REDUCING ROAD TRAFFIC NOISE IN SOUTH AFRICA

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ABSTRACT

This presentation summarises the primary road traffic noise generation mechanisms and relates these to results of recent noise measurements conducted along local roads with different surfaces and how porous road surfaces can significantly reduce the levels of road traffic noise without significant, if any, increase in the cost of road rehabilitation. The addition of noise barriers enables full use of land adjacent to busy roads to be used for residential purposes.

1. BACKGROUND

South Africa is in a stage of rapid densification of urban areas. Many new townships are being constructed while there are large pressures to increase the density of existing residential areas. The almost explosive growth in number of road vehicles is resulting in increasing stress imposed by road traffic noise experienced by a rapidly larger percentage of the population. The pressures on the authorities to “do something about it” are increasing and are currently under serious consideration by the Department of Environmental Affairs and Development Planning of the Western Cape in their revision of the Noise Control Regulations (NCR). Of relevance is the feasibility, including cost considerations, of lowering the permissible levels of road noise on residential land prescribed in the existing NCR to be in line with World Health Organisation recommendations.

2. ROAD NOISE GENERATION MECHANISMS

Noise generated by road traffic consists predominantly of two independent components:

1. Propulsion noise produced by the driveline - engine, exhaust, cooling system, gearbox, axle, etc.
2. Rolling noise generated by the interaction of the tyres with the road surface and which accounts for

2.1 Propulsion noise

In the early days of motoring history the engine was the dominant source of noise. However, due to legislation and market demands, the noise generated by the engine, gearbox and silencers has steadily reduced to below that of rolling noise for speeds in excess of 40 km/h.

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2.2 Rolling noise.

Tyre/road interaction noise, often referred to as "rolling noise", accounts for over 80% of the noise produced by road traffic (de Graaff & van Blokland, 1997). It is a combination of several separate noise generation mechanisms (Sandberg, & Ejsmont). In this presentation only a few of these that have a major influence on road noise are outlined:

Impact of the tyre tread with the uneven texture of the road surface is illustrated in Figure 1. It induces radial vibration in the tyre that radiates a maximum level of noise between 600 Hz and 1000 Hz dependent on road surface texture. Road texture is considered subsequently.

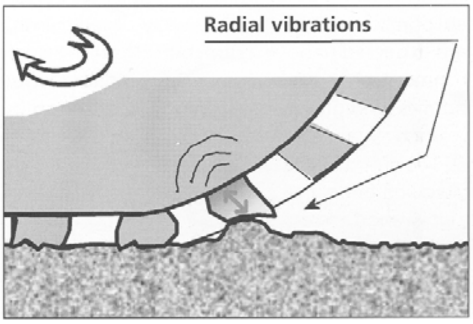


FIGURE 1 (Sandberg, & Ejsmont)

Air-pumping noise is caused by the sucking in and escape of air at the leading and trailing contact points between tyre and road surface as depicted in Figure 2. This generates a maximum level of noise about 1250Hz.

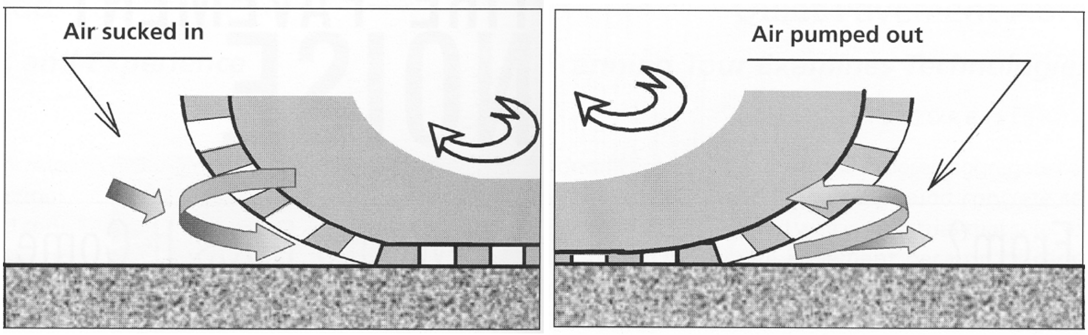


FIGURE 2 (Sandberg, & Ejsmont)

2.3 Sound enhancement mechanism

The **Horn effect** is one of various mechanisms that cause amplification of the noise emitted. At the leading and trailing edge of the tyre a space is formed bounded by tyre wall and road surface in the shape of a horn which increases the efficiency of radiation of the sound generated at the interface. The same effect occurs when we cup our hands around our mouth or use a megaphone to project our voice over a greater distance.

