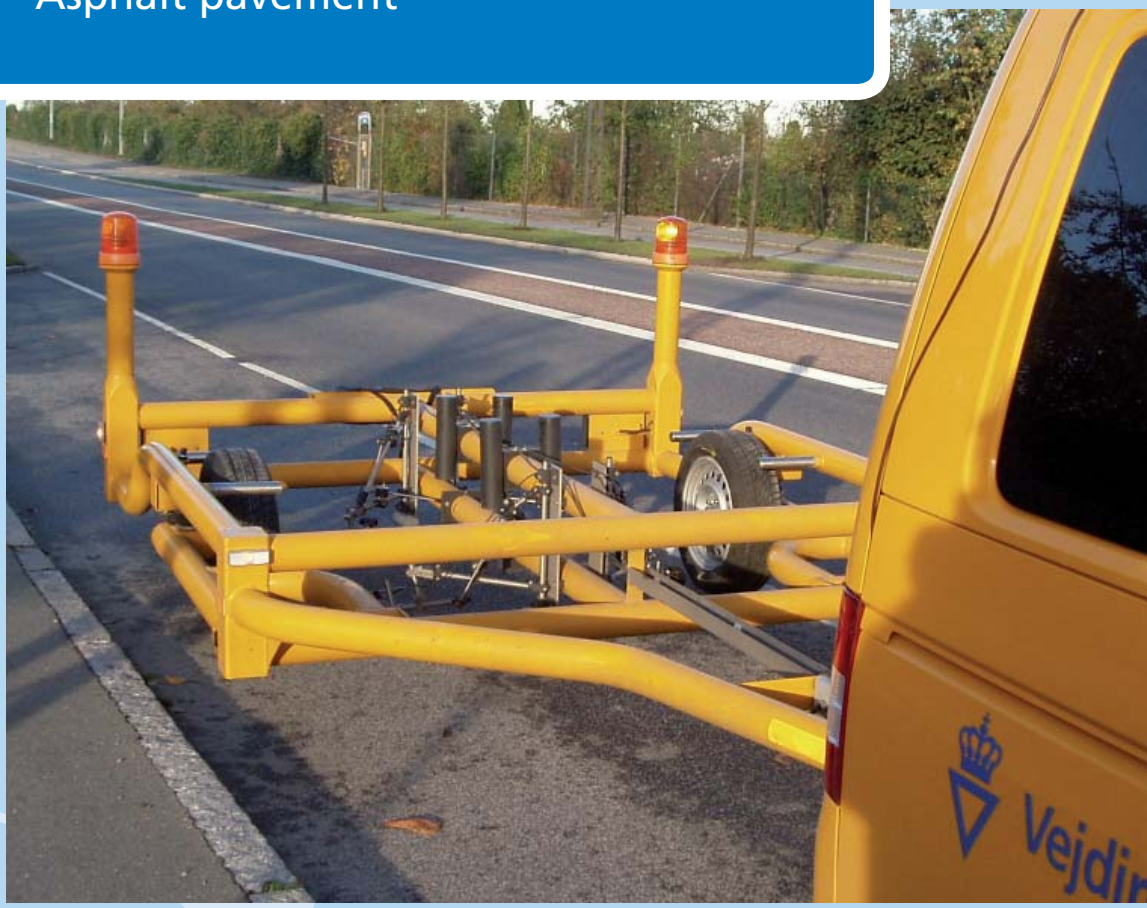
Noise Classification

- Asphalt pavement



Danish Road Institute
Technical note 61
2007

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Ministry of Transport and Energy

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Contents

Preface

In the modern world noise has a great impact on the human environment. Road traffic noise represents a significant part of the total noise level. Noise abatement using traditional means such as noise barriers, walls or speed regulation is often the solution chosen. However, using asphalt surfacings exhibiting noise reducing properties represents an efficient measure for noise abatement that can be used either alone or in combination with other measures.

Until recently asphalt surfacings with noise reducing properties have been used on a trial basis only. However, there is growing interest to use these asphalt surfacings on a wide scale. With the objective to work out procedures and documentation for contracting asphalt surfacings with noise reducing properties, a task group has been established under the Danish Road Directorate (DRD) as an ad hoc group to Road Specification Working Group U.21: "Asphalt Works". In the following the task group is named the SRS group.

The SRS group got the task to work out a proposal for a 1st generation system for the specification and documentation of asphalt surfacings exhibiting noise reducing properties. It is presupposed that the system should be able to ensure consistent measurement, evaluation and documentation of the noise reducing properties of individual asphalt surfacings.

The SRS group initiated its work February 17th 2006 and finalised its proposal in the fall of that year. The proposal is presented in this report. The SRS group has in its work used experience obtained from Danish trial sections and noise measurement programs and used experience obtained from international investigations, first of all from the Netherlands and from the SILVIA program.

The SRS group has representation from road authorities, industry and consultants as follows.

- Peter J. Andersen, Danish Road Directorate (Chairman)
- Tony Andersen, Danish Road Directorate
- Ole Olsen, Danish Road Directorate
- Jørgen Kragh, Danish Road Institute
- Carsten Bredahl Nielsen, Danish Road Institute
- Hans Christian Korsgaard, Grontmij | Carl Bro A/S
- Ole Grann Andersson, Skanska Asfalt I/S
- Jørn Bank Andersen, NCC Roads A/S
- Mikael Thau, LOTCON (Secretary)

The group produced a report in Danish. The present note has been edited by Jørgen Kragh, based on a reworked translation of the report made by Mikael Thau.

Forord

Støjen er den miljøfaktor, som påvirker flest mennesker i hverdagen, og trafikstøjen tegner sig for en meget stor andel af det samlede støjbillede. Trafikstøjen kan bl.a. reduceres ved at opføre støjvolde, -skærme eller –mure, eller ved isolering af berørte boligers facader, men den kan også bekæmpes direkte ved kilden, ved at anvende støjreducerende slidlag. Der er et udbredt ønske om at kunne anvende støjreducerende belægninger i bredere forstand end hidtil, hvor det mest har haft forsøgsmæssig karakter.

Med den målsætning at udarbejde retningslinier for udbud af støjreducerende belægninger er der i et samarbejde mellem vejmyndigheder, industri og rådgivere nedsat en gruppe med det opdrag at udarbejde forslag til et 1. generationssystem for udbud og dokumentation af slidlag med støjreducerende egenskaber. Systemet skal kunne sikre ensartet måling, tolkning og dokumentation af støjreducerende slidlag.

Gruppen benævnes i det følgende SRS-gruppen, hvor SRS står for støjreducerende slidlag. SRS-gruppen indledte arbejdet den 17. februar 2006 og har efterfølgende udarbejdet et forslag til et 1. generationssystem. SRS-gruppen har i sit arbejde anvendt indhøstede erfaringer fra tidligere udførte danske forsøg samt udenlandske erfaringer først og fremmest gennem SILVIA projektet og hollandske erfaringer.

SRS-gruppen har følgende repræsentation:

- Peter Andersen, Vejdirektoratet (formand)
- Tony Andersen, Vejdirektoratet
- Ole Olsen, Vejdirektoratet
- Jørgen Kragh, Vejteknisk Institut
- Carsten Bredahl Nielsen, Vejteknisk Institut
- Ole Grann Andersson, Skanska Asfalt I/S
- Hans Christian Korsgaard, Grontmij | Carl Bro A/S
- Jørn Bank Andersen, NCC Roads A/S
- Mikael Thau, LOTCON ApS (sekretær)

Gruppen har udarbejdet en vejregelforberedende rapport på dansk. Nærværende notat er redigeret af Jørgen Kragh med udgangspunkt i en bearbejdning og oversættelse af rapporten foretaget af Mikael Thau.

