Evaluation of noise reduction of Asphalt Rubber in cities

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ABSTRACT. *The paper introduces the main parameters to develop and test a specific methodology for measuring the acoustical performance of asphalt mixtures in urban scenarios. Measurement of SPB in urban sites, where vehicles speed is low and traffic flows are not regular, do not correspond to the requirements of ISO 11819 neither can be easily replaced by other methods like CPX or measurement of noise at receivers.*

A new approach, derived by an adaptation of SPB to urban scenarios, is presented here, as general method for the evaluation of acoustic efficiency given by low emission paving. It has been defined and tested by authors in some different urban scenarios where traffic noise has been identified as the main source of annoyance for residents. As the most relevant result of the study, a new more general methodology for testing acoustical performance of asphalt friction courses, valid for all kinds of hot mixes, was developed and described.

Asphalt Rubber Gap and Open graded mixes shown very high acoustical performance in urban scenarios.

KEYWORDS: *Noise, Asphalt Rubber Open and Gap graded mixes, statistical pass-by, urban scenarios, environmental noise*

1. Introduction

In the evaluation of the Asphalt Rubber (AR) mixes performance is essential to monitor the functional properties by paying special attention to the evaluation of noise reduction. This problem is nowadays an increasingly strong issue that often affects the choice of materials for road pavement friction courses.

From the compilation of international data and analysis of several studies [1], roadside measurements have shown that AR friction courses can achieve 3 to 5 dB noise level reduction when compared to traditional asphalt dense graded surfaces (DGHMA) and 6 to 12 dB noise level reduction when compared to concrete surfaces (Figure 1) [2]. Most of the international studies focused on the performance of AR in high speed roads (suburban areas) but in Italy AR has been most used in cities.

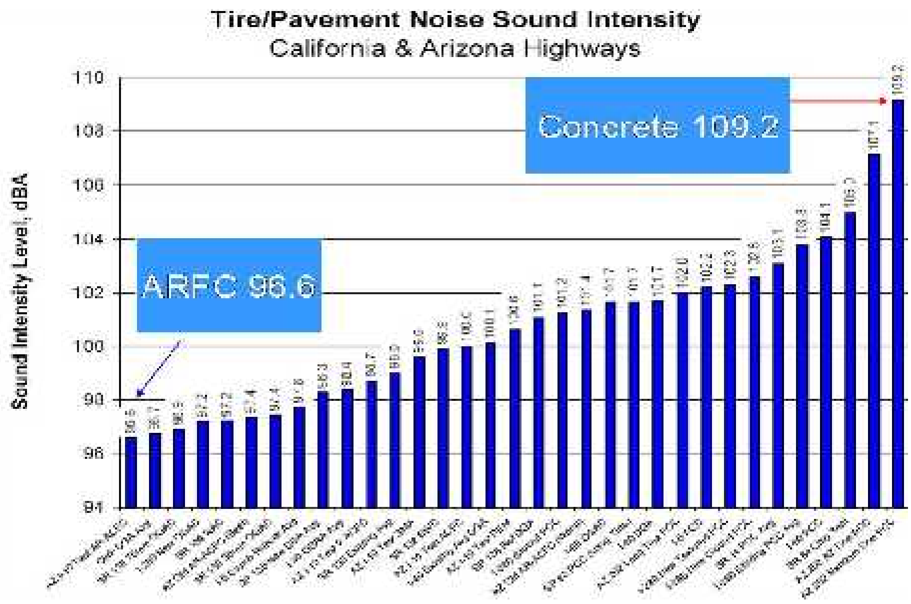

Figure 1. *Noise measurements for many surfaces asphalt rubber the lowest*

Currently almost 70 per cent of the European citizens are living in cities and their number is still growing up to 80 per cent the next decades [3].

Noise levels in cities are usually very high and are affecting the quality of life seriously. In quite all European cities annoyance is cause of discomfort and strongly affects the perception of quality of life. It is part of European Community policy to achieve a high level of health and environmental protection and one of the objectives to be pursued is protection against noise. Reduction of noise in terms of reduction of exposure to harmful environmental noise in urban areas is the most important expected result [3].

The performance of a friction course in terms of noise emissions can be evaluated with several methods, which can be used to check the compliance of the material with the specifications required by laws and standards.

Italian requirements for the acceptance of roads include measurements, following the normative ISO 11819-1, performed on the time situations of ante and post – operam using the Statistical Pass By (SPB) method [4]. To consider a surface layer suitable for noise reduction the results of ante/post – operam measurements must exceed a difference of 3 dB. The acceptance usually is made immediately after paving and without controlling the acoustical performance over time, that is strictly connected to the ageing of the materials.

Urban scenarios present specific conditions: vehicles speed is low and traffic flows are not regular. Despite that, the legislation referenced testing (16/03/1998) for acceptance does not take under consideration the speed of transit vehicles, which is one of the main parameters that determines the acoustical performance of a road. As a consequence, measurement of Statistical Pass By in urban sites do not correspond to the requirements of ISO 11819-1.

