Performance acoustique de protections antibruit de faible hauteur utilisant des moyens naturels

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La réduction du bruit urbain par des moyens naturels est un domaine de recherche grandissant. Dans ce travail mené dans le cadre du projet collaboratif européen HOSANNA, nous proposons d'évaluer, en utilisant la Méthode des Eléments de Frontière (BEM) 2D, l'efficacité acoustique d'un ensemble de familles de protections antibruit innovantes de hauteur limitée et dédiés à la réduction du bruit des transports terrestres en milieu urbain (route, tramway) : écran en substrat végétal avec âme rigide, protections inter-voies, écran en bordure de pont et merlons de forme complexe, tous de faible hauteur (typiquement 1 m). L'analyse est effectuée pour des zones de réception autour de 1,5 m (piétons, cyclistes) et 4 m de hauteur (cartographie stratégique européenne du bruit et PPBE). Les résultats de performance, exprimés en termes de pertes par insertion, montrent que dans un certain nombre de situations le gain acoustique peut être significatif.

1 Introduction

We present in this paper part of the results obtained within WP2 (on "Innovative barriers") of the HOSANNA European collaborative project (Holistic and sustainable abatement of noise by optimized combinations of natural and artificial means) [1-4]. Each section of this document refers to a specific family of low height innovative solution using natural means:

- Low height vegetated barriers,
- Low vegetated inter-lane/track barriers,
- Low vegetated barriers at the edges of bridges,
- Low earth berms.

Concluding recommendations are also formulated on the use of these innovative barriers.

Most calculations have been carried out for four different 20 m long, 1 m high areas of receivers as shown in Figure 1. Zones 1 and 3 (extending from 1 to 2 m in height) characterise sound levels at heights around 1.50 m above ground (i.e. pedestrian, cyclist or building ground floor) when zones 2 and 4 (extending from 3.50 to 4.50 m in height) characterise sound levels at heights close to 4 m above ground (first floor of buildings).

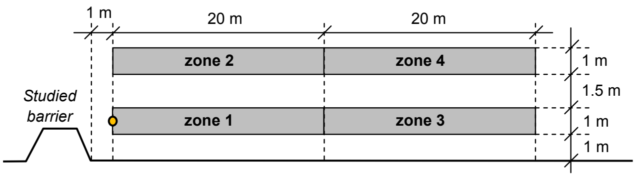


Figure 1: Definition of the 4 receivers' zones and the "pedestrian" receiver (circle)

Simulations have been carried out using a 2D Boundary Element Method developed at CSTB by Jean [5]. The vegetation substrate absorption was modelled using its measured absorption coefficients per 3rd octave band given in Table 1. In the case of tramways the body of the tram was taken into account and meshed so that multiple-reflections effects between car body and barrier are included.

Table 1: Absorption coefficients per 3rd-octave band for vegetation substrate

Frequency (Hz)				***50***	***63***	***80***	***100***
Absorption coefficient				**0.08**	**0.11**	**0.15**	**0.22**
125	***160***	***200***	***250***	***315***	***400***	***500***	***630***
0.30	**0.42**	**0.55**	**0.70**	**0.84**	**0.91**	**0.90**	**0.85**
800	***1000***	***1250***	***1600***	***2000***	***2500***	***3150***	***4000***
0.79	**0.78**	**0.85**	**0.91**	**0.93**	**0.95**	**0.98**	**0.99**

We also considered the single receiver located 1.50 m high, 1 m away from the studied noise protection. This receiver characterising a nearby pedestrian or cyclist is called "pedestrian" hereafter.

In order to analysis the results of simulations carried out, it is important to recall that for HOSANNA WP2 the following quantitative objectives were initially fixed: *to produce designs for vegetated low barriers (or low barriers using natural materials) which leads to a minimum noise abatement of 6 dBA (resp. 8 dBA) in urban areas at a 4 m high (resp. 1.5 m high) receiver location alongside a given surface transport corridor, compared to an untreated situation.*

2 Low height vegetated barriers

2.1 Height's barrier effect

We first assess the effect of the height of a low vegetated straight barrier on its acoustical performance. We consider six different heights of the barrier: 0.4, 0.6, 0.8, 1, 1.2 and 1.4 m, and two types of urban noise source: 2-track tramway and 2-lane urban road. The environment is considered flat and open without buildings. The barrier is located at the edge of the infrastructure, and is made of 40 cm thick vegetation substrate (absorption coefficients given in section 1) with a rigid core inside.

