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EXPERIMENTAL VERIFICATION OF THE EUROPEAN METHODOLOGY FOR TESTING NOISE BARRIERS IN SITU: AIRBORNE SOUND INSULATION

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ABSTRACT

The European project *Adrienne* (1995-97) produced innovative methods for testing the intrinsic characteristics of noise barriers in situ. These methods are now under consideration at CEN to become European standards. This paper reports the verification of the *Adrienne* test method for airborne sound insulation over a selection of seventeen noise barriers, tested both outdoors, using the new method, and in laboratory, following the EN 1793-2 standard. The *Adrienne* method has been found sensitive to quality of mounting, seals and other details typical of outdoor installations. The comparison between outdoor and laboratory results shows an excellent correlation, while differences can be explained with the different sound fields and mounting conditions between the outdoor and laboratory tests. It is concluded that the *Adrienne* method is adequate for its intended use.

1 - INTRODUCTION

The airborne sound insulation of seventeen noise barriers, representative of the Italian and European market, was tested both outdoors, using the new *Adrienne* method [1,2,3], and in laboratory, following the EN 1793-2 standard [4]. In both cases the single number ratings for airborne sound insulation were calculated [4,5,6,7]. The work permitted:

- to test the practicability and the reliability of the new method for different kinds of barriers;
- to test the sensitivity of the new method to quality of workmanship, way of mounting and other details typical of real outdoor installations; these sources of possible problems are present in real situations but are carefully eliminated when preparing laboratory specimens;
- to compare the outdoor and laboratory airborne sound insulation values obtained on the same set of barrier samples and to investigate their correlation, which can be useful for predicting the expected field performance from laboratory data.

2 - THE SAMPLES

All samples had the same global size: about 3.0x3.5 m for the laboratory test (the size of the test opening between the coupled rooms) and 18.0x4.0 m for the outdoor test. In Table 1, the barrier samples are presented with conventional names in order to not disclose the producer names. The barriers submitted to the test can be grouped in six classes:

- concrete barriers (5 samples): barrier elements are made of a heavy concrete back panels supporting front panels made with lighter concrete and with a non flat shape; the posts are large and strong to support the considerable weight of the structure;
- metallic barriers (7 samples): barrier elements are metallic boxes, perforated on one face and partially filled with a high density rock wool; in two cases a high density synthetic damper was added; in two cases the elements were simple, not perforated, metallic sheets; the posts are metallic beams with a "H" section;

- resin barriers (1 sample): the barrier elements are boxes made with polyether resin sheets reinforced using glass fibres; the boxes are perforated on one face and partially filled with a glass fibre blanket; the posts are made using the same polyether resin;
- acrylic barriers (1 sample): the barrier elements are transparent polymethylmethacrylate (PMMA) sheets, 20 mm thick, supported by a light metallic frame;
- mixed barriers (1 sample): the half barrier close to the ground is made of metallic panels, like those described above (point 2); the upper half is made of transparent polymethylmethacrylate (PMMA) sheets, 15 mm thick, supported by a light metallic frame; the posts are metallic beams with a "H" section;
- wood barriers (1 sample): the barrier is made of four layers i.e., from front to back: wood tiles made of spaced laths; rock wool blanket; fibre-concrete aggregate board; wood board; the posts are metallic beams with a "H" section.

3 - LABORATORY MEASUREMENTS

The laboratory test method specified in EN 1793-2 [4] was applied. It fully conforms to the well-known ISO 140-3 [6], with some additions relevant for noise barriers. The specimens were mounted in the test opening and assembled in the same manner as the manufactured devices used in practice, with the same connections and seals between component parts. Where posts are employed in construction, at least one post was included in the specimen, with panels attached on both sides. The side that would face the traffic noise source faced the source room. The values of the airborne sound reduction index R were measured in the one-third octave bands from 100 Hz to 5 kHz [4], [6]. Two kinds of single number rating of sound insulation were calculated: the well-known rating R_w used in building acoustics, as defined in ISO 717-1 [7]; the traffic noise rating DL_R, as defined in EN 1793-2 [4], using the normalized A-weighted sound pressure level of traffic noise defined in EN 1793-3 [5]. All values of the ratings R_w and DL_R are reported in Table 1. The DL_R values were calculated both on the full frequency range 100 Hz to 5 kHz, in one-third octave frequency bands, and in the "restricted" frequency range 200 Hz to 5 kHz; the latter calculation was made in view of the comparison with the single number rating values resulting from the outdoor measurements (see Section 4).