Some standard describe methods to proceed with correct sound level measurements; for non-standard methods technical books and papers only show brief tips on how to proceed with measures and the type of results that can be obtained.

The authors have conducted a study aiming to fill the above mentioned gap of knowledge, specifically related to what concerns the acoustical AR performance in urban scenarios.

In this paper the main measurement methods to state the acoustic performance of a pavement are described, considering different operation modes: standard and not standard, in situ or in laboratory. The study focused on the performance of both Asphalt Rubber hot mixes gap and open graded in cities, evaluating the dependence of results in relation to the speed of passing and test section’s shape (free, L or U).

A new in situ technical method, which broaden the area of applicability of "Statistical Pass By" method, is described and results under these new conditions are presented.

2. State of art in Italy for AR acoustic performance in cities

In cities noise is a very big issue and each time AR (gap or open graded) mixes were used it was evident that the pavement had become much quieter. So much quieter that were the residents to notice noise reduction and express positive comments (Figure 2).

LA SODDISFAZIONE DEI COMMERCIANTI

"La differenza c'è... e si sente"

Figure 2. *Extract of newspaper where residents express positive comments after paving with Asphalt Rubber*

It was important to quantify the acoustical improvement by using Asphalt Rubber as part of the policy disclosure for this technology in Italy but also to demonstrate that the immediately effect of noise reduction was also lasting.

Standard methods are based on protocols developed in the range of European projects for many years, therefore it has been possible to collect a large statistical surveys of numerous sites, both urban and suburban.

The benefits associated with in situ measurements compared to those held in the laboratory are many: the sample must not be removed from its natural location, the acoustic properties are measured under real conditions of installation or operation, without being affected by contamination resulting from different contour conditions. However, if this aspect is an advantage on a side, on the other it exposes the method to the influence of factors not easy to check.

In laboratory measurements for acoustic properties are evaluated under controlled conditions, in the absence of all phenomenon that occur in real conditions, such spurious reflections, absorptions of surfaces present in the analysis area, or other boundary conditions that may affect the final results.

In Italy, the acoustic properties of Asphalt Rubber (gap and open) have been analyzed in a growing number of pilot tests performed in the last 4 years. The main methods used for noise measurements have been those of “pass-by noise” or “close proximity” (CPX – ISO 11819-2).

2.1 In situ acoustic analysis using measurement boxes

One interesting study using measurement boxes was performed in Florence [5] where Gap Graded and Open Graded AR mixes were tested on an urban trial section. Asphalt Rubber material was staggered with some short sections of a traditional DGHMA selected as reference surface layer for traffic noise survey. The thickness of the 3 wearing courses was 30 mm.

The acoustic characterization was carried out performing noise measurements surveys, each lasting one week, according to the Italian technical specifications. Measurement boxes, according to Class 1 of EN 60651 and EN 60804, were fixed at about 4 m high to lampposts situated along the side of the experimental roadway (Figure 3). Noise levels recorded along the side of sections constructed with the studied materials were related with noise levels recorded at the same time on near different sections covered with traditional asphalt concretes and interested by quite the same traffic load.

Measurement boxes were able to determine the A-weighted equivalent sound level Leq for each measuring hour and the results were summarized in one mean A-weighted sound pressure level for night (Leq,wn) and day (Leq,wd) periods, as shown in the example of Figure 4. In order to make the comparative study of the “in situ” acoustic measurement objective, it was supported by traffic investigation. Each investigation was carried out for 24 hours once a week, during the traffic noise finding weeks, recording the number of vehicles and the corresponding speed and length.

Figure 3. *Measurements boxes*

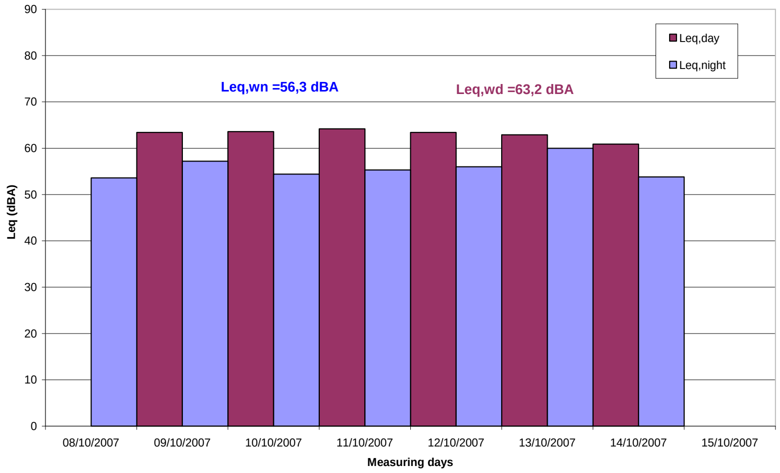

Figure 4. *In situ noise measurements (one week)*

From the analysis of the experimental results (Table 1), noise level recorded for the reference material was not comparable with that of asphalt rubber mixtures because of the not negligible difference of traffic flow and speed between the different sections. But actually, the measurement box corresponding to reference material was placed at a greater distance from traffic stream than those mounted along the asphalt rubber experimental sections in such a way that the distance counterbalanced the different traffic conditions. In fact, it is possible to estimate through, for example, the Italian CNR prediction model [5] that the greater noise level recordable for the reference material due to the higher traffic flow and speed is roughly counterbalanced by the greater distance between measurement box and traffic stream.

