Traffic Noise Prediction with Nord2000 - An Update

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ABSTRACT

A comprehensive method for mapping traffic noise levels is an indispensable tool for road administrations in their effort to mitigate traffic noise. Nord2000 is a new generation prediction method for environmental noise. Predictions can now be made of third-octave band levels of road traffic noise propagating over complex terrain under almost any weather condition. This allows accurate computation of yearly average noise levels as required by the European directive on environmental noise. The Danish Environmental Protection Agency in 2007 decided that computation of surface transportation noise shall be carried out using Nord2000. At the same time the yearly average L_{den} was introduced as the Danish noise measure to characterize population exposure to transportation noise. Computations are made by commercially available software, and test cases have been defined as a measure to prove software compliance. For rough estimates freeware is provided for looking-up pre-calculated noise levels in typical cases. Road surface conditions are taken into account by correcting default values for the pavement lifetime average condition. Noise barriers now seem to come out slightly less effective than before, when noise levels were predicted for conditions of a slight downwind perpendicular to the road.

TRAFFIC NOISE PREDICTION IN GENERAL

Traffic noise prediction is made for a variety of purposes and the computation procedures and required accuracy vary accordingly. For strategic mapping of a complete road network less accuracy is needed than when designing a noise barrier to protect a specific building or area.

With the new generation prediction method highly specialized tools are needed for detailed calculation. Rough estimates of noise levels may be obtained by look-up in precalculated typical cases. Older models often had various degrees of detail the simplest being based on diagrams of A-weighted noise levels or attenuations which could be read quickly to obtain an estimate of the noise level. With Nord2000 such diagrams have been replaced by free software with precalculated transfer functions for 30 selected cases, see the section on rough calculation below. This software can be downloaded from the website given in the list of references.

NORD2000 – METHOD STRUCTURE

This section provides a brief summary of the Nord2000 method. For further overview see (Kragh, 2009a). The idea was to develop a general sound propagation model and source-specific prediction methods for road and rail traffic as well as other types of environmental noise sources. Nord2000 now consists of source models for road and rail traffic and a sound propagation model.

The model works in 1/3 octave bands and for any normal type of weather. Noise levels – for historical reasons – have been computed for different weather conditions in the earlier Nordic models. Now all types of environmental noise can be computed for the same weather.

Earlier models take a skilled user to interpret an actual terrain profile and represent it properly in the model, and such “subjective” methods lead to unwanted variation in results obtained by different users. The new model deals with propagation by means of an explicit procedure that enables all users to reach the same result in a specific case.

Source model

The source model (Jonasson, 2006) distinguishes between: 1) light, 2) medium and 3) heavy vehicles, see Table 1. A vehicle is represented by two (or three) noise sources at different heights (0.01 m, 0.30 m, 0.75 m or 3.5 m). Their horizontal position is 1 m from the vehicle centre line, towards the receiver. This corresponds to an average position of the nearest wheels of heavy and light vehicles.

The source sound power level per 1/3 octave-band from 25 Hz to 10 kHz is calculated by means of tables of coefficients. The sound power of tyre/road noise and propulsion noise are calculated separately. 80 % of tyre/road noise is associated with the lowest source and 20 % with the highest source. For propulsion noise 80 % is associated with the highest source and 20 % with the lowest source. Corrections are given for the influence of a wet road surface on rolling noise from light vehicles while such correction is not possible for heavy vehicle noise due to a lack of data.

Table 1. Vehicle categories in Nord2000

Vehicle category	*Description*	*Characteristics*	*Vehicle length [m]*
1 Light	Passenger cars and delivery vans	Additional input parameters: Studded tyres Wet surfaces	< 5.5
2 Medium	Trucks and buses	2 axles, 6 wheels	5.6 – 12.5
3 Heavy	Heavy trucks and buses	3 or more axles Additional input parameter: Average no. of axles	> 12.5

The point sources are directional, see Figure 1. All point sources are assigned a frequency-dependent vertical directivity to take the screening by the car body into account. The lowest point source is assigned a frequency dependent horizontal directivity to take the so-called horn effect of the tyre/road noise source into account. The 0.75 m point source of propulsion noise from heavy vehicles is assigned a frequency-independent horizontal directivity.

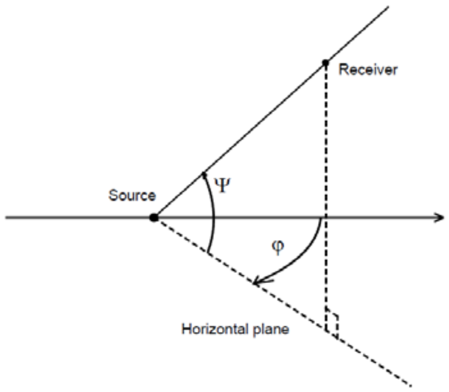

Figure 1. Source vertical and horizontal directivity values are calculated using the angles shown (Jonasson, 2006)

The source output depends on temperature. Default sound power levels are given at 20 ºC air temperature and rolling noise corrections are given for deviations from that. Propulsion noise corrections for acceleration/deceleration and road gradients are also given.

