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THE INFLUENCE OF TYRES ON THE CPX METHOD USED FOR EVALUATING THE EFFICACY OF A NOISE MITIGATION ACTION

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The Italian Tuscany Region has decided to adopt the Close Proximity method (CPX) to evaluate the efficacy of using low noise surfaces as mitigation action against the noise pollution. This decision responds to the LEOPOLDO project indications, which aim to provide guidelines establishing criteria on materials and technologies. This set of recommendations is useful for municipalities, allowing them to plan noise mitigation actions based on low-noise road surfaces. However, the public authorities have also to deal with the fact that, within guidelines, it is also prescribed an acoustical performance monitoring for a 3 years period at least. The current release of the draft refers to a future third part of ISO 11819 for all details about the reference tyre to be used. This is necessary because the previous ISO release was considering just dimensions, kind of tread pattern and maintenance conditions as assessment parameters for the tyres. Several tyres available in the market comply with all the requirements, nevertheless choosing a brand rather than another one could influence results of practical verifications, considering that tyre dimensions and tread patterns are the main sources of variability for rolling noise. In this work are presented the results related to the influence of tyre choice for assessing the acoustical performance of a low-noise road surface. This was done comparing results obtained across several measurement sessions, which were repeated using different tyres. A discussion regarding the importance of verifying the noise mitigation action efficacy and about the most appropriate way to carry it out completes this paper.

1. Introduction

An important issue is the evaluation of the effectiveness of a specific noise mitigation action based on a low-noise road surface, which follows different rules from those used for noise pavement classification. Firstly, the mitigation action effect must be evaluated at the receiver. Secondly, a road surface, laid as mitigation action, can be several kilometers long and the spatial homogeneity of the installation has to be taken into account. Pass-by results [1] could be a proxy of the receiver exposure, however it describes only few meters of road. In order to evaluate the acoustical performances along the whole installation, it is necessary to shift to the CPX method [2] that, combined with pass-by measurements, it is recognized to be a suitable tool to reach the aim of both noise pavement classification and noise mitigation action assessment.

Concerning the tyre to be used in the CPX method, it is known that, for a certain road surface, tyre dimensions are the main source of amplitude variability for rolling noise [3], whilst the tread pattern has a clear influence in the emission spectrum [4]. Moreover, recently some studies had analyzed the tyre hardness influence [5][6][7], too. Thus, the characteristics of the tyre represent an important issue and unfortunately any specific combination between tyre and road surface has a clear influence on results [8]. In the previous draft of the ISO 11819-2 [9] tyre dimensions, kind of tread pattern and maintenance conditions were prescribed, whilst the current release [2] redirects to the ISO/CD 11819-3 [10], in preparation, for all details about reference tyres. The ISO committee that is writing this document suggests the SRTT and the Supervan AV4 [11].

Indeed, whilst waiting for the ISO/CD 11819-3, many laboratories used their own "reference tyre", choosing among many models, marketed by several brands, which comply with all requirements prescribed by the previous draft of the ISO 11819-2. Besides, using only the reference tyre would mean also reducing the possibility to correlate CPX data with pass-by results, above all in European countries where car fleets use smaller tyres.

The aim of this work is to investigate the influence of the tyre choice when the use of CPX method is extended for evaluating the effectiveness of a low-noise road surface laid as noise mitigation action. The study is carried out in the framework of both rubberized surfaces research [12] and LEOPOLDO project [13]. CPX data obtained using different tyres, in according to the ISO 11819-2:2006 draft, have been here collected and results have been compared.

2. Measurement protocol

The Tuscany Region has led the way in Italy, adopting the CPX method for the official test required to assess the efficacy of a low-noise road surface used as noise mitigation action, establishing that the acoustical performances must be monitored at least for three years after the laying. Requirements adopted in Tuscany derive from the LEOPOLDO project [13], which led to guidelines containing criteria on materials and technologies useful for municipalities to plan noise mitigation actions based on low-noise road surfaces. Within the project, a modified measurement protocol of the CPX method was developed [14].

