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Noise classification for tendering quiet asphalt wearing courses

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Abstract

Road administrations request noise reducing pavements and the industry has introduced new products claimed to have noise reducing properties. As a cooperative effort, the Danish Road Directorate, the paving industry and consultants have established a system for specifying such asphalt wearing course systems. Road administrations can now tender pavements with a certain class of traffic noise reduction, based on the Close Proximity (CPX) noise measurement method, ISO/CD 11819-2.

The system represents a first Danish attempt to contract road works comprising noise reducing asphalt wearing course systems based on their functionality. Further development is foreseen concerning the CPX measurement accuracy and the acceptance criteria to be used in contracting.

Keywords: road traffic noise; noise reduction; pavement works; asphalt wearing course system; documentation; declaration

1. Background and aim

Traffic noise is an important issue for road administrations in developed countries concerned with the steadily increasing traffic noise. The Danish Road Directorate aims at traffic noise reduction by applying noise reducing pavements and by constructing and maintaining noise barriers where roads pass residential areas. The present paper aims at presenting the Danish SRS system and the experience obtained during the first five years with the system in practice. SRS is a Danish acronym for noise reducing wearing course systems.

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2. The SRS system

The Danish SRS system is based on CPX measurements according to [ISO, 2000] using special equipment, for example the trailer shown in Figure 1. The system was established in 2006 as a first generation system and issued as a national road standard in an attempt to promote and encourage development and progress, see [Kragh, 2007]. A major reason for its wide acceptance in the Danish asphalt community is that the system was established in a close cooperation between national and local road administrations, asphalt industry and consultants, by an expert group under the Danish Road Standards committee.

2.1. Principle

When an asphalt producer wants to rank one of his asphalt surfacings with respect to its noise reducing properties, 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, which means that he must construct a trial section with the new product and measure CPX noise levels. The noise measurements need to be performed by an approved test laboratory which participates in annual field calibrations, see Section 6. The measurement results are compared with defined reference noise levels, and the asphalt contractor then issues a declaration that his pavement belongs to a specific noise class. Road administrations can now tender road works specifying that they want an asphalt surface with defined noise characteristics, expressed by its noise class.

The noise levels denoted L_A and L_D are measured at a reference speed of 50 km/h and/or 80 km/h using reference tyres 'A' and 'D' as defined in [ISO, 2000] with tyre A mounted on the right side and tyre D mounted on the left side of the trailer. Based on these noise levels, an index denoted CPX_{DK} is calculated according to Eq. (1). *K* is a trailer correction constant derived from a field calibration, see Section 6.

$$CPX_{DK} = 0.85 \cdot (L_A + 1) + 0.15 \cdot L_D + K \qquad (1)$$

Fig. 1. The open trailer 'deciBellA' applied by the Danish Road Directorate for its CPX noise measurements

By its nature, the SRS system classifies wearing course systems when they are new, i.e. according to what might be denoted their *initial* noise reduction properties, although the first generation system does not particularly deal with this aspect. Pavement noise characteristics change with the pavement age and traffic noise levels increase during the service life of a wearing course. Thus, the noise reduction to take into account in traffic noise regulation and planning may differ from the initial value, see Section 6.

2.2. Components

The SRS system encompasses:

- Classes A, B and C of noise reduction compared to eight year old dense graded asphalt, see Table 1
- A guide on how to apply asphalt surface layers in traffic noise abatement
- A paradigm for contracting and for preparing tender documents for pavement works
- Rules on how the producer may declare the noise reducing properties of his asphalt surfacing
- Requirements on the field calibration of measuring devices participating in the SRS system.

Table 1. Definition of SRS noise classes

Noise class	A	B	C
Noise reduction [dB]	> 7	5 - 7	3 - 5
Designation	Particularly noise reducing	Very noise reducing	Noise reducing

2.3. Present status

The SRS system represents a Danish attempt to contract road works comprising asphalt wearing course systems with noise reducing properties. The system does have limitations and several topics are being addressed to develop the system further. In particular, better knowledge is needed on the measurement accuracy provided by the CPX method, and there is also a need to develop acceptance criteria to be used in contracting, for example by specifying that the CPX noise level measured on a recently laid wearing course must not exceed a specified limit value.