The noise source emission levels, as a function of frequency, for propulsion noise and rolling noise combine to produce a characteristic "hill" shape of the total A-weighted sound power emission level spectrum illustrated in Figure 3. The rolling noise spectrum is shown here with a maximum level centred on 1250 Hz. The spectra were derived using the IMAGINE noise emission model for road traffic (M+P, 2007). The relative levels and shapes of the propulsion and rolling noise spectra are dependent on numerous factors including road surface, vehicle speed, vehicle class (light, medium & heavy duty), road gradient, plus other factors.

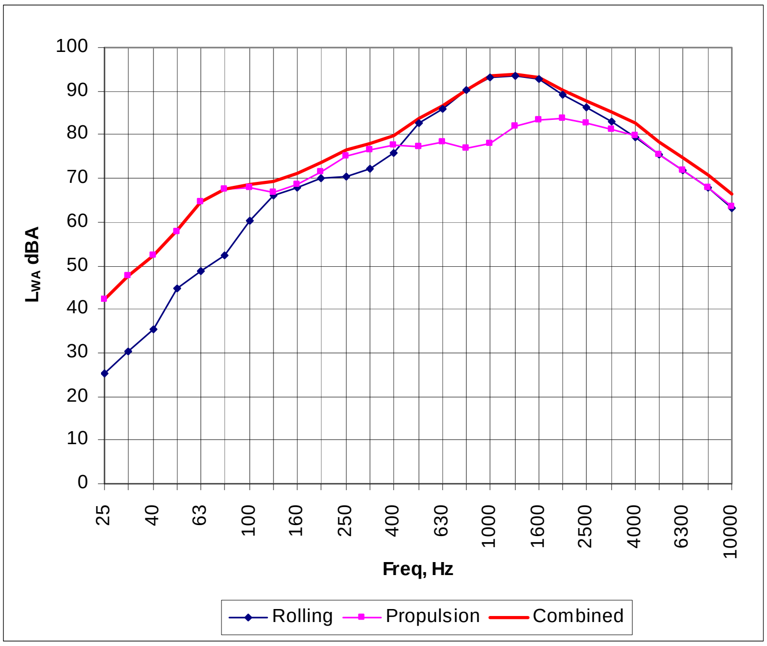
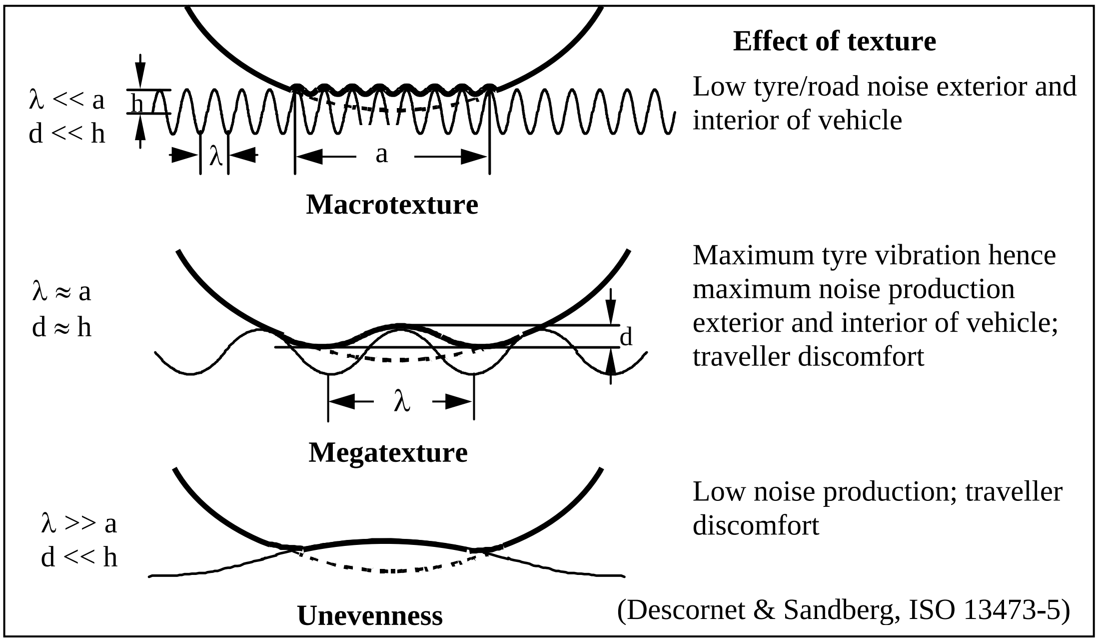