In this paper, this modified protocol is used. Results are shown in terms of tyre/road noise levels, without strictly referring to the actual CPX indexes, but for the sake of simplicity they are hereafter named as LCPX values.

In case of a low-noise road surface laid as mitigation action, according to the procedure, the data acquisition during the measurement session has to be extended over a second road surface, chosen as "reference". In this way, the measurement conditions affect systematically both road surfaces, and the influence of the systematic sources of error are minimized. In particular, it means that the acoustical performances of a low-noise road surface will be assess comparatively to a reference one, typically a DAC 0/12 [15], through the "LCPX differential values" (the "differential criterion" as named in the following).

3. Results

Measurement site and tyres used

Measurements have been carried out on three sites using four different tyres, all of them compliant with the reference type B of the previous ISO release. All tyres were almost new, without any defects and with tread rubber hardness similar and about 63-64 Shore-A. In all tyres, tread pattern has a synchronous randomization, the two sides almost symmetric and bi-directional [4]. Model, brand and noise class are reported in Table 1.

Table 1: Details of the tyres used in this work and their tread pattern.

Id	Brand	Model	Noise class
T1	Bridgestone	Turanza T001	2 (71 dB)
T2	Continental	EcoContact 3	2 (69 dB)
T3	Kebler	Dynaxer HP3	2 (69 dB)
T4	Michelin	Energy XSE	2 (68 dB)

For each site, measurements have been carried out on the low-noise road surface (also “LN” in the following) and on the “reference” one. In two sites the reference surface is a part of the road surface pre-existing to the low-noise one installation, whereas in case of the third site the two road surfaces are coeval. The comparison between the three sites is out of the aim of this work. Details about road surfaces, reported in Table 2, are not relevant to evaluate differences due to tyres, which have been tested on the same road surfaces.

Table 2: Road and related reference surfaces surveyed in each site

Site	Low-noise	Reference
S1	ISO10844 optimized texture dense grade 0/8	DAC 0/12 pre-existing
S2	Dense grade 0/6 with expanded clay	DAC 0/12 pre-existing
S3	Asphalt rubber (wet process) gap grade 0/8	DAC 0/12 coeval

For each site, absolute LCPX levels averaged on the installations of both test road surface and reference one are reported in plotted in Fig. 1, grouped by road surfaces. All values are calculated at the reference speed v_0 = 50 km/h, corrected for air temperature [10] and provided with the 95% level of confidence (i.e. with a coverage factor k = 2).

In each site, differences of about 2-3 dB(A) are detected among tyres, without any relationship with the noise label reported in Table 1. In particular T3 shows always higher levels.

Tread pattern can generate differences both in frequency distribution and in total sound energy. In order to evaluate the influence of the tread pattern in the frequency distribution, in Fig. 2 are compared normalized spectra, for each low-noise road surface. A normalized spectrum has the total energy always equal to 0 dB and it is useful to compare the specific frequency behaviours of spectra containing different sound energy, highlighting the relative sound pressure levels of each band. Analyzing Fig. 2, the frequency distribution is lightly different among tyres, but not enough to justify the differences among absolute A-weighted broadband levels, nor does to explain why T3 shows always higher levels, which is probably due to the rubber compound.

Carrying on the analysis of results shown in Fig. 1, it can be noticed that differences between absolute broadband levels obtained using two different tyres are not always constant among road surfaces. It is easier to understand in Fig. 3, where differences computed for all couples of tyres for each road surface are shown. In case of couple T1 and T2 and in case of couple T1 and T4, differences vary significantly among road surfaces. Data uncertainties shown in Fig. 3 derive from the propagation of those related to the absolute values and they are provided with the 95% level of confidence.

