



Comparing downwind shielding of noise walls and berms

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Classical, vertically erected highway noise walls suffer from a strongly reduced shielding efficiency in case of downwind sound propagation. The driving force for this effect is the presence of strong gradients in the horizontal component of the wind speed. Earth berms, on the other hand, are aerodynamically much smoother. A numerical comparison is made to compare noise walls and berms with a previously validated CFD-FDTD-PE model under downwind conditions. Predictions show that in absence of wind, there is a slight preference for a noise wall if placed at the position of the foot of the berm. Under downwind conditions, noise wall shielding is strongly reduced, while non-steep berms are only affected to a limited degree. When looking at long-term equivalent noise levels, so including periods with wind, shallow berms are therefore preferred upon vertical noise walls.

1 INTRODUCTION

The efficiency of vertically erected noise walls is often largely reduced at downwind locations¹⁻³. The flow field near a vertically erected wall results in large vertical gradients in the horizontal component of the wind velocity, which is the driving force for downward refraction of sound. At close distance, diffracted sound is bent downwards and enters the shadow zone. Since more sound energy reaches this zone, the shielding efficiency decreases compared to a windless atmosphere.

In contrast to noise walls, berms are “aerodynamically smoother”, and therefore the screen-induced refraction of sound (*SIROS*) by wind could be weaker. This is numerically investigated in this section. Especially highway noise barriers could be sensitive to wind effects since these are most often located in open fields. This means that wind shelter from surrounding objects is limited, and large wind speeds might be impinging on the barrier. The worst-case scenario is modelled here namely downwind sound propagation (for a normal incident wind direction). A comparison is made between a noise wall, a steep berm (with a slope of 1:1), and a non-steep berm (with a slope of 3:1), as shown in Fig. 1.

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2 NUMERICAL MODELS AND PARAMETERS

The flow fields are calculated with the CFD software Fluent. The k- ϵ engineering (turbulence closure) model has been used. The vertical (inflow) profile of the horizontal wind velocity is expressed by the following equation (assuming a neutral atmosphere):

$$u_x = \frac{u_*}{\kappa} \ln \left(1 + \frac{z}{z_0} \right) \quad (3)$$

where u^* is the friction velocity, κ is the Von Karman constant (equal to 0.4 for air), z is the height above ground level, and z_0 is the aerodynamic roughness height. The flow simulations were performed for friction velocities of 0.4 m/s and 0.8 m/s, and an aerodynamic roughness length of 0.01 m was used. These values correspond to a wind speed of 6.9 m/s (moderate wind) and 13.8 m/s (strong wind) at a height of 10 m, respectively.

Sound propagation between source and receivers was calculated with the Finite-Difference Time-Domain (FDTD) model, coupled to the Green's Function Parabolic Equation (GFPE) method. This hybrid model⁴ was shown to be a very efficient numerical approach, without loss in accuracy. The effect of complex flows in the source region are accurately taken into account by the FDTD method⁵, solving the sound propagation equations in a moving medium. The computational efficiency of the GFPE⁶ model, on the other hand, is exploited to assess the barrier efficiency at longer distance, still taking into account refraction.

The berm surface has been modelled as a “forest floor”, which is the acoustically soft soil that typically develops under vegetation. Downwind, grass-covered soil has been modelled. The Zwicker and Kosten model⁷ was used to account for the interaction between sound waves and natural soil, based on parameter fits to many in-situ measurements⁸.

The berms and wall a have the same top position. Wall b is located at the same position of the foot of the 3:1-sloped berm. The source was located at 24 m from the top location of the berms. All berms and walls considered have a height of 4 m. A receiver zone, extending from 50 m to 250 m from the source, and from ground level to 10 m, is considered. The geometrical setup is shown in Fig. 2.

The Harmonoise/Imagine road traffic source power model described e.g. in the work of Jonasson⁹ is used to calculate A-weighted traffic noise levels. To reduce the computational cost, a single source height has been considered.

3 RESULTS

The results discussed in this section are insertion loss values (level in absence of wall/berm and in absence of wind, minus the level in presence of wall/berm and in presence/absence of wind), linearly averaged over the receiver zone as defined in Fig. 2.