The Danish emission data are based on measurements made 1999 – 2000 (Andersen, 2005). Some 4000 vehicle pass-bys were recorded at 21 sites with speed limit 30 - 110 km/h and with 2 – 18 years old dense asphalt concrete or stone mastic asphalt with 8 – 12 mm maximum aggregate. So default values are valid for 8 – 9 years old pavement, see the section on pavement ageing below. Emission data from Finland, Norway and Sweden were found to be 1-2 dB higher than the Danish data. This may be due to the use of studded tyres.

Sound propagation model

The sound propagation model (Plovsing, 2006a) is based on geometrical ray theory and gives algorithms for computing 1/3 octave band sound attenuation along the path from source *S* to receiver *R* taking into account the terrain shape and the ground type (acoustic impedance). The vertical terrain cross-section is simplified to a chain of straight-line segments, see Figure 2, and the model combines contributions from all terrain segments to the resulting ground and screen effect.

Figure 2. Vertical terrain cross-section simplified to straight-line segments (Plovsing, 2006a)

The introduction of Fresnel-zones illustrated in Figure 3 in Nord2000 lead to essential improvement compared to earlier methods. The ground effect, for example, is calculated for each type of ground to be found inside the Fresnel-zone and the resulting ground effect is calculated as a weighted average taking into account the fraction of the Fresnel-zone covered by each type of ground surface. Among other things this helped to solve problems of discontinuity in computation results encountered with earlier models.

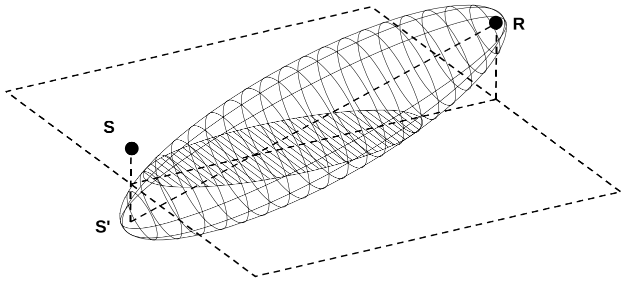

Figure 3. Fresnel-ellipsoid and (hatched) Fresnel-zone (Plovsing, 2006a)

Eight classes of ground surface have been defined, ranging from very soft (moss-like) to very hard (dense asphalt or cement concrete). For noise mapping, normally only two classes: “soft” and “hard” are used. Each class is characterized by a representative flow resistivity.

Terrain data may be entered “manually” into single-receiver software or imported from digital terrain models into “automatic” mapping software. With the complexity of the Nord2000 model “manual” calculation is out of the question.

Weather influence

Because Nord2000 deals with attenuation under different weather conditions it is suited for computing yearly average noise levels. Various weather classes have been defined and their frequency of occurrence during a meteorological reference year has been determined based on data from 10 years of observation (Eurasto, 2006). Each weather class is characterized by a ‘profile’ of the sound speed as a function of the height above the ground. For example, a ‘favourable’ propagation condition is downwind. The sound speed then increases with increasing height. Each weather class is associated with a certain curvature of the model sound rays.

The yearly average noise level is obtained by computing the noise level contribution for each weather class and then combining these levels weighted with their occurrence. For example, at a distance of 300 m from a road with direction North-South the yearly average noise level in Denmark is 2 dB higher at a receiver to the east of the road than at a receiver to the west of the road because south-westerly wind is predominating.

Model validation and software verification

Nord2000 attenuations have been compared with 544 attenuations a) measured in the field (61 cases up to 200 m), b) reference computation results up to 200 m (64 cases most of which were benchmarks (HARMONOISE, 2005)), c) reference computation results for flat ground (281 cases, 1-5 m/s downwind, 50-1000 m) and d) reference results with a screen (138 cases, downwind 3 m/s, 25-400 m) (Plovsing, 2006b).

The overall result of these point-to-point computations was a small average deviation between total A-weighted noise levels. The largest average difference was for thin screens on a flat ground where Nord2000 yielded 1 dB higher noise levels than the reference computation using the Parabolic Equation method. The standard deviation of differences was 1 dB up to 400 m. Above 400 m results were available for flat ground (600 – 1000 m) with a standard deviation of 2 dB. This must be considered a high accuracy.

Test cases have been established to assist developers in verifying that their software yields proper results and users to ensure they apply the software correctly (Plovsing, 2010).

ROAD SURFACE INFLUENCE

The source emission levels in Nord2000 were determined by a fitting process based on measured pass-by noise levels (both sound exposure levels L_{AE} and maximum noise levels L_{AFmax}) at each of two heights: 4 m above the ground and 0,2 m above the ground. The default conditions in Denmark are: constant speed on dense asphalt concrete (DAC 11) with 11 mm maximum aggregate, aged 8-9 years; air temperature 20 ºC. Corrections are given for conditions deviating from this.

Components of vehicle noise

Figure 4 shows the defaults for Danish conditions. The figure shows maximum pass-by noise levels for a passenger car (P) and for a 5-axle heavy truck at constant speed. Rolling noise dominates light vehicle noise above 40 km/h and heavy vehicle noise above 70 km/h.