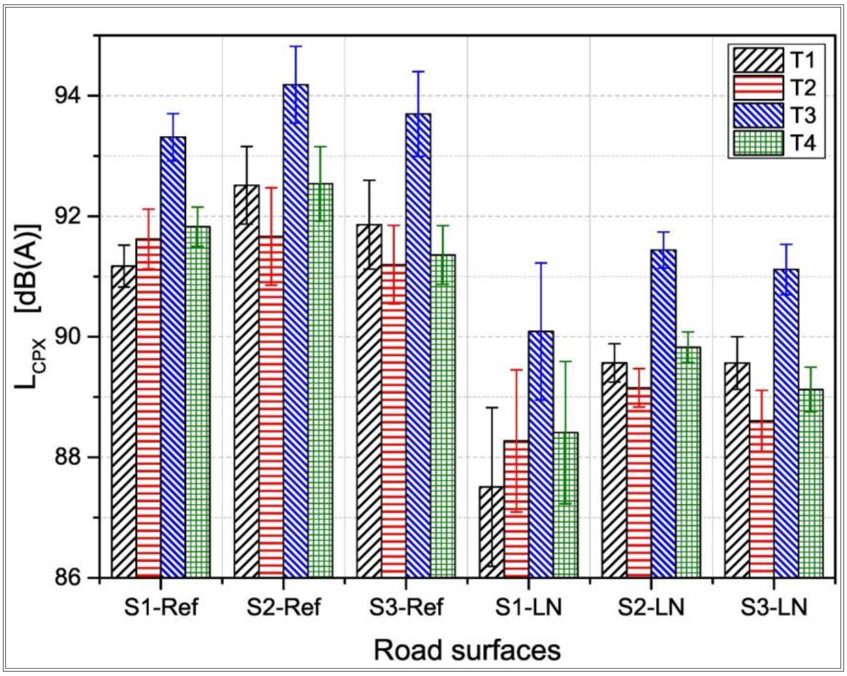

Figure 1: L_{CPX} levels averaged on the installations of every surface grouped by road surfaces.

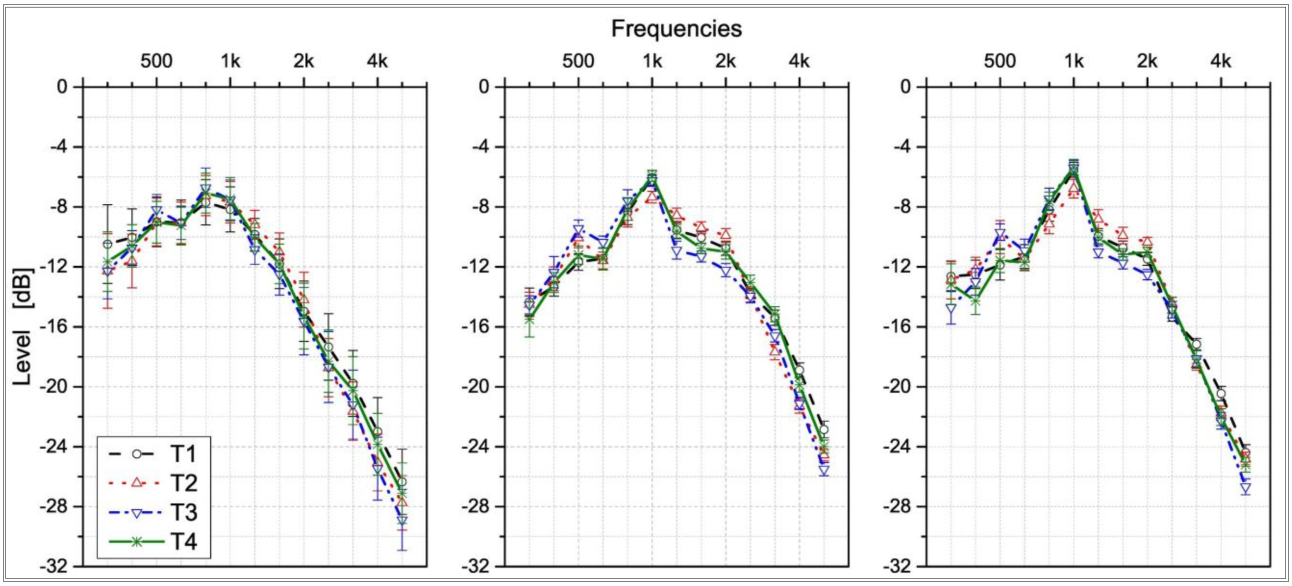

Figure 2: Comparison between normalized noise spectra obtained on the low-noise road surface in each site, depending on tires.