3.1 In absence of wind

The predicted (averaged) light-vehicle insertion losses for noise wall a range from 6.9 dBA to 10.6 dBA for vehicle speeds ranging from 30 km/h to 130 km/h. The heavy-vehicle insertion losses show a smaller dependence on vehicle speed, being only 1.5 dBA difference between the highest and lowest vehicle speed considered. Bringing the wall closer to the source (wall b)

results in an improvement which is more pronounced at the higher vehicle speeds. These improvements range from 1.3 dBA to 4.1 dBA, depending on the vehicle type and vehicle speed.

At low vehicle speeds, the berms perform worse than the wall. At the highest vehicle speeds, the berms perform more or less similar to the screen with the same top position. Compared to the shifted wall b, the performance is predicted to be still somewhat lower.

3.2 Under downwind conditions

The wall efficiency decreases strongly with increasing wind speed. This becomes clear when analysing the insertion loss contourplots in Fig. 3. Zones with insertion losses above 10 dBA disappear as soon as there is wind, and zones with negative insertion loss become prominent at larger distances downwind. For the moderate wind, insertion loss values reduce to 3.4 dBA and 2.8 dBA for light vehicles at speeds 30 km/h and 130 km/h, respectively. This means that the reduction by the action of wind ranges from 3.5 dBA to 7.8 dBA. The contourplots in Fig. 3 further show that wind makes the insertion loss more spatially dependent compared to the windless situation.

Also the steepest berm (with slope 1:1) is strongly affected by the action of wind as illustrated by the field plots in Fig. 3. The insertion losses are, however, slightly higher than in case of the noise wall (3.6 dBA and 4.2 dBA at 30 km/h and 130 km/h, respectively).

The non-steep berm (with slope 3:1), in contrast, is much less sensitive to the action of the wind. Fig. 4 clearly shows that the insertion loss fields stay close to the one in absence of wind. Only at limited heights at the largest distance considered, a reduction is predicted.

Analysis of 2:1-sloped berms and berms with a flattened top in wind, and analysis of the wind fields near berms, can be found in Ref. 10.

4 CONCLUSIONS AND DISCUSSION

The noise wall efficiency largely decreases in case of wind, also when averaging over a large receiver zone. Berms, on the other hand, are less sensitive to the action of wind. With decreasing berm slope angle, the (negative) action of the wind decreases significantly. For berms with a slope of 1:3, the averaged wind effect can be smaller than 1-2 dBA.

Since noise walls can be placed more closely to the source, when keeping the same height as the berms, noise walls are preferred when neglecting wind effects. When berms are acoustically soft (e.g. by vegetation), similar shielding might be obtained when the same top position is taken.

When looking at long-term equivalent noise levels, the periods with downwind sound propagation are often dominant. This statement forms the basis of the calculation of long-term averaged noise level in e.g. the ISO 9613-2 model. Furthermore, measurements¹¹ showed that the downwind loss in shielding is not limited to the periods where the wind is blowing exactly normal to the wall: Similar effects are observed for deviations of ± 45 degrees relative to the normal on the wall.

As a result, it can be expected that in many situations, non-steep and acoustically soft berms are likely to outperform walls in a long-term assessment. In addition, a non-steep berm will limit sound reflection on its source side. Also the many positive non-acoustical benefits¹² of natural berms can be mentioned, certainly in case of non-steep ones. The feeling of openness is preserved and such berms can be easily integrated in landscapes. They can also be grown, which is interesting to further improve visual attractiveness, but also to increase soil porosity. Other advantages are the very long lifetime and the absence of graffiti issues. Safety fences are

not needed as with classical noise walls. Furthermore, excess material (soil) from other locations can be used to construct berms. The major non-acoustical drawback is that berms, especially the non-steep ones, are more land-taking.

