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ROSANNE project: new procedure for noise characterization of road surfaces in Europe

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ABSTRACT

ROSANNE is a collaborative project in the 7th EU Framework Program which aims at harmonizing measurement methods for skid resistance, noise emission and rolling resistance of road pavements as a preparation for standardization. The project started in November 2013 and is developing and improving standards in the field of working group CEN/TC 227/WG 5. Regarding the influence of the pavement on the road traffic noise emission, the main objective is to combine the existing measurement methods of SPB (ISO 11819-1) and CPX (ISO/DIS 11819-2) into a stable and reliable harmonized pavement noise emission characterization method. A respective procedure is being developed within the project and its potential use for noise calculation methods like the one proposed by the CNOSSOS-EU project is investigated. The first two years of research focused on analyzing and comparing existing noise measurement methods to specify the noise properties of road surfaces as well as investigating the temperature influence of possible correction measures; respective results will be presented in a separate paper on this issue within this conference. Activities related to the compatibility with the CNOSSOS-EU calculation method and to the experimental validation are still ongoing. The present paper shows the current draft of the procedure developed.

Keywords: Tire/road noise measurement methods, standards on road surface characterization, ROSANNE project, 81.9, 52.3, 11.7.1

1. INTRODUCTION

Road surface characteristics have a significant influence on the emission and propagation of road traffic noise. The generation of tire/road noise is dependent on pavement texture and pavement porosity. Additionally, porosity leads to sound absorption properties of the pavement that may also reduce the sound propagation of the overall vehicle noise. In certain cases also the elasticity of the pavement may play a role. Pavement influence can lead to substantial differences in sound levels,

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associated with a given traffic flow and composition, from different road surfaces.

In order to successfully use low-noise pavements as noise abatement measures it is essential to accurately evaluate the acoustic performance of such pavements using a standardized procedure.

Currently standardized measurement methods, such as those detailed in ISO 11819 series (the Statistical Pass-By so called SPB (1) and the Close Proximity so called CPX method (2)). In some countries, national road surface characterization procedures exist and make use of one or both measurement methods; however, the methods are not uniformly and consistently applied across Europe and there is little commonality in the characterization procedures.

Furthermore, there are many different national methods for calculating or predicting environmental noise from road traffic that are linked to these acoustic pavement characterization procedures.

With the intended introduction of a common European environmental noise calculation method CNOSSOS-EU (3), a common acoustic pavement characterization procedure could be used to enable road planners, road administrators, contractors, and manufacturers of "low-noise" and other pavements to correctly assess the acoustic performance of road pavements.

Finally, a correct and uniform assessment of the acoustic properties of low noise pavements will help to reduce trade barriers between the Member States and stimulate research and technical development in this field.

2. OBJECTIVES AND USE OF THE NEW PROCEDURE

2.1 General scope of the procedure

The procedure relies on the application of an established measurement method and specifies the detailed conditions for its use to allow the determination of characteristic values for the acoustic performance of road surfaces with a given accuracy. Performance is characterized in absolute terms rather than with respect to a reference surface, as specifications for the latter differ from country to country, therefore avoids any additional uncertainty contribution. The procedure is intended to be suitable for the following applications:

1. For the **acoustic labelling** (i.e. the determination of initial acoustic properties) of generic or proprietary road surface products.
2. For the **conformity-of-production** (COP) assessment of newly laid surfaces, e.g. to assess compliance with acoustic labels and/or contract specifications, or to assess the homogeneity of the surface over its length.
3. For the **monitoring** of the acoustic properties of road surfaces over the course of their working lifetime, so as to help inform surface maintenance/replacement policies and increase understanding of the acoustic durability of road surfaces.

2.2 Main use of the new procedure

The values derived from this procedure are intended to be used for the following purposes:

a) To characterize the initial acoustic properties of a road surface type (the acoustic label) using a common procedure across Europe. Such an acoustic label will serve as a baseline for COP assessments and monitoring over the working lifetime of the surface. The label permits the comparison of different road surface types in an unbiased manner.

b) To verify the acoustic quality and homogeneity of a newly laid road surface.

c) To determine the acoustic quality and homogeneity of a road surface at a given point during its working lifetime; the collation of sufficient data on the same surface over time will allow predictions of acoustic behavior and may help to drive surface design/development.

