G2G short programme project for Serbia G2G09/SB/5/5, “Reducing traffic noise in Serbia” Guidelines

Date

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G2G09/SB/5/5, “Reducing traffic noise in Serbia”
Guidelines

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1 INTRODUCTION

1.1 Bilateral Relations

The project is a proposal by the Serbian government to the Dutch government to share knowledge and experiences from the Netherlands over to Serbia. Based on this transfer, the actual implementation of the proposed measures against noise is to be carried out by Serbian companies and with Serbian materials.

1.2 Project Setting

The project is part of the EVD programme 2g@there in general, which resulted from the activities initiated by Dutch Serbian Business Council (DSBC) for Infrastructure and Environmental Protection in particular. Aim of this is promotion of Dutch businesses abroad, which should eventually lead to the gathering of written orders. The cluster is facilitated here by the Dutch government. Some project information:

Projectnumber	G2G08/SB/5/5	Agentschap NL Ministerie van Economische Zaken
Stakeholder	Public Enterprise “Roads of Serbia	JAVNO PREDUZEĆE PUTEVI SRBIJE
Beneficiaries	The Highway Institute	Институт за путеве
	Ministry of Environment and Spatial Planning	

1.3 Problem Definition

1.3.1 Introduction

Environmental noise "pollution" relates to ambient sound levels beyond the comfort levels as caused by traffic, construction, industrial, as well as some recreational activities. It can aggravate serious direct as well as indirect health effects, for example damage to hearing or sleep and later mental disorder, as well as increasing blood pressure. Noise effects can trigger premature illness and, in extreme cases, death. Night-time effects can differ significantly from day time impacts.

EU-wide action to reduce environmental noise has traditionally had a different priority compared to environmental problems such as air and water pollution also because solutions were often considered best handed at the national or local levels (i.e. there has always been an important subsidiarity consideration). In the early stages, EU regulations on noise management were based on internal market objectives. These were mainly focusing on setting harmonized noise limits for motor vehicles, household appliances and other noise-generating products. As more information about the health impacts of noise became available, the need for a higher level of protection of EU citizens through further EU-wide measures became more imminent.

Following a proposal by the Commission adopted in 2000, the European Parliament and Council adopted Directive 2002/49/EC[1] relating to the assessment and management of environmental noise on 25 June 2002, also known as the "END". The END aims to “define a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects, including annoyance, due to the exposure to environmental noise”. For that purpose several actions are to be progressively implemented. It furthermore aims at providing a basis for developing EU measures to reduce noise emitted by major sources, in particular road and rail vehicles and infrastructure, aircraft, outdoor and industrial equipment and mobile machinery.

- **Monitoring the environmental problem**; by requiring competent authorities in Member States to draw up "strategic noise maps" for major roads, railways, airports and agglomerations, using harmonised noise indicators L_{den} (day-evening-night equivalent level) and L_{night} (night equivalent level). These maps will be used to assess the number of people annoyed and sleep-disturbed respectively throughout Europe

- **Informing and consulting the public** about noise exposure, its effects, and the measures considered to address noise, in line with the principles of the Aarhus Convention

- **Addressing local noise issues** by requiring competent authorities to draw up action plans to reduce noise where necessary and maintain environmental noise quality where it is good. The directive does not set any limit value, nor does it prescribe the measures to be used in the action plans, which remain at the discretion of the competent authorities.

- **Developing a long-term EU strategy**, which includes objectives to reduce the number of people affected by noise in the longer term, and provides a framework for developing existing Community policy on noise reduction from source. With this respect, the Commission has made a declaration with regard to the preparation of legislation relating to sources of noise.

It is important to note, however, that the present Directive does not set binding limit values, nor does it prescribe the measures to be included in the action plans thus leaving those issues at the discretion of the competent authorities.

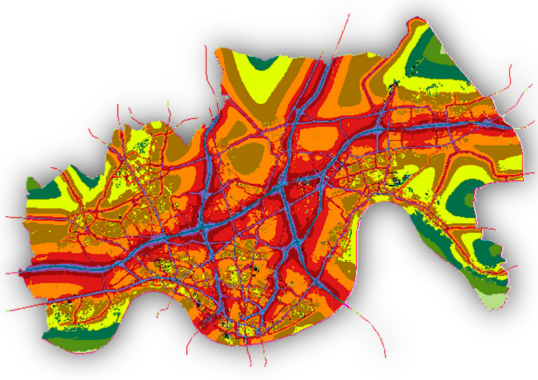
In line with its principal aims, the Environmental Noise Directive applies to noise to which humans are exposed, particularly in built-up areas, in public parks or other quiet areas in an agglomeration, in quiet areas in open country, near schools, hospitals and other noise-sensitive buildings and areas.

1.3.2 Situation in Serbia

Due to the developing economy in Serbia (5.6% in 2008, 7.1% in 2007, 5.6% in 2006) traffic intensities will increase significantly. This has led to unacceptable noise levels especially near highways. Traffic noise is, therefore, the most prominent source of environmental noise. More than 60% of the urban Serbian population is exposed to traffic noise levels that are considered to affect ones well-being seriously. About 25% is exposed to levels where health effects start to occur which was shown clearly by the Institute for Hygiene and Medical Ecology, Belgrade.

Noise measurements have been carried out in Belgrade since the 1970's. Recent measurements (Agency for Land and Building of Belgrade, 2003) showed that too high noise levels are found for more than 1.500.000 inhabitants in Belgrade, 100.000 in Kragujevac, and 25.000 in Paraćin. In that research the application of, amongst others, low-noise roads has been advised. Due to economy induced traffic increase in Serbia these numbers will be even higher in the near future.

According the European Environment and Health Committee Serbia there are problems relating to inadequate legislation and limit values regarding noise, inadequate monitoring of noise in urban areas, lack of spatial planning including noise zoning, improper location of industrial areas, lack of noise protection projects, insufficient control of noise emitted by motor vehicles, and improper traffic management.



The severity of traffic noise requires the large-scale introduction of low noise technology. Of the several technologies available to road authorities is the application of low noise surfaces which is not only the most cost-effective but also can be implemented on relative short notice. These advantages have led in the Netherlands to the development and application of several low noise surfaces. Low-noise road surfaces are considered to be among the most effective means of reducing traffic noise. The number of seriously annoyed people in Serbia will decrease in between 40% and 75%.

However, in Serbia knowledge on the development and application of low-noise roads is missing. Therefore, technologies and knowledge with respect to low-noise roads have to be developed. Existing experiences form the Netherlands have to be transformed with respect to local circumstances.

This will lead to a wide application of low-noise roads in Serbia for acceptable costs and with local people and equipment. Thus the negative environmental aspects of developing infrastructure will be reduced significantly and the noise will remain below acceptable levels according EU standards and Serbian standards for environmental protection (Sl.G.RS br. 66/91, 83/92, 53/93, 67/93, 48/94 and 53/95), Code book for Allowed Level of noise in Urban Environment (Sl.G.RS br.54/92) and ISO 2264, ISO 1996, ISO 140.

1.4 Results

The results of the project to achieve the project goal are:

1. Document with an overview of the current EU directives and Serbian legislation on noise control with any additional guidelines.
2. Symposium and working visits.
3. Final Document with guidelines for techniques, methods, standard, cost optimization and planning to reduce traffic noise.
4. Pilot of the proposed measures to reduce traffic noise are evaluated with a cost - benefit analysis.

1.5 Planning

There are three phases with the following components:

1. Inception phase
   - Compilation of existing EU directives and analysis of the Serbian laws and regulations in terms of traffic noise.
   - Processing of meetings of the Dutch Serbian Business Council
   - Processing of consulting stakeholders within the EVD
   - Processing information during incoming and outgoing missions
2. Main Implementation Phase
   - Developing guidelines.
   - Symposium
   - Working visit by Dutch experts
   - Working visit by Serbian experts
   - Consult experts within the team and project team
   - Case Study
3. Final Phase
   - Prepare final document
   - Concluding discussions with the EVD

This report deals with phase 2 and 3, developing Guidelines in the detailed design of low-noise pavements and noise barriers.

