ICSV12
2005 Lisbon
11 - 14 July

Twelfth International Congress on Sound and Vibration

PERFORMANCES OF RESONANT BARRIERS FOR TRANSPORT NOISE ABATEMENT

Franco Cotana, Federico Rossi, Mirko Filipponi

Università degli Studi di Perugia – Dipartimento di Ingegneria Industriale
Via G. Duranti, 67
06125 Perugia – Italy
E-mail: cotana@unipg.it

Abstract

Noise is usually considered one of the main sources of "outdoor pollution". It may be produced by different sources due to human activities: transport systems, industrial and trading plants, yards and recreative activities. Noise barriers are one of the most commonly employed systems to reduce noise by transport infrastructures. An original noise barrier is here proposed. The barrier is constituted by a concrete base, porous materials and a multi-holed resonant panel (MHRP). Experimental tests were carried out in order to evaluate MHRP performances and the optimum configurations for maximum acoustic absorption.

INTRODUCTION

Noise barriers performances are usually evaluated in terms of transmission loss and diffraction phenomena; noise absorption performances are also important in order to reduce reflection phenomena. This paper deals with the design of an original noise barrier for traffic and rail noise abatement. The design was focused to obtain high noise absorption in all over the noise spectrum. Porous materials are characterized by high absorption properties for frequencies higher than 500 Hz. Absorption at lower frequencies may be obtained only by resonant systems. The proposed barrier is constituted by a multi-holed resonant panel (MHRP) which is mounted on an high insulation concrete support (concrete acoustic insulation index ≥ 55dB). Different barrier configurations were proposed and tested by a measurement campaign at the Perugia University Acoustic Laboratory. Rock wool panels were inserted between MHRP and the concrete support. Different thickness porous panels were tested for several distances to the concrete support. Results show that absorption coefficient is higher than 0.74 in the 200-2000 Hz range for any configurations.

1. THE PROPOSED NOISE BARRIER

The proposed noise barrier is constituted by the following elements:

- a 10 cm thick concrete support (see Figure 1);
- an MHRP plate which is fixed with steel screws to the concrete structural support (source side – see Figure 2);
- porous sound-absorbing panels constituted by rock wool mattresses (thickness = 40 mm, density = 70 kg/m^3);
- a 1.5 mm thick steel plate placed attached to the rock wool panels back side.

Figures 1 and 2 show the tested barrier prospect and detail. Porous material (rock wool) absorption coefficient is higher than 0.85 for frequencies higher than 500 Hz. MHRP was designed to attain an high acoustic absorption in a wider range of frequencies. Single-hole panel acoustic absorption is maximum for its resonance frequency f_r [1]:

$$f_r = \frac{c}{2 \cdot \pi} \cdot \sqrt{\frac{A_f}{D \cdot A \cdot (h + 0.8 \cdot d)}} \quad (1)$$

where A_f is the holed total area [m^2], A is the panel area [m^2], D is the distance between the panel and the concrete structure [m], h is the panel thickness [m] and d is the diameter of each hole [m].