Table 1. *"In situ" acoustic results – Florence trial section for Gap and Open graded AR mixes compared with traditional*

	ARAC (gap)	ARFC (open)	Reference
Leq,wd (dBA)	65.1	63.2	67.9
Leq,wn (dBA)	57.9	56.3	61.5
Traffic (vehicles/day)	6694	5656	8967
Mean speed, day (km/h)	37.7	40.8	48.3
Mean speed, night (km/h)	42.0	44.9	58.3
Heavy vehicles (%)	10.16	2.05	3.51

Thus, ARAC mix proved to be about 3 dB(A) quieter than a traditional dense graded asphalt concrete principally thanks to the asphalt rubber binder employed. A 3 dB(A) noise reduction corresponds to halving traffic flow or doubling the distance between the source and the receiver.

The open graded AR mixture shown 5 dB(A) of noise reduction, achieved by the combination of the acoustic benefits arising from AR binder with those obtainable from high air void content in terms of sound absorption capabilities. Moreover, this mix is characterized also by a reduced maximum chipping size that further enhanced rolling noise reduction properties.

2.2 CPX method (Close Proximity)

The Close Proximity (CPX) method, regulated by ISO/CD 11819-2:2000, allows to characterize the noise generated by the interaction of road surface-wheel (rolling noise). This method is complementary to the Statistical Pass-by (SPB), being more convenient, fast and cheap of it but too much referred to the tire conditions (Figure 5).

Figure 5. *Set of microphones near the tire for the measure with the CPX method*

The measuring system that implements the CPX method consists of two or more microphones, conveniently mounted near a wheel of the test vehicle or near a special trailer. Each segment of the investigated road is calculated examining the average level measured by each microphone, normalizing the value at the reference speed. The resulting arithmetic average levels detected by the microphones at a given reference speed (usually 50, 80 or 110 km/h) takes the name of "Tire/Road sound level" LTR) [6]. A suitable linear combination of the values of LTR measured with different wheels, allows to determine the index CPXI of the segment for each reference speed. The CPX method is characterized by a flexibility of use due to the fact that the measurement is performed in a dynamic manner, allowing to quickly detect the acoustic properties of long stretches of road.

However, like other methods of in situ characterization, CPX also has critical requirements related to due to weather conditions and peculiarities of the specific site, as well as the influence of random external noise sources which can not be controlled [6].

Among the most recent Italian studies using CPX, it's worth mentioning the "Progetto Leopoldo" (Regione Toscana and Università of Pisa), that assessed the environmental sustainability of rubberized asphalts (dry and wet). In particular, Asphalt Rubber Gap graded provided a high friction coefficient (+10÷20% with respect to the traditional friction courses) and road noise reduction from 3 to 6 dB with respect to DGHMA (Figure 6) [7].

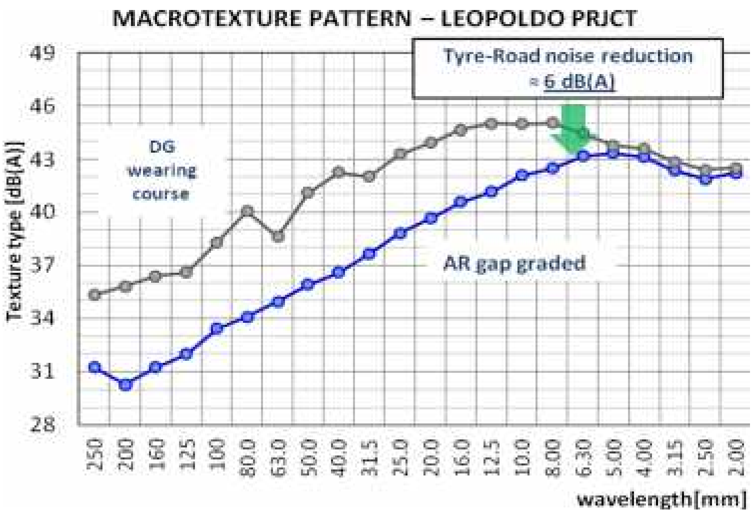

Figure 6. *Results of AR gap graded*

2.3 Tube impedance (Kundt's tube)

Kundt's tube is the main instrument for the assessment of acoustic characteristics of a pavement in laboratory. It allows the measure of sound absorption coefficient for normal incidence. The Kundt's tube (Figure 7) is essentially a plane waves selector consisting of a cavity of cylindrical shape made of acoustically reflective material [6].

