by the nominated Contractors, material mixes etc are tested by Engineers as the works progress.

Q) Specification?

A) Specification is as per the suppliers specification

Q) Construction issues?

A) No Construction Issues

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) Would not have enough data on SMA to provide comparison, as deal with Regional Roads only; generally though, council is in general not too keen as there is a difficulty with the roads holding moisture in winter.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Not able to address as there are not enough cases of SMA adoption in the Authority.

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) Would not have enough data on SMA to provide comparison, as deal with Regional Roads only.

## Noise Pollution Assessment – Task One Output

### Local Authority #7

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) Aware of it, but anything that is applied is done in conjunction with the Environmental Health department.

Q) What surfaces are typically used and why?

A) HRA on approx. 99% of roads; SMA adopted mainly for cost purposes and not noise; Blockwork adopted in some areas.

Q) Experience of various surface materials?

A) SMA is in experimental phase at the moment, but is quite liked to date. Blockwork has a tendency to be noisy.

Q) Concerns with manufacturing of the materials?

A) If the material is mass produced e.g. Marshalls, then there are no concerns;

Q) Procuring of material?

A) The material is procured by the nominated Contractors, material mixes etc are tested by Engineers as the works progress.

Q) Specification?

A) Mostly to local guidelines.

Q) Construction issues?

A) No

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) SMA has just been introduced, so assessment is unfolding.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Considerations are predominantly financial, but with some argument towards noise issues. There is a general co-operation between developers, environmental health, and finance.

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) No

## Noise Pollution Assessment – Task One Output

### Local Authority #8

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) The Authority are unaware of any requirements

Q) What surfaces are typically used and why?

A) HRA – Durability surface binder when it can be afforded. SMA- Cheaper to lay does not require a chipper however it proved to be a poor surface.

Q) Experience of various surface materials?

A) HRA – long life span, the council understands it not a quiet surface material but is cost effective. SMA – Breaks up after 3-4 years, the council have found it to be very costly.

Q) Concerns with manufacturing of the materials?

A) None

Q) Procuring of material?

A) Get all materials from the Scottish Excel group

Q) Specification?

A) DMRB British Standard specification

Q) Construction issues?

A) No

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) Not durable

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Cost and Health and Safety

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) No

## Noise Pollution Assessment – Task One Output

### Local Authority #9

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) Aware of it – moved to SMA to reduce noise.

Q) What surfaces are typically used and why?

A) Roads are HRA at all sites; all SMA has been removed due to defects.

Q) Experience of various surface materials?

A) The SMA was defective because of stripping, problems fretting at joins, and at stress points.

Q) Concerns with manufacturing of the materials?

A) If the material is mass produced e.g. Marshalls, then there are no concerns;

Q) Procuring of material?

A) The material is procured by the nominated Contractors, material mixes etc are tested more at the quarry end of operations.

Q) Specification?

A) National DMRB

Q) Construction issues?

A) No real construction issue with SMA – it was more a case of break-up further down the line. There is a difficulty getting chips in with HRA during winter.

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) SMA had a major issue of break-up after 4-6 years or so.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) The main considerations behind SMA were (i) reduced noise and (ii) easier to lay.

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) No

## Noise Pollution Assessment – Task One Output

### Local Authority #10

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) The council are aware of the Directive and try to meet requirements on all new roads by installing noise bunds.

Q) What surfaces are typically used and why?

A) HRA – Proven material that is designed to a specification; SMA – Cost effective

Q) Experience of various surface materials?

A) HRA – durable surface; SMA – requires a lot of maintenance after laying repairs typically 3 years after installed.

Q) Concerns with manufacturing of the materials?

A) SMA – Buying a proprietary material that has no specification therefore they have to take the suppliers word that the material is fit for use.

Q) Procuring of material?

A) Part of the Scottish EXCEL group

Q) Specification?

A) British Standards - DMRB

Q) Construction issues?

A) SMA is easy to lay and requires less plant and manpower compared to HRA, however this has been proven to be a false saving.