5 ACKNOWLEDGEMENTS

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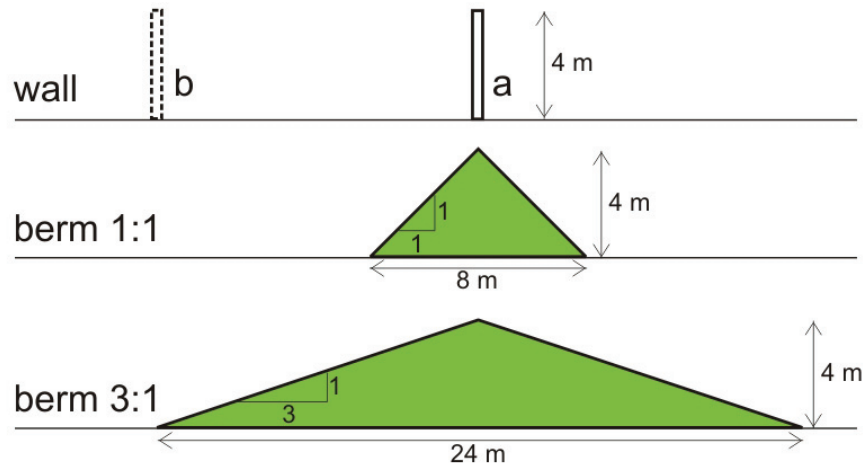


Fig. 1 – Berm geometries considered for studying the effect of wind sensitivity. A noise wall, placed at the same position as the centre of the berms (wall a), and at the same position as the foot of the 3:1-sloped berm (wall b) is also considered.

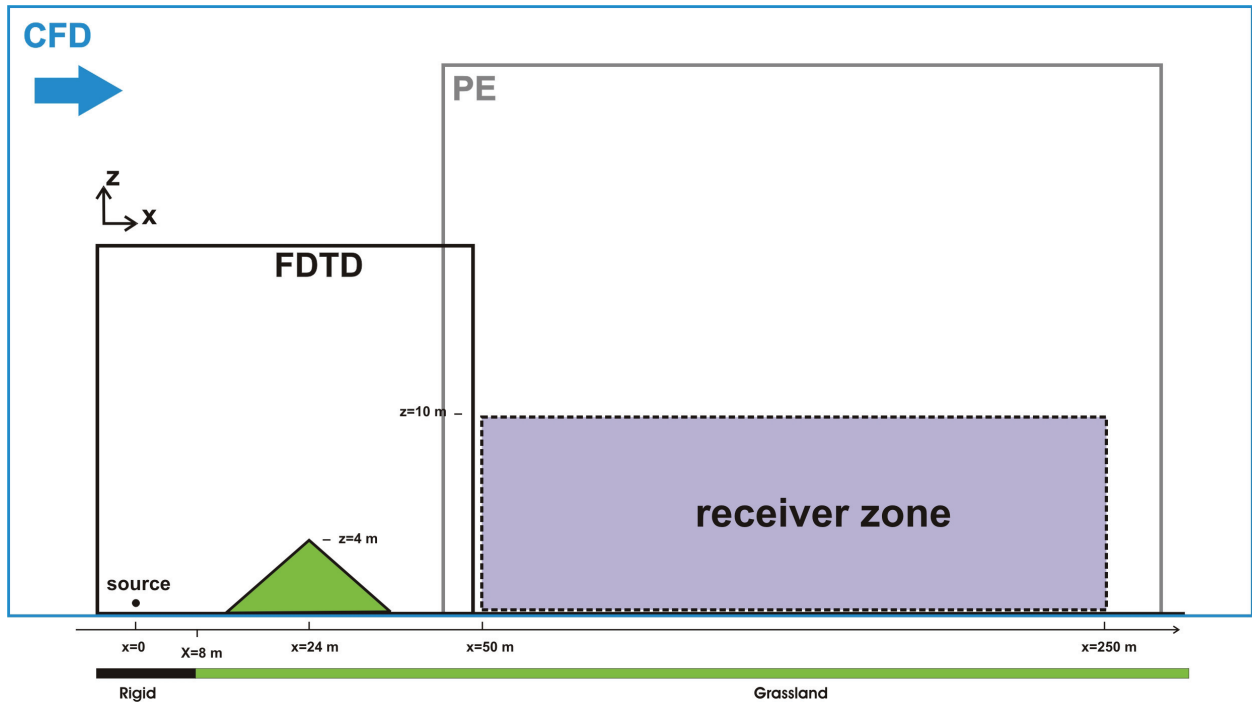


Fig. 2 – Numerical setup for the study of wind effects near berms.