Summary

Traffic noise is essential for the health and well-being of people in the modern society and it has during recent years attracted growing attention in Denmark. The effects of this important type of noise can be mitigated by means of noise barriers or screens but it can also be attenuated directly at the source by applying a noise reducing wearing course. Danish road authorities in conjunction with industry and consultants have worked out a system for the specification and documentation of noise reducing asphalt pavement. The system is based on the Close Proximity Method (CPX) and encompasses:

- A guide to the use of asphalt surfacings in traffic noise abatement.
- A system for the documentation and declaration in classes of the noise reduction of the asphalt surfacing.
- Three classes A, B & C, where class A surfacings exhibit the highest noise reducing effect and class B & C exhibit lower noise reducing effects as compared to regular dense graded asphalt surfacings.
- Reference values of the noise emission as determined by the CPX method.
- Description of the CPX method including the definition of method variables and requirements on supplementary calibration of the measuring device.
- Paradigm for use in contracting and preparation of tender documents.

The system is a first attempt in Denmark for contracting noise reducing asphalt surfacings. The system has some limitations and several subjects need to be addressed in the future development of the system. Especially there is a need for better knowledge on the accuracy offered by the CPX method, and for the development of appropriate acceptance criteria to be used in contracting.

Sammenfatning

Trafikstøj er en væsentlig faktor for menneskers velfærd, og har igennem de seneste år haft stor opmærksomhed i Danmark. Trafikstøjen kan reduceres ved opførelse af støjvolde, -skærme o.l., men den kan også bekæmpes direkte ved kilden, ved anvendelse af støjreducerende slidlag (SRS).

Med den målsætning at udarbejde retningslinier for måling, dokumentation og udbud af støjreducerende belægninger er der i samarbejde med vejmyndigheder, industri og rådgivere udarbejdet et 1. generationssystem for udbud og dokumentation af slidlag med støjreducerende egenskaber. Systemet er baseret på såkaldt CPX-måling af støjen nær ved standardiserede referencedæk og består af:

- En vejledning om brug af støjreducerende asfaltslidlag til at bekæmpe trafikstøjen
- Et system til dokumentation og deklaration af støjdæmpende slidlag i støjklasser
- Tre støjklasser A, B og C, hvor slidlag i støjklasse A giver den største støjreduktion og klasse B og C giver mindre støjreduktion sammenlignet med almindelig tæt graderet asfaltbeton
- Referenceværdier for støjudsendelsen målt efter CPX-metoden
- En beskrivelse af CPX-metoden, herunder definition af variable i metoden og krav til supplerende feltkalibrering af måleudstyr
- Paradigme til brug ved udbud og i kontrakter.

Systemet er et 1. generationsforslag til et grundlag for udbud af støjreducerende asfaltbelægninger. Systemet har nogle begrænsninger og der er adskillige aspekter som skal undersøges i den videre udvikling af systemet. Især er der brug for mere viden om nøjagtigheden af CPX-målinger til brug for fastlæggelse af kriterier for accept af modtagne leverancer.

1. Introduction

To make proper use of asphalt surfacings exhibiting noise reducing properties it is necessary to develop procurement methods to be able to describe the required noise related property and to evaluate bids from the contractors during a tender. The 1st generation system for specification and documentation of asphalt surfacings exhibiting noise reducing properties described in this report represents a proposal to develop such procurement methods.

The system contains a guide on how to use asphalt surfacings with noise reducing properties, a description of the reference values, measurement methods, special specifications and a declaration system wherein the contractor can declare the noise reducing property of his noise reducing surfacing product (hereafter "SRS").

The system to declare the noise reducing property enables the contractor to produce documentation of the characteristic noise reducing property of a specific SRS by comparison of measured values to a national reference value. The reduction in noise emission as compared to the reference is used by the contractor in his declaration of the SRS in a specific noise class.

The 1st generation system describes three noise classes:

A: Very good noise reduction
B: Good noise reduction
C: Noise reduction

Currently the contractors' SRS products are declared in class B and C. Class A has been introduced to drive further development and enhancement.

The reference values included in the 1st generation system refer to the CPX method and are defined as the national CPX_{DK} index. The system of declaration encompasses detailed descriptions of the construction of trial sections, CPX measurements, noise classes and requirements to the measuring device. The system also includes a paradigm of the noise-declaration form.

2. Guide to the use of asphalt surfacings in traffic noise abatement

Today models to estimate traffic noise incorporate the properties of the pavement surface. The contribution from different types of pavement can be calculated by such models, thereby enabling the designer to take individual pavement related noise contributions into account calculating the total noise level.

Use of SRS makes it possible to get a certain noise reduction as compared to the use of conventional asphalt surfacing like dense asphalt concrete depending on the aggregate size and traffic speed. However, the noise reduction potential offered by the pavement technology has limitations. If more noise reduction is needed, other means must be taken into consideration or use of SRS may be combined with barriers, walls, speed reduction etc.

The choice of pavement will be based on several considerations and the surfacing selected will depend on the actual circumstances. If noise is an important issue (e.g. in residential areas) there exist today several new SRS products, which exhibit noise reducing properties as compared to conventional asphalt surfacings. In rural areas on the other hand, the noise issue may not be that important, and other criteria for the choice of pavement and surfacing may be more relevant, such as structural capacity, durability and maintenance. However, when using conventional asphalt surfacings consideration of the noise properties can also be taken into account by proper selection of asphalt type and aggregate size.

In residential areas and in other places, where road traffic noise give inconveniences to the environment, asphalt surfacings with less road traffic noise should be considered either by using a small aggregate size or by using an asphalt surfacing of the SRS type. The SRS types are special designed to optimise for noise reduction. However, long term experience using these new innovative SRS surfacings are not yet available, and other relevant pavement properties such as durability has still to be observed. Therefore, a full scale implementation of these new SRS surfacings should wait until more information on the general performance of these types is present. As guidance it is recommended until further information is available to assume approximately 10 % reduction in service life of these new SRS surfacings as compared to the conventional surfacings (excl. porous asphalt, which may have significantly shorter service life).

The most efficient noise reduction offered by special asphalt surfacings is obtained by using porous asphalt “PA” (at traffic speed below 70 km/h double layer PA is used). When using porous asphalt special procedures in regard to drainage, maintenance and de-icing during winter have to be taken into consideration. In addition, porous asphalt has shorter service life as compared to other asphalt pavements, and the cost for maintenance and resurfacing will be higher for this asphalt type. Porous asphalt should for this reason only be used, where special circumstances are present.

Considering lowering road traffic noise it is important to realise, that an old patched uneven pavement contributes to a significant noise emission. Consequently, resurfacing of such old pavement by itself gives a reduction of the noise level. In such cases the new surfacing should not have a large aggregate size. For example surfacings with aggregates larger than 11 mm are considered to exhibit excessive road traffic noise.

3. System for the declaration of the noise reducing properties of an asphalt surfacing

3.1 Basis

To be able to characterise a noise reduction property for a specific surfacing it is necessary to establish a reference value for the noise emission as measured by a defined measurement method.