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) Maintenance and Durability

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Cost, ease of laying and less manpower

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) No

## Noise Pollution Assessment – Task One Output

### Local Authority #11

Q) Are you aware of the EU Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) Awareness – Yes; action – specifically no, as SMA is adopted as a matter of course.

Q) What surfaces are typically used and why?

A) SMA is used as the preferred surfacing, owing to (i) noise improvements, (ii) better cost, and (iii) less resources and manpower required.

Q) Experience of various surface materials?

A) No problems recorded with SMA as yet.

Q) Concerns with manufacturing of the materials?

A) No

Q) Procuring of material?

A) The material is procured by the nominated Contractors, material mixes etc are tested more at the quarry end of operations.

Q) Specification?

A) Assuming National (not aware of a specification for SMA.)

Q) Construction issues?

A) Each job is looked at in isolation e.g. there are problems with laying SMA at right turning circles, so in certain circumstances may go back to HRA. Also, there is a perception of SMA being a 'shinier' surface when first laid (and in turn a lack of friction).

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) No.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Thought processes do not specifically have a view to lowering noise: SMA is the 'default surface' (i.e. the authority will try to adopt).

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) No.

## Noise Pollution Assessment – Task One Output

### Local Authority #12

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) Have an awareness of it.

Q) What surfaces are typically used and why?

A) HRA is used; SMA was used (see below for withdrawal reasoning)

Q) Experience of various surface materials?

A) The SMA was withdrawn as it was found to be defective because of surface failures relating to breaking up and lifting - especially at areas involving turning movements (roundabouts etc.) Usually faults develop with SMA 1-2 years after laying.

Q) Concerns with manufacturing of the materials?

A) No

Q) Procuring of material?

A) The material is procured by the nominated Contractors, material mixes etc are tested more at the quarry end of operations.

Q) Specification?

A) National DMRB

Q) Construction issues?

A) No real construction issues

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) Not available.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Noise issue hadn't really come into consideration.

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) Nothing for the SMA side (surface has been down for 5-6 years).

## Noise Pollution Assessment – Task One Output

### Local Authority #13

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) Aware of it, but don't really take it too much into account.

Q) What surfaces are typically used and why?

A) HRA, SMA, and Surface Treatments (e.g. nimpacticoat). Surfacing application was mostly SMA until recently, but has reverted bak to HRA owing to deterioration of SMA surfaces.

Q) Experience of various surface materials?

A) SMA has been noted as deteriorating where there are turning circles involved.

Q) Concerns with manufacturing of the materials?

A) There are sometimes concerns with some quarries' perceptions of materials being better than others.

Q) Procuring of material?

A) It is a mixture: the authority has its own surfacing squad, and materials are procured from quarries on an annual tender basis. Otherwise, it would be through the contractor on an external contract.

Q) Specification?

A) SMA would go in accordance with BS & DMRB.

Q) Construction issues?

A) No.

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) The breaking up of the SMA has been a concern.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) SMA was adopted for several factors: cheaper, easier to lay, less noise, and less traffic management when laying.

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) No.

## Noise Pollution Assessment – Task One Output

### Local Authority #14

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) Aware of this, however the council is not taking specific action at present to reduce noise

Q) What surfaces are typically used and why?

A) SMA was used historically as it is easier and safer to lay, however I would not recommend it is laid again in the future as there are maintenance and durability concerns with this material. HRA is used in the vast majority of areas. The majority of areas laid in SMA are now being replaced.

Q) Experience of various surface materials?

A) SMA is particularly poor in areas near junctions and on / around roundabouts where vehicles are continuously stopping and starting and it is not as skid resistant as other materials in inclement weather conditions.

Q) Concerns with manufacturing of the materials?

A) No concerns.

Q) Procuring of material?

A) The material is procured by the nominated Contractors, material mixes etc are tested by Engineers on site as the works progress.

Q) Specification?

A) DMRB for standard road construction make up is used.

Q) Construction issues?

A) No issues - most works are carried out by the DLO (Direct Labour Organisation) Contractors.