2 PROJECT HISTORY

The project started at the 10th of December 2009 with the Inception Phase. During the inception phase, there was intensive contact with the Serbian stakeholders and beneficiary. The following consultations have been held:

2010

- 22 and 23 February, Belgrade: Kick-off meeting. Present were: Đorđe Mitrovic, Bijlana Vuksanović, Ivan Andrić and Kristina Perić and their colleagues from the Serbian side and Wim van Keulen, Ron Westerveld, Ton Kneepkens and Aleksandar Stanković from the Dutch side.
- 12 and 25 May: consultation with the Dutch Serbian Business Council about the state of cases and seek assistance.
- 21 and July 22, Belgrade: consulting Bijlana Vuksanović, Ivan Andrić. Consultations with Nenad Mitošević the assistance of the Dutch embassy.
- 4 and 5 October: Ivan Andrić consultation with relevant agreements of 21 and 22 July.
- 13 October, Belgrade: meeting of Ron Westerveld, Ivan Andrić, Nenad Mitošević, Goran Korić and Zodax company concerning practical details regarding symposium.
- 16 and 19 November: consultation with managers of other G2G projects.
- 24 November: meeting of the Dutch Serbian Business Council.

2011

- 14 February: meeting of W. van Keulen and R. Westerveld about project progress.
- 22 February: meeting Wim van Keulen with EVD: Joost Groen and Hans van der Dool about stagnation of the project.
- 23 March, Belgrade: Meeting W. van Keulen and G. Korić about stagnation of the project.
- 27 April: meeting of the Dutch Serbian Business Council.
- 5 May, Belgrade: Meeting W. van Keulen and G. Korić about changed settings of the project.
- 14 June: meeting of W. van Keulen, R. Westerveld, and M. Duškov about current status of the project and existing bottle necks.
- 16 June, EVD: meeting of Milan Duškov with Joost Groen about necessary prolongation of the deadlines and related improvements/action plan for successful project progress.
- 28 June: meeting of W. van Keulen, R. Westerveld, and M. Duškov about new project planning
- 11 July: adaption of the project by the EVD.

- 3 August, Belgrade: meetings with project beneficiaries and stoke holders Biljana Vuksanović, Ivan Andrić, and others to discuss adapted project planning/action plan and prepare symposium
- 3 August, Belgrade: meeting with IN hotel about possibilities for symposium.
- 4 August, Belgrade: meeting at the embassy with Counsellor Tsjeard Hoekstra about participation of our ambassador in the scope of symposium.
- 18 August, Belgrade: meeting with IN hotel about symposium.
- 25 August and 4 October: meeting W. van Keulen and M. Goorden concerning technical details of noise barriers.
- 19 September, Belgrade, meeting at the embassy with Counsellor Dominique Kühling and Nenad Mitošević.
- 20 September, Belgrade: Symposium
- 18 October: meeting of W. van Keulen, R. Westerveld, T. Kneepkens, and M. Duškov concerning the programme for incoming mission of the Serbian delegation
- 31 October, 1 and 2 November: incoming mission with visit to the Serbian Embassy and the government of Limburg.
- 10 November: concluding discussion with EVD.
- 21 November: meeting with DCMR about interchanging technical experiences from this en their G2G project concerning noise mapping in Serbia.

Until October 2010 the progress of the project was very good. Then the progress stagnated. The main reason was uncertainty about the organisation of the symposium in combination with insufficient communication by email. After the intervention in May 2011 the project was running smoothly again. The symposium itself (see Ch. 3) and the incoming mission was a great success.

Positive aspects of this project are:

- Support from the Dutch Serbian Business Council.
- Corporation with other G2G project leaders.
- Corporation with and support from the Serbian beneficiaries and stakeholders.
- Collaboration with the Dutch Embassy in Belgrade and the Serbian Embassy in The Hague.
- Support in the second half of the project by the EVD.
- The practical organisation by IN Hotel and Omnibus company was near to perfect. Venue, PR material, interpreters, and catering were very good.
- The number of people and their participation levels were very high.
- The ambassador opened the symposium in Serbian
- The various contributions at the symposium were at a high level and strict within time limits.
- Vast interchange of various technical information.
- Great attention from the press.
- Interest from local Dutch governments in the project.

Negative aspects of this project are:

- During the first half of the project, communication to Serbia by email is in general quite problematic and time consuming (later it was improved significantly).
- Role of EVD is limited (also later improved significantly).
- Some additional obligatory tasks (expert VROM and accountant) with accompanying costs were not mentioned by the EVD.
- The presence of native speakers in the project team is essential. Without them organising events is very difficult.
- Long time schedule of two years.

3 SYMPOSIUM AND MISSION

3.1 Symposium “Reducing Traffic Noise in Serbia” in Belgrade

The symposium was held on the 20th of September 2011. The programme was as follows:

Symposium Programme		
09:15	Registration and coffee	
10:00	Welcoming note from the Embassy	H.E. Laurent L. Stokvis, Ambassador of the Kingdom of the Netherlands
10:10	Opening remarks (expectations, agenda)	Ms. Biljana Vuksanović, P.E. Roads of Serbia
	Traffic noise related problems - Chairman Dr. Milan Duškov, InfraDelft bv	
10:20	General introduction regarding Dutch situation and solutions	Mr. Ron Westerveld, Westerveld Advies bv
10:35	Current situation in Serbia	Ms. Biljana Vuksanović, P.E. Roads of Serbia
10:55	Relevant legal regulation in Serbia	Ms. Kristina Perić, Ministry of Environmental and Spatial Planning
11:15	Discussion	
11:35-11:50	Coffee break	
	Low-noise pavements - Chairwoman Ms. Biljana Vuksanović, P.E. Roads of Serbia	
11:50	Current experiences in Serbia	Mr. Ivan Andrić, Highway Institute
12:05	Acoustic aspects	Dr. Wim van Keulen, VANKEULEN advies bv
12:25	Technical aspects	Mr. Ton Kneepkens, Infra Quality Support bv
12:45	Discussion	
13:10-14:15	Lunch	
	Noise barriers - Chairman Mr. Ivan Andrić, Highway Institute	
14:15	Current experience in Serbia	Mr. Djordje Mitrović, Highway Institute
14:30	Technical aspects	Mr. Marco Goorden, G+H AKOESTIEK bv
14:50	Acoustic aspects	Dr. Wim van Keulen, VANKEULEN advies bv
15:10	Discussion	
15:30-17:00	Reception	

In the accompanying invitation it was pointed out that due to the developing economy in Serbia traffic intensities will increase significantly. This has led to unacceptable noise levels especially near highways. More than 60% of the urban Serbian population is exposed to traffic noise levels that seriously affect ones well-being.

Furthermore, it has been stressed that the severity of traffic noise requires the large-scale introduction of low-noise technology. Among these technologies is the application of low-noise surfaces and noise barriers (approximately 500 km along Dutch roads) which are not only the most cost-effective but also can be implemented on relative short notice. These advantages have led in the Netherlands to the development and application of several types of low-noise pavements and noise barriers. Large scale application of both effective low-noise pavements and noise barriers can reduce the number of seriously annoyed people in Serbia between 40% and 75%.

In the scope of the symposium existing experiences and proven technologies from the Netherlands are presented with respect to local circumstances. The public (including two formal state secretaries for infrastructure: Miodrag Jocić and Prof Aleksandar Cvetanović) was reminded that Dutch government financially supports this initiative aimed to stimulate wide application of proven low-noise pavements and noise barriers to be produced in Serbia for acceptable costs by local contractors. In this way the negative environmental aspects of developing infrastructure would be limited significantly and the noise levels would meet the Serbian and EU standards.

Figure 1: Opening speech by the Dutch ambassador.

In his opening speech the Dutch ambassador Laurent Stokvis underlined that Dutch National legislation already in 1979 opened the door for tackling this problem on a level stricter than the EU regulations of that date. It resulted in the fact that in 2001 there were some 450 km of noise barriers positioned next to the national roads in the Netherlands. Development plans includes construction of additional 20 km every year. So called "Quiet asphalt" surfaces are now deployed on over 3.000 km of road network in the Netherlands. Such Dutch experiences in this field can help Serbia get on the fast track for development of noise reduction infrastructure in traffic.

Serbia media shown great interest for the presented issues. A camera team made a camera crew was shooting a report on the symposium, an interview was recorded by a radio reporter and notes were published in some newspapers and on numerous websites.

Bole uši od buke

BEOGRAD - Srbija će u narednom periodu morati da smanji saobraćajnu buku, u skladu sa evropskom direktivom za tu oblast, rečeno je na skupu „Savremena rešenja za saobraćajnu buku u Srbiji". Više od 60 odsto stanovništva u urbanim sredinama u Srbiji izloženo je nivou saobraćajne buke koji se smatra štetnim, a može se smanjiti postavljanjem zaštitnih zidova i ugradnjom „tihog asfalta". Holandski ambasador Loren Stokvis kazao je da ta zemlja ima 3.000 kilometara „tihih" puteva. (E.K.)