FIGURE 3 Sound power emission levels in dBA as a function of frequency for propulsion noise, for rolling noise and the two combined

2.4 Influence of road surface texture on production of rolling noise

The road surface texture has an overriding influence on the production of rolling noise. The terminology used to describe road surface texture and its effects on noise emission is outlined in Figure 4.



a	Contact patch length of tyre with road surface – 100 to 110 mm for passenger vehicles
λ	Road texture wavelength – distance between adjacent peaks of surface texture
d	Vertical displacement of the tyre wall within contact patch
h	Road texture depth

FIGURE 4 Road surface texture descriptors related to tyre contact patch

This is further illustrated in Figure 5 by results of sound measurements recorded at 10 m from the road edge of an old Cape Seal surface and a newly laid Ultra Thin Friction Course (UTFC). In both cases the traffic flow was approximately the same. Mean vehicle speed = 100 km/h 650 vehicles per hour and 5% heavy-duty vehicles. The 1-hour equivalent continuous A-weighted sound level, $L_{Aeq,T}$, is recorded in the legend of the graph. The widths of the photographs are slightly wider than the tyre contact patch length, a, of passenger vehicles defined in Figure 4.

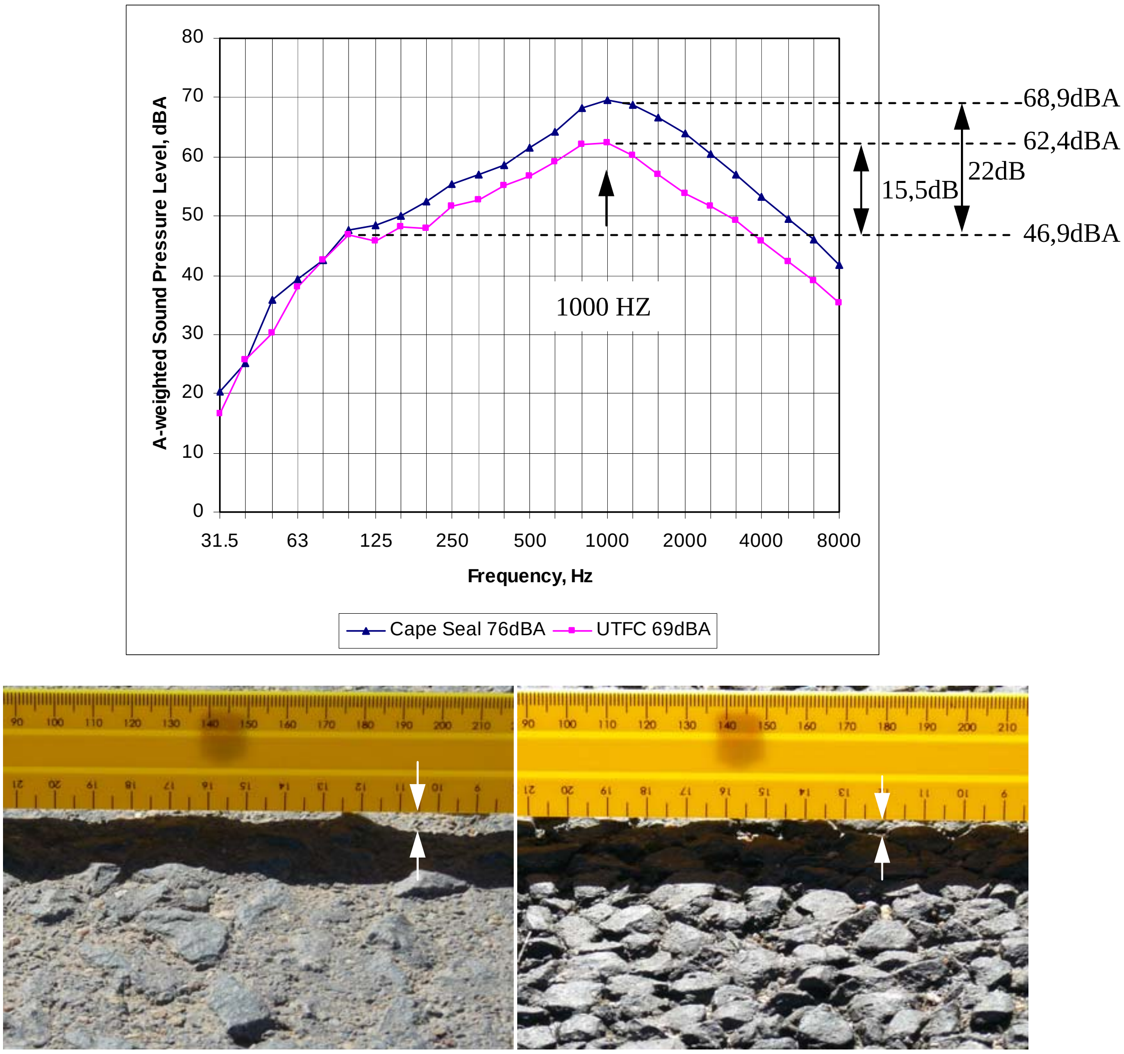
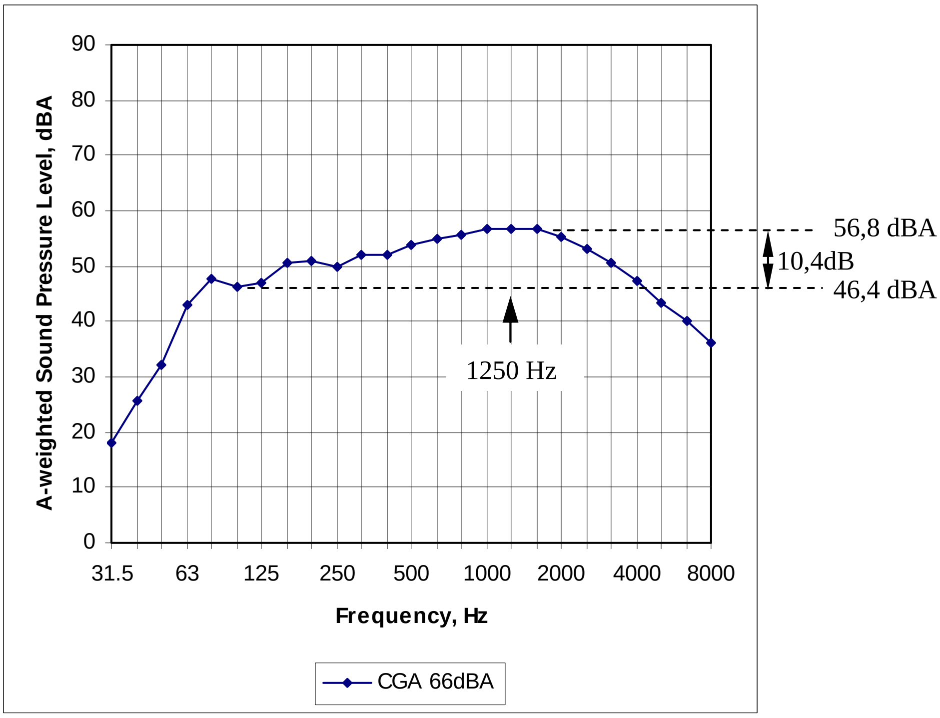


FIGURE 5 Cape Seal (left) and Ultra Thin Friction Course (right) with 1/3rd octave sound level spectrum (dBA) at 10m. Traffic flow: 100 km/hr, 650 veh/h, 5% heavy duty vehicles

Although the texture depth in each case is approximately the same, the texture wavelength is considerably longer in the case of Cape Seal. This correlates with the significant increase in rolling noise and hence the 7 dB increase in overall $L_{Aeq,T}$ of the Cape Seal compared to the UTFC. By comparison with Figure 3 it can be seen that the rolling noise curve of the Cape Seal surface has “shifted” 6,5 dB higher compared to that of the UTFC surface whilst the propulsion curve, of which only levels up to 100 Hz are apparent, has remained constant. The level of engine noise at 100 Hz was 46,9 dBA in both instances.