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) SMA has been used in the past, however there is a preference to use HRA due to durability / maintenance issues and as such the council would not wish to use this again.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Cost / durability and maintenance are all factors, however noise is not such an issue at present and the SMA was selected due to its ease of construction on site as opposed to its noise reduction benefits.

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) Statistics may be available – check with Operations Manager.

## Noise Pollution Assessment – Task One Output

### Local Authority #15

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) No.

Q) What surfaces are typically used and why?

A) Small Roads: Bitmac; HRA used also. SMA has been withdrawn from use because of performance issues.

Q) Experience of various surface materials?

A) SMA has a slippiness in the early months after laying, and also has been noted to break up in the vicinity of turning circles.

Q) Concerns with manufacturing of the materials?

A) Not really as quarries are quality assured.

Q) Procuring of material?

A) Via a contractor (chosen from an annual tender list of contractors with their prices)

Q) Specification?

A) A local specification (based on the DMRB).

Q) Construction issues?

A) Patching is not easy with SMA.

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) SMA has not been specifically applied for noise reduction.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) SMA adopted for financial reasons and the suitability of the conditions.

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) No.

## Noise Pollution Assessment – Task One Output

### Local Authority #16

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) Unaware of any implications of the Directive and to there knowledge no action is being taken to assess / reduce noise levels.

Q) What surfaces are typically used and why?

A) Stone Mastic Asphalt (SMA) is predominately used with a 10mm or 14mm stone. SMA is preferred to HRA and other surfacing materials due to it being easier to lay, more forgiving in the rain and cheaper in terms of labour and cost of material.

Q) Experience of various surface materials?

A) Experience of using SMA has been varied. There are concerns over its durability, the council has become aware of small areas of surfacing becoming rutted and needing repair, these areas are typically 3-4 years old. There is on-going process to try and improve the wearability of SMA and these include such measures as increasing the base course.

Q) Concerns with manufacturing of the materials?

A) No concerns.

Q) Procuring of material?

A) The material is procured by selecting the cheapest supplier from the EXCEL group.

Q) Specification?

A) In the main DMRB is used for standard road construction make up. The Council however supplements the DMRB standards with additives through their own experience.

Q) Construction issues?

A) None

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) Not aware of any. The Council has received no complaints about traffic noise in respect to surfacing

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) None

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) None

## Noise Pollution Assessment – Task One Output

### Local Authority #17

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) Not aware of this.

Q) What surfaces are typically used and why?

A) DBM is used in rural areas as it is cheaper and many horse groups have lobbied against other surface material types. SMA is used, this material has not been selected for its noise reduction capabilities, it should be recognised that there are durability and maintenance concerns with this type of surface material. HRCA is also used in certain localised areas. Anti skid / shell grip are also used at jcts / rfts.

Q) Experience of various surface materials?

A) SMA is the preferred material of choice because of its simplicity in application and reduced plant requirements on site,

Q) Concerns with manufacturing of the materials?

A) No concerns.

Q) Procuring of material?

A) Generally, the DLO (Direct Labour Organisation) provide and lay the materials and materials testing is carried out during site operations to verify certain products / materials.

Q) Specification?

A) DMRB for standard road construction make up on main routes. The council have their own standards for minor development roads.

Q) Construction issues?

A) No issues - most works are carried out by the DLO Contractors and other approved sub contractors.

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) SMA is not as durable as other materials.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Cost / durability and maintenance are all factors, however noise is not such an issue at present and the SMA was selected due to its ease of construction on site as opposed to its noise reduction benefits.

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) Not as detailed to identify surface material types.

## Noise Pollution Assessment – Task One Output

### Local Authority #18

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) Not aware of any requirements of the Directive and no action is being taken to assess / reduce noise levels

Q) What surfaces are typically used and why?

A) Hot Rolled Asphalt (HRA) on all main A-class roads and bust junctions. Dense Bitumen Macadam (DBM) on most other roads and Stone Mastic Asphalt (SMA) on development and urban roads. HRA is used the most due to its durability but this comes with an increase in cost.

Q) Experience of various surface materials?