The reference standard is EN ISO 10534. The measurement of sound absorption coefficient of a road pavement requires that samples are taken for the conglomerate through an invasive procedure of probing [6].

Figure 7. *Kundt's tube for analysis in laboratory*

This methodology does not allow to characterize the road surface as a whole, but only a very limited portion of the material used for paving. However, analysis are performed in a controlled environment, and presents the advantage of allowing an easier management of the parameters that affect the accuracy of the measurement.

Tests conducted by Università delle Marche for an Open Graded mixture showed a not pronounced sound absorption coefficient (Figure 8), confirming that a void content lower than 15% is not able to guarantee good absorption properties because the pores are probably not totally interconnected between them. Moreover, the selected reduced maximum chipping size probably enhanced the air flow resistance of the material limiting sound absorption characteristics [5].

SOUND ABSORPTION COEFFICIENT a							
Specimen	Frequency (Hz)						
	400	500	630	800	1000	1250	1600
OG-ARsitu_1	0.17	0.29	0.38	0.38	0.23	0.10	0.07
OG-ARsitu_2	0.10	0.18	0.34	0.31	0.25	0.05	0.05
OG-ARsitu_3	0.19	0.20	0.35	0.32	0.14	0.03	0.04
OG-ARsitu_4	0.11	0.23	0.45	0.31	0.15	0.03	0.03
OG-ARsitu_5	0.16	0.25	0.34	0.24	0.09	0.05	0.06
mean values	**0.15**	**0.23**	**0.37**	**0.31**	**0.17**	**0.05**	**0.05**

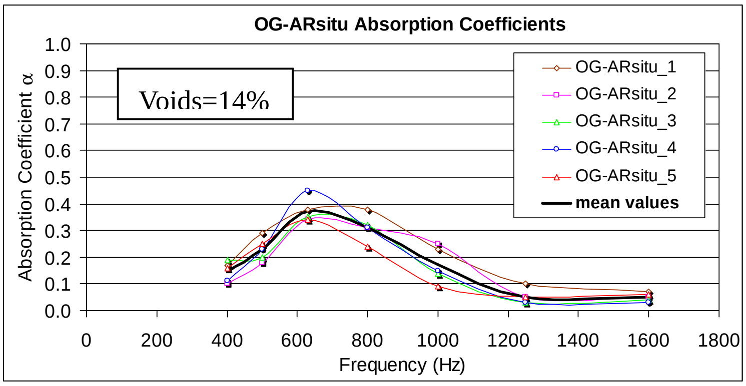

Figure 8. *Absorption coefficients of Open Graded AR mix*

Furthermore, it is very interesting to note that ARFC – Open Graded bituminous mixtures demonstrated a low peak frequency of absorption corresponding to 630 Hz (Figure 8). According to some studies [8], this may be due to the higher tortuosity, i.e. a pores-shape parameter, that arise from the reduced maximum chipping size coupled with to the high binder content that created narrow channels linking up pores.

As a matter of fact, the not elevated sound absorption coefficients recorded for the ARFC material indirectly proved that the very good anti-noise performance demonstrated in situ by this mixture is principally due to the acoustic properties, in terms of reduction of rolling noise generation, arising from the adding of asphalt rubber binder.

Finally, low absorption coefficients were showed by the Gap Graded AR mixture (Figure 9).

This results were considered to be very interesting. This fact proved once again that the asphalt rubber binder is the main author of the acoustic benefits demonstrated by this kind of mixture.

SOUND ABSORPTION COEFFICIENT a							
Specimen	Frequency (Hz)						
	400	500	630	800	1000	1250	1600
GG-AR_1	0.11	0.14	0.14	0.25	0.10	0.04	0.03
GG-AR_2	0.13	0.18	0.12	0.29	0.02	0.07	0.09
GG-AR_3	0.10	0.15	0.18	0.20	0.11	0.01	0.04
GG-AR_4	0.08	0.12	0.18	0.29	0.08	0.05	0.04
GG-AR_5	0.12	0.18	0.20	0.20	0.06	0.05	0.02
mean values	**0.11**	**0.15**	**0.16**	**0.25**	**0.07**	**0.04**	**0.04**

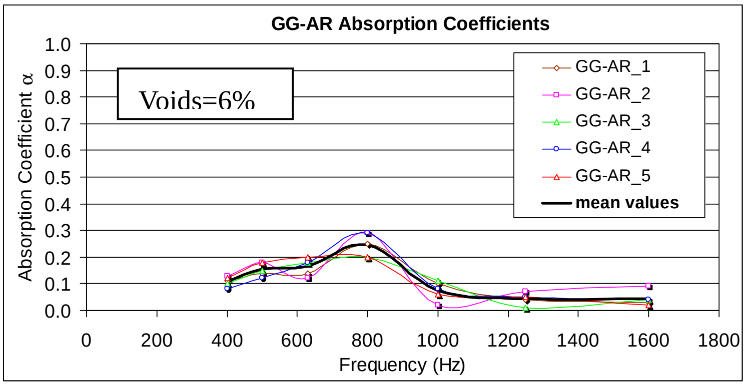

Figure 9. *Absorption coefficients of Gap Graded AR mix*

This results lead the authors to study AR with more attention: Gap graded acoustical performance tested in laboratory show a low absorption coefficient but, in situ the results show the contrary, even at very low speed.