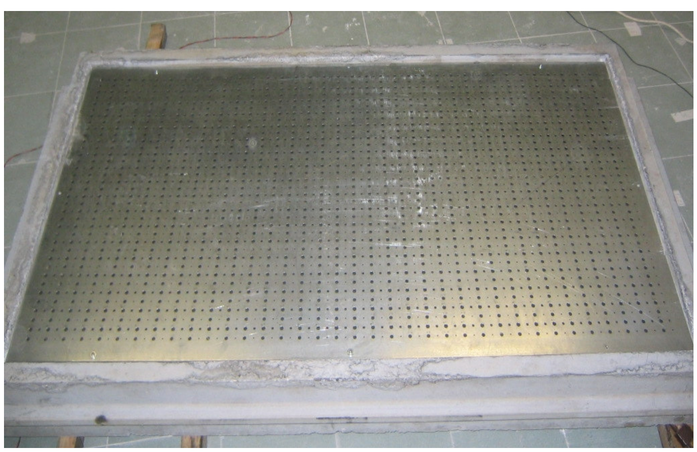

Figure 1 - the proposed noise barrier

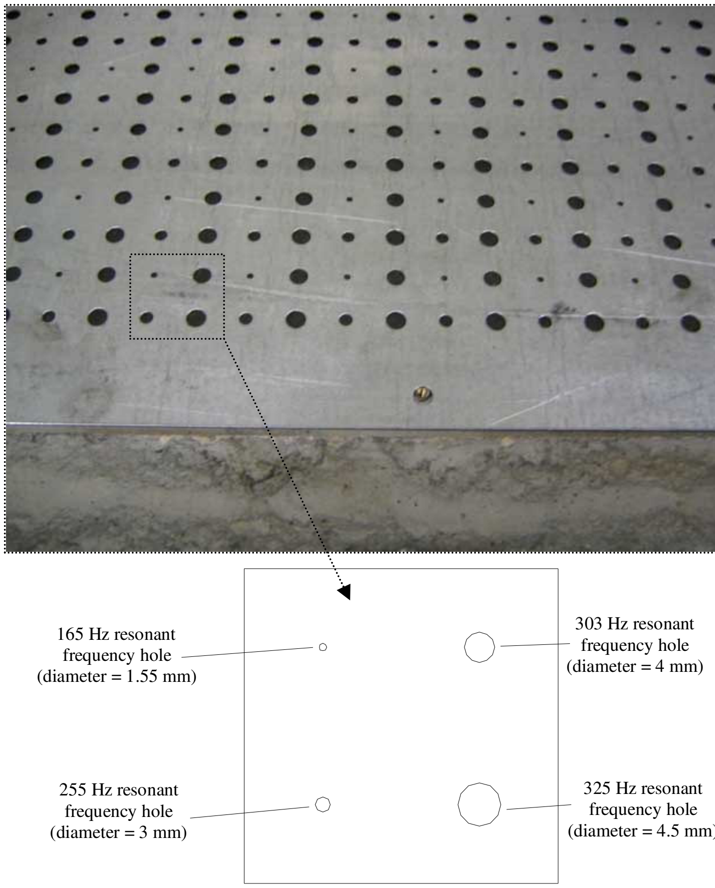

Figure 2 - the designed MHRP

The holes size was chosen to obtain an high absorption for frequencies below 500 Hz. The design was made by following the prescriptions of Italian Railways Standard [2] which defines the constructive characteristics of noise barriers and theirs components for railways applications: each single hole minimum area has to be 78 mm^2; holed/not holed areas ratio doesn't have to exceed 50 %. The Standard defines also barriers with medium and high absorption performance as reported in Table 1.

MHRP design was made as follows: the volume between the panel and the concrete support is supposed to be splitted up in a lot of small cavities: each cavity and the correspondent hole constitute an Helmholtz's resonator. MHRP total area is 1.5 m^2 for each barrier element; the overall internal air volume is 0.15 m^3. It was supposed to divide MHRP surface in a lot of small square elements; each square element side is 45 mm long. The panel thickness h is 1.5 mm; the distance D between MHRP and the concrete support is 100 mm. MHRP is constituted by 738 square primary elements. Four different diameters holes were made on each square primary element to maximize absorption coefficient on a wide frequencies range. The overall holes number is 2952. The system is characterized by four resonance frequencies: 165

Hz, 255 Hz, 303 Hz, 325 Hz which are obtained respectively by the following hole's diameters: 1.55 mm, 3 mm, 4 mm and 4.5 mm. Thus, holed/not holed areas ratio is 7.4 %. Figure 2 shows a four holes square primary element.

Table 1- Noise barrier classes defined by the Italian Technician Disciplinary for railways applications [2]

High performances barriers (f = frequency (Hz), α_s =absorption coefficient)																
f	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000
α_s	0.30	0.45	0.60	0.60	0.70	0.75	0.80	0.80	0.85	0.85	0.85	0.85	0.85	0.80	0.75	0.70
Medium performances barriers (f = frequency (Hz), α_s =absorption coefficient)																
f	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000
α_s	0.10	0.15	0.25	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.65	0.65	0.65	0.60	0.50	0.45

2. MEASUREMENT METHOD

The acoustic absorption properties of the designed noise barrier were measured according to ISO 354 [3]. Absorption noise barrier index for road traffic noise defined by EN 1793-1 was evaluated too [4]. Measurements were carried out in a reverberating room at the Perugia University Acoustic Laboratory. They were led by an interrupted stationary method generating a white noise through a dodecahedral source driven by a 150W rms amplifier. The following measurement equipment was used:

- Bichannel Symphonie data acquisition and elaboration system produced by 01dB;
- ½" Microphone, G.R.A.S. 40AR model, equipped with a PRE12H preamplifier.