The tyre-/road noise represents the most important part of the road traffic noise at traffic speed above 30-40 km/h. The tyre-/road noise can be measured by e.g. the statistic pass by method (SPB) or the close proximity method (CPX).

SPB measures the noise emission in one point at a defined height and distance from the road. Simultaneously the speed of the passing vehicles is determined by radar measurements. The type of vehicle is registered, and together with the measured noise emission and speed of the vehicle, these inputs are used to compute the individual contribution from that vehicle to the resulting combined SPB value obtained for the vehicles chosen during the measurements.

CPX measures the tyre-/road noise directly by using a special trailer equipped with microphones placed close to the tyres. Opposite the SPB method the CPX method gives a continuous measurement of the whole road.

Models to estimate traffic noise will normally use input obtained by the SPB method. However, the SPB method gives significant limitation in day to day use and seems to hamper the progress of use and development of the SRS technology. To speed up progress it was decided to develop the 1st generation system based on the more easily applicable CPX method. Performing proper transformation between SPB data and CPX data makes it possible to take advantage of the ease of testing and continuous data collection offered by the CPX method.

Currently two types of trailers are operating in Denmark (the open trailer and the closed trailer). Before these trailers can be used to produce documentation in accordance with the 1st generation system, these trailers will need to perform a field calibration on specified trial sections to ensure, that any difference between the two trailers is accounted for when evaluating the result of the noise emission measurements.

The CPX method is described in ISO/CD 11819-2. In order to ensure that any CPX trailer perform consistent and give comparable measurements, the 1st generation system prescribes a Danish addition to ISO/CD 11819-2, wherein certain method variables are defined. As a consequence the CPX result for use in the 1st generation system is reported as the index CPX_{DK}. In this index the contribution from light and heavy vehicles are weighted in the ratio 85/15.

3.2 Reference values

A reference value of the noise emission is the basis for the characterisation of the noise reducing property of an asphalt surfacing. The 1st generation system defines such reference values at two traffic speeds, 50 km/h and 80 km/h, respectively.

The reference values defined in the 1st generation system were derived from the Danish noise emission data of the Nord2000 model. Using data obtained from comparison testing between the SPB method and the CPX method conducted by the Danish Road Institute and the Dutch consultant M+P the Nord2000, reference values were transformed to the corresponding CPX_{DK} values, which are used in the 1st generation system. The result of the comparison testing is shown in figure 1.

Based on the relation in figure 1 CPX reference values have been defined as shown below. The CPX values correspond to the noise emission assumed in the Danish part of Nord2000 representing approximately 8 year old asphalt surfacings of dense graded asphalt concrete or SMA both with 11 mm nominal aggregate size.

CPX_{DK} reference at 50 km/h:	94.0 dB(A)
CPX_{DK} reference at 80 km/h:	102.0 dB(A)

The reference values have been rounded up in order to make the values more robust.

No reference has been defined for traffic speed 110 km/h, due to the limited number of data obtained at this speed.

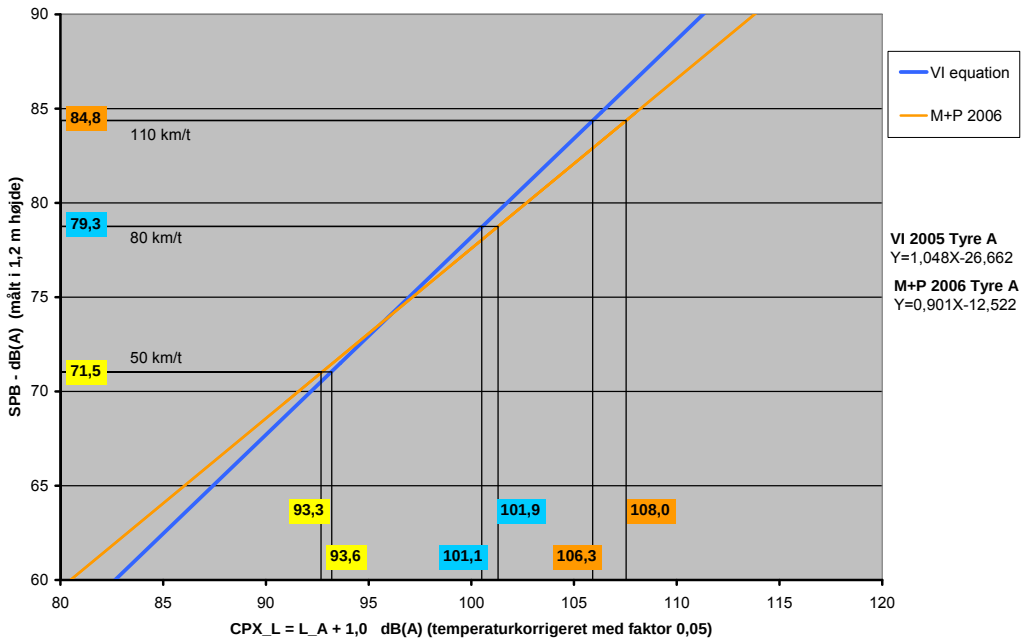


Figure 1. Relation between SPB and CPX (survey method) as determined during comparison testing on Danish and Dutch road sections. In the figure the levels of reference stated in the Danish part of Nord2000 is indicated.

3.3 Declaration in noise classes

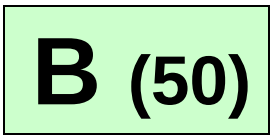
When a producer wants to claim a certain noise reducing property of one of his asphalt surfacings, he will need to declare a noise class appropriate for the product. For the preparation of the necessary documentation, the producer must test his product on a trial section, where proper noise measurements by the CPX method can be performed (see section 4).

The result obtained is then compared to the appropriate reference value and the actual noise reduction is computed as the difference "x".

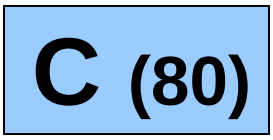
When declaring the noise reducing properties of an asphalt surfacing (by comparison to the proper reference used in Denmark), one of the following noise classes A – C should be used.

Noise class	**Noise reduction in dB(A)**
A: Very good noise reduction	$x \geq 7.0$
B: Good noise reduction	$5.0 \leq x < 7.0$
C: Noise reduction	$3.0 \leq x < 5.0$

The declaration shall indicate the noise class and traffic speed as shown in the example below.



Examples of the declaration of the noise reducing property in class B and class C at the traffic speeds 50 km/h and 80 km/h,respectively.