The Danish Road Directorate has decided to apply noise reducing pavements in construction of new roads. For maintenance of existing roads, the Danish Road Directorate uses noise reducing pavements when the yearly average noise level L_{den} in residential areas or in recreational areas near residential areas exceeds 58 dB. The municipality of Copenhagen and other Danish municipalities have similar policies. Danish asphalt contractors have issued more than 30 product declarations, most of which state a noise class B at 80 km/h and class C at 50 km/h. These contractors regularly advertise noise reducing pavements in technical journals.

3. Tendering and contracting pavement works

The first generation system includes a paradigm for the preparation of tender documents to be used in works, where a pavement providing traffic noise reduction is specified. The structure of the paradigm matches the usual Danish specification concerning the construction of asphalt pavements. Noise reduction is addressed by reference to the SRS system which at the moment is a part of the Danish specification on a trial basis: The documentation (in Danish) can be found on the Danish Road Standard website.

The SRS system is based on pavement functional requirements whereas standard pavement specifications are based on mix recipes. This caused some confusion in the first seasons with the SRS system, and the decision tree in Figure 2 was established to assist decision makers with limited expertise in asphalt technology [Roads, 2008]. In some cases tendering documents were seen requiring, for example, stone mastic asphalt SMA 11 with 11 mm nominal maximum aggregate size and at the same time requesting a noise 'Class B' pavement. This is not feasible. The decision tree prescribes how to either choose a standard product or choose a product with a declared noise class.

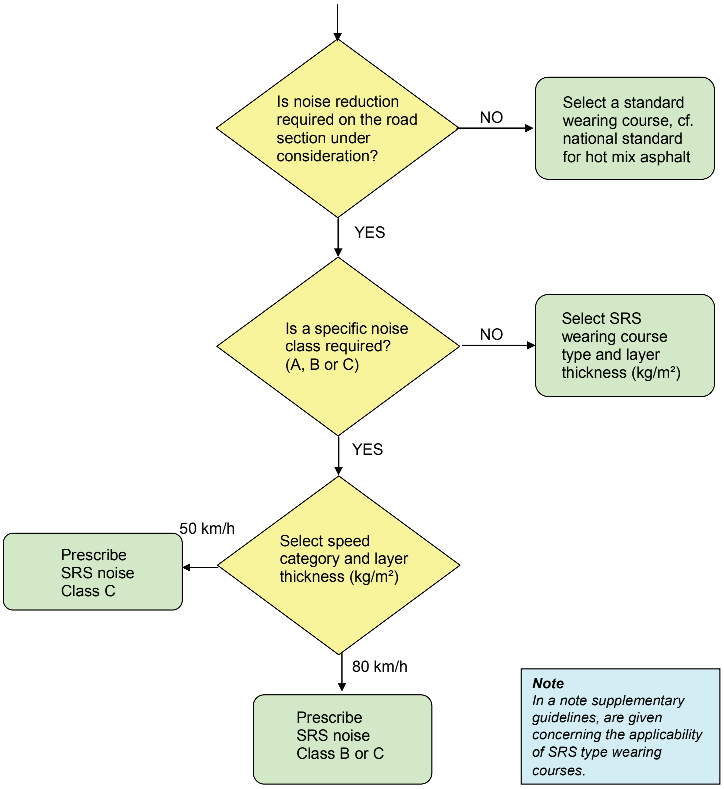

Fig. 2. Illustration of the process of deciding whether a noise reducing wearing course shall be chosen

With the experience local Danish road administrations have built up since the SRS system was introduced it will probably not be necessary to keep Figure 2 in the guideline of the second generation SRS system.

4. Noise reducing asphalt wearing courses – products and noise classes

4.1. General on the use of noise reducing wearing courses

Dutch road administrations apply to a wide extent porous asphalt to reduce traffic noise. Such porous asphalt is also applied to some extent in France, Germany and other European countries, while for example in Denmark porous asphalt up to now has only been used on a purely experimental basis. The main reason for the latter is a fear of difficult winter maintenance with numerous freeze/thaw cycles. Instead, the Danish policy has been to apply thin asphalt layers with small maximum aggregate size and an open grading. Varying mix designs leading to reduced traffic noise levels have been developed in national Danish projects and in the European projects SILVIA and SILENCE. Such thin layer asphalt wearing courses are also applied to a wide extent in France. The State-of-the-Art report [Sandberg, 2010] from the OPTHINAL project mentioned in Section 5 contains an overview of the application of such thin asphalt layers.