One of the smoothest local road surfaces is provided by rolled Continuously Graded Asphalt (CGA). The results of sound measurements recorded at 10 m from the road edge containing a CGA surface are displayed in Figure 6. Unfortunately dissimilar traffic flow conditions could not enable a direct comparison with the previous surfaces. The results are for a mean speed of 80 km/h; 15% heavy-duty vehicles and 560 vehicles per hour. Apparent is a virtually zero texture wavelength and texture depth.



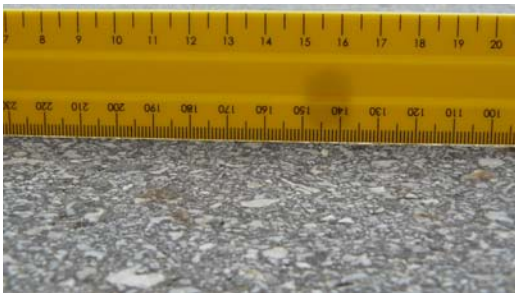


FIGURE 6 Continuously Graded Asphalt with 1/3rd octave sound level spectrum (dBA) at 10m. Traffic flow: 80 km/h, 560 veh/h, 15% heavy duty veh

The significant reduction in rolling noise for the smoother surface is immediately apparent. The frequency of maximum rolling noise has increased from 1000 Hz for the previous two surfaces to 1250 Hz due to the emission of air-pumping noise on the smooth surface.

Of interest is that the level of engine noise of 46,4 dBA at 100 Hz was within 0,5 dB of the previous results for a mean speed of 100 km/h. An increased contribution of propulsion noise between 63 Hz and 400 Hz is apparent due to the greater percentage of heavy-duty vehicles. Refer to Figure 3.

The three examples are typical of numerous other measurements conducted by the author on South African Roads. They confirm the results of numerous studies conducted in Europe and other countries that the primary component of road traffic noise is the texture wavelength of the surface.

The “flatter” shape of the rolling noise spectrum of CGA compared to the other two surfaces renders the CGA surface subjectively “quieter” than indicated solely by the quantitative difference in $L_{Aeq,T}$ of noise from the surfaces.

3. REDUCTION OF ROAD TRAFFIC NOISE EMISSION

The first stage in attaining a meaningful reduction of road traffic noise is the reduction of rolling noise. This requires a well rolled, smooth surface. This excludes all sealed surfaces.

A further significant reduction in both rolling and propulsion noise requires a porous road surface.

Porous, open grade asphalt was originally developed to improve road traffic safety by providing greater friction between tyre and road surface during dry and wet weather plus better visibility of traffic and road markings due to less surface water and reduced spray during wet weather. In 1991 an overall saving of approximately R100 000 per kilometre in terms of reduced accidents and casualties was calculated in The Netherlands for porous asphalt to be used on all national roads (VBW Asfalt, 1991). Subsequently the benefit of porous road surfaces in also reducing road traffic noise became apparent and much research work has since been conducted in initially understanding the noise generation complexities and then implementing the derived knowledge in designing road pavement mixes that today are significantly quieter than non-porous road surfaces.

A well rolled, porous road surface consisting of aggregates no greater than 6 mm reduces the texture wavelength thereby dramatically reducing the radial tyre vibrations to the levels produced by a rolled, continuously graded asphalt surface.

There are several factors that render a porous surface significantly “quieter” than even a CGA surface:

- A porous surface virtually eliminates the production of air-pumping noise due to the release of air pressure between the tyre treads into the voids of the porous asphalt.
- The amplification by the horn effect of the noise emitted is significantly reduced.
- The porous surface absorbs part of, not only the rolling noise, but also the emission of engine and driveline noise from beneath the vehicle as the noise from the various noise sources propagates away from the vehicle over the porous surface.

By varying the surface texture, porosity, air flow resistance and thickness of the porous layer, and consequently the absorption spectrum, optimum reduction of the noise generated by various mechanisms can be achieved to provide large reductions in road traffic noise both at low and particularly at high vehicle speeds.

Road surfaces comprising 2-layer, small aggregate, porous, rubber-bitumen asphalt are the most effective low-noise surfaces to date used on freeways. An example is illustrated in Figure 7. It comprises a 2 cm thick 4/8 upper layer over 11/16 lower layer. The 6cm total thickness of the combined porous layers optimises the reduction of tyre radiation noise between 600Hz and 800 Hz in addition to attenuating engine driveline noise. The surface exhibits resistance to clogging and excellent water drainage properties providing excellent traction during both wet and dry weather. The use of a rubber-bitumen binder provides a durable and stable wearing surface.