Saobraćajna buka

Javno preduzoće „Putevi Srbije" i Institut za puteve organizuje danas u Beogradu simpozijum „Savremena rešenja za saobraćajnu buku u Srbiji", na kojem će biti predstavljena iskustva Holandije u toj oblasti. Procenjuje se da je više od 60 odsto gradskog stanovništva u Srbiji izloženo nivou saobraćajne buke koji se smatra štetnim, saopštili su organizatori. Rešavanje problema zahteva široku primenu tehnololoških rešenja za snižavanje nivoa saobraćajne buke. Od raspoloživih tehnologija za puteve, takozvani tihi kolovozi i zvučne barijere su ne samo najekonomičnije nego i mere koje se mogu realizovati u relativno kratkom roku. Ovakve prednosti su u Holandiji doprinele razvoju specifičnih asfaltnih mešavina za „tihe" kolovoze i efikasnih zvučnih barijera.

Figure 2: Notes in Serbian newspapers about the symposium.

Figure 3: The Dutch and (part of the) Serbian project

3.2 Incoming mission from Serbia

The incoming mission was held on the 31st of October, 1st and 2nd of November 2011. In accordance with the agreements on the first day of the mission a meeting was organised in Serbian embassy in The Hague open to all interested Dutch companies.

Due to recently realised interesting projects and an invitation of the government Limburg to share their experience with Serbian counter partners Limburg was chosen as mission major destination. Also the asphalt plant of a participating company is located in Roermond. Additional advantage was all kind of noise barriers along motorway A2 during driving to Maastricht. Our Serbian colleagues could see different noise barriers made from glass, wood, concrete, sheet piles and aluminium (pipes).

The programme for the visit at the government Limburg was as follows:

provincie limburg

Program Road Traffic Noise in Limburg

Datum	1-11-2011
Tijdstip	10.00 – 12.30
Locatie	Provinciehuis Maastricht - Maaszaal

10.00 – 10.15: Introduction
10.15 – 10.45: Road traffic noise (Anne de Vreeze):
- investigation 2006
- plan of action
- coöperation in Limburg
- 2012 and further

10.45 – 11.00: Discussion – short break

11.00 – 11.30: Road surface and noise improvement (Herman Dijk en Allard Geerlings)
- properties 'noice reducing thin layers'
- quality assurance
- maintenance and measurements
- the future of 'noice reducing thin layers'

11.30 – 11.45: Discussion

11.45 – 12.15: Tour through the Province House

12.15 - 12.30: Lunch

Government experts from Limburg gave an overview of their more than 10 years' experience with various noise-reducing asphalt top-layers. Besides technical also budgetary details about both construction and maintenance costs were presented. Present Serbian decision makers received the relevant reports which help them staring and managing implementation of efficient solutions for traffic noise related problems in Serbia. Even famous Limburg's cake was served.

Figure 4: Meeting at the Limburg government in Maastricht.

The visited construction with aluminium absorbing panels in Brunssum proved to be an excellent solution. At the street level 5 m far from the edge of the tunnel it was impossible to hear/count passing cars. Due to implemented aluminium absorbing panels, traffic noise is inaudible on the adjacent streets.

Figure 5: Visited construction with aluminium absorbing panels in Brunssum.

PART I: LOW-NOISE PAVEMENTS

4 CONDITIONS

4.1 General preconditions

Here follow some general preconditions that are important for the choice of low-noise pavements:

- Amount of irregular settings in the underground.
- Wanted looks of a road.
- reachability of underground infrastructure
- Requested noise reduction.
- traffic intensity and speed on the track
- balance between light and heavy traffic
- Amount of wringing traffic (crossings, exits, parking places, bus stops, loading areas, etc.).
- Available width of the lane.
- Presence of discontinuities (bridges, junctions, speed reducers, etc.).
- Presence of traffic lights.
- Extra costs of the road surface, initial and maintenance
- Technical possible (no turning traffic)
- Speed > 30 km/h
- Is the application efficient (enough adjacent houses)?

4.2 Specific preconditions

During the meetings, symposium and missions more specific boundaries were specified:

- No cracks or rutting in the asphalt layers under the top layer.
- The top layer cannot be put directly on a milled surface. An interface layer has to be applied.
- No hand work on parts that are loaded with traffic.
- No extra surface treatment with fine aggregate or sand.
- Minimum temperature during putting is 5°C.
- Fluent transitions from low noise pavement to the adjacent pavements.
- Reparation with a technique that keeps the noise reduction above intervention value (see also Ch. 5.3).

The above preconditions serve as a base for the functional demands in the contract with the contractor. The choice for a specific contractor is determined by a number of factors:

1. Contractor had to have experience with putting special mixtures.
2. Contractor has to show in front by durability tests in the laboratory or model calculations that his product is durable.

Applying these two demands in contracts will induce innovation by the contractors with respect to durability and sustainability.

5 NOISE REDUCTIONS

5.1 Initial state

The noise reduction has to be determined relative to a fixed standard road type. In Serbia this can be Dense Asphaltic Concrete (DAC) 0/8. This is very similar to the reverence in the Netherlands. However, the absolute emission levels from Dutch cars on the Dutch reference cannot be compared to Serbian cars on the Serbian reverence due to differences in the car and tyre population. Therefore, the reference in Serbia has to be determined numerically by noise measurements.

If noise mappings, action plans or legal demands play a role all vehicle types have to be taken into account in order to choose the right low-noise pavement. However, checking if the road surface meets its requirements only light vehicles have to be measured. It is known from various researches that the noise reductions of light and heavy vehicles are quite similar, at least in case of a Thin Layer. The emission of the different categories, however, is significantly different.

The above implies that in contracts only noise reductions for light vehicles are demanded, while in noise immision calculations all vehicles are incorporated.

In contracts noise reductions are expressed with no decimals (for example: 4 dB(A) at 100 km/h for light vehicles). De demanded noise reduction have to be met by the measurement results. Important aspect is that measurement uncertainty is not to be included in the analyses because the uncertainty is incorporated is the number of decimals in the demanded noise reduction.

The initial noise reduction has to be measured by the SPB method (see Ch. 6.4).

5.2 Testing

To test whether a surface meets the durability with respect to noise every 2 years a CPX measurement (see CH. 6.3) has to be performed.

The requested noise reductions during the monitor period have to be expressed absolutely. Stating a loss reduction on base on the initial results would lead to unclear and not unique criteria:

1. The initial measurement has a measurement uncertainty. If the next measurements are related to the initial one, the measurement uncertainty will be doubled.
2. The intervention value (see next chapter) would be not unique. If the initial results are very positive the intervention value is too strict and vice versa.

5.3 Intervention value

The intervention value is defined as the value at which the road surface is disapproved. This value is equal to the initial value minus 2,0 dB(A). In this case one decimal has to be used (for example: 2,0 dB(A) at 100 km/h for light vehicles).

In the contacts have to be included that if the intervention value is not met, then the contactor has to apply measures (see also Ch. 4.2) in order that the noise reduction is again above the intervention value.

6 MEASUREMENT METHODS

Noise measurements must be performed in a consistent manner, so that the impact of external factors such as propagation effects and background noise are sufficiently suppressed. At the same time, measurement conditions need to be representative for ‘normal’ situations for both road surfacings and microphone positions simulating the environmental noise levels**.**

For all measurements it is essential to log all environmental data such as air and surface temperatures. In the literature there is an on-going discussion on the influence of temperature. Various large scale tests do not correlate in this aspect.

The most frequently used measurement techniques to determine the characteristics of road surfacings are:

- Texture measurements (only partial characterization)
- Porosity and/or sound absorption measurements
- Close proximity method (CPX)
- Statistical Pass-by method (SPB)
- Psychoacoustic assessment of recorded (or *in-situ*) noise

6.1 Texture measurements

The texture of a road surface has major influence on the tyre/road noise of vehicles on the road. In particular texture with wavelengths between 5 mm and 200 mm is important for the emission of sound due to tyre/road contact. Texture with these wavelengths is characterised as micro/macro to macro/mega texture.

The texture of a road surface is measured by scanning the road surface with a laser distance sensor. This laser can be either mounted on a vehicle or in stationary measurement set-up.

Analysis of measured texture profiles consists of calculating the texture parameters MPD, ETD, and RMS and calculating the spectrum by means of a Fast Fourier Transform.

