# CPX NOISE MEASUREMENTS IN DIFFERENT ROAD SURFACES

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## ABSTRACT

One of the aims of Directive 2002/49/EC as stated in article 1 is to define a common approach intended to avoid, prevent or reduce the harmful effects due to exposure to environmental noise.

Within this framework, the European Commission is working on the assessment of road traffic noise. The noise production of a vehicle is defined by the two main parameters - category, speed - and it also depends on several environmental or specific effects. One of them is the type of road surface, as it can lead to differences in sound levels up to 15 dB for the same traffic flow and composition. Therefore, it becomes of the highest importance to know the influence of the different road surfaces in the vehicle noise emission. At this moment, there is also an open debate within the EU whether to develop some kind of noise classification procedure for the different road surfaces or not.

In relation to these subjects, CEDEX is working on the measurement of tyre-road noise with the CPX method in several road surfaces in the Spanish National Road Network. The CPX method, as stated in the ISO/CD11819-2, allows measuring the influence of surface characteristics on tyre-road noise.

## 1. INTRODUCTION

The reduction of tyre-road noise emission is one of the challenges of road researchers. With this purpose, the Centro de Estudios del Transporte from CEDEX is very concerned about the factors of road surfaces that influence the emission of traffic noise. Therefore, CEDEX participates actively in different standardization working groups on this subject, and it is one of its interests to investigate the possibility and scope of a pavement noise emission classification in Europe.

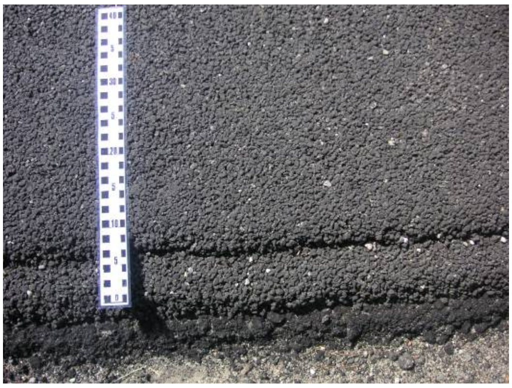
These concerns are shared by the Spanish General Directorate of Roads, which has commissioned CEDEX to test several road sections and study their evolution with time from the point of view of noise emission. Due to the results obtained in some roads where sound pressure levels vary highly in the same type of surface, CEDEX has been asked to investigate whether this variability could be explained by the possible influence of other surface characteristics. The Ministry of Public Works is also interested in improving its knowledge about the noise emission behaviour of road surfaces built with polymer or crumb rubber modified bitumen.

Within this framework, CEDEX has carried out measurements with the CPX trailer in several road surfaces (figure 1). Some of them are being widely used in Spain (asphalt concrete, asphalt concrete for very thin layers and porous asphalt) and some others are experimental ones (double layer porous asphalt). The results of these measures are presented in this paper as well as the possible influence of its characteristics (type of binder - polymer or crumb rubber bitumen -, voids, thickness of the layer) in noise emission. In some cases, unevenness and macrotexture have also been measured in order to try to determine if they are correlated with the sound pressure levels. In addition, some of the test sections have been measured several times. The analysis of all these data has led to some interesting findings that are presented in this paper.

BBTM 11B.

AC 16 surf S.

Porous Asphalt.



Double Layer Porous Asphalt.

Figure 1 – Detail images of different types of surface layer.

## 2. CPX EQUIPMENT

Traffic noise is produced by the following sources: engine noise, aerodynamic noise and rolling noise. It is generally accepted that for speeds over around 40 km/h (for light vehicles) and around 50 km/h (for heavy vehicles) the dominating source is the tyre-pavement noise (rolling noise).

The CPX equipment measures the noise produced when the tyre rolls over the pavement surface by means of at least 2 microphones that are located at a very short distance from the source. CEDEX CPX equipment (figure 2) has two semi anechoic chambers that allow isolating this noise from the outside environment. Thus, the measuring conditions are the most similar to the measurements that would take place in the free field, without the influence of the rest of the traffic or any other external source.

Figure 2 - CEDEX CPX equipment.

The tyres used are the ones that have been recommended by the ISO/TC43/SC1/WG33 “Measuring methods for comparing traffic noise on different surfaces”: Tyre A is the Uniroyal, Tigerpaw, 225/60-R16 (SRTT), and Tyre D is the Avon, Supervan AV4, 195-R14C tyre [6].

## 3. CPX METHOD

ISO/TC43/SC1/WG33 is actively working in the development of ISO 11819-2. However, at this moment the standard is at the stage of Committee Draft, which means that it still has to be submitted to vote by the standardization bodies prior to its approval as a Draft International Standard (DIS). In the practical, this has been a problem since there is not an official standard to be used. CEDEX has been working according to the ISO/CD 11819-2:2000 until September 2009, when it was decided to follow the ISO/CD 11819-2:2008 [2], due to the very relevant changes that had been introduced into it.

As one of CEDEX objectives is to follow the evolution with time of some road sections in relation to noise emission, it is important that all measurements are done according to the same method. This was not possible due to the change in the CPX calculation method, as it has been previously explained. Also the reference tyres were changed; therefore it was decided to do as follows:

- For those sites where the initial measurements had been done according to ISO/CD 11819-2:2000, a “connecting” measurement would be done. This means that two consecutive measurements were done: September 2009 (according to ISO/CD 11819-2:2000) and October 2009 (according to ISO/CD 11819-2:2008). This way, although the measurements can not be directly compared one with the other, the increments that were produced within one year could be assessed, due to the fact that measurements in 2008 and September 2009 follow the same draft, ISO/CD 11819-2:2000, and measurements done after October 2009 also follow the same draft, in this case, ISO/CD 11819-2:2008.
- For those sites where all the measurements were done after October 2009, the CPX method is according to ISO/CD 11819-2:2008.

Some other changes have been done to the drat standard since 2008, but it has been preferred not to modify the calculation method again in order to avoid further problems.

## 4. MEASUREMENTS

CPX measurements (table 1**)** have been performed at reference speeds of 50 and 80 km/h, depending on the type of road. Test sections showed no cracking of any kind.