4.2. Products declared under the SRS system

At present, thin layer wearing course systems with the properties summarized in Table 1 are the main types designated as "SRS types". UTLAC is ultrathin layer asphalt concrete; AC *x*o is open graded asphalt concrete with *x* mm nominal maximum aggregate size. SMA is stone mastic asphalt, and SMA *x*+ is SMA with *x* mm nominal maximum aggregate size plus a small portion of a larger aggregate. VMA is the void volume in the mineral aggregate, V_B is the volume percentage of binder and V_A is the volume percentage of aggregate in the mix.

Table 1. Summary of properties of wearing course systems included in the present Danish SRS system

SRS type: Danish designation:	UTLAC 6 TB 6k SRS	UTLAC 8 TB 8k SRS	AC 6o AB 6å SRS	AC 8o AB 8å SRS	SMA 6+8 SMA 6+8 SRS	SMA 6+11 SMA 6+11 SRS	SMA 8 SMA 8 SRS
Bituminous binder:	70/100 – 160/220 or modified 1)		Polymer modified 2)		40/60 – 160/220 or modified 1)		
Max. aggregate	6 mm	8 mm	6 mm	8 mm	6+8 mm	6+11 mm	8 mm
Marshall-criteria:							
VMA [%]	≥ 23	≥ 23	≥ 20	≥ 20	≥ 20	≥ 19	≥ 22
Void [%]	10 – 16	10 – 18	6 – 14	8 – 16	4 – 10	3 – 10	4 – 12
V_B/V_A	≥ 0,15	≥ 0,15	≥ 0,15	≥ 0,15	≥ 0,18	≥ 0,17	≥ 0,18
Minimum amount 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						
Residual binder	≥ 600 g/m^2	≥ 700 g/m^2					

Notes with details: 1) Bitumen 160/220 is not applicable on heavily trafficked roads
2) Bitumen for AC 6o SRS or AC 8o SRS must be elastomer modified
3) There are no requirements in Denmark on the compaction of layers with < 55 kg/m^2
4) Excess amounts of emulsion may destroy the noise reduction.

4.3. Measured noise levels – noise classes

Figure 3 summarises the results of CPX noise measurements carried out during 2007 – 2009 by the Danish Road Directorate on wearing courses all of which were aged less than one year at the time of measurement. For each type of asphalt wearing course shown in the labels on the horizontal axis the green column shows the average value of CPX_{DK}, Eq. (1). The error bars mark the range of the measurement results and the label at the bottom of each column gives the number of measurement results from pavements of that type. The blue dotted lines mark the reference values at 80 km/h and 50 km/h, respectively, and the noise classes A, B and C are marked with red dotted lines in the figure. A few new wearing courses belonged to class A at 80 km/h (the top part of Figure 3), while all else were noise Class B or yielded higher noise levels. At 50 km/h (the bottom part of Figure 3) no pavements made Class A.

5. Other surface properties

5.1. General

The focus of this paper is on traffic noise reduction and on paving tendering/contracting procedures and Section 6 - 7 addresses other aspects of the noise reduction. The present section, however, briefly deals with the trade-offs between noise reducing properties and other performance characteristics such as durability, maintenance, cost, and environmental impact. The content of this section is mainly based on results from a recent transnational European research project designated the acronym OPTHINAL on the