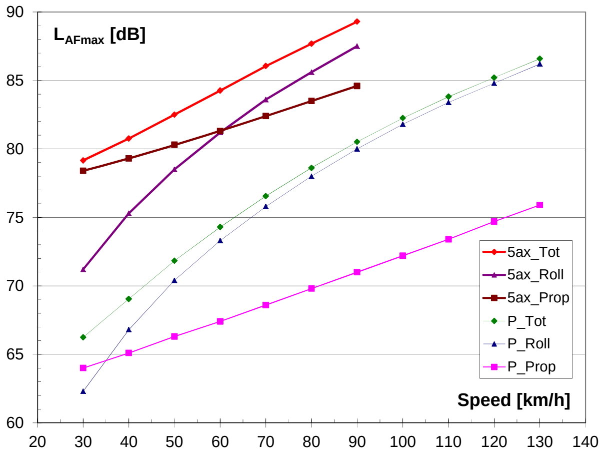

Figure 4. Default rolling noise, propulsion noise, and total pass-by noise levels at 7.5 m distance as a function of the vehicle speed for a passenger car and a 5-axle heavy truck

Danish noise classification of pavements

Danish road administrations request noise reducing pavement and the industry has introduced many new products which they claim have noise reducing properties. The Danish Road Directorate in conjunction with the pavement industry and consultants has established a system for specifying such asphalt wearing course systems (Kragh, 2007b). Road administrations can now tender pavements requesting a certain class of traffic noise reduction.

The classification is based on the so-called Close Proximity (CPX) measurement method. This involves the measurement of tyre/road rolling noise close to standardized reference tyres, for example by means of a trailer as shown in Figure 5. The system encompasses, among other things:

• A guide for applying asphalt surface layers in traffic noise abatement and a paradigm for contracting and for preparing tender documents

• A system for documenting and declaring the pavement noise reducing properties determined by the CPX method

• Three classes A, B and C, with class A exhibiting the highest effect and class B and C exhibiting lower noise reduction as compared to regular dense graded asphalt

• Requirements on the calibration of the measuring device.

The system represents a first Danish attempt to contract road works comprising asphalt wearing course systems having noise reducing properties. It does have limitations and several topics are currently being addressed in developing the system. In particular, better knowledge is needed on the measurement accuracy provided by the CPX method, and acceptance criteria need to be developed for use in contracting.

Noise reducing pavement products are classified when the pavement is new, i.e. according to what might be denoted its *initial* noise reduction. However, their noise reducing properties will almost certainly change during the pavement lifetime and therefore the noise reduction to take into account in noise prediction may differ from this initial value.

Figure 5. The Danish Road Institute CPX trailer 'deciBellA'

Pavement acoustic ageing

Road surface layers get worn by traffic and they deteriorate gradually due their exposure to sunlight, water, salt and other environment factors. Therefore traffic noise levels tend to increase with pavement age. Data on the effects of acoustic ageing can be found in (Kragh, 2008) and (Bendtsen, 2009).

Figure 6 shows, as an example, the noise level time history during the first seven years of service life of test sections on an urban road in Copenhagen, Kongelundsvej. These surfaces may be considered the first generation of Danish noise reducing thin asphalt layers. The average daily traffic is 12,500 vehicles, 8 % of which are heavy. The speed limit is 60 km/h. Two of the surface layers are dense asphalt concrete reference surfaces, AC 11d or AC 8d with 11 mm and 8 mm nominal maximum aggregate size. The remainder of test sections were designed to be noise reducing. For details on asphalt mix etc., see (Bendtsen, 2005). The trend in Figure 6 is for the noise reducing surfacings to display a steeper slope than the reference surfaces. This means, for example, that the initial 3 dB noise reduction provided by the surface layer denoted UTLAC 6 has disappeared after seven years of service life when compared with the AC 11d reference surface.

Figure 7 shows results of an experiment with two-layer porous asphalt on another city street in Copenhagen, Øster Søgade. For details, see (Kragh, 2007a) and (Ellebjerg, 2008). The figure shows the first eight years of noise level time histories for a reference surface of dense asphalt concrete with 8 mm maximum aggregate size and for three different types of two-layer porous asphalt with 8 mm or 5 mm maximum aggregate in the top layer. The porous asphalts were cleaned every May and November with high pressure water washing and subsequent suction in an attempt to prevent pavement voids from clogging with dirt. In spite of this

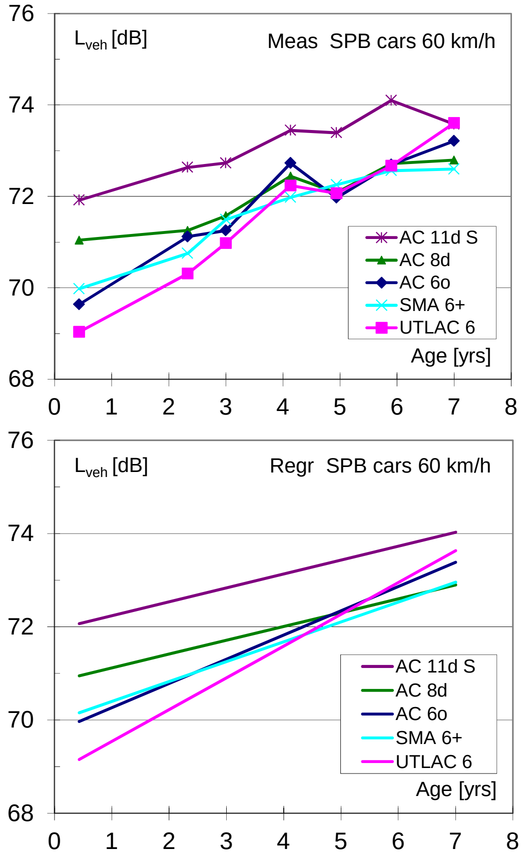

Figure 6. Noise level time histories for thin asphalt layers. Top: measurement results; Bottom: linear regression lines