Results are presented hereafter in terms of Insertion Losses IL (compared to the case without any barrier) for the pedestrian receiver as well as the four receiving zones as defined in section 1.

2.2 Tramway case

Tables 2 and 3 present IL results, the tramway being considered to move either on the close track or on both tracks (one track at a time) respectively. One can remark that all initial objectives may be reached for a barrier no less than 0.6 m high for one close track and 0.8 m for both.

Table 2: IL results in dBA - Tramway (close track)

Barrier's height m	Pedestr. dBA	Zone 1 dBA	Zone 2 dBA	Zone 3 dBA	Zone 4 dBA
0.4	**6.5**	**10.1**	**8.0**	**8.9**	**10.9**
0.6	**13.1**	**14.6**	**12.7**	**13.8**	**15.1**
0.8	**17.6**	**17.5**	**16.5**	**16.7**	**17.2**
1	**19.4**	**18.9**	**18.2**	**17.6**	**18.3**
1.2	**20.8**	**20.2**	**19.5**	**18.8**	**19.5**
1.4	**21.4**	**21.3**	**20.4**	**19.6**	**20.2**

Table 3: IL results in dBA - Tramway (both tracks)

Barrier's height m	Pedestr. dBA	Zone 1 dBA	Zone 2 dBA	Zone 3 dBA	Zone 4 dBA
0.4	**3.8**	**5.1**	**3.4**	**4.1**	**5.0**
0.6	**6.6**	**7.4**	**5.1**	**5.9**	**7.1**
0.8	**9.1**	**9.3**	**6.7**	**7.3**	**8.8**
1	**11.2**	**10.7**	**8.0**	**8.3**	**10.1**
1.2	**12.9**	**12.0**	**9.2**	**9.2**	**11.2**
1.4	**14.4**	**13.1**	**10.2**	**9.9**	**12.1**

2.3 2-lane urban road case

Table 4 presents IL results for the case of a 2-lane traffic composed of 95 % of cars (50 km/h) and 5 % of lorries (50 km/h).

Table 4: IL results in dBA – 2-lane urban road

Barrier's height m	Pedestr. dBA	Zone 1 dBA	Zone 2 dBA	Zone 3 dBA	Zone 4 dBA
0.4	**1.1**	**2.0**	**1.2**	**1.8**	**1.6**
0.6	**2.0**	**3.7**	**2.0**	**3.6**	**3.1**
0.8	**3.7**	**5.8**	**3.2**	**5.6**	**5.2**
1	**6.0**	**7.8**	**4.6**	**7.3**	**7.1**
1.2	**8.3**	**9.4**	**6.1**	**8.7**	**8.6**
1.4	**10.4**	**10.7**	**7.5**	**9.8**	**9.8**

In conclusion all initial objectives may be reached for a barrier no less than 1.2 m high.

3 Low inter-lane/track barriers

3.1 Summary of studied cases

The aim is now to assess the shielding effect of adding a low absorbing barrier between two traffic lanes or two tramway tracks when a low barrier is already built at the edge of the infrastructure, along the walkway.

The barriers are 1 m high and are made of vegetation substrate (40 cm thick) with a thin rigid core inside. Two cases have been considered: a 2-track tramway with trams moving at 30 km/h ("A" being the inter-track barrier, see Figure 2) and a 4-lane urban street ("B" and "D" being the inter-lane barriers) with 95% of light vehicles (50 km/h) and 5% of heavy vehicles (50 km/h). In the road traffic case, a 50-cm wide emergency platform is inserted on both sides of the low barriers, i.e. the distance between vehicles and barrier is not smaller than 0.5 m.

Three urban situations have been simulated: open area (no building), building on receiver side and buildings on both sides.