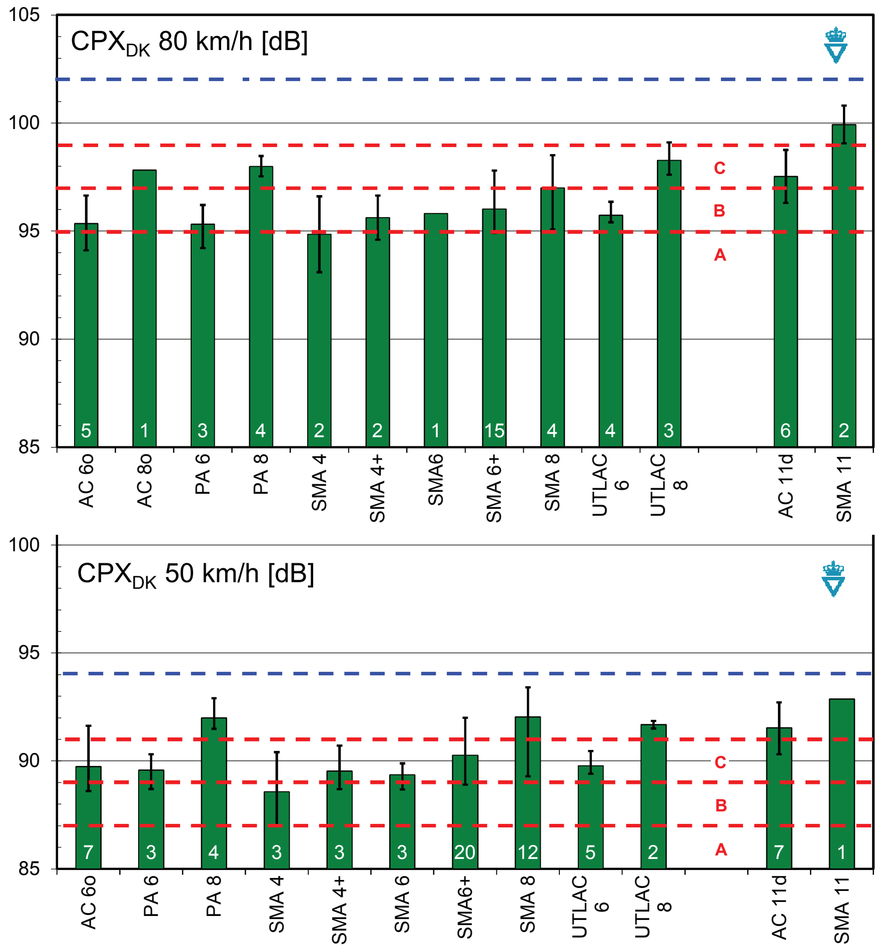

Fig. 3. Summary of SRS measurement results collected by the Danish Road Directorate at new wearing courses during the first three years of operating the SRS system. Top: 80 km/h; Bottom: 50 km/h.

optimization of thin asphalt layers. The project was pool funded through the ERA-NET ROAD consortium and carried out by a consortium consisting of the Danish Road Directorate, the Belgian Road Research Centre and the Swedish National Road and Transport Research Institute. The results are documented in the final project report [Kragh, 2011]. The first phase of the project was a literature study and an inventory of experience obtained when using thin asphalt layers. The results are documented in a State-of-the-Art report [Sandberg, 2011].

The main conclusion of the project was that it is certainly worthwhile to apply thin asphalt layers, in particular as a renewable "skin" on top of a road construction having sufficient bearing capacity. The philosophy in the "perpetual pavement" concept is that the pavement base is designed to have almost eternal bearing capacity and is paved with a thin long-lasting "skin" of surface layer which must be renewed from time to time, due to effects of water, ageing and traffic conditions. The “skin” serves road users' need for skid resistance and other important functions. Thin asphalt layers seem to be increasingly used due to the needs of road administrations for cost-effective maintenance of the road infrastructure.

This is consistent with the need for lower traffic noise levels in residential areas near major roads, in particular when winter maintenance policy/conditions exclude the use of porous asphalt. Reduced traffic noise levels may be one of the positive effects when a thin asphalt layer is applied. The use of thin asphalt layers also imply less curb and gutter works.

5.2. Durability and bearing capacity

The OPTHINAL project attempted to evaluate the properties of thin asphalt layers compared to those of more traditional surfaces such as dense asphalt concrete DAC 11 or stone mastic asphalt SMA 11. Thin asphalt layers in general come out somewhat better than the references in most respects; for example concerning cost, use of natural resources, rolling resistance, and traffic noise emission. However, problems are encountered, for example concerning the durability under severe traffic, and a limited bearing capacity. Very little extra bearing capacity is provided by thin asphalt layers. If studded tyres are used the wear of thin asphalt layers is usually significantly worse than the wear of thicker pavements with larger aggregate.

No regular Danish SRS pavement has been observed until the end of its service life so their lifetime cannot be documented. The Danish Road Directorate at present estimates the service life of such pavements to be one year shorter than that of standard DAC 11 or SMA 11. Problems with thin-layer wearing course durability have been encountered in a few cases. At present it is believed that these are associated with thin-layer wearing courses laid during night time (i.e. in cold conditions) on surfaces where the old wearing course had been removed with a coarse milling drum. When coarse milling drums are applied, the milled surface tends to be so rough that the normal amount of asphalt of SRS types in kg/m^2 must be increased to compensate for this roughness. Furthermore, the moisture sensitivity of the milled surface needs to be assessed thoroughly before applying a thin surfacing. The Danish Road Directorate has decided that until further investigations have been carried out, SRS pavements shall not be laid on surfaces having been milled with a coarse milling drum. In such cases standard stone mastic asphalt providing thicker lifts shall be applied. If SRS pavement is specified, milling must be made with a fine milling drum. As an immediate remedy it has been decided to add extra 10 kg/m^2 of asphalt mix on milled surfaces.