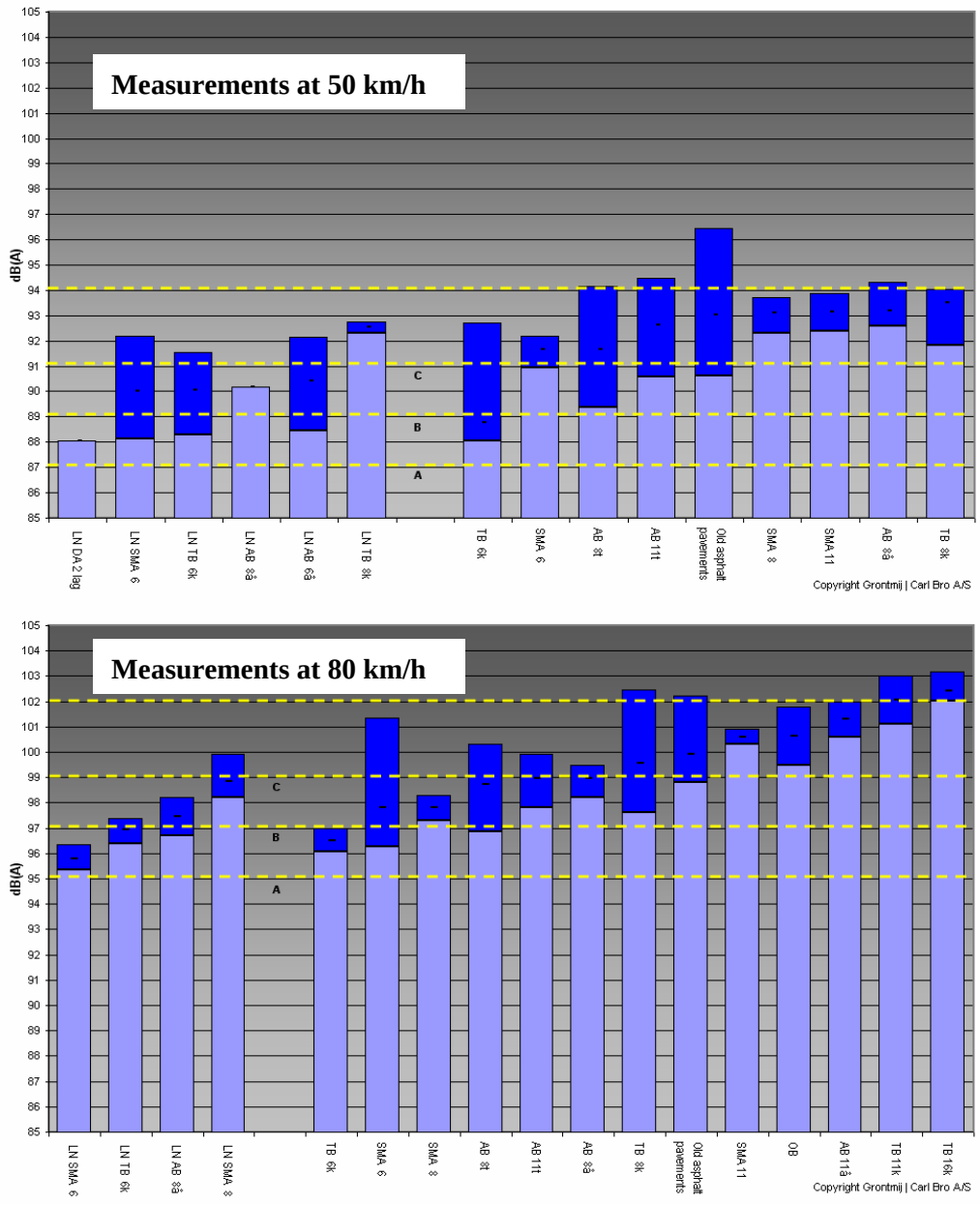


Note: An actual surfacing may not necessarily be declared in the same noise class at the traffic speeds 50 km/h and 80 km/h.

Surfacings with limited noise reduction properties below 3,0 dB(A) will not be classified as a noise reducing surfacing. At present the producers offer surfacings in class B and C. The higher class A has been introduced as a driver for future development and improvement of the noise reduction properties.

For the traffic speed 110 km/h no noise classes are defined. Before noise classes at higher traffic speeds can be defined, more experience is needed.

Example 1:
Results of CPX-measurements in Denmark on new asphalt surfacings as compared to old pavements ("Old asphalt pavement") at 50 km/h and 80 km/h, respectively. The testing was conducted by M+P in 2004-2005 using the closed trailer for Grontmij | Carl Bro A/S.



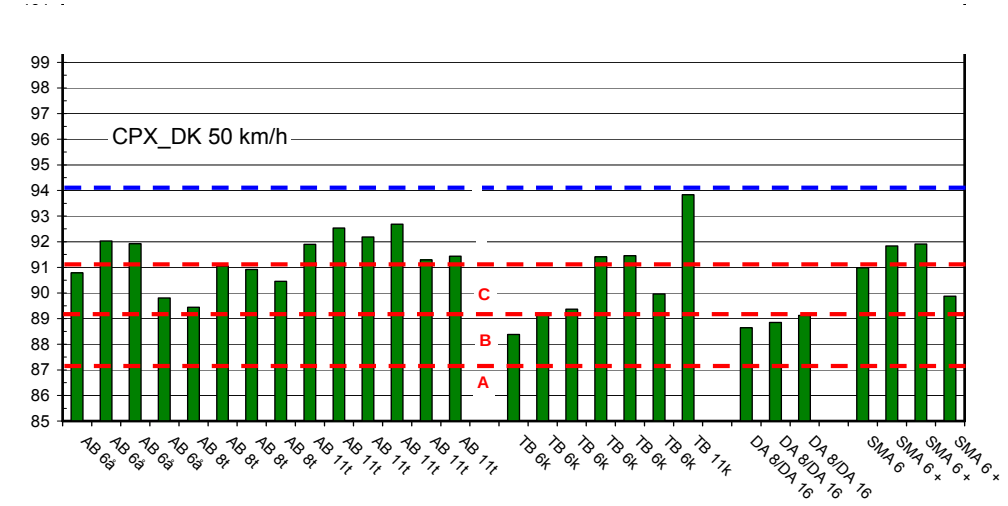
Note: The dark blue area show max. and min. values obtained for different surfacings. LN: Low noise; AB t: Asphalt Concrete; AB å: Asphalt Concrete open; TB: Ultra Thin Layer AC; OB: Surface Dressing; DA: Porous Asphalt; SMA: Stone Mastic Asphalt.

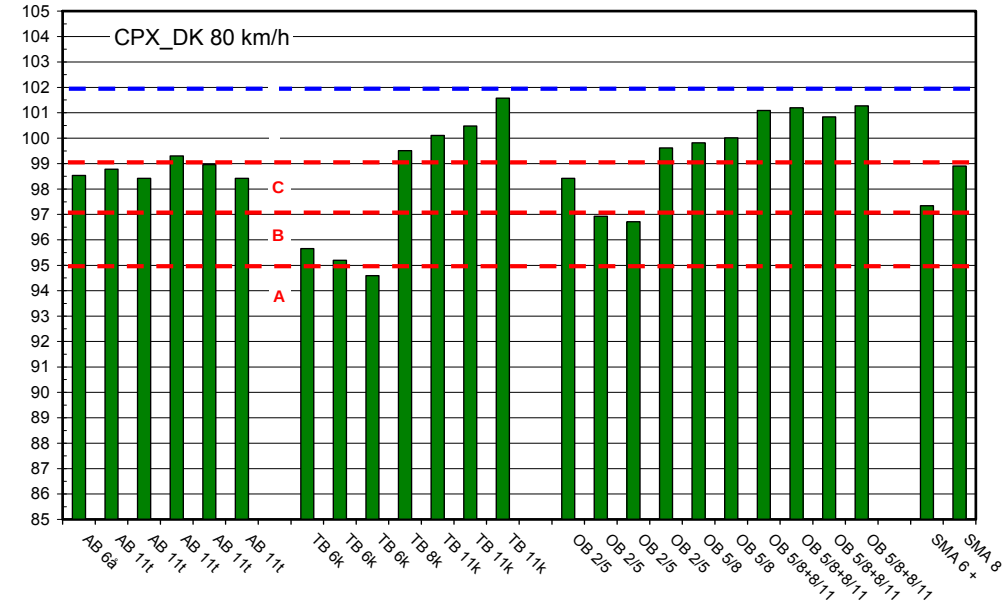
Example 2:
Results of CPX-measurements at sections selected for field calibration of the CPX trailers used in Denmark. The sections are located on Kongelundsvej in Copenhagen and on M10 at Solrød. The testing was conducted by M+P using the closed trailer for Grontmij | Carl Bro A/S.