Table 1- CPX measurements.

| SITE | CLIMATE | ROAD SURFACE | DATE | AGE |
|---|---|---|---|---|
| Site 1 | Dry | Porous Asphalt | sep-08 | 0 |
| | | Double Layer Porous Asphalt | sep-09 | 1 |
| | | | oct-09 | 1 |
| | | | sep-10 | 2 |
| | | | oct-11 | 3 |
| Site 2 | Dry | BBTM 11B | sep-08 | 0 |
| | | | sep-09 | 1 |
| | | | oct-09 | 1 |
| | | | sep-10 | 2 |
| | | | oct-11 | 3 |
| Site 3 | Dry | BBTM 11B | nov-10 | 0 |
| | | AC22 surf S | oct-11 | 1 |

| SITE | CLIMATE | ROAD SURFACE | DATE | AGE |
|---|---|---|---|---|
| Site 4 | Dry | Porous Asphalt | nov-10 | 0 |
| | | Double Layer Porous Asphalt | | |
| | | AC16 surf S | | |
| | | AC22 surf S | | |
| Site 5 | Dry | Porous Asphalt | oct-09 | 0 |
| | | Double Layer Porous Asphalt | may-11 | 2 |
| | | BBTM 11A (conventional bitumen) | | |
| | | BBTM 11A (rubber bitumen) | | |
| | | BBTM 11A (modified bitumen) | | |
| | | BBTM 11A (rubber modified bitumen) | | |
| Site 6 | Wet | BBTM 11B (conventional bitumen) | nov-09 | 0 |
| | | BBTM 11B (rubber bitumen) | may-11 | 2 |

Air temperatures were between 15 and 40 ºC, and the corresponding temperature correction has been done in every case, according to ISO/CD 11819-2:2008. Therefore the temperature correction factor was 0.05 dB(A) per degree centigrade. However, this coefficient might be too low as it has been pointed out in some recent studies [1]. CEDEX has also found that in some cases the results obtained when using this correction lead to strange values. This subject is being studied in ISO/TC43/SC1/WG27 and WG33, in order to modify these values in the final ISO 11819-2.

## 5. RESULTS

An overall view of the results obtained shows a great spread of the values for the same type of road surface (figure 3). This paper is intended to throw some light in the understanding of the results obtained.

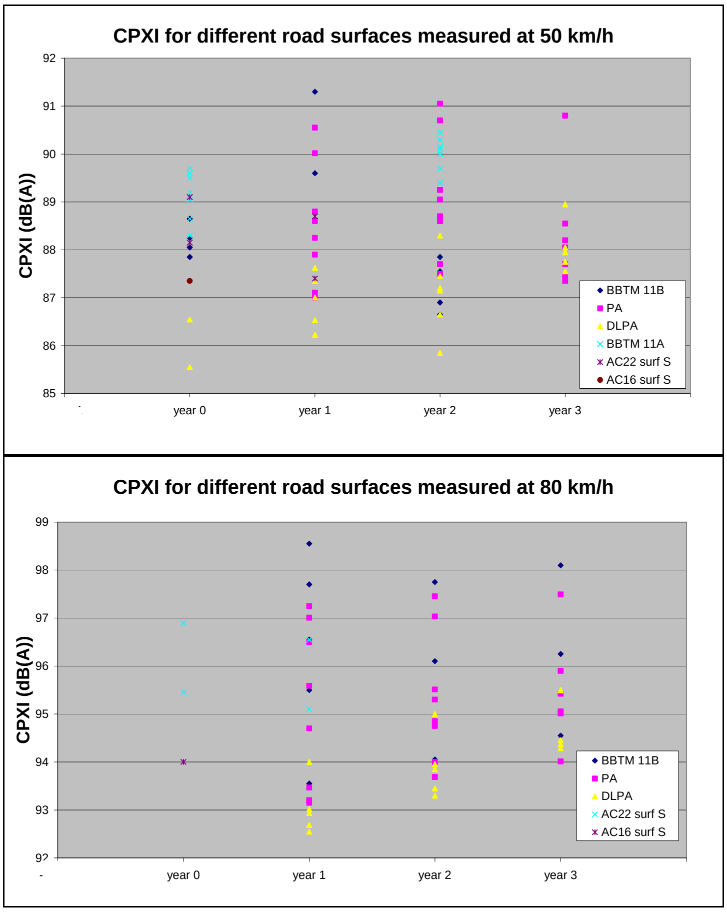



Figure 3 - CPXI in different road surfaces, at 50 and 80 km/h (ISO/CD 11819-2:2008).

With the purpose of better assessing the results obtained, they have been grouped by type of road surface (taking into account that within each type of surface they had different characteristics) and then, the main factors that influence the CPXI have been studied. Also, the influence of the type of bitumen has been analysed, due to the fact that crumb rubber and polymer modified binder have been used in some of the test sections that appear in the graphs above.

## 5.1 POROUS ASPHALT

Measurements have been carried out in three different sites along the south of Spain (sites 1, 4 and 5) including eight sections with different types of porous asphalt surfaces. The differences between them refer to porosity (ranging between 17.2 and 20.2%), layer thickness (ranging between 3.0 and 4.0 cm) and maximum aggregate size (from 5 to 11 mm). These factors are analyzed below. Also, different bitumen and construction equipment was used, but this has not been addressed in this case. Some of these test sites have been built with experimental purposes, pursuing noise reduction. Sections have been measured at 50 and 80 km/h.

Site 1 was firstly measured in 2008, when the road was built; therefore the data for year 0 were processed according to draft ISO from 2000. When these values are used, it is reflected in the graphs as year 0*. These data have been used for the assessment of the influence of porosity and layer thickness, because more information on this regard was available, but it has to be pointed out that they are not directly comparable to those obtained in 2009 and afterwards, due to the fact that they were processed using the draft ISO from 2008. The other two sites (sites 4 and 5), were measured for the first time in

2009 and 2010. These data have been used for the study of the influence of maximum aggregate size.

### 5.1.1 *Influence of voids content*

The analysis of the influence of voids content has been done with CPX measurements carried out in 2008 in Site 1, few months after the road sections were laid. It has been assumed that any study of porosity influence on sound pressure levels should be done with measurements done in year 0, due to the fact that the percentage of voids is likely to decrease throughout the years, mainly because of colmatage and post compaction caused by traffic.

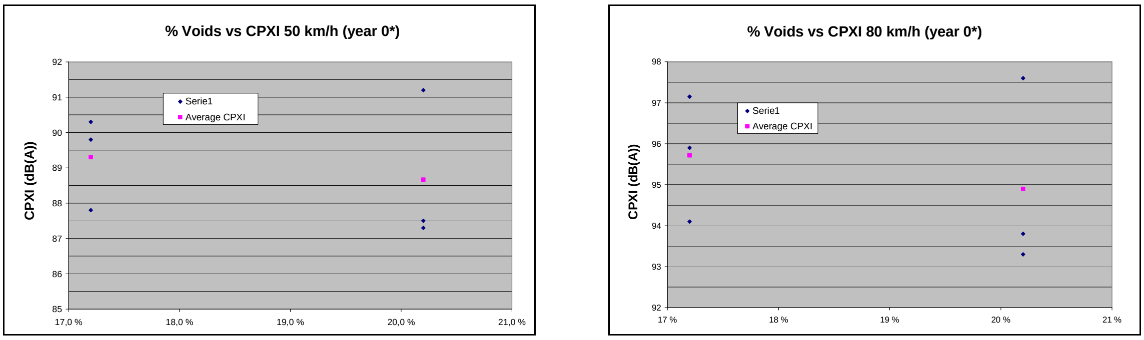



Figure 4 - CPXI vs voids percentage for PA sections, at 50 and 80 km/h, year 0*.