In addition the procedure described within this document also allows:

a) The establishment of reference values for wider road surface 'families' or categories of surface types;

b) Derivation of input parameters for road surface corrections within environmental noise calculation methods (in particular, the harmonized CNOSSOS-EU method (3).

3. BASIC PRINCIPLES

3.1 General

The test method to be used for the current characterization procedure is solely based on the so called close proximity method (also abbreviated as CPX-method) as defined in ISO/FDIS 11819-2:2016 - Acoustics -- Measurement of the influence of road surfaces on traffic noise -- Part 2: The close-proximity method. In accordance to that the design and the calibration of the test vehicle should satisfy the requirements set out in Clause 9/ Annex E and Annex A respectively of ISO/FDIS 11819-2:2016. Figure 1a (left) and 1b (right) show exemplary two CPX trailers currently used in Europe for measuring the acoustic properties of road surfaces.

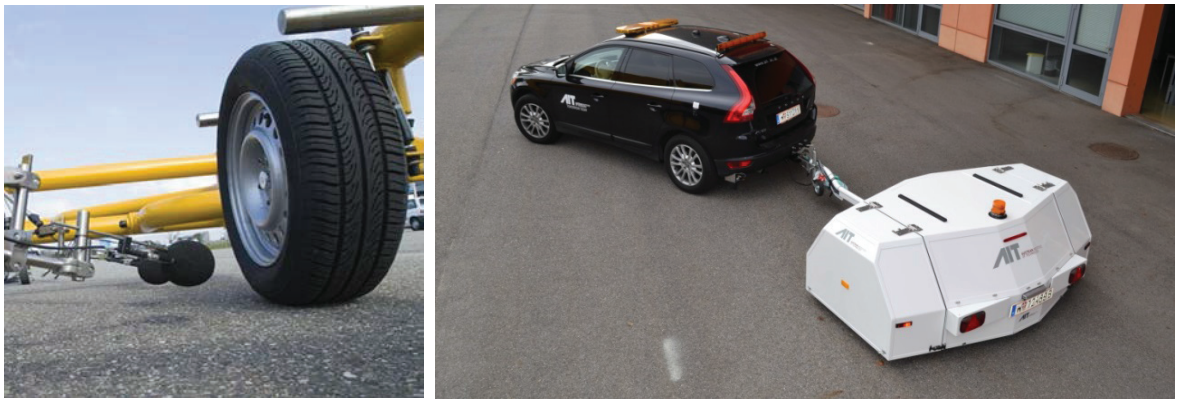

Figure 1: CPX trailer used for measuring road surface properties (left: the open trailer by DRD, right the closed trailer by AIT).

3.2 Road speed categories and associated reference speeds

Three categories of roads are defined with respect to the range of speeds at which the traffic flows; these are usually associated with the road type (e.g. motorways, rural highways) and/or areas through which the road passes (e.g. urban, suburban, rural, etc.). Each road speed category has an associated reference speed at which the CPX measurements shall be undertaken. The reference speeds for the three categories are defined as follows:

- **Low** road speed category: having a corresponding reference speed of 50 km/h
- **Medium** road speed category: having a corresponding reference speed of 80 km/h
- **High** road speed category: having a corresponding reference speed of 100 km/h.

As it was recognized that when testing on some roads, use of the appropriate reference speeds as defined above may be unachievable for either safety reasons and/or legislative reasons related to the testing vehicle (e.g. the reference speed exceeds the permitted speed for un-braked trailers), the testing organization must liaise in advance with the client and the responsible road authority to determine whether dispensation can be agreed to allow testing at the required reference speed or whether measurements should be performed at a lower (target) speed and the measured levels adjusted to give noise levels at the required reference speed. Any deviation from the required reference speed shall be fully justified within the test report. In addition to that and mainly for practical reasons for 'low' road speed category measurements, if the reference speed is unachievable, the lowest permissible target speed shall be 30 km/h, while for 'high' road speed category measurements, if the reference speed is unachievable, the lowest permissible target speed shall be 80 km/h.

3.3 Reporting acoustic performance: the Road Surface Noise Label (RSNL)

The acoustic performance of the road surface for the required shall be reported in terms of the CPX level(s) for car tires (denoted as LCPXP) and, if measured, the level for heavy vehicle tires (denoted as LCPXH).