	Year	Speed [km/h]	CPX_{DK} M+P	Reference	Class
Kongelundsvej:					
AB 11t	2004	50	91.8	94.0	-
	2005	50	91.6	94.0	-
AB 8t	2004	50	90.7	94.0	C
	2005	50	91.0	94.0	C
LN AB 6å	2004	50	89.4	94.0	C
	2005	50	90.4	94.0	C
LN SMA 6+	2004	50	90.0	94.0	C
	2005	50	90.5	94.0	C
LN TB 6k	2004	50	90.7	94.0	C
	2005	50	90.8	94.0	C
M10:					
AB 11t	2004	80	-	-	-
	2005	80	99.5	102.0	-

Note: LN: Low noise; AB t: Asphalt Concrete dense; AB å: Asphalt Concrete open; TB: Ultra Thin Layer AC; OB: Surface Dressing; SMA: Stone Mastic Asphalt.

Example 3:
Results of CPX-measurements in Denmark on new asphalt surfacings (up to 15 months after laying) at 50 km/h and 80 km/h, respectively. The testing was conducted by DGMR Industrie. Verkeer en Milieu B.V. using the open trailer in 2004-2005 for the Danish Road Institute.





Note: AB t: Asphalt Concrete; AB å: Asphalt Concrete open; *TB: Ultra Thin Layer AC; OB: Surface Dressing; DA: Porous Asphalt; SMA: Stone Mastic Asphalt*

4. Noise measurements of test sections for the documentation of the noise reducing property

The CPX measurements performed in the 1st generation system are executed by using the survey method. However, the CPX method in the draft standard ISO/CD 11819-2 describes several variables when conducting the testing which may compromise accuracy and thereby the documentation. In the Danish 1st generation system, a number of these variables have been eliminated by selecting certain parameters with the purpose to define and clarify how to run the test. Such clarification includes tire mounting and driving pattern. The clarifications are prescribed in a Danish addition to ISO/CD 11819-2 and are contained in Annex 1 of the present report. Results of CPX measurements performed within the 1st generation system are expressed as index denoted CPX_{DK} combining CPX-results for light and heavy vehicles in the ratio 85/15.

The trial section shall be at least 100 m long and shall have sufficient drive-in and drive-out area to make a proper measurement. The measurements shall be performed over a distance of minimum 400 m. This shall be accomplished either by measurements on a 400 m trial section or alternatively repeated runs over shorter sections.

The noise measurement shall be reported as the CPX_{DK} index as prescribed in the Danish addition to ISO/CD 11819-2.

- $CPX_{DK} = 0.85 * CPXL + 0.15 * CPXH + K$.
- CPXL is the light vehicle contribution: $CPXL = 1.00 * L_A + 1.00$.
- CPXH is the heavy vehicle contribution: $CPXH = 1.00 * L_D$.
- K is a correction constant related to the actuel CPX trailer (see section 5).
- L_A is the CPX sound pressure level measured at reference tyre A.
- L_D is the CPX sound pressure level measured at reference tyre D.

The 1st generation system does not contain any restrictions in regard to how quickly after construction the contractor may decide to perform CPX measurements for declaration purposes.

5. Requirements on supplementary calibration of the measuring device (field calibration)

Before any equipment can be used for CPX measurement to prepare documentation of the noise reducing property of a surfacing, the CPX trailer must have carried out the supplementary calibration protocol (field calibration) described in the 1st generation system. The supplementary calibration protocol is mandatory and is introduced in order to be certain, that different equipment will give consistent and comparable results.

If any differences between results obtained by different CPX trailers are encountered, such differences are compensated for by a correction constant attributed to each piece of equipment. The field calibration is carried out by annual measurements on selected reference sections.

Supervision of the field calibration and evaluation of the results is the responsibility of the Danish SRS Committee, which prescribes the actual correction constants attributed to each CPX trailer. The SRS Committee will also prescribe those reference sections, where field calibration shall be made.

Currently field calibration occurs at the trial sections on Kongelundsvej in Copenhagen and on M10 at Solrød. The field calibration shall encompass the SRS trial sections and the dense asphalt concrete reference sections. Field calibration shall be conducted during the period from May 1st thru September 30th with a minimum frequency of one per year. An overview of the sections selected for field calibration can be found in Annex 2 of the present report.

Based on measurements in 2006 and earlier results the SRS Committee has prescribed the following correction constants, which are valid until September 30th 2007 if not changed before by the SRS Committee.

- Carl Bro (M+P trailer): K: 0.0 dB(A).

- Vejteknisk Institut (DGMR/JR trailer): K: 0.0 dB(A).

The correction constants ar revised by the SRS Committee and this is mandatory for all CPX measurements applied under the 1st generation system for specification and documentation of asphalt surfacings exhibiting noise-reducing properties.

The table below show the result of field calibration conducted in 2004-2005.

	Year	Speed	CPX-values					
			CPXL		CPXH		CPX_{DK}	
			VI	M+P	VI	M+P	VI	M+P
Kongelundsvej								
AB 11t	2004	50 km/h	91.7	92.0	91.3	90.6	91.6	91.8
	2005	50 km/h	(90.1)	91.8	91.7	90.5	-	91.6
AB 8t	2004	50 km/h	90.5	90.7	91.4	90.4	90.6	90.7
	2005	50 km/h	90.3	91.1	92.2	90.4	90.6	91.0
LN AB 6å	2004	50 km/h	89.9	89.4	90.6	89.3	90.0	89.4
	2005	50 km/h	90.6	90.5	91.5	89.8	90.7	90.4
LN SMA 6+	2004	50 km/h	90.0	90.1	90.4	89.5	90.1	90.0
	2005	50 km/h	90.0	90.7	91.2	89.6	90.2	90.5
LN TB 6k	2004	50 km/h	90.1	90.8	90.5	90.1	90.2	90.7
	2005	50 km/h	91.3	90.9	91.6	90.4	91.3	90.8
M10:								
AB 11t	2004	80 km/h	98.9	-	100.7	-	99.2	-
	2005	80 km/h	-	99.6	-	99.0	-	99.5

Note: LN: Low noise; AB t: Asphalt Concrete dense; AB å: Asphalt Concrete open; TB: Ultra Thin Layer AC; OB: Surface Dressing; DA: Porous Asphalt; SMA: Stone Mastic Asphalt

6. The noise declaration issued by the contractor

When a contractor wants to declare a SRS surfacing, he shall work out a declaration form, wherein he declares the actual noise class and presents the documentation achieved during CPX measurements on a trial section.

The declaration document shall be prepared in accordance with the paradigm of the noise-declaration form. The contractor writes his name and address and type of SRS (e.g. DA. TB k or SMA) incl. certain details of the asphalt mixture. Furthermore, he shall report details of the test section used for the documentation. The paradigm of the noise-declaration form is enclosed in Annex 3.

The noise declaration will be valid for 5 years or until significant changes in the SRS product occurs.