For porous road surfacings, the measured texture profile does not directly provide useful information on the sound emission due to tyre/road contact. This is caused by the fact that the tyres of a vehicle do not make contact with the deep holes in the porous road surface. This effect can be accounted for by appropriate pre or post processing.

The texture of the test tracks should be measured with a vehicle mounted laser over a length of about 20 m around the microphone position in both the wheel tracks.

6.2 Porosity and Absorption Measurements

Sound absorption is an important acoustical property of (semi) porous road surfacings. To assess, evaluate and optimise the sound absorption properties of road surfacings, it is necessary to perform sound absorption measurements. These measurements can be performed in situ according ISO 13472-1[1] or with bore cores in the laboratory according ISO 10534-1[2]. A better method is by using a PU probe which can be applied in laboratory as well as *in situ*.

Figure 6: Acoustical impedance measurement on field and on bore cores

The result of the measurements is the sound absorption as a function of the frequency. The frequency at which the first maximum in sound absorption occurs indicates the effective thickness of the road surface. The height of this maximum indicates the amount of accessible air cavities.

Clogging (pollution) of porous road surfacings has serious consequences for the sound absorption properties of the road surfacings and possibly for the achieved reduction of traffic noise. Sound absorption measurements enable assessment of clogging of porous road surfacings.

The flow resistivity measured only of the open surfacings will allow additional insight into the material properties.

6.3 Close Proximity method (CPX)

For CPX measurements according ISO/CD 11819-2[3], special vehicles and near-field microphones are used. The measurements are performed with microphones close to the test tyres on a special testing vehicle.

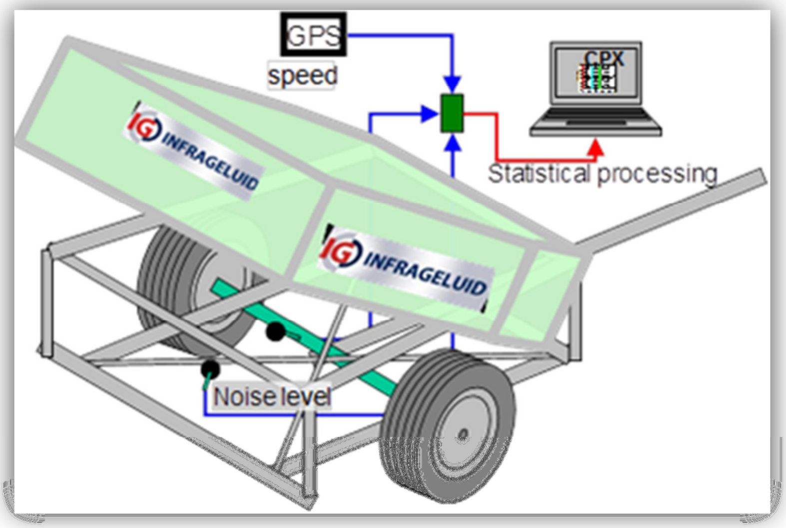


Figure 7: Measurement set-up of the CPX-method.

This vehicle will be driven across a designated or arbitrary part of the road. The obtained measurement results are normalised to the nominal speed that belongs to the road category. Generally speaking, the CPX method is a measurement procedure specifically designed to assess the influence of the road surfacing properties on vehicle and traffic noise. This can be done on distinct sections of the road surface. The conditions for the measurement are such that tyre/road noise is dominant over propulsion noise. The CPX method gives a good estimate of the acoustic quality of the road surfacings. The method can be used to study the homogeneity of the road surfacing over a long distance and under a variety of conditions.

6.4 Statistical Pass-by method (SPB)

The SPB method according ISO 11819-1[4] consists of the measurement of the emitted noise of vehicles in the vehicle fleet. It is used merely to determine the road surfacing influence on the noise emission of road traffic. This is a standardised measuring method in which the microphone is placed at 7,5 m from the centre of the driving lane. The standardised microphone height is 1,2 m. The advantage in practice of a microphone height of 5,0 m is the exclusion of unwanted propagation effects effectively.

Measurements pointed out that a microphone height of 5,0 m represents noise emission of all vehicle types as well the standard microphone height of 1,2 m does. Therefore, according to the Dutch standard the microphone height is fixed at 5,0 m. In Harmonoise a microphone height of 3,5 m has been chosen.

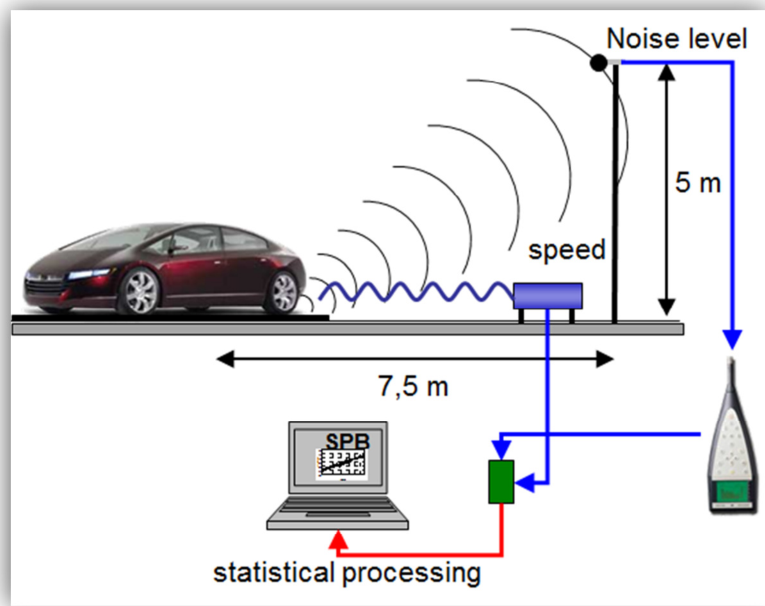


Figure 8: Measurement set-up of the SPB-method.

Of every passing vehicle the maximum A-weighted sound level and the vehicle speed are registered simultaneously. The results are processed in a scatter diagram in which the maximum sound level is depicted as a function of the logarithm of the speed. A best-fitting linear function follows from this scatter diagram. At a reference speed of 70 km/h for truck tyres and 80 km/h for passenger-car tyres the level is observed from the linear function. SPB measurements are taking the overall noise emission into account including propulsion noise.

6.5 Psychoacoustics

A major concern with the introduction of measures to control traffic noise is the perception of the effect by the public. The quantification of these perceived benefits is essential to conducting a meaning cost-benefit analysis. Several studies have shown that the long term relation between average noise exposure and annoyance does not properly describe reactions to traffic management or other noise reduction measures. The simple dose response relationship between traffic noise and annoyance cannot be applied to the perception of noise reduction measures. Important issue of the correct interpretation of the various measurement data, therefore, is the involvement of psychoacoustics. Due to psychoacoustics a better description of traffic noise can be deduced that correlates better with the subjective impression of people who perceive traffic noise daily. New and better measures based on advanced insights from room acoustics have been derived. The possibilities which offer those insights have to be evaluated further.

6.6 Skid resistance

Since road surfacing types are to be applied under normal circumstances, other requirements play a role as well. One of the most important requirements for a road surfacing is its skid resistance. This resistance can be measured locally by either a SRT or pendulum system.

Over a longer distance the skid resistance can be measured with a special purpose trailer. In this trailer the measurement wheel has been mounted. The speed of this measurement wheel is 86% of the two supporting wheels. The loading of the measurement wheel has been standardised to 1.962 N.

7 STANDARD MIXTURE

7.1 General

The design of the low-noise pavement for low and high speeds differ significantly. This difference is caused by a number of mechanisms that play a role (the small pictures illuminate the mechanism):

- Tyre induced vibrations. 
- Absorption: this effect is minimal since the porosity of the standard is much lower than that of porous asphalt. 
- Air pumping: this effect is largely influenced by the porosity.
- Horn effect: this effect is largely influenced by the porosity. 

The balance of the respective contributions depends largely on the speed. At low speeds the effect that are related to porosity is relatively smaller than at high speeds, this holds especially for air pumping.

Furthermore, the porosity has a negative influence on durability as can be seen in figure 1.