Results shown in Fig. 3 can be computed as the difference of the mean values of data obtained for each tyre along the two road surfaces or averaging the differences between data obtained per each segment using two tyres. Even though both averaging calculus are weighted by the uncertainty, results do not change significantly.

Data shown in Fig. 1 and Fig. 3 have two outcomes: first of all, it is confirmed the influence of each specific tyre/road configuration on noise levels, without any clear relationship among tyres used and levels recorded.

As a matter of fact, differences computed for all couples of tyres show a better agreement for low-noise and reference surfaces of the same site. This is a confirmation of the high influence of the measurement conditions on tyre/road noise measurements, which will be minimized applying the differential criterion.

Even thought the differences among absolute values are also due to the measurement conditions influence, the CPX results obtained using just one tyre, cannot be a suitable indicator to describe the actual tyre/road noise emission due to the car fleet noise, since each vehicle presents a different sound level emission caused by the different tyre/road configuration.

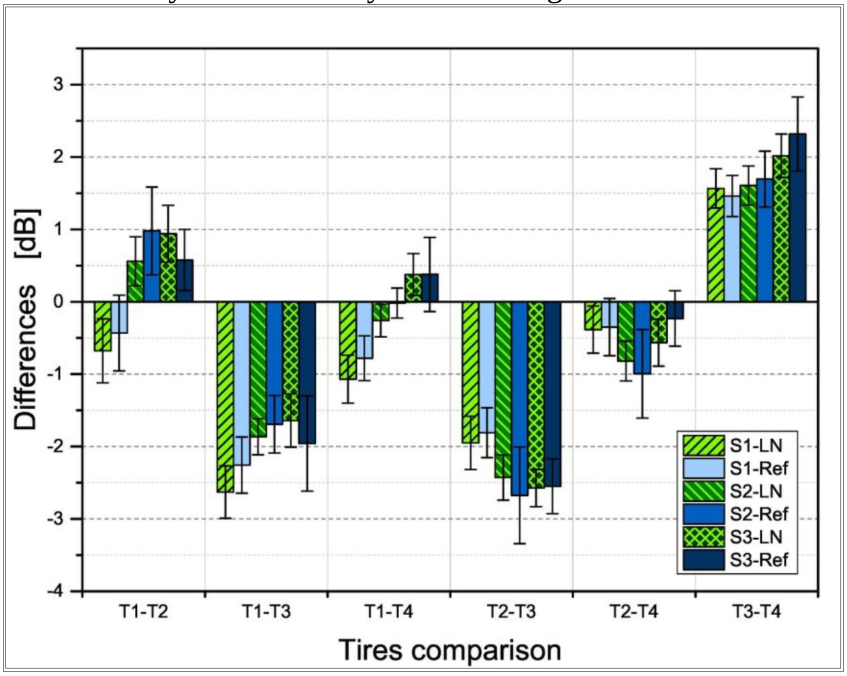

Figure 3: Differences between tires, calculated for every couple and for each road surface.