5.3. Skid resistance

Thin asphalt layers were generally found in OPTHINAL to have fine skid resistance properties, although a few exceptions have been reported. Skid resistance seemed to be better than for standard dense asphalt concrete, perhaps due to a larger number of contact points between the tyre and a pavement with smaller aggregate. The durability of the skid resistance was excellent according to a British study but experience with thin asphalt layers is limited and longer time series need to be studied. However, any initial reservation concerning skid resistance on thin asphalt layers with small aggregate sizes has not been justified.

5.4. Environmental impact

The OPTHINAL reports briefly touch on the environmental impact of CO_2 emission from traffic. Road surface characteristics influence rolling resistance and hence energy consumption and CO_2 emission. Thin asphalt layers offer relatively low rolling resistance because of their favourable surface texture. Therefore they may have a positive impact on the reduction of CO_2 emission, but at this stage the quantitative effect cannot be documented.

Recycling of materials is another important environmental aspect. To build noise reducing thin asphalt wearing courses requires strict control of the grading curve. In reality this is only possible with virgin aggregate fractions. Such noise reducing surface layers are so thin that with the milling and handling techniques presently applied, they cannot be removed without downgrading the material. This material cannot be used in a new thin asphalt layer but has to go into standard wearing course mix or base course mixes.

6. Other aspects of pavement noise classification

6.1. Field calibration of noise measuring equipment

In order to prepare documentation of the noise reducing property of a surfacing, any CPX equipment used in the Danish SRS system must have carried out a supplementary calibration protocol, as described in the first generation system. This supplementary calibration protocol is mandatory and has been introduced to ensure that different equipment will give consistent and comparable results. The measurement method provides a correction for the influence of temperature on the resilience of tyres and hence on the measured noise levels. If any differences between results obtained by different pieces of equipment are encountered in this calibration, such differences are compensated for by a constant attributed to each piece of equipment. The supplementary calibration is carried out by annual measurements on a number of selected reference sections with known performance. Two CPX trailers have participated and measured simultaneously in these annual calibration measurements. The assignment of calibration constants is administered by an expert group under the Danish Road Standards Committee consisting of persons representing road administrations, asphalt industry and consultants, the national SRS group.

6.2. The use of classification in traffic noise prediction

The ageing of the pavement and the wear and tear from traffic causes vehicle noise levels to increase with time. Therefore, a classification value obtained for a new wearing course system may not be characteristic for the pavement during its entire service lifetime.

The exposure of road neighbours to traffic noise is most often assessed by calculation using a prediction scheme. Such schemes are normally based on default conditions concerning the road surface, for example the most commonly used pavement. Advanced prediction schemes have corrections one can use to take special pavement conditions into account when calculating the noise exposure for assessing the environmental impact of road traffic. A few of these are mentioned briefly in the following.

A fixed Danish practice for taking actual road surface conditions into account in noise mapping still needs to be defined. The Danish Road Directorate policy is to apply a noise reducing pavement when constructing a new road or when maintaining the road network in such cases, where the yearly average noise level L_{den} in residential areas or in recreational areas associated with residential areas exceeds 58 dB.

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

Reference is made to [Sandberg, 2011] for a summary of practices in a few other countries. In the Netherlands which is in the forefront on traffic noise reduction, pavements are classified via a "surface correction" C_{road} applied in noise calculation. The Dutch system requires SPB measurements at five or more trial sections on at least five different sites (individual road works) to determine C_{road}. The noise reduction is assumed to be the same throughout the pavement lifetime. The British system concerning lifetime average noise performance is based on the expectation that HAPAS procedures will assure an average noise reduction as given by the initial noise reduction multiplied by 0.7, but limited to a maximum of 3.5 dB. In Germany, the prediction of traffic noise levels is regulated by law. The system includes a correction D_{StrO} defined for a few types of pavement.

