Bamboo plants as a noise barrier to reduce road traffic noise

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ABSTRACT

Research shows that it is possible to use living bamboo plants along roads as a noise barrier to reduce road traffic noise. The benefit is that a barrier of bamboo looks much nicer than a "hard" screen. A barrier of living bamboo is much more environmental friendly, cheap in construction and management, and contributes to a sustainable infrastructure.

From the acoustical point of view, the most critical factor is the sound isolation which is limited by leakage through openings between the bamboo stems. The best solution is obtained by a bamboo species with a very high density: more stems per square meter. In other words, when bamboo grows closer together the results on noise reduction is better. This feasibility study shows that the noise-reducing effect of a bamboo noise barrier with a height of 5 meters and a thickness of 6 meters is roughly comparable to a 3 meter high solid noise barrier.

Keywords: Barrier, Sound, Insulation, Transmission
I-INCE Classification of Subjects Number(s): 31.1, 24.5

1. INTRODUCTION

All things considered, in a landscape, noise barriers are visually unwanted objects, sometimes even called Berlin Walls. Of course, noise barriers are functional. A screen reduces the sound levels in the vicinity of a highway, decreasing nuisance by road traffic noise.

The Engineers Division Amsterdam came up with the idea of growing noise barriers, of developing a screen made of vegetation. The idea of bamboo emerged. There are species of bamboo that are evergreen; these sorts keep their leaves in the winter. The stems of some species grow together very closely, creating the ability of sufficiently isolating sound. The structure also has the ability of scattering sound. Bamboo makes the noise barrier green, which people living in the direct vicinity will very probably appreciate. And bamboo could have a positive influence on air quality as well.

Together with the provincie Noord-Holland, ‘province North Holland’ and with the advice of Rijkswaterstaat (responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands), The Engineers Division Amsterdam initiated research on the noise-reducing qualities of bamboo. Students of Wageningen University (University and Research centre) conducted the study. This article describes the results. Students of Wageningen University have explored the most promising vegetation. In a trial setting, DGMR Consulting engineers has examined the acoustical aspects of this most promising bamboo vegetation.

2. POSSIBLE KINDS OF VEGETATION

The study of the students of Wageningen University [1] focussed on a series of designs of sound screens consisting of vegetation with a thickness of about six meters, made to screen off road traffic noise. Different designs and different types of vegetation were examined. One precondition is evergreen vegetation. The size of the leaves (and of the stems as well) is important, since we are dealing with road traffic noise mostly consisting of energy in the lower frequency ranges, below 2000 Hz. A first selection resulted in four species: holly, bamboo, viburnum and willow. This last kind needs a soil filling between the sides of a screen. The sorts are both indigenous and exotic. After deciding the nature of the vegetation, a detailed plan was made. This plan includes dimensions, planting schedule, type of filling soil and maintenance costs.

Based on literature of previous studies, the volume of sound damping was calculated next. In literature [2] the noise reduction of a vegetation fence with a 1 to 3 m thickness was determined. In order to reach a reduction in sound comparable to a massive sound screen, a thicker fence is necessary, which, however, still needs to fit alongside a road. The estimated noise reduction therefore applies to a 'screen' with a 6 meter thickness. The reduction for holly, bamboo and viburnum was respectively 4-6 dB(A), 3,5-4 dB(A) and 15 dB(A) and for the willow screen 30 dB(A). [2]. Although its noise reduction is not the greatest, bamboo is still chosen from a practical point of view, because of rapid growth, frost and salt resistance, little defoliation (traffic safety).

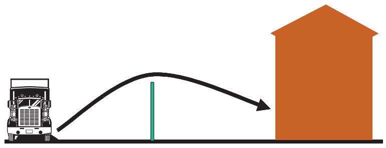
Although vegetation barriers, with a thickness of six meters, may not deliver high results in sound damping, they do have extra advantages when considering air quality, ecological values and acceptance by society. People do not appreciate noise barriers merely based on their noise reduction, but also based on their appearance. A vegetation screen is more positively appreciated than a conventional one. [3].

Additional to the regular demands for noise barriers, research presented a number of supplementary demands for vegetation at the side of the road. These are particularly demands on the areas of not blowing over, resistance to salt on the road, ample water and foundation (peaty soil). Bamboo is chosen as the most suitable fence. Best applicable is the bamboo sort Fargesia Robusta, an approximately 5 meter robust, frost, salt and disease resistant bamboo that has a dense growth and therefore offers the most reduction in noise. To prevent overhanging plants, one row of Nahira Drake, a stiff upright bamboo species, will be planted on the side of the road.