4 - OUTDOOR MEASUREMENTS

The *Adrienne* test method was already presented in several publications, e.g. [1,2,3], and will not be detailed here. It is only worth recalling that each final value of the *sound insulation index SI* is the logarithmic average of the values measured at nine points placed on an ideal grid (scanning points) in front of the barrier. The analysis window must be the new *Adrienne* window, uniquely defined in shape, length and position [1,2,3]. The low frequency limit of sound insulation index measurements is inversely proportional to the width of the analysis window and depends also on its shape; taking the first notch in the magnitude spectrum of the window as an indicator of the low frequency limit, for an *Adrienne* window 7.4 ms wide this limit is about 160 Hz. Strictly speaking, the outdoor measured values shown in the following for 4 m tall barriers are therefore valid only starting from the 200 Hz one-third octave band.

The measurement system was similar to that described in [2,3]. The test signal was a MLS sequence of order 16; 64 averages were performed for each impulse response acquisition. The test site is a flat, grass covered ground. The grass was cut before the beginning of the tests. All samples were built in the same place and removed after the test, one after the other. Measurements were taken in good meteorological conditions, with no rain or strong wind (wind speed always < 4 m/s). Background noise did not influence the measurements.

For each noise barrier, the outdoor measurement procedure was repeated two times, placing the measuring equipment first close to the acoustic elements and then close to a post. This permitted the investigation of the two most common kinds of sound leak, which are usually located at panel-panel and panel-post connections. The outdoor single number rating DL_{SI} was computed using a formula similar to that for DL_R [4]; due to the above mentioned low frequency limit, the calculations were performed in the one-third frequency bands from 200 Hz to 5 kHz. The results are reported in Table 1.

Sample	Type	R_w [dB] lab.	DL_R [dB] lab.	DL_R [dB] lab.	DL_{SI} [dB] outdoors elements	DL_{SI} [dB] outdoors posts
		100 to 5k Hz	100 to 5k Hz	200 to 5k Hz	200 to 5k Hz	200 to 5k Hz
CON1	Concrete	56	52	54	63	61
CON2(Q)	Concrete	46	44	44	57	38
CON2(A)	Concrete	56	52	53	57	38
CON3	Concrete	53	48	50	62	54
CON4	Concrete	55	50	51	60	64
CON5	Concrete	48	45	45	55	57
CON6	Concrete	53	50	51	59	55
MET1	Metal	36	31	33	39	33
MET2	Metal	33	29	31	32	35
MET3	Metal	36	31	34	37	33
MET4	Metal	26	23	23	31	26
MET5	Metal	30	26	26	32	32
MET6	Metal	34	28	31	30	34
MET7	Metal	30	28	28	33	36
RES1	Resin	27	23	25	25	23
ACR1	Acrylic	36	33	33	40	40
MIX1	Met./Acr.	32	30	31	37	29
WOOD	Wood	34	30	30	34	27

Table 1: Single number ratings of airborne sound insulation.

5 - COMPARISON BETWEEN LABORATORY AND OUTDOOR DATA

Differences between laboratory and outdoor values were expected for the following reasons:

- the sound field in front of the test specimen is a diffuse field in laboratory and a frontal free-field outdoors. The oblique components of the indoor diffuse field generate the coincidence effect, which is not possible outdoors. For sample ACR1, constituted by a simple homogeneous acrylic sheet (Fig. 1), the laboratory curve exhibits a clear coincidence dip in the 1600 Hz one-third octave band, not found outdoors.
- The steady state signal recorded in the laboratory is very different from the impulse response recorded outdoors.
- The test samples are rigidly clamped on four sides in the laboratory, relatively free on three sides outdoors.

