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"Low Road Traffic Noise"
The German research program "Leistra2"

Arne Lorenzen
Bundesanstalt für Strassenwesen
Federal Highway Research Institute
Brüderstrasse 53
51427 Bergisch Gladbach
Germany

Abstract

The German Federal Ministry of Economics and Technology is funding a project called "Leistra2" with the aim of understanding the tire road contact and to find measures to reduce traffic noise, in particular to reduce the noise of tires rolling on pavements, i.e. tire-road noise. The project is composed out of three mayor subjects, low noise tires, low noise pavements and verification of the results, each made out of single sub-projects. The purpose of this paper is to give a survey about Leistra2 and to report about the latest activities and results. More detailed information and contact data of the partners involved can be found at **http:// www. LeiStra2. de .** The program is the successor of the program LeiStra (Leiser Strassenverkehr), dealing with similar topics [1].

1. LOW NOISE TIRES

1.1 Development of low noise truck tires

Figure 1 shows a typical distribution of road traffic noise with day time, separate for trucks and passenger cars. From such measurements we learn, that especially at night times, where the legal noise limits are 10 dB(A) lower, the noise originating by trucks contributes

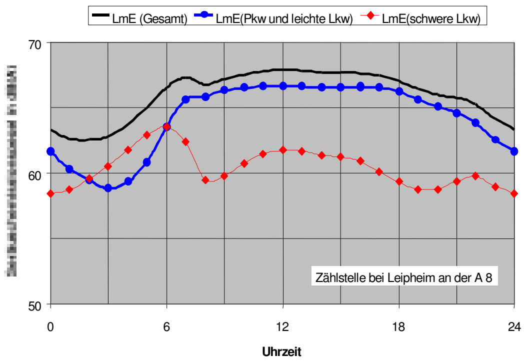

Figure 1: Heavy weight truck noise dominates at night times
(red: truck noise, blue: passenger car noise)

email address: Lorenzen@BASt.de

the main part to the overall noise level. Furthermore traffic experts predict an increase in traffic by as much as 30% within a few years. It is also well known, that already at moderate vehicle speeds the rolling noise is the main source for the traffic noise. For these reasons it is very important to develop new truck tires, which emit less noise than today's truck tires. One main part of the Leistra2 project therefore is the development of a low noise tire for the drive-wheels of trucks.

The partner in Leistra 2 for this research-task is the tire manufacturer Continental AG. They developed six different tires for the drive-wheels of trucks. This work is very expensive and there is a substantial business interest involved, which is the reason, why certain details are not available for the public. Nevertheless, with some internal knowledge it can be said, that the resulting noise level measured under ISO standard conditions for the six tires do show significant differences. The lowest noise level measured was a little less than 71 dB(A) and the highest noise level was more than 77 dB(A). This result demonstrates, that there is a wide span of noise levels emitted by truck tires and the profile of the tread pattern plays has strong influence on this result. However, it turned out, that the tire with the second lowest noise level is much more favourable, when other tire features are taking into consideration, e.g. rolling resistance, wear etc.. The tests for the six tires are not yet completed. Long distance tests are in progress and will be continued. Additional efforts will be made to improve the abilities of the tire with the lowest noise level. No information exists so far about the question whether the noise level of these tires will remain constant over the life time of the tires.

1.2 Development of a software tool to simulate the tire road contact and to calculate the emitted noise level

Only a short summary about this sub-project is given here, as a separate paper in this issue will deal in detail with the aims and results.

Four partners are cooperating in order to develop a numerical simulation tool, that is capable to calculate the tire vibrations and the emitted noise caused by these vibrations. Once this software tool is available it is intended to be used to make predictions about tire rolling noise and thus enabling the tire engineers to design low noise tires and secondly to design low noise pavement surfaces. The four project partners are:

The Continental AG, Hanover. They develop the numerical tire model, manufacture the tires and contribute certain acoustic and vibration measurements.

The University of Hanover is developing the numerical code to calculate the tire vibrations.

The Technical University of Hamburg-Harburg is developing the numerical code to calculate the sound field emitted from the vibrating tire.

The Federal Highway Research Institute (BASt) is the project manager and contributes certain measurement data.