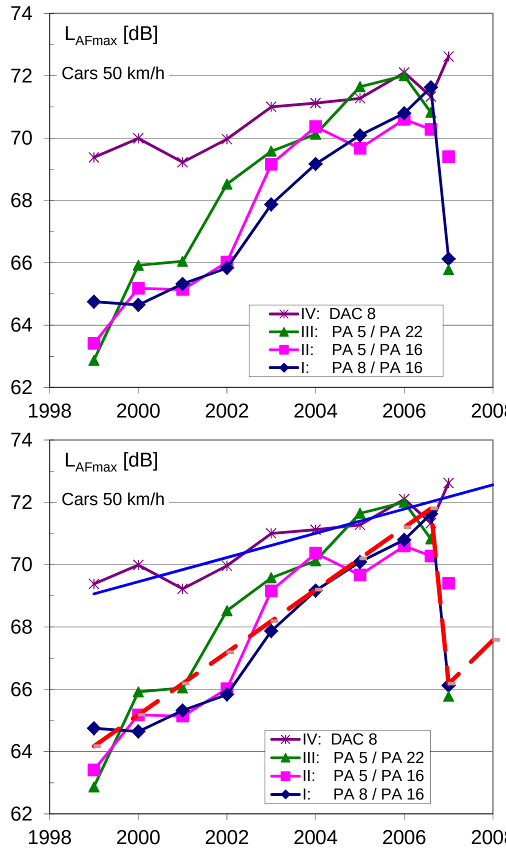

Figure 7. Top: Noise level time histories for two-layer porous asphalt and a reference surface on a city street. Bottom: Same results but with linear regression lines added

the pavement voids gradually clogged. The noise levels increased with time. This increase happened faster at the porous surfacings than at the dense reference pavement. The rate was around 0.3 dB per year at the dense surface and in the order of 1 dB per year at the porous pavements. The steepest slope is seen at the surface denoted III in Figure 7. This section was next to the dense reference section and clogged fastest. After 8 years the top layer with 5 mm maximum aggregate began ravelling and the Municipality of Copenhagen decided to mill off the top layer of all three test sections to replace it with a new top layer having 8 mm maximum aggregate. The data points from 2007 in Figure 7 are from measurements made just before and some months after the top layer was replaced.

Definition of noise reduction

The bottom part of Figure 7 shows the same data as the top part of the figure but lines have been added representing linear regression of the noise levels on time. In the following these lines are assumed to be idealized time histories of the noise level at the dense reference surface and at the porous pavements, respectively.

In Figure 8 the time histories have been prolonged, assuming a future linear development. The figure illustrates a scenario in which the top layer of the porous pavement is replaced by a new layer of porous asphalt. Such a time history of noise levels has yet to bee seen in reality. The noise levels averaged over 14 years of pavement service lifetime are also shown in the figure. The difference between the average noise level at the porous and the dense asphalt surface could be defined as the *average lifetime noise reduction* relative to the reference surface.

Finally, Figure 8 also illustrates other definitions of the noise reduction met in literature and product descriptions: 1 = initial noise reduction compared to a new reference surface; 2 = initial noise reduction compared to the average lifetime noise level at the reference surface. This average, for example, is the reference value in Nord2000, except that the default is AC 11d in Nord2000 while Figure 8 has AC 8d; 3 = the noise reduction obtained when replacing old dense asphalt concrete by new two-layer porous asphalt. This is the immediate improvement experienced by road neighbours.

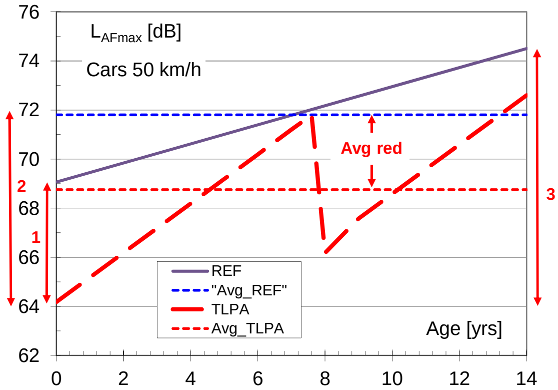

Figure 8. Idealized noise level histories, average lifetime noise levels and various noise reductions stated in literature

Figure 9 further illustrates how the stated noise reduction depends on the chosen reference. The top part of the figure shows the noise reduction at the porous asphalt sections related to the noise level measured at the same time at the reference section with dense asphalt concrete on the same road.

The bottom part of the figure shows the noise reduction at the porous asphalts related to the fixed default value in Nord2000. In the latter case even the dense asphalt reference surface provides a noise reduction of 2 dB when new.