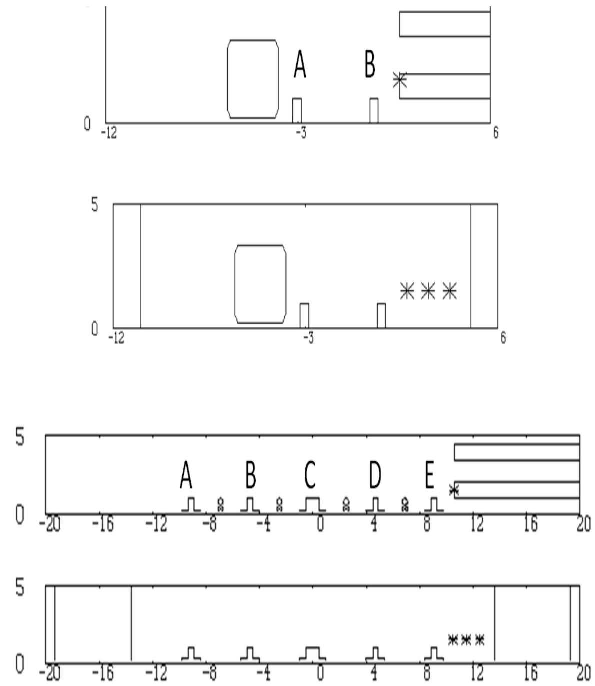


Figure 2: Pedestrian receivers location (*) and possible locations of the low barriers (without or with buildings): A-B for the tramway case, A being the inter-track barrier (upper figures) and A-B-C-D-E for the 4-lane road case, B and D being the inter-lane barriers (lower figures)

3.2 Results

The extra noise attenuation due to the addition of a central inter-track low absorbing barrier on a 2-track tramway in an open-area (no building), is in the range 6-8 dBA for all receiver zones (see Figure 1). A value of 9 dBA is obtained for the "pedestrian" receiver. These results remain of the same order in built-up areas for the three 1.5 m high "pedestrian" receivers (Figure 2): 8 dBA in the case of one building on receiver side and 7 dBA in the case of buildings on both sides.

The extra noise attenuation due to the addition of a central inter-track low absorbing barrier between the two first lanes (barrier D in Figure 2, between the two right lanes) of a 4-lane urban street in an open-area (no buildings), is 10 dBA for the pedestrian receiver (14 dBA when considering only the farther track, i.e. left track in Figure 2). The noise reduction is 5 dBA in the 1.5 m high receiver zones and 2-3 dBA for the 4 m high receiver zones. In built-up areas (a building on receiver side or buildings on both sides), the extra noise attenuation is in the range 4-5 dBA for the three 1.5 m high "pedestrian" receivers.

The addition of a central low absorbing barrier at the very middle of the road infrastructure (barrier C in Figure 2) results an extra noise attenuation of 3 to 5 dBA. For an already constructed central concrete barrier, these values of extra noise attenuation can be reached if it is covered with an absorbing material such as vegetation substrate.

If noise abatement is sought on both sides of the 4-lane street an extra inter-lane low absorbing barrier has to be installed on the other side as well (barrier B in Figure 2, between the two left lanes).

3.3 Recommendations

The shielding effect of adding a low absorbing barrier between two traffic lanes or two tramway tracks shows to be very important. We highly recommend that this principle be used to create "quiet" road or tramway infrastructures if need be. This can be the case when a cycle path is constructed along tramway tracks or when a road runs along a square, an urban park or a recreational area.

This principle could be applied also in sufficiently wide canyon streets (such as avenues and boulevard) where the ambient noise for pedestrians walking on the pavement or cyclists moving along the road is often too high. This type of action would improve the quality of such places.

The shielding effect is also efficient for the lowest floors (up to 5 m high) of buildings built along road and tramways. However for higher floors such absorbing low barriers have only small noise abatement impact.

4 Low barriers at the edge of bridges

4.1 Summary of studied cases

In this section we assess the extra noise attenuation due to a 1 m high absorbing barrier (consisting of a 40 cm wide vegetation substrate surrounding a thin rigid core), compared with a non-absorbing barrier, built at the edge of a 6 m high bridge (on one or two sides). Two cases of infrastructure are studied: a 4-lane motorway (traffic composed of 85% of light vehicles at 120 km/h and 15% of heavy vehicles at 90 km/h) and a 2-track tramway (trams moving at 30 km/h), as shown in Figures 3 and 4.