3. THE INVESTIGATED NOISE BARRIER CONFIGURATIONS

Experimental tests were carried out for the following different barrier configurations:

Configuration 1) the system is made of six slices: MHRP, a 20 mm thick air interspace, a 40 mm thick rockwool panel, a 1.5 mm thick carbon steel sheet, a 40 mm thick air interspace and the concrete support (see scheme in Figure 3(a).

Configuration 2) the system is made of five slices: MHRP, a 20 mm thick air interspace, a 40 mm thick rockwool panel, a 40 mm thick air interspace and the concrete support (see scheme Figure 3(b)).

Configuration 3) the system is made of four slices: MHRP, a 60 mm thick air interspace, a 40 mm thick rockwool panel and the concrete support (see scheme in Figure 3(c)).

Configuration 4) the system is made of four slices: MHRP, a 20 mm thick air interspace, two 40 mm thick rockwool panels and the concrete

	support (see scheme in Figure 3(d)).
Configuration 5)	the system is the same of configuration 3, but 3 mm thick polyurethane elastic gaskets are placed below MHRP along the concrete support perimeter (see scheme in Figure 3(e)).

4. MEASUREMENTS RESULTS

Table 2 shows the measured absorption coefficient values relative to the tested configurations. Table 3 reports the measured DL_α values and barrier absorption classes according to EN 1793-1 [4].

Table 2 - Comparison between the measured absorption coefficients for the proposed configurations

Freq (Hz)	*100*	*125*	*160*	*200*	*250*	*315*	*400*	*500*	*630*	*800*	*1000*	*1250*	*1600*	*2000*	*2500*	*3150*	*4000*	*5000*
α_s *Conf 1*	0,11	0,32	0,49	0,79	0,81	0,94	1,03	1,09	1,09	1,07	1,05	1,02	0,92	0,80	0,56	0,51	0,27	0,06
α_s *Conf 2*	0,08	0,27	0,50	0,74	0,85	1,02	1,11	1,15	1,14	1,12	1,10	1,03	0,93	0,77	0,56	0,47	0,25	0,12
α_s *Conf 3*	0,13	0,30	0,51	0,81	0,97	1,06	1,07	1,12	1,11	1,12	1,13	1,05	0,89	0,76	0,56	0,44	0,25	0,03
α_s *Conf 4*	0,18	0,34	0,69	0,88	0,94	0,92	1,01	1,14	1,15	1,15	1,09	1,05	0,92	0,84	0,61	0,51	0,30	0,06
α_s *Conf 5*	0,13	0,31	0,66	0,76	1,01	1,05	1,16	1,15	1,09	1,13	1,02	1,00	0,79	0,74	0,50	0,45	0,35	0,15

Table 3 – Measured DL_α values and barrier absorption classes according to EN 1793-1

Configuration	**DL_α (dB)**	**Barrier Absorption Class**
1	*10*	*A3*
2	*12*	*A4*
3	*12*	*A4*
4	*13*	*A4*
5	*10*	*A3*

In Figure 4 the measured absorption coefficients are sketched and compared. It is shown that the proposed barrier configurations allow to obtain absorption coefficients higher than 0.74 for [200, 500] Hz frequency range (see values in Table 2). Besides, absorption coefficient is higher than 0.49 at 160 Hz. Low performances occur for high frequencies (higher than 2000 Hz) due to MHRP low holed area. Thus, the proposed barrier configurations are characterized by absorption coefficient higher than 0.74 for the 200-2000 Hz frequency range.