7. The second generation SRS system

The SRS system was launched in 2006 as a first generation system in order to promote the development of noise reducing wearing courses and contracting procedures. At the time it was clear that a revision would be needed in light of experience obtained during the first few years of its use. A second generation system hopefully will be approved by the Danish Road Standards Committee in time for the 2012 season.

An important reason for having a second generation system is that the reference tyres 'A' and 'D' in [ISO, 2000] have been out of production for a long time and they are no longer available. The old tyres have hardened so that they may no longer represent the tyres in the current vehicle fleet. So one challenge met in introducing a second generation Danish classification system is to define new reference tyres. The most probable choice is tyres often designated as Standard Reference Test Tyres (SRTT).

Another challenge will be to establish reliable relations between the CPX noise level measured with these new reference tyres and the noise levels produced by vehicles driving in normal traffic. The connection between the CPX noise level and the Statistical Pass-By (SPB) noise level is important in order to have a transparent system of noise classification accepted by road neighbours [Kragh, 2010].

Knowing that traffic noise levels increase with increasing pavement age it is appropriate to specify a period of time during which a wearing course shall be exposed to traffic before measurements are made to classify its noise characteristics. To illustrate this, Figure 4 shows measured CPX noise levels as a function of the pavement age during the first six weeks of service life of six Danish road sections built in August 2010 [Oddershede, 2011]. The increase in noise level was 1 or 2 dB during these first six weeks.

8. Conclusions

A national cooperative effort has created a system for the specification of noise reducing asphalt wearing courses. The first generation system has been applied with success since 2006. More than thirty products have been declared using the concept, which is used by both levels of road administrations in Denmark. One of the most important elements in the system is the field measurement of noise levels using the Close Proximity measurement method.

A second generation system is expected to be implemented for use in 2012. The revised system will build on the experience obtained from the first generation system.

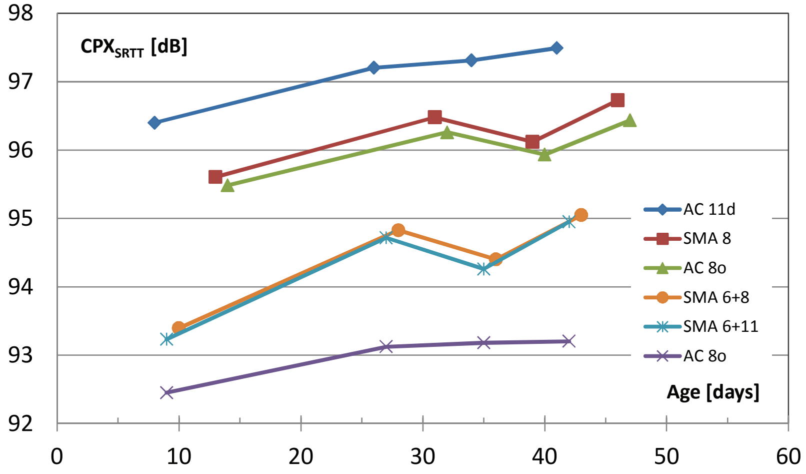

Fig. 4. CPX noise levels as a function of the pavement age during the first weeks of service of six road sections [Oddershede, 2011]

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References

ISO/CD 11819-2: Acoustics – Measurement of the influence of road surfaces on traffic noise – Part 2: The close-proximity method, ISO, 2000-12-13

Kragh, J. Noise Classification - Asphalt Pavement, Danish Road Institute /Danish Road Directorate, Technical Note 61, 2007, see www.roadinstitute.dk

Kragh, J. et al., Experience with new reference tyre for CPX measurement in pavement noise classification, Proceedings Internoise 2010, Lisbon 2010

Kragh, J. et al., OPTHINAL Final report, Danish Road Directorate/Danish Road Institute, Report 190, 2011, see www.roadinstitute.dk

Kragh, J. et al., Danish Road Directorate / Road Institute report on the preparation of the second generation SRS system (to be published), 2012

Roads. Noise reducing wearing courses (SRS). Collection of experience. Tendering procedures (in Danish), Road Standards Committee), January 2008

Oddershede, J., Early increase of noise from newly laid road surfaces, Paper presented at FEHRL Young Researchers Seminar; Lyngby 2011

Sandberg, U. et al., OPTHINAL State-of-the-Art Report, VTI report, see www.vti.se