A) HRA – Better Durability but expensive. DBM (Bitmac) – enhanced with a surface dressing after 2 years. SMA – used in towns and urban development schemes due to these areas having less traffic.

Q) Concerns with manufacturing of the materials?

A) None concerns.

Q) Procuring of material?

A) Material is procured from local quarries in the Council area.

Q) Specification?

A) DMRB for standard road construction make up. Council development guidelines are to supplement DMRB.

Q) Construction issues?

A) Based on budget constraints typically done in-house.

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) None.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) None

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) No specific process for gaining statistics.

## Noise Pollution Assessment – Task One Output

### Local Authority #19

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) The roads department recently met with Drew Hill of Transport Scotland with regards to the above. Certain trial sites have been identified within the Council's area for further noise assessment

Q) What surfaces are typically used and why?

A) Hot Rolled Asphalt is used on the vast majority of roads, this is preferred for cost / durability reasons. Noise was not mentioned as a factor which would influence road surface material selection.

Q) Experience of various surface materials?

A) Experience of Stone Mastic Asphalt (SMA) has not been good and there have been maintenance and durability issues, as such confidence in this material is low. Nimpacticoat has also been used in predominantly lightly trafficked areas, it was believed that this would not be suitable in heavily trafficked areas. Anti skid / shell grip materials have also been used.

Q) Concerns with manufacturing of the materials?

A) No concerns.

Q) Procuring of material?

A) The material is procured by the nominated Contractors, material mixes etc are tested by Engineers as the works progress.

Q) Specification?

A) DMRB for standard road construction make up. NLC developer guidelines are also used for new roads within small developments.

Q) Construction issues?

A) Most works are carried out by the DLO Contractors and other approved sub contractors. There have been difficulties experienced in the past with new products (anti skid specialist materials) and this has led to delays and increased costs in projects. These problems are not as common when HRA or standard materials are selected.

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) SMA has been used, however there is a preference to use HRA due to durability / maintenance issues.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Cost / durability and maintenance are all factors, however noise is not such an issue at present and the SMA was selected due to its ease of construction on site as opposed to its noise reduction benefits.

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) There is an issue with traffic statistics at present. It is not felt that the mechanisms for retrieving statistics are sophisticated enough to identify the specific surface types and their impact on speed / safety / durability etc. This information could be determined by analysing the available statistics in relation to what is currently on site.

## Noise Pollution Assessment – Task One Output

### Local Authority #20

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) Aware of the Directive but little is being done to reduce noise levels as they see there is no issue with noise pollution due to the remoteness of the council area

Q) What surfaces are typically used and why?

A) Council uses Dense Bitumen Macadam (DBM) with a 40mm wearing course. This is the only type of surfacing used by the council as it has found that asphalts are not best suited to the local temperatures, there is also a limited amount of materials present.

Q) Experience of various surface materials?

A) DBM with surface dressing after 2 years and 7 years then at intervals of 7 years.

Q) Concerns with manufacturing of the materials?

A) None

Q) Procuring of material?

A) From a council owned quarry.

Q) Specification?

A) National Specification with a delay set material. The 40mm BDM binder is modified so it can be subjected to lower temperatures which makes easier to transport to the island.

Q) Construction issues?

A) None, all work done in-house.

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) None

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) None

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) Scrim survey undertaken last year. A quarter of the network assessed and no problems were identified.

## Noise Pollution Assessment – Task One Output

### Local Authority #21

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) Aware of the regulations however no action or monitoring is taking place. They do where possible lay SMA.

Q) What surfaces are typically used and why?

A) SMA – cost amount of plant; HRA – Durability; Surface Dressing – micro surfacing

Q) Experience of various surface materials?

A) SMA – requires a lot of maintenance; HRA – tried and tested; Surface dressing – noise problems, rural only

Q) Concerns with manufacturing of the materials?

A) Variable

Q) Procuring of material?

A) Collace Quarry – Tayside Contracts – DLO contracts

Q) Specification?

A) British Standard - DMRB

Q) Construction issues?

A) No

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) Durability and maintenance issues

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Partly reduction in noise, Ease of laying – no chipper needed therefore no road closures. Recently the council have been patching up SMA with micro surfacing on top and this is giving a bit more life expectancy.