If CPX levels are available for both reference tires, the acoustic performance may also be reported in terms of the **Road Surface Noise Label (RSNL)** defined by the following equation:

$$RSNL_{\text{cat}} = \left(W_{\text{P,cat}} \times L_{CPXP,v_{ref}}\right) + \left(W_{\text{H,cat}} \times L_{CPXH,v_{ref}}\right) \quad (1)$$

Where "cat" denotes the road speed category and $W_{\text{P,cat}}$ and $W_{\text{H,cat}}$ are weighting factors for the fraction of passenger cars and heavy vehicles in the traffic mix for a given road speed category as defined in Table 1. Those figures are tentatively fixed and subject for review by the ROSANNE consortium first and after that by CEN/TC227/WG5.

Table 1 – Tentative coefficients for traffic mix composition to be used for calculation of the RSNL values for each road speed category for both reference tires.

Road speed category	Reference speed (km/h)	$W_{\text{P,cat}}$	$W_{\text{H,cat}}$
Low	50	0.90	0.10
Medium	80	0.80	0.20
High	100	0.70	0.30

4. PROCEDURE FOR ACOUSTIC LABELLING

4.1 General

The acoustic characterization of the initial acoustic properties of a road surface type is also referred to as 'acoustic labelling'. The acoustic label should preferably be applied to 'new' surfaces, where there is no evidence of ageing effects. Nevertheless it is also possible to label an older road surface. The acoustic label shall be determined for all road speed categories where it is expected to be used.

4.2 Description of road surface type

The road surface under assessment shall be described in terms of the following material and physical properties: road surface type (both generic type and proprietary product name), date of laying, surface treatment (if relevant), aggregate size, layer thickness, void content (accessible or non-accessible), open-graded/ dense/ absorbing and (if relevant) binder type.

4.3 Selection of test sections

The test sections shall be carefully selected through consultation involving measurement institution and road manufacturers and shall be compliant with the site requirements set out in Clause 7 of ISO/FDIS 11819-2:2016. The different test sections should be laid using different day batches and by different crews.

4.4 Minimum number of test sections for noise labelling

A minimum number of two test sections shall be tested to determine the acoustic label. If the average LCPX levels on the sections are not within a permitted tolerance of 2.0 dB an additional section would be required. The average of the closest values should be chosen for the label.

4.5 Age, length and homogeneity of test sections

The test sections shall be tested between 2 and 6 months after paving is completed and prior to exposure to winter maintenance practices. The traffic volume on the test section shall be such that at least 50.000 vehicle passages have occurred in the test lane prior to testing.

The length of each test section shall be a minimum of 200 m without interruption of the road surface; ideally the length shall be 500 m or longer. For 90% of the 20 m segments within the test section the measured values of LCPXP,vr (and LCPXH,vr if applicable) shall not differ by more than 0.5 dB from the average values of the whole section.

4.6 Number of repetitions

CPX measurements shall be performed at least twice on each test section for each reference tire and for each applicable reference speed. In any case this number will be updated after the statistical analysis of the measurement campaign in spring 2016.

4.7 Test tires

CPX measurements shall be performed on each test section using all reference tires that are relevant to the intended use of the road surface type. If the road surface type under test is intended for use on roads carrying both light and heavy traffic, (passenger cars and trucks) both reference tires (tire P and tire H) shall be used. If the road surface under test is intended for use on roads carrying only light traffic (passenger cars only) then only tire P is mandatory (those tires are specified in the current version of ISO/TS 11819-3 (5)).

4.8 Reference speeds

Measurements shall be taken at the reference speeds corresponding to each road speed category where the surface is expected to be used, as specified in Section 3.2, unless dispensation is given to measure at different (lower) speeds.

4.9 Results

For each reference speed used, LCPXP,vr (and LCPXH,vr if measured) shall be determined as the arithmetic average of all of the measured sections. These average value(s) shall be reported as the appropriate road speed category acoustic labels for the road surface under assessment. The corresponding octave band frequency spectra shall also be reported.

Where measurements have been taken using both reference tires, reporting of the Road Surface Noise Label (RSNL) is optional. Section 3.3 includes information on how this shall be calculated.

5. PROCEDURE FOR CONFORMITY OF PRODUCTION

5.1 General

Conformity-of-production (COP) measurements using the following procedure are intended to assess compliance of a newly laid road surface with its acoustic label(s) or may be used to assess compliance with individual contract specifications and to set up as a benchmark for possible routine acoustic monitoring.