As it can be seen in figure 4, the average CPXI value decreases when the percentage of voids increases. The difference between PA layers with 17.2% to 20.2% voids is of 0.6 dB(A), when measurements were carried out at 50 km/h and 0.8 dB(A), at 80 km/h. This is a reasonable result as it seems evident that when there are more voids, a larger part of the noise generated is absorbed within these voids. However, not all the results are consistent and it can be found that in some cases the individual CPXI value is higher in layers where the percentage of voids is larger. This can be explained by the fact that other factors influence the CPXI, like for example layer thickness and maximum aggregate size.

### 5.1.2 *Influence of layer thickness*

Results show that when the porous asphalt layer is thicker, the average CPXI obtained is lower. This effect seems to be maintained at least within the first year after the road is open to traffic. Only in year 3, at 80 km/h, CPXI in the wider layer (4.0 cm) gives a result slightly higher than the averaged value of the test sections whose porous asphalt layer was 3.5 cm.

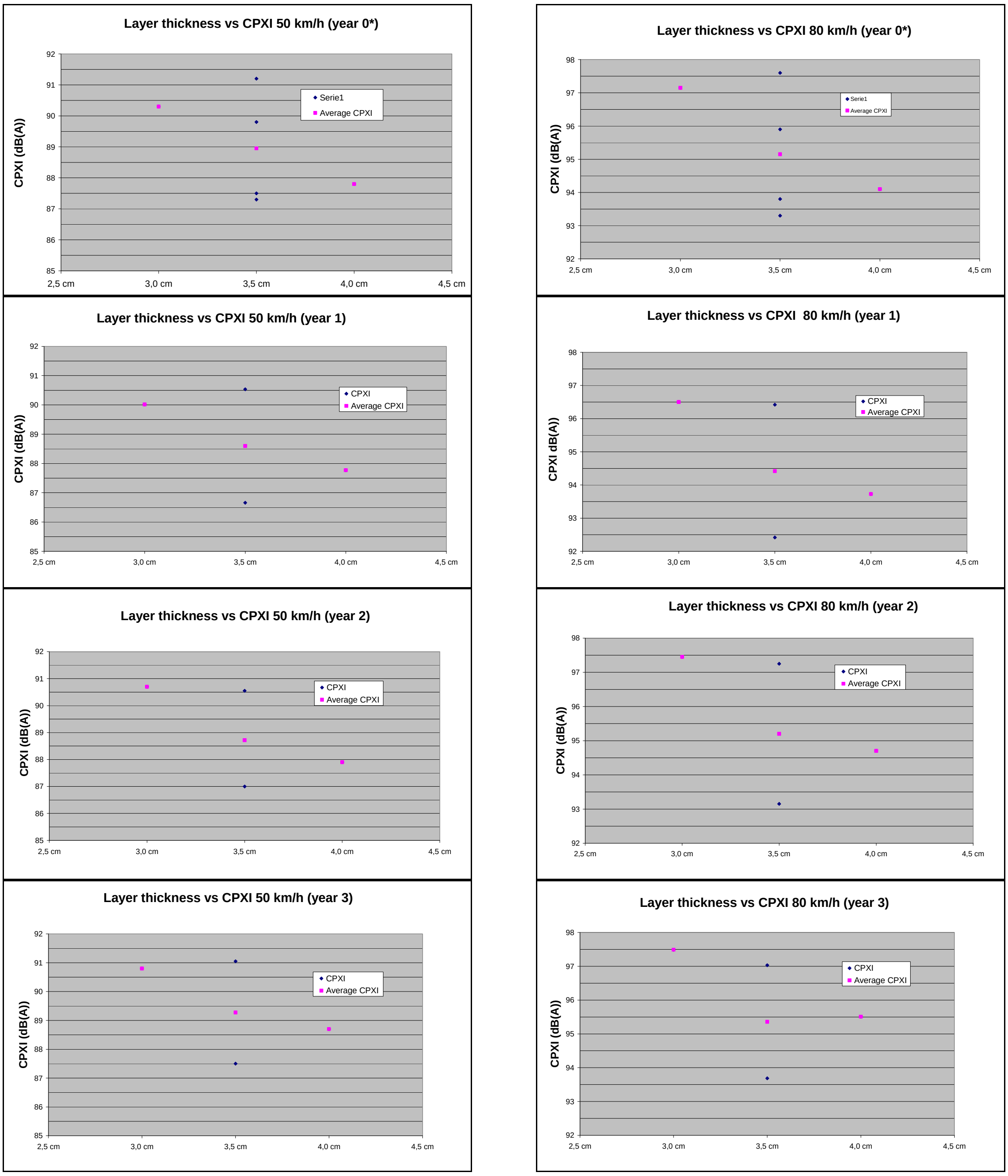



Figure 5 – CPXI vs layer thickness for PA sections, at 50 and 80 km/h, year 0* to 3.

### *5.1.3 Influence of maximum aggregate size*

Below it can be seen the influence of aggregate size. Only data for year 0 were available.

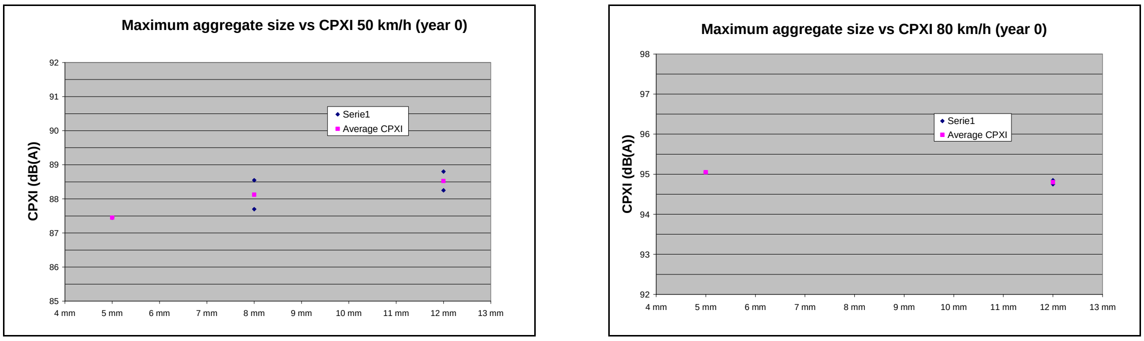



Figure 6 - CPXI vs maximum aggregate size for PA sections, at 50 and 80 km/h, year 0.

When CPXI is measured at 50 km/h the results clearly show that larger maximum aggregate sizes give higher average CPXI values. At 80 km/h the results are quite similar for both surfaces. In this case, it has to be taken into account that less measurements have been done at 80 km/h than at 50 km/h.

### *5.1.4 Influence of layer age*

Figure 7 shows that the overall tendency is that the CPXI increases with the age of the surface. It has to be noted that the total average increment between year 0 and year 3 is 1.0 dB(A) when measurements were done at 50 km/h, and 0.6 dB(A) when carried out at 80 km/h. These results seem too low, and it might be due to the fact that for Site 1 year 0* data have not been represented in the diagram whereas data for year 1, 2 and 3 have (because of the changes in the CEDEX CPX equipment and methodology), which can obviously distort the results. However, it has to be pointed out again that there is a large variability in the results, as high as 4.3 dB(A). This can be consequence of the very important differences between the porous asphalt surfaces studied and also of the variability of the CPX method.