Often, sound insulation index values measured outdoor close to a post are worse than values measured close to the acoustic elements, especially at high frequency (see Fig. 2). This happens when the connections between the acoustic elements and the posts are not perfect and may depend not only from the workmanship, but also from the design of connections and the lack of good seals. In these cases, the laboratory performance is influenced by the element/post connections and is closer to the outdoor performance in front of a post. This confirms the importance of including a post in the test, both in laboratory and outdoors. For the concrete barrier CON2 Fig. 2, the laboratory test was repeated two times, the first with a "quick" seal at posts − similar to those used outdoors − and the second with an accurate seal. With the quick seal the laboratory performance is closer to the outdoor performance measured in front of a post, while with the accurate seal the laboratory performance is closer to the outdoor performance in front of barrier panels. The two different cases are indicated in Table 1 with CON2(Q) and CON2(A), respectively.

Comparing the values reported in Table 1 with the categories recommended in EN 1793-2 [4], all samples, excluding MET4 (laboratory test) and RES1 (laboratory test 100 Hz to 5 kHz and outdoor post test), got a category B3 of airborne sound insulation: the present EN classification does not allow to discriminate among barriers with single number ratings greater than 24 dB.

The application of standard statistical theory to data of Table 1 permitted to obtain various correlation laws between the airborne sound insulation ratings insofar obtained.

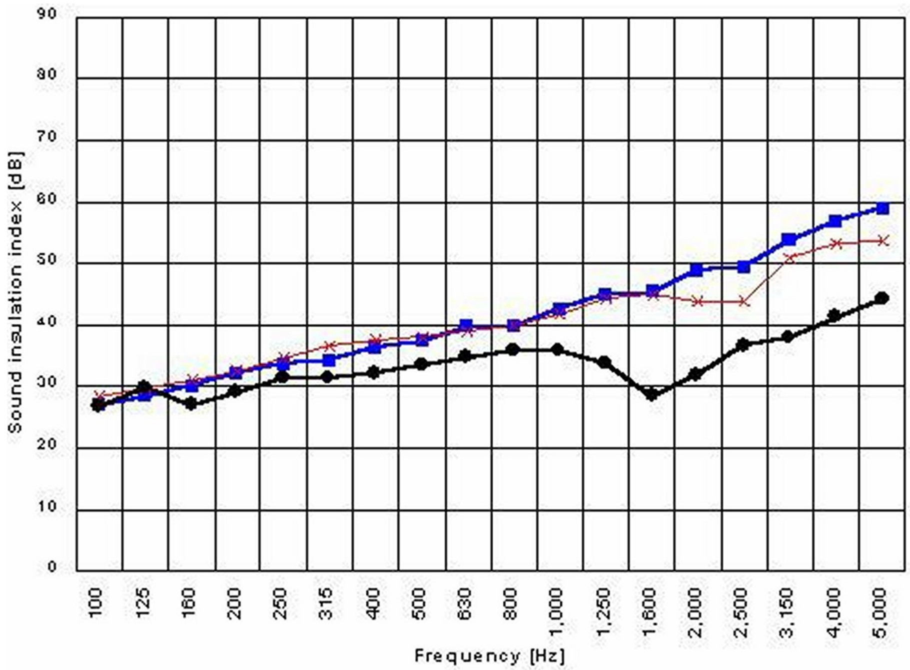

Figure 1: Sound insulation index values for barrier ACR1: (æ) laboratory measurements; (') outdoor measurements - elements; (%) outdoor measurements - post.