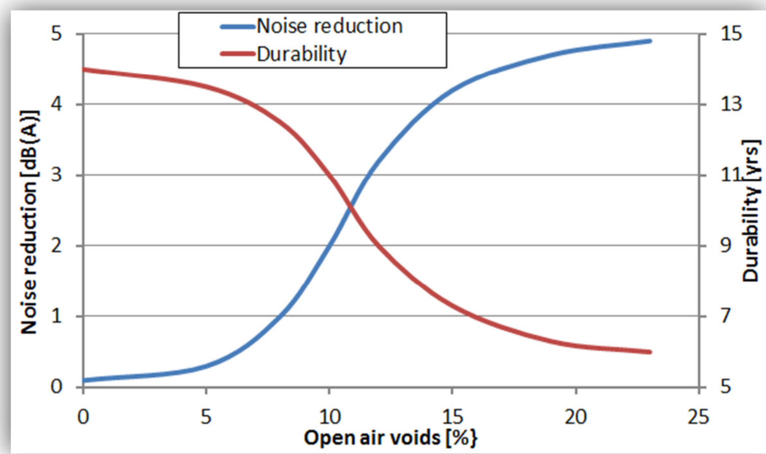


Figure 1: Noise reduction and durability as function of porosity.

The porosity has, therefore, to be as low as possible. The corresponding negative effects on the noise reduction have to be compensated for by choosing a optimal texture. And texture is highly negative correlated to the maximum aggregate size.

Figure 2: Ravelling probably due to too high porosity.

7.2 Mixture for low speeds

Based on the latest theory and practical experience, the following standard construction for low speeds has been designed:

- Gradation: 0/4 gap-graded
- Layer thickness: 25 mm
- Bitumen: high modified SBS, 7%
- Porosity: 9%
- High PSV
- Flakiness: < 10%

7.3 Mixture for high speeds

- Gradation: 0/8, gap-graded
- Layer thickness: 40 mm
- Bitumen: high modified SBS, 7%
- Porosity: 14%
- High PSV
- Flakiness: < 15%

PART II: NOISE BARRIERS

8 DESIGN

8.1 General

The following are some of the points which should be considered when the design is checked:

1. The intensity for wind load and calculations for acoustic performance.
2. The quality of the materials proposed to be incorporated in the barrier, particularly those, if any, that are not included in the Material Specifications.
3. That the structural grades of materials used are in accordance with those quoted in the calculations.
4. The supply, transportation and storage of noise barrier materials. Workmanship, particularly any pre-installation treatment required and the method of fixing.
5. That the acoustic properties are maintained by the avoidance of gaps, including gaps due to shrinkage or thermal movement.
6. Easy replacement of parts following accidental or wilful damage.
7. Security of components and nature of materials used to discourage wilful damage.
8. Maintenance access is provided at appropriate location.

Noise barriers achieve their effect by interrupting or blocking the direct path between the sound source and the receiver. The barrier may also reflect the noise. This will increase the noise for the people living on the opposite side of a road up to 6 dB when there are reflecting surfaces on both sides of a road. Therefore, noise barriers have to be absorptive.

8.2 Technical demands

8.2.1 Aluminium

The noise barrier has to be built from self-supporting elements. These can be stacked easily in between steel posts (HEA160).

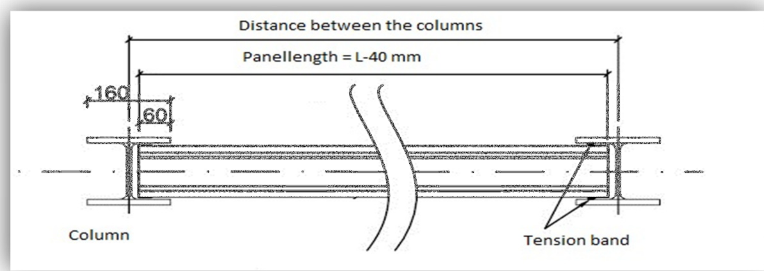
The elements exist of special profiles that are provided with a profiled aluminium plate at the outside and a perforated profiled aluminium plate at the inside of the panel. The dimensions of these perforations are: 5 mm diameter and 8 mm distance between centrelines.

The aluminium plate can be ALMN1MG0, 5H26, Stucco.

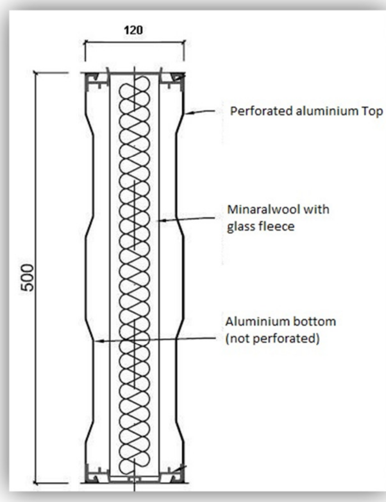
In between the aluminium plates has to be a water resistant, fire proof, and noise absorbing material like rock wool. De mineral wool has to have ventilation of minimal 20 mm at both sides.

The characteristics of this wool are:

- Rockwool, 60 mm, 100 kg/m³
- black covering fleece
- fire proof according DIN 4102, class A1.
- Length specific flow resistance: AF > 50.



The connection of the panels to the steel posts has to be a click system. The drainage of rainwater requires drainage channels at the ends of the panels. In order to seal properly the elements and the steel posts rubber strips have to be placed on the panels. The rubber has to be 60 ± 5, Shore A.



The barrier shall be constructed to the line and grades specified with the tolerance of ±10 mm. The post shall be plumb within a tolerance of ±10 mm in 5 m.

Sound "leaks", due to holes, slits, cracks, or gaps through or beneath a noise barrier should be avoided. Efforts should be spent at design and construction stages to avoid holes, slits or gaps, either with the adjoining panels, along the bottom edge or gaps for road traffic signs, lighting poles, fire hydrants, construction joints or expansion joints.

In figure 3 a schematic representation can be seen of an example of a noise barrier which is based on panels like the ones described above.

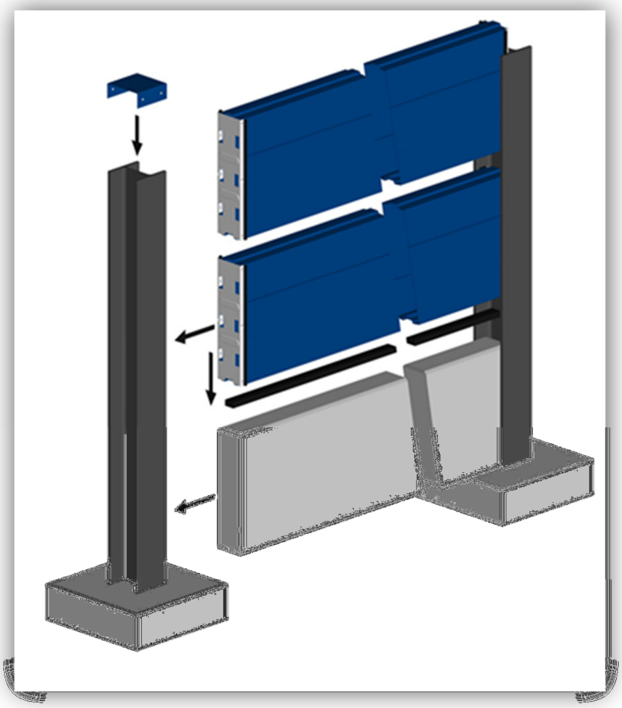


Figure 3: Schematic representation of a barrier made from panels.

8.2.2 *Concrete*

For noise barriers made of concrete, the planks must be tongue-and-grooved, carefully lapped, or extremely well butted, to ensure a good air seal at joints. "Alternating boards", planks mounted on alternate sides of horizontal supports, should not be used.

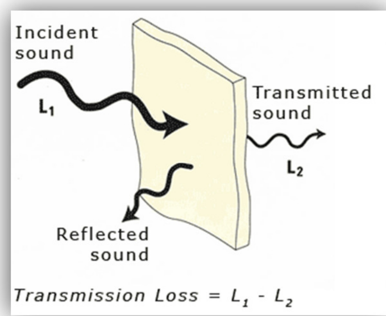
The widths of dilation slits should not exceed 50 mm. This will lead to a reduction of the TL of about 1 dB(A) at 5 m distance. The height of the water disposal slit should not exceed 10 cm.

The open structure of absorptive concrete will pollute during the time. Also weathering will diminish the abortive characteristics significantly. It is fairly impossible to prevent this or to clean these barriers. This implies that the porous structure has to be shielded by a protective plate to insure that the absorption will stay intact.

8.3 Acoustical demands

8.3.1 *Transmission loss*

For acoustical purposes, any material may be used for a barrier between a noise source and a noise receiver as long as it has a Transmission Loss (TL).of



at least 10 dB(A) greater than the desired noise reduction (i.e. Insertion Loss (IL). This ensures that the only noise path to be considered in the acoustical design of a noise barrier is the diffracted noise path, i.e. the path over (or around) the barrier.