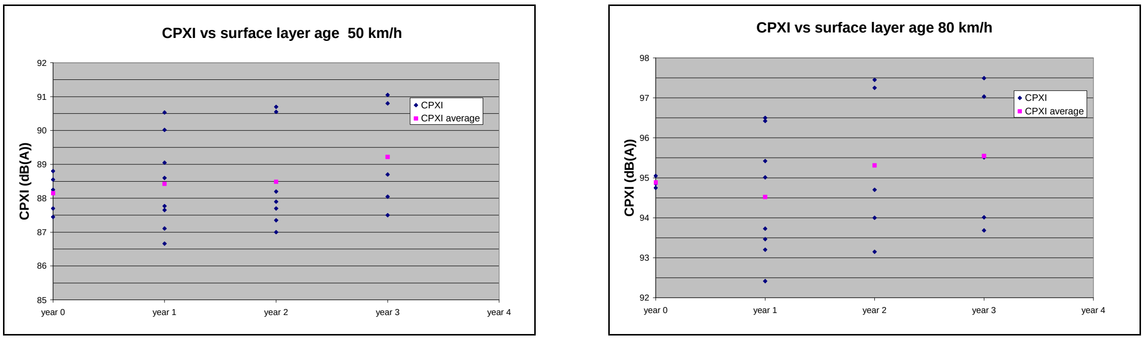



Figure 7 - CPXI vs surface layer age for PA sections, at 50 and 80 km/h.

## 5.2 DOUBLE LAYER POROUS ASPHALT

Measurements have been carried out in three different sites (sites 1, 4 and 5) including eight different types of double layer porous asphalt surfaces (DLPA). The difference between them refer to porosity in the second layer (ranging between 20.2 and 28.0 %) being the porosity in the upper layer around 20.0 %, total layer thickness (going from 6.5 to 7.0 cm) and maximum aggregate size in the upper layer between 8 and 11 mm, and in the second layer between 8 and 16 mm. These factors have been analyzed below. As it was commented in the previous chapter, the differences regarding type of binder or construction procedures have not been addressed here. Some of these test sites have been built with experimental purposes, pursuing noise reduction. Measurements were carried out at 50 and 80 km/h.

### *5.2.1 Influence of voids content*

All double layer porous asphalt sections studied had approximately the same percentage of voids, around 20.0%, in the upper layer. This is due to the fact that the objective of DLPA is that the upper layer performs as a filter or protection preventing the bottom layer of being clogged. On the contrary, bottom layers analyzed did have different content of voids, around 20.0% and 28.0%, pursuing the maximum noise reducing effect, so this has been the main parameter analyzed regarding the porosity of the DLPA. In this case, the analysis has been done for years 0* to 3.

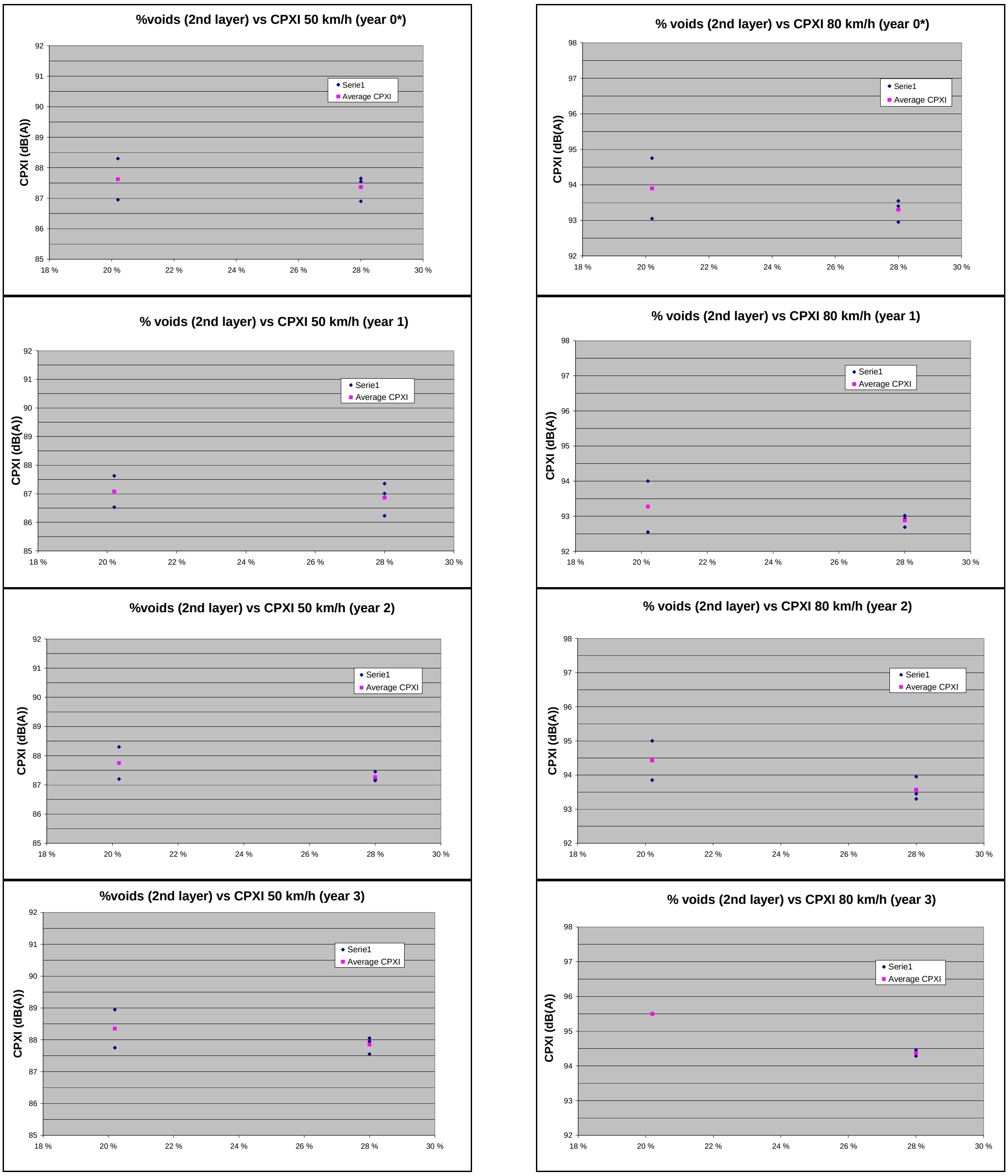


Figure 8 - CPXI vs voids percentage for DLPA sections, at 50 and 80 km/h, year 0* to 3.