5.2 Description of road surface type

The road section under assessment shall be described in terms of the following material and physical properties together with other relevant data as follows: road surface type (both generic type and proprietary product name), date of laying, surface treatment (if relevant), aggregate size, layer thickness, void content (accessible or non-accessible), open-graded/ dense/ absorbing, binder type, as well as the declared acoustic label for the road surface type under test, LCPXP,vr and, if applicable, LCPXH,vr.

5.3 Selection of road section

The location and length of the road section to be assessed will most likely be advised by the customer and should be assessed for compliance with the site requirements set out in Clause 7 of ISO/FDIS 11819-2:2016.

5.4 Age and length of test sections

COP measurements on a road section shall be performed between 2 and 6 months after paving is completed and prior to exposure to winter maintenance practices. The traffic volume on the test section shall be such that at least 50.000 vehicle passages have occurred in the test lane prior to testing.

The length of the road section shall be a minimum of 100 m without interruption of the road surface.

5.5 Number of repetitions

CPX measurements shall be performed at least twice on the road section with reference tire P (in the case that also tire H is requested by the contracting party, CPX measurements shall also be performed at least twice with tire H). In any case this number will be updated after the statistical analysis of the measurement campaign in spring 2016.

5.6 Reference speed

For the purposes of conformity of production, a single reference speed shall be used as specified in Section 3.2, corresponding to the road speed category where the road section is laid, unless

dispensation is given to measure at a different (lower) speed. Ideally this will be the same test speed as used for defining the acoustic label for that road speed category.

5.7 Test tires

CPX measurements should be performed using reference tires P. The use of tire reference H is not mandatory. In any case measurements with tire H can be performed as additional information for the contracting party (those tires are specified in the current version of ISO/TS 11819-3 (5)).

5.8 Results

For the surface to be deemed compliant with the acoustic label(s), the measured values of LCPXP (and LCPXH if applicable) shall not deviate by more than 2.0 dB from the relevant acoustic label for 90% of the 20 m segments within the road section under test.

The average CPX level for all of the 20 m segments in the road section shall be reported, together with the standard deviation of the measurements.

For the purposes of using the data as a benchmark for routine acoustic monitoring, it is recommended to also report CPX levels every 100 m (calculated as the numerical average of five consecutive 20 m segments unless the road section is less than 300 m long, in which case levels should reported as the average of three consecutive 20 m sections.

6. PROCEDURE FOR ACOUSTIC MONITORING

6.1 General

The routine monitoring of the acoustic performance of road surfaces can provide data to increase understanding of how a surface degrades acoustically over its working lifetime and help to inform surface maintenance/replacement strategies.

6.2 Description of road surface type

The road section under assessment should ideally be described in terms of the following material and physical properties: road surface type (both generic type and proprietary product name), date of laying, surface treatment (if relevant), aggregate size, layer thickness, void content (accessible or non-accessible), open-graded/ dense/ absorbing, binder type, as well as the declared acoustic label for the road surface type under test, LCPXP,vr and, if applicable, LCPXH,vr and the initial acoustic performance (COP) if known, LCPXP,vr and, if applicable, LCPXH,vr.

6.3 8.3 Selection of road section

The location and length of the road sections to be assessed will most likely be advised by the customer and should be assessed for compliance with the site requirements set out in Clause 7 of ISO/FDIS 11819-2:2016. Location of the test sections should be specified and recorded with accuracy and without any ambiguity (e.g. using GPS coordinates) in order to ensure comparability with future measurements.

6.4 Age of road section and frequency of acoustic monitoring

The age of the road section will be based upon when the road surface was laid; it has no influence on whether or not CPX testing can be undertaken.

Whilst the frequency of monitoring is likely to be dictated by the specific requirements and budgets of road administrations, it is recommended that acoustic monitoring measurements are performed as follows:

- for dense surfaces: 3 years and 5 years after the surface is laid and then every 3 years after that, as recommended in (6).
- for porous surfaces: 1 year, 3 years and 5 years after laying, and then every 3 years after that, as recommended in (6).
- ideally, measurement should be made during the same season, i.e. with similar temperature conditions

6.5 Number of repetitions

CPX measurements shall be performed once for each reference tire. For monitoring purpose no repetitions are requested. In any case this number will be updated after the statistical analysis of the measurement campaign in spring 2016.

