DEUFRAKO "Prediction and Propagation of Rolling Noise"

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Aim of the project

Prediction

This module is intended to demonstrate the change of paradigm in road construction. Low noise road design will be realised on real road pavements. That is the opposite of realising road pavements incidentally, analysing their acoustical properties and hoping that results would come along well.

The SPERoN [2] and the HyRoNE [5] models are applied as adapted tools to design new textures for low noise road surfaces. After a theoretical description of the optimized surface texture issued from the fitting calculations, some samples are being built and tested in a first step in laboratory (Eiffage, Colas) and finally in situ following the current updated experimental techniques.

Propagation

The main goal is to examine whether the acoustical qualities of the new optimized texture measured in the near field of the vehicle will persist at large distances, in front of the façades, or not.

In order to identify this relationship, a method developed in France [4] is used. This method requires to use accurate propagation models which can take into account both ground effects (for heterogeneous ground) and atmospheric effects which can be very important at large distances.

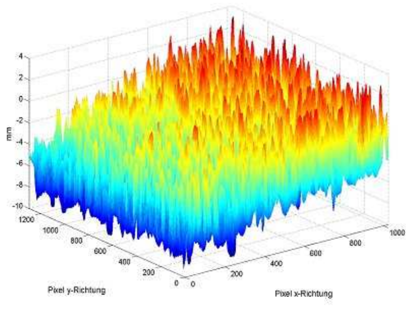


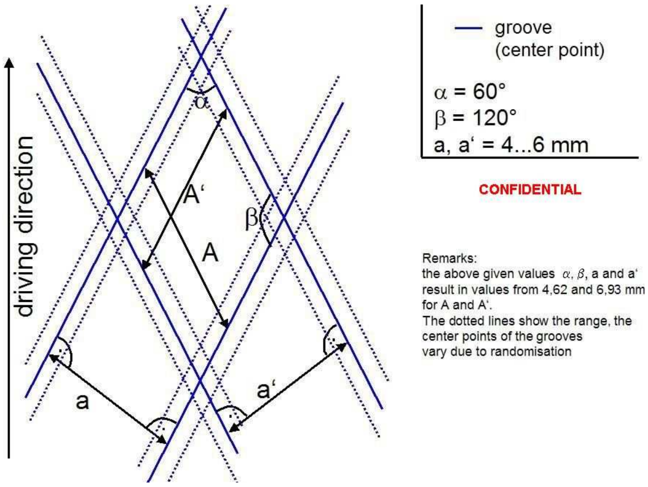
Figure 1: Typical measurement result for a 3D texture measurement

Prediction of noise emissions of novel surfaces

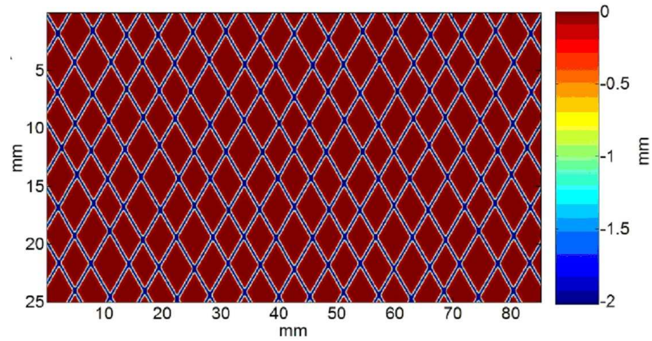
The SPERoN [2] approach combines a physical model with a statistical model. The main difference between most of the empirical models and the hybrid model is the fact that pre-processed input data are used, which are of the same quality as one would apply in a deterministic model simulating the rolling process in detail. This means that starting from the description of the road texture (i.e. texture profile (Fig. 1), mechanical impedance) and of the tyre (material data for the tyre model, tread stiffness and tread pattern, the radial contact forces are calculated for a certain speed and load case. In this way one achieves several advantages in comparison with usual pure statistical models. Firstly one can rely on a linearised relation between input data (contact force) and output (radiated sound pressure). Secondly only the relevant roughness is taken into account. This is similar to the so-called envelope technique as used e.g. in the HyRoNE [5] model. However, here the dynamic system “tyre” is taken into account when determining the envelope while otherwise often the procedure is limited to the static contact problem (e.g. roughness and elastic halfspace) only.