A void percentage of 28.0% in the bottom layer results in road surfaces that are less noisy than those with 20.0% of voids. The average difference in the CPXI is bigger for measurements carried out at 80 km/h than at 50 km/h and also it increases as time increases (from 0.2 dB(A) and 0.6 dB(A) on newly laid surfaces at 50 and 80 km/h, respectively, to 0.5 dB(A) and 1.1 dB(A) in year 3, at 50 and 80 km/h).

### *5.2.2 Influence of layer thickness*

The sections measured had two different layer thicknesss, whose influence is analyzed in the graphs below.

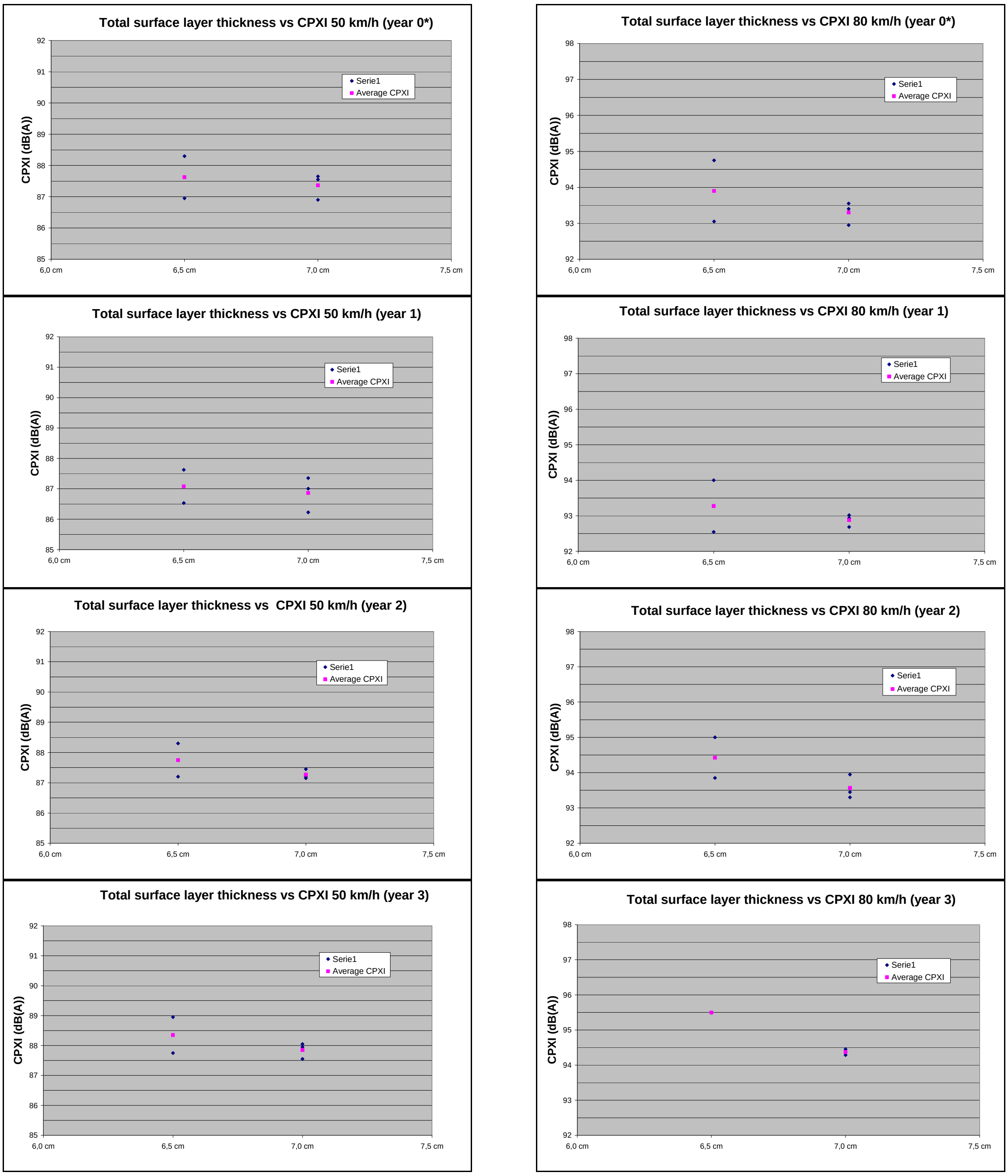



Figure 9 - CPXI vs total surface layer thickness for DLPA sections, at 50 and 80 km/h, year 0* to 3.

Results show that DLPA 7 cm wide is less noisy than 6.5 cm. This difference is more important for measurements carried out at 80 km/h than at 50 km/h (0.2 dB(A) at 50 km/h and 0.6 dB(A) at 80 km/h, in year 0, and 0.5 dB(A) at 50 km/h and 1.1 dB(A) at 80 km/h, in year 3).

### *5.2.3 Influence of maximum aggregate size (surface layer)*

Maximum aggregate size in the upper layer is another important parameter regarding road traffic sound pressure levels.