The TL of a continuous barrier should be 25 dB or higher according ISO 1793-2. A material surface density of 10 kg/m^2 is typically sufficient for low barriers (< 2 m) and 17 kg/m^2 for higher barriers. The TL should be measured according ISO 1793-2 in a reverberation chamber. However, if the material surface density is 40 kg/m^2 or higher, no measurements are necessary. The TL of the emergency doors should not be more than 5 dB(A) lower than the TL of the barrier.

The TL can be measured in situ according the next measurement set-up in figure 4.

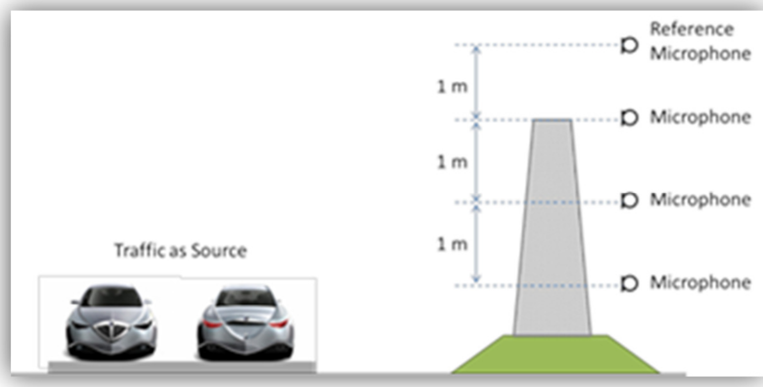


Figure 4: Measurement setup for determine the TL in situ.

The TL is the difference of the levels form a microphone relative to the level of the reference microphone.

8.3.2 *Absorption*

The (weighted) absorption coefficients have to be better than 0,8 at frequencies which are significant in the traffic noise spectrum. In general, the peak traffic noise frequencies lie between 500 – 1.500 Hz. The absorption has to be determined according ISO 1793-1 in a reverberation chamber[9].

The absorption should be 13 dB or higher according ISO 1793-1.

The absorption can be measured *in situ* according the same set-up as for low noise pavements (see Ch. 6.2).

9 INSTALLATION AND CONSTRUCTION

9.1 Footing

The footing shall be founded on undisturbed soil at the design embedment length as required but shall be minimal below freezing depth of the area. The founding surface shall be confirmed by a Geotechnical Engineer. All the soft spots to be removed and bottom of the footing protected from freezing. In case of solid rock encountered at a depth less than the freezing depth, foundation shall be carried minimum 300 mm in the rock. The concrete of footing shall be as follows:

- Minimum 28 days compressive strength to be 20 MPa.
- All site placed concrete to be protected from freezing and to be protected in excessive summer temperature from drying.
- The concrete in the footing shall be cured for a minimum period of 5 days before the installation of panels.

9.1.1 Footing in Earth

If drilled footing is used, it shall be cast entirely against undisturbed soil. Footing other than drilled caisson to be formed and the excavation shall be backfilled with granular material. The backfilled material to be compacted to 98% of the granular material.

9.1.2 Footing in Rock

When rock is encountered with in the excavation depth of the footing, the footing depth to be embedded minimum 300 mm into the solid rock.

All excavation into rock shall be back filled entirely with concrete. The excavation above the top of rock may be formed to the required dimensions and the remainder of the excavation backfilled with granular materials.

9.2 Access

Gates or gaps should be provided at about 200 m intervals to provide access for the maintenance of both the noise barrier and any planting behind the noise barrier. Where possible these access points should be located to provide access to any traffic control and communications equipment.

Where access point is to be provided for pedestrian but doors are not practical, then, another section of parallel barrier should be provided in front of the access point to avoid degrading of the acoustic performance. One face of this barrier should be provided with absorptive materials to avoid multiple reflections between parallel barriers. The length of this additional barrier should be at least several times of the width of the gap/opening (3 – 4 times).

PART 3: IMPLEMENTATION GUIDELINES

10 PILOTS

10.1 Noise maps

The noise levels over an area will be varying all the time. For example, noise levels may rise as a vehicle approaches, and reduce again after it has passed. This would cause a short-term variations in noise level. In the slightly longer term, noise levels may be higher in peak periods when the roads are busy, and lower in off-peak periods. Then again, there is a greater volume of activity from more people and traffic in the day-time than in the evening or at night. In the longer term, wind, weather and season all affect noise levels.

This means that it is not possible to say with confidence what the noise level will be at any particular point at any instant in time, but where the noise sources are well-defined, such as road or rail traffic, or aircraft, then it is possible to say with some confidence what the long-term average noise level will be.

It may be thought that the best way of doing this is by measurement, but experience shows that this is not the case. For a start, a long-term average must be measured over a long period of time. Secondly, to obtain complete coverage of an area, measurements would have to be made on private property, where access might be difficult, and thirdly, measurements cannot distinguish the different sources of noise, so they would not be able to give information on how much noise was being made by each of the sources in an area.

For these and other reasons, noise mapping is usually done by calculation based on a computerised noise model of an area, although measurements may be appropriate in some cases.

A further benefit of having a noise model is that it can be used to assess the effects of transportation and other plans. Thus the effect of a proposed new road can be assessed and suitable noise mitigation can be designed to minimise its impact. This is particularly important in noise action planning, where a cost-benefit analysis of various options can be tested before a decision is made.

Noise maps produced for the Environmental Noise Directive represent the annual average noise levels at a height of 4 metres above the local ground level. The Environmental Noise Directive requires noise levels to be assessed in terms of Lden and Lnight.

Lden is the equivalent continuous noise level over a whole 24-hour period, but with noise in the evening (19:00 to 23:00) increased by 5 dB(A) and noise at night (23:00 to 07:00) increased by 10 dB(A) to reflect the greater noise-sensitivity of people at those times.

Lnight is the equivalent continuous noise level over the night-time period (23:00 to 07:00). Lnight does not contain any night-time noise weighting.

A Noise Map is a map of an area which is coloured according to the noise levels in the area. Sometimes, the noise levels may be shown by contour lines which show the boundaries between different noise levels in an area. There are several models for making noise maps. Most of the models are based in the physics of propagation of sound outdoors (defined in ISO 9613). The use of these software packages is quite easy, and the accuracy of results is very high depending on the quality of input data to the models. For road traffic noise, the description of the sources is usually made in terms of easy to know parameters, such as speed, number of vehicles etc.

At this moment, another G2G project deals with this special aspect. Some typical results from that G2G are presented here. The guidelines that are developed in this G2G project will be used in the pilot of the other G2G project.

In the next figure an example that also has been shown at the symposium can be seen.

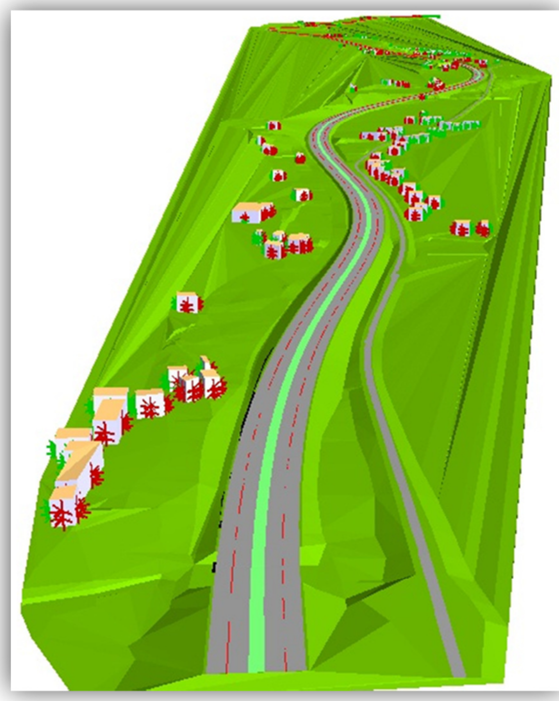


Figure 5: Example of a 3D modelling of a road, its surroundings, and the receivers.

With such a model the immision at various receiver points or the noise contours can be determined. In the next figure an example can be seen.

Figure 6: noise contour lines of a case in Serbia.

Based on these studies the height of a barrier can be determined in order to obtain the required immision levels. In Serbia a limited number of noise barriers have been built.

Figure 7: Noise barrier in Serbia.

10.2 Combination low-noise pavement and noise barrier

In these guidelines the reducing effect of pavements and barriers can be determined simultaneously. The actual noise reduction of a barrier depends on the geometry of source-barrier-receiver. Therefore, a barrier does not have a fixed noise reduction. However, the effect of barriers can be combined with that of low-noise pavements.