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) Part of their network is surveyed every year and from this and historical data they hope to be able to provide statistics on length of repair in the future.

## Noise Pollution Assessment – Task One Output

### Local Authority #22

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) Council aware of the Directive due to the sections of Motorway running through the council area. Renfrewshire Council have produced noise pollution mapping and the Environmental Division have carried out studies into SMA

Q) What surfaces are typically used and why?

A) HRA – Good Durability SMA – Cost Benefits

Q) Experience of various surface materials?

A) HRA - No issues ease of construction and durable; SMA – Starts to wear after 3-4 years and require maintenance. The council is laying motorway standard of SMA on all its roads in the next financial year.

Q) Concerns with manufacturing of the materials?

A) None concerns.

Q) Procuring of material?

A) Council have recently entered into a 3 year contract with TARMAC who provided all materials for the council

Q) Specification?

A) DMRB for standard road construction make up.

Q) Construction issues?

A) No. The council tries to keep up to date with latest techniques and works closely with the TARMAC. All works carried out in-house.

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) Longevity – they are more dry and brittle. Recently upgrading road to motorway grade to try and increase life span.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Economics. SMA is cheaper and the cost of HRA is rising.

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) No specific process. However the council investigate identified problem found by on-going maintenance and public comments.

## Noise Pollution Assessment – Task One Output

### Local Authority #23

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) The Authority are aware of the Directive requirements but at this stage they do not have any specific bearing on the selection of road surfacing to reduce noise levels.

Q) What surfaces are typically used and why?

A) HRA – Long life span; SMA – Cost

Q) Experience of various surface materials?

A) HRA is very durable. SMA allows easy construction but has excessive failures.

Q) Concerns with manufacturing of the materials?

A) None

Q) Procuring of material?

A) The material is procured by the nominated Contractors, material mixes etc are tested by Engineers as the works progress.

Q) Specification?

A) DMRB. Authority developer guidelines are also used for new roads within small developments.

Q) Construction issues?

A) Most works are carried out by the DLO Contractors. No construction issues

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) Authority understand the benefits of lower noise surfaces such as SMA. But the amount of failures that are witnessed with SMA has lead the council to use predominately HRA

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) The main thought process of using lower noise surfaces is the area in which the surface is being laid. i.e. urban areas may require SMA

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) No record

## Noise Pollution Assessment – Task One Output

### Local Authority #24

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) Not fully aware of any requirements at at this time no measures are in place to reduce or assess noise levels

Q) What surfaces are typically used and why?

A) Bitmac with a surface dressing K170. The council does not use asphalts due to there being a small weather window in which to lay the material. The asphalt suffers from wind chill

Q) Experience of various surface materials?

A) Bitmac only. The council surface dressed after 5-6 years and lay resurfacing when required. Due to large areas of council land being peat they have a large amount of cracking problems therefore they use a sealing agent to try and overcome this problem.

Q) Concerns with manufacturing of the materials?

A) None

Q) Procuring of material?

A) Only 1 plant on the Island.

Q) Specification?

A) British Bitmac Specification

Q) Construction issues?

A) None all jobs go out to Tender

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) None

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) None

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) None

## Noise Pollution Assessment – Task One Output

### Local Authority #25

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) Not aware of any requirements, but the council previously used SMA but is now moving away from it.

Q) What surfaces are typically used and why?

A) The council uses SMA – Less noise, cheaper and ease of laying. HRA – Long life span uses predominately on A-class roads. DBM – cheap and used on minor roads

Q) Experience of various surface materials?

A) SMA – Durability is a problem. HRA - good life expectancy. DBM- is easy to lay and very cost effective.

Q) Concerns with manufacturing of the materials?

A) None

Q) Procuring of material?

A) Two quarries in the council area

Q) Specification?

A) DMRB specification

Q) Construction issues?

A) None. All work done In-house. The council used to do testing when laying surfacing but have cut back on this to bring down costs. They are looking to restart there full testing procedures in the near future.