The declaration document can on request be followed by the CPX measurement report and also the Job Mix Formula prepared in accordance with the Danish general specification for hot mixed asphalt (AAB Varmblandet asfalt).

The declaration document shall be certified by the contractor.

7. Paradigm for use in contracting and preparation of tender documents in regard to bituminous surfacings exhibiting noise reducing properties

The 1st generation system contains a paradigm for the preparation of tender documents to be used in works, where a noise reducing effect in the pavement is specified. The paradigm contains an introduction, special specifications for noise reducing surfacings (SRS), example of a noise declaration document and example of Bill of Quantities.

7.1 Introduction

The structure of the paradigm matches the Danish general specification for hot mixed asphalt (AAB Varmblandet asfalt). The noise reduction is addressed by reference to the 1st generation system for specification and documentation of asphalt surfacings exhibiting noise-reducing properties.

The existing methods to measure road traffic noise are not yet sufficiently developed that a functional noise reduction requirement to the pavement can be implemented properly in the procuring documents. Before sufficient documentation of the measuring accuracy is present, the documentation of the noise reducing property of a SRS surfacing has to be demonstrated by the execution of test sections followed by measurements of the noise emission. The 1st generation system for specification and documentation of asphalt surfacings exhibiting noise-reducing properties defines the requirements for such documentation.

The 1st generation system describes a method on how to declare the characteristic noise reducing property of an actual SRS surfacing. When declaring the noise reducing properties of an asphalt surfacing (by comparison to the proper reference used in Denmark), one of the following noise classes A – C should be used.

Noise class	**Noise reduction in dB(A)**
A: Very good noise reduction	$x \geq 7.0$
B: Good noise reduction	$5.0 \leq x < 7.0$
C: Noise reduction	$3.0 \leq x < 5.0$

The documentation of the noise reducing property in the 1st generation system is based on CPX measurements. However, the CPX method in ISO/CD 11819-2 describes several testing variables. Clarification and selection of certain test parameters has been defined in the Danish addition to ISO/CD 11819-2. Results of CPX measurements performed including the Danish addition are expressed as an index denoted CPX_{DK}.

Noise measurements for declaration purposes will typically be executed on a rather newly laid surfacing. When using thin layer SRS types the noise reducing property is assumed to be effective during a significant part of their service life. However, if a surfacing is somehow damaged or if loss of texture or premature deterioration takes place, the noise reducing property will be lost. Pavements with porous asphalt differ from the thin layer SRS types. Since the noise reducing effect of porous asphalt depends on the pore structure any clogging of the pores will diminish the noise reducing effect.

The service life of the thin layer SRS types of surfacings is assumed to be approximately one year shorter than the conventional asphalt surfacings due to higher air voids in the SRS. Porous asphalt on the other hand often will have even shorter service life, which gives higher maintenance cost.

7.2 Special specifications for noise reducing surfacings (SRS)

Special specifications for noise reducing surfacings are supplementary to the requirements of AAB Varmblandet asfalt, November 2006 (hereafter "AAB").

Note: The numbering of the following sections refers to the numbering in "AAB".

1. General

The documentation of the noise reducing property of the surfacing shall be in compliance with the 1st Generation system for specification and documentation of asphalt surfacings exhibiting noise-reducing properties "SRS".

Noise reducing surfacings (SRS) has been developed from known conventional surfacings described in AAB (excl. SMA 6 types, which have a smaller aggregate size than conventional SMA), and some requirements exist, which are common for both SRS and conventional surfacings.

To ensure further innovation it may be possible to bid with an alternative SRS type. If an alternative SRS type, different from the types shown in subsection 2.2 are proposed, the contractor shall present documentation for the properties of the surfacing. This documentation shall include the noise reducing property (declared noise class) and other properties, which can make it convincing, that the surfacing will have a service life comparable with the SRS surfacings contained in subsection 2.2 (e.g. by reference to one of the SRS types). The documentation shall follow the bid.

The experience using the CPX method for noise measurements is at present not sufficient to define acceptance tolerances based on measured CPX values. Therefore it is not possible to use CPX results as acceptance criteria.

Thin layer SRS types laid down in thickness less than corresponding to 55 kg/m^2 will not be subject to compaction requirements. Concerning large jobs (job size type II) special arrangements shall be agreed on before commencement of the paving when layer thickness exceeds 55 kg/m^2 (excl. TB k).

1.3 Requirements to Job Mix Formula and quality control

A declaration of the noise reducing property shall be given in accordance with the 1st Generation system for specification and documentation of asphalt surfacings exhibiting noise-reducing properties "SRS".

The grading envelope valid for the declaration shall be specified using sieve sizes in compliance with AAB for the similar asphalt types. If the asphalt type is not included in AAB, the grading envelope shall be specified similar to SMA.

Quality control is described in subsection 4.2.

2.2 Hot Mixed Asphalt (general requirement)

Requirements for noise reducing surfacings. SRS

The grading envelope specified in AAB is not waived.

The following requirements substitute similar requirements in AAB. The requirements ensure a minimum quality in regard to durability. The produced mix shall comply with the requirements.

SRS- type:	**TB 6k SRS**	**TB 8k SRS**	**AB 6å SRS**	**AB 8å SRS**	**SMA 6+ SRS**		**SMA 8 SRS**
Bitumen:	70/100 – 160/220 or modified[1)]		70/100 – 160/220 or modified[1) 2)]		40/60 – 160/220 or modified[1)]		
Max. aggr. size	6 mm	8 mm	6 mm	8 mm	8 mm	11 mm	8 mm
Marshall-volumetric:							
VMA	≥ 23	≥ 23	≥ 20	≥ 20	≥ 20	≥ 19	≥ 22
Air voids	10 – 16	10 – 18	6 – 14	8 – 16	4 – 10	3-10	4-12
V_B/V_S	≥ 0.15	≥ 0.15	≥ 0.15	≥ 0.15	≥ 0.18	≥ 0.17	≥ 0.18
Minimum layer thickness[3)]	40 kg/m^2	45 kg/m^2	45 kg/m^2	55 kg/m^2	45 kg/m^2	50 kg/m^2	55 kg/m^2
Tack coat emulsion[4)]	Polymer modified		Standard				
Amount of residual binder	≥ 600 g/m^2	≥ 700 g/m^2					

Notes: AB å: Asphalt Concrete open; TB: Ultra Thin Layer AC; OB: Surface Dressing; DA: Porous Asphalt; SMA: Stone Mastic Asphalt; VMA: Volume Mineral Aggregate; V_B/V_S: Volume bit. / Volume aggr.

1) *Bitumen 160/220 shall not be used for traffic intensities above 2000 ADT or 50 ESAL due to preservation of the noise reducing surface texture.*

2) *Due to relative high air voids in AB 6å SRS and AB 8å it is recommended to produce these SRS types using polymer modification (elastomeric type), due to increased risk of ageing of the bitumen.*

3) *There are no requirements to compaction for SRS laid down in thickness* ≤ 55 *kg/m*^{2}.

4) *Concerning TB k it is important that the tack coat is not applied in too high quantities so that the surface texture is disturbed.*

4.2 Quality control

For job size type I larger than 100 tons documentation concerning grading and bitumen content shall be submitted for each 500 tons.

4.3.4 Tolerances

Noise reducing properties
The tolerances described in subsection 2.2 represent that interval, wherein an actual noise reducing surfacing is assumed to exhibit the noise reducing properties as declared. If those tolerances are exceeded, the appearance of the surfacing must be evaluated to justify, if the noise reducing properties can be expected to be present.