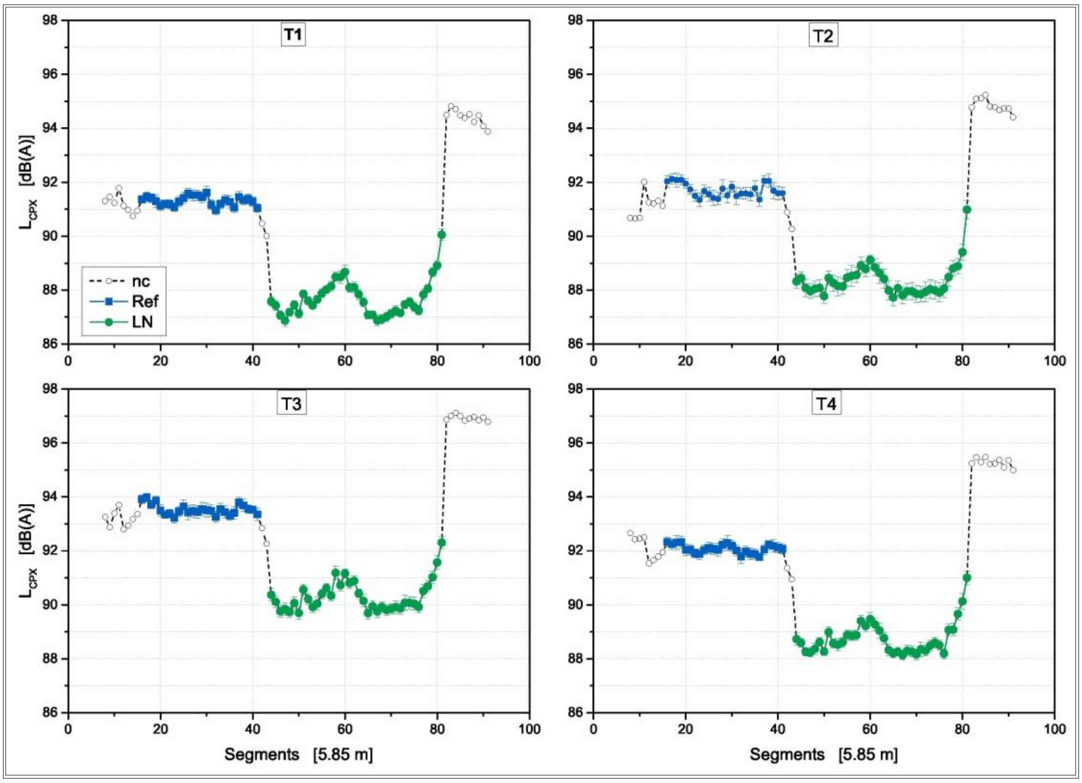

Figure 4: Spatial curve trend of sound levels obtained in case of the site 1 using the four tires. In blue is indicate the Reference road surface, in green the low-noise one.

Moreover, it is worth considering the role of the uncertainty having in mind the aim to assess differences of performances. The main part of the uncertainty is due to the spatial homogeneity. The spatial distribution of sound levels is mainly due to the road surface inhomogeneity, caused by physical characteristics as for example the texture profile. Changing the tyre does not cause any significant differences. In fact, in each site, data show the same spatial distribution of sound levels, independently from the tyre used, as here shown in Fig. 4 in case of the site 1.

In Fig. 5, the uncertainties related to the LCPX mean values are shown for each tyre and each road surface. It can be noticed that the uncertainties vary significantly, showing differences among road surfaces (Fig. 5a), however turning out to be quite constant among tyres (Fig. 5b).