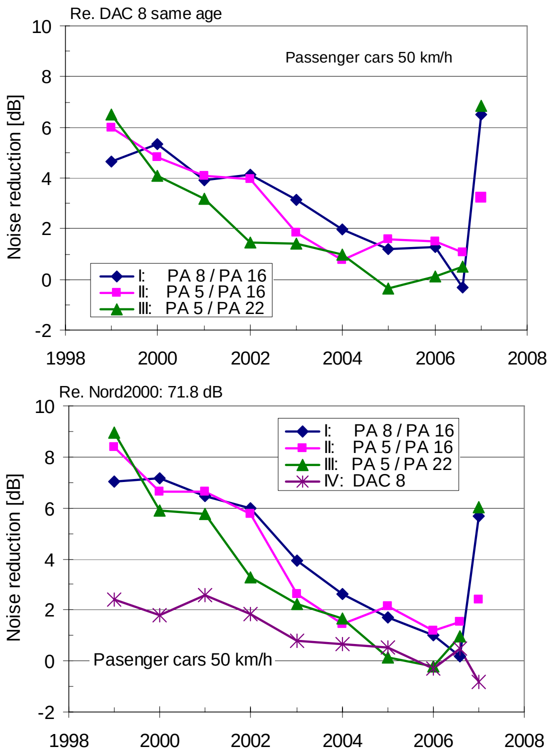

Figure 9. Noise reduction; Top: relative to reference surface having the same age; Bottom: relative to a fixed reference

Definition of low-noise/noise reducing pavement

In Denmark, a noise reducing road surfacing at present is defined as one yielding at least 3 dB lower tyre/road rolling noise level from passenger cars than 8 – 9 years old DAC 11 (Kragh, 2007b). Pavements yielding 3 – 5 dB noise reduction are denoted Class C; 5 – 7 dB reduction is Class B; while a noise reduction exceeding 7 dB is Class A. The present Danish system has no requirement as to the age of the surface layer at the time of testing. Usually products are tested when they are newly laid.

A Swiss research project defined “long-term low-noise urban pavement” as pavement with an initial acoustic improvement of at least 3 dB and with a reduction maintained at 1 dB or more for at least 12–15 years of service life, Figure 10 (Schlachter, 2009). The reference in the official Swiss noise calculation model, “STL 86+”, was defined at a time when people were not highly aware of the pavement influence: average dense or semi-dense asphalt concrete or mastic asphalt. The evaluation is based on SPB measurements and is for mixed traffic with 15 % heavy vehicles on motorways and 8 % on other roads.

The UK Highways Agency (HA) defines a noise reducing surfacing as one with a Road Surface Influence RSI ≤ -2.5 dB. RSI is defined in a so-called HAPAS guideline (HA Product Approval System). A brief description can be found in (Bendtsen, 2008). Noise testing must be made at two road sections with the same pavement type. The noise level used to determine the RSI is a combined SPB noise level from light, dual-axle heavy and multi-axle heavy vehicles. Such surfacing is denoted “Thin surface system (for highways)”, and it can be any surfacing as long as RSI ≤ -2.5 dB. The

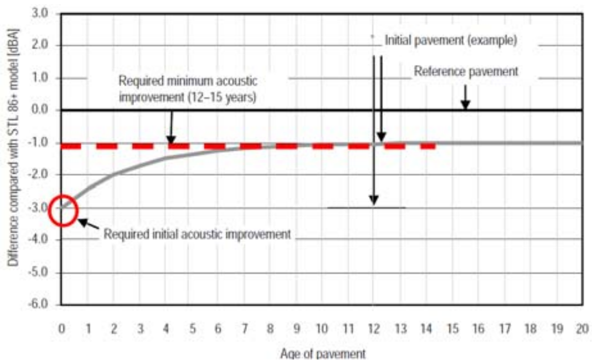

Figure 10. Illustration of a Swiss definition of a “long-term low-noise urban pavement” (Slachter, 2009)

reference for comparison is “new” (i.e. at least 12 months old) hot rolled asphalt with 20 mm nominal maximum aggregate size and with an aimed mean texture depth MTD = 1.5 mm (sand patch). The reference values were established in the 1970-1980s based on average pass-by measurement results at many sites. Compared to the dense asphalt concrete reference pavements used in other European countries, the British reference is a rather noisy pavement.

Road surface influence in traffic noise prediction

A fixed Danish practice for taking the actual road surface conditions into account in noise mapping has not yet been defined. The Danish Road Directorate general policy is to apply noise reducing pavement in new road construction or in maintaining the national road network when the noise level in residential areas or in recreational areas associated with residential areas exceeds a yearly average L_{den} = 58 dB.

The trend is for applying the pavement average lifetime noise reduction in traffic noise prediction. This is not necessarily the same as the classification value mentioned in the previous section which is based on the initial noise level relative to the reference noise level at a dense asphalt concrete DAC 11 aged 8 – 9 years. One of the difficulties encountered is that the end of lifetime has not yet been reached for the new noise reducing road surfaces. As a rule of thumb, when applying a class B noise reducing pavement yielding 5 – 7 dB noise reduction when new, the lifetime average noise reduction is 3 – 4 dB on high speed roads and 2 – 3 dB on urban roads.

Porous asphalt, be it single-layer or two-layer, is only used for experimental purposes in Denmark. The average lifetime noise reduction of both rolling noise and propulsion noise would probably be in the order of 3 dB.