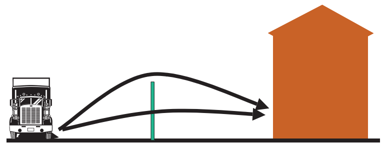
3. HOW DOES SOUND WITH ACOUSTICAL SHIELDING WORK?

The noise-reducing effect of a sound screen is based on the fact that sound has to make a detour along and over the barrier. The length of the detour decides the degree of the noise reduction. Therefore, a higher screen is better, and a barrier is less effective when further away from the source. It is assumed here that there is hardly any leakage transmission noise through the sound barrier itself. Consequently, an optimal sound isolation of the screen is important. The aspects that play a part in the physical operation of a noise barrier are concisely presented in the framework below.

The diffraction of the noise. This is the effect where, on the basis of the detour of the sound a screening effect is created. The noise reduction is also dependent on the curvature of the noise over the screen.

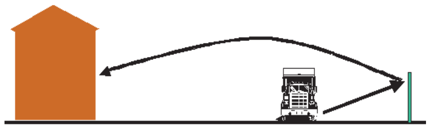


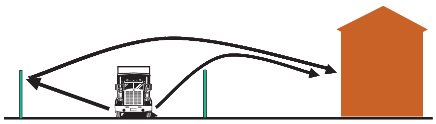
The noise insulation. A limited isolation of the barrier will ensure that the effect of screening is less because there is also a noise contribution the leakage transmission through the screen. With bamboo screens, this is very relevant.

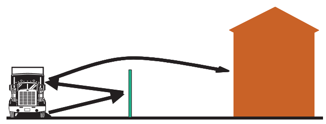


Reflections on the noise barrier. This has to do particularly with the acoustic absorption of the noise barrier. The following can be distinguished:

- the reflections on the screen on the opposite side of the road;
- a reduced effect due to reflections against the screen as a result of the double-sided placement of acoustic barriers;
- a reduced effect of the screen by reflections off the vehicle and the screen.







A possible additional advantage of the use of bamboo is that this vegetation causes a more optimal wind profile to reduce so called reswing effects (the effect of the wind on objects and the direction of their sound waves) (see eg. Van Renterghem en Botteldooren literature [5]). This advantage has not been studied yet, considering the fact that reswing effects can only be measured in a fully in situ test setting. In this feasibility study, measurements were made only to determine the transmission loss caused by limited transmission noise through the grove.

The shielding function of bamboo barriers depends on the correct placement and shape. Literature [6] and [7] describe more on this subject. The detour of the noise can be calculated with a standard method, as described in the nationale Reken- en meetvoorschriften, 'national calculation and measuring instructions' [7]. Software such as Geomilieu is based on this. The regulations [4] and [8] determine that sound isolation needs to meet certain minimal conditions, in order to make the transmission through the barrier negligible as compared to the acoustical energy that passes over the barrier. However, the sound transmission through bamboo noise barriers is rather considerable (due to restricted sound isolation). Therefore, the specific effect of the sound isolation which is limited by leakage through openings between the bamboo stems on the total function of the sound barrier needs to be examined.

With respect to the possible reflections on the bamboo noise barrier, it is important that the acoustical absorption of the barrier is high. Subsequently, incoming sound energy will not be reflected, but absorbed in the barrier.

4. RESEARCH ON SOUND ISOLATION

The most significant aspect is the sound isolation of the bamboo bundle. Isolation that is too limited will directly result in a noise barrier with a restricted function or with no function at all. In order to determine the sound isolation, sound measurements were carried out on an existing bamboo grove with a height of approximately 5 meters. Figure 1 outlines the applied measurement setting.

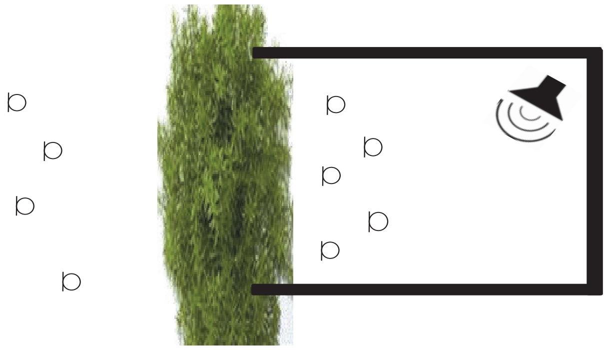


Figure 1. The measurement set-up with the enclosure (top view)

This measurement research includes comparable measurements with and without the bamboo grove. The damping of the bamboo depends on the thickness of the grove, in other words on the path length that sound covers between the bamboo's stems and leaves. The damping per frequency band has been measured and determined per meter path length. Subsequently, this measurement was converted to the expected transmission loss of a bamboo barrier with a thickness of 6 meters. Figure 2 shows this loss in transmission.