What method can be truly representative of the behavior of AR in urban scenarios? What differences are noticeable, under the conditions of an urban scenario (where the test condition is not free field and traffic flow has low speeds), between the performance of the AR Gap graded and the AR Open graded?

3. Urban Statistical Pass-By: the proposed methodology

AR performance evaluation in the proposed study has been evaluated by means of Field Testing program, considering in background the Strategic action plans of urban agglomerates, as established by Environmental Noise Directive (END, for the in-field testing side of the study, the following specific Italian Law and Regulations regarding traffic noise have been considered:

- Legge 447/95 "Framework Law on Noise";
- D.M. Ambiente 16 marzo 1998 "Measuring and assessment noise techniques";
- Standard ISO EN UNI for the evaluation of noise emission and immission;
- Standard ISO EN UNI for noise sources characterization.

Several case studies have been chosen, focusing on in-field performance of AR and on a possible classification of this technology, to be employed in Noise Reduction Plans and, more generally, as a solution for noise control and reduction actions in cities. In selected sites, AR paving has been recently implemented as a part of Noise Reduction Plans and Strategic Action Plans.

3.1 Statistical by-pass

The "Statistical Pass-By" method allow to determine the noise contribution produced by the passage of a vehicle on the road surface.

The method applies to passing traffic, on a statistically significant sample for number and type of vehicles. The maximum sound pressure level of each passage is recorded in third-octave bands spectrum; the acquired data are then appropriately processed by an operation of linear regression, to provide a characterization of the acoustic performance of pavement investigated (Figure 10) [6].

Figure 10. *SPB in situ measurement*

The Pass-By method is based on the measuring the noise level generated from a sample of vehicles, representative of the traffic flow of the road analyzed. The specifications for the proper execution of the measures are defined by the EN ISO 118189-1:2004 standard. For each passage, the simultaneous acquisition of the sound level LAFmax in dB (A) and the transit speed in km/h is provided.

As for the speed passage, the procedure considers 3 ranges of values:

- Low: average speed of traffic flow between 45 km/h and 64 km/h;
- Average: average speed of traffic flow between 65 km/h and 99 km/h;
- High: average flow velocity greater than or equal to 100 km/h.

Speed passages under 45 km are not taken into account in standard procedure, hence the proposal to enlarge the area of applicability with USPB ("Urban Statistical Pass By") described follow.

The main gap of Statistical Pass-By method is that it lends to characterize the site as a whole and not the pavement specifically. Another fault is that to obtain significant results several conditions must be satisfied, thus making complicate the application of the method and increasing the execution time.

As consequence from what described above, other measurement methods have been developed recently: one of these is the SPB-BB (statistical pass by backing board) method. It has been developed in order to extend the scope of the method SPB even in the presence of reflective surfaces close to the measurement station (eg. in urban areas). Another one, developed by the authors, is the USPB method, which permit to broaden the range of SPB even at transit speed below 45 km/h.

3.2 Statiscal Pass-By – Backing Board

The SPB method has many stringent requirements for its proper application, and what is very limiting is the lack of reflective surfaces in the proximity of the measurement station. In particular sites, such as in urban areas, the proximity of buildings to roads makes it difficult to identify scenarios that conform to specifications of the SPB [6].

The presence of reflective surfaces near the measurement location could make it difficult the respect of EN ISO 11819-1:2004 requirements. To avoid this problem the SPB-BB method, a variant of SPB, is carried out, which provides for the use of a screen (backing board) on where to position the microphone. The backing board is a panel that emulates the effect of a surface infinitely stiff and perfectly reflecting. The effect produced by the backing board is to double the sound pressure measured on the surface itself, or to generate a variation of the sound pressure level greater than that detectable in free field conditions of about +6 dB (Figure 11) [6].

Figure 11. *SPB-BB method*

The panel has, however, finite size and therefore introduces diffraction effects at the edges, which generate the discontinuities in the sound field, so it is necessary to identify a suitable position for the microphone inside the panel so that the corrective term appears in fact equal to +6 dB.

The comparison between the spectral analyzes performed with the technique of SPB and the SPB-BB showed a deviation not constant at the variation of the frequency bands, for which it is necessary to analyze the characteristics of this method to better define the limits of applicability.

3.3 USPB (Urban Statistical Pass-By) method

In relation to the speed range, the SPB standard sets that only vehicles having a speed of transit exceeding 45 km/h can be taken in account. This limit significantly reduces the possibility of using this method of analysis in urban areas, where a large number of vehicles circulate at lower speed. Therefore, the authors have carried out a survey in urban setting in order to gather information on vehicles circulating with speeds that are both lower and upper than 45 km/h, in the same measurement location.