The Netherlands do not seem to have an explicit definition of “low-noise” pavement. Pavements are classified via a “surface correction” denoted C_{road} applied in traffic noise calculation (CROW). The Dutch system requires SPB measurements at five or more different trial sections on at least five different sites (individual road works) to determine this road surface correction. The noise reduction is assumed to be the same throughout the pavement lifetime. The Dutch reference is dense asphalt concrete, most probably DAC 16, but the aggregate size and the pavement age are not stated explicitly. Probably it is DAC 16 on high speed roads and at low speed roads it is a mix of DAC 16 and DAC 11. The road surface correction is published in a list on the website of the CROW organisation. Besides corrections for 12 generic surfacings, their table contains corrections for a number of proprietary products. For each product a test report can be downloaded from (CROW).

The British system concerning lifetime average noise performance is based on the expectation that HAPAS procedures will assure an average noise reduction as given by the RSI mentioned earlier multiplied by a factor 0.7, but limited to a maximum noise reduction of 3.5 dB.

In Germany the prediction of traffic noise levels is regulated by law. The system includes a correction denoted D_{StrO} defined for a few types of pavement. The same correction is valid for light and heavy vehicle noise. It is based on SPB measurements at probably five or more different sites, but no explicit requirements have been defined as to the number of sites. See for example (Straβe, 2010). The reference pavement is mastic asphalt of unspecified age ("nicht geriffeltem Gussasphalt").

NOISE BARRIER EFFICIENCY

After having implemented Nord2000 and having the yearly average Day-Evening-Night noise level L_{den} introduced as a Danish measure of noise exposure, barriers along roads seemed to come out providing slightly less noise reduction than before, when noise levels were predicted for a situation with a slight downwind perpendicularly to the road. L_{den} is a weighted energy average noise level with 5 dB penalty for noise occurring during the evening (19.00 – 22.00) and 10 dB penalty during the night (22.00 – 07.00).

The effect of a noise barrier may be expressed in terms of its insertion loss. That is the reduction in noise level at a receiver caused by the introduction of the barrier. This measure is a bit tricky because it is a combination of the effect of diffraction around the barrier edges and the change in ground effect caused by the presence of the barrier in the sound field. The fact that the noise level at the receiver is now a yearly average for certain weather statistics further complicates things.

In the theoretical case of an infinitely long barrier along a motorway the yearly average L_{den} insertion loss is in the order of 2 dB per metre of efficient screen height up to 4 m, and in the order of 1 dB more per metre above 4 m. At a two-lane road the insertion loss may be 3 - 5 dB higher than this because the sources are closer to the barrier (Kragh, 2011).

Figure 11 shows the insertion loss provided by a 4 m high, infinitely long barrier situated 15 m from the centre line of an infinitely long straight four-lane road in a flat terrain (Kragh, 2011). The insertion loss has been calculated for the Danish meteorological reference year, see (Eurasto, 2006), at a receiver position to the east of the road. The road is in the direction North-South. The receiver was 1.5 m above grass-covered ground, at a distance of 100 m (Pos 2) and 200 m (Pos 3) from the road, respectively. The insertion loss is shown as a function of the "immission angle". That is the angle between a line from source to receiver and a line from the receiver perpendicular to the road. The figure shows that the insertion loss is highest when the source is nearest to the receiver, at 0º immission angle. When the source moves North or South, the insertion loss gradually becomes smaller, and it becomes zero when the immission angle approaches 90º in either direction.

Figure 12 illustrates the same results as Figure 11 but expressed in a different way. Figure 12 shows the contribution to the yearly average L_{den} at the two selected receiver posi tions as a function of the immission angle. The noise level contribution per degree of immission angle is shown relative to the total noise level from all immission angles between -90º and + 90º. The energy average of all contributions in

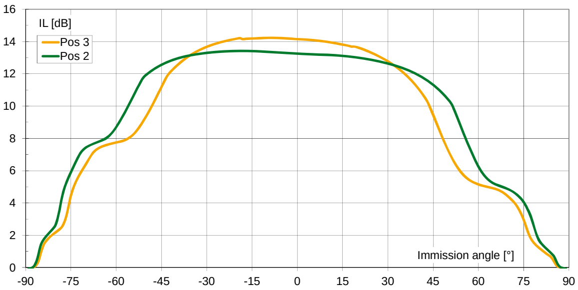

Figure 11. Insertion loss of a 4 m high barrier as a function of the immission angle. Yearly average noise level L_{den}

Figure 12 is 0 dB. The smallest contributions arrive from angles around 0º. Here, the source is closest to the barrier and the barrier is most efficient. Source horizontal directivity also plays a part. The largest contributions come from source positions at immission angles around -80º and +80º. At these angles the source is far away from the screen. During periods when sound propagation conditions are favourable from these source positions to the receiver, essential parts of the yearly average sound energy travel along these paths.

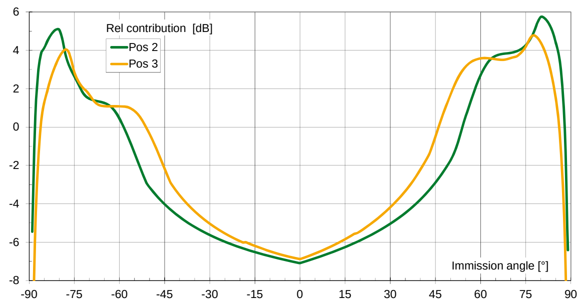

Figure 12. Relative contributions from different immission angles to the yearly average noise level L_{den} at positions behind a 4 m high barrier

Figure 13 shows the curves (with dotted lines) from Figure 12. These are valid for the yearly average L_{den}. The figure also shows (with fat lines) the insertion loss calculated with a slight crosswind from the road to the receiver. That is a wind speed of 1.5 m/s perpendicular to the road. This was the weather condition presupposed in the former Nordic prediction method for road traffic noise. The figure shows that with such crosswind the insertion loss at immission angles around 0º is 1 – 2 dB smaller than the yearly average insertion loss. It also shows that at immission angles exceeding 50º or 60º the insertion loss with a crosswind is higher than the yearly average. This is the main reason why, with the new noise measure and new prediction method, barriers seem to come out slightly less efficient than before.