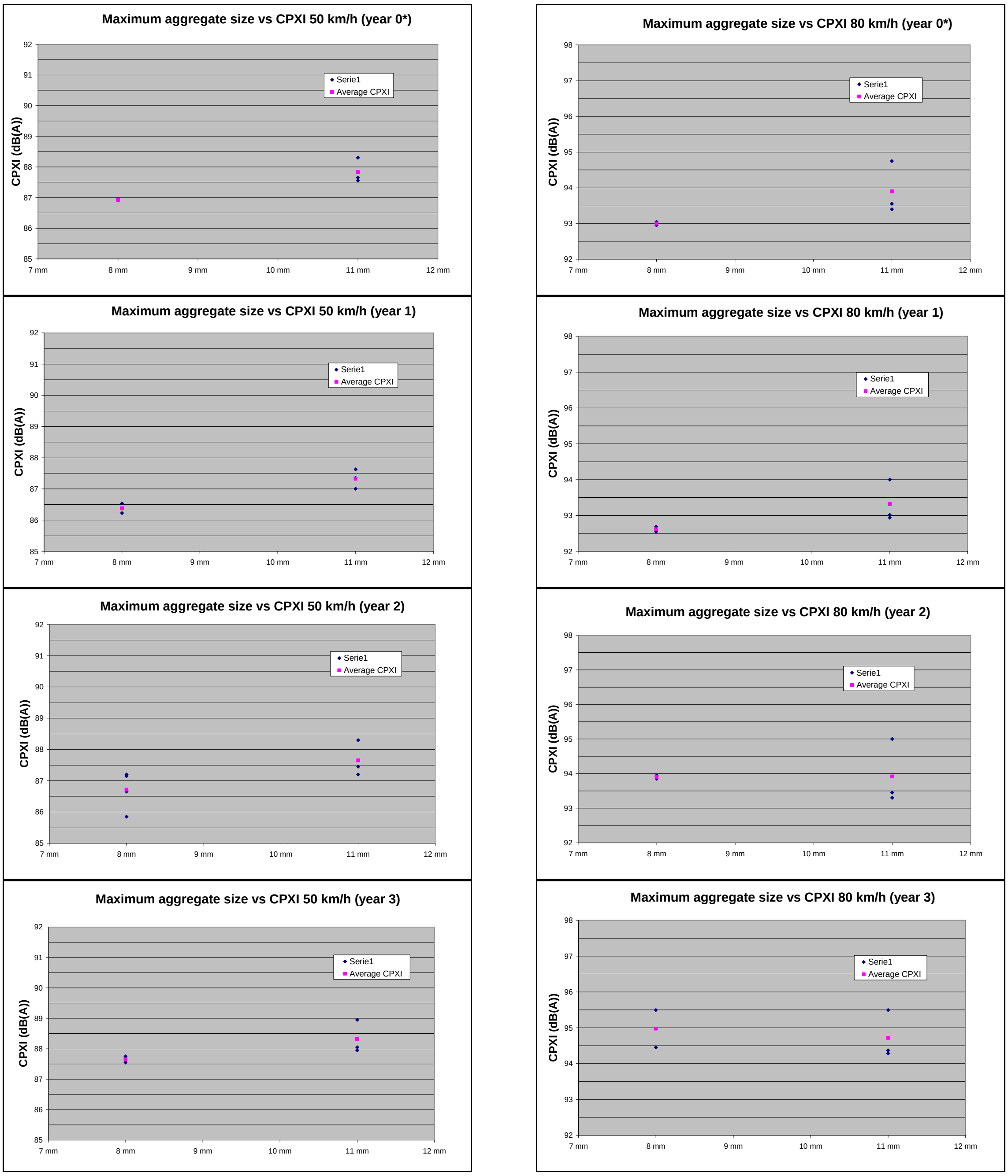



Figure 10 - CPXI vs maximum aggregate size for DLPA sections, at 50 and 80 km/h, year 0* to 3.

Larger maximum aggregate sizes produce higher sound pressure levels. The average CPXI difference is around 1.0 dB(A) both for measurements done at 50 km/h or at 80 km/h. This result was independent of the road age, except for results obtained on 3 years old surfaces, where the difference was -0.3 dB(A) at 80 km/h, being this the only case where average CPXI was smaller when the maximum aggregate size was larger.

Results obtained in sections with a maximum aggregate size of 5 mm were higher than expected. In this case, they have not been taken into account in the analysis.

### *5.2.4 Influence of layer age*

It is widely accepted that surfaces have the best acoustical behaviour when newly laid. However it is of the uttermost importance that these acoustical characteristics are maintained with time. In the figure below it can be seen that CPXI increases with age.

Average increment is 1.0 dB(A) per year (both for 50 and 80 km/h), except between year 1 and 2 for measurements done at 50 km/h, when results were almost the same.

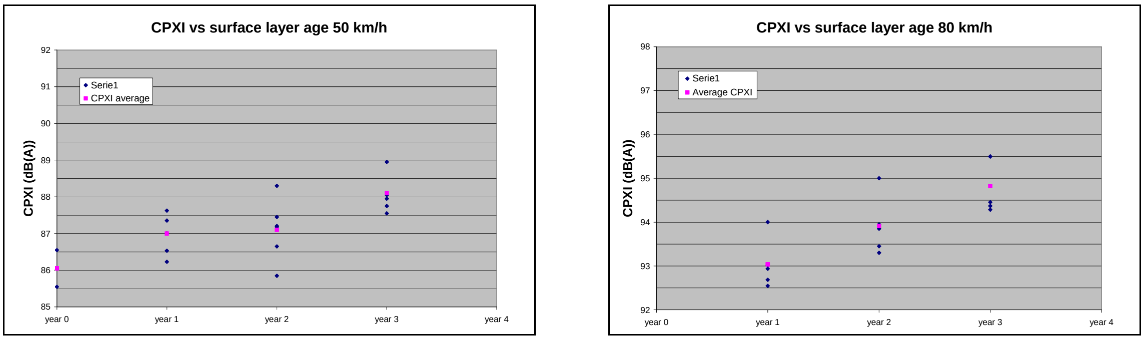



Figure 11 - CPXI for DLPA sections, at 50 km/h and 80 km/h, years 0 to 3.

## 5.3 BBTM 11A and 11B

BBTM 11A and BBTM 11B surface layers main difference is the voids percentage. BBTM 11B sections porosity is around 18% whereas BBTM 11A sections porosity is about 7%.

Four BBTM 11A and two BBTM 11B sections in Site 5 and 6 (southern and northern Spain, respectively) have been analysed. CPX measurements were carried out at 50 km/h in years 0 and 2. Results indicate clearly that sections with higher porosity give lower CPXI, being this difference of 1.0 dB(A), year 0, and 2.7 dB(A), year 2 (figure 12).

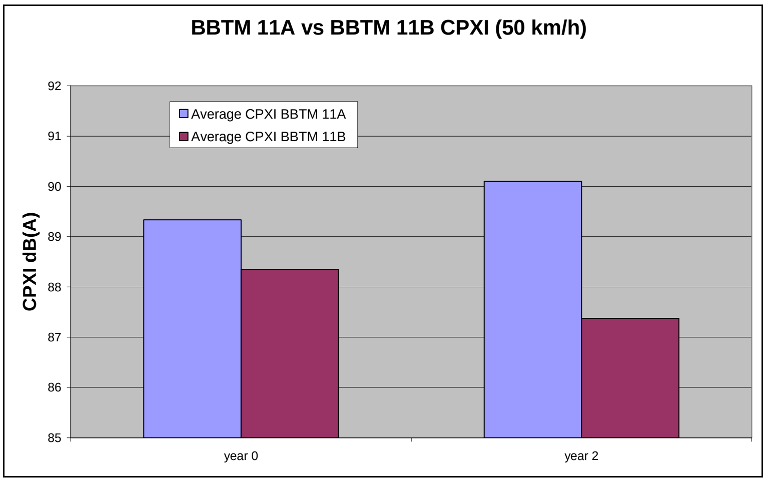



Figure 12 – CPXI for BBTM 11A and BBTM 11B, at 50 km/h, year 0 and 2.

In relation to the results obtained in BBTM 11B sections in Site 6, it has to be pointed out that the average CPXI in year 2 was 1.0 dB(A) lower than in year 0, which is rather surprising. In this case, measurements carried out in year 2 were taken at 30 ºC whereas in year 0 they were taken at 15 ºC. Therefore, it can be suspected that this result might be due to the use of a too low temperature coefficient correction factor. According to the ISO draft 2008, this coefficient is 0.05 dB(A)/ºC but there are some recent research results indicating that it could be as high as 0.15ºC [1]. If this was the case, a difference of 15 ºC between CPX measurements would mean a 1.5 dB(A) gap, and then CPXI values measured in year 2 would be higher than in year 0, as it would be expectable.

## 5.4 AC SURF S

Maximum aggregate size influence has been studied by carrying out CPX measurements in one AC16 SURF S (Site 4) and two AC22 SURF S (Sites 3 and 4), at 50 and 80 km/h. In all cases, the sections had been recently laid (year 0). Results are shown in figure 13 and clearly indicate the very positive effect of smaller maximum aggregate size in noise emission. The differences are in both cases of 1.3 dB(A).