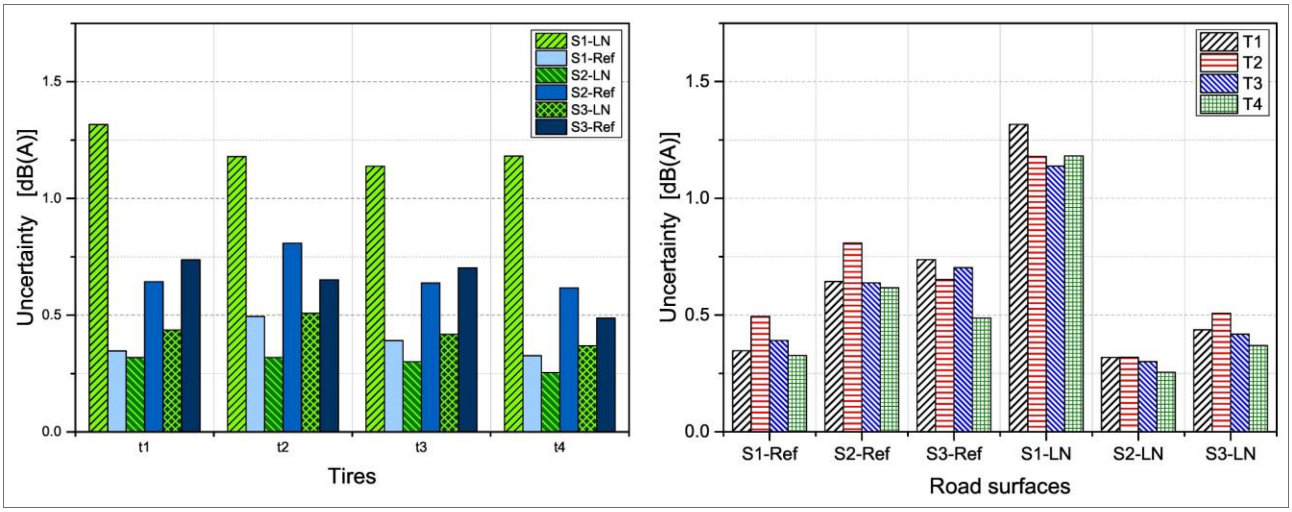

Figure 5: Uncertainties related to the LCPX mean values, for each tyre and each pavement. In the left (a), uncertainties are grouped by tire, on the right by road surfaces (b).

Thus, the third outcome of this analysis is that the spatial homogeneity can be described in terms of LCPX uncertainty without necessarily using the reference tyres as required in the Annex H of the ISO 11819-2.

Analysis of LCPX differential values

Differential values obtained, computing the differences between the low noise road surface levels and the reference ones, for all sites per each tyre are reported in Fig. 6. The *differential criterion* allows to describe the acoustical performance of the low-noise road surface better than the analysis of the LCPX absolute values, because differential ones do not depend on the tyre and are not influenced by the measurement conditions.

Anyway, differential values reported in Fig. 6 turn out to be equal among tyres, only considering the related uncertainties, which are computed as propagation of the ones related to the absolute levels.

Providing a mean value without the related uncertainty would obviously have no significance, because it is a part not negligible of the result itself and has to be declared. Hence, in order to answer to the question about if the differential values are not influenced by tyres, further analysis can be carried out, starting from the purpose of the mitigation action assessment.

For planning a noise mitigation action, a public administration needs to know how many decibels the installation of the low noise road surface is able to lower at the receiver. Noise level lowering has necessarily to be defined in comparison with another road surface. According to the idea of an absolute reference road surface, followed by the noise pavement classification, the S1-ref one, which has the lower related uncertainty, can be used and the differential values can be computed for the three low-noise road surfaces for each tyre. Results are reported in Fig. 7.