Grading
Target values refer to the grading as specified by the contractor, and which are followed by his declaration.

Marshall volumetrics
The result shall comply with the requirements described in subsection 2.2.

Example of Bill of Quantities:

BILL OF QUANTITIES (SRS), 20XX

JOB No.:
ROAD No.: EXISTING SURFACE:
KM: ADT (total): ESAL (total):
TIME OF EXECUTION:

Description	Unit	Quantity	Unit rate DKK	Total amount DKK	Comments
1. 50 kg/m² SRS, Class B (80 km/h), crushed granite.	m^2				
2. Milling	m^2				
3. Levelling	t				
4. Local repair	t				
5. Removal of road marking	m^2				
6. Echange of well covers	Piece			-	
Total				-	

Day / Month- 20xx

Contractor

8. Follow up on the 1st generation system

The system described in this paper represents the first attempt in Denmark to be used in contracting asphalt surfacings exhibiting noise reducing properties. Several aspects need to be addressed in the future development of the system.

Establishment of the SRS Committee
It is proposed to appoint a SRS Committee to be responsible for the future management of the 1st generation system. The SRS Committee is proposed to be organised within the national organisation working out road standards.

SRS link at the Danish Road Directorate WEB site
The 1st generation system including paradigm. noise-declaration form and actual results of the field calibration incl. correction constants should be available at the DRD Web site.

Measurement techniques and measurement methods
In the 1st generation system the CPX method is used to characterise a surfacing in regard to its noise reducing properties. It is important for the further development of the system, that knowledge of other measurement methods is gathered e.g. surface texture. Furthermore, it is important to develop better knowledge concerning the accuracy of the noise measurements and risk assessment. It is recommended to initiate thorough measuring programs in order to evaluate the use of the CPX method in regard to acceptance testing. The measuring programs can include trial sections and ordinary sections as well.

In addition, it is recommended to continue the documentation of the correlation between SPB and CPX measurements.

Repair methods
In general all irregularities in a pavement will increase the noise emission. Road sections which are subject to noise considerations, will probably need to be resurfaced more often. In case any need for repair of the pavement occurs, it will be necessary to consider the method of repair in the perspective of increased noise. The repair methods used today should be examined in order to evaluate their use in SRS.

Updating of the noise contribution of surfacings
In the Danish part of Nord2000 it is possible to add in the noise contributions from the pavement. If the noise emission differs from the assumed emission of the reference pavement, the model enables the designer to adjust the total noise level. However, the procedure on how to introduce the CPX_{DK} values into Nord2000 has not yet been developed.

Requirements to the underlying layer before laying of SRS surfacings
The construction of thin layer SRS surfacings requires a good regularity of the substrate. whereupon the SRS are to be laid. A construction guide describing the special considerations needed for laying SRS surfacings should be prepared.

Follow up on the CPX_{DK} index
In the CPX_{DK} index CPX-results for light and heavy vehicles are combined in the ratio 85/15. This ratio should be considered in regard to the response of the A tyre and the D tyre for different maximum aggregate size.

Tolerances of the CPX measurement
It is the intention that the noise reducing property should be used as a functional requirement referred to in the procuring documents. However, before such a functional requirement can be used, it is necessary to know the precision of the CPX measurements and the typical variation of the noise reducing property of a SRS surfacing within the normal production tolerances. More experience is needed before a functional requirement can be operated.

Annex 1
Danish addition to ISO/CD 11819-2

The CPX measurements performed in the 1st generation system are executed by using the survey method. However, the CPX method in the draft standard ISO/CD 11819-2 describes several variables when conducting the testing. In order to ensure that any CPX trailer performs consistent and give comparable measurements, the 1st generation system prescribes a Danish addition to ISO/CD 11819-2, which defines and clarifies certain method variables. Such clarification includes tire mounting and driving pattern. Results of CPX measurements performed in the 1st generation system are expressed as an index denoted CPX_{DK} combining CPX-results for light and heavy vehicles in the ratio 85/15.

Note: The numbering in the following refers to the numbering in ISO/CD 11819-2.

Section 6.1: Selection of measuring site
A trial section for use in regard to documentation and declaration of noise reducing properties shall as a minimum be 100 m long excl. necessary entrance and outlet in order for measurement personnel to be able to execute proper measurement on the trial section.

Section 7.4: Reference tyres
Tyres shall be tyre A and tyre D.

Section 8.3: The "Investigatory" and "Survey" methods - Number of test tyres

All measurements for use for declaration purposes of noise reducing properties shall be executed in accordance with the "Survey" method.

Section 8.4: Lateral position on the road
All measurements for use for declaration purposes of noise reducing properties shall have tyre A at the right side of the trailer and tyre D at the left side. The measurement shall be executed with tyre A running in the right wheel path of the carriageway.

Section 9.6: Correction of sound levels according to temperature
The result of the measurement shall be corrected according to temperature. The test report shall include results with and without correction ($L_{measured}$ and $L_{corrected}$).

When computing CPX_{DK} $L_{corrected}$ is used.

- Air temperature during measurement: t_{air}, °C.
- $L_{corrected} = L_{measured} + 0.05 \cdot (t_{air} - 20)$

Section 9.8: Determination of the Close-Proximity Sound index (CPXI) - Survey method

The result of the noise measurement is reported as the corrected CPX_{DK} index:

- CPX_{DK} = 0.85 * CPXL + 0.15 * CPXH + K.
- CPXL is the contribution from light vehicles: CPXL = 1.00 * L_A + 1.00.
- CPXH is the contribution from heavy vehicles: CPXH = 1.00 * L_D.
- K: Correction constant related to the actual used equipment. The valid correction constant "K" is defined annually by the SRS Committee and shall be used for all measurements used for the declaration of noise reducing properties.

Note: The equation used for computing CPX_{DK} differ from the CPX indices described in ISO/CD 11819-2. Consequently, all data based on the Danish addition to ISO/CD 11819-2 shall always be indicated as CPX_{DK}.

Section 12: Reported data

General information:

Reference is made to the Danish addition to ISO/CD 11819-2.

Point 22:

The pavement temperature shall always be reported.

Annex 2
Field calibration

Before any equipment can be used for CPX measurement to prepare documentation of the noise reducing property of a surfacing, the CPX trailer must have carried out the supplementary calibration protocol (field calibration). The supplementary calibration protocol is mandatory. If any differences between results obtained by different CPX trailers are encountered, such differences are compensated for by a correction constant attributed to each piece of equipment.

The field calibration shall be carried out annually during the period from 1 May thru 30 September.

Supervision of the field calibration and evaluation of the results is the responsibility of the SRS Committee, which prescribes the actual correction constant attributed to each CPX trailer.

Currently field calibration occurs at the trial sections on Kongelundsvej in Copenhagen and on M10 at Solrød shown in the table below.

Sections appointed for field calibrations 1 May 2006.

		Chainage	
		From	**To**
Kongelundsvej*:			
AB 11t	R	87	227
LN AB 6å	R	284	444
LN TB 6k	R	557	685
AB 11t	L	218	87
AB 8t	L	428	268
LN SMA 6+	L	685	478
M10:**			
Combifalt 8	R	28.800	30.150
SMA 6P	R	30.200	31.500
Microville 8	L	28.800	30.150
LN SMA 8	L	30.200	31.500
AB 11t	L	31.500	32.700

* Chainage at Kongelundsvej starts at the centerline at Løjtegårdsvej.