One of the main tasks of this module was to find appropriate materials, construction methods and machinery to have the novel road surfaces laid in a controlled and reproducible way. This was achieved with help of road construction companies. The road companies Colas and Eiffage contributed from the French side, by designing asphalt mix recipes, preparing samples and finally building up short test sections for the three optimal solutions. One of them included the structuring of a surface with a moulding tool. This was a perforated metal sheet structured with the negative of the texture to be printed into the resin surface. The others were a very regular surface realised with small glass balls and a “conventional approach” with a surface dressing having the same chipping size as the glass balls.

The theoretical approach is based on the SPERoN ("Statistical Physical Explanation of Rolling Noise") model. In a first stage, the model was validated for different kinds of French road surfaces and compared to the French model “HyRoNE”. The validation showed differences of the computations and the measurements on the test tracks of the LCPC in Nantes of mostly less



(a) Dimensions and positions of grooves



(b) Calculated texture

Figure 2: Model texture type 2

than 2 dB(A) which shows that SPERoN is a valuable prediction tool. In a second step, the model was applied as an adapted tool to design and build new textures for low noise road surfaces.

Two new approaches were developped together with a third more conventional for comparison. The first approach were glass beads closely packed in a matrix of resin. The second new approach was a very smooth surface with diagonal grooves of randomly varying distance. This structure cannot be built with conventional means. Therefore a moulding tool was produced to be imprinted into a specially designed asphalt mix surface.

A comparison of the sound pressure levels computed with SPERoN due to the real, measured texture data and those ones measured on the testtracks of the INRETS at Satolas shows a nice agreement. However the textures produced in this project are not yet reproducing the originally intended texture and accordingly the noise levels are still higher than those of the ideal computed texture. Therefore the development of new production processes and materials which reproduce the ideal texture and its noise level could be the aim of potential follow-up projects.

level in dB(A) at 80 km/h	72,3	72,9	77,1
surface	optimum (SPERoN prediction)	Single layer porous asphalt	German reference

Table 1: Predicted emission level in comparison to conventional surfaces

In parallel to these hybrid approaches which need a physical model of tyre-road contact as input, this project has also permitted to develop a tyre-road contact model which takes into account the viscoelastic behaviour of the tyre tread. In this study, it has been focussed on the contact between a single indenter and a viscoelastic halfspace with rubber-like properties. This represents a first attempt before modelling the contact between a real road surface and a tyre in the time domain. Such a model could then be used in hybrid as well as in fully physical approaches for a more realistic tyre-road noise prediction.

Propagation calculations

Benchmark

Low noise pavements currently developed or in study in France and Germany should permit to reduce traffic noise of a few decibels. Results have been already found for some pavement families and simple configurations only. The question is: may we extend these first conclusions to other new types of pavements and for complex situations where ground and meteorological effects can widely influence traffic noise propagation?

In order to simulate a large number of road configurations, a benchmark has been built. Ten cases have been selected and the calculations have been carried out both with analytical and numerical models. After comparison between the different excess attenuations computed with each model, the most adapted approach has been associated to each configuration in order to optimize the ratio accuracy/computing time.

All the excess attenuations finally obtained are used in a ranking procedure of French and German pavements in terms of L_{den}, in the far field and for all of the road configurations.

Depending on the complexity of the situation, from geometrical and micrometeorological points of view, several theoretical approaches can be used [3]. For simple cases analytical models are adapted. For more complex situations numerical approaches are needed.

- **Analytical models:** These approaches are based on the ray tracing theory. The sound field is split into three terms: a direct wave between the source and the receiver, a reflected wave on the ground and a surface wave.

- **Numerical models:** Different methods can be used to calculate the sound propagation in the atmosphere. Some are based on Boundary Element formulations and the other on the Parabolic Equation formulation. On one hand, the Boundary Element Method (BEM) is quite accurate for solving the equation of sound propagation in a homogeneous non refracting atmosphere but on the other hand it can lead to large computation times when the distance of propagation is large as well as for high frequencies. It can deal with very complex shapes such as grounds with irregular profiles and with complex obstacles such as noise barriers. The Parabolic Equation seems to be the most appropriate to solve the problem of acoustic propagation above a mixed ground with topographical irregularities in a both refractive and turbulent atmosphere.