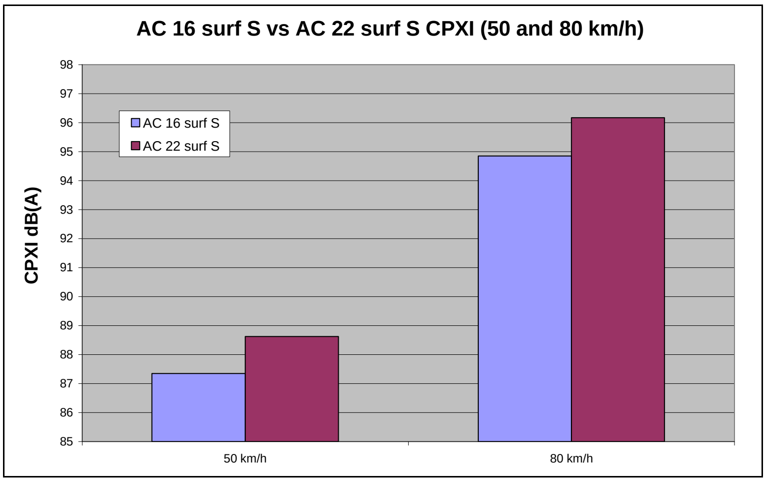



Figure 13 - CPXI for AC 16 surf S and AC 22 surf S, at 50 and 80 km/h, year 0.

## 6. INFLUENCE OF THE TYPE OF BINDER ON NOISE EMISSION

### 6.1 CRUMB RUBBER IMPROVED BITUMEN VS CONVENTIONAL BITUMEN

Measurements were carried out at 50 km/h in a BBTM 11B surface layer road in Site 6 where four sections were selected, two of them built with conventional bitumen (B 60/70) and the other two with crumb rubber improved bitumen (BC 35/50), firstly when the surface had just been laid and then two years after. The thickness of the layer was 4 cm and porosity was around 18.5%.

Average CPXI values indicate that sound pressure levels are similar on both types of surfaces (with or without crumb rubber improved bitumen). Therefore, it can not be concluded that addition of rubber in the bitumen has a substantial benefit in the surface layer acoustical behaviour, being the average CPXI difference between the two types of surfaces of 0.3 dB(A) in year 0 and in year 2.

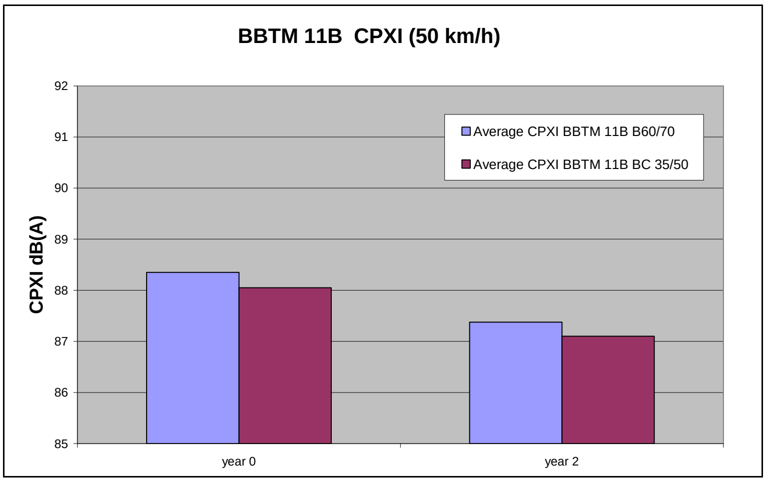



Figure 14 - CPXI for BBTM 11B (with and without crumb rubber improved bitumen), at 50 km/h, year 0 and 2.

Regarding the evolution of the index CPXI, it can be seen that it was higher in year 0 than in year 2. As it has been already indicated in chapter 5.3, this result might be due to the use of a too low temperature correction factor.

## 6.2 POLYMER BITUMEN

In this case, the influence of the bitumen was studied by selecting eight sections with BBTM 11A surface layer in Site 5, two with conventional bitumen (B 40/50), two with polymer modified bitumen (BM-3b), two with crumb rubber improved bitumen (BC 35/50) and the last two with crumb rubber modified bitumen (BMC-3b). CPX measurements were carried out at 50 km/h, in year 0 and 2. The thickness of the layers in which rubber was mixed in the bitumen was 2.6 cm and porosity was 7.2%. In the rest of the sections, built with conventional and modified binder, thickness was 3.1 cm and porosity 7%.

Results show that the less noisy road surface is the one built with the rubber modified bitumen (BMC-3b) and the noisiest is the one with conventional bitumen (B 40/50), being the difference between them of 1.1 dB(A) in year 0 and 0.4 dB(A) in year 2 (figure 15). It reinforces the hypothesis that the noise reducing effect that rubber seems to have is not significant, being more important in the beginning,  and decreasing to almost nothing in a couple of years.

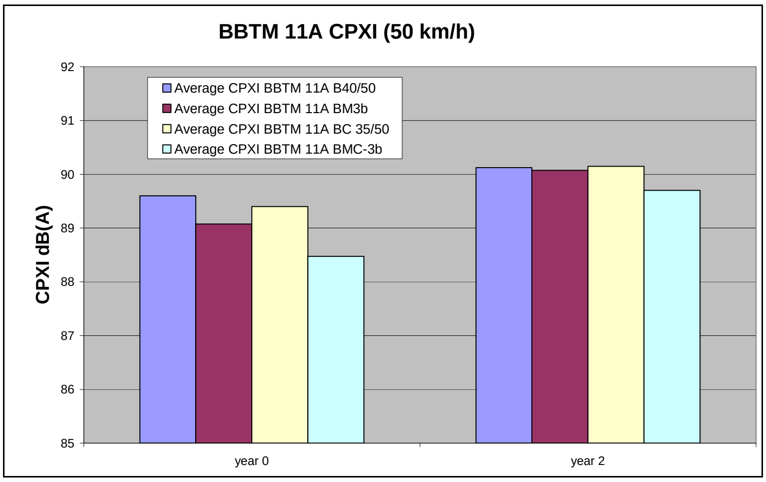



Figure 15 - CPXI for BBTM 11A (with different type of bitumen), at 50 km/h, year 0 and 2

It has to be taken into account that the addition of crumb rubber in the binder affects compaction processes, resulting in higher voids content. This may contribute to this small noise reducing effect of the surface layer with crumb rubber.

# 7. INFLUENCE OF OTHER SURFACE CHARACTERISTICS

CEDEX has carried out CPX measurements together with unevenness and macrotexture in order to try to assess if some kind of correlation can be found between the indicators that represent these surface characteristics, according to [3], [4] and [5]. Measurements were done with CEDEX Profilometer. Results are not very optimistic in this regard.