By reducing the thickness of the porous layer the cost can be significantly reduced while still exhibiting good noise reduction properties. Figure 8 shows a photograph of a 2 to 3cm thick, rolled, porous road surface with fine aggregate of 6mm or less now used extensively in cities and residential areas of The Netherlands. The surface is so quiet that the author was unaware of an approaching vehicle while photographing the surface!

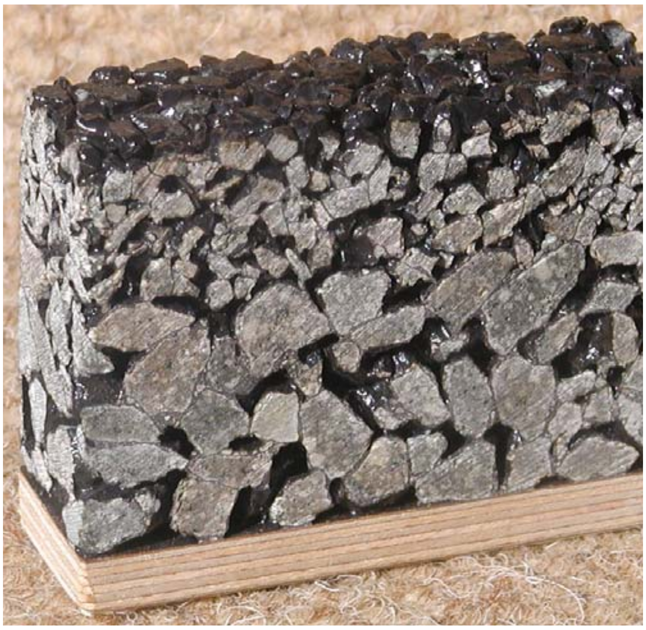


FIGURE 7 2-layer, low-noise porous rubber-bitumen asphalt road surface used on freeways

1 MICROFLEX 0/6
Porosity 15% Thickness 2 - 3cm

FIGURE 8 Thin, low-noise, porous rubber-bitumen asphalt road surface used in cities and residential suburbs

Figure 9 displays the graph of Figure 6 with the approximate spectra to be expected by replacing the CGA surface, for the same traffic flow, with a single-layer and a 2-layer low-noise porous surface. The single layer is effective at reducing the higher frequency rolling noise and higher frequency driveline noise whist the increased thickness of the 2-layer extends this reduction to lower frequencies including noise radiating from the engine and gearbox.

A direct comparison with the CGA surface (Figure 6 & 9) and a UTFC surface (Figure 5) is difficult due to the large difference in heavy duty traffic on the two surfaces at the time of sound measurements. However the reduction presented by a single-layer low-noise surface may be expected to be at least 5 dB. The level of noise from a road decreases by 3dB for every doubling of distance of the observer from the road. Thus, a reduction of 5dB at source due to a low-noise surface is equivalent to what an observer would experience at a threefold increase in distance from a road with a conventional surface.