The above considerations are valid for infinitely long barriers. Finite barriers do not cover the whole range of immission angles, so noise level contributions from certain areas will rest unaffected by the barrier, resulting in smaller average insertion losses.

ROUGH CALCULATION

During work on Nord2000 efforts were made to enable planners and environment officers to obtain quick estimates of the traffic noise level without having to perform complex computations. For a set of 'Type Cases' noise levels were pre-calculated and tabled. The results can be accessed via look-up

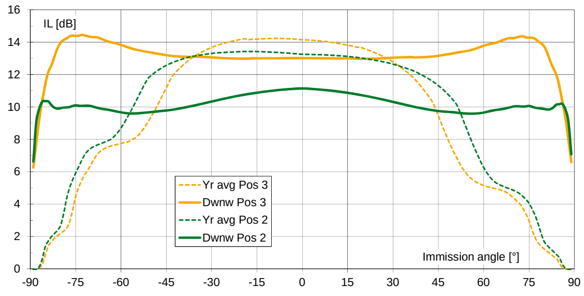

Figure 13. Barrier insertion loss as in Figure 12, but for a slight downwind and for the yearly average as a function of the immission angle

software at www.sintef.no. Search for ‘N2kR’ symbolizing ‘Nord2000 Road’. A main feature is that noise level pre-calculations were made for various weather conditions. The Norwegian research organisation SINTEF ICT developed the software. The user interface is illustrated in Fig. 14.

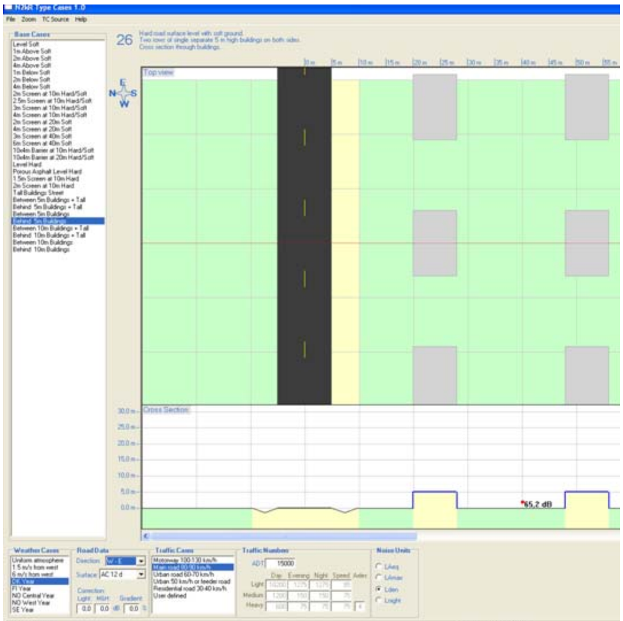

Figure 14. User interface with the free Nord2000 software

In the upper left corner users may select one of 30 different cases with roads at level, above or below the adjacent hard or soft terrain, with or without screens or buildings. When selecting a type case the upper right part of the screen displays a plan view and a vertical cross section illustrating the case.

At the lower left the user may choose the weather situation wanted, e.g. ‘DK Year’, ‘1.5 m/s from west’ or ‘uniform atmosphere’. At the lower right the traffic situation may be specified, either defined in detail by the user or selected from default cases. In the lower middle the road geographical direction may be specified together with the road surface type and with user defined corrections of light or heavy vehicle noise levels as well as the road gradient. Finally, at the very low right corner the user may specify the kind of noise level wanted. Choices are: L_{Aeq}, L_{AFmax}, L_{den} or L_{night}.

When all choices have been made, a click on the receiver position in the cross section picture will lead to the display of the pre-calculated noise level. The bottom of the screen displays the chosen receiver height and distance from the road.

OUTLOOK

A European prediction method

The European Commission initiated a project denoted CNOSSOS-EU on common noise assessment methods to be used in EU member states for mapping environmental noise beginning in the 3rd round of noise mapping scheduled for 2017. The project will complete earlier projects such as HARMONOISE and IMAGINE. CNOSSOS-EU is coordinated by the European Commission Joint Research Centre (JRC). Various groups work on 1) a quality framework, 2) road noise sources, 3) railway noise sources, 4) aircraft noise, 5) sound propagation, 6) a good practice guidelines, and on 7) assigning people and noise levels to buildings.

The core of the project will be described in a JRC Reference report expected in 2012. After that a second phase is planned for implementing CNOSSOS-EU during 2012-2015. This will include the production of reference software, setting up a database of input values and method validation based on ideal and real test cases. According to the project coordinator, no specific information and details on the methodological framework can be dispatched until perhaps by the end of 2011. The present author expects the upcoming European method to appear similar to Nord2000 and one could probably argue that CNOSSOS-EU at present is at a stage the Nord 2000 method passed around 2001.