This method has been called Urban Statistical Pass-By (USPB).

The idea is to propose a method that can really make possible Pass-By measurements in urban scenarios, where the presence of buildings makes the sites not conform to those provided by the standard and speed of transit is particularly low.

This method provides two types of tests:

1. Measurements of SPB in adjacent sections of the road, presenting similar conditions for reflection, although not fully meeting the requirements of ISO 11819-1: these measures should have full validity and statistical significance, but, as reported to the same scenario, they can not be considered in terms of assessing the absolute level of emissions. In addition, to strengthen the analysis even with a reduced sample (number of vehicles), when compared to the current specifications of the standard, it was proposed to use the passages relating to the same vehicle in the two coupled sites.
2. Measurements of Pass-By using the same vehicle sample (or a number of representative samples, each of a different class of vehicles) in adjacent sections of the same road: the conditions of use of the source sample must be congruent, in terms of speed and acceleration - deceleration, with one or more passages of predetermined values. The measured data has not a clear statistical significance (given that the vehicle is always the same), but still provide a useful comparison between the effectiveness of several surface layers or in any case different contexts (free field section, L-shape or U-shape).

The test configurations and the position of the measurement location are as defined by the protocol of ISO 11819-1.

In conclusion, the tests described in step 1 are proposed for the evaluation of the benefit of the relative noise between two adjacent friction layers, even in conditions of lower speed (under 45 km/h). The tests described in item 2 are used to determine the variation of noise level in the presence of several stretches of the road infrastructure.

Knowing the emission level of a surface layer in a section of L-shape geometry (determined by the test described in item 1) and the existing correlation between an L-shaped section and a U-shaped section (determined through the tests in paragraph 2) it becomes possible to normalize the level of the emission to the condition of free field.

Following the above methodology, several case studies have been investigated in 2011 in the frame of a more general research regarding performance of Asphalt Rubber layers compared with traditional ones. Most of the in-field tests have been performed in the frame of intervention connected to City Noise reduction Plans and/or Strategic Action Plans, thus ensuring the real representativeness of case studies located in situations where the effective presence of polluting noise is clearly established as well as the need of reduction of it.

3.3.1 Performance of Asphalt Rubber at low speed level: less than 45 Km/h

One of the selected scenarios is located in Borgo San Lorenzo, in Tuscany. Three different pavements have been implemented on three consecutive sectors of the same straight road, using traditional asphalt, open graded asphalt rubber and gap graded asphalt rubber respectively. Figure 12 indicates in blue the open graded stretch, in green the traditional asphalt stretch and in red the gap graded stretch.

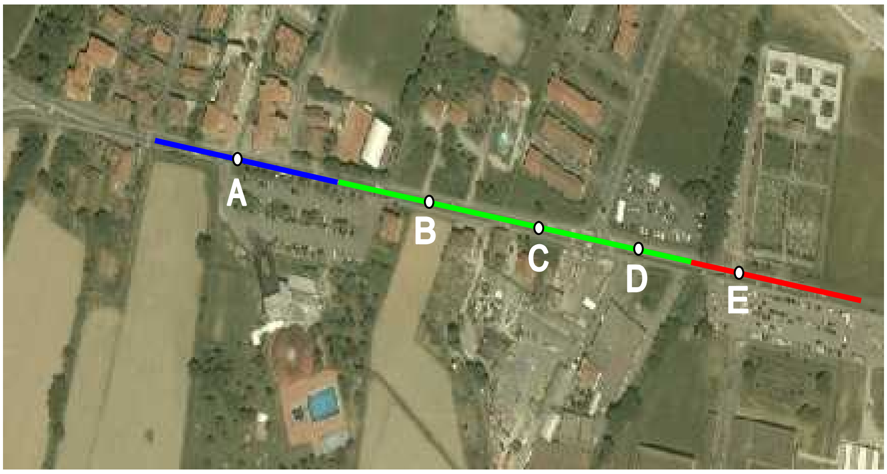

Figure 12. *Points of measure in the town of Borgo San Lorenzo*

Acoustic measurement were made using the SPB method in 5 locations, indicated in Figure 12 with letters from A to E. Acoustic data were reported on a "LAFmax-Speed" graph, and the interpolation of these data has been carried out, in order to obtain distinct straight lines for speeds below and above 45 km/h, as shown in Figure 13.

The blue lines refer to the noise emissions of vehicles on the open graded pavement, the green line to those passing on the traditional pavement, the red line to those related to the gap graded pavement.