6.6 Reference speed

For the purposes of acoustic monitoring, a single reference speed shall be used as specified in Section 3.2, corresponding to the road speed category where the road section is laid, unless dispensation is given to measure at a different (lower) speed. Ideally this will be the same test speed as used for defining the acoustic label for that road speed category.

6.7 Test tires

CPX measurements should be performed using only reference tire P. The use of tire reference H is not mandatory. In any case measurements with tire H can be performed as additional information for the contractor (those tires are specified in the current version of ISO/TS 11819-3 (5)).

6.8 Results

CPX levels shall be reported for every 100 m segment in the road section (calculated as the numerical average of five consecutive 20 m segments unless the road section is less than 300 m long, in which case levels should reported as the average of three consecutive 20 m sections

A comparison with results of previous measurements shall be performed and reported where that data are available.

7. UNCERTAINITIES RELATED TO THE PROCEDURE

The proposed characterization procedure will be affected by various sources of uncertainty as illustrated in Figure 2. In the scope of the verification tests performed in ROSANNE, an analysis of these uncertainties shall be conducted. As the sources of unwanted (measurement) uncertainty are superimposed on the constructional variations of the road surface types that are to be determined by the classification procedure, these effects have to be considered together. The sources of uncertainty and variations are as follows:

1. Measurement uncertainty: The procedure will be based solely on CPX measurements, which are affected by different influences, such as air/road surface/tire temperature, tire hardness, trailer type, speed variations during the measurement, etc. These uncertainties may be different for the tires CPXP (measured with tire ASTM SRTT) and CPXH (measured with tire Avon AV4).
2. Construction variation within one contract section: The installation of the road surface may be affected e.g. by changes in weather conditions, varying temperatures of e.g. the binder during construction, thickness variation, inhomogeneity of mix, separations, and rolling, resulting in varying road surface textures, void contents, etc., and thus resulting in varying acoustic properties.
3. Construction variation between different contract sections: the installation of the road surface may be affected e.g. by different construction machinery, construction team, different quality of the asphalt, the type and shape of aggregate, compaction, etc., thus resulting in different acoustic properties of the road surface.
4. As the scope of the characterization procedure also includes enabling a bridge to the CNOSSOS-EU noise prediction scheme, and the input parameters of this calculation procedure are based essentially on SPB measurements, additional uncertainties need to be considered for the conversion to CNOSSOS parameters. In deliverable report D2.3 (7), the relationship between CPXP and SPBP as well as CPXH and SPBH were investigated. Correlations were found and a conversion procedure based on a linear regression analysis was established. This conversion procedure is also affected by uncertainties of the measurement data used and thereby of the uncertainties of the SPB and CPX method.

An important scope of the experimental validation currently ongoing is the investigation of these uncertainties. The measurements performed shall enable the project consortium to estimate the

standard deviations of the different sources of uncertainty and variation under the a priori assumption of normal distributions.

Due to this, focus shall be laid on a detailed description of a small number of different road surfaces instead of a superficial examination of a large number of road surface types. Thereby sound conclusions may be drawn on the finally needed number of measurements for the road surface characterization.

During the verification of the road surface characterization procedure, the dependency of the standard deviations s_P, s_H, s_Q, s_{homo} and the corresponding number of measurements M_P, M_H, N, Q will be described. It should be noted that, depending on the installation quality of road surface types, also high quantities of measurement sub-sections N and Q may not necessarily lead to low standard deviations of the road surface. In this context it is relevant to underline that:

1. for characterization purposes (acoustic labelling) s_Q and s_{homo} are to be determined;
2. for conformity-of-production (COP) s_Q is to be determined;
3. for acoustic monitoring purposes s_{homo} is to be determined.