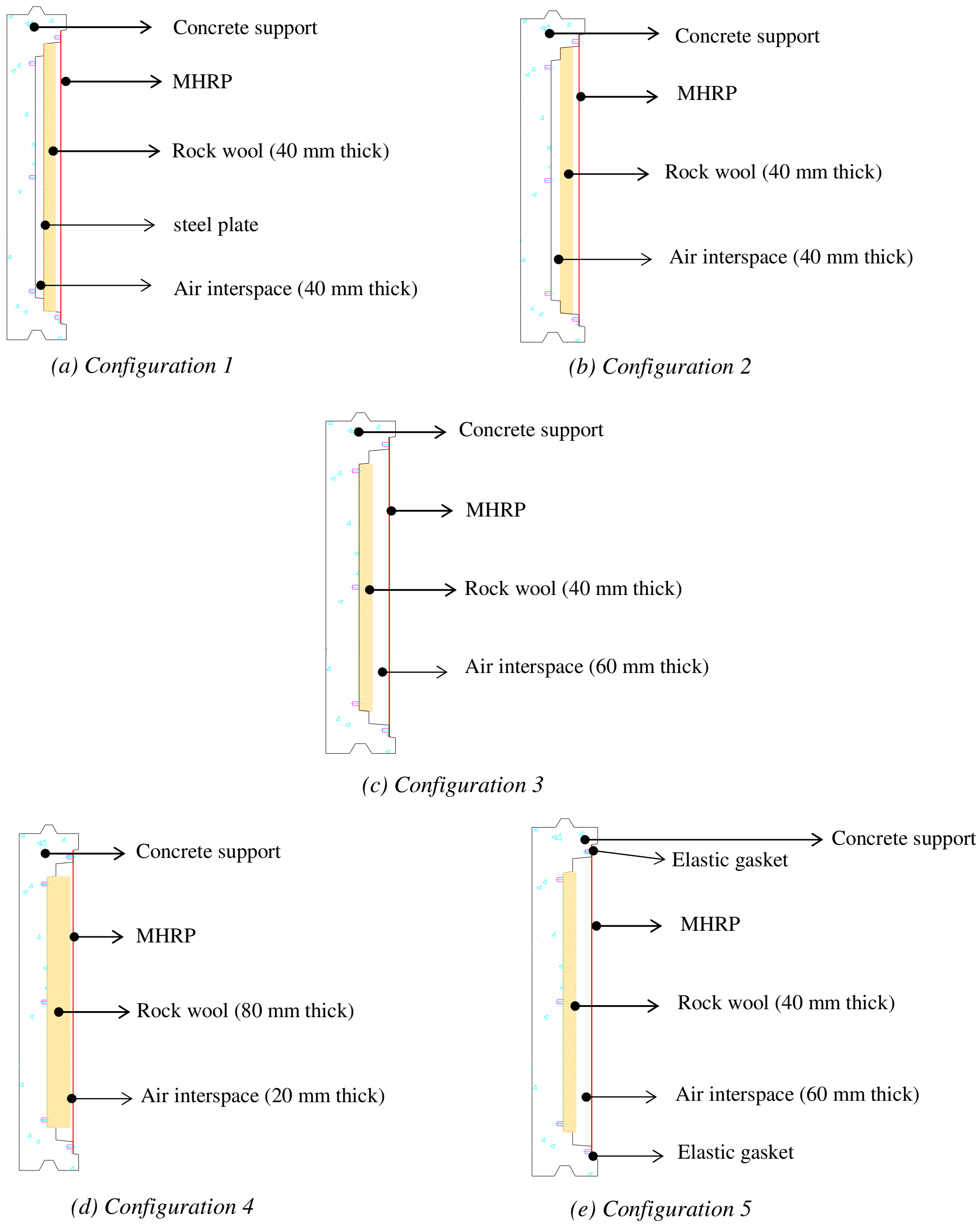

Figure 3 – The proposed noise barrier configurations

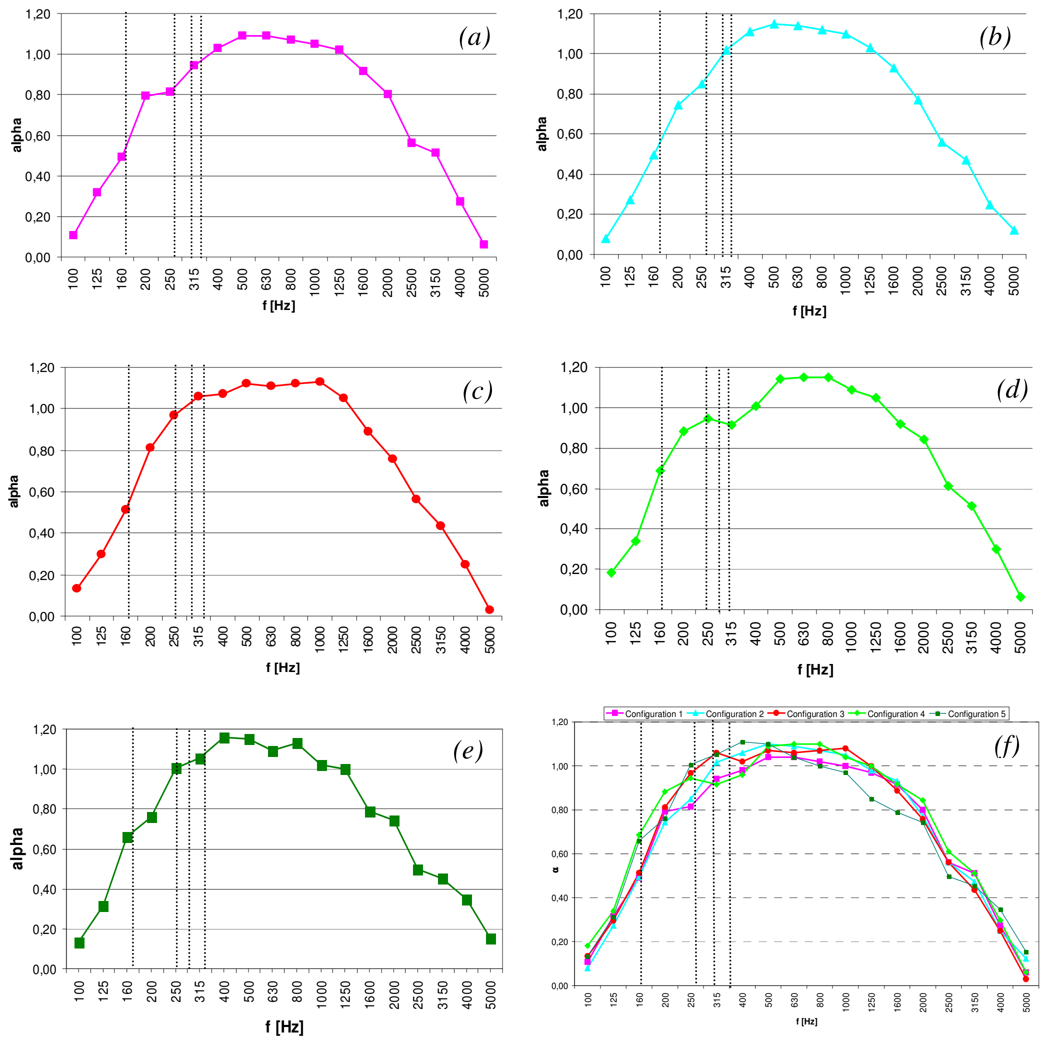

Figure 4 – (a) configuration 1 absorption coefficient; (b) configuration 2 absorption coefficient; (c) configuration 3 absorption coefficient; (d) configuration 4 absorption coefficient;(e) configuration 5 absorption coefficient; (f) comparison between the measured absorption coefficients - sketched lines show the designed resonant frequencies.

CONCLUSIONS

In this paper the absorption performances of an original noise barrier were analysed. Five configurations were tested consisting of a multi-holed resonant panel (MHRP), porous rockwool panel in different position and thickness, a metallic plate (only for configuration 1) and a concrete support. Absorption performances due to the different configurations were compared. DL_{α} values according to EN 1793-1 show that configurations 2, 3 and 4 belong to A4 barrier class, while configurations 1 and 5 belong to A3 class. Measured absorption coefficients values were also compared to the prescriptions of Italian Railway Standards [2]. Results show that:

- Configuration 1 is an "high performances" barrier for frequencies lower than 1600 Hz and a "medium performances" barrier for frequencies lower than 2500 Hz [2];