If a low noise pavement is applied then obviously the noise barrier can be lower. In most software packages for calculated noise levels this is not a standard feature. VANKEULEN advies developed a tool (BARDODAN) in which the acoustical properties of low-noise pavement and barriers can be interchanged easily and reversely. In the pilot this tool has been applied. In table 1 the results are presented.

Table 1: The barrier height as function of the noise reduction [dB(A)] of the pavement

noise reduction pavement	barrier height [m]			
	2	3	4	5
0	2,0	3,0	4,0	5,0
1	1,7	2,6	3,4	4,3
2	1,4	2,2	3,0	3,8
3	1,2	1,9	2,5	3,2
4	1,0	1,6	2,2	2,8
5	1,0	1,3	1,8	2,4

The data from table 1 can be approximated quite accurately by:

$$H_{barrier,new} = 0{,}84 - 0{,}37 \cdot NR_{road} + 0{,}73 \cdot H_{barrier,original}$$

With the above formula the total costs can be calculated for all barrier heights and the combination of low-noise pavement and barrier can be found. In the next example the optimum lies at a reduction of 4 dB(A).

10.3 Case I

10.3.1 Location

Next to the E75 from 30 km from Belgrade at the Vrčin conjunction a noise barrier has been planned.

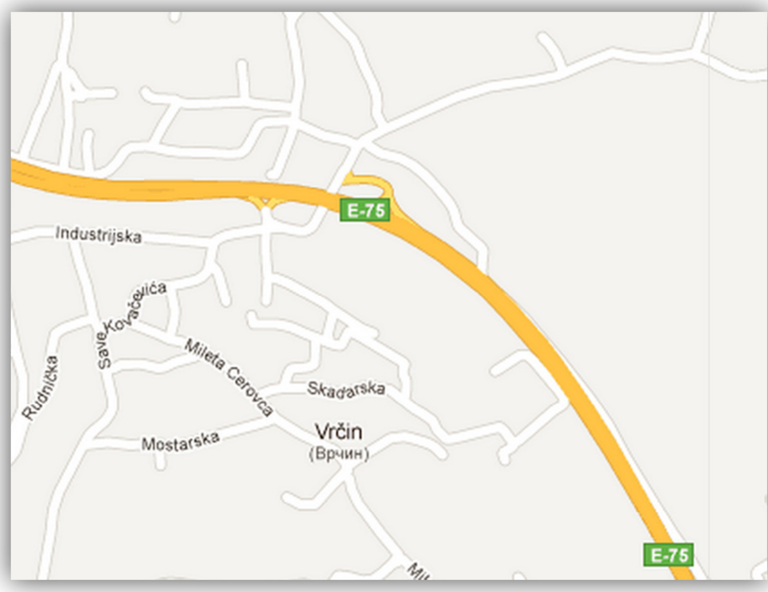


Figure 8: Location of the noise barrier near Vrčin

10.3.2 Barrier

The total length of the barrier is 1.136 m and the height is 6,5 – 7,0 m. In figure 9 a schematic representation of a part of the barrier can be seen.

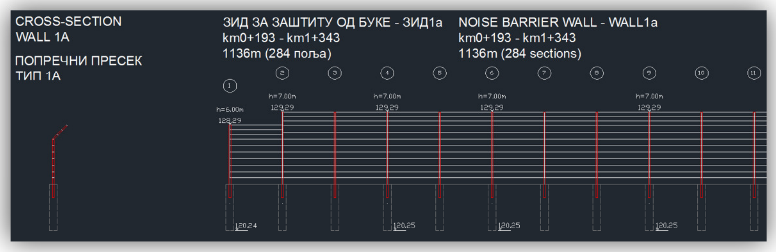


Figure 9: Lay-out of the noise barrier.

10.3.3 Civil engineering aspects

All excavation into rock shall be back filled entirely with concrete. The excavation above the top of rock may be formed to the required dimensions and the remainder of the excavation backfilled with granular materials.

10.3.4 Acoustical aspects

Because the road section has doubled sided dwellings the barrier has to be absorptive according Ch. 8.2.1. The excavation depth of the footing, the footing depth to be embedded minimum 300 mm into the solid rock according Ch. 9.1.2.

With the theory from Ch. 10.2 the effect on the height of the noise barrier as function of the noise reduction of the pavement can be calculated. The results can be seen in figure 10.

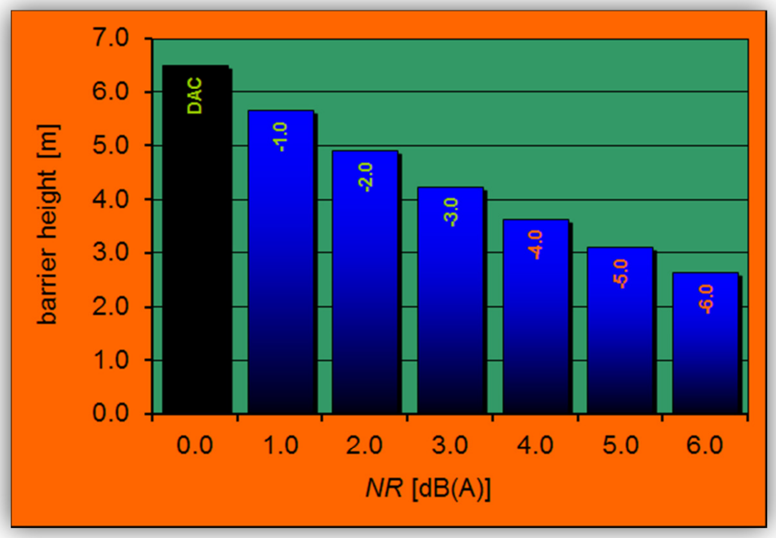


Figure 10: The height of the noise barrier.as function of the noise reduction (NR) of the surface.

From figure 10 it can be seen that applied a noise-reducing pavement with a noise reduction of 4 dB(A) the height of the barrier can be almost 3 m lower. This 4 dB(A) corresponds to the noise reduction of the standard noise reducing road type according Ch. 7.3.

10.3.5 Costs

If the (extra) costs of a low-noise pavement (for example 10 €/m^2) and the barrier (for example 250 € /m^2) are known, it is possible to calculate to total costs as function of the noise reduction of the low-noise pavements. The results for this pilot can be seen in figure 11.

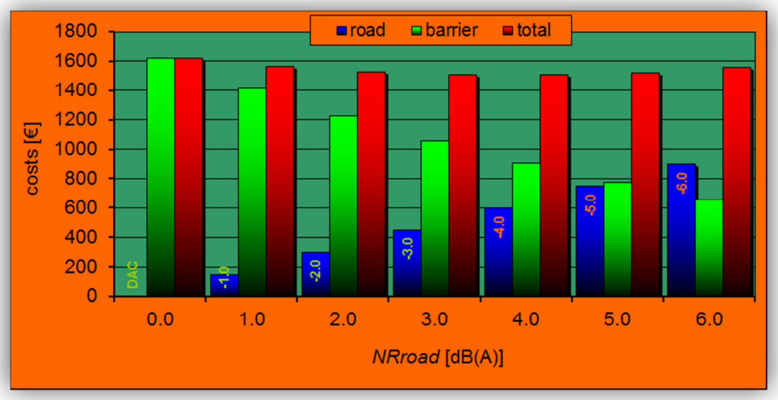


Figure 11: Costs of low-noise pavements and barriers.

From figure 11 it follows that with these assumptions the optimal noise reduction of the pavement is about 3 dB(A).

One should bear in mind that the results depend largely on the applied cost functions.

10.4 Case II

10.4.1 Location

Next to the E763 near Belgrade, km 56 + 809.13 – km 57 + 027.15, right side, a noise barrier has been planned. Only acoustical aspects will be considered here.

10.4.2 Barrier

The total length of the barrier is 216 m and the height is 4,5 m. In figure 12 a schematic representation of a part of the barrier can be seen.