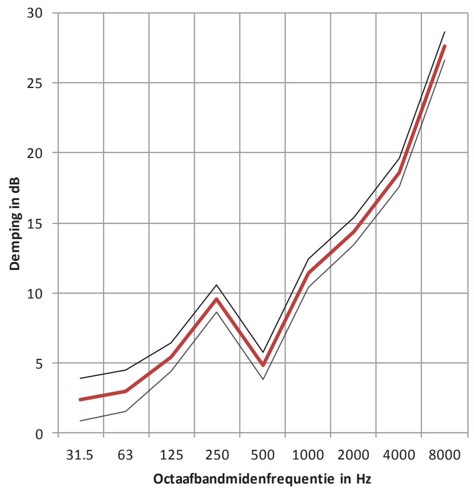


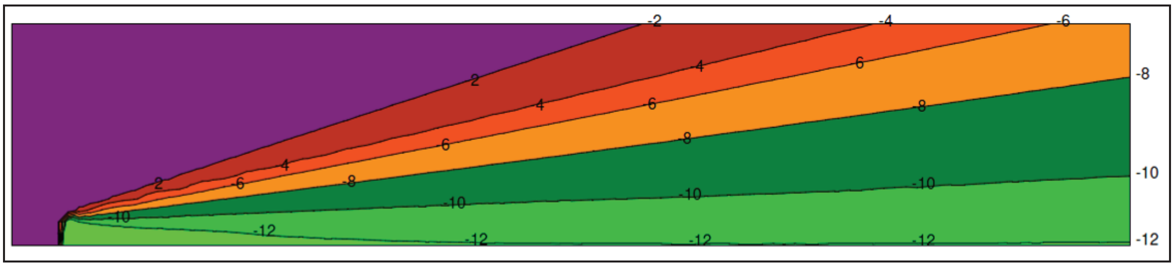
Figure 2. Damping per frequency band of a bamboo grove with a thickness of 6 meters.

At 500 Hz the damping dips, partly caused by the effects of the ground's low flow resistance. In practice, this dip will shift to a lower frequency band, hereby improving the total effect of the bamboo vegetation. The higher damping values at higher frequency ranges are the result of scattering and reflection effects at (quarter-) wavelengths in the order of magnitude of stem and leave sizes.

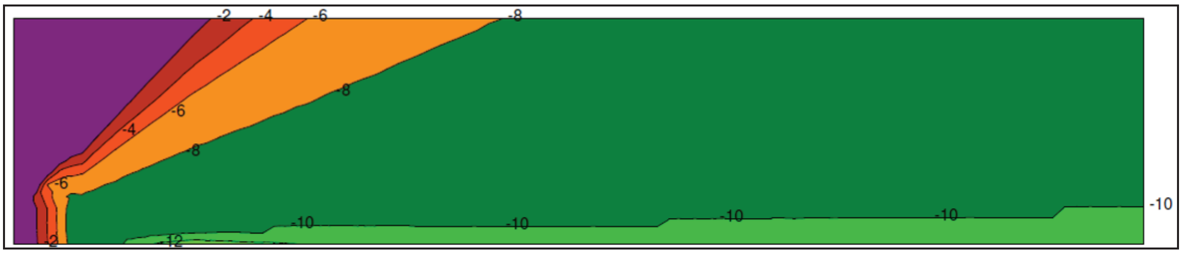
The damping value of leakage transmission through the grove has been calculated for the average road traffic noise spectrum and amounts 9,2 ± 2,0 dB(A). The stated inaccuracy is based on the possible measuring errors and the applied measurement setting. The noise reduction is more extensive than previous research shows. Consequently, the chosen bamboo species has been a good choice.

5. A BAMBOO BARRIER'S EFFECTS

Using the calculation method for the effectivity of noise barriers, calculations have been made for a frequently used, conventional, massive noise barrier with a height of 3 meters and for a noise barrier consisting of bamboo, with a height of five meters above ground level. With the help of an acoustical computer simulation model, a prediction was made on the acoustical effect of the bamboo barrier, with the diffraction over the 'screen' and the transmission through the 'screen' combined (see figure 3). Reference point is the configuration of a bamboo barrier along a provincial road, the thickness of the bamboo fence is 3 plus 3 meters with a space of 1 meter in between both fences. In the intermediate strip, 1 meter wide, a restricted wall of 1 meter high is chosen.