- Configuration 2 is an "high performances" barrier for [160, 2000] Hz frequency range; it is a "medium performances" barrier for frequencies lower than 2000 Hz [2];
- Configurations 3 and 4 are "high performances" barriers for frequencies lower than 2000 Hz [2];
- Configuration 5 is an "high performances" barrier for frequencies lower than 1250 Hz and a "medium performances" barrier for frequencies lower than 2000 Hz [2].

Thus, the proposed barrier configurations 2, 3 and 4 allows an "high noise absorption" in [160, 2000] Hz frequency range. It is in progress a free-field measurement campaign for a further results validation.

ACKNOWLEDGMENTS

Authors thank Ing. Sofia Simoni for the precious collaboration in the execution of experimental tests.

REFERENCES

[1] L. L. Beranek, *Noise and Vibration Control*. (Mc Graw Hill, New York, 1971).
[2] "Barriere antirumore per impieghi ferroviari - Disciplinare Tecnico", Armamento e Opere d'Arte – Istituto Sperimentale Progettazione, Divisione Infrastruttura – Direzione Tecnica (Dicembre 1998).
[3] ISO 354, "Acoustics - Measurement of sound absorption in a reverberation room", 2003.
[4] EN 1793-1, "Road traffic noise reducing devices - Test methods for determining the acoustic performance – Part 1: Intrinsic characteristics - Sound absorption", 1997.