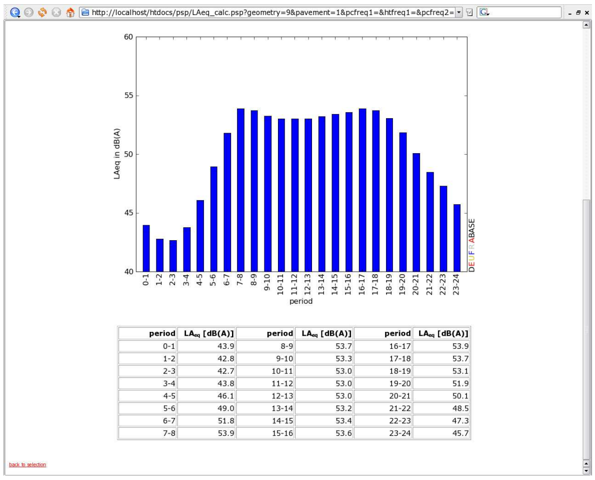
For the calculation of the access attenuation 10 typical road configurations were defined to analyse the following influences on the sound propagation:

- the effect of a homogeneous ground for short and large distances
- the effect of an impedance discontinuity on a flat ground for short and large distances
- the effect of an embankment (positive slope) with and without an impedance discontinuity for short and large distances
- the effect of a terrain depression (negative slope) with and without an impedance discontinuity for short and large distances
- the effect of a barrier with and without an impedance discontinuity for medium distances
- the effect of a positive vertical sound speed gradient for large distances

L_{Aeq} calculation

This ranking procedure is based on the calculation of L_{Aeq} in front of the façades, function of the pass-by sound pressure level L_{Amax}. Knowing the L_{Aeq} for the various day, evening and night periods, L_{den} can be estimated for each situation and each pavement family. This procedure [4] needs the knowledge of the following minimum informations :

- The traffic distribution during the day [6:00-18:00], evening [18:00-22:00] and night [22:00-6:00] periods for each vehicle class : passenger cars (n_{PC}) and heavy trucks (n_{HT}),
- the reference speed of each vehicle class (v_{Ref}),
- the A-weighted pass-by maximum sound pressure level L_{Amax} (in global or third octave values) at a reference microphone located in the road vicinity, 7.50 m from the right lane axis and 1.20 m above the road surface, for each vehicle class, according to the SPB method [1],
- the number and width of traffic lanes,
- different input parameters



period	LA_{eq} [dB(A)]	period	LA_{eq} [dB(A)]	period	LA_{eq} [dB(A)]
0-1	43.9	8-9	53.7	16-17	53.9
1-2	42.8	9-10	53.3	17-18	53.7
2-3	42.7	10-11	53.0	18-19	53.1
3-4	43.8	11-12	53.0	19-20	51.9
4-5	46.1	12-13	53.0	20-21	50.1
5-6	49.0	13-14	53.2	21-22	48.5
6-7	51.8	14-15	53.4	22-23	47.3
7-8	53.9	15-16	53.6	23-24	45.7

Figure 3: Results of the L_{Aeq} calculation: case 4b, 2 lanes per direction, 20000 vehicles per direction, 15 % heavy trucks, 2 lanes per direction, twin layer porous asphalt 0/8

DEUFRABASE

All the data described in the previous section were connected to a common German-French database called DEUFRABASE to calculate the L_{Aeq} in front of facades. This database and the calculations of the L_{Aeq} are published at the internet: *http://deufrako.bast.de*.