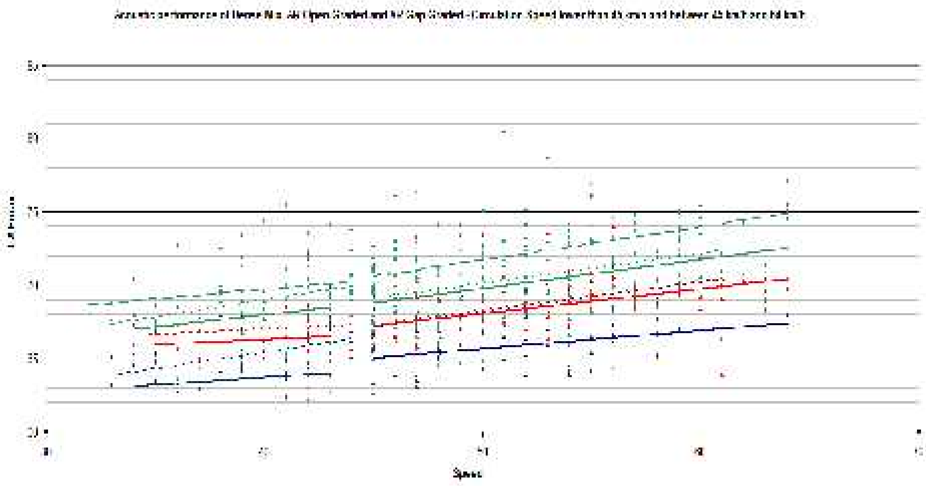

Figure 13. *Vehicle noise emission below and above 45 km/h with SPB method*

It is possible to see that the trend of the slopes shows a substantial similarity between the upper and the lower transit speed, which means a not significant variance under the speed of 45 km/h: the straight lines are represented almost as a natural continuation of each other.

A different example can be taken from the analysis on the scenario of Pistoia that was conducted as described in paragraph 3.3. The major differences are related to the value of the intercept of the straight lines, which shows a difference between the two pairs of straight lines (Open Asphalt Rubber and traditional) of 1-2 dB (A). In this case a substantial variation occur in relation to the levels of intercepts between the various pairs of straight lines given that, as can be seen in the graph.

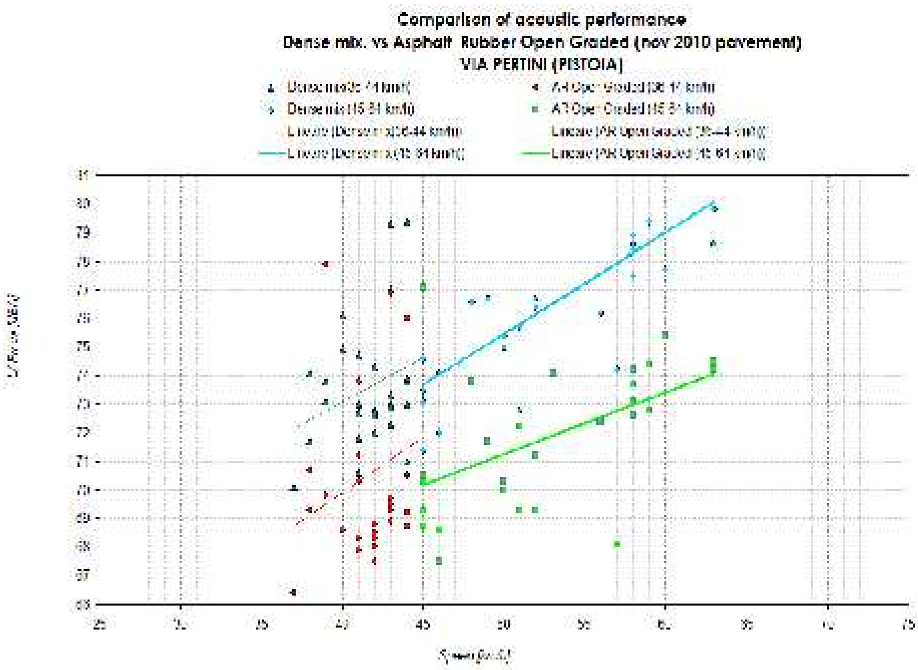

Figure 14. *Comparison of acoustic performance for an AR Open graded and a dense mix for two speed ranges*

3.3.2 Results for the application of the method for the assessment of the influence of road section geometry

Using the methodology proposed in point 2: which means using a standard vehicle in transit it has been possible to determine some corrections relating to the type (shape) of road section.

In particular, this methodology was used in the following scenarios:

- Open section vs. L-shape section (Borgo San Lorenzo; AR in comparison to a 5 years old traditional friction course);

- Section U vs. L-shape section (Florence; type of flooring: AR in comparison to a 5 years old traditional friction course).

The value of the correction determined by the tests carried out, evaluated for the known vehicle (or standard vehicle) in transit at average speed of 50 km/h, for the parameter LAFmax, is equal to 3 dBA in the case of Borgo San Lorenzo and 2 dBA in the case of Florence.

In the remainder of the activity is expected to characterize the different types of section, filling a database of sections, divided by shape, to be used for the normalization of emission data of the materials when they are determined by the free field in different scenarios.