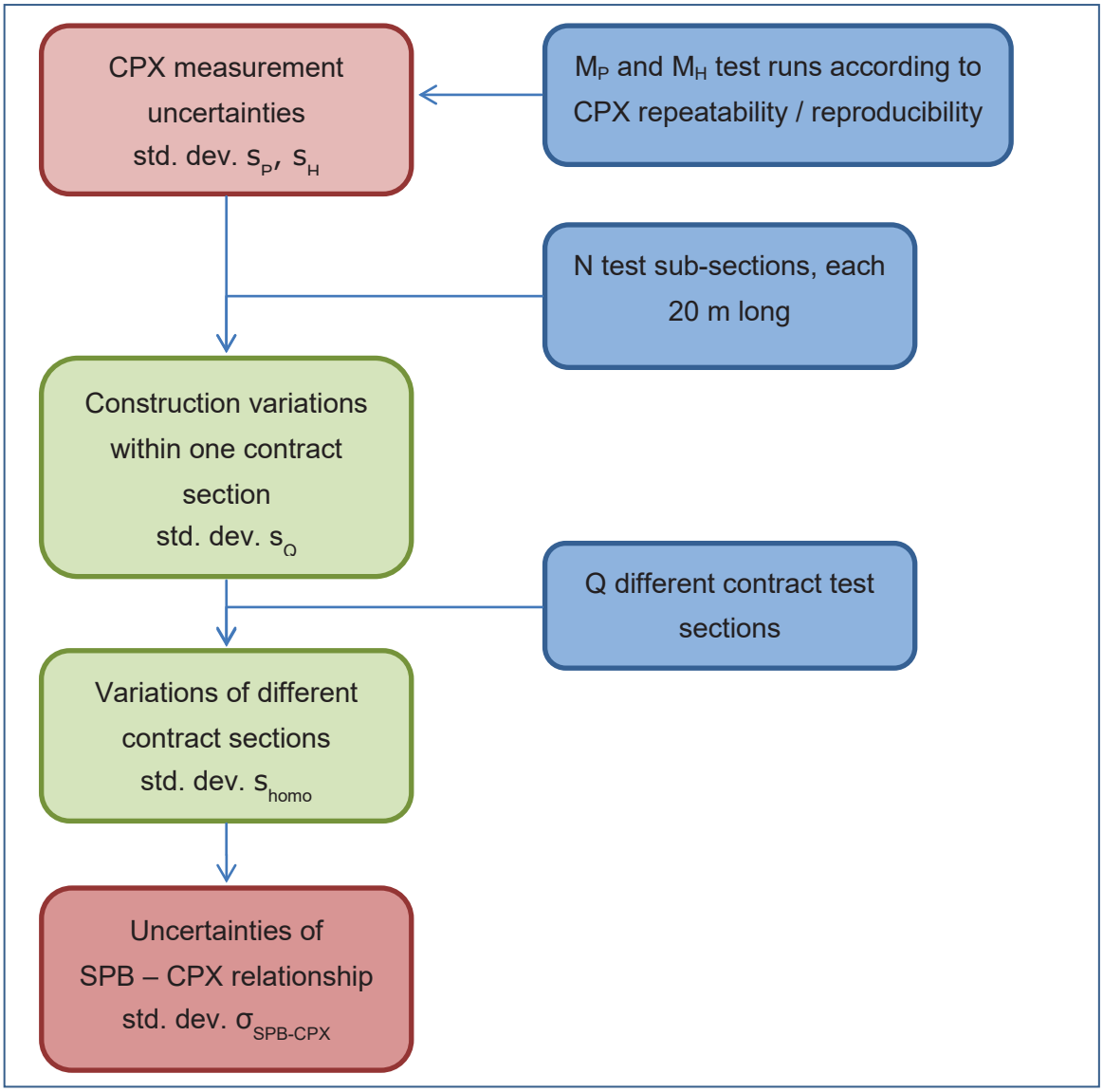

Figure 2: sources of uncertainty and variation for the characterization procedure including also a possible bridge to CNOSSOS-EU (3) (red: unwanted (measurement) uncertainties; green: acoustic variations of and within the road surface types, to be determined by the characterization method; blue: number of inputs for correct determination of uncertainties and variations).

8. CONCLUSION AND OUTLOOK

In this paper a new procedure for noise characterization of road surfaces in Europe was shortly presented. The procedure has been developed in the frame of the ongoing EU-FP7 project ROSANNE. As the experimental validation is currently ongoing, the procedure could be slightly updated during the summer 2016 and presented as a final output of the project during the final event in October 2016. The final version of the procedure will be submitted to the working group 5 of the TC 227 of CEN on road surface characteristics for possible adoption as a European standard. More detailed information on the ROSANNE project can be found in the deliverable reports (7) (8) on the project website: http://rosanne-project.eu/.

ACKNOWLEDGEMENTS

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