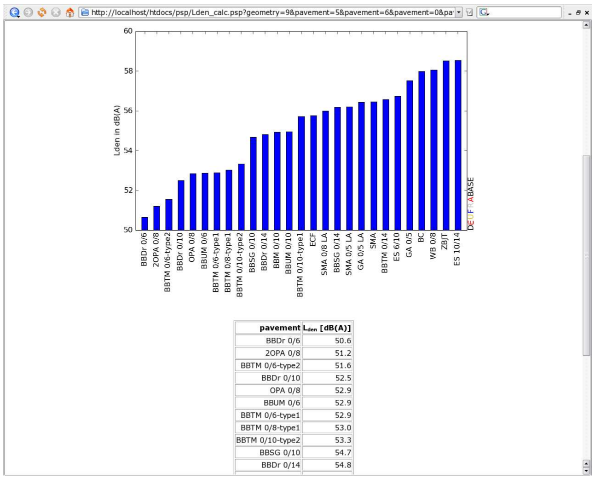
In a first step the user of this website gets a short review of the used method to calculate the L_{Aeq}, the given pavement and traffic data and the existent attenuation data. For more information about the data and the calculation method links to other pages are available. With this information the calculation can be run and the results are visualised in bar plots:

- the L_{den} for several pavements, one geometry and one traffic situation
- the hourly L_{Aeq} distribution for one pavement, one geometry and one traffic situation
- the L_{Aeq} spectral evolution for one pavement, one geometry and one traffic situation for one hour

How to use the DEUFRABASE

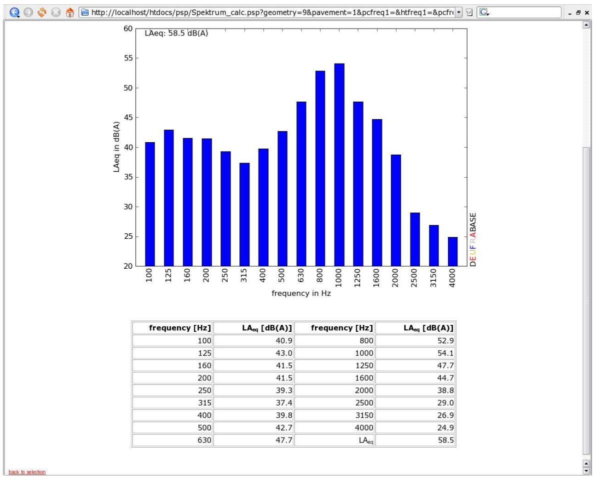
The usage of the websites ought to demonstrate on the example of the calcultation of the L_{Aeq} for one pavement, one geometry, one traffic situation and a whole day.

In a first step the user must choose a topography for which the excess attenuation is given. Then a pavement must be selected. Here the user has the possibility to use a given L_{Amax} spectrum from the database or to enter a new dataset of L_{Amax} from his own pavement. At this it is important that the entered data corresponds



pavement	L_{den} [dB(A)]
BBDr 0/6	50.6
2OPA 0/8	51.2
BBTM 0/6-type2	51.6
BBDr 0/10	52.5
OPA 0/8	52.9
BBUM 0/6	52.9
BBTM 0/6-type1	52.9
BBTM 0/8-type1	53.0
BBTM 0/10-type2	53.3
BBSG 0/10	54.7
BBDr 0/14	54.8

Figure 4: Results of the L_{den} calculation: case 4b, 2 lanes per direction, 20000 vehicles per direction, 15 % heavy trucks



frequency [Hz]	LA_{eq} [dB(A)]	frequency [Hz]	LA_{eq} [dB(A)]
100	40.9	800	52.9
125	43.0	1000	54.1
160	41.5	1250	47.7
200	41.5	1600	44.7
250	39.3	2000	38.8
315	37.4	2500	29.0
400	39.8	3150	26.9
500	42.7	4000	24.9
630	47.7	LA_{eq}	58.5

Figure 5: Results of the spectrum calculation: case 4b, 2 lanes per direction, 4000 passenger cars per direction, 500 heavy trucks twin layer porous asphalt 0/8

with the position of the microphone at SPB or CPB measurements (7.50 m from the middle of the right lane and 1.20 m above the ground). Additionally the data must be calculated for velocities of 90 km/h or 110 km/h for passenger cars and 80 km/h for heavy trucks. In a next step the user must choose the velocity of the vehicles (if an own L_{Amax} spectrum is used the selected velocities of the vehicles must correspond to the velocity of the L_{Amax} spectra) and the number of lanes per direction. In the end the traffic volume must be selected: either a hourly traffic distribution with variable number of vehicles and a variable proportion of heavy trucks can be used or own hourly traffic distribution data can be entered (absolute values).

Figs. 3 to 5 show the results of the three calculations.

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