Other investigations have been carried out in Livorno, using Asphalt Rubber open graded. The new road, clearly identifiable by the darker color in the center of the image (Figure 15) was constructed in June 2010 and it wasn't possible to make measurements of the ante-post operam on the same site. In this case the methodology adopted was to compare the AR test section with another similar one of new construction and then apply a correction coefficient.

Figura 15. *Livorno: Open graded test section*

The measurements were made using the method of "Statistical Pass By," which could be applied without any particular problems as the infrastructure was a new construction, built on a scenario sufficiently open and away from residential buildings. The figure below shows the graphs of the correlation between speed and SEL -speed (A), expressible by law regression of the linear type, respectively for the new AR layer and the of similar characteristics as a reference considerable pre-operational (Figure 16) [9].

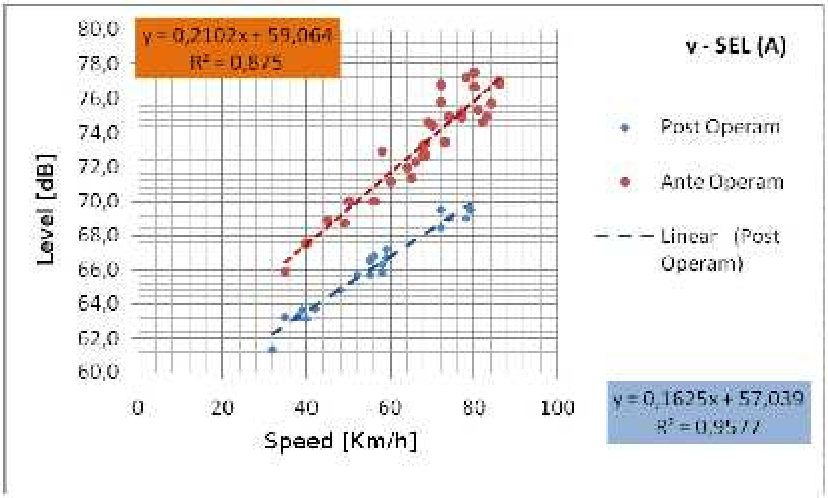

Figure 16. *Measurements SPB ante/post operam AR Open graded, Livorno*

On the basis of what has emerged from the phonometric is therefore possible to bring in tabular form, the reduction level in terms of emission to the receptor as dependent from the range of speed, in the case of passages of only light vehicles (Table 2) [9].

Table 2. *Performance improvement AR Open graded*

Speed (Km/h)	30-40	40-50	50-60	60-70	70-80	80-90	90-100
Performance improvement AR Open graded [dB(A)]	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5	5.5-6.0	6.0-6.5	6.5-7.0

6. Conclusions

The smoothness and quietness of pavements have received increasing attention from both the public and transportation agencies as issues of quality of life for highway users and neighboring residents. Measures are needed, on local, national and European level as well in a vertical and horizontal way. Cities must apply all possible measures that can be taken at local level. Quiet road surfaces, insulation, traffic management, co-mobility and so on.

In this paper a study relative to Asphalt Rubber testing in urban scenarios is presented. The adopted approach consists in developing theoretical and experimental parallel activities, with the main purpose of disclosing experimental findings to encourage the use of AR in the Italian road network, in the awareness of technical, environmental and economic benefits of this technology.

From the results of the experience described above is possible to note that the new proposed method, that has been called Urban Statistical Pass-By (USPB), can give a decisive contribution to the development of a test strategy of low noise asphalt performance in urban sites.

In particular low speed circulation can be considered, thus overwhelming the restriction of SBP method, as indicated by EN ISO 11819-1:2004.

In the investigated urban scenarios, the sample of vehicles has been enlarged, including also those circulating at low speed, without great variation in the slopes of curves representing acoustic performance of asphalts. It is the first step to make SPB method applicable also in urban scenarios with regular vehicular traffic.

The new methodical approach solves two problems:

- Problem of speed - Solution: widen the sample of vehicles taking even those at speeds below the lower limit of applicability of the SPB (45 km/h) and make paired tests with a standard vehicle to eliminate the problems related to having a very large statistical sample. Another effect is to reduce uncertainty related to the intrinsic noise of vehicles and the driving style of driver. This factor allows to obtain a good relative comparison between several surface layers.

- Problem of measurements made with propagation environment not conforming to standard (other field configuration) - Solution: define normalization coefficients for the type of road and pavement section, so that it is possible to measure in different section geometries (other than free field) and thus without the need to comply with the requirements of the standard. Obviously, in such analysis it is necessary to define the distance between the roadway and the obstacle.

To what concerns AR acoustical performance we can conclude that noise reduction in urban scenarios is very significant. Usually the differences between the acoustical performance of the open graded and the gap graded do not exceed 1 dBA, under the urban conditions of reflective test section and low speed.

Both AR gap and open graded presented lasting noise reduction, especially when compared to other types of different innovative noise reducing road surfaces.

So Asphalt Rubber technology allows the recycling of ground tires in road construction and is actually an important resource to solve another environmental problem: quietness.

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