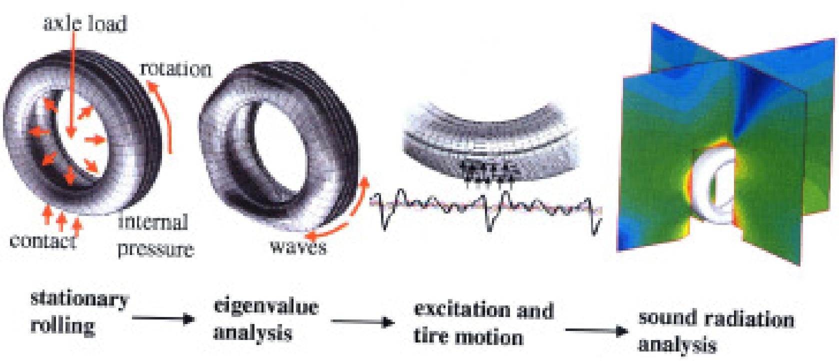

Figure 2: Procedure from formulating the FEM of the tire to calculating the noise field

All parts of the tire, e.g. the tread, the side walls and the various plies, are resolved in the finite element formulation of the tire (FEM) including the different material properties. So far the model is restricted to slick tires, which means real tread patterns are not included in the model. The procedure of calculating the sound field is sketched in figure 2. An axes load is applied to the FEM of the tire, contact is made with the road surface and the tire is set into rotation. An eigenmode analysis, yields the vibration mode spectrum of the tire under consideration. Then a realistic excitation function is fed into the tread pattern FEM-elements to simulate the influence of the road roughness on the eigenvalue spectrum and finally the calculated vibration of the tire surface is used to calculate the sound field (here a combined formulation FEM and iFEM, infinite-finite element method, is applied).

2. LOW NOISE ROAD PAVEMENTS

In the last about 20 years there has been a lot of research gone into the acoustical features of road pavements in order to give civil engineers guidelines to build roads, which are not only save and durable, but in addition reduce traffic noise. Among the various different road constructions the porous asphalt offers the highest potential to reduce road traffic noise. State of the art is a double layer porous asphalt each layer is made from a different maximum aggregate (stone) size. Noise reduction in comparison with conventional dense road surfaces of up to 10 dB(A) are reported for new road surfaces. However, porous asphalt also has at least two disadvantages. The pores clog up after typically six to eight years and road maintenance in the winter period causes certain problems. This has to be set into relation with an average road with a life time of up to 20 years. It is for these reasons, that it is desirable to improve the features of porous asphalt. Four project partners focus their work on this aim.

2.1 Improvement of porous asphalt

In order to prevent a porous asphalt layer from clogging up two ideas from the field of nano technology are under investigation, both with the aim to enhance the self cleansing abilities of the pores. One idea is to make the surface of the pores hydrophobic and the other idea is the opposite, to make the surface hydrophilic. It is the research of our partner from the Institute for Pigments and Paint to find suitable substances and techniques to this purpose and the Institute for Roads and Traffic, both from the University of Stuttgart, the evaluate the efficiency of such measures.

The first idea is well known as the "lotus effect" were a polymeric paint is used to cover the pores. The lotus effect increases the contact angle between a water drop and the surface and thus making it easier for water drops to flow down the surface. In doing this small (dirt) particles can be collected by the water drop while flowing through the porous layer rather than to stick to the mainly bitumen surface. See also figure 3 for this general picture to explain the lotus effect. Sofar a commercial paint is used for this project.

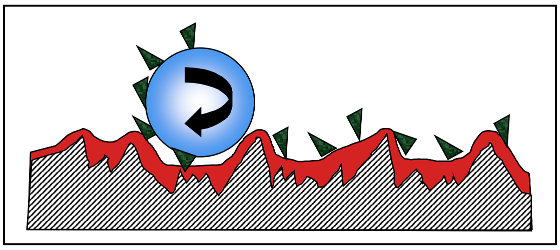

Figure 3: Sketch of the „Lotus Effect". Hydrophobic paint covers the surface (red). Water drops collect dirt particles, but cannot stick to the wall.

For the opposite idea polymeric additives are used to modify the bitumen. Due to the Marangoni effect the polymer migrates to the surface of the bitumen, see figure 4, and in such way the contact angle between a water drop and the surface is reduced. Water thus penetrates underneath the dirt particles and spreads on the bitumen surface. Thus dirt particles cannot stick to the bitumen surface and are transported through the porous layer. For details about the substance used see our web site.