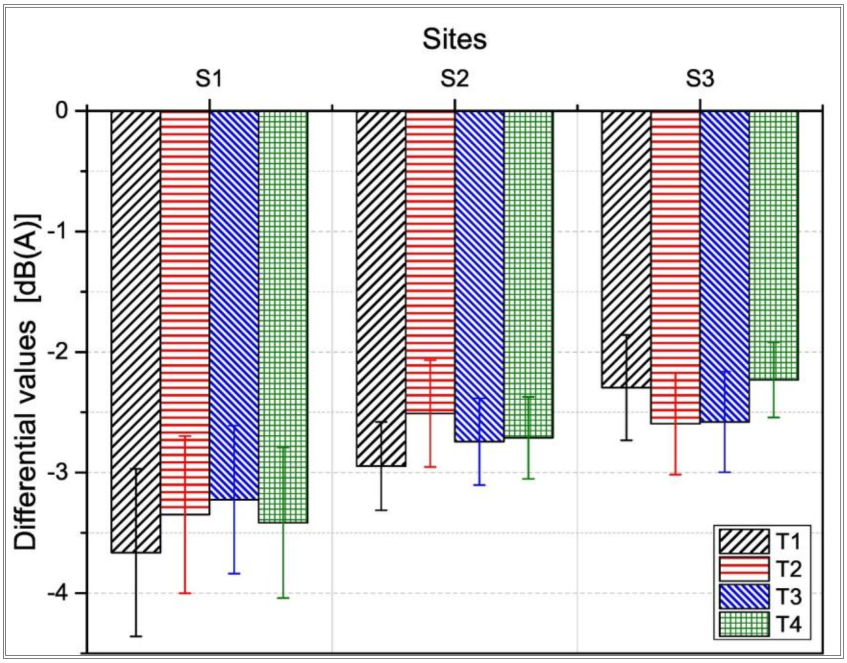

Figure 6: LCPX differential values obtained as difference of low-noise road surface results and reference ones for all sites per each tire

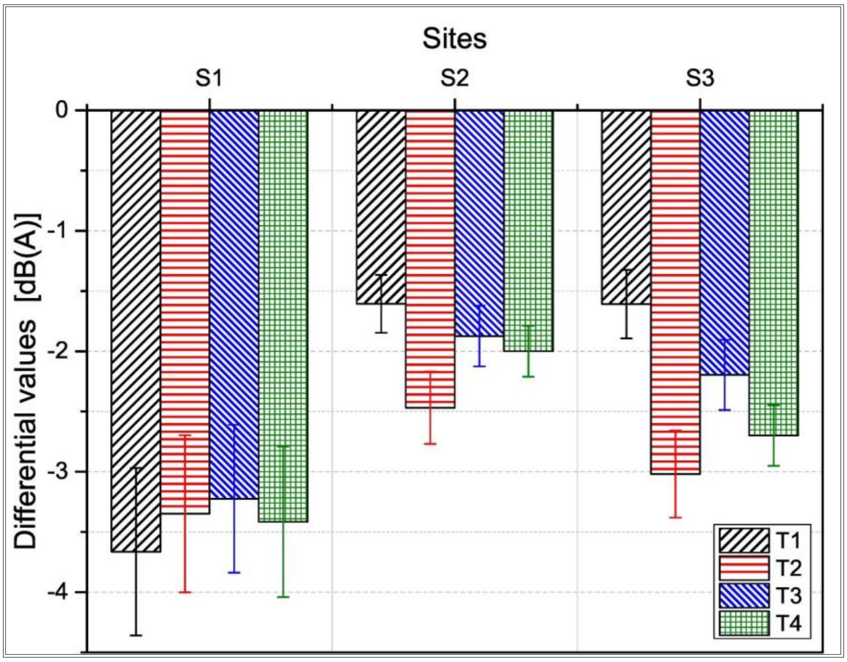

Figure 7: Differential values obtained for the three low-noise road surface, using the S1-Ref as common reference.

4. Conclusions

Among other things, CPX measurements allow to highlight the spatial homogeneity of the installation, directly related to the quality of the laying work, but results depend on specific tyre/road configuration. The influence of the tyre, mainly due to dimensions and tread pattern, on tyre/road noise levels depending on the road surface characteristics is still subject of research. Aiming to extend the CPX method for evaluating the effectiveness of a noise mitigation action based on a low-noise road surface, the problem about the choice of the tyre has to be faced. At this purpose, the measurements presented in this paper have been carried out on several sites with different tyres. Results show that road surface acoustic performances cannot be correctly evaluated using just one tyre. This is true unless a differential criterion is applied, using as term of comparison a reference road surface laid on the same site, which allows to monitor the temporal trend of the road acoustical performance. New additional studies will be necessary to analyze the advantages of using several tyres in a new procedure suggested, in order to correlate CPX results with real reduction of noise level at the receiver.

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