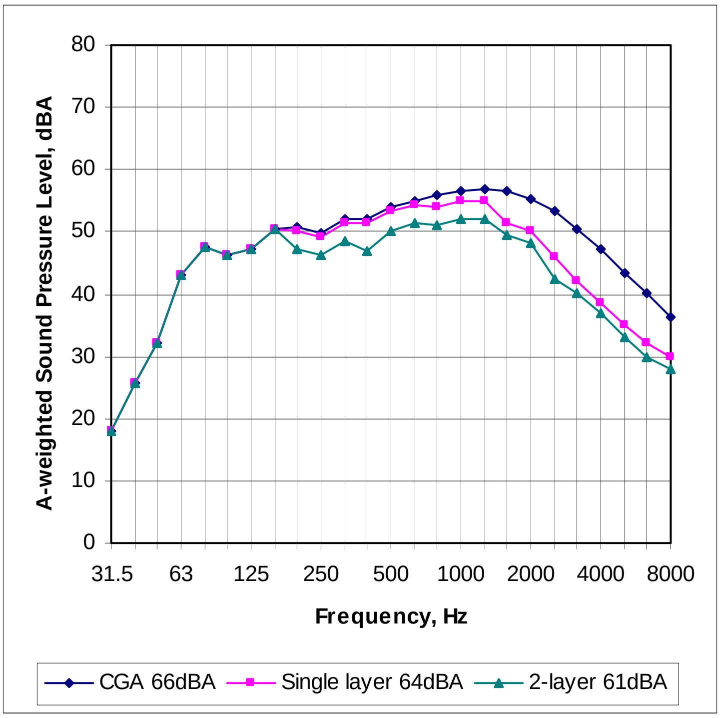


FIGURE 9 Approximate $L_{Aeq,T}$ and noise level spectra of single- and 2-layer low-noise porous asphalt surfaces compared to a CGA surface

4. COST

Whenever the use of low-noise porous asphalt is recommended near noise sensitive land, such as residential suburbs, it immediately elicits strong objections because of the perceived 3 to 4-fold increase in cost.

In this country the cost of laying new or rehabilitating existing road surfaces is sadly still considered in isolation to the social cost imposed on adjacent communities exposed to noise from such roads. The capital cost of a 2-layer, low-noise surface in this country has not been determined at the time of preparing this presentation but may be assumed to be high.

The resurfacing of existing pavements with Ultra Thin Friction Courses is becoming more common. Recently the N2 Freeway in the vicinity of the N2 Gateway housing project outside Cape Town was resurfaced with a 3 cm thick, open-grade wearing course containing 13 mm aggregate. This unfortunately has resulted in a noisier surface than that which it replaced due to the large aggregate size and spacing of the aggregates (large texture wavelength). The author enquired from the road builder and a major supplier of road materials what the cost would be of laying a similar thickness, low-noise rubber-bitumen road surface illustrated in Figure 8. The answer: 1 Rand less per square metre of road surface compared to the existing surface! Indeed, the cost of ensuring watertight integrity of the base layer is not included.

The rubber-bitumen binder provides improved durability. Thus, a substantial decrease in the exposure to noise from our roads can be achieved over large areas of land and hence on thousands of residences at a lower cost than conventional friction courses.

The rubber used in the binder is obtained from recycling of motor vehicle tyres. Thus wide scale use of rubber-bitumen binder would not only present a positive impact on the environment by getting rid of disposed tyres but would reduce the cost of this material thereby providing a further cost benefit in using low-noise friction courses.

5. COMBINATION OF LOW-NOISE ROAD SURFACES WITH NOISE BARRIERS

Where residences are located close to a busy road even the “quietest” road surface will not reduce the outdoor noise level sufficiently to comply with the maximum recommended level of 55 dBA. Additional noise mitigation will be required in the form of continuous noise barriers, at least 5 m high, erected close to the road. An example is presented here of the combined effect of noise barriers and low-noise road surface. Figure 10 shows a recently developed residential complex adjacent to the N2 Freeway close to Cape Town.

FIGURE 10 New housing development close to N2 freeway near Cape Town

The outdoor $L_{Aeq,T}$ at the nearest façade at 60 m from the nearest road edge was measured to be 70 dBA. This is significantly higher than recommended and will lead to noise induced stress of the residents. Compare this to Figure 11 of a residential township in The Netherlands where the nearest houses are at the same distance from a busy road. The author could not hear road traffic noise anywhere within this township.

FIGURE 11 Upper photograph shows residential township at right screened by landscaped berms from road shown in the lower photograph

The combination of low-noise, porous road surface and noise barriers has provided a win-win solution by enabling people to reside in a beautiful, peaceful setting close to major access roads without the negative effects of noise, exhaust and dust pollution and the visual distraction of passing vehicles.

With always a need to dispose of builders’ rubble the cost of an earth berm is primarily limited to the cost of a surface layer of soil required for sustaining the growth of local vegetation. When distributing the once-off cost of erecting a berm, or any other noise barrier, over the properties within the township the increased purchase cost of each property is negligible.

6. CONCLUSIONS

This presentation has touched on some of the physical causes of road traffic noise and technical means to significantly mitigate that noise to the benefit of a large percentage of the population within and around urban areas without significant, if any, cost penalty.

The contents of this presentation is part of a large body of tried-and-tested technical noise mitigation and associated town planning knowledge available that can be incorporated by planners and decision makers in South Africa in marrying the commercial need for road links with the equally important need to protect society from the adverse impacts of such roads.

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