Dutch-Danish project on noise reducing pavement

The Dutch Centre for Transport and Navigation (DVS) and the Danish Road Institute (DRI) carried out a joint project to clarify if available pavement solutions would yield a 10 dB traffic noise reduction when applied on high speed roads (with mixed traffic as defined in Figure 15), and to identify potentials for future development aimed at such high noise reduction. DVS-DRI invited the Swedish National Road and Transport Research Institute (VTI) to take part in the research. Results of the work are reported in (Kragh, 2009b).

The project consisted in collecting, analysing and evaluating information found by searching literature and patents, patent applications and trademarks. The authors’ network was utilized to contact industry and researchers active in national or international projects for the latest news, so the results are based on a worldwide search for pavement types and concepts made to be able to point at design principles and criteria for pavements with high potential for noise reduction.

The graph in Figure 15 attempts to illustrate how 10 dB of mixed traffic noise reduction may be achieved. For example, a pavement reducing both light and heavy vehicle noise emission by 10 dB will of course reduce the noise level from mixed traffic by 10 dB. But also a pavement reducing light vehicle noise by more than 10 dB and heavy vehicle noise by less than 10 dB may be a candidate. If, for example, heavy vehicle noise is reduced by 7 dB, it takes 15 dB light vehicle noise reduction to get 10 dB reduction of mixed traffic noise. 8 dB light vehicle noise reduction combined with 4 dB heavy vehicle noise reduction yields 6 dB of traffic noise reduction.

The main outcome of the project was that none of the available “ready-to-use” commercial products are able to provide the magnitude of noise reduction looked for, namely 10 dB relative to the present Dutch reference.

The most promising product identified was undergoing road testing in Japan in the summer of 2009. It is a poro-elastic road surface and based on Japanese measurement results it was estimated to provide 10 dB passenger car noise reduction in new condition compared to the Dutch reference. Heavy vehicle noise has not been tested, but it was estimated to be significantly smaller than 10 dB. Another promising product is a thin layer open graded asphalt wearing course with small maximum aggregate. However, it is uncertain whether such a wearing course is applicable on Dutch and Danish motorways. And if so, it will almost certainly not provide 10 dB reduction of the noise from a traffic mix of heavy and light vehicles, because it cannot be expected to be efficient in reducing heavy vehicle noise. Optimized two-layer porous asphalt will probably be more efficient in this respect.

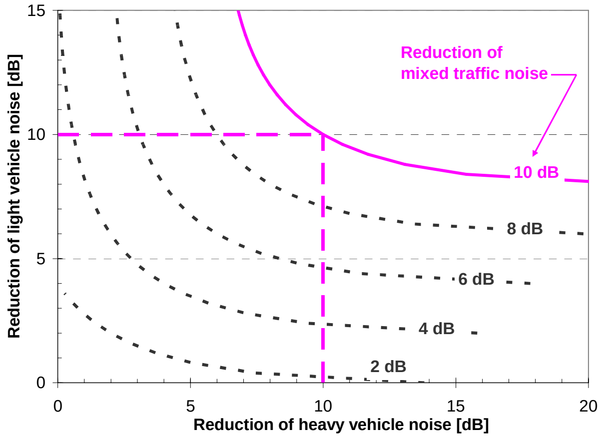

Figure 15. Reduction (in dB shown in the legend) of noise from mixed traffic (85 % light vehicles at 115 km/h and 15 % 5-axle heavy vehicles at 85 km/h), as a function of heavy and light vehicle noise reduction

To progress in obtaining a traffic noise reduction of 10 dB it will be necessary to add more porosity and/or to develop a wearing course having an elastic skeleton. This can perhaps be made into reality by adding rubber to the asphalt mix combined with using special aggregates and binders. Various solutions are discussed in (Kragh, 2009b). Some may be realistic after further development while others may prove purely speculative, and an assessment of the durability, cost or other properties of such future solutions is not feasible.

European project on poro-elastic pavement

The year 2009 saw the beginning of an innovative EU project on noise reducing road pavements. Its acronym is PERSUADE, Poro-Elastic Road SUrface: an innovation to Avoid Damages to the Environment. Twelve European research institutes and companies participate with the Belgian road laboratory as a coordinator (PERSUADE, 2009).

The project aims at very high traffic noise reduction by combining the properties of porous asphalt having a high void content with elasticity obtained by having a high percentage of rubber material replace traditional stone aggregate. By using rubber granulate from worn out vehicle tyres the project also aims at recycling vehicle tyres. Substantial noise reduction is expected to be documented combined with a reasonable lifetime and acceptable skidding resistance (traffic safety), energy consumption and CO_2 emission. Such poro-elastic road surfaces are foreseen for use on 'black spots' in densely populated areas with no space for noise barriers.

The first couple of years of the project are devoted to laboratory work on new materials. Full-scale field testing is planned in five European countries, including Denmark. Comprehensive measurements will be made of noise, skidding resistance, rolling resistance, etc. Cost/benefit analyses will compare the cost of poro-elastic pavement with the cost of more ”traditional” noise mitigation measures such as façade insulation and ”ordinary” noise reducing pavement. Life cycle analyses will also be included.

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