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) The durability of the SMA is a problem and this has led them back to using HRA due to restricted budgets.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Low noise and cost. SMA is mainly used in urban and rural areas.

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) Records kept by the Road Safety Section. The council feels that HRA performs better than SMA

## Noise Pollution Assessment – Task One Output

### Local Authority #26

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) Are aware of noise pollution but isn't really a factor when considering road surfacing.

Q) What surfaces are typically used and why?

A) SMA- Manpower – cost; HRA – Durability

Q) Experience of various surface materials?

A) SMA- Poor durability – problems with cracking – 4 years life in some areas; HRA – moved away from HRA to use SMA but in recent years they have moved back to using HRA at major junctions and main roads.

Q) Concerns with manufacturing of the materials?

A) No

Q) Procuring of material?

A) Local Quarries

Q) Specification?

A) British Standard – DMRB

Q) Construction issues?

A) No real issues a small council area so most of the work is done in-house.

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) Main problems are maintenance and durability. They do also have problems with utilities with laying SMA on smaller jobs.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Man power

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates).

A) Accidents stats kept but not in great depth.

## Noise Pollution Assessment – Task One Output

### Local Authority #27

Q) Are you aware of the EU Environmental Noise Directive requirements and is action being taken to assess / reduce noise levels?

A) We as a Council do take account of Noise Pollution levels and these are written into our contracts and refer to specific times of work during the day and night. If we are suspicious that noise levels are excessive then we would have these monitored by our Environmental Health Department.

Q) What surfaces are typically used and why?

A) We use mostly HRA because it's tried, trusted and durable. We have used SMA's in the past but mostly these have been unsuccessful. We have also used some bitumen enhanced DBM's over the past 3 to 4 years which initially appear to be reasonably successful but more time is required to make a full assessment. We also use micro asphalts and surface dressing, as a means of cost effective maintenance.

Q) Experience of various surface materials?

A) As Above

Q) Concerns with manufacturing of the materials?

A) Not enough bitumen in the mixes. Materials become too brittle early in their lifespan. Materials mostly always meet the required pass % at the bottom end of the envelope. Manufacture and monitoring needs to be more stringent.

Q) Procuring of material?

A) We have a separate materials contract with various suppliers, although I would have to say that continuity of supply and trying to get material on time is very often an issue.

Q) Specification?

A) We work to national specifications or propriety specs - and methods of working.

Q) Construction issues?

A) Due to requirements under Health and Safety legislation it's becoming ever more necessary to work under road closures. This can be unpopular with the public but it does allow the work to be carried out quicker and it's safer for the workmen on site. Poor quality of material can also be an issue – it can make it difficult to produce a decent job.

Q) Initial and long term performance of lower noise surfaces compared with traditional surfaces?

A) My experience is that the performance and durability of low noise surfaces is much less than that of say, an HRA.

Q) What are the thought processes behind the decision making when specifying lower noise surfaces?

A) Have never specified for this reason.

Q) Any traffic statistics on the different types of surfaces – key facts are durability (could be length between repairs) and skid resistance (could be accident rates)?

A) None





# A review of current research on road surface noise reduction techniques



The EU Environmental Noise Directive (2002/49/EC; END) requires Member States to produce Noise Action Plans which, amongst other things, aim to reduce environmental noise where necessary. The Scottish Government has produced Noise Action Plans which have been published on the Scottish Government Website. Road and rail noise reduction methods need to be evaluated and, in the case of the former, one potential option is the use of low-noise surfaces.

The Scottish Government commissioned the Transport Research Laboratory (TRL) to undertake a review of the different low-noise road surfaces currently available and comment on their relevance and suitability for use in Scotland, incorporating the views of key staff holders. This review was to take into account not only acoustic performance but also safety, skid resistance, structural durability, environmental sustainability and whole life costing.

This report presents the findings from the review, discussing the potential implications of using low-noise road surfaces as a mitigation tool within Scottish Noise Action Plans. Advice on how to make a preliminary selection of appropriate low-noise surfaces is also set out, based on indicative acoustic and non-acoustic characteristics.

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