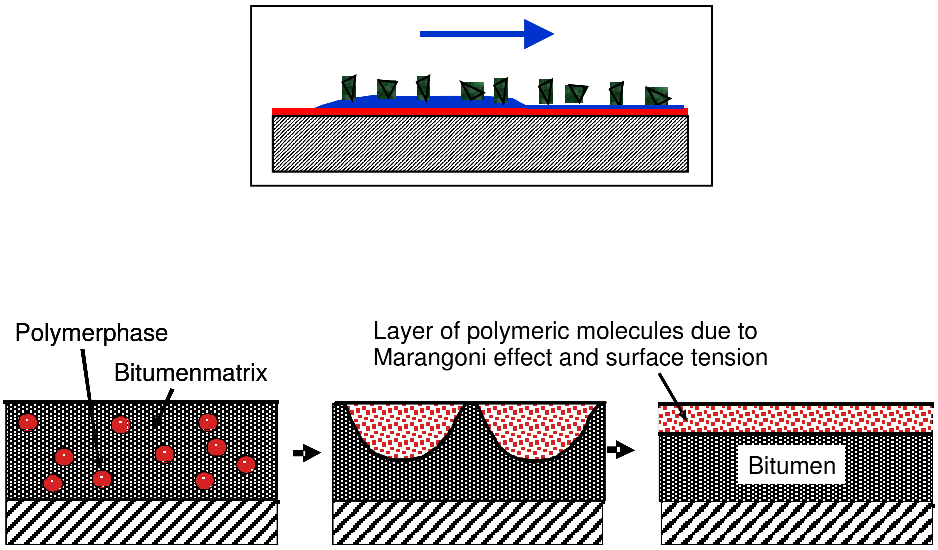

Figure 4: Formation of a hydrophilic surface (red) due to Maragoni Effect and surface tension. Water (blue) penetrates underneath dirt particles (black).

The findings so far are, that it is comparatively easy to cover the surface of the void fraction of the asphalt layer and to achieve a substantial lotus effect. For the opposite measure, however, up to 20% of polymeric material has to be added to the bitumen, which seems to be not very practical.

Figure 5: Test assembly for dirt transport, drain abilities and sound absorption.

In laboratory experiments, see figure 5, porous asphalt layers were artificially clogged up with a suitable dirt mixture and then exposed to artificial rain followed by drying periods. These experiments are in progress and various different combinations of porous asphalt layers

without and with polymeric modification are on the program. The first findings without polymeric modification are not very promising. Only a small fraction of the artificial dirt was found in the drain water, whereas most of the dirt obviously remained in the porous asphalt.

2.2 Flow field in porous asphalt

Scientists from the Technical University of Munich are investigating the flow of water through a porous asphalt layer. Numerical simulations of the flow field through a cubic space with 30mm * 30mm * 30mm using a super computer is shown in figure 6. These calculations show, that sufficiently high water velocities are achieved only in about 40% of the void fraction. In further about 20% the velocities are already fairly low and will hardly contribute to a dirt transport through the layer and in another about 40% the water velocities are practically zero. These are dead or recirculation zones of the flow field. In general it was found, that the flow field is not homogeneous but rather different in X,Y or Z direction.

The possibillities to clean clogged up porous layers are also part of the program to improve porous asphalts. These investigation have been started recently.

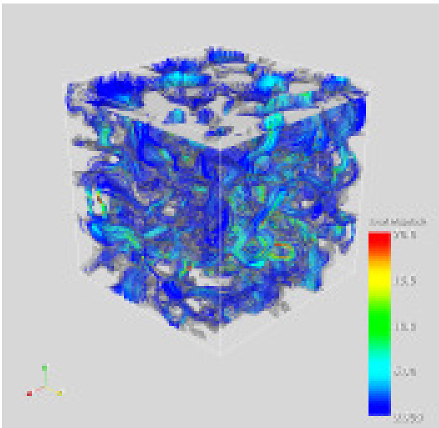

Figure 6: Calculated flow velocities in the pores of a porous asphalt cubus 30mm * 30mm * 30mm.

2.3 Structure of porous asphalt

Computer tomography is used by the Federal Institute for Materials Research and Testing to gain a deeper insight into the porous layers. They did develop the method such that a sufficient accuracy is achieved. Furthermore, since recently a distinction between solid material of the porous layer and (certain) dirt can be made. Figure 7 is an example of a picture obtained with CT of a porous test body. This partner also did provide the data for the flow field calculation, see above.

Figure 7: Computer tomographic picure of a porous asphalt sample.

2.4 Environmental aspects and improved sound absorption of porous asphalt

The consultancy and engineering bureau Müller-BBM (Munich) contributes to Leistra2 with various acoustical and flow measurements and chemical analysis. In particular these are the determination of the flow resistance of the new and clogged up porous asphalt layers, there sound absorbing ability and the analysis of the environmental impact of the various substances and chemicals used in the project, e.g. tensides for cleaning the porous layers etc..

An example of a measurement of the sound absorption coefficient for a two layer porous asphalt is given in figure 8 showing the distinct resonances. The principle finding is, that in order to improve the sound absorption it would be necessary to increase the sound absorption in the frequency range in between these peaks. This, however, can only be achieved if the flow resistance is increased and to this aim it would be necessary to increase the void fraction. This, however, is not really practicable.