We focus here on the pedestrian on a walkway or the cyclist moving below the bridge, the receivers being at height of 1.5 m (dots on Figures 3 and 4).

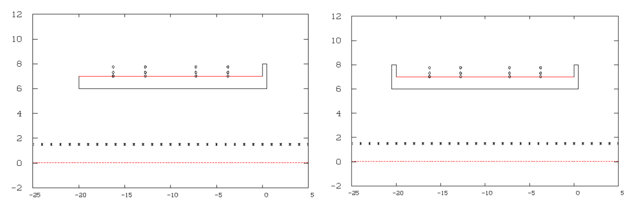


Figure 3: Overview of bridge with barrier on 1 or two sides. Motorway case

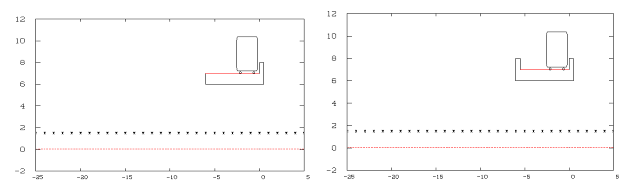


Figure 4: Overview of bridge with barrier on 1 or two sides. Tramway case

4.2 Results

The 40 cm wide, 1 m high barrier made from vegetation substrate over a core is very efficient for improving the noise environment below the bridge where pedestrians and cyclists are moving.

Even when no inner rigid core is used inside the barrier, a high noise reducing effect is predicted for both infrastructure types.

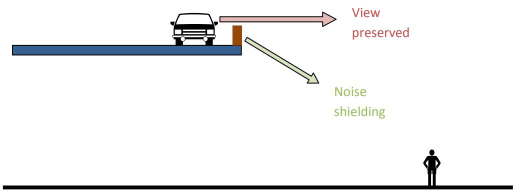
For the motorway configuration, the extra noise reducing effect (in comparison with a situation without barrier) is in the range 6-8 dBA.

In the case of the tramway, the extra noise reducing effect is about 12 dBA; the attenuation being in the range 16-20 dBA for the closest tramway alone.

4.3 Recommendations

The shielding effect of adding a low absorbing barrier at the edge of bridges can be very large, for both road and tramway infrastructures. We recommend the use of such low barriers to improve the noise environment below bridges, notably where pedestrian and cycle paths have been designed.

One may note that the addition of a 1 m high absorbing barrier at the edge of bridges does not prevent car drivers and tramway passengers from seeing the landscape beyond the bridge.



Moreover the light weight of vegetation substrate makes the product suitable for bridges.

By creating quieter areas below bridges we aim at promoting environmental-friendly transportation modes (cycling, walking) as well as urban parks and recreational areas along rivers where natural environmental characteristics have to be kept.

5 Low earth berms

5.1 Summary of studied cases

The aim is to assess the shielding effect of low height grassy earth berms in open areas (no building nearby) whose height is 1 m and cross sectional area is 1 m^2. The geometries of the studied berms are given in Figure 5.

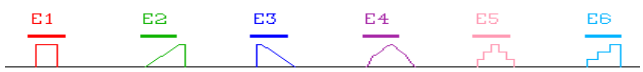


Figure 5: Geometries of the studied earth berms (B1 to B6)

A first series of simulations was dedicated to flat terrain topography in open area. Two cases were then addressed: a 2-lane urban road (95% of light vehicles at 50 km/h and 5% of heavy vehicles at 50 km/h) and a 2-track tramway (30 km/h) as shown in Figure 6.