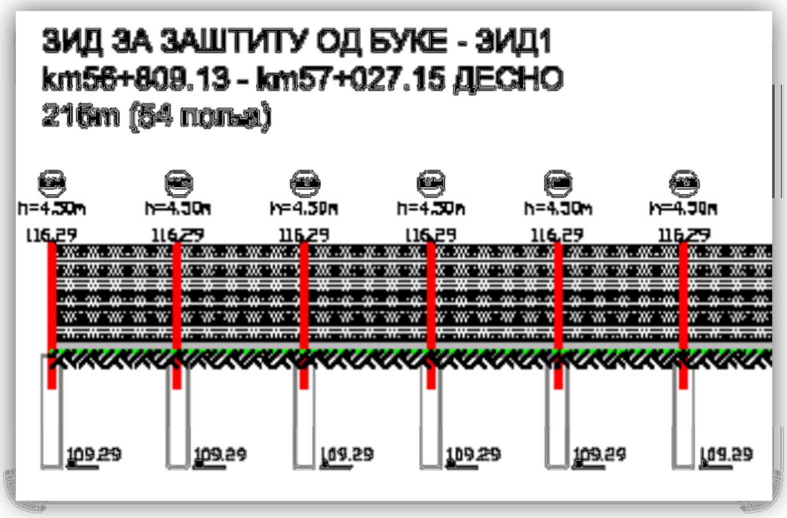


Figure 12: Lay-out of the noise barrier.

10.4.3 Acoustical aspects

Because the road section has doubled sided dwellings the barrier has to be absorptive according Ch. 8.2.1. The excavation depth of the footing, the footing depth to be embedded minimum 300 mm into the solid rock according Ch. 9.1.2.

With the theory from Ch. 10.2 the effect on the height of the noise barrier as function of the noise reduction of the pavement can be calculated. The results can be seen in figure 13.

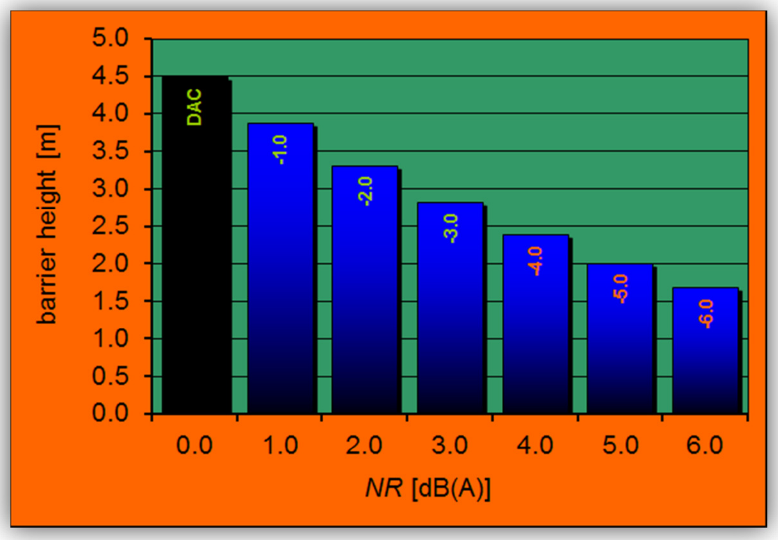


Figure 13: The height of the noise barrier.as function of the noise reduction (NR) of the surface.

From figure 13 it can be seen that applied a noise-reducing pavement with a noise reduction of 4 dB(A) the height of the barrier can be approximately 2 m lower.

10.4.4 Costs

If the (extra) costs of a low-noise pavement (for example 10 €/m^2) and the barrier (for example 250 € /m^2) are known, it is possible to calculate to total costs as function of the noise reduction of the low-noise pavements. The results for this pilot can be seen in figure 14.

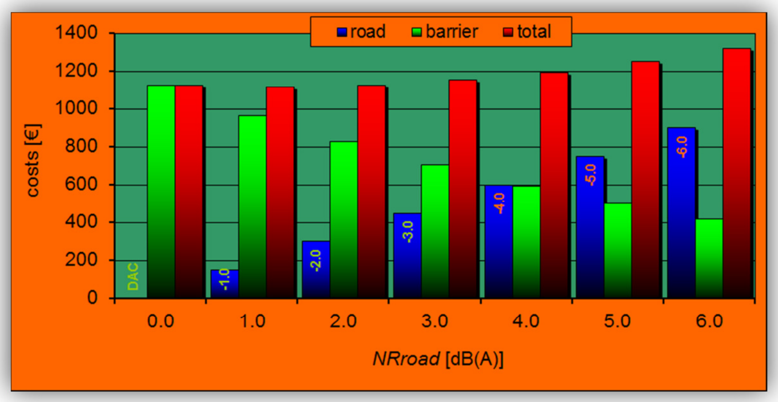


Figure 14: Costs of low-noise pavements and barriers.

From figure 14 it follows that with these assumptions the optimal noise reduction of the pavement is about 1 dB(A). In this case the application of SMA and a 50 cm lower noise barrier would be optimal with respect to costs.

Again, one should bear in mind that the results depend largely on the applied cost functions.

11 REFERENCES

[1] Directive 2002/49/EC, relating to the assessment and management of environmental noise, 25 June 2002.

[2] SRPS EN 1793-1, Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 1: Intrinsic characteristics of sound absorption, 1 September 1997

[3] SRPS EN 1793-2, Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 2: Intrinsic characteristics of airborne sound insulation, 1 September 1997

[4] Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 3: Normalized traffic noise spectrum, 1 September 1997

[1] ISO 13472-1, "Measurement of sound absorption properties of road surfacings in situ – Part 1: Extended surface method", 2002;

[2] ISO 10534-1, "Determination of sound absorption coefficient and impedance in impedance tubes – Part 1: Method using standing wave ratio", 1996;

[3] ISO/CD-11819-2, "Method for measuring the influence of road surfacings on traffic noise - Part 2: 'The Close Proximity method'";

[4] ISO 11819-1, "Method for measuring the influence of road surfacings on traffic noise - Part 1: 'The Statistical Pass-by method'";

[5] Guidance Manual for the Implementation of Low-Noise Road Surfaces, FEHRL Report 2006/02, 2006

[6] W. van Keulen en J. Schuddeboom, On the numerical effects of replacing silent roadtypes by non-silent roadtypes on roundabouts" 13[de] International Congress on Sound and Vibrations, Wenen 2006

[7] Method for measuring the influence of road surfaces on traffic noise - part 2: 'The Close Proximity method', ISO/CD-11819-2

[8] Method for measuring the influence of road surfaces on traffic noise - part 1: 'The Statistical Pass-by method', ISO 11819-1

[9] ISO 354, Acoustics -- Measurement of sound absorption in a reverberation room2003

12 LIST OF RELEVANT STANDARDS

- SRPS ISO 1996-1:2010 identical to ISO 1996-1:2003 ISO/TC 43/SC1

  Acoustics - Description, measurement and assessment of environmental noise - Part 1: Basic quantities and procedures

- SRPS ISO 1996-2:2010 identical to ISO 1996-2:2007 ISO/TC 43/SC1

  Acoustics - Description, measurement and assessment of environmental noise - Part 2: Determination of environmental noise level

- SRPS EN 14388:2008 (en) identical to EN 14388:2005

  Road traffic noise reducing devices – Specifications

- SRPS EN 14388:2008/AC:2011 (en) identical to EN 14388:2005/AC:2008 CEN/TC 226

  Road traffic noise reducing devices – Specifications

- SRPS EN 14389-1:2011 (en) identical to EN 14389-1:2007 CEN/TC 226

  Road traffic noise reducing devices – Procedures for assessing long term performance – Part 1: Acoustical characteristics

- SRPS EN 14389-2:2008 (en) identical to EN 14389-2:2004

  Road traffic noise reducing devices – Procedures for assessing long term performance – Part 2: Non-acoustical characteristics

- SRPS EN 1793-3:2008 (en) identical to EN 1793-3:1997

  Road traffic noise reducing devices – Test method for determining the acoustic performance – Part 3:Normalized traffic noise spectrum

- SRPS CEN/TS 1793-4:2008 (en) identical to CEN/TS 1793-4:2003

  Road traffic noise reducing devices – Test method for determining the acoustic performance – Part 4:Intrinsic characteristics – In situ values of sound diffraction

- SRPS CEN/TS 1793-5:2008 (en) identical to CEN/TS 1793-5:2003

  Road traffic noise reducing devices – Test method for determining the acoustic performance – Part 5: Intrinsic characteristics – In situ values of sound reflection and airborne sound insulation

- SRPS EN 1794-1:2008 (en) identical to EN 1794-1:2003

  Road traffic noise reducing devices – Non-acoustical characteristics – Part 1: Mechanical performance and stability requirements

- SRPS EN 1794-2:2008 (en) identical to EN 1794-2:2003

Road traffic noise reducing devices – Non-acoustical characteristics
– Part 2:General safety and environmental requirements