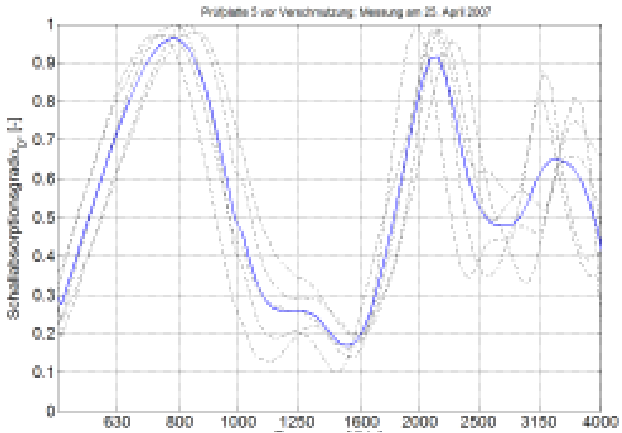

Figure 8: Measured sound absoption coefficient versus frequency
for a two layer porous asphalt showing typical resonances.

In order to improve the sound absorbing abilities of such porous layers an idea has been developed employing reactive Helmholtz resonators. A sketch of the principle arrangement is shown in figure 9. These absorbers consists out of cavities build of a suitable material and will be placed below the porous layer. It is believed, that if such a measure proves to be useful under real traffic load conditions an additional noise reduction potential of porous asphalt of 3 dB(A) is realistic.

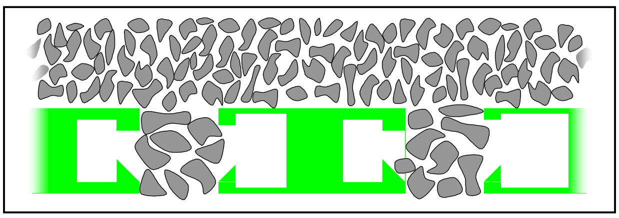

Figure 9: Sketch of principle idea to improve the sound absoption of
porous asphalt layers by means of Helmholtz resonators (green).

2.5 Improved expansion joints

Those parts of a road connecting the road with a bridge are known as expansion joints. These expansion joints are, however, also known to cause tremendous noise obstructions. It is therefore very desirable to improve the acoustic features of expansion joint. The main idea to achieve this aim is to modify the surface structure of the expansion joint, which usually are made from a small number of metal bars placed lateral to the road. These surface modification will consist out metal rhombs, as shown in figure 10, fixed onto these lateral bars.

Figure 10: Surface modification of expansion joints to reduce noise emission. left: summer and right: winter expansion

3. VERIFICATION OF RESULTS

3.1 Tires

Information about the application of the research results for truck tires and for the design of low noise car tires have been given already, see above, as well as in the other paper in this issue about this topic.

3.2 Pavements

In this report of the Leistra2 project to reduce traffic noise so far research activities concerning porous asphalt has been mentioned. However, there is certain recent knowledge about noise reduction potential of other road pavements. These are therefore included in the Leistra2 program.

Five federal highways (BAB) and trunkroads (B) will be used in order to verify the research results:

- BAB 61 near Jackerrath: Testing of exposed aggregate cement concrete (Waschbeton)
- BAB 61 near Kerpen: Testing of Gussasphalt
- B 56 near Düren: Testing of low noise stone mastic asphalt (SMA)
- BAB 24 near Neuruppin: Testing of improved porous asphalt
- Test section in Bavaria (Bayern): Testing of improved porous asphalt

Their realisation is in process and will be completed late summer 2008 and is followed by an extensive measurement campaign to evaluate the various properties of these pavements under real traffic conditions, including the acoustical properties.

The realisation of an acoustically optimised expansion joint is also part of the Leistra2 program.

4. OUTLOOK

Some sub-projects of the research program Leitra2 will be completed in 2008. Especially the verification of the research results, however, will need more time and it is planed to finish the program about summer 2009. It is rather probable, that the results of Leitra2 will influence the development of guidelines and standards and those pavements, that proof to be acoustically advantageous, will be realised more often in due course. The development of acoustically improved car and truck tires are very likely and also the realisation of an acoustically improved expansion joint.

5. REFERENCES

[1] W. Bartolomaeus et al., “Verbundprojekt “Leiser Strassenverkehr – Reduzierte Reifen-Fahrbahn-Geräusche”, Berichte der Bundesanstalt für Strassenwesen, Heft 537, Bergisch Gladbach, Dezember 2004

[2] http://www. LeiStra2. de

6. ACKNOWLEDGEMENT

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