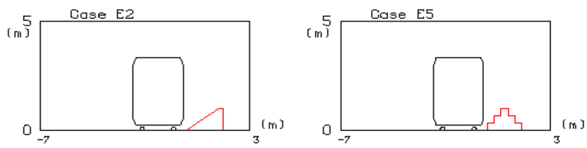


Figure 6: Overview for berms B2 and B5 (closest tram)

A second series of calculations was made for infrastructures on a 3 m high embankment in open area, with cases of a 4-lane motorway (traffic composed of 85% of light vehicles at 120 km/h and 15% of heavy vehicles at 90 km/h) and a 2-track TGV railway (trains at 300 km/h). Note that for the TGV cases, the berms are 1 m high above the ballast plane, so that their total height is 1.5 m.

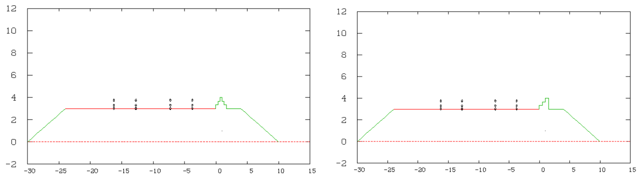


Figure 7: Overview for berms B5 and B6 (motorway)

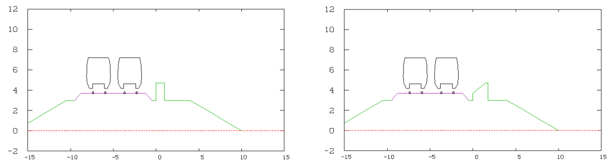


Figure 8: Overview for berms B1 and B2 (high speed train)

5.2 Results

The extra attenuation due to the addition of a low earth berm along a 2–track tramway on flat terrain, is in the range 9-12 dBA for 1.5 m receiver zones and 7-12 dBA for the 4 m high receiver zone. The highest average extra attenuations are obtained for the “stairs” shapes B5 and B6 (defined in Fig. 20).

The extra attenuation due to the addition of a low earth berm next to a 2-lane road on flat terrain, is in the range 5-8 dBA for 1.5 m receiver zones and 3-7 dBA for the 4 m high receiver zone. The highest average extra attenuation is obtained for the “square” shape B1 when the lowest one is observed for the “rounded” shape B4.

The extra attenuation due to the addition of a low earth berm along a 2–track TGV railway on a 3 m high embankment, is in the range 4-8 dBA for 1.5 m receiver zones and 5-9 dBA for the 4 m high receiver zone. The highest average extra attenuations are obtained for the “square” and “stairs” shapes B2, B5 and B6, the lowest ones being for the “slope” shape B3.

The extra attenuation due to the addition of a low earth berm along a motorway on an embankment is in the range 3-6 dBA for 1.5 m receiver zones and 4-6 dBA for the 4 m high receiver zone. The highest average extra attenuations are obtained for the “square” shape B1 and “stairs” shape B5 when the lowest one is observed for the “rounded” shape B4.

5.3 Recommendations

Low height earth berms prove to be a possible noise shielding solution for receivers up to 5 m high.

In the case of flat terrain we recommend their use when noise sources are sufficiently close to them, that is to say along 1-lane or 2-lane urban roads as well as tramways.

For high speed road and rail infrastructures, we recommend use of this type of noise abatement solution only when the motorway or the TGV railways are embanked (at least a few meter high) or when the altitude of the receiver area is lower by a few meters compared to the infrastructure reference plane.

We also recommend the building of “square” or “stairs” low earth berms (shapes B1, B5 and B6 in Figure 5) instead of the more standard “triangle” shapes (B2, B3 and B4).

6 Conclusion

This research achieved in the frame of WP2 of HOSANNA project shows that families of low innovative barriers using natural materials are effective, promising solutions to abate ground transportation noise for receivers up to 5 m high. These novel solutions depend on both transportation and environment types.

From this work one can draw the following conclusions:

- Vegetation substrate is predicted to be very suitable for use on low barriers (this product may be vegetated with no sensible loss of sound absorbing properties).
- The noise abatement due to the addition of an extra inter-lane (streets) or inter-track (tramways) absorbing low barrier is very significant: this is a very promising solution to create real “quiet” areas and walkways in cities.
- Low vegetated barriers at the edge of bridges seem to be very promising, easy-to-implement solutions to improve the soundscape for walking and cycling paths below them.
- Low earth berms are efficient alternative “natural” solutions.

Acknowledgement

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