** Measurements in the middle lane.

Annex 3
Paradigm of the noise-declaration form

Below procedures for the preparation of the noise declaration form are described following the requirements described in the 1st generation system for specification and documentation of asphalt surfacings exhibiting noise-reducing properties.

Producer:	Name of the producer and address of the production facility.
Product: **Type:** **Declaration:**	Brand name of the SRS surfacing. Type of surfacing as referred to "AAB Varmblandet asfalt" or to special specification. Declaration of noise class (A, B eller C) for the actual traffic speed. Substitute "X" with the correct noise class.
Noise measurement:	All measurements for declaration purposes shall be executed with approved and calibrated equipment which shall have performed the mandatory field calibration. Measurements shall be in accordance with ISO/CD 11819-2 including the Danish addition. All CPX results shall be reported as the CPX_{DK} index.
Trial section:	The trial section shall be precisely identified by name of the road, chainage (where no chainage marking is present at the road side, the chainage direction and starting point shall be described), and the side of the road (Right hand side is always given by the direction of the chainage). Date for the construction shall be reported.
Job Mix Formula:	Number and date for the Job Mix Formula shall be reported. The Job Mix Formula shall describe used test methods and specified values. The specified values shall as a minimum follow "AAB Varmblandet asfalt" for the relevant type of surfacing. Copy of the Job Mix Formula shall follow the Noise declaration on request.

QC test results:	QC test results for the trial section shall document all values specified in the Job Mix Formula. The test results are referred to by indication of test ID and date. Copy of the test results shall be presented on request.
CPX–measurements procedure:	The trial section shall be at least 100 m long and have sufficient drive-in and drive-out area to make a proper measurement. The measurements shall be performed over a distance of minimum 400 m. This shall be accomplished either by measurements on a 400 m trial section or alternatively by repeated runs over shorter sections. The test report shall contain proper and precise identification of the trial section. Measurement performed before the introduction of the 1st generation system can be used as documentation for declaration purposes. Copy of the noise measurement report shall be presented on request.
CPX-results:	Results of CPX measurements performed in the 1st generation system are expressed as index denoted CPX_{DK} combining CPX-results for light and heavy vehicles in the ratio 85/15, as this is described in the Danish addition to ISO/CD 11819-2. The declared noise reduction shall be reported (1 decimal).
Recipe:	The declaration form shall be followed by specific information of the asphalt mixture. This includes the bitumen type. category of coarse aggregate. Marshall voids and gradation on key sieve sizes.
Certification:	The producer shall be to certify the declaration form.

SRS NOISE-DECLARATION

X (80)
X (50)

Producer:_____
Product: _____ **Type:**_____
Recipe No.: _____

NOISE MEASUREMENT:	**CPX-measurement at 50 km/h**	**CPX- measurement at 80 km/h**
Declaration section Name/number: Chainage: Side of road: Constrution date:		
Job Mix Formula Identification/date:		
QC test results Production & constr. Lab. ID. No:		
CPX-measurement Execution. date: Measuring firm: Measuring report-ID: Measured section:		
CPX-results. CPX_{DK} Measured value: *DK reference:* Noise reduction:	dB(A) 94.0	dB(A) 102.0
Remarks:		

JOB MIX FORMULA DETAILS:

Bitumen type:	☐ 40/60 – 160/220	☐ 250-330 – 330/430	☐ Other (describe)
$Aggregate_{Coarse\ part:}$	☐ Quarried	☐ Crushed Gravel	☐ Other (describe)
Marshall-Voids:	____ (1 decimal)	☐ Geometric	☐ Volumetric (air/water)
Gradation. % passing:	0.063 mm: ____ 8 mm: ____	2 mm: ____ 11 mm: ____	5.6 mm: ____

Certified by: **Name:**_____ **Date:**_____

Noise Class	A	B	C
Noise reduction (dB_A)	> 7	5 - 7	3 - 5
	Very good noise reduction	Good noise reduction	Noise reduction

Complies with SRS-requirements for declaration of noise reducing surfacings in Denmark

Eksternt notat / Technical notes		
Nr. No.	Titel/Title/Shortcut	Forfatter/Author
32/05	Workshop on Optimization of Noise Reducing Pavements	Hans Bendtsen Helen Hasz-Singh Carsten Bredahl Nielsen
33/05	Friktion og MPD-tal	Bjarne Schmidt Birger Roland Jensen
34/05	Trafikstøjmåling Tesdorpfsvej – September 2005	Sigurd N. Thomsen Bent Andersen Jørgen Kragh
35/06	Test of thin layers on highway - Year 1 measurement report	Sigurd N. Thomsen Hans Bendtsen Jørgen Kragh
36/06	Noise reducing thin layers - Promising concepts	Hans Bendtsen Erik Nielsen
37/06	Seminar on road noise abatement	Hans Bendtsen Carsten Bredahl Nielsen Helen Hasz Singh
38/06	Acoustical characteristics of Danish road surfaces	Jørgen Kragh
39/06	Noise reducing SMA pavements – Mix design for Silence – F2	Erik Nielsen Jørn Raaberg Hans Bendtsen
40/06	Ravelling of porous asphalt - Seletion of road sections	Carsten Bredahl Nielsen
41/06	Durability of porous asphalt - International experience	Carsten Bredahl Nielsen
42/06	Porous pavements with PMB – Selection of road sections	Carsten Bredahl Nielsen
43/06	Notes from INTER-NOISE 2006	Hans Bendtsen
44/06	Acoustic performance - low noise road pavements	Bent Andersen Jørgen Kragh Hans Bendtsen
45/06	Noise reducing pavements – Evaluation workshop	Carsten B. Nielsen Hans Bendtsen
46/06	Traffic noise at two-layer porous asphalt – Øster Søgade, Year No. 7	Jørgen Kragh
47/07	Microstructure of porous pavements – experimental procedures	Carsten B. Nielsen
48/07	Ravelling of porous pavements – assessments of test sections	Carsten B. Nielsen
49/07	Railway crossings - Road traffic noise measurements	Sigurd N. Thomsen Jørgen Kragh Hans Bendtsen
50/07	Roads with paving Stones - Noise measurements	Sigurd N. Thomsen Jørgen Kragh Hans Bendtsen
51/07	Trafikstøj ved rumleriller – et pilotforsøg	Jørgen Kragh Bent Andersen
52/07	Traffic Safety and Noise Reduction - Thin Layers	Hans Bendtsen Jørn Raaberg
53/07	Modified bitumen in porous pavements – Assessment of test sections	Carsten B. Nielsen
54/07	Clogging of Porous Pavements - Assessment of test sections	Carsten B. Nielsen
55/07	Clogging of Porous Pavements - International Experiences	Hans Bendtsen Jørn Raaberg
56/07	Ageing of Porous Pavements – Acoustical effects	Jørgen Kragh
57/07	Acoustical Characteristics of Danish Road Surfaces - Part 2	Bent Andersen
58/07	Replacement of Porous Top Layer - Process and noise effect	Jørgen Kragh Sigurd N. Thomsen
59/07	Faglig strategi for støjtemaet	Hans Bendtsen
60/07	Clogging of porous pavements – The cleaning experiment	Carsten B. Nielsen
61/07	Noise Classification – Asphalt pavement	Jørgen Kragh

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