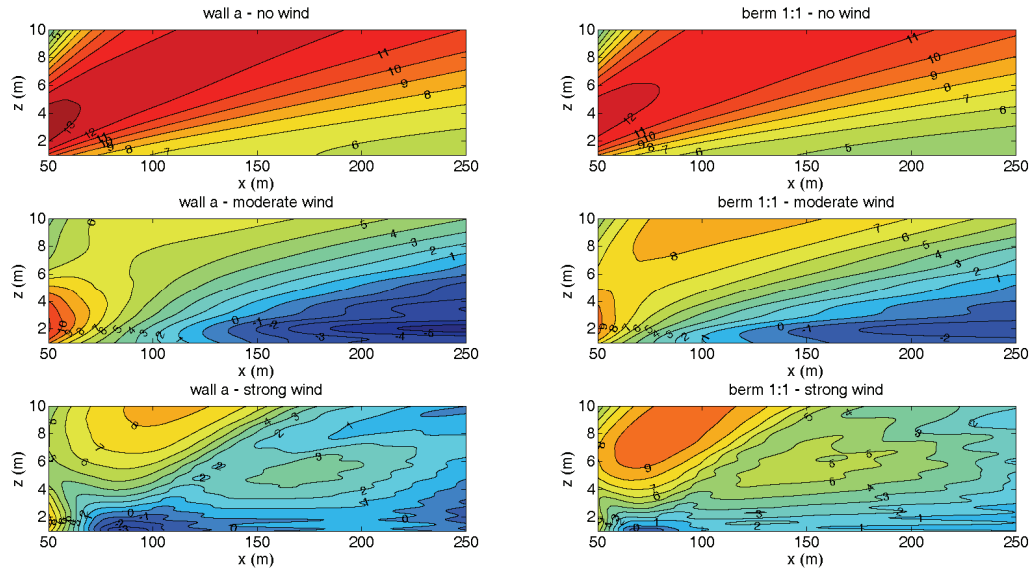


Fig. 3 – Contour plots of the total A-weighted traffic noise insertion loss for a light vehicle at 100 km/h, for a straight wall (position a) and a **1:1-sloped berm** (forest floor), in absence of wind, in case of moderate wind ($u^*=0.4$ m/s) and in case of strong wind ($u^*=0.8$ m/s).

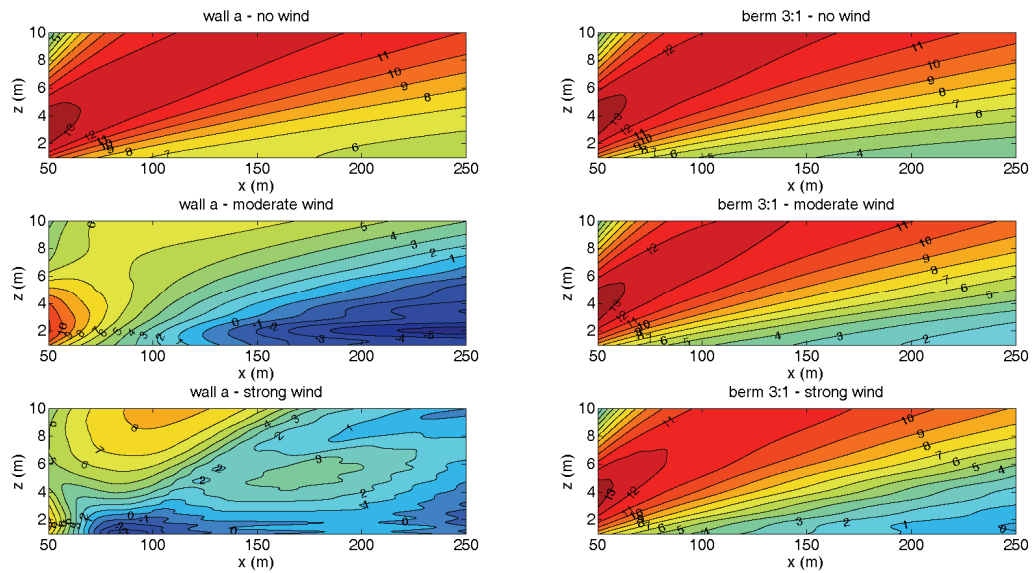


Fig. 4 – Contour plots of the total A-weighted traffic noise insertion loss for a light vehicle at 100 km/h, for a straight wall (position a) and a **3:1-sloped berm** (forest floor), in absence of wind, in case of moderate wind ($u^*=0.4$ m/s) and in case of strong wind ($u^*=0.8$ m/s).