The linear correlation between the two single number ratings R_w and DL_R obtained from laboratory measurements, calculated over the frequency range 100 Hz to 5 kHz, is:

$$DL_R = 0.98R_w - 3.05 \ \ (r = 0.995) \tag{1}$$

Using the values of DL_R calculated over the frequency range 200 Hz to 5 kHz, it becomes:

$$DL_R = 0.93R_w + 0.37 \ \ (r = 0.992) \tag{2}$$

The controlled conditions of the tests and the excellent value of the correlation coefficient r support the conclusion that on average the EN single number rating DL_R is few decibels lower than the index R_w used in building acoustics.
The linear correlation laws between the single number ratings DL_R, obtained from laboratory data, and DL_{SI}, obtained from outdoor data (all calculated over the frequency range 200 Hz to 5 kHz), are:

$$\text{Elements} \ : DL_{SI} = 1.18DL_R - 0.94 \ \ (r = 0.97) \tag{3}$$

$$\text{Posts} \ : DL_{SI} = 1.18DL_R - 3.16 \ \ (r = 0.93) \tag{4}$$

For barrier CON2 the "quick" seal rating (44 dB) was taken for the correlation with the outdoor ratings of measurements close to a post and the accurate seal rating (53 dB) was taken for the correlation with the outdoor ratings of measurements close to the acoustic elements.
The linear correlation coefficient r is excellent for elements and very good for posts; this difference was expected, because outdoor results are less regular at posts due to the above mentioned problems of panel-post connections. In any case, the high values of the correlation coefficient support the conclusion that Equations (3) and (4) can be useful for predicting the expected field performance from laboratory data measured according to EN 1793-2.

6 - CONCLUSIONS

The new *Adrienne* method proved to be easy to use and reliable for all kinds of barriers. It has been found sensitive to quality of mounting, presence of seals and other details typical of outdoor installations. The comparison between outdoor and laboratory results shows a very good correlation, while existing differences can be explained with the different sound fields and mounting conditions between the outdoor and laboratory tests. In other words, results obtained using the *Adrienne* test method [1,2,3] are

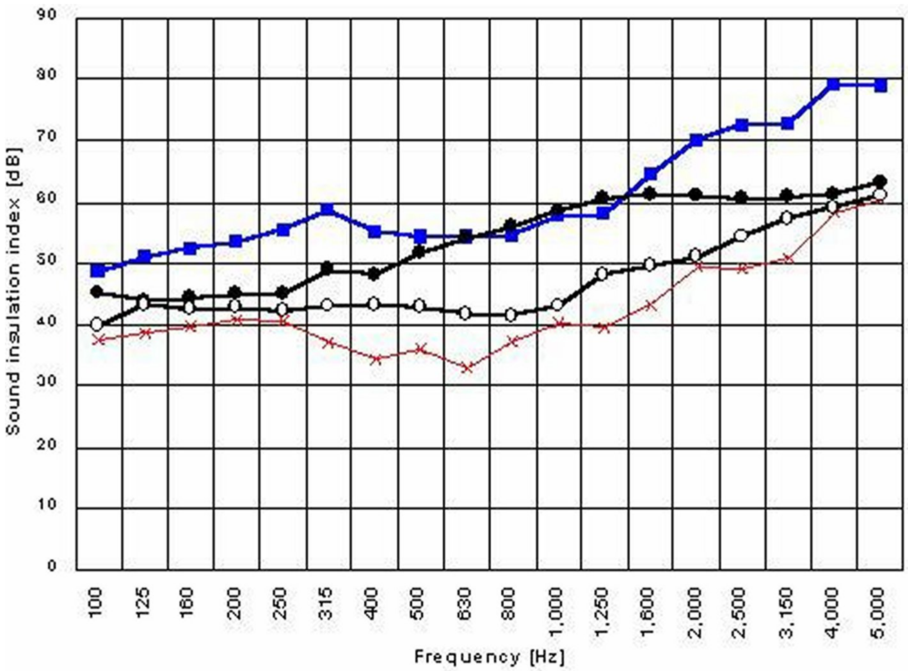

Figure 2: Sound insulation index values for barrier CON2: (æ) laboratory measurements - accurate seal; (□) laboratory measurements - quick seal; (’) outdoor measurements - elements; (%) outdoor measurements - post.

consistent with laboratory results obtained using EN 1793-2 [4]. The correlation laws resulting from the present work can be useful for predicting the airborne sound insulation performance of noise barriers in the field from laboratory data. It can be concluded that the *Adrienne* method is adequate for its intended use.

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