## 7.1 UNEVENNESS

IRI has been compared with CPXI measurements in several PA and DLPA sections in Site 1 and in BBTM 11B sections in Site 2. Some results are shown in figure 16. For a better comparison, IRI has been calculated using a base line of 20 m (IRI 20), instead of the more standard value of 100 m, due to the fact that CPXI is based in the averaged value of sound pressure levels every 20 metres.

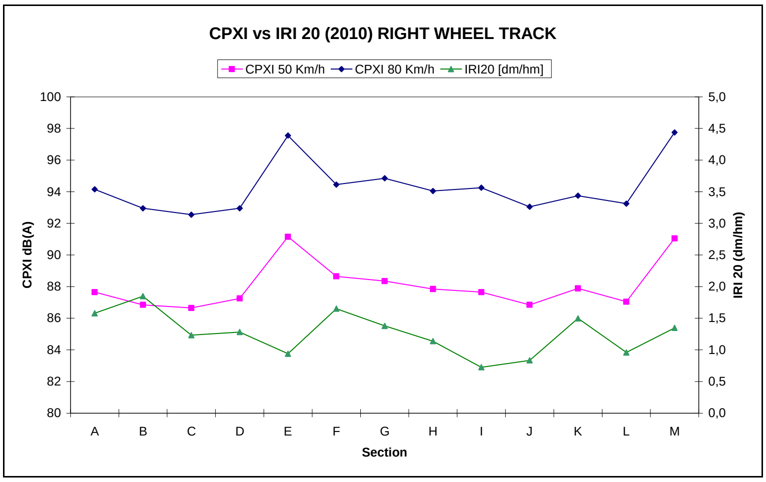



Figure 16 - CPXI vs IRI 20. Measurements in PA and DLPA test sections (2010).

In all cases studied, $R^2$ is under 0.05, meaning that there is no correlation between the parameters. The correlations may be negatively influenced by the very different range of the parameters; CPXI is calculated in a logarithmic scale, with values between 86.7 and 97.8 dB(A) whereas IRI20 values are between 0.7 to 2.3 dm/hm, in this example.

### 7.2 MACROTEXTURE

MPD values have been compared with CPXI in the same cases than unevenness measurements. Some results are shown in figure 17. In all cases analyzed, determination coefficients are under 0.4, meaning that the linear model can explain no more than 40% of the relation between CPXI and MPD. This result is rather in agreement with existing knowledge, as it is assessed that there is a partial relationship between noise and texture. In this case, only irregularities corresponding to macrotexture (0.5 to 50 mm) have been analyzed, whereas the irregularities affecting noise are considered to be the whole range between 0.5 and 500 mm. A more thorough study should be needed about this.

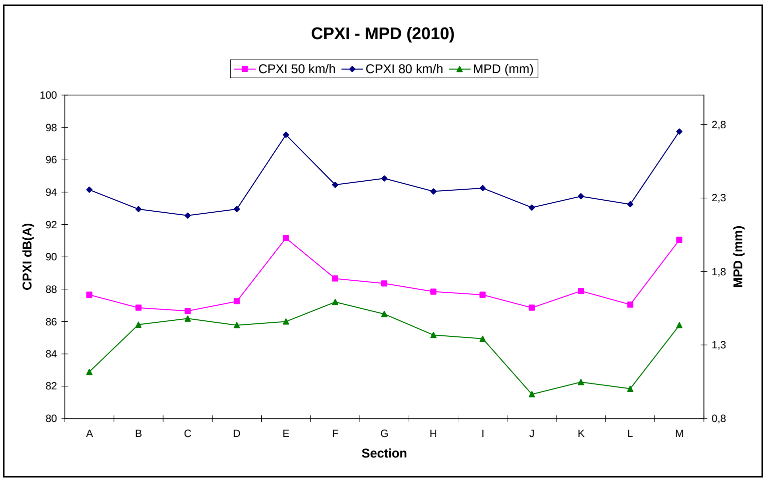



Figure 17 - CPXI vs MPD. Measurements in PA and DLPA test sections (2010).

## 8. CONCLUSIONS

This paper is the result of the assessment of CPX measurements carried out by CEDEX in different types of road surfaces: asphalt concrete, asphalt concrete for very thin layers, porous asphalt and double layer porous asphalt. The analysis has focused on the influence of its characteristics (type of binder - polymer or rubber modified bitumen -, voids, maximum aggregate size, thickness and age of the layer) in noise emission.

It has been found a very big variability in the results, with differences of up to 4.5 dB(A) in the CPXI for the same kind of road surface. According to the data analysed, the authors consider that this might be due to the fact that different characteristics within the same type of road surface (voids content, layer thickness, maximum aggregate size) have a decisive influence in tyre-road noise emission. However, when assessing average results, it can be said that the most important factor affecting noise emission is voids content.

Based on CEDEX CPX measurements, results regarding the influence of the individual characteristics analyzed in the CPXI average values for different road surfaces have been rather consistent. In relation to porosity, it seems clear that larger percentage of voids have a positive effect in the reduction of noise. Also, in general, road surfaces with smaller maximum aggregate size are less noisy (although more research should be done with maximum aggregate sizes under 8 mm), and road surfaces with thicker layers also contribute to reduce noise emission. It has also been found that average CPXI levels increase throughout the years (for measurements carried out in more or less similar ambient conditions), as it was expected. In relation with this, it has been found that the temperature correction coefficient used might be too low. Concerning the use of crumb rubber modified bitumen, the results obtained are not conclusive. Average CPXI values indicate that sound pressure levels are similar on both types of surfaces (with or without crumb rubber improved bitumen). Therefore, it can not be concluded that addition of rubber in the bitumen has a substantial benefit in the surface layer acoustical behaviour. Finally, unevenness and texture measurements were also carried out, in order to try to determine if they are correlated with sound pressure levels. Only a partial relationship was found with the macrotexture, which might be due to the fact that macrotexture irregularities correspond to the interval ranging from 0.5 to 50 mm, whereas irregularities affecting noise are considered to be the whole range between 0.5 and 500 mm.

All these considerations should be taken into account when designing road surface layers with the purpose of reducing sound pressure levels. However, a lot of research has to be done for a better understanding of traffic road noise and how it can be reduced by means of the use of silent pavements.

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## REFERENCES

1. Bühlmann, E. (2011). “Temperature effects on tyre/road noise measurements”. Internoise 2011. Japan.
2. ISO CD 11819-2:2008. “Acoustics – Measurement of the influence of road surfaces on traffic noise – Part 2: The close-proximity method”.
3. ISO CD 13473/2009 “Characterization of pavement texture by use of surface profiles -- Part 1: Determination of Mean Profile Depth”.
4. Norma NLT-330/98 “Cálculo del índice de regularidad internacional (IRI) en pavimentos de carreteras”.
5. Norma UNE-EN 13036-6 “Medición de los perfiles transversales y longitudinales en las longitudes de onda de la regularidad superficial y la megatextura”.
6. Morgan, P. (2008). “Technical Note: The selection of new reference test tyres for the CPX method, to be specified in ISO/TS 11819-3”.