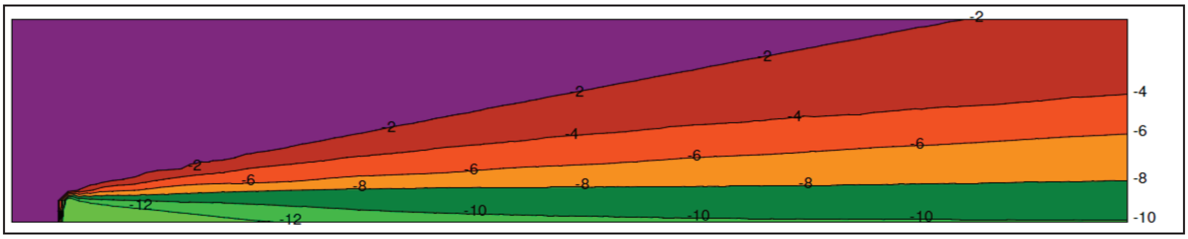


The effect of the screening with a massive barrier of 3 meters along a provincial road with two single lanes, 80 km/h-road

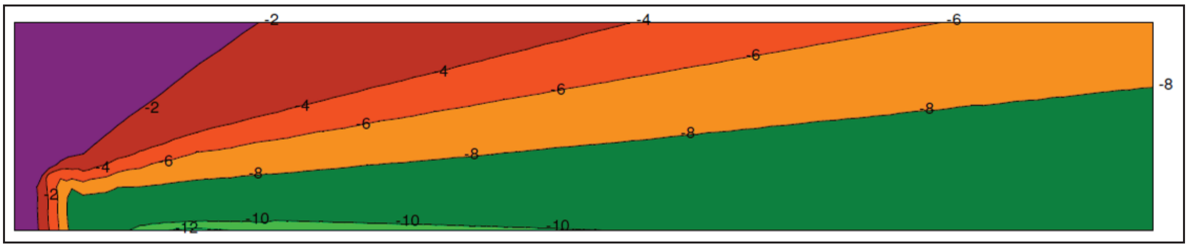


The effect of the screening of the bamboo barrier along a provincial road with two single lanes, 80 km/h-road

Figure 3. Shielding effects of a massive screen and of a bamboo barrier along a provincial road with two single lanes.



The effect of the screening with a massive barrier of 3 meters along a major road, 130 km/h with 2x2 lanes



The effect of the screening of the bamboo barrier along a major road, 130 km/h with 2x2 lanes

Figure 4. Shielding effects of a massive screen and of a bamboo barrier along a highway.

The calculations have been made at a maximum distance of 100 meters from the road with a configuration of a provincial road and a highway, both consisting of two lanes. We assumed an underestimation of the bamboo screen's noise reduction, by presuming perpendicular leakage transmission while, apart from this, the bamboo's transmission damping is higher.

When comparing the figures, taking uncertainty margins into account, it can be concluded that a noise barrier of bamboo is a match for a massive screen with a height of 3 meters. The differences between a road with two single lanes and a road with two double lanes are negligible.

The absolute noise-reducing effects of a bamboo screen, but also of a massive screen with a height of 3 meters, are higher when the road consists of two single lanes. This is because the noise sources in this configuration are closer to the screen, causing the detour of the noise over the screen to be bigger. When the position of the observers is lower than the road and the screen (in other words deeper in the so called shadow zone), the noise-reducing effects are always bigger.

As indicated, there are extra chances for better noise-reducing effects of a bamboo noise barrier than the model calculations show. This is because a bamboo screen is expected to have a much more optimal wind profile to reduce reswing effects. Reswing effects can only be assessed and measured in a fully in situ test setting. If possible, the wind profile that occurs on the location should be monitored, to be able to conclude that this results in higher shielding effects than the models show.

6. CONCLUSIONS

It seems to be a real possibility to use living green noise barriers along roads. Although vegetation screens may not give the highest values in noise damping, it is to be expected that they have extra advantages for the air quality (even though this needs to be further examined), ecological value and acceptance by society. People do not appreciate noise barriers merely based on their noise reduction, but also based on their appearance. A vegetation screen is expected to be more positively appreciated than a conventional one.

The most critical factor, from the acoustical point of view, is the sound isolation by leakage transmission noise through the grove. The best solution to this issue is a bamboo species with a very high density of vegetation. More stems per square meter, or in other words, a plant/bamboo species that grows closely intertwined, gives the best results.

The examined bamboo noise barrier with a height of 5 meters and a thickness of 6 meters has a noise shielding effect that is slightly better than the noise shielding effect of a massive noise barrier with a height of 3 meters. The differences between a road with two single lanes and a road with two double lanes are negligible. The absolute noise-reducing effect of a bamboo screen, but also of a massive screen with a height of 3 meters, is higher at a provincial road than at a highway. This is because in this configuration the vehicles drive closer to the screen, causing the detour of the noise over the screen to be bigger.

There is a realistic expectation that the noise-reducing effect of bamboo is better than calculated in this article, because a bamboo barrier can reduce reswing effects. All things considered, there are ample reasons to further develop bamboo as a noise barrier.

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